Phase II of the Total Maximum Daily Load for Total Nitrogen to the Neuse River Estuary, North Carolina

December, 2001

Neuse River Basin

Prepared by:
NC Department of Environment and Natural Resources
Division of Water Quality
1617 Mail Service Center
Raleigh, NC 27699-1617
(919) 733-5083

TABLE OF CONTENTS

Phase II of the TMDL for Total Nitrogen to the Neuse River Estuary

1.0 Introduction

The first phase of the TMDL for Total Nitrogen to the Neuse River estuary was conditionally approved in July 1999. It called for a second phase, to be completed by July 2001, that would incorporate the latest tools including the Neuse River Modeling and Monitoring Project (ModMon) monitoring data and models. This document will satisfy that requirement. The 1999 TMDL will continue to be the document of record until the final phase II TMDL is approved.

It should be acknowledged from the outset that though the predictions and decisions contained in this document are based on the best currently available information, there is substantial uncertainty in them. For this reason, DWQ intends to follow an adaptive approach to managing the estuary. In other words, DWQ will use the models to guide decision making, but continuing observation of the watershed and estuary, as nitrogen controls are implemented (i.e., Neuse Rules, and other measures such as wetlands restoration and establishment of conservation easements), is expected to be our best approach for determining the appropriate level of management.

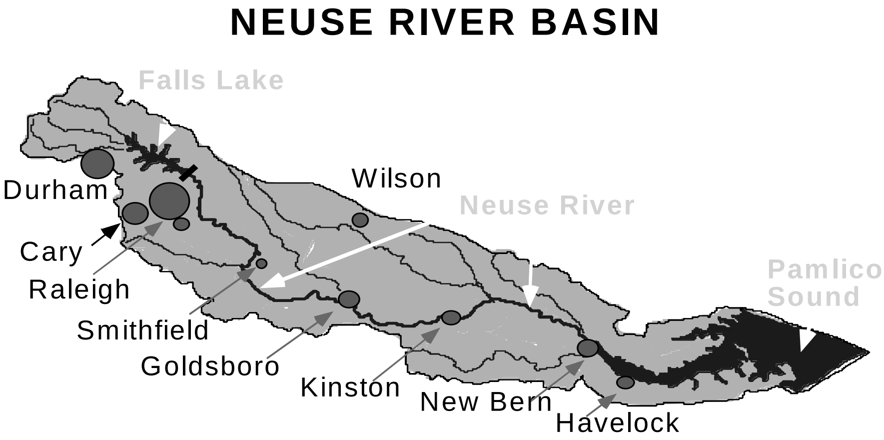
1.1 Basin Description

The Neuse River originates northwest of Durham and flows southeasterly for over 150 miles past the municipalities of Raleigh, Smithfield, Goldsboro and Kinston before it reaches its estuary around New Bern (Figure 1). The Neuse River basin encompasses nearly 6000 square miles over 19 counties. At New Bern, the Neuse takes on estuarine characteristics as it widens but remains shallow, frequently resulting in minimal discharge and long hydraulic residence times. The Neuse River estuary stretches to the southeast for 25 miles until it reaches Cherry Point (Minnesott Beach on the north side), where it bends to the northeast and continues for 20 miles before meeting Pamlico Sound.

1.2 Water Quality Target

The Neuse River estuary between Streets Ferry Bridge and Cherry Point appears on North Carolina's 303(d) list for chlorophyll-a (about 8 miles upstream to about 17 miles downstream from the Neuse's confluence with Trent River). This TMDL will address chlorophyll-a (hereafter referred to as chlorophyll) as its endpoint, but will seek to manage total nitrogen, which is the nutrient that has the best potential to limit excessive growth of chlorophyll in the estuary. Various parties have suggested that inorganic nitrogen (i.e., excluding organic nitrogen) should be the basis for the TMDL, but lack of source data for inorganic nitrogen (required for nitrogen delivery model) alone makes this problematic. For the chlorophyll endpoint, this assessment will consider the current use support criterion. Specifically, the TMDL target is to have less than or equal to 10% of the samples collected in a specified area and time (EPA guidance for use support determination) above the chlorophyll-a standard of 40 ug/l. Hereafter, this will be referred to as the 10/40 criterion. This document will assess the amount of total nitrogen load reduction (TMDL) that is necessary to comply with the 10/40 criterion.

Figure 1.



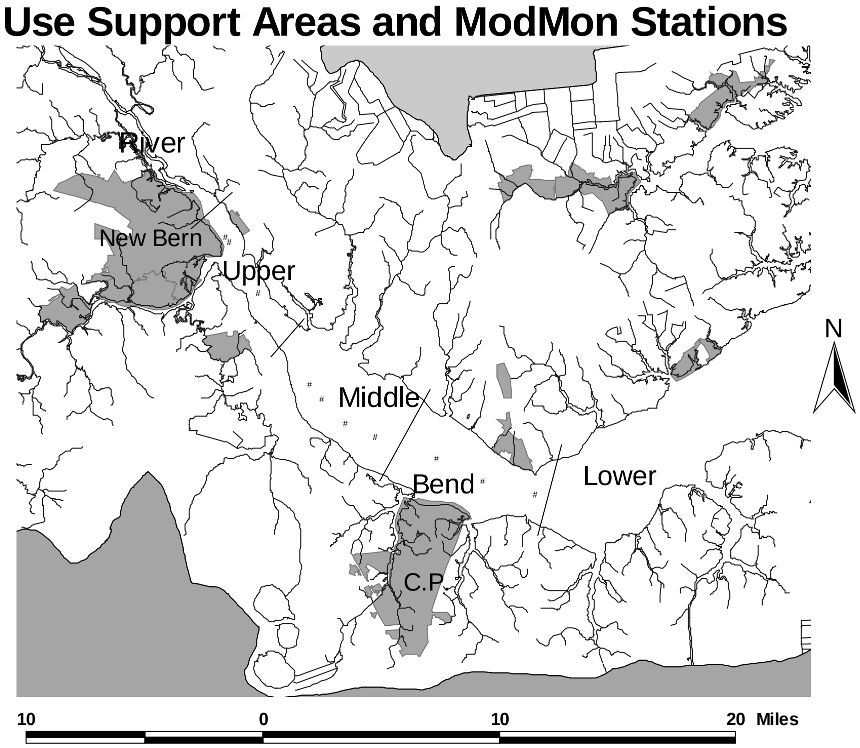
1.3 Modeling Approach to Reduction Target

Three models have been employed to determine the appropriate TMDL to meet the 10/40 criterion for chlorophyll. The models used for this purpose are:

- A CE-Qual W2 application to the Neuse estuary, also know as the Neuse Estuary Eutrophication Model (NEEM).
- A probability network model called the Neuse Estuary Bayesian Ecological Response Network (Neu-BERN).
- A Water Analysis Simulation Program (WASP) application to the Neuse estuary.

The five use support areas of the estuary in which the three models group their predictions may be seen in Figure 2 on the following page. The areas are referred to as River, Upper, Middle, Bend and Lower, and are the spatial endpoints of the TMDL. Model predictions are grouped in these areas because the observed data within them show similar behavior, and because they generally correspond to where DWQ has assessed use support, which determines if a particular estuary segment is impaired or not.

Figure 2. (Mid-channel stations in River and Lower areas are not shown)



2.0 Model descriptions

Each of the models will be explained further in the following sections.

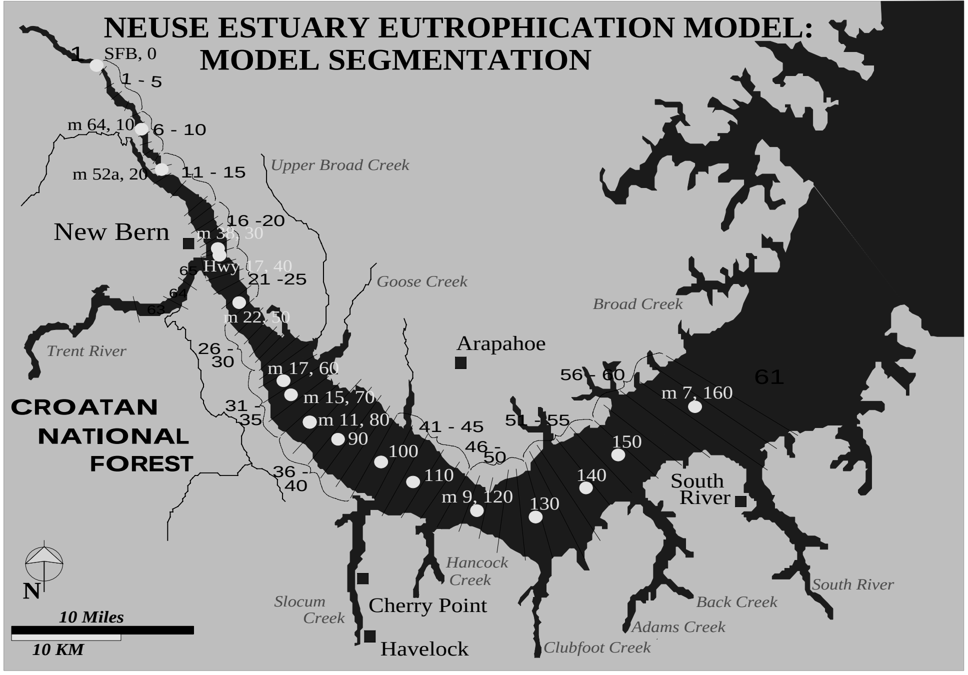
2.1 NEEM

The NEEM is a deterministic, material balance simulation model that tracks an assortment of water quality variables related to eutrophication. Its compartments are in two dimensions: longitudinal segments along the estuary and vertical layers through the water column. It does not divide the estuary laterally (e.g. from bank to bank). It has been calibrated to data collected at estuary mid-channel stations by UNC Institute of Marine Science (IMS) and Weyerhaeuser Corporation as part of the ModMon (Neuse River Modeling and Monitoring) project for the period beginning January 1, 1998 and ending December 31, 2000. DWQ detected a problem with its lab analysis of chlorophyll; consequently DWQ chlorophyll data are not used in the TMDL. More is said about DWQ chlorophyll data in Section 6.1.1 on page 17.

The model developers have made numerous presentations during model development to stakeholders in the Neuse basin over the past three years. One of the model components that resulted from stakeholder input is a separate sediment diagenesis sub-model. This sub-model will provide insight on how the nutrient flux from and oxygen demand by the sediment layer will evolve following watershed nutrient load reductions.

Dr. Jim Bowen and Jeff Hieronymus of the University of North Carolina at Charlotte developed the NEEM (Bowen and Hieronymus, 2000). The model tracks material balances throughout the estuary. Materials in this case are 16 state variables, including three types of phytoplankton, organic matter, dissolved oxygen and benthically-derived oxygen demand, and inorganic and organic nutrients. These variables are accounted for over the two dimensional modeling framework. The longitudinal segments vary in length but are approximately one-half mile long. The model divides the water column into approximately half-meter increments from the water surface to the sediment bottom. There are two branches to the model: (1) the Neuse branch has 62 segments and stretches from Streets Ferry Bridge, which is about 8 miles upstream of New Bern, to about 1 mile downstream of Oriental, and (2) the Trent branch has four segments and extends about 4 miles upstream from its confluence with the Neuse. Figure 3 is a map of the model segmentation of the estuary.

Figure 3.



2.2 Neu-BERN

The Neuse Estuary Bayesian Ecological Response Network (Neu-BERN), which Mark Borsuk developed for his Ph.D. dissertation at Duke University, is a probability network model. While initially structured to focus on broader ecological endpoints, much effort has been put into this model in the past few months to enable it to predict algal response (chlorophyll a) to various nitrogen loads. This predictive link, which can be thought of as a multiple regression model, will be the focus of Neu-BERN in this assessment. Considering the multiple regression model framework, chlorophyll-a is the response variable, and there are five predictor variables: (1) daily flow at Ft. Barnwell, (2) daily total N concentration at Ft. Barnwell, (3) estuarine water temperature (4) dummy variable for institution collecting the sample (UNC-IMS or WEY) and (5) location (i.e. in which use support area the station is). The institution and the temperature effects are assumed constant across all use support areas, while the other effects vary by area. Two parameters are used to describe the flow effect in each area and one parameter is used to describe the nitrogen effect in each area.

Note that the inclusion of a dummy variable to represent the effect of the sampling institution has merit, as there is a significant and predictable relationship between Weyerhaeuser and IMS data. Both are analyzed in the IMS lab, but IMS takes a surface grab sample while Weyerhaeuser takes a horizontal grab sample at 1 meter (until August 1999 when they switched to a vertical composite sample from 0.5 m to 1.5 m). However, including the dummy variable has a strong affect on the model results and consequently, it may be considered to be a "conservative" model assumption. Conservative in this sense means that by including this variable, there is the potential that the result may be overprotective of water quality; this certainly depends on the other model assumptions and treatment of the margin of safety, etc. To cover the range of possibilities, model results will be provided with and without the dummy variable.

Total phosphorus at Ft. Barnwell was also considered as a predictor variable. A stimulatory phosphorus effect was found, but it was statistically insignificant, so total phosphorus was not included in the final model. Neu-BERN was calibrated to mid-channel UNC-IMS and Weyerhaeuser data that were collected between 1994 and 1999.

The focus of Neu-BERN has been to allow for the prediction of ecological responses that have been characterized as more meaningful to stakeholders. These model responses include prediction of fishkills, habitat quality, shellfish abundance, and fish population health resulting from a reduction in nutrient loading.

2.3 WASP

USEPA Region IV developed a Neuse River application of the Water Quality Simulation Program (WASP). WASP is a detailed water quality model that can be coupled with a hydrodynamic model. In this case, Environmental Fluid Dynamics Code (EFDC) was used as the hydrodynamic model. EFDC/WASP is similar to CE-QUAL W2 (NEEM) in that it is also a deterministic, simulation model that tracks an assortment of water quality variables related to eutrophication. The key difference between the two models is that WASP has been configured for compartments in three dimensions, rather than two for CE-QUAL W2. In addition to having longitudinal segments and vertical layers, WASP divides the estuary laterally (e.g. from bank to bank). In other words, where CE-QUAL W2 aggregates predictions in the lateral dimension, WASP makes spatially explicit predictions.

The WASP application to the Neuse has been calibrated to data collected at estuary mid-channel stations by UNC Institute of Marine Science (IMS) as part of the ModMon project for the period beginning January 1, 1998 and ending December 31, 2000. The side channel of the estuary in the model has been calibrated to data collected by North Carolina State University in 1998 and 1999.

3.0 Model Treatment of Estuary Sediment Conditions

One of the most significant unknowns of this TMDL is how the estuary sediment layer contributions of nitrogen will change following nutrient reductions. This process will be referred to as sediment diagenesis in this assessment. Along with watershed nutrient loading, nutrient loading from the estuary's sediment layer is a primary source of nutrients to algae. One possible scenario for sediment diagenesis is that management strategies will decrease the watershed nutrient load, and this leads to less delivery of organic matter and associated nutrients to the estuary sediment layer. Subsequently, the flux of nutrients from the sediment layer to the water column is reduced and further water quality benefits are realized. A second possible scenario is that, through decreased watershed nutrient loading, the sediment layer receives less organic matter and nitrate, which are two primary components of denitrification. Consequently, denitrification is decreased and chlorophyll levels do not decrease beyond the improvement realized by reducing watershed load. This occurs because denitrification is the conversion of nitrate (usable by algae) to a form of nitrogen that is not usable by algae (N_2 or N_2O). Neu-BERN has no mechanism to model sediment diagenesis, and so its predictions are for the period specified. The NEEM has a separate sediment sub-model. Using this sub-model, the NEEM can make predictions on how the sediment layer might evolve and the response of water quality at that time. More explanation on this sub-model can be found in the NEEM Predictions section. WASP uses a constant flux of nutrients from the sediment in all scenarios.

4.0 Calibration Results

In the following sections, calibration fit statistics will be presented for each model. Additionally, a verification exercise on 2000 data was conducted by each of the models, and the results from that will be discussed.

4.1 Neu-BERN Calibration Results

Table 1, on the following page, displays the calibration fit statistics for Neu-BERN from 1994-1999. Shown in Table 1 on the following page are model fit statistics for each of the ModMon (UNC-IMS and Weyerhaeuser chlorophyll data) mid-channel monitoring stations, and in summary for each use support area. DWQ chlorophyll data were unavailable due to lab analysis problems. The calibration objectives were to achieve a mean error (ME) of 0 and a minimum root mean square error (RMSE) for the total model. The model R^2 value is an indication of the variability in the observed data that is explained by the model. If there is not much variability in the observed data, the model R^2 may be lower because there is not much variability to explain; this is the case in the Lower area of the estuary. The total model R^2 of 0.53 is typical to somewhat high for **model prediction** of chlorophyll a. To some extent, this apparently low R^2 is due to natural variability in observed chlorophyll. The root mean squared error (RMSE) is the standard deviation of the model residuals, which are the differences between model predictions and observed data. The mean error (ME) is the difference between the observations and the corresponding predictions. Regression-based models, such as Neu-BERN, assume normally distributed errors (difference between observed and predicted values) with a mean of 0 (the model "goes through the middle of the data"). Compliance with this assumption allows us to alter the model predictions to include error about the predictions, as will be explained shortly. In this case, a log transformation of chlorophyll was used to achieve errors that were normally distributed. It should be noted that the calibration statistics for Neu-BERN are for the model that includes the dummy variable.

Table 1. Neu-BERN calibration statistics for chlorophyll

Use Support Area	**Station**	**1/94–12/99**			
		Number of Observations	**Log (Chla)**		
			R^2	**RMSE**	**ME**
River	**0**	199	0.08	1.05	-0.08
	10	200	0.12	1.05	0.00
	20	201	0.21	1.07	0.17
Upper	**30**	202	0.52	0.93	-0.11
	50	146	0.56	0.86	0.16
Middle	**60**	98	0.48	0.85	-0.13
	70	201	0.33	0.84	0.05
Bend	**100**	66	0.18	0.88	-0.15
	120	197	0.11	0.78	0.06
Lower	**140**	84	0.03	0.74	0.08
	160	82	0.11	0.72	0.00
River	**Summary**	600	0.13	1.06	0.03
Upper	"	349	0.53	0.91	0.00
Middle	"	299	0.38	0.84	0.00
Bend	"	263	0.14	0.81	0.00
Lower	"	166	0.07	0.73	0.04
Total		1677	0.53	0.92	0.00

4.2 NEEM Calibration Results

On two pages following, Table 2 displays the NEEM calibration fit statistics for chlorophyll from January 1, 1998 through December 31, 2000. Shown are the fit statistics for each of the ModMon mid-channel monitoring stations, and a summary for each use support area. The calibration objectives were to match the cumulative distribution function of the observed data as closely as possible, to obtain a maximum R^2 for the total model (entire estuary), and to achieve a mean error of zero. The total model R^2 of 0.58 (58%) is somewhat high for model prediction of chlorophyll a. A mean error of zero indicates that the model is not biased in either direction compared to the observed data. The NEEM calibration statistics used a base of log10, while Neu-BERN used a base of log e; this means that some of the model results are not directly comparable. Multiply the NEEM RMSE and ME by 2.3 to compare it with Neu-BERN's fit statistics. The R^2 values are directly comparable.

A separate model calibration presentation for the NEEM is available electronically upon request.

To account for sample collection differences, the NEEM was calibrated separately to IMS and Weyerhaeuser data. Again, IMS samples are collected by a surface grab, and Weyerhaeuser samples were collected by a horizontal grab at 1 m (in August 1999 Weyerhaeuser switched to a vertical composite between 0.5 m and 1.5 m). Thus, the NEEM surface layer was calibrated to IMS data, while the second layer was calibrated to Weyerhaeuser data. The NEEM does not have a carbon to chlorophyll ratio (model parameter) that varies with depth, so this approach does not fully account for observed differences in chlorophyll values. Despite this, no adjustment factor was applied to any of the observed data in order to maintain a pure data set.

Table 2. NEEM calibration fit statistics for chlorophyll

Section	Station	1/98 - 12/00			
		# obs	Log10(Chla ug/l)		
			ME	RMSE	R^2
River	**0**	192	-0.59	0.96	62.2%
	10	162	-0.21	1.05	43.0%
	20	193	0.19	1.31	33.0%
Upper	**30**	195	-0.06	1.08	60.8%
	50	195	-0.28	1.10	61.1%
Middle	**60**	154	-0.22	1.18	48.2%
	70	194	-0.17	1.22	41.1%
Bend	**100**	154	-0.09	1.15	32.8%
	120	193	-0.17	1.09	24.7%
Lower	**140**	175	-0.08	1.15	6.9%
	160	171	-0.21	0.98	17.5%
River		548	-0.20	1.12	41.6%
Upper		390	-0.17	1.09	61.0%
Middle		348	-0.19	1.20	44.4%
Bend		347	-0.13	1.12	28.8%
Lower		346	-0.14	1.07	11.3%
Total		1980	-0.17	1.12	58.2%

4.3 WASP Calibration Results

On pages following, Tables 3 and 4 display the WASP calibration fit statistics for chlorophyll for 1998 and 1999. Shown are the fit statistics for each of the ModMon mid-channel monitoring stations (0-160), and the NCSU side-channel stations (Side). Fit statistics were not provided in summary for each use support area. The calibration objectives were to "parameterize the model to best represent the nutrient gradients in the Neuse River/Estuary system, account for seasonal variability, and to predict the chlorophyll concentrations in both time and space. The judgement of fit of the calibration was both a qualitative (best professional judgment of model fit observed data) and quantitative (statistical methods used to determine goodness of fit)" (EPA Region IV, 2001). The WASP calibration statistics used the original metric (log values not used) for RMSE and ME, while the NEEM and Neu-BERN used log bases for those statistics; this means that the statistics are not directly comparable. The R^2 values are computed using a log base 10.

EPA provided calibration statistics on an annual basis, as opposed to a cumulative period for the NEEM and Neu-BERN.

Table 3. 1998 WASP calibration fit statistics for chlorophyll

Section	Station	1/98 - 12/98			
		# obs	Log(Chla)		
			R^2	RMSE	ME
River	**0**	24	0.34	0.15	0.57
	10	24	0.61	0.15	1.08
	20	24	0.46	0.13	2.01
Upper	**30**	24	0.57	0.18	7.27
	50	24	0.38	1.16	8.44
Middle	**60**	24	0.38	2.43	6.13
	70	24	0.11	2.63	-0.97
Bend	**100**	24	0.42	3.34	9.76
	120	24	0.24	2.47	6.10
Lower	**140**	20	0.26	2.27	10.55
	160	18	0.07	2.49	9.05
Side	**Bullseye**	23	0.34	0.51	-4.72
	Flanner	18	0.37	3.15	-11.90
	Kennel	20	0.24	1.47	-4.15
	Cherry Point	21	0.23	1.97	-7.47
	Beard	23	0.21	0.81	-11.17
	Minnesott	23	0.41	0.20	-10.21

Table 4. 1999 WASP calibration fit statistics for chlorophyll

Section	Station	1/99 - 12/99			
		# obs	Log(Chl a)		
			R^2	RMSE	ME
River	**0**	25	0.88	0.01	-0.28
	10	24	0.60	0.02	-0.70
	20	24	0.30	0.02	-0.21
Upper	**30**	25	0.78	0.18	-0.43
	50	25	0.75	0.28	0.47
Middle	**60**	24	0.63	2.17	-3.23
	70	25	0.73	4.35	-2.68
Bend	**100**	24	0.57	2.66	-10.38
	120	24	0.55	1.77	-5.17
Lower	**140**	23	0.05	2.24	-4.13
	160	23	0.88	5.59	-8.48
Side	**Bullseye**	31	0.01	2.33	-7.11
	Flanner	26	0.33	1.61	-6.63
	Kennel	26	0.00	0.18	-8.00
	Cherry Point	31	0.01	0.75	-6.72
	Beard	21	0.05	1.40	-12.66
	Minnesott	31	0.01	0.57	-9.19

4.4 2000 Verification Exercise

Using model calibrations prior to 2000 (2000 was not included), the three models were run to provide baseline chlorophyll predictions for 2000. The predictions were compared to observed chlorophyll data in 2000 to get an idea of how the models predict during a time to which they were not calibrated. Granted this is not as difficult a task as predicting chlorophyll under nutrient reduction scenarios, but it does provide some level of model verification.

All of the models require boundary condition information (minimum of flow and nutrients at Fort Barnwell) before they can be run for 2000, though they require different amounts of data. Both the NEEM and WASP required upstream and downstream boundary (Streets Ferry and near Oriental) condition information that includes chlorophyll, so one would expect their predictions to be closer at those two stations, and probably closer at other River area stations as well depending on hydraulic residence time. Neu-BERN uses the boundary condition minimum information of flow and nutrient concentration at Fort Barnwell.

It is most appropriate to focus on the areas of the estuary where chlorophyll standard exceedances occur most frequently, and where having set boundary conditions are less likely to affect the outcome. Thus, statistics are provided in Table 5 for the Upper, Middle and Bend areas of the estuary.

Table 5. Verification Exercise Results (statistics defined below)

2000 Verification Exercise Statistics					
Area	# obs	Log base e (Chla ug/l)			
Model		R^2	RMSE	ME	MAE
Upper	72				
NEEM		0.43	0.84	0.17	0.79
Neu-BERN		0.43	0.84	0.35	0.70
WASP		0.50	0.79	0.16	0.61
Middle	60				
NEEM		0.16	0.67	0.00	0.64
Neu-BERN		0.13	0.69	0.28	0.49
WASP		0.08	0.70	0.14	0.49
Bend	60				
NEEM		0.01	0.65	-0.11	0.65
Neu-BERN		0.05	0.66	0.25	0.49
WASP		0.01	0.66	0.23	0.54
All	355				
NEEM		0.54	0.84	-0.01	0.78
Neu-BERN		0.58	0.58	0.28	0.67
WASP		0.57	0.81	0.20	0.57

It is better to evaluate R^2 with a measure of error (particularly RMSE and MAE, but also ME) since it would be possible to explain more of the variability but have a sizeable error. Root mean squared error (RMSE) is the standard deviation of the model residuals (difference between observation and prediction). A lower RMSE is better. Mean error (ME) is the average difference between the observation and prediction. A mean error close to zero is desirable, a positive value indicates the model under predicts on average, and a negative value indicates that the model over predicts on average. How the models predict at the standard (40 ug/l) may be different from how they predict on average. Mean absolute error (MAE) is the absolute value of the differences between the observations and the corresponding model predictions. The lower the mean absolute error, the better. Along with R^2, MAE and RMSE are considered to be the best statistics for model comparison. The principal difference between MAE and RMSE is that RMSE counts large errors more.

The models performed similarly in the verification exercise. The model R^2 values decreased moving down the estuary, though the mean errors and the mean absolute errors generally decreased as well. None of the models performed well in the Middle and Bend areas. The NEEM had a mean error that was closest to zero, but the largest mean absolute error. Neu-BERN and WASP performed the best on MAE. The three models performed similarly with RMSE.

Modeling efficiency

Another statistic to consider for the verification exercise is modeling efficiency. It is calculated using the following formula:

$$\frac{\left(\sum_{i=1}^{n} (Oi - \overline{O})^{2} - \sum_{i=1}^{n} (Pi - Oi)^{2} \right)}{\sum_{i=1}^{n} (Oi - \overline{O})^{2}}$$

where:
O_i = ith observation
P_i = ith prediction

$\overline{O}$ = mean of the observations

The closer to 1 the better.
if > 0, then the model predicts better than the mean of the observations
if < 0, then the mean of the observations does better than the model

Table 6. **Modeling efficiency** results from verification exercise

	All areas
WASP	0.497
BERN	0.530
NEEM	0.408
	U,M,B only
WASP	0.372
BERN	0.386
NEEM	0.142
	M,B only
WASP	0.330
BERN	0.432
NEEM	0.067

U –Upper
M - Middle
B - Bend

In terms of modeling efficiency, Neu-BERN performs the best, especially considering it does not use set boundary conditions. In the areas where the reduction target will be determined (Upper, Middle and Bend), model performance decreases though the models remain better than the mean of the observations.

Prediction uncertainty will be higher in the reduction scenarios than the 2000 verification exercise, as uncertainty increases as the models move away from calibration conditions with greater nutrient reduction.

One final note is that the NEEM and WASP were further calibrated to 2000 data once the verification exercise predictions were provided. This should improve their predictive capability for the TMDL (see calibration results in Tables 2-4).

5.0 Effects of Management Actions between 1995 and 1998

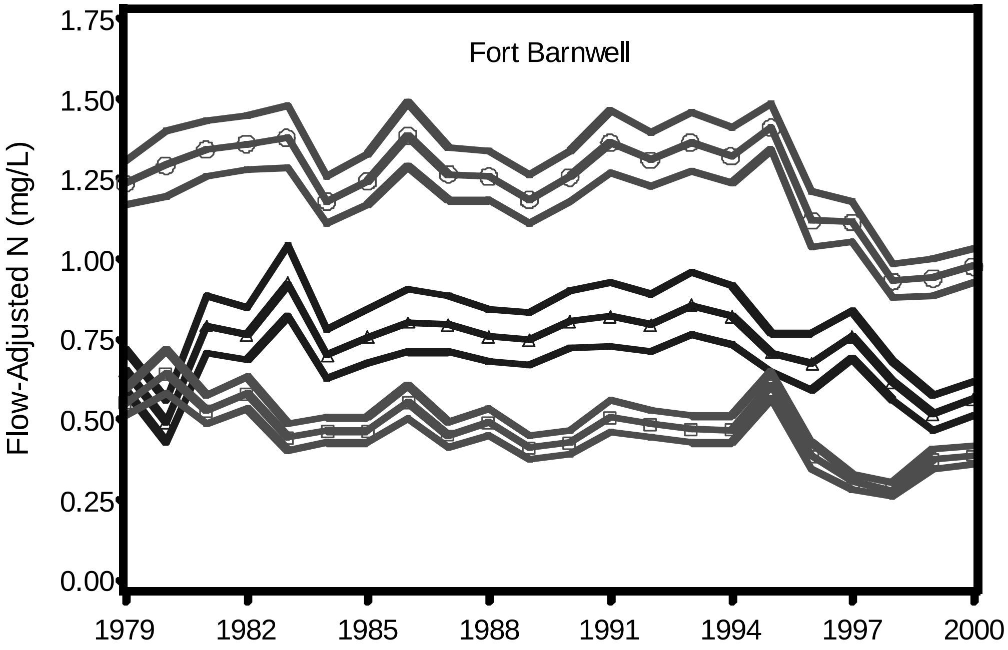
The 1995-1998 period spans the initiation of nitrogen load reductions through the Neuse Rules. All of the models consider 1998-2000, so to reference the 1995 baseline load from the first TMDL we must estimate what has happened between 1995 and 1998. Duke University researchers Craig Stow and Mark Borsuk, based on their analysis of historic nitrogen data, indicate an **approximately** 30% reduction in **flow adjusted nitrogen concentration** between 1995 and 1998 (Overall methods and Kinston flow adjusted concentration trends in WRRI report 325e, July 2000. Most recent analysis of flow adjusted concentration at Ft. Barnwell through 2000 in draft form). Flow adjusted concentration is a useful metric for assessing change in watershed nutrient inputs as it essentially holds climate constant from year to year. However, there is reason to believe that the 30% estimate is high, since we think that the point sources had reduced about that much by 1998 (based on end-of-pipe, recently more than 30% - Brookhart, 2001) and the nonpoint sources have probably not reduced 30% yet. It should be noted that **actual nitrogen loading** does not follow the downward trend of flow adjusted concentration because of inter-annual differences in meteorology. The mean estimated change between 1991-1995 loads and 1998-2000 loads is an increase of 1.5%. In summary, between 1995 and 1998 there is an approximately 30% decline in flow adjusted concentration, while actual loading is relatively unchanged.

Flow adjusted concentration essentially removes the effects of stream flow from consideration; it is **not** equal to real loading. Flow adjusted concentration is estimated by determining the concentration at long-term median flow from annual regressions of log concentration versus log flow. Shown in Figure 4 are concentrations at median long-term flow with error bars representing plus and minus one standard error. Using the median long-term flow allows for relative, rather than absolute, comparison of flow adjusted nitrogen concentrations. Flow adjusted load produces a very similar looking result (personal communication with Craig Stow). When flow adjustment is included, concentration and load become fairly synonymous.

The mean estimated flow adjusted total nitrogen concentration for 1991-1995 and 1998-2000 is 1.35 mg/l and 0.95 mg/l, respectively. This indicates a 30% reduction in the nitrogen contributed by sources upstream of Fort Barnwell between 1995 and 1998. For some indication of uncertainty, the difference between the mean **1998-2000 upper** total nitrogen limit (again, based on one standard error – see standard error lines in Figure 4 above) and the mean **1991-1995 lower** total nitrogen limit is 20%. The difference between the mean **1998-2000 lower** total nitrogen limit and the mean **1991-1995 upper** total nitrogen limit is 38%. Similarly, the standard error on the percent reduction is .052. Thus, a 95%

confidence interval, which includes plus or minus two standard errors, is a 20% to 40% reduction in flow adjusted concentration between 1995 and 1998 (C. Stow, 2001).

Figure 4. Flow adjusted nitrogen concentration at Fort Barnwell (Stow and Borsuk, in draft). Fort Barnwell is located just below the confluence between the Neuse River and Contentnea Creek (between Kinston and New Bern in Figure 1). The top set of lines is total nitrogen with one standard error, the middle lines are nitrate, and the bottom lines are total Kjedahl nitrogen (NH3 plus organic N).



Again, there is reason to believe that the 30% estimate is high, since we think that the point sources had reduced about that much (more recently - Brookhart, 2001) and the nonpoint sources have most likely not reduced 30% yet. Another theory for decreased flow adjusted nitrogen is that the hurricanes of 1996 and 1999, and the high precipitation in early 1998 washed much of the accumulated nonpoint source nitrogen from the landscape, which effectively reduced loading during those and subsequent years.

Actual loading does not follow the downward trend of flow adjusted concentration because of inter-annual differences in meteorology. The mean estimated change between 1991-1995 loads and 1998-2000 loads is an increase of 1.5%. The uncertainty on this estimate is rather small; as determined above, it is 0% (no change) to a 3% increase. This can be seen in **Figure 5** where the top line is total nitrogen, the middle line is nitrate, and the bottom line is total Kjedahl nitrogen (NH3 plus organic N) (Standard error lines included but are small). Basically, 1998 and 1999 were high precipitation years, so total nitrogen load does not show the downward trend of flow adjusted nitrogen concentration. Again, the downward trend in actual load may become more evident with additional future years in the analysis.

In light of this uncertainty, **DWQ will examine a range of between 0% and 30%** as the change in nitrogen inputs between 1995 and 1998 (1991-1995 and 1998-2000); this range will be used in determining the TMDL reduction target. By using this range, change in actual load and flow adjusted concentration may be considered. A decline in actual nitrogen load may become evident with additional future years of analysis. Over time, if the flow adjusted concentration remained constant, then that would translate into a load reduction (C. Stow, 2001). DWQ will continue to collect and track nitrogen and flow data to determine how management efforts are affecting nitrogen loading.

Figure 5. Nitrogen load at Fort Barnwell (Stow and Borsuk, in draft)

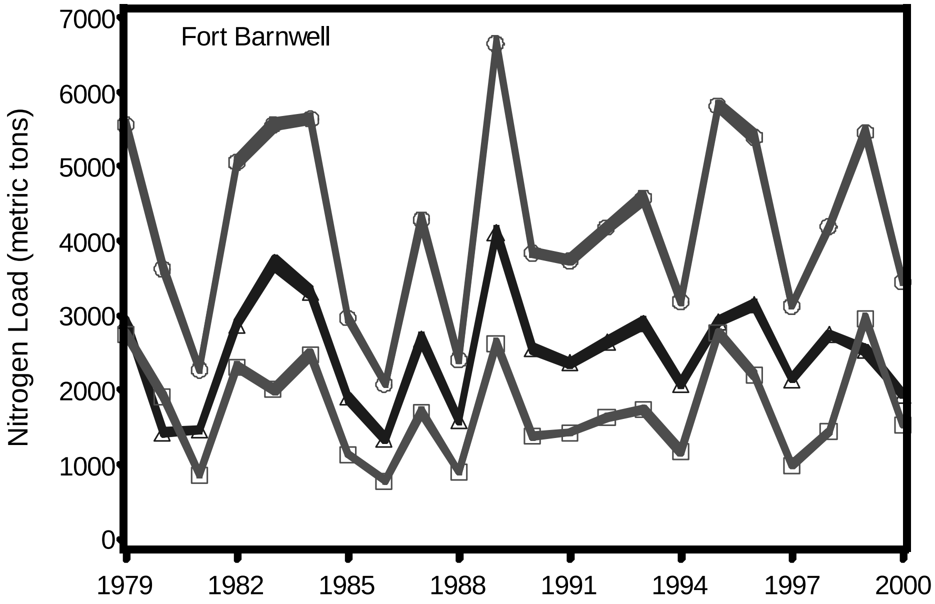
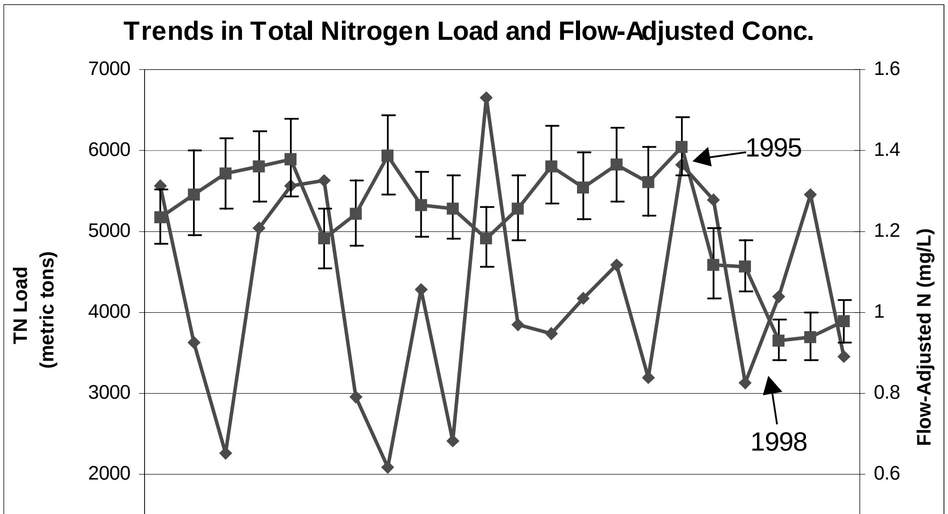


Figure 6. Combined Plot of Total Nitrogen Load (left scale) and Flow-Adjusted Conc. (right scale). One standard error bars shown on concentration. Error on load estimates is relatively minimal and not shown.



A word of caution is warranted here as reductions in nutrient inputs may take time to appear in measured (estimated) loading; this is due to year to year variability in precipitation and flow. With the background year to year variability, an instant 30% decrease in nitrogen inputs would take 4-5 years to be statistically discernable in nitrogen load at a 0.05 p-value. Since the reduction achieved is not likely to be instantaneous, these estimates should be considered as a lower bound on the time needed to see a change (Stow et al, 2001).

6.0 Model predictions

For TMDL determination, the primary prediction from each of the models is exceedance probability, or the expected frequency of exceeding the chlorophyll standard in a specified period. Neu-BERN determines this in a different way than the NEEM or WASP; that difference will be explained in the following sections. Also, Neu-BERN is able to provide predictions for 1991-1995 in addition to the 1998-2000, for which all models provide predictions. Finally, Neu-BERN is the only model that provides uncertainty analysis.

Predictions will be provided for Neu-BERN, NEEM and WASP. For Neu-BERN, there will be four sets of predictions: 1991-1995 with and without conservative assumptions, and 1998-2000 with and without conservative assumptions. The NEEM and WASP model only 1998-2000. The NEEM also models a scenario in the future, after the sediment layer has been exposed to reduced nutrient loading for fifteen years.

6.1 Neu-BERN predictions

The primary endpoint that will be considered in this assessment is the current use support criterion for chlorophyll-a, previously described as the 10/40 criterion. All predictions are for a depth of 1-meter (predictions corresponding to Weyerhaeuser-collected samples) when the dummy variable is included. Weyerhaeuser data were used as the reference values since they more closely approximate DWQ data, which estimate a photic zone composite (DWQ ambient chlorophyll data will be the primary data used in the future to assess 10/40 compliance, as is the case with all impairment decisions; other data will be considered, but there are no guarantees that it will be collected). The generation of this set of predictions is accomplished in Neu-BERN through the application of the Weyerhauser dummy variable as described earlier. This conservative assumption results in predicted chlorophyll values that are approximately 29% higher than would result if IMS data (surface grab samples) were chosen as the reference. Model results that do not include the dummy variable will be provided as well; these results are more akin to that of the NEEM and WASP, which do not apply a corrective factor to the observed data.

Predictions are provided for two model periods: 1/91-12/95 and 1/98-12/00. They are also provided for the baseline total nitrogen load (model run with observed loading) at Fort Barnwell, and for various percentages of load subtracted from baseline (reduction scenarios). The latter scenarios provide predictions for what chlorophyll levels during 1991-1995 and 1998-2000 **would have been** with lower nitrogen loading. Additionally, since the River and Lower use support areas do not show much impairment (have lower exceedance probabilities, see below) relative to the other areas, the reduction target scenarios focus on the Upper, Middle and Bend use support areas (see Figure 2).

The four categories of predictions that are displayed for each period and scenario include the average chlorophyll a concentration, the expected exceedance probability (expressed as a percentage – this is consistent for all probabilities in the assessment), the 90% confidence interval for the exceedance probability, and the confidence of compliance. Each of these will be explained further below. Predictions are shown on Tables 6-8 and Figures 5-10.

Average Chl a: This value represents the arithmetic mean predicted chlorophyll concentration for the specified model period.

Exceedance Probability: As previously mentioned, the model is fit so that the model predictions "go through the middle of the data". We may expect there to be error about this prediction, as evidenced by the difference between the observed data and the model prediction (model errors). In the regression framework, this unexplained variation is assumed to have a consistent normal distribution (in this case, after a log transformation). In other words, the model is fit to the mean of that distribution, but we may expect the residuals to vary in either direction (above and below) in a log normal fashion. This error is included to display the exceedance probability of the 40-ug/l chlorophyll standard. See Figure 7 on the following page for a graphical display of exceedance probability. It may be helpful to think of the x-axis as representing time for the data (small circles) and likelihood for the log normal distribution (curve). The exceedance probability is the area below the log normal distribution (curve) and above the 40-ug/l standard (higher horizontal line).

The exceedance probability is calculated for each day in a given model period; this has direct relevance to the chlorophyll-a standard. The reported exceedance probability for each model period is the average exceedance probability over all days. To comply with the 10/40 criterion, the average exceedance probability should be at or below 10%.

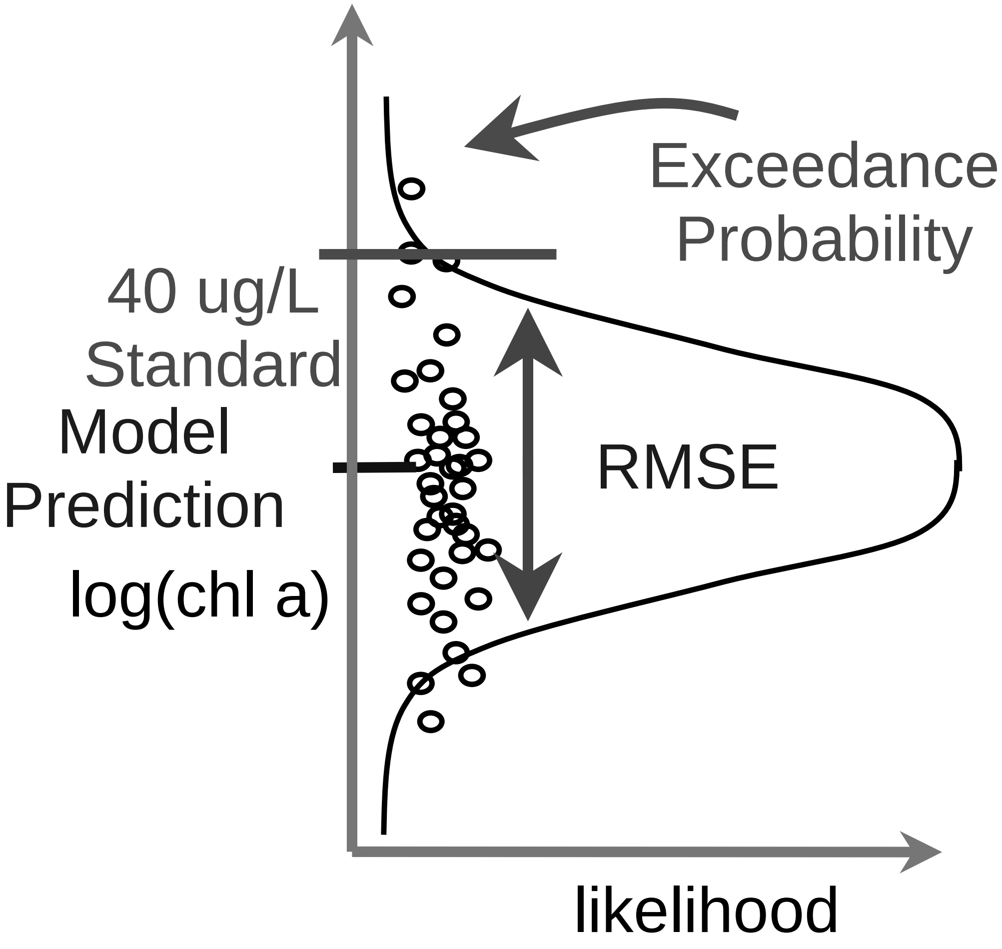
Finally, two necessary assumptions that must be met before this method for calculating the exceedance probability can be applied are equal error variance throughout the modeled time period, and normally distributed (after a log transformation) model residuals. Neu-BERN's calibration fit to the data met both of these assumptions.

90% Confidence Interval (for Exceedance Probability): This prediction is the result of uncertainty analysis on the coefficients of the predictor variables in the regression. There are many model combinations that will fit the observed data and thus each one must be evaluated to get an idea of the possible outcomes. The 90% confidence interval is the middle 90% (5% removed from each end) of the exceedance probability predictions from the many adequate model combinations. The single value for exceedance probability given in the table may be considered the "expected exceedance probability" since it uses the means of all the coefficients, and represents the middle value of the predictive distribution.

Confidence of Compliance: This prediction is based on the uncertainty analysis and the resulting 90% confidence interval. It examines the proportion of the predictive distribution that is below 10%, which again is the 10% part of the 10/40 criterion. Since the predictive distribution is not normally distributed and symmetric, the confidence of compliance is not intuitive from the 90% confidence interval.

One point to note is that the overall prediction uncertainty increases as you move away from mean calibration conditions. For example, the Middle use support area in 1991-1995 shows an increasing upper bound on the 90% confidence interval as the reduction percent increases (see Table 7). This may appear counterintuitive, but, again, this occurs because we have more uncertainty as we move away from calibration (baseline during 1994-1999) conditions. This additional uncertainty effectively reduces the confidence of compliance.

Figure 7.



6.1.1 Neu-BERN 1991-1995 Predictions (with the Dummy Variable)

This period is the closest to "critical conditions". Critical conditions may be defined as the period when chlorophyll standard exceedances in the estuary are most prevalent. Average 1991-1995 loading is also the baseline for phase I of the Neuse TMDL for total nitrogen. Water quality conditions during these years prompted development of the Neuse Rules (implementation strategy that is in progress).

Table 7, and Figures 7 and 8 below show Neu-BERN's predictions for 1991-1995 in tabular and graphical formats.

Note that the model predictions for exceedance probability and 90% confidence interval are rounded to the nearest whole number. The confidence of compliance is rounded to the nearest 10%. This rounding reflects the expected precision of the model predictions.

Table 7. Neu-BERN model predictions for 1991-1995 **with** the dummy variable. Baseline in this table is the model calibration run using the observed total nitrogen load at Fort Barnwell. –30 through -55% are reductions in total nitrogen from that baseline.

1/91 - 12/95				
	Upper Estuary (Stations 30-50)			
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline (0%)	17.9	11	7 - 14	30
-30%	15.7	9	7 - 12	80
-35%	15.6	9	6 - 11	80
-40%	15.0	8	6 - 11	80
-45%	15.0	8	5 - 11	80
-50%	14.9	8	5 - 11	80
-55%	14.4	8	5 - 11	90
	Middle Estuary (Stations 60-90)			
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline (0%)	22.5	14	10 - 18	5
-30%	20.2	12	9 - 15	20
-35%	19.5	11	8 - 14	30
-40%	18.9	11	7 - 14	40
-45%	18.9	10	7 - 14	50
-50%	18.6	10	6 - 16	50
-55%	18.4	10	6 - 16	60
	Bend of Estuary (Stations 100-120)			
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline (0%)	26.7	18	13 - 24	0
-30%	20.5	12	9 - 15	20
-35%	19.5	11	7 - 14	40
-40%	18.8	10	7 - 14	50
-45%	17.6	9	6 - 13	70
-50%	17.4	9	5 - 12	80
-55%	16.7	8	4 - 12	80

There are three important considerations regarding model results for the 1991-1995 period:

1. Neu-BERN was calibrated to data from 1994-1999, so the first three years of this period are outside of the model calibration period.
2. Weyerhaeuser data do not begin until April 1996, though the model adjusts predictions as they relate to Weyerhaeuser data to standardize all predictions to 1-meter depth.
3. DWQ detected a problem with its laboratory analysis of chlorophyll; consequently DWQ chlorophyll data were not used in this assessment. DWQ is hopeful that it can correct the past problems with chlorophyll analysis, so that its historic data is usable. This should be completed within several months. Additionally, the DWQ laboratory problems with chlorophyll analysis have been rectified and the current chlorophyll results are considered to be good.

Again, the overall prediction uncertainty increases as you move away from mean calibration conditions; bearing this in mind, these three considerations effectively lower the confidence of compliance estimates for 1991-1995 from what it might be if we had a more complete data set.

The predictions displayed in Figures 8 and 9 below are the chlorophyll levels that would have occurred during 1991-1995 with lower nutrient loading.

Figure 8. (90% confidence intervals included)

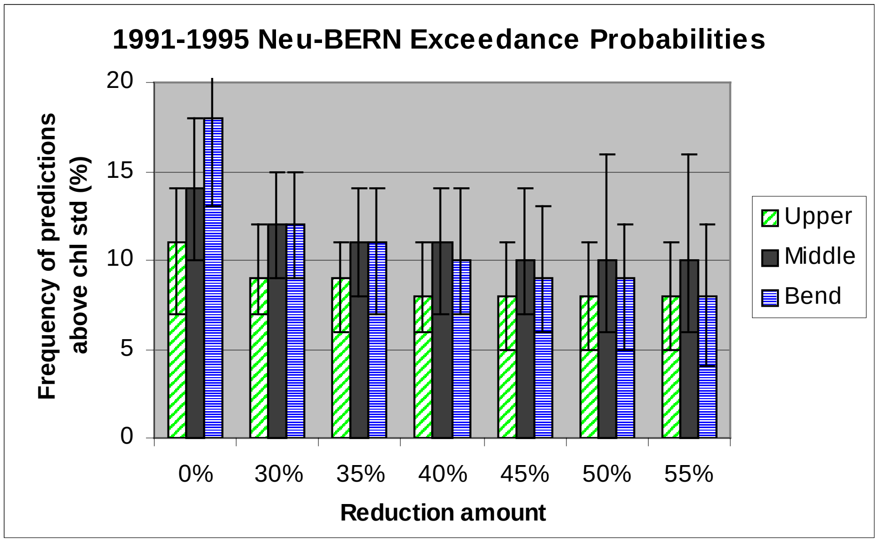
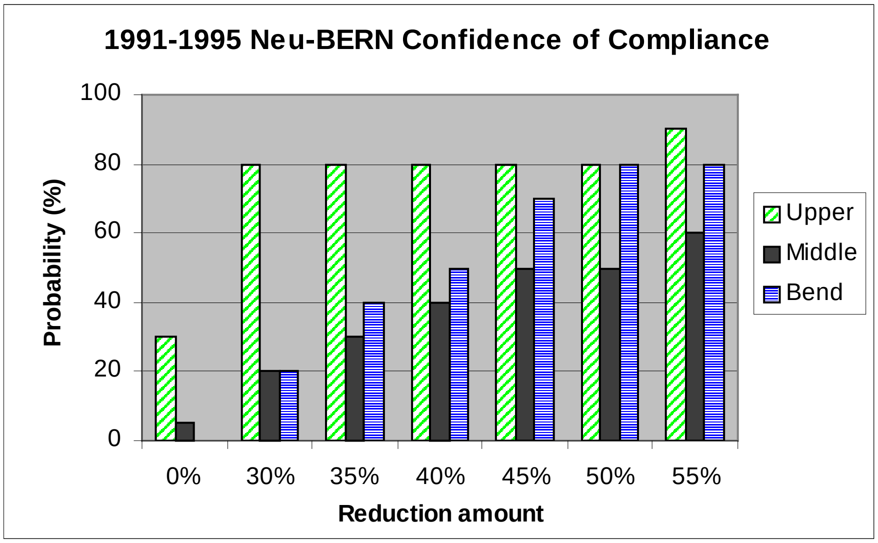


Figure 9.



6.1.2 Neu-BERN 1991-1995 Predictions without the Dummy Variable

Inclusion of the dummy variable explains additional chlorophyll variability, but it also produces results that may be considered overly "conservative" (more protective of water quality). This may result in difficulties for the following reasons:

(1) There is already a conservative assumption in Neu-BERN in that the model uses total nitrogen instead of a breakdown between inorganic and organic nitrogen. A greater decrease in inorganic nitrogen relative to organic nitrogen, as has occurred since the early 1990s, will cause the model to overpredict the required total nitrogen reduction to achieve the chlorophyll criterion. This occurs because algae are much more apt to use inorganic nitrogen than organic nitrogen, and the model does not recognize a relatively greater reduction in inorganic nitrogen (it only uses total nitrogen).

(2) To arrive at the final TMDL, an implicit or explicit margin of safety must be applied. The difference is that an implicit margin of safety is incorporated through conservative model assumptions, while an explicit margin of safety is added by considering the desired confidence of compliance and critical conditions. If the dummy variable is included, then it may be argued that the TMDL includes an implicit margin of safety. An explicit margin of safety more directly assesses the prediction uncertainty.

(3) Neither the NEEM nor WASP applies a corrective factor to the observed chlorophyll data, which is essentially the effect of the dummy variable. Consequently, Neu-BERN's results without the dummy variable are more comparable to the results from the NEEM and WASP.

In the final analysis, it seems most reasonable to provide results from Neu-BERN with and without the dummy variable. Then, the full range of results may be considered.

Table 8. Neu-BERN model predictions for 1991-1995 **without** the dummy variable. Baseline in this table is the model calibration run using the observed total nitrogen load at Fort Barnwell. –15, -30 and –45% are reductions in total nitrogen from that baseline.

1/91 - 12/95				
	Upper Estuary (Stations 30-50)			
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline (0%)	14.5	8	6 - 10	90
-15%	13.9	7	6 - 9	99
-30%	13.4	7	5 - 9	99
-45%	13.0	7	4 - 9	99
	Middle Estuary (Stations 60-90)			
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline (0%)	17.7	9	6 - 12	70
-15%	16.9	8	7 - 11	90
-30%	16.2	8	6 - 10	90
-45%	15.6	7	4 - 10	90
	Bend of Estuary (Stations 100-120)			
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline (0%)	21.5	13	9 - 16	10
-15%	18.9	10	8 - 12	50
-30%	16.7	8	6 - 10	90
-45%	14.9	6	4 - 9	99

6.1.3 Neu-BERN 1998-2000 Predictions (with the Dummy Variable)

The 1998-2000 period, according to the Stow and Borsuk analysis, represents a period where we may be seeing the effects of reduced nitrogen sources (see Section 5.0). With limitations, this allows us to consider the affect of less nitrogen entering the estuary on estuary chlorophyll levels. Table 9 and 10 display Neu-BERN's predictions for 1998-2000.

Table 9. Neu-BERN model predictions for 1998-2000 **with** the dummy variable. Baseline in this table is the model run using the 1998-2000 observed total nitrogen load at Fort Barnwell. -5% through -30% are reductions in total nitrogen from that baseline.

1/98 - 12/00				
	Upper Estuary (Stations 30-50)			
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline (0%)	13.6	7	5 - 9	99
-5%	13.4	7	5 - 9	99
-10%	13.2	7	5 - 9	99
-15%	13	7	5 - 9	99
-20%	12.6	6	4 - 8	99
-25%	12.7	6	4 - 9	99
-30%	12.4	6	4 - 9	99
	Middle Estuary (Stations 60-90)			
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline (0%)	19.2	11	8 - 14	20
-5%	18.7	11	8 - 13	40
-10%	18.5	11	8 - 14	40
-15%	18.6	11	8 - 14	40
-20%	18.3	10	7 - 14	50
-25%	18.1	10	7 - 14	50
-30%	17.9	10	6 - 15	50
	Bend of Estuary (St. 100-120)			
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline (0%)	20.6	12	9 - 15	10
-5%	19.7	11	8 - 14	30
-10%	19.1	10	7 - 15	50
-15%	19	10	7 - 15	50
-20%	17.8	9	6 - 13	70
-25%	17.7	9	6 - 13	70
-30%	17.1	8	5 - 13	80

When considering percentage reductions for 1998-2000, we cannot just add this percentage reduction to the estimated percentage drop between 1995-1998 to reference the 1995 baseline load from the first phase of the TMDL (see Section 5.0). Instead, we must first use the percentage reduction thought to have occurred during 1995-1998 to reduce the 1995 baseline load, and then take the 1998-2000 percentage reduction from that smaller load. **In this manner, we can use the 1998-2000 reduction and 1995-1998 change to reference the reduction necessary from the phase I TMDL 1995 baseline load.**

Figures 10 and 11 below show Neu-BERN's predictions for 1998-2000 in graphical format Again, the predictions displayed are the chlorophyll levels that would have occurred during 1998-2000 with lower nutrient loading.

Figure 10. (90% confidence intervals included)

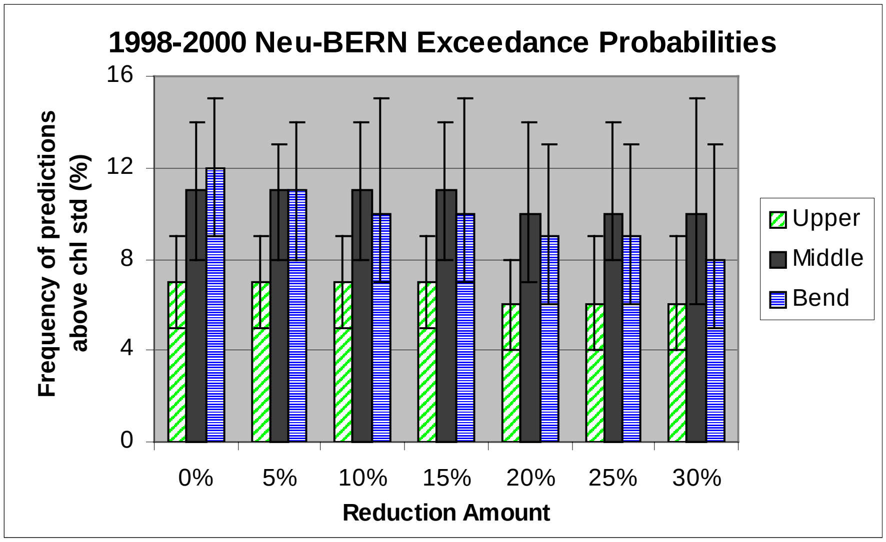
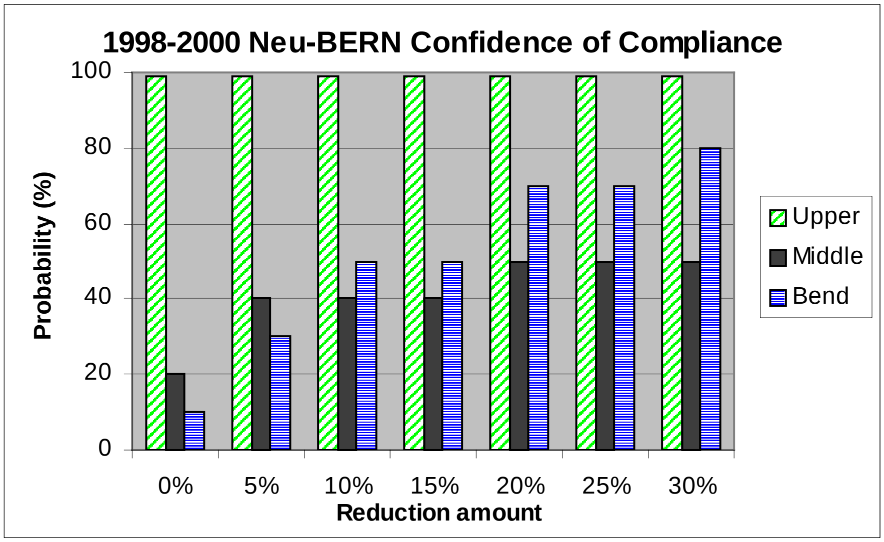


Figure 11.



6.1.4 Neu-BERN 1998-2000 Predictions without the Dummy Variable

As discussed in Section 6.1.2 (page 23), results from Neu-BERN are provided with and without the dummy variable.

Table 10. Neu-BERN model predictions for 1998-2000 **without** the dummy variable. Baseline in this table is the model run using the 1998-2000 observed total nitrogen load at Fort Barnwell. -15%, -30% and –45% are reductions in total nitrogen from that baseline.

1/98 - 12/99				
	Upper Estuary	**Stations 30-50**		
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline	11.9	5.9	4 - 8	99
-15%	11.5	5.6	4 - 8	99
-30%	11.1	5.3	3 - 8	99
-45%	10.8	5.0	3 - 8	99
	Middle Estuary	**Stations 60-90**		
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline	15	7.3	5 - 9	99
-15%	14.6	6.9	5 - 9	99
-30%	14.3	6.6	4 - 10	95
-45%	13.9	6.3	3 - 11	90
	Bend of Estuary	**Stations 100-120**		
TN Reduction	Avg. Chl a (ug/L)	Exceedances (%)	90% C.I.	Conf. Compl. (%)
Baseline	15.8	7.2	5 - 9	99
-15%	14.4	5.9	4 - 8	99
-30%	13.2	4.9	3 - 8	99
-45%	12.1	4.0	2 - 7	99

6.1.5 Neu-BERN Reduction Target

Listed below are several factors to consider when determining the preliminary nitrogen load reduction target (margin of safety added later).

- 50% probability of compliance (confidence of compliance – see Section 5.1) was selected as the initial goal because this is the point at which the "expected exceedance" reaches 10%. More confidence may be added when considering the margin of safety.

- The probabilities of compliance are for immediate reductions in chlorophyll; **no time is allowed for reduction of the estuary sediment load**. The estuary sediment portion of the total nitrogen load may be substantial. This load may change as nutrient reduction occurs, and loading of organic matter and nutrients to the sediment decreases.
- The confidence of compliance is largely a function of the uncertainty in the model. Model uncertainty increases when it is applied to conditions that are different from calibration conditions (e.g. at higher nutrient reductions). This may be seen when the 90% confidence intervals widen, and the confidence of compliance remains flat or even decrease with higher nutrient reductions. The observed level of impairment during that time may play an equal or lesser role than uncertainty in the calculation of confidence of compliance.

Worst case scenarios for compliance

This section looks at the required nitrogen reduction during each of the modeled periods. The preliminary estimated reduction is determined by ensuring that each area of the estuary complies with the 10/40 criterion. To achieve compliance, each area should have an exceedance probability of 10% or less, and a confidence of compliance probability of 50% or greater. To simplify this procedure, only the area with the highest exceedance probability will be reviewed. In this manner, all of the areas will be ensured of complying with the 10/40 criterion.

1991-1995 Critical Conditions - Using results **with** the dummy variable

- 40% reduction in total nitrogen load is predicted to yield a 40% probability of complying (confidence of compliance) with the 10/40 criterion in the Middle area.
- 45% reduction in total nitrogen load is predicted to yield a 50% probability of complying with the 10/40 criterion in the Middle area.
- 50% reduction in total nitrogen load is predicted to yield a 50% probability of complying with the 10/40 criterion in the Middle area.

1991-1995 Critical Conditions - Using results **without** the dummy variable

- 15% reduction in total nitrogen load is predicted to yield a 50% probability of complying (confidence of compliance) with the 10/40 criterion in the Bend area.
- 30% reduction in total nitrogen load is predicted to yield a 90% probability of complying with the 10/40 criterion in the Middle and Bend areas.
- 45% reduction in total nitrogen load is predicted to yield a 90% probability of complying with the 10/40 criterion in the Middle area.

According to the reduction target guidelines above, the preliminary estimate of needed reduction from 1991-1995 loading ranges from 15% (without dummy variable) to 45% (with dummy variable).

1998-2000 Current Conditions - Using results **with** the dummy variable

- 15% reduction in total nitrogen load is predicted to yield a 40% probability of complying (confidence of compliance) with the 10/40 criterion in the Middle area.
- 20% reduction in total nitrogen load is predicted to yield a 50% probability of complying with the 10/40 criterion in the Middle area.
- 25% reduction in total nitrogen load is predicted to yield a 50% probability of complying with the 10/40 criterion in Middle area.

1998-2000 Current Conditions - Using results **without** the dummy variable

- 0% reduction in total nitrogen load is predicted to yield a 99% probability of complying (confidence of compliance) with the 10/40 criterion in all areas.
- 15% reduction in total nitrogen load is predicted to yield a 99% probability of complying with the 10/40 criterion in all areas.
- 30% reduction in total nitrogen load is predicted to yield a 95% probability of complying with the 10/40 criterion in Middle area.

According to the reduction target guidelines above, the preliminary estimate of needed reduction from 1998-2000 loading ranges from 0 (without dummy variable) to 20% (with dummy variable).

The 0-20% reduction suggested in 1998-2000 would be in addition to the reduction that has been achieved between 1995 and 1998 (see Section 6.1.3 below Table 9). For instance, to reference 1995 baseline load from the first phase of the TMDL you must take X% (trend analysis estimate) from 100, and then take 0-20% from 100 – X. We estimate that X is between 0 and 30% (see Section 5.0). So if we estimate that X is 0% and the needed 1998-2000 reduction is 0%, the estimate of total reduction is 0%. At the other extreme, if we estimate that X is 30% and the 1998-2000 reduction needed is 20%, the estimate of total reduction is 44% (20% from 70 equals 56). In summary, the preliminary range for necessary nitrogen reduction using Neu-BERN 1998-2000 and 1995-1998 change is 0-44%.

Seasonality

This assessment considered seasonality in the loading through the simulation of daily watershed loadings over all seasons based on historic precipitation records. The evaluation of nutrient impacts in the estuary was considered for conditions representing the response to long term, cumulative nutrient loading. The TMDL will be presented as an annual average load consistent with the type of impairment (eutrophication) and the waterbody type (estuary). Reduction of the average annual load is expected to result in achievement of water quality standards.

6.1.6 Neu-BERN Reduction Target Summary

To summarize, based on the 1991-1995 model period and the 1998-2000 model period with consideration for load reduction achieved between 1995 and 1998, the preliminary results indicate that the reduction needed from 1995 loads, based on Neu-BERN results **alone,** ranges from 0 to 45%. When the dummy variable is included, Neu-BERN estimates a needed reduction of 20-45%, while if the dummy variable is omitted, Neu-BERN estimates that anywhere from zero to 15% reduction is needed. However, a margin of safety must still be considered in these cases.

Margin of Safety for Neu-BERN Reduction Target

When using the dummy variable, there are enough conservative model assumptions (use of dummy variable which increases IMS chlorophyll data by 17-41% even though it is the more abundant data set, total nitrogen instead of separate inorganic and organic nitrogen) to conclude that a margin of safety has been implicitly included. The question then becomes, what is the final reduction recommendation using these results when a range of 20%-45% is possible? DWQ will leave it as a range once again, but somewhere towards the upper half is probably the most likely result, since it is likely that some reduction in nitrogen inputs occurred between 1995 and 1998.

Without the dummy variable an explicit margin of safety must be added. A 15 percent reduction during 1991-1995 appears to be inadequate as it provides only a 50% confidence of compliance during critical conditions. The next available model result is a 30% reduction, and that provides a 90% confidence of compliance. If this is accepted as the result for Neu-BERN without the dummy variable, then it breaks down into a 15% model reduction (to meet minimum chlorophyll criterion) and a 15% explicit margin of safety. This is a substantial margin of safety. Additionally, this margin of safety is applied on top of critical conditions results.

6.2 NEEM predictions

As with Neu-BERN, the NEEM will consider the 10/40 criterion. All predictions are for the top two layers, which range from the water surface to about 1.5 meters depth.

Because the NEEM could not achieve log normal model residuals, nor equal variance through the range of chlorophyll levels, the model developers could not apply the same exceedance probability method as was employed by Neu-BERN. Thus for the NEEM, exceedance probability simply means the frequency of model chlorophyll predictions above the 40 ug/l standard; no consideration could be given to the spread of observed data about the model predictions. Model predictions were taken on a daily basis from the top two layers of each segment in a use support area. The exceedance probability is the proportion of these predictions that are over 40 ug/l.

Also, because of the large number of calibration parameters in the NEEM, it is not feasible to do uncertainty analysis. This means that we cannot derive the confidence intervals or confidence of compliance estimates that Neu-BERN provided. An inability to provide uncertainty analysis is common to nearly all complex, deterministic models because of long model run times and the relatively much larger number of model parameters compared to mechanistically simple models like Neu-BERN.

Predictions are provided for the period covering 1/98-12/00, and for seven scenarios: the baseline total nitrogen load (observed load), and reductions every 5% from 5% through 30% from the baseline. The NEEM and WASP differentiate between inorganic and organic nitrogen, so to achieve the total nitrogen reductions, a rationale for how the various forms are reduced must be determined. Since we expect that most management activities will preferentially reduce inorganic nitrogen, the models used a 2:1 efficiency ratio, which says that two thirds of the total nitrogen reduction would come from inorganic nitrogen. For example, based on an initial nitrogen composition of 65% inorganic nitrogen and 35% organic nitrogen (based on daily measurements of nitrogen concentration and flow at Fort Barnwell during 1/98 –12/00), a 10% total nitrogen reduction would be captured by the NEEM and WASP with a 12% inorganic reduction and a 6% organic reduction. The Neuse modeling group, consisting of researchers and scientists from academia, private industry, and state and federal government, reached consensus on the composition of inorganic and organic nitrogen following reductions, based on best professional judgement and available data.

Both the NEEM and EPA's EFDC/WASP application focus on 1998-2000. Both of those models require additional data (principally downstream water elevation) that were not collected before June 1997.

Additionally, the NEEM has a sediment module that simulates evolution of the sediment layer (diagenesis) following nutrient reductions. To examine the effects of sediment diagenesis, model predictions will be provided for years 15 through 17 following reductions in nitrogen load. In other words, the model was run five consecutive times (three years per run) with the specified, reduced loading. During this period, organic loading to the sediment decreased and the sediment layer was altered. The NEEM was then run with new sediment conditions for the three-year model, and with the same load reductions, to estimate the impact of changes in sediment quality on water quality.

For those that are interested, a description of the sediment diagenesis sub-model follows: The sediment diagenesis sub-model is used to predict the fluxes of organic matter, inorganic nutrients, sulfide, and dissolved oxygen between the sediment layer and the water column. Settleable organic matter in the water column accumulates in the sediment layer. This material is assumed to be composed of labile and refractory fractions. The sediment organic matter degrades in a first order fashion over monthly time scales for the labile fraction, and yearly time scales for the refractory fraction. The rate of sediment organic matter oxidation is stoichiometrically coupled first to reduction of dissolved oxygen, then to nitrate, if the dissolved oxygen is insufficient in the bottom waters, and then finally to sulfate, if both DO and nitrate are insufficient. The maximum rate of nitrate reduction to elemental nitrogen (denitrification) is calculated using a second order formulation dependent on the bottom water nitrate concentration and the sediment layer organic matter concentration. Sediment organic matter decomposition is also assumed to produce fluxes to the water column of ammonia and phosphate according to the specified carbon, nitrogen and phosphorus composition of the sediment organic matter.

6.2.1 NEEM 1998-2000 Predictions

This is the only period that will be modeled by the NEEM because it requires data, mainly downstream water level, that are unavailable in earlier years. Again, this period follows initiation of nitrogen load reductions through the Neuse Rules, so to reference the 1995 baseline load from the first phase of the TMDL, the estimated reduction achieved between 1995 and 1998 must be included as shown in Section 6.1.5.

The NEEM predictions may be seen on the following pages in Table 11 and Figures 12 and 13.

Table 11. NEEM model predictions for 1998-2000. 0% in this table is the model run using the 1998-2000 observed total nitrogen load at Fort Barnwell (baseline). -5% through -30% are reductions in total nitrogen from that baseline.

Simulation Period = 1/98 - 12/00				
Reduction	**Upper Estuary (Segments 20-25)**			
	Year 0 Sediments		Year 15 Sediments	
	Avg. Chl a (ug/L)	Exceedances (%)	Avg. Chl a (ug/L)	Exceedances (%)
0%	13.10	10.3%	13.10	10.3%
-5%	12.71	9.4%	12.75	9.6%
-10%	12.31	8.5%	12.38	8.7%
-15%	11.88	7.4%	11.99	7.6%
-20%	11.43	6.6%	11.58	6.7%
-25%	10.97	5.6%	11.14	5.8%
-30%	10.48	4.7%	10.68	4.9%
Reduction	**Middle Estuary (Segments 33-38)**			
	Year 0 Sediments		Year 15 Sediments	
	Avg. Chl a (ug/L)	Exceedances (%)	Avg. Chl a (ug/L)	Exceedances (%)
0%	20.08	11.4%	20.11	11.8%
-5%	19.59	9.4%	19.67	9.9%
-10%	19.09	7.7%	19.21	8.1%
-15%	18.56	6.3%	18.72	6.6%
-20%	18.01	5.1%	18.22	5.4%
-25%	17.44	4.0%	17.68	4.2%
-30%	16.84	3.1%	17.12	3.3%
Reduction	**Bend of Estuary (Segments 41-47)**			
	Year 0 Sediments		Year 15 Sediments	
	Avg. Chl a (ug/L)	Exceedances (%)	Avg. Chl a (ug/L)	Exceedances (%)
0%	21.86	9.8%	21.90	10.0%
-5%	21.43	8.8%	21.50	8.9%
-10%	20.98	7.6%	21.09	7.8%
-15%	20.51	6.1%	20.66	6.2%
-20%	20.01	5.1%	20.20	5.3%
-25%	19.50	4.4%	19.71	4.5%
-30%	18.96	3.7%	19.20	3.8%

Figures 12 and 13 below show the NEEM's predictions for 1998-2000 in graphical format. Again, the predictions displayed are the chlorophyll levels that would have occurred during 1998-2000 with lower nutrient loading.

Figure 12.

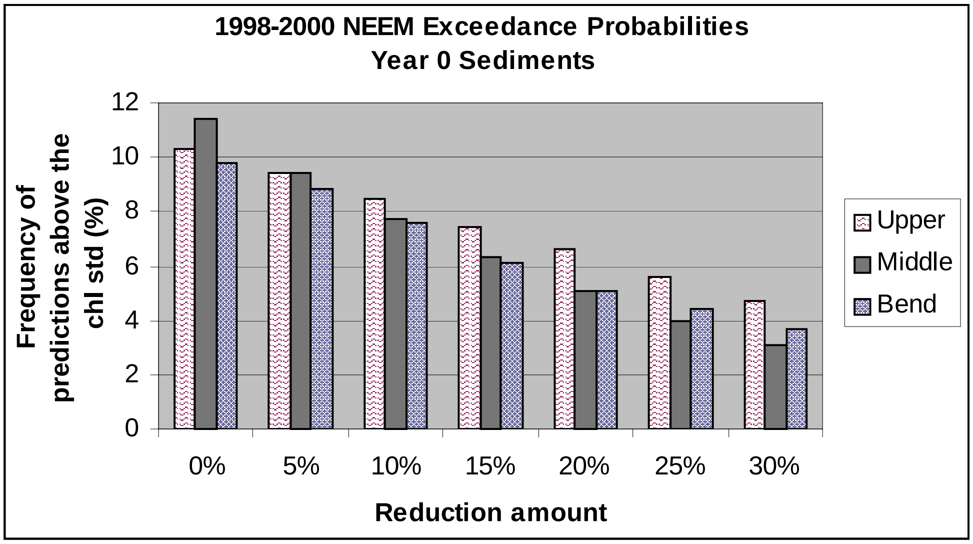
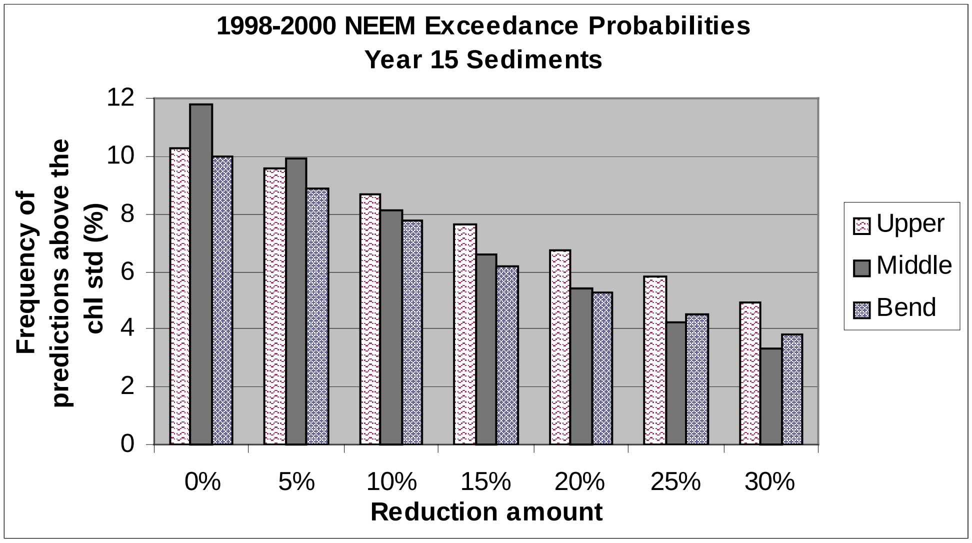


Figure 13.



6.2.2 NEEM Reduction Target

Listed below is the guideline DWQ used to determine the nitrogen load reduction target based on NEEM predictions.

- The exceedance probability should be equal to or less than 10% per EPA guidance.

Worst case scenario for compliance

The NEEM predicts that only the Middle use support area has an exceedance probability above 10%. The calibration run, or baseline loading (no load reduction) with Year 0 sediments, has an exceedance probability of 11.4%. Considering Year 15 sediment scenarios, the baseline exceedance probability is 11.8%. The NEEM predicts that, in the long term, sediment diagenesis will not improve chlorophyll levels. In fact, chlorophyll levels are predicted to increase slightly in most instances. The NEEM predicts that the scenario of reduced denitrification occurs (see Section 3.0).

To reduce the exceedance probability to 10% in both the Year 0 and the Year 15 Sediment scenarios, a 5% reduction is needed. Because uncertainty analysis was not included, we cannot say anything specific about confidence of compliance. It is certain, however, that the uncertainty associated with the predictions is large.

Seasonality

This assessment considered seasonality in the loading through the simulation of daily watershed loading over all seasons based on historic precipitation records. The evaluation of nutrient impacts in the estuary was considered for the conditions representing the response to long term, cumulative nutrient loading. The TMDL will be presented as an annual average load consistent with the type of impairment (eutrophication) and the waterbody type (estuary). Reduction of the average annual load is expected to result in achievement of water quality standards.

6.2.3 NEEM Reduction Target Summary

The preliminary estimated total nitrogen reduction required to meet the 10/40 criterion in 1998-2000 using the NEEM is 5%. This 5% reduction would be in addition to the reduction that has been achieved between 1995 and 1998. For instance, to reference the 1995 baseline load from the first phase of the TMDL you must take X% (trend analysis estimate) from 100, and then take 5% from 100 – X. We estimate that X is between 0 and 30% (see Section 5.0); in this case, the preliminary estimate of total nitrogen reduction needed from the 1995 baseline load from the first phase of the TMDL is 5 to 33% (5% from 70 to 100 equals 67 to 95). DWQ will leave this as a range, but somewhere towards the upper half is probably the most likely result, since it is likely that some reduction in nitrogen inputs occurred between 1995 and 1998.

Margin of Safety for NEEM Reduction Target

In setting the margin of safety for the NEEM, it is necessary to examine the exceedance probabilities beyond the 5% reduction for the Middle estuary. For example, in the Year 15 sediment scenario, a 5% reduction gives a 9.9% exceedance probability, and a 10% reduction gives an 8.1% exceedance probability. With Year 0 sediments, a 5% reduction gives a 9.4% exceedance probability, and a 10% reduction gives a 7.7% exceedance probability. In the

Upper estuary, a 10% reduction gives exceedance probabilities of 8.5% and 8.7% in the Year 0 and Year 15 sediments, respectively.

Based on the above predictions, DWQ selects 10% as the estimated reduction required to meet the 10/40 criterion including a margin of safety in 1998-2000 using the NEEM. The 10% reduction suggested in 1998-2000 would be in addition to the reduction that has been achieved between 1995 and 1998. For instance, to reference the baseline 1991-1995 load from the first phase of the TMDL you must take X% (trend analysis estimate) from 100, and then take 10% from 100 – X. We estimate that X is between 0 and 30% (see Section 5.0); in this case the estimate of total reduction from the 1995 baseline load from the first phase of the TMDL is 10 to 36% (10% from 70-100 is 67 to 95). Thus by referencing percent reduction in terms of the 1991-1995 baseline load, the explicit margin of safety from the NEEM is 3-5% (36% - 33% and 10% - 5%).

6.3 WASP Predictions

As with Neu-BERN and the NEEM, WASP will consider the reduction required to meet the 10/40 criterion. Predictions are garnered on a daily basis from the top two layers of each segment in a use support area. The exceedance probability for WASP is the proportion of those predictions that are over 40 ug/l. Predictions are provided for the period covering 1/98-12/00, and for five scenarios: the baseline total nitrogen load (observed load), and reductions every 5% from 5% through 20% from the baseline.

The WASP and NEEM differentiate between inorganic and organic nitrogen, so to achieve the total nitrogen reductions, a rationale for how the various forms are reduced must be determined. Since we expect that most management activities will preferentially reduce inorganic nitrogen, the models used a 2:1 efficiency ratio, which says that two thirds of the total nitrogen reduction would come from inorganic nitrogen. For example, based on an initial nitrogen composition of 65% inorganic nitrogen and 35% organic nitrogen (based on daily measurements of nitrogen concentration and flow at Fort Barnwell during 1/98 – 12/00), a 10% total nitrogen reduction would be captured by the NEEM and WASP with a 12% inorganic reduction and a 6% organic reduction. The Neuse modeling group, consisting of researchers and scientists from academia, private industry, and state and federal government, reached consensus on the composition of inorganic and organic nitrogen following reductions, based on best professional judgement and available data.

A different aspect of the WASP model is that it includes side channel data from North Carolina State University. Those data were not available during model development of the NEEM and Neu-BERN.

EPA examined exceedance probability in additional areas besides the designated use support areas by dividing the bend and middle areas numerous times. Results are only provided for the upper, middle and bend areas since these additional divisions do not change the results. EPA's modeling report is available electronically upon request.

Uncertainty analysis was not performed with WASP, so prediction confidence intervals and the confidence of compliance metric are not available.

Table 12. WASP model predictions for 1998-2000. Baseline in this table is the model using the 1998-2000 observed total nitrogen load at Fort Barnwell. –5% through –20% are reductions in total nitrogen from that baseline.

Simulation Period = 1/98 - 12/00		
	Upper Estuary	
Reduction	Avg. Chl a (ug/L)	Exceedances (%)
Baseline	13.53	2.42
-5%	13.19	2.17
-10%	12.87	1.42
-15%	12.50	0.99
-20%	12.11	0.63
	Middle Estuary	
Reduction	Avg. Chl a (ug/L)	Exceedances (%)
Baseline	14.15	0.14
-5%	13.76	0.07
-10%	13.47	0.04
-15%	13.09	0.03
-20%	12.68	0.00
	Upper Estuary	
Reduction	Avg. Chl a (ug/L)	Exceedances (%)
Baseline	14.17	0.00
-5%	13.87	0.00
-10%	13.57	0.00
-15%	13.23	0.00
-20%	12.88	0.00

6.3.1 WASP Reduction Target

Listed below is the guideline DWQ used to determine the nitrogen load reduction target based on WASP predictions.

- The exceedance probability should be equal to or less than 10% per EPA guidance.

Worst case scenario for compliance

WASP predicts that no use support area in the estuary has an exceedance probability above 10%. Accordingly, the preliminary estimate of nitrogen reduction needed is 0%.

This provides indication that the assumptions used in applying the NEEM and Neu-BERN to produce exceedance probability predictions were, to some degree, “conservative”.

Seasonality

This assessment considered seasonality in the loading through the simulation of daily watershed loading over all seasons based on historic precipitation records. The evaluation of nutrient impacts in the estuary was considered for the conditions representing the response to long term, cumulative nutrient loading. The TMDL will be presented as an annual average load consistent with the type of impairment (eutrophication) and the waterbody type (estuary). Reduction of the average annual load is expected to result in achievement of water quality standards.

6.3.2 WASP Reduction Target Summary

The preliminary estimated total nitrogen reduction required to meet the 10/40 criterion in 1998-2000 using WASP is 0%. The 0% reduction would be in addition to the reduction that has been achieved between 1995 and 1998. For instance, to reference the 1995 baseline load from the first phase of the TMDL you must take X% (trend analysis estimate) from 100, and then take 0% from 100 – X. We estimate that X is between 0 and 30% (see Section 5.0); in this case the preliminary estimate of total nitrogen reduction needed from the 1995 baseline load is 0 to 30% (0-30% from 100 equals 70-100).

Margin of safety for WASP Reduction Target

Since the highest predicted exceedance probability for WASP is less than 3%, DWQ assumes that a margin of safety has been included for this period.

EPA, in their modeling report to DWQ, which is available to the public electronically upon request, maintains that 1995-1996 is the critical period for chlorophyll standard exceedances. However, since this period was not modeled using WASP, it cannot be considered in the array of model results. It should be noted that DWQ has model predictions from Neu-BERN and observed data from 1994 through 1999 (calibration period for Neu-BERN). 1995-1996 does not stand out as an anomalously impaired period when using Neu-BERN and observed, mid-channel data. Regardless of this discrepancy, the estuary will need to meet its designated uses (including the chlorophyll criterion) in the coming years to ensure that 1998-2000 were not just favorable years in terms of chlorophyll standard exceedances.

6.4 Differences between the predictions by the NEEM, WASP and Neu-BERN

The predicted chlorophyll exceedance probabilities by the NEEM, WASP and Neu-BERN, and consequently the nutrient reduction (TMDL), differ in magnitude.

The primary differences between the three models are:

(1) Neu-BERN includes model residuals in the exceedance probability while the NEEM and WASP do not (see Section 5.1, p. 11). As previously stated, significant effort was made to include the model residuals in the exceedance probability predictions by the NEEM. It could not be done, however, because the calibrated model did not satisfy the requirements of equal error variance throughout the time period and log normal model

residuals. It is unknown how the preliminary estimated reduction from the NEEM would change if this type of analysis were included.

(2) The NEEM has a sediment diagenesis model that simulates the impacts of sediment diagenesis, whereas Neu-BERN and WASP do not have that capability. Neu-BERN's predictions are for immediate effects of reduction during the model periods. WASP uses a constant flux of nutrients from the sediment for all years. Based on the NEEM results, since the reduction difference is small between the Year 0 and the Year 15 sediment cases and the uncertainty in these predictions is very high, we cannot predict how the reduction estimate from Neu-BERN or WASP would change if time were allowed for sediment diagenesis. This is another instance where adaptive management, through continued monitoring of estuary sediment load, is warranted.

(3) Only Neu-BERN is able to consider the 1991-1995 period (NEEM and WASP can only model 1998-2000 since downstream water level recorder was not in place until then), which DWQ considers to be critical conditions. Comparing the Neu-BERN reductions from 1991-1995 with the Neu-BERN reductions from 1998-2000, consideration of critical conditions results in required reductions that are in the uppermost estimates of the 1998-2000 ranges.

(4) The NEEM and WASP use inorganic and organic nitrogen, and more of the total nitrogen reduction is made in inorganic nitrogen (2:1 efficiency ratio, see Section 5.3). Neu-BERN does not distinguish between inorganic and organic nitrogen, it simply uses total nitrogen. Inorganic nitrogen is much more available for uptake by algae, and so further reduction in it would reduce predicted chlorophyll levels. The result is that Neu-BERN's predictions are somewhat high by using just total nitrogen.

(5) Neu-BERN may index the chlorophyll observations to Weyerhauser data, which increase the IMS data by 30% on average. This is the aforementioned dummy variable. The Weyerhaeuser depth index (dummy variable) used in Neu-BERN is a conservative model assumption that increases its recommended reduction relative to the NEEM and WASP.

(6) WASP uses side channel data collected by NCSU. The side channel data collected and analyzed by NCSU appears to be somewhat higher than the ModMon mid channel data, though this is based on limited (1.5 years) comparison. Also, this relationship is not clear because there are no overlapping sites where all institutions sample or NCSU mid-channel sites. This allows for the possibility that differences in collection, preparation or analysis (there are many valid ways to perform each of these) may account for the apparent difference in chlorophyll levels. DWQ had an interest in analyzing and incorporating the side channel data, however those data were not available during the time of model development of the NEEM and Neu-BERN.

(7) WASP models in three dimensions, as opposed to two for the NEEM and one for Neu-BERN. The third dimension (across the estuary) does not appear to be significant in terms of chlorophyll exceedances as the results from WASP do not vary in that direction. EPA divided the estuary into many more sections in the middle and bend areas, but the results did not change.

The net effect of the model differences is that we would expect a lower reduction from Neu-BERN if inorganic and organic nitrogen were modeled individually, and a higher reduction from the NEEM and WASP if critical conditions were modeled. It is difficult to quantitatively describe how these differences would affect the results from the three models. One option is to qualitatively consider them when viewing all of the results.

7.0 Reduction Target

Monitoring Data

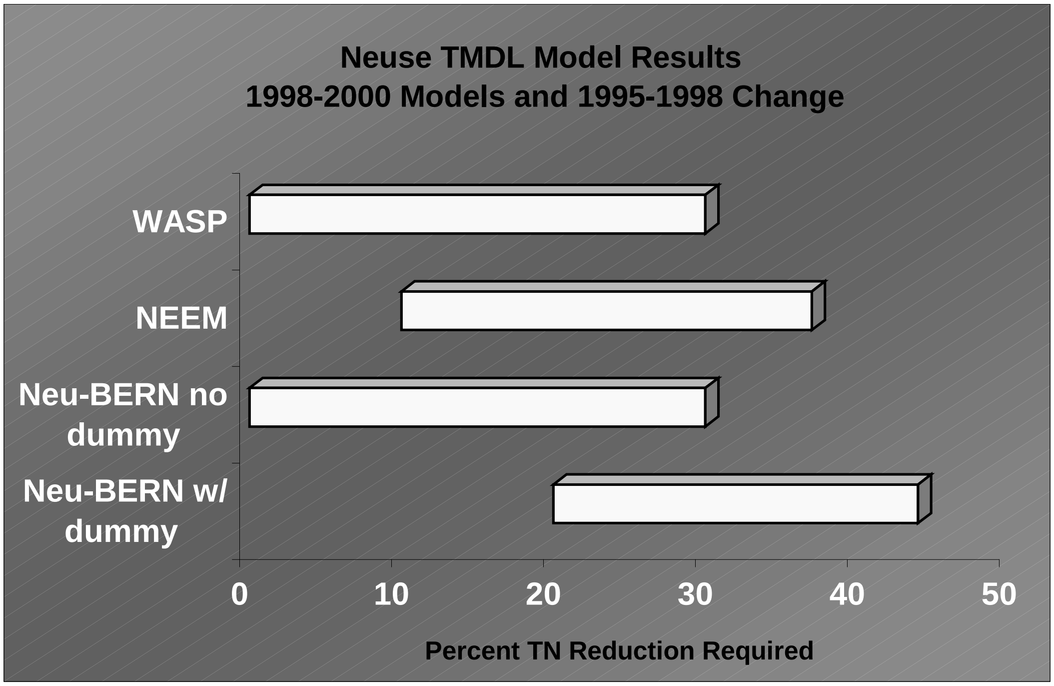
A **key recognition** that has not been acknowledged to this point is that during 1998-2000, data from each of the monitoring stations indicate that standard exceedances occur at a frequency of 10% or lower. EPA, in their modeling report, states that between 1998 and 2000, exceedances of the chlorophyll standard using UNC-IMS and NCSU data comprise less than 10% of the sample population at each station, and that based on these years, the estuary is meeting this designated use.

This has occurred during the earlier stages of implementing the Neuse Rules. Further reductions from the Neuse Rules and other nitrogen management efforts will be realized in 2001 and beyond. Full implementation of the Neuse Rules is scheduled for 2003. Given these positive recent results, it seems reasonable to stay the course with the current management effort, especially if the modeling agrees.

Modeling Results

For recent, non-critical conditions (1998-2000) the estimated reductions may be seen in Figure 14 below.

Figure 14.



Only Neu-BERN models critical conditions (1991-1995) and that modeling estimates a 30-45% reduction is needed to comply with the chlorophyll criterion.

When the results are examined with a variety of models and corresponding assumptions, a 30% reduction from the 1995 baseline total nitrogen load appears to be a reasonable initial target and is likely to be a more defensible option. The Phase II TMDL model results and recent estuary monitoring data do not offer enough reason to go beyond the current 30% reduction target. **Consequently, the Phase II TMDL reduction target will be a 30% reduction from the 1991-1995 baseline total nitrogen loading.**

Several qualifying comments should go with the reduction target recommendation. First, it is important that North Carolina does a conscientious job of achieving the 30% reduction. The Neuse Rules are scheduled to be fully implemented by 2003, and every effort should be made to meet that date. Second, based on the range of results seen in the Phase II modeling, it may turn out that more than a 30% reduction is needed. This will be more evident as we progress with adaptive management. Specifically, the river should be monitored to determine if the 30% total nitrogen load reduction is achieved, and the estuary should be monitored to determine if the chlorophyll criterion is met. This observed data may then be used in subsequent modeling efforts (updates to existing estuary models) to update the expected reduction needed.

By making use of additional data and updating the models and analyses, we will be able to reduce the prediction uncertainty, or in other words, to narrow the range of reduction required. It is also important to note that no matter where the reduction target is set in this phase of the TMDL, the estuary will not be removed from the list of impaired waters until it meets its designated uses.

Finally, DWQ would like to reiterate that reductions in nutrient inputs may take time to appear in measured loading, due to year to year variability in precipitation and flow. It may take more than 5 years to statistically discern a 30% decrease in load, even while reduction in inputs total 30% (Stow et al., 2001) (See Section 5.0).

8.0 Allocation Strategy

It should be stated from the outset that this allocation strategy is not based on a calibrated nitrogen delivery model, and consequently it should not be used for implementation purposes. An application of USGS' SPARROW (SPAtially Referenced Regressions On Watershed attributes) model is being developed for the Neuse basin. It has fallen behind schedule and its predictions of nitrogen contribution by source to the estuary are not available for this TMDL. SPARROW is expected to be completed in the near future. DWQ will be evaluating the model to determine its applicability to making any changes to the implementation of the Neuse TMDL. Other efforts that initially appeared to fit the need for a nitrogen delivery model turned out to be unsuited for the task. The land use/land cover classification from one effort, EPA-RTP's landscape-based delineation of nonpoint nitrogen sources and sinks, will be an important component of the Neuse SPARROW model.

Given the lack of a nitrogen delivery model, EPA-Region IV's recommendation for an allocation strategy in this TMDL was to determine a breakdown between point and nonpoint sources. DWQ will provide rough estimates of total nitrogen contribution from point, nonpoint and background sources in this TMDL that follows the logic used in the first phase of the TMDL.

A Neuse TMDL stakeholder panel was formed for this TMDL. Additional information on their work can be found in the Public Participation section of this document. Their primary purpose has been to recommend an allocation strategy for the TMDL. They were prepared to provide this complete recommendation, but their work was limited by the lack of calibrated nitrogen delivery model. They did complete an **interim** document, which can be seen in Appendix II, that provides a general framework that will be applied more specifically once the results from SPARROW are available.

8.0.1 Baseline load

The second phase of the Neuse total nitrogen TMDL will use the same baseline load as the first phase of the TMDL. Recall that the earlier baseline load was based on: 1) 1991-1995 loading at Fort Barnwell; 2) 1995-1996 loading from the Trent River; 3) effluent monitoring data from Weyerhaeuser, Cherry Point, and other WWTPs below Fort Barnwell were used to determine the additional point source load to the estuary; and 4) direct atmospheric load to the impaired portion of the estuary.

As in the first phase of the TMDL, the average TN load of 9.65 million pounds per year at New Bern is the baseline load from which the second phase TMDL is calculated.

8.1 TN TMDL

The TMDL for total nitrogen is a 30% reduction from the baseline load. This equates to 30% of the baseline load of 9.65 million pounds per year for a TMDL of 6.75 million pounds per year at New Bern.

8.2 Allocation of Allowable Nitrogen Load

This allocation will be based on model results that are uncalibrated and highly uncertain, so it should not be used for implementation purposes. As in the first phase of the TMDL, DWQ will initiate the allocation by providing a preliminary estimate of the amount of point source total nitrogen that is delivered to the estuary. Next, the preliminary estimate of the point source contribution to the estuary will be subtracted from the total TMDL. The remaining nitrogen load will be allocated to nonpoint sources and background (forest and wetland, as recommended by the Neuse stakeholder panel – see Appendix II) sources according to their land cover area and the export coefficients that were used in the first phase of the TMDL. These steps will produce a preliminary baseline load from point and nonpoint sources, as well as background load. To arrive at the TMDL, the 30% reduction will be subtracted from the point source and nonpoint source baseline load; reductions from the background load will not be expected so that the needed background reduction (to reach the TMDL) will be required from point and nonpoint sources in proportion to their contribution to the estuary. This framework will be explained in greater detail in the following sections.

1995 will continue to be the baseline year for which the TMDL is established.

8.2.1 Point Sources

For point sources, the 1995 load was estimated by first calculating the end-of-pipe nitrogen load based on actual flow and concentration data submitted by the wastewater treatment plants. For the minor facilities, where total nitrogen data were not available or the data provided were inconsistent (ammonia concentrations in excess of total nitrogen concentrations), the concentration was assumed to be equal to 21 mg/l, the average concentration of other minor facilities in the basin. The annual total nitrogen load at the end-of-pipe for each facility was calculated as the sum of the loads calculated from monthly average flows and concentrations. If monthly data were not available, available data were averaged over quarterly periods.

The next step was to determine the percentage of total nitrogen from each major facility that was transported to the estuary. This was done using a general nutrient transport model. A certain percentage of the nutrients traveling through streams in the basin is lost to denitrification, which is the conversion of bioavailable nitrogen to inert nitrogen. Fate and transport models account for this nitrogen loss, and so they are used to estimate nutrient delivery to the estuary.

DWQ has developed a spreadsheet nutrient fate and transport model for the 26 major (design flow is greater than 0.5 million gallons per day) point sources in the Neuse River

Basin to New Bern. Within the model, the delivered load is assumed to be a function of the location of a source within the basin, the stream velocities between the source and the estuary, and the rate at which the pollutant decays along the route.

The nitrogen transport model is based on measured distances from the major point sources to the estuary, using Reach File 3.0 (RF3) and a GIS measuring tool. A first order decay equation is used to simulate loss of nitrogen down the network as described by the following equation:

$$\text{Percent TN delivered} = e^{(-k * t)}$$

k = decay coefficient that represents the loss of total nitrogen the system in units of d^{-1}
t = time of travel from a stream reach to the estuary in days.

For this model application, it was assumed that the velocity was equivalent to 18 miles per day throughout the basin. The velocity assumption is based on data collected at U.S. Geological Survey gaging stations, and by earlier DWQ analysis (Schinke, 1996). In the DWQ analysis, log adjusted historical gaging station measurements are used to establish a site specific functional relation between flow and velocity. The functional relation for a station is then used to convert daily discharge values at a station into daily velocity values. Table 13 shows the estimated velocities for four locations in the Neuse basin. The categories are designed to represent summer conditions, and a winter/spring condition during which faster transport occurs.

Table 13. Summary of Velocities (in miles per day)

Station name	Low Flow	High Flow
Nahunta Swamp	8.0	12.8
Crabtree Creek	14.1	19.3
Neuse (Smithfield)	18.3	24.1
Neuse (Ft. Barnwell)	13.3	23.4

From these numbers it was assumed that a constant 18 miles per day would be reasonable in the model based on the locations of the major point sources, and the benefit of keeping the model simple. A sensitivity analysis showed that the model predictions are much more sensitive to the decay constant than the velocity (Anderson, 2001).

The decay rate in the first phase of the TMDL was assumed to be a constant, which was based on literature values. Studies were performed over the past year and a half by Dr. Marc Alperin and others at UNC-Chapel Hill to assess the rate of denitrification in the Neuse basin. The denitrification rates seen in the Neuse are in line with literature values from similar studies in a Texas estuary and in Chesapeake Bay (Yoon and Benner, 1992, and Kana et al., 1998). These denitrification rates were used to calculate seasonal k coefficients for Neuse tributaries and for the Neuse mainstem. The newly calculated constants, for the most part, are considerably lower than the 0.2 used in the first phase. (See Table 14 and Appendix I)

Table 14. New K constants used in spreadsheet model

Neuse Tributaries	Kw = 0.40	Kc = 0.10	
Neuse Mainstem	Kw = 0.03	Kc = 0.01	
Contentnea Cr.	Kw = 0.10	Kc = 0.05	(assumed)
Kw = May-Oct	Kc = Nov-Mar		

Additionally, the decay constants should probably only apply to nitrate concentration but they were assumed to apply to total nitrogen. Errors resulting from this assumption may be balanced by the possibility that some point source nitrogen may be denitrified in the flood plain following high flow events.

The spreadsheet model independently routes the nitrogen load from each major point source to the estuary, except for those above Falls Lake. For the three major dischargers above Falls Lake, 85% retention was assumed for the lake (as in first phase of TMDL), and from there the nitrogen was routed to the estuary using the model. The spreadsheet model considers: 1) the total nitrogen load in pounds per season; 2) the travel distance along each stream from a point source to the estuary; 3) a warm season and a cool season decay constant for tributaries and the Neuse mainstem; and 4) time of travel based on stream distances and the constant 18 miles per day velocity.

The minor facilities were not run through the spreadsheet model. They were assumed to deliver 42 percent more to the estuary than phase I of the TMDL, since that is the change in the major discharge delivery estimate. That changes their contribution from 78,000 lbs./year to 110,000 lbs./year.

The method described above estimates that approximately 3.32 million pounds per year of total nitrogen that originates from the point sources arrives at New Bern; this will be the baseline point source number.

Uncertainty in Point Source estimate

The estimate of point source loading is highly uncertain, and it should not be used for implementation purposes. Primarily, it is not based on a calibrated model where all sources of nitrogen (nonpoint as well), and their differential rates of transport, are considered and accounted for at monitoring locations. SPARROW will be calibrated in this manner, and for that reason it will be the basis for reevaluation of the implementation strategy. The major sources of uncertainty in the spreadsheet point source model used in this assessment are: 1) decays constants because of the small sample population for denitrification rates (actual number and locations in basin), assumptions of seasonal depth and median nitrate concentration (see Appendix I), and application to total nitrogen; and 2) the time of travel because of the constant velocity assumption.

8.2.2 Nonpoint Sources

The determination of the nonpoint source and the background baselines follows a similar method to the first phase of the TMDL. The notable exception is that the second phase uses 1998-1999 SPOT/Landsat 7 ETM land cover data developed by EPA-RTP (Lunetta et al., 2001). Though this is three years after the baseline year (1995), it is considered to have much better accuracy, especially with urban land cover, than the 1992 MRLC land cover data that was used in the first phase. Additionally, wetlands will be separated from forestland and considered to export no nitrogen since they are most often considered to be a nitrogen sink. Since this is a temporary allocation of the TMDL, no emphasis will be placed on the individual nonpoint sources. The nonpoint categories with an allocation will simply be "nonpoint" and "background".

Baseline NPS Loading

Since point sources contribute approximately 3.32 million pounds of total nitrogen per year, nonpoint sources were calculated by difference to contribute the remainder of the baseline load or 6.33 million pounds per year (9.65 – 3.32 million pounds per year).

In order to partition the baseline load into nonpoint source and background contribution, land cover estimates and export coefficients were used to estimate the amount of nitrogen that enters surface waters from the general land uses/land covers. The export coefficient approach can be used to describe the amount of nutrients leaving a given land use type (field scale) on an annual basis. The export coefficient itself is derived from an examination of actual field measurements taken over a period of time and is usually a single number expressed as mass/area/time.

The export coefficients developed by Research Triangle Institute (Dodd and McMahon, 1992) were used as a basis for determining export. The export coefficient for atmospheric deposition was updated using data available from the National Atmospheric Deposition Program (NCEMC, 1997). Table 15 contains the export coefficients.

Table 15. Export coefficients used in TN loading calculations
(in lbs./acre-year)

Land Use	Export Coefficient
Urban	8.06
Cultivated	13.56
Mgd. Herbaceous	4.37
Forest	1.72
Open Water	8.75

The nonpoint sources are considered to be urban land, cultivated land, managed herbaceous land (almost entirely pasture/hay in 98-99 land cover) and open water (atmospheric deposition), while forestland and wetlands are considered to be background sources. Wetlands will be considered to export zero nitrogen since they are normally thought to be a nitrogen sink.

Table 16. The 1998-1999 SPOT/Landsat 7 ETM land cover divided into five major categories.

Land cover	(acres)	%
Urban	485,301	14%
Cultivated	641,807	18%
Herbaceous	414,101	12%
Forest	1,381,454	38%
Wetland	513,593	14%
Open Water	154,943	4%
Total	3,591,199	100%

Based on the export coefficients in Table 15 and land cover in Table 16, DWQ estimates of the baseline loading in million pounds per year can be seen Table 17.

Table 17. Estimated TN Baseline Load for Neuse River Basin (million pounds per year).

Baseline TN Loads by General Source	
Point	3.32
Nonpoint	5.50
Background	0.83
Total	9.65

8.2.3 Allowable Point and Nonpoint Source Loads

Since we do not expect any reduction from the background load, reductions from that source will need to be achieved elsewhere. According to the stakeholder allocation framework (see Appendix II), the necessary reduction should be achieved by the point and nonpoint sources in proportion to their contributions to the 1995 baseline loading to the estuary. Thus, to arrive at the TMDL of 6.75 million pounds, the background reduction should come from 5.92 million pounds (TMDL of 6.75 million pound minus background 0.83 million pounds). If this is achieved in proportion to their estimated contribution shown in Table 17, the allocation shown in Table 18 is the result (calculation below Table 18).

Table 18. TMDL allocation between point, nonpoint and background nitrogen sources. (calculations follow)

TMDL Allocation	(million lbs./year)
Point	2.23
Nonpoint	3.69
Background	0.83
Total	6.75

Point Source Load = (3.32/(3.32 + 5.50))*(5.92)
= 2.23 million lbs.

Nonpoint Source Load = (5.50/(3.32 + 5.50))*(5.92)
= 3.69 million lbs.

Background Load = 0.83 million lbs.

9.0 Summary and Future Considerations

Much consideration has been given to the development of the 2001 TMDL for the Neuse River estuary, and consequently, there is a relative abundance of information to support the decisions by the State of North Carolina and the stakeholders in the Neuse basin. Despite this relative abundance of information compared to other TMDLs, there remains a large degree of uncertainty in the results. DWQ has tried to show where this uncertainty exists and will work to decrease it. The prime areas of uncertainty and the corresponding responses include: 1) reduction target based on Neu-BERN – decrease by adding future monitoring data; may also add historical DWQ data once it has been quality assured (the NEEM and WASP predictions are highly uncertain but that uncertainty is presently unquantifiable); 2) the proper number to use for change in nitrogen load between 1995 and 1998 – continue to monitor and assess loads to verify that the estimated change is reasonable; 3) how sediment diagenesis will affect nitrogen load contribution from the sediment – continue to monitor to determine what changes occur; and 4) the nitrogen contribution by major sources in the basin and subsequent allocation strategy – decrease by completing SPARROW, and later supplementing that model with additional individual nitrogen source assessments.

There has been and will continue to be substantive communication among the stakeholders, the scientists, EPA and DWQ on how to best use the data and models to guide decision making for the TMDL. The Neuse TMDL stakeholders have achieved substantial progress in drafting an allocation framework, and they will eventually produce a recommended strategy for the TMDL.

North Carolina has developed a substantial framework upon which to base the TMDL decisions. There is reason to believe that the process will lead to the best solution possible for all involved. DWQ encourages those involved to continue this constructive process.

9.1 Monitoring

The monitoring in the Neuse estuary, though extensive in spatial coverage and thorough in technique, is in need of some reorganization. Four institutions (UNC-IMS, Weyerhaeuser, NCSU and DWQ) sample in the estuary and each employs a different collection technique for chlorophyll. DWQ is working to standardize the collection methodologies.

The DWQ lab analysis problems that have plagued past chlorophyll sampling have been rectified. This was confirmed in a spring 2001 split sample exercise when all of the institutions divided samples and analyzed them separately in their respective laboratories.

9.2 Implementation

The Neuse Rules goal of a 30% nitrogen reduction by 2003 remains intact. The 2001 TMDL unequivocally states that the allocation strategy is a temporary one, and it will remain so pending the completion of the SPARROW model. The SPARROW model will provide the baseline loading estimates for the sources described in the stakeholder allocation framework recommendation (Appendix II in 2001 TMDL). At this point, we will need to reconvene the stakeholders to apply their framework to the baseline loading estimates. The stakeholders have asked that their work be considered as interim, until they can verify the results from the SPARROW model and assess the impact that the framework has on the allocation. We are expecting the SPARROW results in early 2002, and the stakeholders should finish their work not long after SPARROW's completion. At that time, DWQ will work with the Environmental Management Commission (EMC) to determine how the new allocation will be implemented, and in what time frame.

10.0 Public Participation

A Neuse TMDL stakeholder panel was formed in September 2000 as part the second phase of the Neuse total nitrogen TMDL. This process evolved from a group of Neuse stakeholders who were kept informed of the ModMon project and who advised ModMon scientists. The main purpose of the stakeholder panel was to draft a plan for how responsibility for reducing nitrogen (allocation strategy) should be distributed among different sources of nitrogen (e.g., point sources, agriculture, urban stormwater runoff) at different locations in the watershed. DWQ has agreed that stakeholder input on the allocation strategy will play a strong advisory role in the TMDL proposal that will be forwarded to EPA. Members of the stakeholder panel also stay abreast of the work of modelers and regulatory agency personnel to review their progress with the models and analysis. Dr. Lynn A. Maguire, a faculty member from the Nicholas School of the Environment and Earth Sciences at Duke University, facilitated the stakeholder meetings.

The Neuse TMDL stakeholder panel comprises about 35 individuals who represent a broad spectrum of interests including environmental advocates, municipalities, farmers, industry, and government agencies. See Appendix III for the list of people on the Neuse ModMon/TMDL stakeholder panel. DWQ and the Water Resources Research Institute developed the initial list. We considered those who could be affected by the outcome and those who could affect the outcome. It was important that the size of the group remain small enough to allow active participation, to progress with the meeting's agenda and to fit in available meeting spaces. The initial group was polled to see who should be added. Each of the stakeholders could send an alternate in their absence, and observers were encouraged to attend.

Description of the process

The facilitator was the real driver behind the process outline. Initially, the stakeholder panel decided on the following:

- Principles to guide the allocation strategy
- What a good agreement would look like
- The role of the stakeholders
- Who should be represented
- The ground rules
- The meeting schedule

The results of these decisions include that there would be eight meetings between September 2000 and May 2001. DWQ decided that the stakeholders would have a strong advisory role in the TMDL's allocation strategy, and DWQ and EPA determined that they would be able to comment on the modeling and analysis used to develop the TMDL.

At subsequent meetings the group decided to appoint a sub-committee of stakeholders who would attend the more technical modeling meetings. DWQ informed the sub-committee that the primary purpose of the modeling meetings was to facilitate communication among DWQ, EPA and their consultants. However, the stakeholders were welcome to attend and were encouraged to express their thoughts. The technical subcommittee of the stakeholders attended four of the Neuse modeling meetings between January 2001 and May 2001.

Early in the process, it became clear the chlorophyll standard would be the primary endpoint since it is a legal standard. This is not to say the standard is without problems; rather, it was not based on cost and benefit considerations, it is not being applied as it was developed, and there are no guidelines as to how, where and when it should be applied. Everyone recognized that the standard must be accepted in the near term, but that the stakeholder panel would comment on its inadequacy in their final report.

The group also discussed what a good allocation strategy would look like so that they could fall back on these guidelines during moments of conflict or indecision. The allocation strategies from Chesapeake Bay's management strategy and the Long Island Sound TMDL were used as examples.

Decisions made

The stakeholder panel made their recommendation to the State in the form of an allocation recommendation document that was compiled by the facilitator. This document may be seen in Appendix II. The document outlines a framework for allocating the TMDL among the sources and geographic regions of the Neuse basin, but give no numerical formula for allocating reduction responsibility among sources. Other sections include principles for implementation and a critique of the chlorophyll a standard. Because of the delay in the modeling results and data, particularly pertaining to nitrogen delivery from different sources in different locations in the basin, the stakeholders view their report as very much an interim document. It represents general consensus among the group, but there are still elements of disagreement and not every stakeholder endorses every part of the report. There seems to be little point in continuing with the stakeholder discussion of allocation strategies until it can be better informed by results from the nitrogen delivery modeling that is underway. Some stakeholders will participate in obtaining input data and scrutinizing results for the nitrogen delivery modeling. The stakeholders want the opportunity to revisit the allocation strategy in light of the nitrogen delivery results, as soon as these become available.

References Cited

Alperin, M. 2001. Personal communication.

Anderson, W.H. 2001. Undergraduate Thesis from Princeton University.

Bowen, J.D., and J. Hieronymus. 2000. The Neuse River estuary's response to reduced nutrient loading: predictions and an uncertainty analysis using a mechanistic eutrophication model. UNC Water Resources Research Institute, North Carolina State University, Raleigh.

Bowen, J.D. 1998-2001. Personal communication

Borsuk, M.E. 1999-2001. Personal communication.

Brookhart, Morris, 2001. "The Lower Neuse Basin Association: A successful program of reducing nitrogen in wastewater discharge." Handout presented to the Neuse MODMON/TMDL Stakeholder Group, 3/29/01.

Dodd, R.C. and G. McMahon. 1992. Watershed Planning in the A/P Study Area – Phase 1: Annual Average Nutrient Budget. Research Triangle Institute, Research Triangle Park, NC.

Kana et al. (1998). Limnology and Oceanography, 43: 334.

Lunetta, R.S., J. Ediriwickrema, J. Iiames, D. Johnson, J.G. Lyon, A. McKerrow, and D. Pilant, 2001. A quantitative evaluation of a multi-sensor land-cover classification of the Neuse River basin, North Carolina, USA. International Journal GIS, in review.

Schinke, P.S. 1996. DWQ memo entitled "Neuse River Transport Model Median Velocity Summary Sheet".

Stow, C.A., and M.E. Borsuk, 2000. Neuse River Estuary Modeling and Monitoring Project Stage 1: An examination of Long Term Nutrient Data in the Neuse River Watershed. Water Resources Research Institute Report No. 325-E.

Stow, C.A., M.E. Borsuk, and D.W. Stanley, 2001. Long-term changes in watershed nutrient inputs and riverine exports in the Neuse River, North Carolina. Water Research 35 (6): 1489-1499.

Stow, C.A. 2001. Personal communication.

Yoon and Benner (1992). Marine Ecology Progress Series, 90: 157.

Appendix I

K determination for 1st order decay equation **6/7/01**
NC Division of Water Quality

Based on UNC's denitrification studies at Crabtree Creek, Nahunta Swamp, and Smithfield and Fort Barnwell on the Neuse River (see below) the following are **mean** observed denitrification rates (confirmed in the literature according to Marc Alperin):

C = cool season, W = warm season

Crabtree Creek (above WWTP outflow)
C: 0.7 mmol m^{-2} d^{-1} n = 3 (+ 1 artificial)
W: 1.7 " n = 4 (+ 1 ND)

Crabtree Creek (below outflow)
C: 0.6 mmol m^{-2} d^{-1} n = 4
W: 1.5 " n = 3 (+ 1 ND)

Neuse River (Smithfield)
C: 0.6 mmol m^{-2} d^{-1} n = 2
W: 0.7 " n = 3

Nahunta Swamp
C: 0.7 mmol m^{-2} d^{-1} n = 2
W: 1.0 " n = 5

Neuse River (Ft. Barnwell)
C: 1.5 mmol m^{-2} d^{-1} n = 2
W: 0.1 " n = 3

C (All):
Mean 0.67 n = 13
Median 0.60

W (All):
Mean 1.05 n = 18
Median 0.98

K calculation

K = (deN/([NO3]*d))

Denitrication rate (deN) is in units of: mmol m^{-2} d^{-1}
[NO3] is in units of: umol/L or mmol/m^3
conversion factor for [NO3]: 100 uM = 100 mmol/m3 = 1.4 mg/L
d is depth in meters – determined from Neuse Qual2e Report, Crabtree Report and observation in Nahunta Swamp.
Average [NO2 + NO3] is from 1995-2000 DWQ ambient data (treated as just [NO3])

Crabtree
Median [NO3] is 0.20 mg/L (std. error is 0.09)
Depth is 0.3 m in warmer months and 0.5 m in cooler months
K is 1.6 mmol/m2*d in warmer months and 0.7 mmol/m2*d in cooler months

K_c = (0.7 mmol/m2*d)/(14 uM*0.5 m) = 0.10
K_w = (1.6 mmol/m2*d)/(14 uM*0.3 m) = 0.38

Smithfield
Median [NO3] is 0.90 mg/L (std. error is 0.09)
Depth is 0.8 m in warmer months and 1.0 m in cooler months
K is 1.5 mmol/m2*d in warmer months and 0.7 mmol/m2*d in cooler months

K_c = (0.7 mmol/m2*d)/(65 uM*1.0 m) = 0.01
K_w = (1.5 mmol/m2*d)/(65 uM*0.8 m) = 0.03

Nahunta
Probably shouldn't use this site for point source decay since it is a swampy watershed with no point sources on it.

Median [NO3] is 0.10 mg/L (std. error of 0.01) at Lucama (Wilson)
And 0.68 mg/L (std. error of 0.01) at Hookerton
Use difference between them or 0.4 mg/L
Depth is 1.2 m year round (assumed, based on M. Alperin's description)
K is 1.5 mmol/m2*d in warmer months and 0.8 mmol/m2*d in cooler months

K_c = (0.8 mmol/m2*d)/(30 uM*1.2 m) = 0.02
K_w = (1.5 mmol/m2*d)/(30 uM*1.2 m) = 0.04

Fort Barnwell
Median [NO3] is 0.71 mg/L (std. error of 0.01)
Depth is 1.5 m in warmer months and 2.0 m in cooler months
K is 1.5 mmol/m2*d in warmer months and 1.5 mmol/m2*d in cooler months

K_c = (1.5 mmol/m2*d)/(51 uM*2.0 m) = 0.015

K_w = (1.5 mmol/m2*d)/(51 uM*1.5 m) = 0.02

The Crabtree site in summer has a high decay rate but the other sites have a rather low one relative to the k of 0.2 used in the first TMDL and Neuse Rules.

K Ranges selected by DWQ:

Neuse Tributaries	Kw = 0.4	Kc = 0.1	
Neuse Mainstem	Kw = 0.03	Kc = 0.01	
Contentnea	Kw = 0.1	Kc = 0.05	(assumed)

from Marc Alperin, 6/7/01

Measured denitrification rates in sediments from the Neuse River main stem and tributaries.

Site	Date	Temperature (ºC)	Nitrate (μM)	Denitrification Rate (mmol m^{-2} d^{-1})	Method*
Crabtree Creek (above outflow)	2-28-00	15.5	20.0	0.83	IPT
	2-28-00#	**27.0**	**20.0**	**5.28**	**IPT**
	6-6-00	24.0	20.0	1.92	IPT
	6-6-00	24.0	20.0	2.49	IPT
	12-19-00	3.0	30.8	0	MIMS
	12-19-00	3.0	29.1	0.48	MIMS
	5-8-01	19.0	20.0	N.D.	IPT
	5-8-01	19.0		2.2	MIMS
	5-8-01	19.0		0	MIMS
Crabtree Creek (below outflow)	2-28-00	15.5	20.0	0.30	IPT
	2-28-00	27.0	20.0	0.60	IPT
	6-6-00	24.0	20.0	2.66	IPT
	12-19-00	3.0	10.3	0.96	MIMS
	12-19-00	3.0	10.8	0	MIMS
	5-8-01	19.5	71.0	N.D.	IPT
	5-8-01	19.5		1.3	MIMS
	5-8-01	19.5		0.65	MIMS
Smithfield	12-19-00	3.0	59.3	0.38	MIMS
	12-19-00	3.0	63.7	0.79	MIMS
	5-8-01	20.0	55.0	0.09	IPT
	5-8-01	20.0		1.1	MIMS
	5-8-01	20.0		1.0	MIMS

Nahunta Swamp	5-30-00	17.0	66.0	0.96	IPT
	5-30-00	17.0	66.0	1.16	IPT
	12-19-00	3.0	60.0	0.59	MIMS
	12-19-00	3.0	61.2	0.86	MIMS
	5-8-01	18.5	73.0	1.96	IPT
	5-8-01	18.5		0.16	MIMS
	5-8-01	18.5		0.94	MIMS
Fort Barnwell	12-19-01	3.0	48.6	0.90	MIMS
	12-19-01	3.0	46.1	2.00	MIMS
	5-8-01	22.0	48.0	0.34	IPT
	5-8-01	22.0		0	MIMS
	5-8-01	22.0		0	MIMS

* IPT = isotope pairing technique; MIMS = membrane inlet mass spectrometry.

N.D. = below detection limit due to large sample heterogeneity.

- sample warmed to 27^{oC} in laboratory – did not use in k estimation for Crabtree Cr.

Appendix II

REPORT FROM THE NEUSE TMDL STAKEHOLDERS' GROUP TO THE NORTH CAROLINA DIVISION OF WATER QUALITY – JUNE 2001

This interim report presents the stakeholder group's conceptual framework and guiding principles for allocating the total maximum daily load (TMDL) of nitrogen that may be required in the Neuse River basin. It includes a tentative allocation strategy, along with some principles for implementation and some comments on the TMDL process. The allocation strategy has been developed under the assumption that any future TMDL will be applicable to both point and non-point sources. The framework presented here represents a general consensus of the group; however, this does not imply that every stakeholder agrees with every statement. Furthermore, this consensus should be considered tentative, pending stakeholders' review of additional watershed and estuary modeling results that were not available for consideration prior to preparation of this report.

There are two reasons for the interim nature of this document, one short-term and one longer-term: (1) The stakeholders' group has not yet seen the results of watershed loading models, such as SPARROW, on which numerical estimates of loads from various sources are to be based. Also, the stakeholders' group has not had a chance to review all of the estuary response models (especially WASP/EFDC) and their roles in developing the TMDL. This information, plus documentation, should be available within the next several months, and the stakeholders wish to review these materials as they become available and perhaps modify the framework presented here in light of these new results. (2) Even with these additional modeling results, there will be considerable uncertainty regarding the reductions in nitrogen necessary to improve water quality in the Neuse estuary. The stakeholders urge the regulatory agencies to use an adaptive approach to reducing nitrogen, as described under Principles for Implementation, part II.7, and to continue the modeling and monitoring necessary to support such an approach.

I. Interim framework for allocating responsibility for meeting TMDL among sources and among geographic regions:

  A. Calculation of N loading for purposes of determining the 1995 baseline load, the TMDL and required reductions in N will be based on load delivered to the estuary, as estimated by N delivery models, such as SPARROW, that account for transformation and transport of N as it moves down the watershed.

  B. Sources will be divided into two categories: (1) those from which little or no reduction is expected, and (2) remaining sources, among which reductions will be allocated to meet the TMDL.

    1. Sources where little or no reduction is expected:

      a. Forests

b. Wetlands

2. Sources for reduction allocation (in no particular order of priority):

a. Point
b. Nonpoint

i. Atmospheric
ii. Terrestrial

- Onsite wastewater
- Stormwater

  - Urban
  - Rural

- Fertilized land

  - Urban – golf courses, lawns
  - Rural – crops, pasture

- Animals/livestock

C. The reductions necessary to achieve the TMDL will be allocated among the sources listed under 2 above in proportion to their contributions to the 1995 baseline loading to the estuary (which will account for differential rates of transport of N from sources in different parts of the watershed).

D. Since this plan does not allocate any part of the TMDL for future growth or changes in land use in the basin, any future activities that result in a net increase in N must be offset by a corresponding reduction in N loading from existing sources.

II. Principles for implementation (not in any order of priority)

A. Full participation

The stakeholders' group has designated some sources as those from which little or no reduction is expected and recognizes that there will be many other sources that will have no specific numeral reduction targets upon implementation. Nevertheless, the group wants to stress the importance of widespread participation in N reduction efforts from all sources in all parts of the watershed. Both existing and newly developed programs to provide incentives, technical assistance, and monitoring to secure reductions from sources with no mandated reductions are essential. For example, although forestland does not have a required reduction target, forest management should conform to applicable BMP's and Forest Practices Guidelines. In addition, new guidelines and additional monitoring to verify compliance with forest BMP's are needed. In a similar vein, sufficient funds from state and federal sources to monitor compliance with BMPs and practice guidelines for other land uses, such as roads and construction sites, are required. Incentive systems, technical assistance and monitoring will help improve performance of onsite wastewater systems in both urban and rural areas. Public education to alert citizens in all parts of the watershed to their contributions to nitrogen loading as they manage their homes, lawns, pets, and vehicles will encourage widespread participation.

B. Equity

Equitable treatment of different sources and of different regions of the watershed is a principle the stakeholders' group has tried to follow throughout this allocation draft. Implementation strategies should consider the same principle because some strategies that are desirable from the standpoint of cost-effectiveness could compromise equity. For example, cost-effective N reduction using nutrient trading could change the distribution of land uses in the lower watershed toward those taxed at lower rates, with financial consequences for municipalities and counties there.

C. Cost effectiveness

The costs of achieving a given level of reduction in N loading at the estuary vary enormously among different regions of the watershed and among different types of sources. We believe that implementation programs that achieve a given level of N reduction at the least cost are the way to do the most for water quality improvement with the fewest unwanted side effects. A flexible nutrient trading scheme, allowing trades among unlike sources and among different regions of the watershed, will be essential to making N reductions cost-effectively. The configuration of sources in the Neuse, with large point sources upstream and large nonpoint sources downstream, is unusual among coastal watersheds, and trading schemes that have been proposed for watersheds such as the Long Island Sound may not work appropriately here. Exchange ratios should include factors such as transformation and transport of N downstream, uncertainty about levels of reduction achieved by nonpoint sources, and, possibly, different levels of biological effect from different N species. Even where nutrient trading is not the mechanism for achieving cost-effectiveness, implementation programs should pursue reductions first from those sources where the greatest improvements can be had with the least overall cost (including those that may be difficult to express in monetary terms).

D. Fiscal rationality

Meeting the TMDL may require new expenditures from both public and private entities. All parties must begin right away to plan how to meet these new financial demands. It is unreasonable to expect water quality to change without new inputs of both public and private funds.

E. Avoidance of unintended negative consequences

N reduction schemes could have unintended negative consequences. For example, nutrient trades in which upstream point sources accomplish part of their N reduction by removing downstream agricultural land from production (perhaps in a conservation reserve program) could change the economic and the cultural character of downstream communities. Regulatory strategies that apply only to some jurisdictions within the watershed could shift development into unregulated areas, perhaps offsetting expected nitrogen reductions. Those designing implementation strategies should make every effort to foresee such consequences, and, where they occur unexpectedly, make provisions to mitigate unintended negative effects.

F. Stability/predictability

Many stakeholders are being required to meet a constantly changing array of regulations, and they value a more predictable operating environment. The stakeholders' group recognizes that this desire for stability of regulatory expectations may conflict with otherwise advantageous adaptive approaches to water quality management. Considering that current regulatory decisions are being made under a great deal of uncertainty about the effects of N reduction on water quality, the ability to monitor effects as reductions are implemented, and then make changes if the results are not what was expected, would be helpful. Stakeholders recognize that such an adaptive approach would be welcome if it allows more targeted, and thus more cost-effective, reductions; however, they fear being subject to new, frequently changing, and unexpected regulatory requirements or unintended negative consequences.

G. Monitoring and adaptability of regulatory approach

The stakeholders' group recognizes that more effort has gone into water quality monitoring and modeling in support of the Neuse TMDL process than for most other such regulatory efforts. The group also recognizes the need to take action based on the best synthesis that can be made from the predictive tools and data_available currently. Nevertheless, the group is concerned that, even after the results from the watershed and estuary modeling and data analysis that will be completed over the next several months have been incorporated in the TMDL, substantial uncertainty will still remain. Limitations in current scientific understanding of nutrient dynamics in the Neuse could lead to regulations that are either more stringent than needed to meet desired water quality standards (at greater cost to private and public entities than is warranted) or too lax to accomplish the desired improvements. A few examples of the specific concerns about the scientific basis for TMDL decisions are: lack of water quality and flow monitoring stations well-distributed throughout the basin, particularly deficiencies in coastal plain data; inconsistencies in methods for water quality sampling and analysis; emphasis on total nitrogen, rather than on forms with differing biological activity; use of different time periods for calibration and validation of the various models that are being developed, especially in relation to the time periods used for regulatory decisions; and model simplifications, such as limited representation of sediment processes.

As a consequence of these limitations, there may be extra uncertainty and error in the model predictions that are being used to set the TMDL and determine an allocation strategy. The stakeholders urge regulatory decision makers to recognize the uncertainty surrounding their recommendations by taking an adaptive approach to modifying those regulations in the future. The regulatory framework should be flexible enough to respond with new recommendations for water quality management, as new data and models suggest. Stakeholders want to be sure that a monitoring design is put in place that will supply data needed to assess the effectiveness of actions already taken and to improve the models that will be used to make future regulatory decisions. A number of stakeholders have been involved with the technical aspects of water quality modeling and monitoring and have specific suggestions that should be heard before a more comprehensive water quality monitoring scheme is put in place. Stakeholders wish to continue to be involved in reviewing monitoring data and modeling efforts based on those data.

III. Reservations about use of the chlorophyll a standard for regulatory decisions

Some stakeholders were concerned about the way the chlorophyll a standard is being used in the TMDL process. Stakeholders are asking: Is chlorophyll a the right measure to use for setting water quality regulations? If so, is the current standard (fewer than 10% exceedances of 40 ug/l) set at the right level? Is it appropriate to base standards for an estuary on observations taken in inland lakes? Is it clear how to implement the standard, in terms of where and when chlorophyll a is to be measured; is the implementation consistent with how the standard was developed? Has variability in time and space, and particularly between seasons, been accounted for properly in the standard? Are the right field and laboratory procedures for assessing chlorophyll a levels being followed? Is there a way to draw a closer connection between chlorophyll and the biological endpoints (e.g., algal blooms, fish kills, fish health) that are more directly meaningful to stakeholders? In the future, other parameters besides chlorophyll might be used to measure improvement in water quality resulting from nitrogen reduction; dissolved oxygen and direct measurement of various nitrogen species are possible candidates.

Appendix III

Contact List for Neuse TMDL Stakeholders Panel
Updated 10/02/01

Facilitator:

Lynn Maguire
Associate Professor of the Practice
Nicholas School of the Environment
Duke University
Box 90328
Durham, NC 27708
Phone: (919) 613-8034
Fax: (919) 684-8741
Email: lmaguire@duke.edu

Primary Representatives:

Ken Reckhow
Director, WRRI
Water Resources Research Institute
North Carolina State University
Campus Box 7912
Raleigh, NC 27695
Phone: (919) 515-2815
Fax: (919) 515-2839
Email: ken_reckhow@ncsu.edu

Chris Roessler
Environmental Modeler
DWQ - PLANNING
NC DENR
1617 Mail Service Center
Raleigh, NC 27699-1617
Phone: (919) 733-5083 x506
Fax: (919) 733-9919
Email: chris.roessler@ncmail.net

Tom Augspurger
Ecologist
U.S. Fish & Wildlife Service
P.O. Box 33726
Raleigh, NC 27636-3726
Phone: (919) 856-4520 x21
Fax: (919) 856-4556
Email: tom_augspurger@fws.gov

Georgiana Bircher
Director, Lower Neuse Initiative
P.O. Drawer C
New Bern, NC 28563
Phone: (252) 634-2888
Fax: (252) 637-7541
Email: gbircher@lowerneuse.org

Nick Blackerby
NC Chapter President
Coastal Conservation Association
5315 Trentwoods Drive
New Bern, NC 28562
Phone: (252) 633-2789
Fax: (252) 633 4911
Email: janb@cconnect.net

Morris Brookhart
Lower Neuse Basin Association
P.O. Box 72076
Durham, N.C. 27722
Phone: (919) 477-6656/(252) 354-9766
Fax: (252) 354-9293
Email: mvbpe@earthlink.net

Bob Chiles
Robert M. Chiles Engineers
P.O. Box 3496
New Bern, NC 28560
Phone: (252) 637-4702
Fax: (252) 637-3100
Email: rmcengr@cconnect.com

Anne Coan
NC Farm Bureau Federation
P.O. Box 27766
Raleigh, NC 27611
Phone: (919) 788-1005
Fax: (919) 783-3593
Email: coanaf@ncfb.com

John Cox
Civil Engineer
Department of Public Works
-Stormwater Services
City of Durham
Durham, NC 27701
Phone: (919) 560-4326 x238
Fax: (919) 560-4316
Email: jcox@ci.durham.nc.us

Dale Crisp
Director of Public Utilities
City of Raleigh
P.O. Box 590
Raleigh, NC 27602
Phone: (919) 890-3400
Fax: (919) 890-3600
Email: crispd@raleigh-nc.org

Jim Cummings
NC Department of Agriculture
Phone: (919) 733-7125
Email: jim.cummings@ncmail.net

Pat Davis
Water Resources Project Director
Triangle J Council of Governments
P.O. Box 12276
Research Triangle Park, NC 27709
Phone: (919) 558-9392
Fax: (919) 549-9390
Email: pdavis@tjcog.org

Michelle Duval
Environmental Defense
2500 Blue Ridge Road
Raleigh, NC 27607
Phone: (919) 881-2601
Fax: (919) 881-2607
Email: mduval@environmentaldefense.org

Pat Elliott
Camp SeaFarer
2744 SeaFarer Rd.
Arapahoe, NC 28510
Phone: (252) 249-1212
Fax:
Email: pat.elliott@seagull-seafarer.org

Barbara Hartley Grimes
NPS Pollution Program Coordinator
On-Site Wastewater Section, DENR
Division of Environmental Health
1642 Mail Service Center
Raleigh, NC 27699-1642
Phone: (919) 715-0141
Fax: (919) 715-3227
Email: barbara.grimes@ncmail.net

Jerry Hardesty
NC Pork Council
2300 Rex Woods Dr.
Suite 340
Raleigh, NC 27607
Phone: (919) 781-0361
Fax:
Email: hardywolf@aol.com

Preston Howard
Manufacturers' rep.
Phone: (919) 834-9459
Email: preston.howard@mcicnc.org

Gail Hughes
Soil Conservationist
Orange Soil and Water Conservation District
P.O. Box 8181
Hillsborough, NC 27278
Phone: 919-245-2750
Fax: 919-732-7559
Email: gail-hughes@nc.nacdnet.org

Jenny Lassiter
Pamlico Co. Env. Health
Phone: (252) 745-5634
Email: pchd@coastalnet.com

Martin Lebo
Weyerhaeuser Company
Box 1391
New Bern, NC 28563
Phone: (252) 633-7511
Fax: (252) 633-7634
Email: martin.lebo@weyerhaeuser.com

Don Lee
Roadside Environmental Unit State Operations Engineer
NC DOT/REU
1 South Wilmington Street
Raleigh, NC 27611
Phone: (919) 733-2920
Fax: (919) 733-9810
Email: dlee@dot.state.nc.us

Gene Maples
Executive Director
Turfgrass Council of NC
P.O. Box 289
Southern Pines, NC 28388
Phone: 1-888-695-1333
Fax:
Email: mmrtcnc@aol.com

Lisa Martin
Executive Director
Upper Neuse River Basin Association
P.O. Box 12276
Research Triangle Park, NC 27709
Phone: (919) 558-2702
Mobile: (919) 274-7491
Fax: (919) 549-9390
Email: lmartin@tjcog.org

Danny Meadows
Stormwater engineer
City of New Bern
Phone: (252) 636-4024
Email: meadowsd@newbern-nc.org

Ron Mikulak
U.S. EPA Region IV
Water Management Division
61 Forsyth Street, S.W.
Atlanta, GA 30303-8950
Phone: (404) 562-9233
Fax: (404) 562-9224
Email: mikulak.ronald@epa.gov

Nathaniel Mund
Lobbyist
Conservation Council of NC
P.O. Box 12671
Raleigh, NC 27605
Phone: (919) 839-0020
Fax:
Email: mund@mindspring.com

Kurt Olson for NCCBI
Maupin, Taylor & Ellis
3200 Beechleaf Ct.
P.O. Drawer 19764
Raleigh, NC 27619
Phone: (919) 981-4000
Fax: (919) 981-4300
Email: kolson@maupintaylor.com

Deanna Osmond
Associate Professor and Extension Specialist
NCSU
Dept. of Soil Science
Box 7619
Raleigh, NC 27695-7619
Phone: (919) 515-7303
Fax: (919) 515-7494
Email: deanna_osmond@ncsu.edu

Connie Price
Planning Director
Wayne County
P.O. Box 227
Goldsboro, NC 27533
Phone: (919) 731-1650
Email: connie.price@ncmail.net

Ed Regan
Deputy Director
NC Association of County Commissioners
P.O. Box 1488
Raleigh, NC 27602-1488
Phone: (919) 715-2893
Fax: (919) 733-1065
Email: eregan@ncacc.org

Terry Rolan
Director of Environmental Resources
City of Durham
1600 Mistlake Drive
Durham, NC 27704
Phone: (919) 560-4381
Fax: (919) 560-4479
Email: trolan@ci.durham.nc.us

Marion Smith
Executive Director
Neuse River Foundation
P.O Box 15451
New Bern, NC 28561
Phone: (252) 637-7972
Fax: (252) 514-0051
Email: marion@neuseriver.org

Bob Slocum
NC Forestry Association
1600 Glenwood Avenue
Raleigh, NC 27611
Phone: (919) 834-3943
Fax: (919) 832-6188
Email: rwslocum@ncforestry.org

Scott Stevens
City of Kinston
Stormwater Engineer
P.O. Drawer 339
Kinston, NC 28502
Phone: (252) 929-3238
Email: scott.stevens@ci.kinston.nc.us

Paula Thomas
Director of Environmental Policy
NC League of Municipalities
P.O. Box 3069
Raleigh, NC 27602
Phone: (919) 715-3930
Fax: (919) 733-9519
Email: pthomas@nclm.org

Jerry Tweed
Heater Utilities, Inc.
P.O. Box 4889
Cary, NC 27519
Phone: (919) 467-7854
Fax: (919) 460-1788
Email: jtweed@huinc.com

Paul Wilms
NC Homebuilders Association, Inc.
P.O. Box 99090
Raleigh, NC 27624-9090
Phone: (919) 676-9090
Fax: (919) 676-0402
Email: pwilms@nchba.org

Mitch Woodward
Neuse Education Team
Wake County Extension Center
NC Cooperative Extension Service
College of Agriculture and Life Sciences
4001-E Carya Drive
Raleigh, NC 27610-2914
Phone: (919) 250-1100
Fax: (919) 250-1097
Email: mwoodward@co.wake.nc.us

Alternate Representatives:

Neuse River Foundation:
Heather Beard
Upper Neuse Operations Director
112 South Blount Street
Raleigh, NC 27601
Phone: (919) 856-1180
Fax: (919) 856-1182
Email: heathernrf@mindspring.com

NC Farm Bureau Federation:
Mitch Peele – 1st Alternate
P.O. Box 27766
Raleigh, NC 27722-2076
Phone: (919) 788-1004
Fax: (919) 783-3593
Email: peelema@ncfb.com

Chester Lowder – 2nd Alternate
P.O. Box 27766
Raleigh, NC 27722-2076
Phone: (919) 788-1016
Fax: (919) 783-3593
Email: lowderwc@ncfb.com

Lower Neuse Initiative:
Frank Sheffield
Ward and Smith, P.A.
1001 College Court
New Bern, NC 28562
Phone: (252) 672-5507
Fax: (252) 672-5477
Email: fhs@wardandsmith.com

On-Site Wastewater Section, DENR:
Steve Steinbeck
Division of Environmental Health
1642 Mail Service Center
Raleigh, NC 27699-1642
Phone: (919) 715-3273
Fax: (919) 715-3227
Email: steve.steinbeck@ncmail.net

Environmental Defense
Joe Rudek
2500 Blue Ridge Rd., Suite 330
Raleigh, NC 27607
Phone: (919) 881-2601
Fax: (919) 881-2607
Email: jrudek@environmentaldefense.org

City of Durham
Bill Telford – 1st Alternate
City of Durham
1600 Mistlake Drive
Durham, NC 27704
Phone: (919) 560-4385
Fax: (919) 560-4479
Email: wtelford@ci.durham.nc.us

Susan Turbak – 2nd Alternate
City of Durham
1600 Mistlake Drive
Durham, NC 27704
Phone: (919) 560-4381
Fax: (919) 560-4479
Email: sturbak@ci.durham.nc.us

Turfgrass Council of NC
Charles Peacock
Professor of Crop Science
North Carolina State University
Campus Box 7620
Raleigh, NC 27695
Phone: (919) 515-7615
Fax: (919) 515-7959
Email: charles_peacock@ncsu.edu

City of Raleigh
Marti Gibson
City of Raleigh
Public Utilities Department
P.O. Box 590
Raleigh, NC 27602
Phone: (919) 890-3400
Fax: (919) 890-3600
Email: gibsonmm@raleigh-nc.org

Heater Utilities
Jill Strickler
202 MacKenan Court
Cary, NC 27511
Phone (919) 467-8712 x41
Fax:
Email: Jstrickler@huinc.com

Sherol Lappala
Broad industry rep
NCCBI
Phone: (919) 793-9064
Email: slappala@eagleresources.com

Informational Mailing-List:

Don Cox
Supervisor
Orange County Soil and Water
Conservation District
7010 Thunder Mountain
Efland, NC 27243-9607
Phone: (919) 732-9351
Fax: (919) 563-8911
Email:

Sharon Haggett
US Army Corps of Engineers
P.O. Box 1890
Wilmington, NC 28402-1890
Phone: (910) 251-4441
Fax:
Email:sharon.f.haggett@saw02.usace.army.mil

Mark Borsuk
Nicholas School of the Environment
Duke University
Box 90328
Durham, NC 27708-0328
Phone: (919) 613-8054
Fax: (919) 613-8741
Email: meb6@duke.edu

Gail Mitchell
U.S. EPA Region IV
Water Management Division
61 Forsyth Street, S.W.
Atlanta, GA 30303-8950
Phone: (404) 562-9234
Fax: (404) 562-9224
Email: mitchell.gail@epa.gov