# Nutrient Sensitive Water Strategy

## OVERVIEW

Nutrients (nitrogen and phosphorus), which occur in fertilizers, human and animal wastes and air pollution, can promote phytoplankton blooms. These blooms, in turn, can deplete the water column of oxygen causing fish kills. Recurring nutrient-related problems have been documented in the Pamlico River Estuary through the latter half of the 20$^{th}$ century. Control of nutrients is necessary to limit algal growth potential, to assure protection of the instream chlorophyll *a* standard, and to avoid anoxic conditions and fish kills in the state's waterways. A large portion of the estuarine eutrophication problems have been linked to an overabundance of nutrients from agricultural and urban runoff, wastewater treatment plant discharges and atmospheric deposition.

The entire basin was classified as nutrient sensitive waters (NSW) by the North Carolina Environmental Management Commission (EMC) in 1989. As a result, a NSW strategy was developed to help assess progress towards meeting instream nutrient loading goals of a 30% reduction in total nitrogen (TN) loading and no increase in total phosphorus (TP) loading from the 1991 baseline. The strategy is to be implemented by WWTP dischargers, municipal stormwater programs and agriculture. Each of these programs report to DWR annually on their progress of meeting nutrient loading goals. Despite the fact that the targeted point and nonpoint pollution sources have been able to meet their nutrient reductions, total nitrogen and total phosphorous concentrations do not show a downward trend and loads have not permanently fallen below the 1991 baseline load goals.

While individual implementation dates varied, all of the rules were fully implemented by 2006. This report provides a summary of the nutrient strategy implementation progress followed by an evaluation of the strategy which identifies additional opportunities and research needs to address nutrient loading to the Pamlico River Estuary. For the complete NSW rules, visit http://portal.ncdenr.org/web/wq/ps/nps/tarpamlico. It is important to note that at this time, DWR is not reassessing the Total Maximum Daily Load (TMDL) or suggesting that the current NSW rules be modified. However, all rules are currently going through a review process as result of N.C. Gen. Stat. §150B-21.3A. For more information about the rules review process please go to the DWR rules review website at http://portal.ncdenr.org/web/wq/ps/csu/rules

Large portions of the Pamlico River Estuary remains impaired for chlorophyll *a* due to continuing standard violations throughout the estuary as result of elevated nutrient concentrations delivered to the estuary from all parts of the watershed. The water quality assessment of the Pamlico River Estuary occurs every two years, as part of the EPA 303(d) assessment, using 5 years worth of data. The identification of supporting and impaired segments of the estuary fluctuates as the data included in the assessment period represent different climatic conditions that influence algal distribution within the estuary (Table 1).

Table 1: Estimated Pamlico River Estuarine Chlorophyll *a* Acreage Exceeding the 40 µg/L Standard More than Ten Percent of the Time and Associated Flows at Upstream USGS gages.

| Assessment Period | 5 Yr Data Window | Total Estuarine Acres Exceeding Standard[2] | Percentage of Estuarine Acres[3] Exceeding Standard[2] | Tarboro 5 year Average Flow (cfs) | Greenville 5 year Average Flow (cfs) |
|---|---|---|---|---|---|
| 1994 Basin Plan[1] | 1988-1992 | 32,793 | 47.8 % | 2,133 | NA |
| 2006 IR | 2000-2004 | 27,764 | 41.0 % | 2,320 | 2,735 |
| 2008 IR | 2002-2006 | 27,764 | 41.0 % | 2,455 | 2,898 |
| 2010 IR | 2004-2008 | 28,892 | 42.7 % | 1,746 | 2,035 |
| 2012 IR | 2006-2010 | 28,892 | 42.7 % | 1,666 | 1,985 |
| 2014 IR | 2008-2012 | 10,045 | 15.2 % | 1,294 | 1,600 |

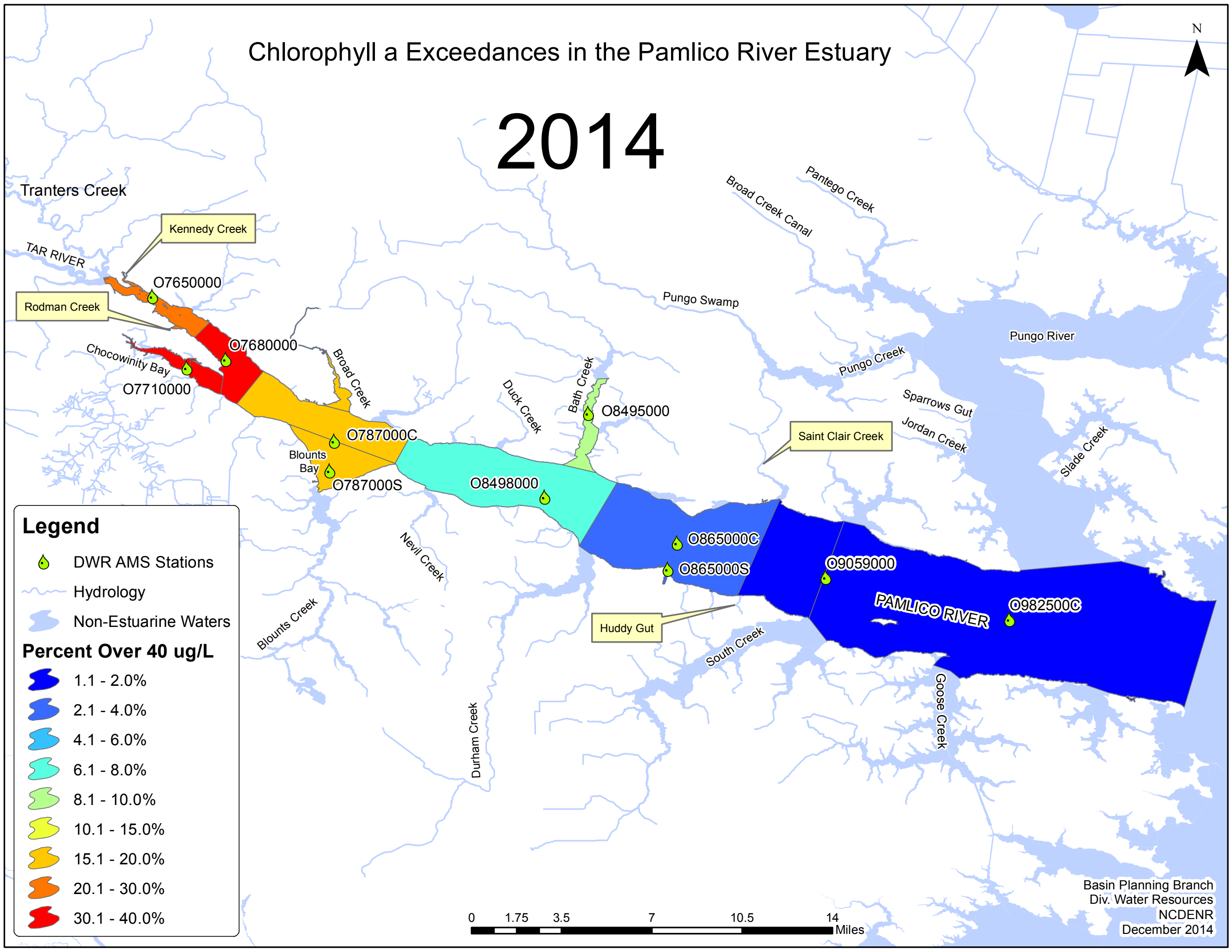
1 - The 1994 Tar-Pamlico River Basin Plan is the approved EPA TMDL and the impaired estuarine segments were based off of the shellfish growing areas (SGA), not assessment unit (AU) lengths;
2 - Number of acres that are exceeding the 40 µg/L chl *a* standard more than 10% of the time;
Pamlico River Estuary covers a total of 93,947 acres. Only those that have been assessed are include in the percentages provided (68,538 acres) (excluding Pungo River, South Creek and Goose Creek);
IR - Integrated Report (303(d)/305(b) use support assessment) period.

Assessment methods have changed over the IR (Integrated Report) periods but are generally based on whether the 5 year data set exceeds the chlorophyll *a* (chl *a*) standard of 40 µg/L in more than 10% of the samples collected at an ambient monitoring station, which represents a specific segment of the estuary (Table 2). For the purposes of comparing the different segment (AU's) in the Estuary and how they vary over time, the percent exceedances of the chl *a* standard is used as shown in Table 1 and Table 2.

Table 2: Tar-Pamlico TMDL Estuarine Segments and the Exceedance Assessment Over Time (click the link to view this table)

The data collected thus far shows that when the basin is in a low flow hydrologic condition, the higher chl *a* concentrations and percent exceedances move into the upstream portion of the estuary (2014 IR period). In contrast, under normal or elevated flows, the higher chl *a* concentrations and percent exceedance are pushed downstream and can be found as far down as the mouth of Huddy Gut (south shore) and Saint Claire Creek (north shore) (2006, 2008, 2010, and 2012 IR period)(Figure 1).

# FIGURE 1: PAMLICO RIVER ESTUARY PERCENT EXCEEDANCE OF THE CHL *a* STANDARD MAPS OVER FIVE ASSESSMENT PERIODS (2006 IR-2014 IR) (CLICK THE MAP BELOW FOR A PRINTABLE VERSION)

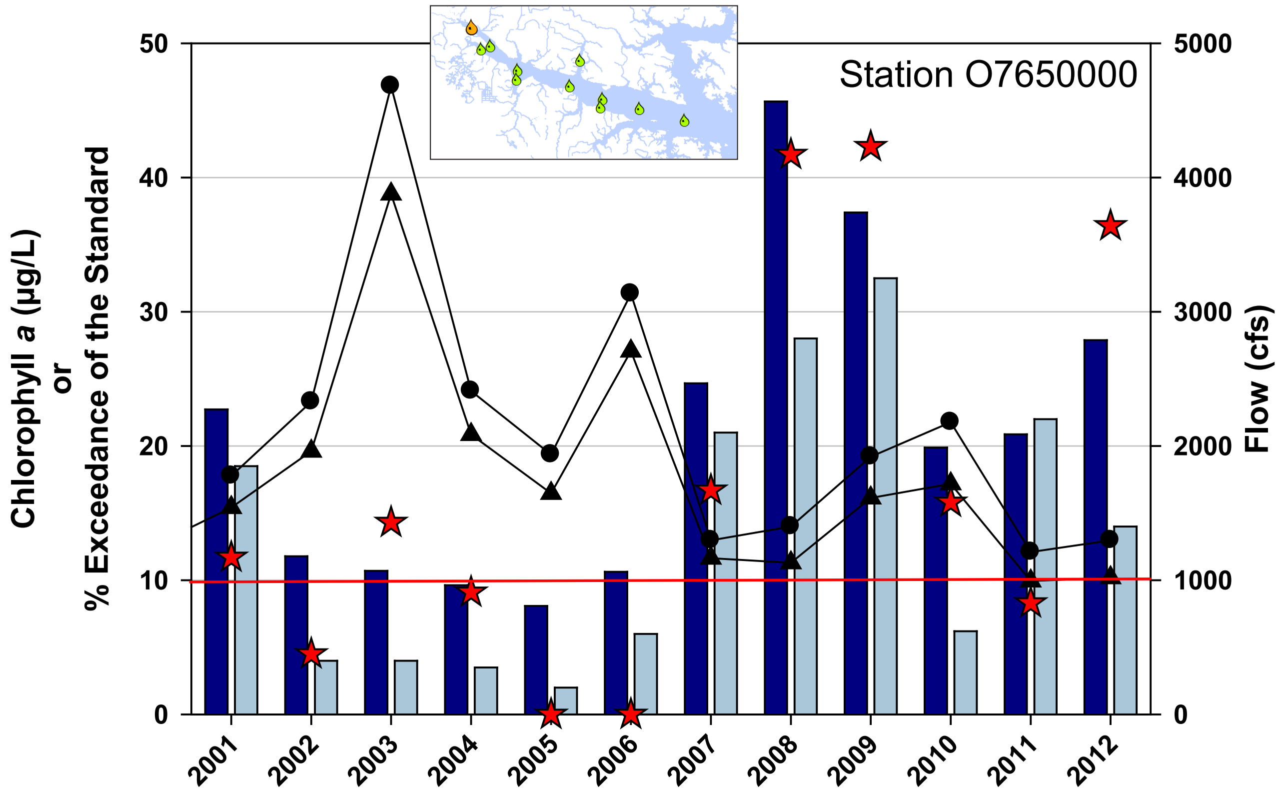



[Click here to view animated chlorophyll a percent exceedances for IR periods 2006 to 2014.]

The dramatic shift in chl *a* concentrations and number of exceedances that occur in the upper portion of the estuary as a result of the extended lower flows (2007-2012) can be seen in Figure 2A. The chl *a* concentration increased from a mean of 10.6 in 2006 (high flow) to 45.7 µg/L in 2008 (low flow) and the percent exceedances increased from zero to 42% respectively (Figure 2A). The oscillation effect can also be seen downstream in the middle and lower portions of the estuary. The chl *a* concentration at the middle estuarine station O865000C dropped from a mean of 24.7 to 10.1 µg/L and the percent exceedance from 12.5 to zero % in 2006 and 2008 respectively (Figure 2B). These shifts in chl *a* and percent exceedances can be seen in Figure 1 and Figure 3 throughout the estuary. Even at the most downstream station O982500C near the mouth of the estuary experiences high chl a concentrations and exceedances of the standard during the peak flow years of 2003, 2006 and 2010 (Figure 3).

FIGURE 2: CHLOROPHYLL *a* MEAN AND MEDIAN, PERCENT EXCEEDANCE OF THE CHLOROPHYLL *a* STANDARD OF 40 µg/L AND USGS YEARLY MEAN FLOW.

A) UPPER PAMLICO RIVER ESTUARINE STATION O7650000




B) MIDDLE PAMLICO RIVER ESTUARINE STATION O865000C

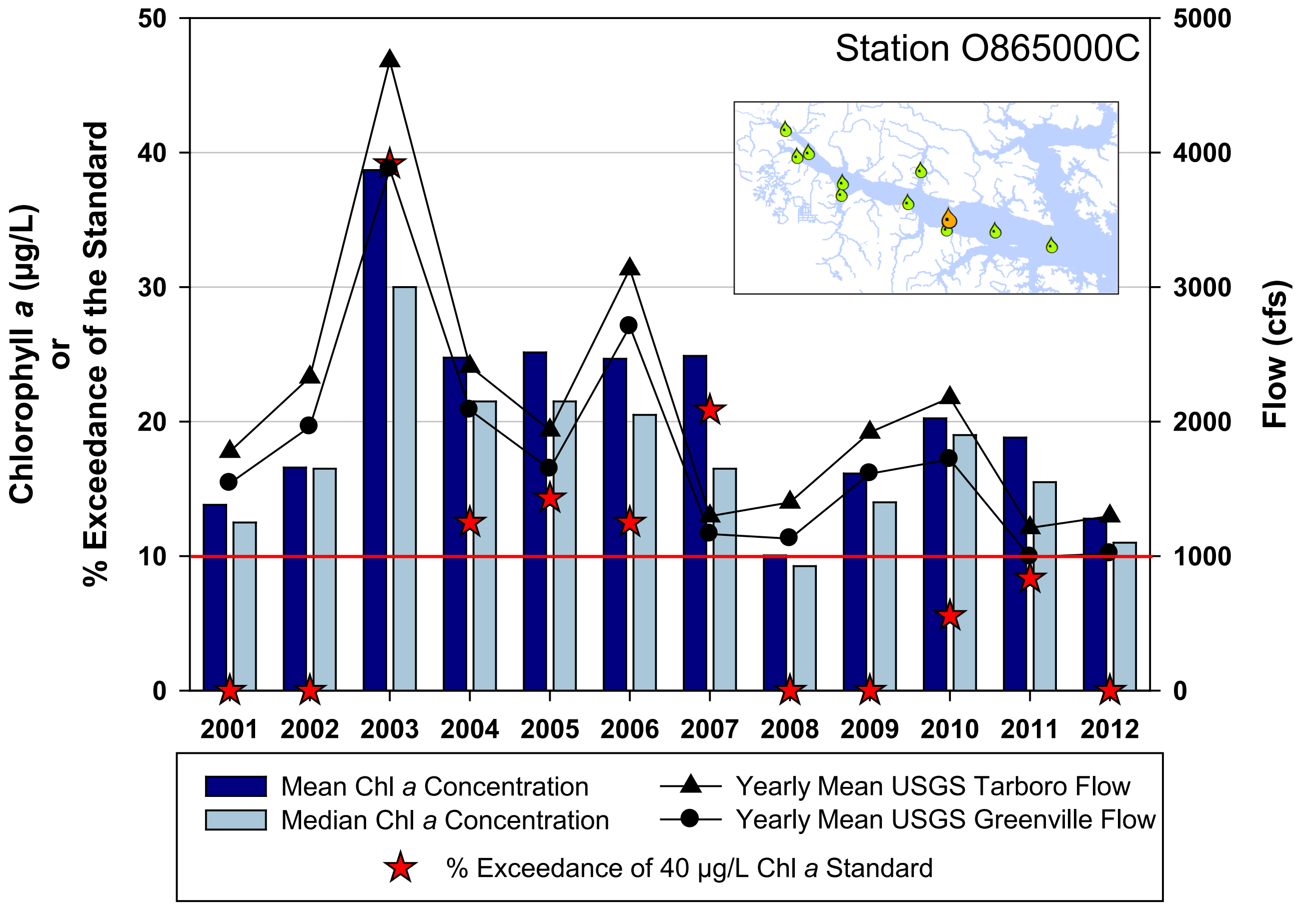
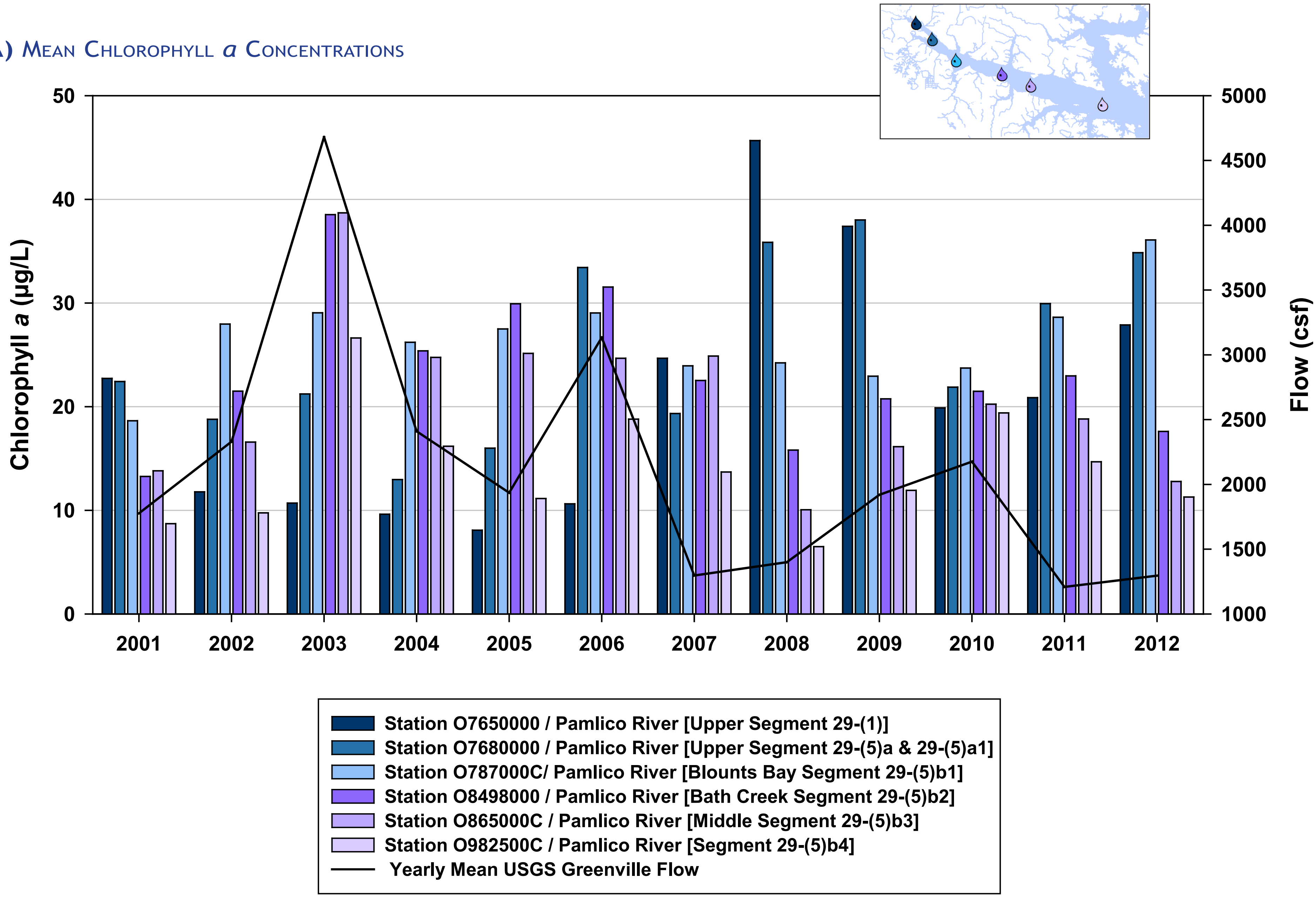


Figure 3: (**A**) Mean Chlorophyll *a* Concentrations & (**B**) Percent Exceedance of the Chlorophyll *a* 40 µg/L Standard Throughout the Pamlico Estuary for Years 2001-2012 and the Yearly Mean Flow at USGS Greenville Gage.

## A) Mean Chlorophyll *a* Concentrations

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B) Percent Exceedance of the Chlorophyll *a* 40 µg/L Standard Throughout the Pamlico Estuary for Years 2001-2012 and the Yearly Mean Flow at USGS Greenville Gage

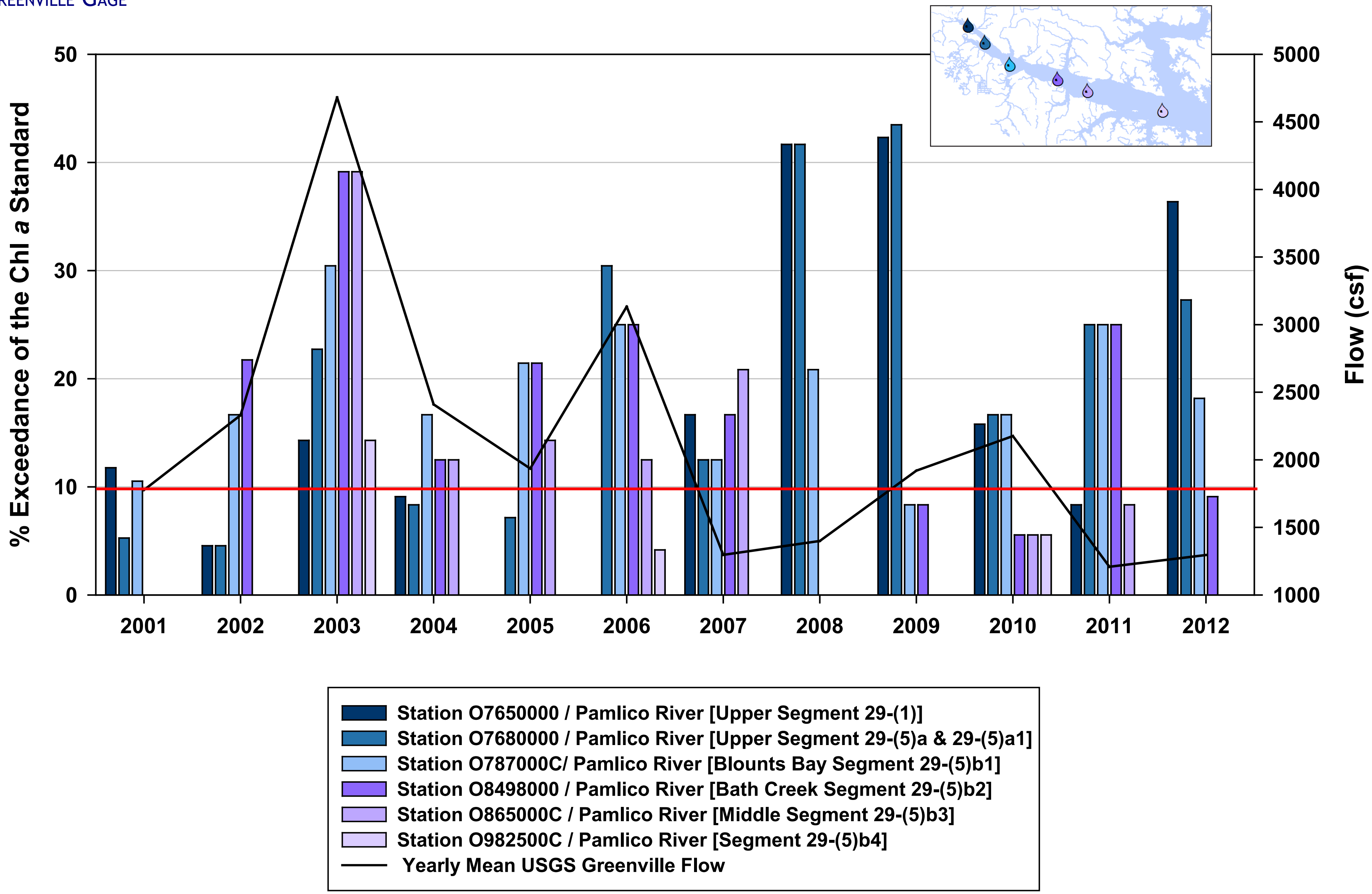




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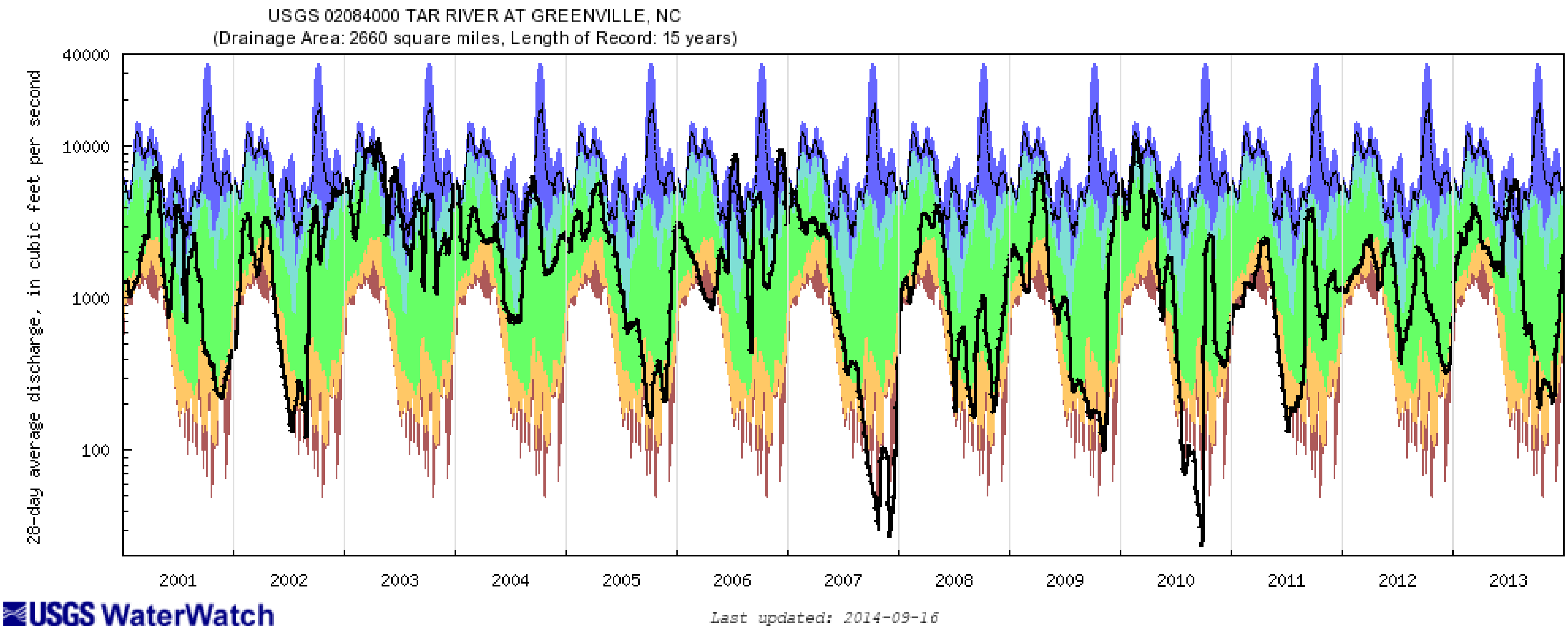
Figure 4 represents the hydrograph at the USGS Greenville gage (02084000) and shows the extended low flow period starting in early 2007. This is in comparison to the high flows seen in 2003, 2004, and 2006. Since the 2006 IR period, the portion of the Pamlico River Estuary identified as having exceedances greater than 10% of have ranged from 15.2 to 42.7% of the estuarine acres and will continue to fluctuate in response to instream flows, climatic conditions and nutrient contribution changes (Table 1 and Appendix II).

### Figure 4: Tar River Streamflow Duration Hydrograph at USGS Greenville Gage Station 02084000 (2000-2013)




| Explanation - Percentile classes | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| lowest- 10th percentile | 5 | 10-24 | 25-75 | 76-90 | 95 | 90th percentile -highest | Flow |
| Much below normal | | Below normal | Normal | Above normal | Much above normal | | |

# Trends in Nutrient Loading to the Pamlico River Estuary

## Pamlico River Estuary TMDL

A Total Maximum Daily Load (TMDL) is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant. Pollutant sources are characterized as either point sources or nonpoint sources. In 1995, the EPA approved the estuarine response modeling reported in the 1994 Basinwide Plan as the TMDL for nutrients in the Pamlico River Estuary.

Due to a combination of hydrologic conditions and nutrient inputs from upstream, the estuary from Washington downstream to Saint Claire Creek has and continues to experience excessive algal activity. Estuary response modeling was conducted to determine appropriate nutrient reduction goals, described in detail in the 1994 Basinwide Plan. DWR applied the model under the 1991 calibration conditions as well as under various nutrient reduction scenarios and plotted the results for a site located near Washington in order to evaluate possible management strategies. The model was calibrated under relatively high nutrient loading conditions, but also represented the typical estuary impairment conditions. However, 1991 was a much dryer than average year; 1991 mean annual flow measured at the USGS Tarboro gauging station was 1,249 cfs, whereas the average annual flow from 1897-2013 was 2,165 cfs. In wetter years, both nutrient loading and estuary response will differ from dry-year results (see Figure 2 and 3). Therefore, the modeling results were evaluated within the context of the model calibration.

The model recommendations include an instream reduction goal of 30% for total nitrogen (TN) (1,361,000 kg/yr target) and maintenance of existing total phosphorus (TP) loading (180,000 kg/yr) at Washington. The model indicated that NPDES permitted wastewater discharges contribute only 5% of the total nitrogen in the entire basin and approximately 8% of the total nitrogen in the basin upstream from the estuary. Nonpoint sources (including stormwater) therefore account for 92% of the TN loading. Based on the overall annual TN reduction goal of 583,000 kg/yr at Washington from all sources, annual point and nonpoint source reduction goals at Washington are as follows:

NPDES Permitted Wastewater Discharges/Point Source = 46,640 kg/yr (583,000 kg/yr x .08)

Nonpoint Sources (including stormwater) = 536,350 kg/yr (583,000 kg/yr x .92)

Reductions in nutrient inputs may take time to detect in measured loading, due to year-to-year variability in precipitation and flow. Based on the results of recent trend analysis (see trend analysis summary below) in the basin, it is evident that it will take more time to discern a 30 percent decrease in load to the estuary. The Pamlico River Estuary will continue to be monitored to determine if the chlorophyll *a* criterion is met and the Tar-Pamlico River will continue to be monitored to determine if the 30 percent TN load reduction and no increase in TP load from the 1991 level is being achieved. This information will help direct adaptive management in TMDL compliance activities.



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# Trend Analyses

## Introduction

DWR's Modeling and Assessment Branch used multiple trend and loading estimation tools to assess the progress towards meeting the NSW strategy goals. The trend analysis of annual nutrient concentrations for TN, TP, Total Kjeldahl Nitrogen (TKN), ammonia ($NH_3$-N), and nitrite+nitrate ($NO_x$-N) was conducted. TN is not directly measured, but is calculated as $NO_x$ plus TKN. The trend analyses focused on data from the ambient monitoring station O6500000, between 1991–2013, to evaluate progress towards meeting NSW reduction goals. This station is located at Grimesland, which is approximately 7 miles upstream of Washington.

Trend analyses were also completed for an additional four waterbodies within the watershed that drain to the Grimesland compliance point (Table 3 and Figure 5). These four ambient monitoring stations were chosen as result of their proximity to a USGS flow gages which allow for the most accurate assessment. These stations are spread throughout the basin (Figure 5) and provide additional insight as to what impact the nutrient reduction strategy has had in these smaller watersheds and where additional attention is needed to help meet the reduction goals. This information can help focus limited resources to those areas that might result in the greatest improvement in water quality.

Table 3: Ambient and USGS Gage Stations Used to Assess Tar-Pamlico River Basin Trends Analyses

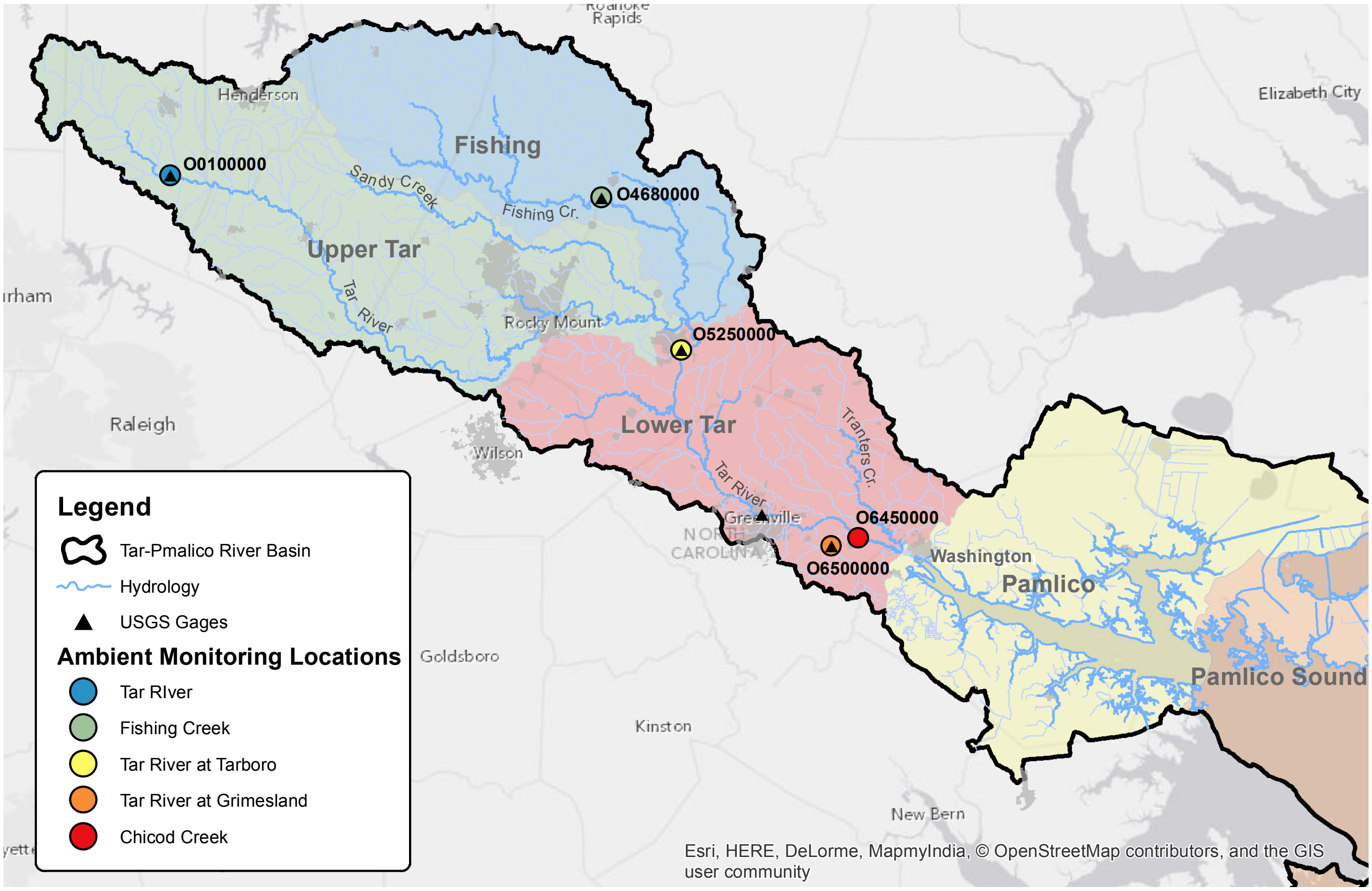
| River | Station Number | Station Location | USGS Flow Gage | Watershed Drainage Size ($mi^2$) | Trend Years |
|---|---|---|---|---|---|
| Tar River (Upper Portion) | O0100000 | Tar River at NC 96 near Tar River | 02081500 | 166.5 | 1991-2013 |
| Fishing Creek | O4680000 | Fishing Creek at US 301 near Enfield | 02083000 | 529.7 | 1991-2013 |
| Tar River (Middle Portion) | O5250000 | Tar River near Tarboro | 02083500 | 2,224.2 | 1991-2013 |
| Chicod Creek | O6450000 | Chicod Creek at SR 1960 near Simpson | 02084160 | 44.0 | 1993-2013 |
| Tar River (Lower Portion) | O6500000* | Tar River at SR 1565 near Grimesland | 02084000^ | 2,897.0 | 1991-2013 |

* Tar-River station O6500000 at Grimesland is used as the NSW compliance point because this station is close the City of Washington at the head of the estuary but is generally out of the tidal influence in the estuary which interferes with flow estimates.
^Greenville USGS gage station (02084000) is the closest upstream gage (~13 miles).

The purpose of any statistical trend testing is to determine whether a set of data that arise from a particular probability distribution represent a detectable increase or decrease over time (or space). There are a wide variety of trend testing techniques, all of which have certain assumptions that must be met for the analysis to be valid.

Detecting trends in a water quality data series is not as simple as drawing a line of best fit and measuring the slope. There are likely to be multiple factors contributing to variation in water quality over time, many of which can hide or exaggerate trend components in the data. Changes in water quality brought about by human activity will usually be superimposed on natural sources of variation such as flow and season. Identification and separation of these components is one of the most important tasks in trend testing. A complete review of the trend analysis, methodologies use and results are presented in Appendix I. For purposes of the *NSW Strategy* overview report, only the trend results are summarized within the main body of this report.

Figure 5: Tar-Pamlico River Basin Map Showing the Ambient and USGS Gage Stations Used for Trend Analysis.




Analysis completed for the Tar-Pamlico basin assessment includes:

***Seasonal and flow-adjusted concentration trends***; used to evaluate long term changes in instream concentrations.

***Flow-normalized (FN) nutrient loads estimates***

- **Annual nutrient load using flow weighted average concentrations**; used to evaluate which flow interval (low, medium or high) delivers the largest portion of the overall load to the system.
- **Long term flow-normalized load estimates**; used to evaluate long term changes in nutrient loads associate with different flow regimes and comparing to a benchmark 5 year period (1991-1995, except for Chicod Creek which is 1993-1997)

***USGS LOAD ESTimator (LOADEST) annual load***; used to estimate an annual load time series and estimated unit area loading time series (using watershed area).

## Trend Analysis Results

*Flow-Adjusted Concentration at Grimesland -TMDL watershed compliance point*

The results of the Seasonal Kendall test for flow-adjusted concentrations of TP, TN, TKN, $NH_3$-N, and $NO_x$-N at station O6500000 (Grimesland) are provided in Table 4 (highlighted in yellow). The results indicate that there were statistically significant concentration trends for TN, $NH_3$-N, $NO_x$-N, and TKN (Table 4). There was not a statistically significant trend for TP. TN and TKN showed increasing trends in concentration, while both $NH_3$-N and $NO_x$-N showed decreasing trends. Additonal trends done on just data from 2002-2013 show significant increases in TKN, TN and TP at Grimesland; these results are found in Appendix I.

The reductions in $NH_3$-N and $NO_x$-N through 2013 are estimated to be 33% and 22%, respectively; and increases in TN and TKN are estimated to be 11% and 55%, respectively (Table 4). The rate of change in instream concentrations are likely to vary over time as more data is available, which increases confidence in a trends assessment. The trend will also vary due to the implementation of the NSW strategy, along with changing weather patterns that directly affect the rate of nutrient inputs or dilution effects in the system. The lack of progress in achieving the TN reduction appears to be the result of the continuing increase in organic nitrogen (TKN minus $NH_3$-N) component of TN. Identifying the source of the organic nitrogen appears to be crucial in understanding how to control the increasing TN concentration and to achieve the required reductions needed throughout the Tar-Pamlico basin.

Table 4: Percent change for Seasonal Kendall Trend Analysis for Flow-adjusted Concentration at all Stations

| Water Quality Constituents (mg/L) | O0100000 Tar River (Tar River) | O4680000 Fishing Creek | O5250000 Tar River (Tarboro) | O6450000 Chicod Creek | O6500000 Tar River (Grimesland) |
|---|---|---|---|---|---|
| $NH_3$-N | | - 39% | - 41% | - 38% | **- 33%** |
| $NO_x$-N | - 160% | - 58% | - 42% | - 57% | **- 22%** |
| TKN | + 37% | + 60% | + 44% | | **+ 55%** |
| TN | | + 36% | | | **+ 11%** |
| TP | + 36% | | | | |

Data provided for only those found to be statistically significant;
Minus - Denotes constituent concentration declining and water quality improving;
Plus - Denotes constituent concentration increasing and water quality declining

*Flow-Adjusted Concentration Trends for the Remaining Four Tar-Pamlico Watershed Stations.*

Four additional watershed stations were chosen for assessment of nutrient concentration trends similar to those completed above for Grimesland (O6500000), the Tar-Pamlico River Basin NSW nutrient compliance point. A summary of the estimated changes in concentration for those that are statistically significant from 1991 baseline are in Table 4.

All watersheds draining to these stations except the upper Tar River at station O0100000 are experiencing a reduction in $NH_3$-N concentration. All watersheds assessed also showed a decreasing trend in $NO_x$-N concentration ranging from 160% decline in the upper Tar River (O0100000) to a minimum decline of 22% at Grimesland (O6500000). All watersheds except Chicod Creek (O6450000), a heavily agricultural watershed (40.48% Ag), showed a significant increasing trend in organic nitrogen concentration (TKN is comprised of $NH_3$-N and organic nitrogen).

Since $NH_3$-N is decreasing in most of these watersheds, the increasing component of TKN is the organic fraction. The significant increases ranged between 37 and 60 % of the original instream concentrations.

Significant increases in TN concentrations were found at Fishing Creek (O4680000) (36%) and at Tar River at Grimesland (O6500000)(11%). TN concentration is determined by adding TKN plus $NO_x$. The reductions in the $NO_x$-N concentration at all the stations tested in the watershed are offset by increases in TKN (organic nitrogen fraction) at almost all the stations in the watershed. Only the upper Tar River watershed (O0100000) has a significant increase in TP concentration of 36%.

### *Flow-Normalized Nutrient Load Estimates*

### Annual Nutrient Load Estimation

Annual nutrient load assessments were calculated using flow-weighted average concentrations. The 1991-2013 flow records were used for each station to develop flow thresholds that were used to group nutrient data by low (0-33%), middle (34-66%), and high (67-100%) flow regimes. This approach allows for the determination of which flow interval delivers the largest portion of the overall load to the Tar-Pamlico system. The data in Table 5 clearly show that the largest contribution of nutrients occur during the high flow events at Grimesland and throughout the system. The average TN contribution at Grimesland from low, middle, and high flow intervals were 6, 20 and 74% respectively and for TP contribution was 6, 19, and 75% respectively. The contribution of TN and TP from high flows throughout the Tar-Pamlico River watershed ranged between 77 to 92.8% (Table 5). For tables presenting the average concentration of TN, TKN, NOx-N and TP by five-year periods and flow intervals for all stations see Appendix II at the end of this report.

Table 5: Average TN and TP Percent Contribution from Flow Intervals (1991-2013).

| Flow Interval | Tar River at Tar River O0100000 | | Fishing Cr. O4680000 | | Tar River at Tarboro O5250000 | | Chicod Cr. O4650000 | | Tar River Grimesland O6500000 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | TN (%) | TP (%) | TN (%) | TP (%) | TN (%) | TP (%) | TN (%) | TP (%) | TN (%) | TP (%) |
| Low | 1 | 0.6 | 5 | 4 | 5 | 4.4 | 1 | 2 | 6 | 6 |
| Medium | 7 | 6.6 | 16 | 19 | 18 | 16.2 | 7 | 9 | 20 | 19 |
| High | 92 | 92.8 | 79 | 77 | 77 | 79.4 | 92 | 89 | 74 | 75 |

Over the 1991-2013 assessment period, annual TN loads at Grimesland ranged between 2.2 to 9.3 x $10^6$ lbs/yr with a mean value of 4,700,000 lbs/yr and TP loads ranged between 0.24 to 1.27 x $10^6$ lbs/yr with a mean value of 567,000 lbs/yr (Table 6). Figure 15a & 15b representing the annual load for the TN and TP flow-normalized time series can be seen in Appendix III. The load of TN and TP at the Tar River at Tarboro is approximately 61.5% of the load at Grimesland (Table 6). This indicates that about 38.5% of the load to Grimesland is being delivered from the 03020103 (Lower Tar River) watershed which accounts for 23.2% of the watershed area.

### Table 6: 1991-2013 TN and TP Annual Loading Estimates at Each Watershed Station.

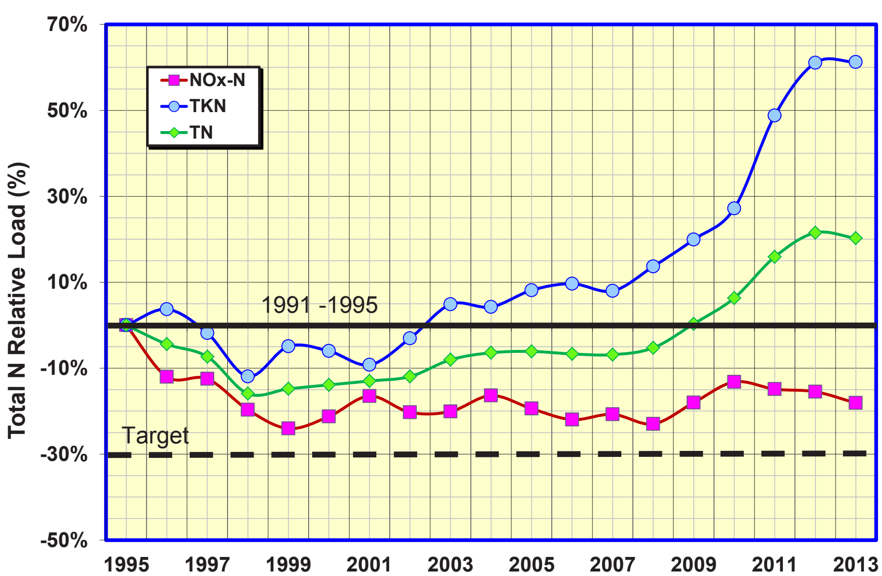
| Watershed | Station Number | TN Loading Range 1991-2013 (lbs/yr) | TN Mean Value (lbs/yr) | % of Load* | TP Loading Range 1991-2013 (lbs/yr) | TP Mean Value (lbs/yr) | % of Load* |
|---|---|---|---|---|---|---|---|
| Tar River at Tar River | 00100000 | 0.1 to 4.4 x $10^5$ | 190,000 | 4.0% | 0.06 to 0.7 x $10^5$ | 23,000 | 4.1% |
| Fishing Cr. | 04680000 | 0.65 to 9.6 x $10^5$ | 409,000 | 8.7% | 0.1 to 1.2 x $10^5$ | 47,000 | 8.3% |
| Tar River at Tarboro | 05250000 | 0.74 to 6.2 x $10^6$ | 2,892,000 | 61.5% | 0.5 to 8.9 x $10^5$ | 361,000 | 63.7% |
| Chicod Cr. | 06450000 | 0.12 to 3.34 x $10^5$ | 142,800 | 3.0% | 0.04 to 0.67 x $10^5$ | 25,700 | 4.5% |
| Tar River at Grimesland | 06500000 | 2.2 to 9.3 x $10^6$ | 4,700,000 | | 0.24 to 1.27 x $10^6$ | 567,000 | |

* Percent of total load to Tar River at Grimesland station 06500000, NSW nutrient compliance point;
The NSW Tar River TN target at Washington is 3,000,491 lbs/yr (1,361,000 kg/yr) or less and the TP target is not to exceed 396,832 lbs/yr (180,000 kg/yr).

## Long Term Flow-Normalized Nutrient Load Estimation

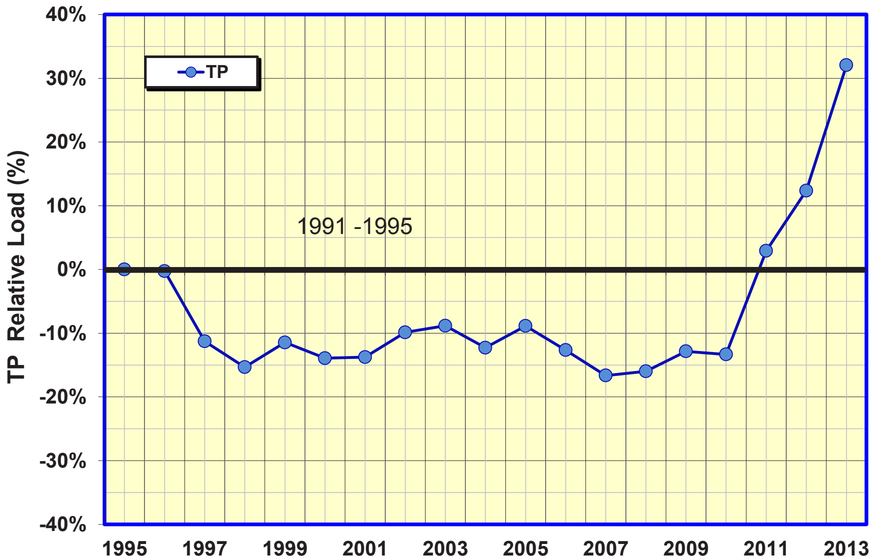
In order to evaluate progress in achieving the nutrient reduction goal set by the Tar Pamlico River Basin NSW Strategy, Flow-Normalized (FN) load estimated under long-term average flow conditions were compared to the average load for the 1991-1995 period. Five-year moving averages of $NO_x$-N, TKN, TN and TP loads were computed and compared with the corresponding value for the 1991–1995 period (Figure 6 and Figure 7).

### Figure 6: Relative Flow-Normalized TN load Reduction Comparison to 1991-1995 at Tar River Grimesland Station 06500000.




Similar to the concentration trend analysis at Grimesland, the results of the FN loading analysis indicates a reduction in FN NOx-N loading along with an increase in TKN (organic nitrogen) loading (Figure 6). Flow-normalized NOx-N loading gradually decreased from the 1991-1995 period to the end of the study period. It reached a minimum value of -24.1% in the 1995–1999 time period. The average reduction achieved was approximately 18% for all periods beginning with 1992–1996. Flow-normalized TKN loading decreased from the baseline period and reached the minimum values of -12.0% in the 1994-1998 period and increased substantially afterwards. Flow-normalized TKN loading has been consistently higher than the 1991–1995 period throughout the past 11 five-year periods and increased to greater than 60% for the last five-year period ending in 2013. The flow-normalized TN loading decreased to a minimum value of -15.9% in the 1994-1998 period and increased gradually afterwards in response to the increasing TKN (Organic fraction).

FIGURE 7: RELATIVE FLOW-NORMALIZED TP LOAD REDUCTION COMPARISON TO 1991-1995 AT TAR RIVER GRIMESLAND STATION O6500000.




Flow-normalized TP loading at Grimesland has been consistently lower than the corresponding 1991-1995 loading until the 2007-2011 period when the load began to increase and has climbed to approximately 30% greater than the 1991-1995 load (Figure 7). The increase in TKN and TP over the last three to four, five-year periods need further investigation in order to determine the cause of such a drastic shift in the loading of these two nutrient parameters. The data range for this shift is about 2006 to 2013. There was an extended low flow period during this time frame which should have resulted in lower loading if in fact the highest loads come from high flow events as described earlier. It will take some time to understand all of the possible contributing factors that have led to these results. As information becomes available, this section of the plan will be updated to reflect new information and research results.

Similar FN trends were seen at the other watershed stations assessed with the exception of Chicod Creek (all Flow-Normalized graphs provided in Appendix IV). The results of the FN loading analysis for Chicod Creek indicate reductions in FN TN, NOx-N, TKN and TP loadings relative to the 1993-1997 period. It is important to remember that the Chicod Creek assessment is relative to 1993-1997 instead of 1991-1995 like the rest of the stations. Data is not available for Chicod Creek prior to 1993. By using 1993 instead of 1991 as the baseline in Chicod Creek, which according to the annual loading graph in the Appendix III was a high loading year for Chicod Creek watershed, the reduction needed to fall below this threshold is not as difficult to achieve. Since the 2004-2008 five-year period, TN, NOx-N and TKN have all increased but are still below the 1993-1997 initial loading period.



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### *LOADEST TN and TP Estimated Annual Load Time Series and Unit Area Loading Results*

The USGS LOAD ESTimator (LOADEST) tool for estimating constituent loads in streams and rivers was used to produce the TN and TP annual load time series. Load assessments (concentration x flow) are highly impacted by precipitation as can be seen in 1999 (hurricane Floyd) and 2003 (unusually wet year). This assessment is used to see the general pattern of loading compared to the 1991 baseline year. It is important to remember that 1991 was a very dry, low stream flow year which affected the overall loading for both nitrogen and phosphorus.

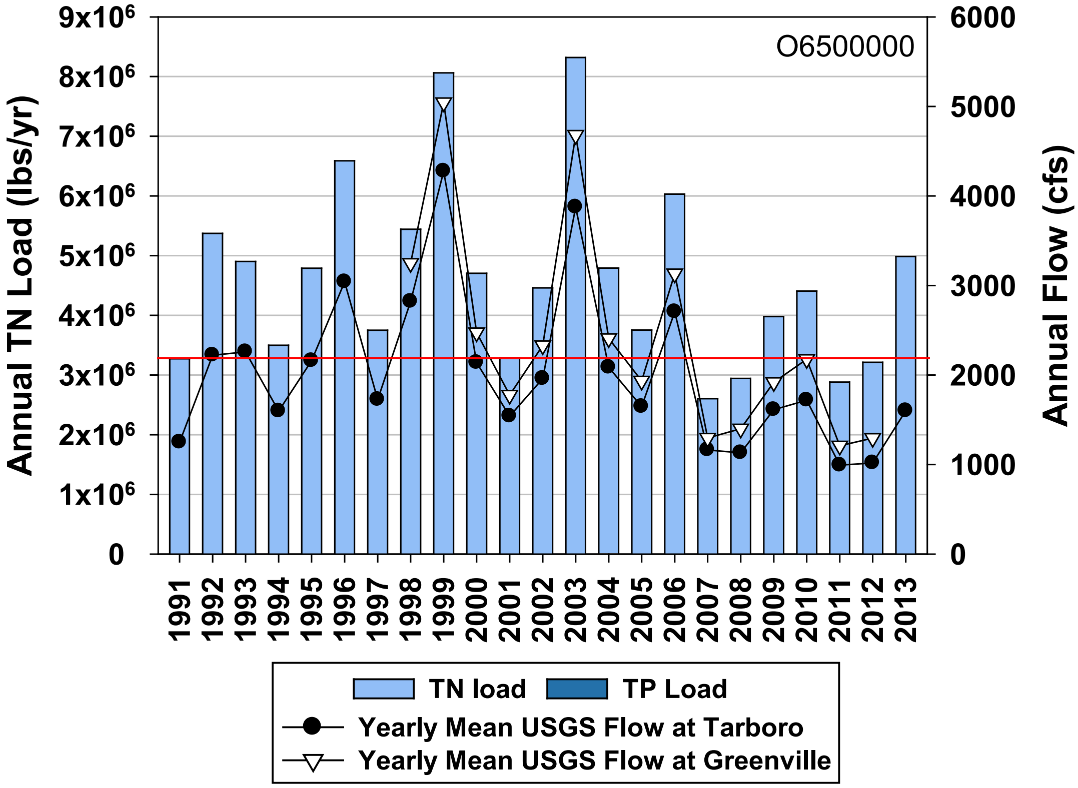
The NSW Tar River TN load target at Washington is 3,000,491 lbs/yr (1,361,000 kg/yr) or less and the TP target is not to exceed 396,832 lbs/yr (180,000 kg/yr). Tar-River station O6500000 at Grimesland is used as the NSW compliance point because this station is close to the City of Washington at the head of the estuary but is generally out of the tidal influence in the estuary which interferes with flow estimates used in loading analysis.

The LOADEST TN annual load time series at Grimesland is provided below is Figure 8(A). The red line in Figure 8 denotes the 1991 estimated load. The only years that fell below the 1991 estimated load was 2007, 2008, 2011 and 2012.

The TP annual load time series at Grimesland is provided in Figure 8(B). Similar to the TN loading summary, the only years with estimated total TP loads less than the 1991 baseline are 2007, 2008 and 2011. It should be noted that 2007, 2008, 2011 and parts of 2012 were impacted by drought conditions. This implies that the total load is being driven more by the amount of precipitation, which drives flow, than by nutrient concentrations.

Figure 8: LOADEST Time Series of Annual Load of TN and TP (lbs/yr) at Grimesland O6500000 with Mean Flow at Tarboro and Grimesland USGS Tar River Gages.

A) TN Estimated Annual Load Series




Red Line Denotes 1991 Estimated Load.

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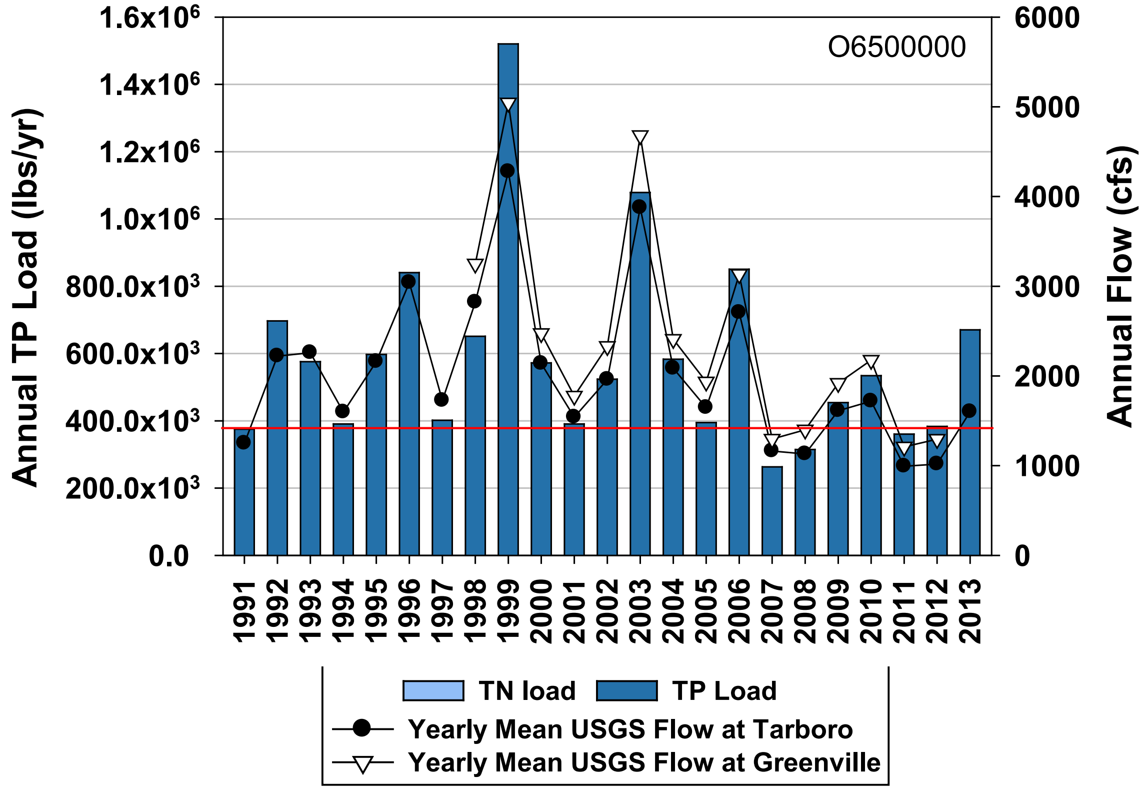
### B) TP Estimated Annual Load Series




Red Line Denotes 1991 Estimated Load.

The LOADEST TN and TP annual load estimations were also done for the four additional watersheds throughout the basin in order to understand the loads coming from each and how they contribute to the overall loading at the Grimesland compliance point (Figure 5). Table 7 (TN) and Table 8 (TP) provide the load range and average load with a list of the years in which the yearly mean load fell below the 1991 baseline load. They also provide the Unit Area Load (UAL) for each watershed. The individual watershed estimated annual load series graphs are located in Appendix V and are also presented as a group in the detailed trends review in Appendix I, Figure 19-22.

The upper Tar River at Tar River (O0100000) has a relatively high level TN and TP loading for a head water region that is mostly forested. Additional research is needed in order to determine the source of the high loading in this small headwater portion of the upper Tar River watershed.

Fishing Creek (O4680000) had the lowest TN and TP UAL of all the watersheds tested. The TN and TP UAL is 5.2 time and 5.6 times higher at Grimesland than in Fishing Creek. The yearly estimated TN and TP loading was lower in 10 and 9 of the 22 years post the 1991 baseline loads respectively (Table 7 and Table 8). Additional research is needed to determine what land use changes have occurred and what nutrient reduction controls have been utilized to help protect this watershed.

The loading at Tar River at Tarboro (O5250000) represents what is coming into this station from the two upstream subbasins. The UAL is fairly equivalent to that at Grimesland.

### Table 7: LOADEST Estimated Total Nitrogen Annual Load and Unit Area Loading.

| Watershed | Station Number | Watershed Drainage Size (mi²) | TN Loading Range 1991-2013 (lbs/yr) | Mean TN Load (lbs/yr) | Years Below 1991 Mean TN Load | TN UAL Loading Range 1991-2013 (lbs/mi²/yr) | TN Mean UAL Load (lbs/mi²/yr) |
|---|---|---|---|---|---|---|---|
| Tar River at Tar River | 00100000 | 166.5 | 0.65 to 7.83 x $10^5$ | 300,929 | 2005, 2007, 2011, 2012 | 390-4,702 | 1,807 |
| Fishing Cr. | 04680000 | 529.7 | 0.45 to 3.63 x $10^5$ | 160,917 | 1992, 1994, 2000, 2001, 2005, 2006, 2007, 2010, 2011 2012 | 86-685 | 304 |
| Tar River at Tarboro | 05250000 | 2,224.2 | 1.70 to 6.40 x $10^6$ | 3,161,774 | 2001, 2007, 2008, 2011, 2012 | 750-2,878 | 1,423 |
| Chicod Cr.* | 06450000 | 44.0 | 0.47 to 6.35 x $10^5$ | 188,112 | 1994, 1995, 1997, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2011, 2012 | 1,068-14,420 | **4,275** |
| Tar River at Grimesland | 06500000 | 2,897.0 | 2.60 to 8.32 x $10^6$ | 4,593,624 | 2007, 2008, 2011, 2012 | 899-2,872 | 1,586 |

UAL - Unit Area Loading (lbs/mi²/yr);
*Chicod Creek load compared to 1993 instead of 1991.
The NSW Tar River TN target at Washington is 3,000,491 lbs/yr (1,361,000 kg/yr) or less and the TP target is not to exceed 396,832 lbs/yr (180,000 kg/yr).

### Table 8: LOADEST Estimated Total Phosphorus Annual Load and Unit Area Loading.

| Watershed | Station Number | Watershed Drainage Size (mi²) | TP Loading Range 1991-2013 (lbs/yr) | Mean TP Load (lbs/yr) | Years Below 1991* Mean TP Load | TP UAL Loading Range 1991-2013 (lbs/mi²/yr) | TP Mean UAL Load (lbs/mi²/yr) |
|---|---|---|---|---|---|---|---|
| Tar River at Tar River | 00100000 | 166.5 | 0.07 to 1.12 x $10^5$ | 39,106 | 2007, 2011, 2012 | 42-675 | 235 |
| Fishing Cr. | 04680000 | 529.7 | 0.05 to 0.42 x $10^5$ | 19,264 | 1992, 1997, 2000, 2001, 2005, 2007, 2010, 2011 2012 | 9-79 | 36 |
| Tar River at Tarboro | 05250000 | 2,224.2 | 0.19 to 0.95 x $10^6$ | 393,712 | 2007, 2008, 2011, 2012 | 85-429 | 177 |
| Chicod Cr.* | 06450000 | 44.0 | 0.06 to 1.29 x $10^5$ | 32,111 | 1994, 1997, 2000, 2001, 2002, 2004, 2005, 2007, 2008, 2009, 2010,2011, 2013 | 138-2,927 | **730** |
| Tar River at Grimesland | 06500000 | 2,897.0 | 0.26 to 1.52 x $10^6$ | 579,692 | 2007, 2008, 2011 | 91-525 | 200 |

UAL - Unit Area Loading;
*Chicod Creek load compared to 1993 instead of 1991.
The NSW Tar River TN target at Washington is 3,000,491 lbs/yr (1,361,000 kg/yr) or less and the TP target is not to exceed 396,832 lbs/yr (180,000 kg/yr).

The estimated mean TN loading in Chicod Creek was 188,112 lbs/yr with a UAL mean of 4,275 lbs/mi$^2$/yr (Table 7). The estimated mean TP loading was 32,110 lbs/yr with a UAL of 730 lbs/mi$^2$/yr (Table 8). The UAL from Chicod Creek is substantially higher than all the other watersheds assessed and the TN and TP UAL is 2.7 time and 3.7 times higher from the Chicod Creek watershed than at the Tar River at Grimesland station. Chicod Creek is a small 44 square mile agricultural based watershed but is located in close proximity to Grimesland and the estuary. Chicod Creek watershed only accounts for 1.5% of the overall Grimesland watershed area but accounts for 4.1% of the overall estimated mean load. While it appears that the loads are lower than the 1993 baseline load, it is considerably high and the sources of nutrients in this watershed should be identified. DWR should work closely with the Soil and Water Conservation District to determine what BMPs have been utilized and if additional practices are likely to help reduce the high instream concentrations and overall load. Chicod Creek is a highly agricultural watershed and likely represent conditions in similar agricultural watersheds in the lower coastal plain.

The NSW TN loading target at Grimesland is 3,000,491 lbs/yr. The estimated annual TN loading range at Grimesland was 2,603,728 to 8,319,762 lbs/yr with a mean of 4,593,624 (Table 7). The target falls within the loading range seen at Grimesland but has only fallen below the target in 2007, 2008 and 2011, all of which were very low flow years. The NSW TP target is not greater than 396,832 lbs/yr. The estimated annual TP loading range at Grimesland was 263,069 to 1,520,328 lbs/yr with a mean of 579,692 lbs/yr. The target for TP loading also fell within the range of loading delivered to Grimesland in 7 of the 22 years post the 1991 baseline period (1994, 2001, 2005, 2007, 2008, 2011 and 2012), again these were all low flow periods.

## Trend Analysis Discussion & Next Steps

Based on the trend analyses the TN 30% loading reduction goal has not been reached and the TP load has exceeded the 1991 maintenance level. There is also no decrease in TN or TP concentrations trends. Reevaluation of the TMDL is justified when the 30% TN instream load reduction has been achieved and chlorophyll *a* standards are still not being met.

Even though significant efforts have been taken by point sources and the agricultural community to reduce their collective nutrient loading, the implementation of the NSW strategy has thus far not resulted in meeting water quality standards in the Pamlico River Estuary. The decrease in annual loads of TP and TN below the baseline levels as shown in Figure 8 (low flow years) suggest that nutrient loading to the estuary is likely a result of nonpoint source contributions. However, the fact that the instream nutrient concentrations are higher during the low flow periods also indicates that the source of nutrients during these periods is possibly coming from groundwater. Groundwater makes up the majority of the base flow in streams during low flow periods. Groundwater contribution was also likely reduced during the drought of the late 2000's as the drought extended over several years and impacted groundwater levels as well. This is an area of research that is needed to help understand the effects and nutrient contributions of groundwater in the Tar-Pamlico River system.

The NSW strategy accounts for aspects of agriculture and stormwater nonpoint source contributions however, it is recognized that some nonpoint sources may have not been accounted for or are exceeding the original source contributions. Specifically, looking at the different forms of nitrogen, organic nitrogen has increased and thus warrants identifying sources and reducing inputs of organic nitrogen throughout the basin.

By expanding the analysis outside of the TMDL compliance point and focusing on specific watersheds with dominant land use types, staff may be able to better gauge the effectiveness and progress of strategy implementation. For this reason DWR's Modeling and Assessment Branch conducted additional trend analyses on tributaries within the basin that represent predominately agriculture and urban watersheds. Additional analysis is needed to tease out the impacts of the different land use practices. The data clearly show a substantial nutrient contribution from the agricultural watershed assessed in this study (Chicod Creek). The unit area loading for Chicod Creek was the highest in the basin with the mean 2.7 times higher than that of the whole watershed (Grimesland). The need to understand if the nutrient loads are getting into the system through runoff or through groundwater contributions is needed. Work with the local Soil and Water Conservation District staff is necessary to help understand the practices that are occurring in this watershed and what additional areas can be address to help focus limited resources to best improve water quality throughout agricultural watersheds. The flow-normalized annual loading assessment for the Lower Tar subbasin 03020103 (a heavily agricultural watershed) accounts for approximately 39% of the annual mean load but only accounts for 23% of the watershed area draining to Grimesland. Taking what is learned from the Chicod Creek assessment and applying them to other agricultural watersheds could help improve the water quality in those areas as well.

Additional analysis is needed to better understand the process occurring for the other watershed as well. There is a need to understand the sources of TKN and TP loading in the upper Tar River at Tar River in order to  understand this headwater area and why the load is relatively high for this headwater watershed. It is also important to understanding what is happening in the Fishing Creek watershed to decipher why the loading is lower in this watershed. While the loading is lower relative to the other watersheds, there has been a significant increase in the TKN and TN instream concentrations over the baseline period, therefore additional reductions are needed in the Fishing Creek watershed as well.

While we believe that further analyses of existing data and additional years of data collection will provide greater certainty as to the effect of the strategy on the estuary, we also recognize other basin factors (e.g., groundwater, atmospheric deposition, nutrient recycling) may contribute to the results seen in these analyses and conditions in the estuary.

Additional trends analysis at other flow gages throughout the basin could help decipher changing waters quality patterns as the NSW strategy is implemented. Ambient nutrient monitoring is needed at flow gages throughout the state to help in these types of analysis as we move forward.

## NSW Strategy Program Reviews

The goal of a 30 percent reduction in TN loading and no increase in TP loading from 1991 conditions at Washington and the goal of meeting chlorophyll *a* water quality standards within the Pamlico River Estuary has not been achieved to date. However, the efforts to reduce nitrogen from several sources have been very successful and additional reductions are likely needed in areas that were not completely covered by the initial set of management rules. Identifying additional nonpoint source pollution sources and potential reduction measures is a priority to reduce TP & TN loads beyond the >30% reduction already achieved by a majority of dischargers and agriculture. The estuary is a complex and dynamic system and due to the decades of chronic overloading of nutrients and the likelihood of nutrient recycling, it may be some time before current reductions in nutrient loading will reflect in improved water quality.

# Point to Nonpoint Source Nutrient Trading Program:

The Tar-Pamlico NSW includes four phases to address both point and nonpoint source pollution contributions to the estuary. A detailed description of the phases are available on the DWR Nonpoint Source website: http://portal.ncdenr.org/web/wq/ps/nps/tarpampointsource

## Phase I

The strategy's first phase, which ran from 1990 through 1994, produced an innovative point source/nonpoint source trading program that allows point sources, such as wastewater treatment plants and industry, to achieve reductions in nutrient loading in more cost-effective ways. The Tar-Pamlico Basin Association (TPBA) made up of 14 point source dischargers, was established and they received collective annual end-of-pipe nitrogen and phosphorus loading caps. The TPBA members did not exceed their cap, but were given 4,608 kg nitrogen credit for financially supporting agricultural BMPs. The credits were predetermined to offset discharger nutrient exceedances with funds to be used for agricultural BMPs.

## Phase II

The second phase, which ran through 2004, established nutrient goals of a 30% reduction in nitrogen loading from 1991 levels and holding phosphorus loading to 1991 levels based on estuarine conditions. Phase II required new point source nutrient caps and required nonpoint sources to contribute to estuary goals. It established a set of nonpoint source rules addressing agriculture, urban stormwater, fertilizer management across all land uses, and riparian buffer protection. The Phase II Agreement established requirements for existing and expanding domestic and industrial non-association dischargers and all new facilities that enter the basin.

## Phase III

Phase III was approved by the EMC on April 14, 2005 and it spans an additional ten years through December 31, 2014. The Phase III Agreement updates TPBA membership and related nutrient caps. During the first two years, the parties agreed to actions to improve the offset rate, resolve related temporal issues, and revisit alternative offset options. It also establishes 10-year estuary performance objectives and alternative management options. Non-association dischargers are to maintain permit limits required in Phase II. The Agreement further provides that the TPBA may accrue and bank nitrogen credits by funding nonpoint source nutrient reduction measures (e.g., agricultural BMPs) and that it may purchase credits or apply banked credits in anticipation of future cap exceedances. The TPBA has consistently and reliably kept its nutrient loadings beneath the caps without relying on banked credits.

The parties in the Agreement identified actions to be taken by the conclusion of Phase III and addressed in Phase IV, these include:

1. Evaluate the NC Agricultural Cost Share Program to determine if it continues to provide the most efficient method of implementing the pollution credits trading program. This evaluation should consider the effect of delays in BMP implementation relative to nutrient cap exceedance and how such delays may impact the allowable point source nutrient budget.

2. Evaluate the trading offset credit cost calculation method to ensure the offset rate reflects all actual costs incurred in program development and implementation and reflects the costs of the type of agricultural BMPs implemented through this program.

3. Conduct a water quality trend analysis, including evaluation of TN losses occurring during transport to the estuary. This analysis will inform the parties regarding the need for changes in acceptable loads and the relative impacts of point and non-point contributions.

## Phase IV

Individual discharger permit limits will be incorporated in 2014 during the fourth phase of the Agreement. This agreement is currently being complete and will likely be presented to the NC Environmental Management Commission in May 2015 for their approval. The details of the agreement will be included in this section of the plan as soon as it is approved. The list of dischargers and their individual discharger permit limits will be included in the Table 9 below.

### *Tar-Pamlico Basin Association Facilities Loading Requirements*

The TPBA dischargers (Table 9) account for 98.7% of the known effluent flow to the basin. As part of Phase I the TPBA members agreed to optimize their nutrient reduction performance with the goal of each facility attaining TP of 2 mg/L and TN of 4 mg/L in the summer and 8 mg/L in the winter. A collective nutrient cap was established for years 1991-1994 (Table 10). The cap was reevaluated for years 1995-2004 after model results suggested the 30% TN cumulative point and nonpoint source reduction and no increase in TP from baseline 1991 levels (Table 11). For Phase III, the TPBA's end-of-pipe nitrogen cap is 404,274 kg TN and the final phosphorus cap of 73,060 kg TP (Table 11). Cap values are adjusted for any change in TPBA membership.

Since the Tar-Pamlico strategy's inception, the EPA has praised the strategy for its innovative and integrative approach to nutrient management and has touted it repeatedly as a model for others to use. However, guidance released by the EPA's Office of Water Management in 2007 re-iterates that federal NPDES regulations (40 C.F.R. 122.44(d)(1)) and Section 301(b)(1)(C) of the federal Clean Water Act require that NPDES permits include any applicable limitations established in or based upon an approved TMDL. The Tar-Pamlico permits have not included individual nutrient limits, because the Agreement specified the TPBA's caps and, until recently, the EPA Region 4 office had accepted that approach. In light of the 2007 guidance, Region 4 has modified its position on the matter and is requiring that the members' permits include the group nutrient limits at this time and individual limits in 2014.

During Phase III of the Agreement, the division worked closely with the TPBA and the parties to the Agreement on the methodology and development of individual limits to incorporate in each member's individual NPDES permits during the 2014 permit cycle. The individual allocation will be reported below in Table 9 once the Phase IV Agreement is approved by the EMC.

### Table 9: 2014 Tar-Pamlico Basin Association Discharge Members and 2015 Individual Permitted TN and TP Load Allocation

| Permit | Owner | Facility | Permitted Flow (MGD) | Total Nitrogen Allocation* (lbs/yr) | Total Phosphorus Allocation* (lbs/yr) | Subbasin HUC | Receiving Stream |
|---|---|---|---|---|---|---|---|
| NC0042269 | Town of Bunn | Bunn WWTP | 0.3 | | | 3020101 | Crooked Cr. |
| NC0020061 | Town of Spring Hope | Spring Hope WWTP | 0.4 | | | 3020101 | Tar River |
| NC0020231 | Town of Louisburg | Louisburg WWTP | 1.37 | | | 3020101 | Tar River |
| NC0069311 | Franklin County | Franklin County WWTP | 3 | | | 3020101 | Cedar Cr. |
| NC0025054 | City of Oxford | Oxford WWTP | 3.5 | | | 3020101 | Fishing Cr. |
| NC0030317 | City of Rocky Mount | Tar River Regional WWTP | 21 | | | 3020101 | Tar River |
| NC0023337 | Town of Scotland Neck | Scotland Neck WWTP | 0.675 | | | 3020102 | Canal Cr. |
| NC0025402 | Town of Enfield | Enfield WWTP | 1 | | | 3020102 | Fishing Cr. |
| NC0020834 | Town of Warrenton | Warrenton WWTP | 2 | | | 3020102 | Fishing Cr. |
| NC0020435 | Town of Pinetops | Pinetops WWTP | 0.3 | | | 3020103 | Town Cr. |
| NC0026042 | Town of Robersonville | Robersonville WWTP | 1.8 | | | 3020103 | Flat Swamp |
| NC0020605 | Town of Tarboro | Tarboro WWTP | 5 | | | 3020103 | Tar River |
| NC0023931 | Greenville Utilities Commission | GUC WWTP | 17.5 | | | 3020103 | Tar River |
| NC0026492 | Town of Belhaven | Belhaven WWTP | 1 | | | 3020104 | Battalina Cr. |
| NC0020648 | City of Washington | Washington WWTP | 3.65 | | | 3020104 | Tar River |
| | | **Totals** | **62.495** | **889,403** | **160,732** | | |

*Individual total nitrogen and total phosphorus load allocations are new as part of the 2014 NPDES discharge permits as required by the USEPA. These are currently being developed along with the Phase IV trading agreement and will be updated as soon as they are approved.





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### Table 10: Phase I TPBA Nutrient Caps and Reported Loads

| Combined N+P | Phase I | | | |
|---|---|---|---|---|
| | 1991[1] | 1992[1] | 1993[1] | 1994[1] |
| Loading Cap [a] (lb/yr) | 1,155,000 | 1,100,000 | 1,045,000 | 935,000 |
| Actual Load (lb/yr) | 1,015,067 | 959,482 | 917,877 | 816,640 |
| % of Cap | 88 | 87 | 88 | 87 |
| Average Daily Flow (MGD) | 24.88 | 26.86 | 28.46 | 26.65 |

### Table 11: Phase II & III TPBA Nutrient Caps and Reported Loads

| Separate N & P | Phase II | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1995[2] | 1996[2] | 1997[2] | 1998[2] | 1999[2] | 2000[2] | 2001[3] | 2002[4] | 2003[4] |
| Loading Cap [a] (lb/yr) | N: 891,563<br>P: 153,437 | N: 891,563<br>P: 153,437 | N: 891,563<br>P: 153,437 | N: 891,563<br>P: 153,437 | N: 891,563<br>P: 153,437 | N: 891,563<br>P: 153,437 | N: 938,920<br>P: 162,127 | N: 938,920<br>P: 162,127 | N: 938,920<br>P: 162,127 |
| Actual Load (lb/yr) | N: 819,680<br>P: 82,192 | N: 779,282<br>P: 95,185 | N: 705,474<br>P: 80,370 | N: 758,518<br>P: 81,101 | N: 680,847<br>P: 70,514 | N: 655,574<br>P: 66,609 | N: 615,908<br>P: 72,006 | N: 614,526<br>P: 74,967 | N: 681,393<br>P: 67,883 |
| % of Cap | N: 92<br>P: 54 | N: 87<br>P: 62 | N: 79<br>P: 52 | N: 85<br>P: 53 | N: 76<br>P: 46 | N: 74<br>P: 43 | N: 66<br>P: 45 | N: 65<br>P: 46 | N: 72<br>P: 42 |
| Average Daily Flow (MGD) | 31.03 | 33.57 | 29.84 | 33.31 | 33.39 | 32.74 | 30.21 | 30.54 | 36.86 |

| Separate N & P | Phase II | Phase III | | | | | |
|---|---|---|---|---|---|---|---|
| | 2004[4] | 2005[5] | 2006[5] | 2007[5] | 2008[5] | 2009[5] | 2010[5] |
| Loading Cap [a] (lb/yr) | N: 938,920<br>P: 162,127 | N: 889,403<br>P: 160,732 | N: 889,403<br>P: 160,732 | N: 889,403<br>P: 160,732 | N: 889,403<br>P: 160,732 | N: 889,403<br>P: 160,732 | N: 889,403<br>P: 160,732 |
| Actual Load (lb/yr) | N: 575,144<br>P: 74,754 | N: 532,444<br>P: 86,387 | N: 511,650<br>P: 103,389 | N: 542,223<br>P: 110,169 | N: 558,400<br>P: 96,406 | N: 600,776<br>P: 89,593 | N: 636,579<br>P: 92,196 |
| % of Cap | N: 61<br>P: 46 | N: 60<br>P: 54 | N: 58<br>P: 64 | N: 61<br>P: 69 | N: 63<br>P: 60 | N: 67<br>P: 56 | N: 72<br>P: 51 |
| Average Daily Flow (MGD) | 29.65 | 29.21 | 32.85 | 27.05 | 27.39 | 28.0 | 30.5 |

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| Separate N & P | Phase III | | |
|---|---|---|---|
| | 2011[5] | 2012[5] | 2013[5] |
| Loading Cap [a] (lb/yr) | N: 889,403<br>P: 160,732 | N: 889,403<br>P: 160,732 | N: 889,403<br>P: 160,732 |
| Actual Load (lb/yr) | N: 645,176<br>P: 99,757 | N: 623,355<br>P: 101,592 | N: 599,430<br>P: 98,982 |
| % of Cap | N: 73<br>P: 62 | N: 70<br>P: 63 | N: 67<br>P: 62 |
| Average Daily Flow (MGD) | 28.6 | 30.5 | 30.0 |

Loads were estimated by NC Division of Water Quality as the sum of calendar-year monthly load values for each facility, which are based on minimum biweekly nutrient concentrations and daily mass flows.

[a] Cap values and changes result from the following:

1 Phase I – Original 12-member Association

2 Phase II through 2000 – 14-member Association.

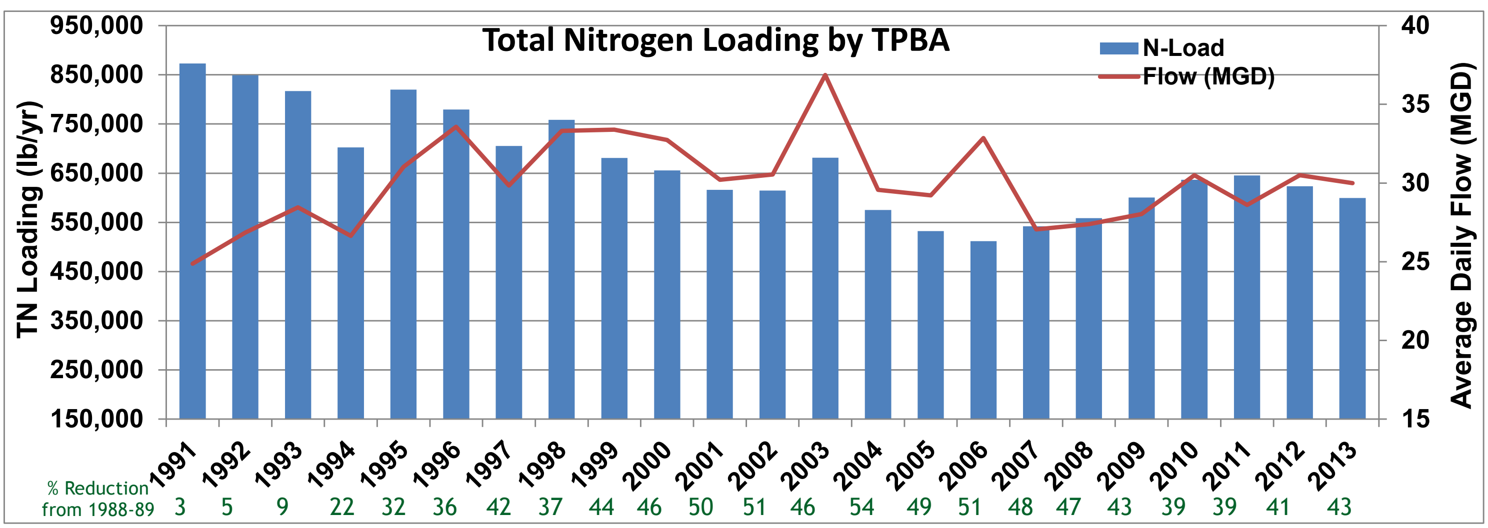
3 Robersonville added in 2001, making a 15-member Association.

4 Scotland Neck added in 2002, making a 16-member Association.

5 National Spinning Removed in 2005, making a 15 member Association in Phase III

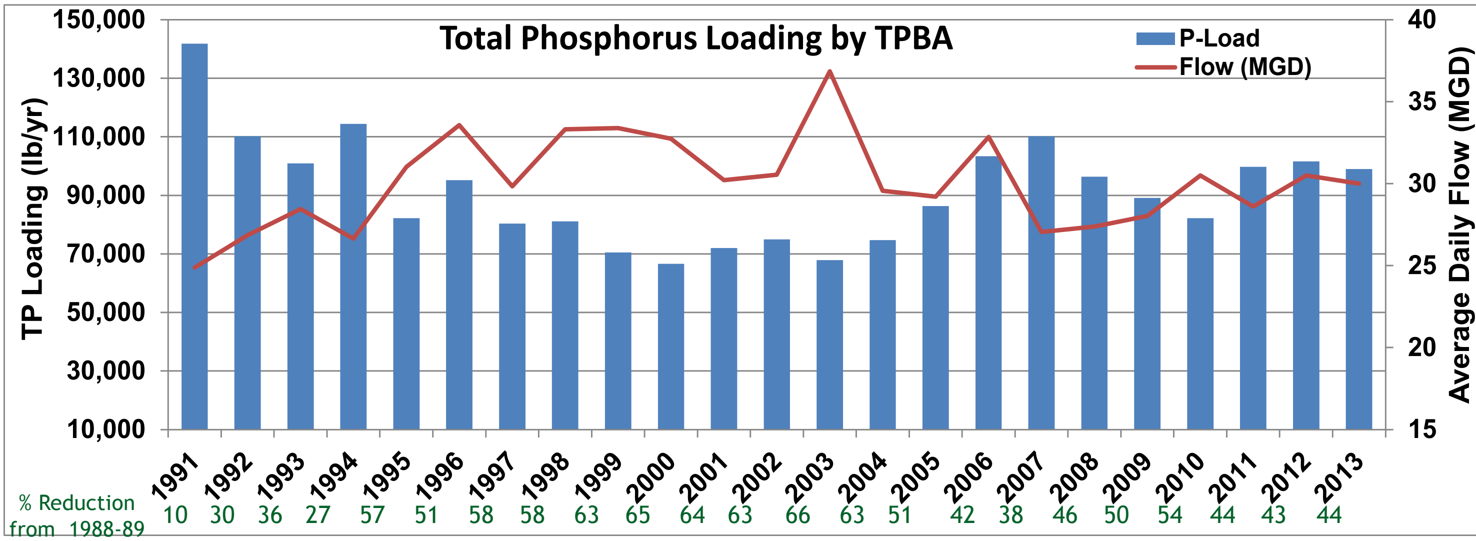
The TPBA has consistently and reliably kept its nutrient loadings beneath the caps without relying on banked credits. Relaxation of these caps in future amendments to this Agreement would only be contemplated if monitoring and modeling results suggest all water quality standards and goals are being met and that assimilative capacity is available to the TPBA while maintaining a margin of safety, all consistent with the TMDL. The dischargers TN loads and MGD average daily flow are seen in Figure 9. The percent reduction in TN loads from 1988-89 (pre-reduction) load levels are listed in green below the years; these percents have been adjusted appropriately for the number of TPBA members active for the particular year.

Figure 9: Total Nitrogen Estimated Loading by TPBA Members between 1991-2013.




The reductions in TP since 1991 are shown in Figure 10 in correlation to the discharges average daily flow levels. The percent reduction in TP loads from 1988-89 (pre-reduction) load levels are listed in green below the years; these percents have been adjusted appropriately for the number of TPBA members active for the particular year.

FIGURE 10: TOTAL PHOSPHORUS ESTIMATED LOADING BY TPBA MEMBERS BETWEEN 1991-2013




## *Non-Association Discharge Facilities Loading Requirements*

The non-association dischargers account for less than 2% of the effluent flow within the basin (Table 12). The Phase II Agreement established requirements for existing and expanding domestic and industrial dischargers and all new facilities to enter the basin. Those requirements are maintained in Phase III and IV. Existing domestic facilities permitted at or above flows of 0.5 million gallons per day (MGD) have received 6 mg/L TN and 1 mg/L TP effluent concentration limits in all NPDES permit renewals beginning in Phase II, while existing industrial dischargers have received Best Available Technology (BAT) limits.

Phase II Agreement requirements for expanding and new facilities were codified as rules 15A NCAC 2B .0229 and .0237, which were effective April 1, 1997. No changes were recommended to these requirements under Phase III or IV. Domestic and industrial dischargers expanding to 0.5 MGD or greater and all new dischargers are required to offset all new nutrient loads at 110 percent of the rate established. Payment for the life of the permit is required at issuance or renewal. In addition, domestic and industrial dischargers expanding to at least 0.5 MGD are faced with 6 mg/L TN and 1 mg/L TP effluent concentration limits and BAT limits respectively, while new dischargers of any kind receive 1 mg/L TP effluent concentration limits if they exceed 0.05 MGD permitted flow, and additionally 6 mg/L TN effluent concentration limits if they exceed 0.5 MGD permitted flow.

## Table 12: Tar-Pamlico Basin Non-Association Dischargers

| Permit | Owner | Facility | Permitted Flow (MGD) | Subbasin HUC | Receiving Stream |
|---|---|---|---|---|---|
| Non-Association Domestic Less than 0.05 MGD | | | | | |
| NC0050415 | Edgecombe County Schools | Phillips Middle School | 0.010 | 03020101 | Moccasin Creek |
| NC0050431 | Edgecombe County Schools | North Edgecombe H S | 0.02 | 03020101 | Swift Creek |
| NC0037885 | Nash/Rocky Mount Schools | Southern Nash Junior H S | 0.015 | 03020101 | Tar River |
| NC0047279 | C&J Bradshaw LLC | Heritage Meadows WWTP | 0.010 | 03020101 | North Fork Tar River |
| NC0029131 | Kittrell Job Corps Center | Kittrell Job Corps Center | 0.025 | 03020101 | Long Creek |
| NC0048631 | Interstate Property Mgmt Inc | Long Creek Court WWTP | 0.007 | 03020101 | Long Creek |
| NC0038580 | Halifax County Schools | Eastman M School WWTP | 0.0048 | 03020102 | Little Fishing Creek |
| NC0038610 | Halifax County Schools | Pittman El School WWTP | 0.0096 | 03020102 | Burnt Coat Swamp |
| NC0038644 | Halifax County Schools | Dawson El School WWTP | 0.0073 | 03020102 | Deep Creek |
| NC0037231 | Martin County Schools | Bear Grass El Sc WWTP | 0.005 | 03020103 | Turkey Swamp |
| NC0036919 | Town of Pantego | Pantego WWTP | 0.006 | 03020104 | Pantego Creek |
| NC0040584 | Pantego Rest Home | Pantego Rest Home | 0.004 | 03020104 | Pantego Creek |
| | | Total Permitted Flow = | 0.1237 | | |
| | | | | | |
| Non-Association Domestic 0.05 to 0.5 MGD | | | | | |
| NC0042510 | Total EnvSolutions Inc | Lake Royale WWTP | 0.080 | 03020101 | Cypress Creek |
| NC0025691 | Town of Littleton | Littleton WWTP | 0.28 | 03020102 | Butterwood Creek |
| NC0050661 | Town of Macclesfield | Macclesfield WWTP | 0.175 | 03020103 | Bynums Mill Creek |
| NC0021521 | Town of Aurora | Aurora WWTP | 0.12 | 03020104 | South Creek |
| NC0069426 | Dowry Creek Community Assc. | Dowry Creek | 0.05 | 03020104 | Pungo River |
| | | Total Permitted Flow = | 0.705 | | |
| | | | | | |
| Non-Association Domestic 0.5 MGD or Greater | | | | | |
| None | | | | | |
| Non-Association Industrial Discharging Nutrients | | | | | |
| NC0003255 | PCS Phosphate Company Inc | PCS Phosphate Co- Aurora | No Limit | 03020104 | Pamlico River |
| | | **Total Permitted Flow = 0.83** | | | |

## Nonpoint Source Controls

The Phase II Agreement called for a nonpoint source strategy, which was approved by the EMC in December 1995. The EMC then received annual reports on the progress of implementation under this voluntary plan. The implementation of this strategy is to help meet the instream TN reduction target of 766,228 kg/yr. After two years of implementation, the EMC found that progress was insufficient and initiated rule making for nonpoint sources. Modeled after rules implemented in the adjacent Neuse River Basin in 1998, a set of rules addressing agriculture, urban stormwater, riparian buffer protection and fertilizer management went into effect during 2000 and 2001.

# Agriculture Rule

Effective September 2001, the Tar-Pamlico Agricultural Nutrient Control Strategy Rule and Law provides for a collective strategy for farmers to meet nutrient reductions required by the TMDL. Farmers in the basin are to implement land management practices that achieve certain nutrient reduction goals. The goals are a 30 percent reduction in nitrogen loading from 1991 levels within five to eight years of the rule's implementation, and control of phosphorus levels at or below 1991 levels within four years of the approval of a phosphorus accounting methodology. The main agriculture rule details the process and options for achieving the nutrient goals. Implementation relies on cooperation between a Basin Oversight Committee (BOC) and Local Advisory Committees (LACs). The BOC has representatives from governmental, environmental, farming and scientific communities. It developed a tracking and accounting methodology to gauge progress toward the nutrient goals based on implementation of various nutrient-reducing management practices. The Soil and Water Conservation Commission approved standard practices in 2002 based on the recommendations of a Technical Review Committee and consultation with farming commodity groups. Each Local Advisory Committee, comprised of farmers and local agriculture agency representatives, developed a local strategy and submit annual reports quantifying progress toward the nutrient goals to the BOC. Farmers, who are involved in the commercial production of crops or horticultural products, or whose livestock or poultry holdings exceed specified numbers, are subject to the rule and are required to register with their local committee. More information about the Agriculture rules are available on the DWR Non-Point Source Unit's website: http://portal.ncdenr.org/web/wq/ps/nps/tarpamlicoagriculture.

## Implementation Results

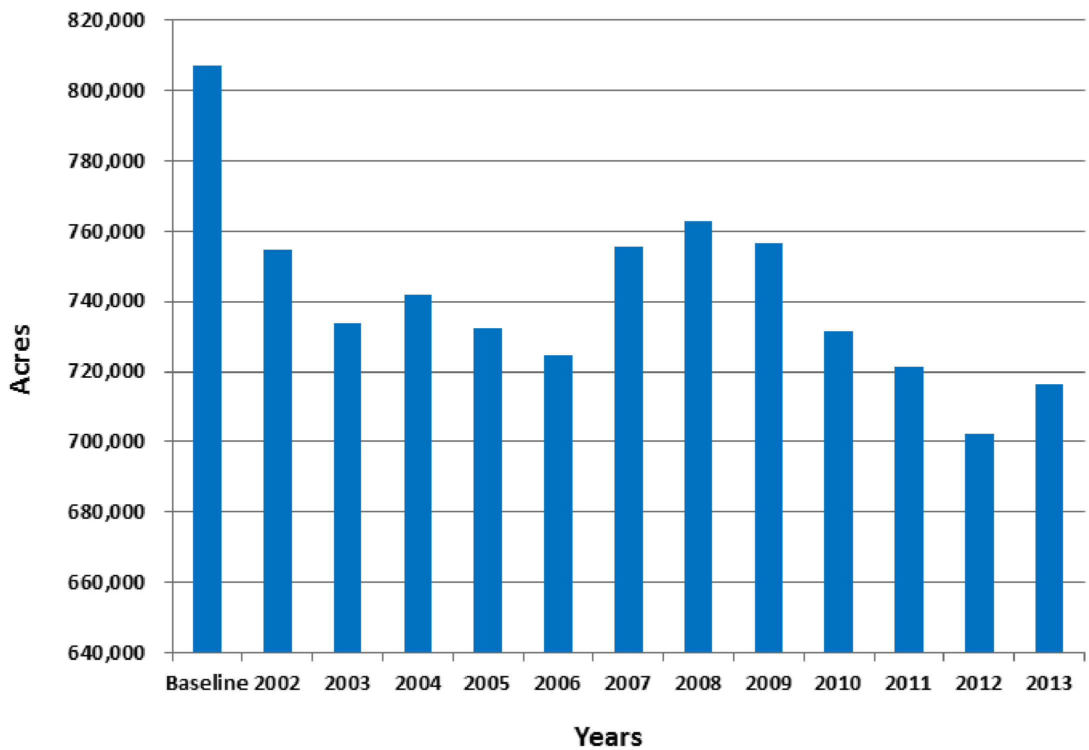
The 2010 basin plan reported that there were five full time Soil and Water Conservation District (SWCD) technicians, but as of 2014 there is only a single full time technician that work with local farmers on designing BMPs to reduce nutrient runoff from their agricultural operations. This technician works with LACs to coordinate nitrogen and phosphorous management information for the BOC annual report. Fertilizer information used in these reports are based on best professional judgment and BMPs implemented are often only accounted for if funded through the NC Agricultural Cost Share Program.

In addition to the BOC annual accounting reports, a 319 grant was awarded to NCSU to do an agriculture sample analysis of fertilizer and BMP usage within the basin (Osmond et al., 2006). The sample analysis conclusions indicate farmers are implementing agricultural practices that minimize their environmental impact. A majority of farmers were found to use a fertilizer plan for a particular crop and did not compensate for soil test results. However, this did not result in an excess of fertilization, except in the application of phosphorus. The reduction of phosphorus fertilizer application is recommended for over 2/3 of the fields. The survey data found that information collected by the LACs tended to over report fertilizer rates, while conservation tillage was under reported. Buffers were found along most stream/field interfaces in the upper portion of the basin while water control structures were more commonly used in coastal areas where topography is suitable. The full report (Osmond et al., 2006) is available here: Delineating Agriculture in the Tar-Pamlico River Basin.

The following nitrogen and phosphorus reduction information is summarized from the BOC Annual Progress Report for Crop Year 2013. The information was collected by the SWCD technicians and summarized to meet annual reporting requirements. The annual progress reports on the Tar-Pamlico Agricultural rules are available on the Tar-Pamlico: Tracking Progress webpage.

It is estimated that approximately 11,605 acres have been permanently lost to development and more than 46,647 acres have been converted to grass or trees since 1991. Figure 11 shows the fluctuation of cropland acres over time with an 11.3 % reduction from the 1991 cropland estimate of 807,053 acres. Not included in these total are also approximate 10,087 acres reported as idle in 2013.

FIGURE 11: CHANGES IN ESTIMATED TAR-PAMLICO CROPLAND ACREAGE

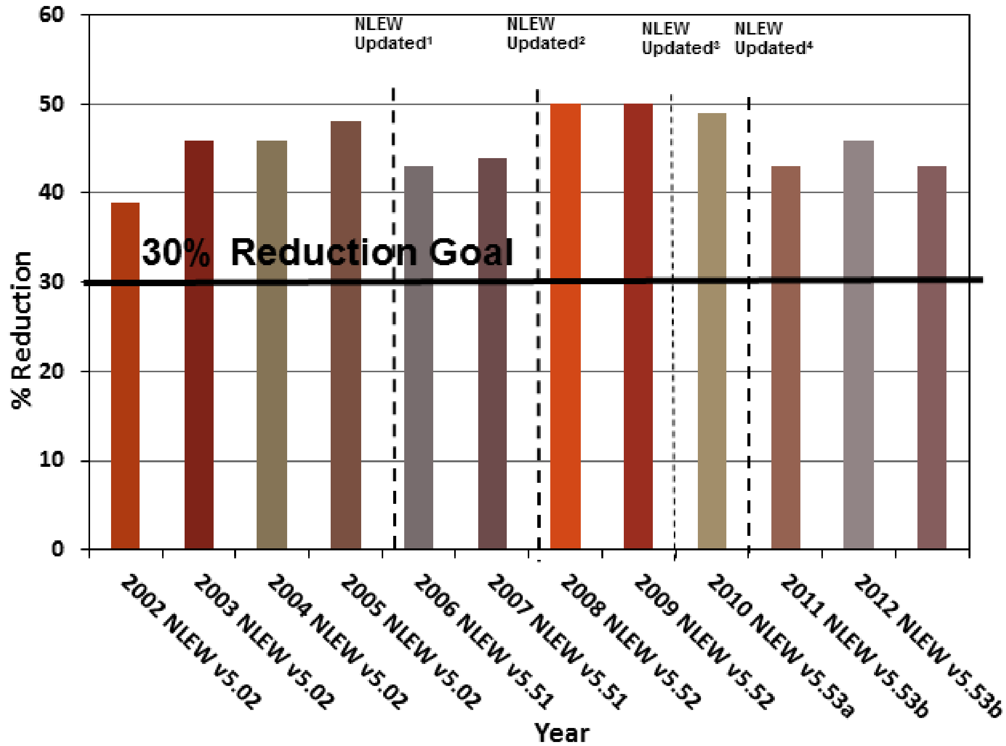



## Nitrogen Reductions

All fourteen LACs submitted their first annual report in November 2003, which collectively estimated a 34% reduction in nitrogen, and 10 of 14 LACs individually exceeded the 30%. Collective reductions have gradually increased in succeeding years and by 2008 all LACs exceeded the 30% nitrogen loss reduction goal. In crop year 2013, all but one of the LACs achieved at least a 30% nitrogen loss and as a whole achieved a 43% nitrogen loss reduction. Nitrogen loss reductions are achieved through the combination of fertilization rate decreases, cropping shifts, BMP implementation and cropland loss. The most significant factor continues to be fertilization management.

Martin County's individual nitrogen reduction has remained below the 30% reduction goal since 2011 with a nitrogen loss estimate of 24%, 28% and 25% for crop years 2011, 2012 and 2013 respectively. The decrease in their nitrogen loss reductions are mainly due to a shift in higher nutrient demanding crops and the fact that the county has only reduced cropland acres by 2,261 from the baseline. Martin county has reported a decrease in cotton production and an increase in wheat and corn which require significantly more nitrogen fertilization. It is also important to note that only ~25% of Martin County is within the Tar-Pamlico River Basin. It is recommended that the BOC work with the Martin County LAC on their reduction targets. Figure 12 shows the collective percent nitrogen reduction since the implementation of the agriculture rule.

### Figure 12: Collective Nitrogen Loss Reduction Percent 2002 to 2013




1-Between CY2005 & CY2006 NLEW was updated to incorporate revised soil management units and buffer nitrogen reduction efficiencies were reduced.
2-Between CY2007 & CY2008 NLEW was updated to incorporate revised soil management units and correct realistic yield errors.
3-Between CY2009 & CY2010 NLEW was an administration software update with no effect on accounting.
4-In 2011 NLEW was updated to significantly decrease buffer nitrogen removal efficiencies based on the most current research; CY2010 and the baseline reductions were recalculated to reflect changes in NLEW.

Nitrogen reductions are estimated using the Nitrogen Loss Estimation Worksheet (NLEW); the calculations represent county-wide nitrogen loss from cropland agriculture. NLEW captures application of both inorganic and animal waste sources of fertilizer to cropland. It does not capture the effects of managed livestock on nitrogen movement, including pastured, confined, and non-commercial livestock. NLEW is an "edge-of-management unit" accounting tool; it estimates changes in nitrogen loss from croplands, but does not estimate changes in nitrogen loading to surface waters. Table 13 shows the percentage of nitrogen loss reductions through the combination of fertilization rate decreases, cropping shifts, BMP implementation and cropland reductions (idle lands, conversion to grass/trees or development). Additional details on these practices and how they have varied over the implementation period can be found in the annual progress reports found on the [Tar-Pamlico: Tracking Progress](#) webpage.

### Table 13: Factors Influence on Nitrogen Reduction by Percentage on Agricultural Lands

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BMP implementation | 2% | 3% | 5% | 6% | 10% | 8% | 10% | 10% | 11% | 9% | 9% | 10% | 8% |
| Fertilization Management | 24% | 24% | 23% | 23% | 21% | 20% | 20% | 21% | 20% | 23% | 17% | 17% | 21% |
| Cropping shifts | 8% | 7% | 11% | 11% | 10% | 7% | 8% | 10% | 11% | 10% | 8% | 10% | 6% |
| Reduction in cropland due to idle land | *% | *% | *% | *% | *% | 4% | 3% | 4% | 3.5% | 3% | 4% | 4% | 1% |
| Reduction in cropland due to conversion to grass/trees | *% | *% | *% | *% | *% | 3% | 2% | 4% | 3.5% | 3% | 3% | 5% | 5% |
| Reduction in cropland due to development | *% | *% | *% | *% | *% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| **TOTAL** | **38%** | **40%** | **46%** | **46%** | **48%** | **43%** | **44%** | **50%** | **50%** | **49%** | **43%** | **46%** | **43%** |

*Not calculated prior to 2006.

The percentage of nitrogen reductions as result of BMP implementation have not change much over the last 9 years. The increase in 2005 was due to an increase in water control structures, 20’ and 50’ buffers added during that period. BMPs have a specific life expectancy so as some practices age out of the accounting processes, new practices are put in place. Crop year 2013 yielded an increase in 1,604 acres affected by water control structures and an increase of 27,046 acres if nutrient scavenger crops utilized, while buffer acres remained relatively steady. It has been estimated that the actual acres of BMPs installed through federal, state and local cost share programs in the Tar-Pamlico watershed total 716,289 cropland acres, accounting for over half of all reported croplands having received some type of BMP treatment.

Fertilization management counts for the largest source of nitrogen reductions seen in the Tar-Pamlico River basin. The fertilizer application rates are revisited and adjusted annually by LACs using data from farmers, commercial applicators and state and federal agency professional estimates.

While fertilization rates have decreased for all crops since the baseline period, certain crops require higher nitrogen fertilizer rates, like corn and wheat as compared to cotton and soybeans. The change is the mix of crops grown can have a significant impact on the cumulative yearly nitrogen loss reduction. In crop year 2013, cotton acreage declined while corn increased, which resulted in less nitrogen reduction from the previous year.

The number of cropland acres fluctuate every year due to cropland conversion, idle land and development. Each year, some cropland is permanently lost to development or converted to grass or trees and is likely to be lost from agricultural production. As of 2013, there is an estimate of 716,289 total cropland acres in production. Approximately 11,605 acres have been lost to development and more than 46,647 acres converted to grass and trees since the 1991 baseline.

## Agriculture Phosphorus Reductions

Phosphorus Technical Advisory Committee (PTAC) developed recommendations for qualitative tracking of relative changes in land use management that either increase or decrease the risk of phosphorus loss from agricultural lands in the basin on an annual basis. The phosphorus predicted loss or gain is shown for several land management practices in Table 14.

Table 14: Agriculture Land Use Phosphorus Changes

| Parameter | Units | 1991 Baseline | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|
| Agricultural land | Acres | 807,026 | 732,139 | 724,778 | 755,489 | 763,066 | 756,365 |
| Cropland conversion (to grass & trees) | Acres | 660 | 22,369 | 23,083 | 20,754 | 31,110 | 31,168 |
| CRP / WRP (cumulative) | Acres | 19,241 | 25,921 | 30,768 | 34,614 | 38,375 | 38,967 |
| Conservation tillage | Acres | 41,415 | 362,102 | 362,102 | 66,079 | 31,421 | 33,905* |
| Vegetated buffers (cumulative) | Acres | 50,836 | 193,867 | 195,673 | 210,488 | 214,043 | 211,360 |
| Water control structures (cumulative) | Acres Affected | 52,984 | 75,980 | 75,641 | 79,167 | 80,418 | 81,348 |
| Scavenger crop | Acres | 13,272 | 80,604 | 97,405 | 120,565 | 109,741 | 92,379 |
| Animal waste P | lbs of P/yr | 13,597,734 | 14,064,368 | 14,728,831 | 14,626,960 | 14,560,934 | 14,608,377** |
| Soil test P median | mg/kg | 83 | 85 | 85 | 89 | 89 | 89 |

| Parameter | Units | 1991 Baseline | 2010 | 2011 | 2012 | 2013 | 1991-2013 % Change | 2013 P Loss Risk +/- |
|---|---|---|---|---|---|---|---|---|
| Agricultural land | Acres | 807,026 | 731,408 | 721,432 | 702,227 | 716,289 | -13% | - |
| Cropland conversion (to grass & trees) | Acres | 660 | 31,596 | 31,631 | 42,330 | 46,647 | 6314% | - |
| CRP / WRP (cumulative) | Acres | 19,241 | 41,833 | 41,833 | 41,833 | 41,833 | 117% | - |
| Conservation tillage | Acres | 41,415 | 35,946 | 40,612 | 46,808 | 52,185 | 13% | - |
| Vegetated buffers (cumulative) | Acres | 50,836 | 215,606 | 227,528 | 212,212 | 218,236 | 317% | - |
| Water control structures (cumulative) | Acres Affected | 52,984 | 82,844 | 84,442 | 88,755 | 90,356 | 68% | - |
| Scavenger crop | Acres | 13,272 | 108,888 | 86,283 | 73,177 | 92,269 | 451% | - |
| Animal waste P | lbs of P/yr | 13,597,734 | 15,202,037 | 16,695,543 | 16,561,052 | 16,880,526** | 22% | + |
| Soil test P median | mg/kg | 83 | 86 | 87 | 85 | 85 | 2.41% | + |

CRP - Conservation Reserve Program.
WRP - Wetlands Reserve Program.
* Conservation tillage is still being practiced on additional acres but this number only reflects active cost share contract acres, not acres where contracts have expired.
** Due to the delay in the 2012 Census of Agriculture release and the five-year program review the livestock county estimates are delayed until January 2015. Where animal waste P data has not been released, CY2012 numbers have been used.

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Most parameters indicate less risk of phosphorus loss than in the baseline period except for animal waste P and soil test P median. It should also be noted that the median phosphorus soil test number reported for the basin fluctuates each year due to the nature of how the data are collected and compiled. A 22% increase in the animal waste P to approximately 16,880,500 lbs/yr of phosphorus is likely the result of the increasing poultry operations in the basin.

Contributing to the reduced risk of phosphorus loss is the increase of nutrient reducing BMPs in the basin. As indicated in the Table 14, the acres affected in the basin by vegetated buffers and water control structures have steadily increased. The study by NCSU (Osmond et al., 2006) reported excess phosphorus fertilizer application was occurring on 2/3 of the fields in the basin. Given these results it is recommended that the soil test P levels guide the appropriate application rate of phosphorus fertilizer applied in order to avoid excess phosphorus from running off into surface waters.

The nutrient loading assessments presented earlier in this report indicate that both nitrogen and phosphorus are increasing in many areas throughout the Tar-Pamlico River basin and have not declined at the TMDL compliance point (Grimesland). The data for Chicod Creek, a heavily agricultural watershed (40.5% agriculture, 2011 NLCD) has reduced nutrient loading over the implementation period but generally has the highest yearly unit area loading rate for TN and TP of those watershed assessed (Figure 23 and Figure 24 respectively). The unit area loading appeared to jump up over the last 4 years of the assessment (2010-2013) over the previous 3 years. The Chicod Creek watershed has 16 swine CAFO permits for at total of 75,000 Hogs. It has been reported that much of the farm land in coastal North Carolina are extensively drained by ditches and tile drains which can bypass nutrient reducing BMPs (Harden and Spruill, 2004).

It is likely that groundwater contributions in heavily agricultural watershed are contributing higher levels of nitrogen and phosphorus (Harden and Spruill, 2004). Harden and Spruill (2008) recommend using stream flow statistics along with other factors such as land use, soil drainage, extent of riparian vegetation, geochemical conditions and subsurface tile drainage in the Coastal Plain to identify watersheds that are most likely to export excessive nitrogen due to nonpoint source loading. While great strides have been made by the agricultural community throughout the Tar-Pamlico River basin, additional BMP and other practices to help reduce nutrient contribution to the watershed are critical in the continued effort to achieve the overall goal of improved water quality in the Pamlico River Estuary.

## Stormwater Rule

The stormwater rule which became effective in April 2001, required six municipalities and five counties in the Tar-Pamlico Basin to develop and implement stormwater programs within two and a half years. The municipalities are: Greenville, Henderson, Oxford, Rocky Mount, Tarboro, and Washington. The counties are: Beaufort, Edgecombe, Franklin, Nash, and Pitt. These local governments were identified based on their potential nutrient contributions to the Pamlico River Estuary. The EMC may add other local governments as appropriate in the future through rule-making. Local programs are to include the permitting of new development to reduce nitrogen runoff by 30 percent compared to pre-development loading conditions, and to keep phosphorus inputs from increasing from 1991 levels. The local programs must also identify and remove illicit discharges, educate developers, businesses, and homeowners, and make efforts toward treating runoff from existing developed areas. More information about the stormwater rules are available on the DWR Non-Point Source Unit's website: http://portal.ncdenr.org/web/wq/ps/nps/tarpamstorm.

## New Development Nutrient Offset

Under the requirements of the rule, the nutrient export goal for new development projects is limited to a total nitrogen export of 4 lbs/acre/yr and 0.4 lbs/acre/yr of total phosphorus with limits on peak flows to not exceed the predevelopment conditions for the 1-year 24-hour storm. The lbs/ac/yr export target represents the 30% reduction goal applied to new development. It represents a 30% reduction from the average pre-development loading conditions. The nitrogen export goal is achieved through a combination of site design and the use of on-site best management practices (BMPs). Developers also have the option to offset the nutrient export off site by making offset payments to a private party with available offset credits or by making payments to the North Carolina Ecosystem Enhancement Program (NCEEP) nutrient offset program. If the nitrogen export for a planned project site is calculated to be greater than 6.0 lbs/ac/yr or 10.0 lbs/ac/yr for residential or commercial development respectively, the developer must first implement onsite BMPs or take part in an approved regional or jurisdiction-wide stormwater strategy to lower the nitrogen export to at least those levels before being allowed to "buy down" the remainder of their nitrogen export to the lbs/ac/yr target through either a private party with approved nutrient offset credits or the NCEEP nutrient offset program.

## Implementation Results

By 2006, each of the six local governments subject to the Tar-Pam Stormwater Rule adopted and implemented their local permitting programs requiring new development projects to control stormwater runoff. The City of Washington was the last municipality to adopt a local stormwater ordinance in April 2006. The other municipalities implemented their stormwater programs in 2004 and began reporting to DWR in 2005. Between April 2006 and December 2013, EEP has received 291 nutrient offset payments totaling over $2.3 million for new development projects to offset ~96,474 lbs of nitrogen and ~6,108 lbs of phosphorus from the Tar-Pamlico River Basin. A private mitigation bank was established in September 2013 and has received one payment for 774 lbs of nitrogen and two payments for 43 lbs of phosphorus.

A number of public education programs have been implemented in the various communities, as required under the rule. All of the local governments under the rule are supporting partners of the Clean Water Education Partnership (CWEP) which is a cooperative effort between local governments, state agencies, and nonprofit organizations to educate the general public about water quality in the Tar-Pamlico, Neuse, and Cape Fear River Basins. The education and outreach programs conducted include workshops, development of web sites, newsletters, brochures, storm drain stenciling, participation at school programs such as science fairs, field days, development of environmental fact sheets, and implementation of demonstration projects for stormwater control. Several communities have also partnered with other agencies such as the NC Cooperative Extension Service and local Soil and Water Conservation Districts to aid in the development of their public education and outreach programs.

All of the local governments subject to the Tar-Pamlico Stormwater Rule have also developed ordinances and programs that, in addition to requiring the nutrient export goal be met, establish local authority for the removal of illegal discharges. This includes establishing a 24-hour hotline the public can use to report an illegal discharge. Each local program is also responsible for maintaining a database that tracks illicit discharge detection and removal activities, and a number of local governments have noted in their annual reports to DWR that this element of the stormwater program has resulted in the removal of several illicit dischargers to date.

Each reporting year, local governments also identify a pre-set number of viable stormwater retrofit sites for existing developments in their jurisdictional areas. These sites are made available to groups that may have funding to implement retrofit activities for nitrogen reduction. In addition to identifying retrofit sites, a few local governments have reported activities completed or underway that have worked to reduce existing nitrogen loading. One example of such an effort is the development of local programs to buy out properties in floodplain areas and restore these areas to natural conditions for water quality improvements.

## Buffer Rule- Protection and Maintenance of Existing Forested Riparian Areas

A set of three buffer rules were adopted. The main rule, called the buffer protection rule, requires that existing vegetated riparian buffers in the basin be protected and maintained on both sides of intermittent and perennial streams, lakes, ponds, and estuarine waters. This rule does not establish new buffers unless the existing use in the buffer area changes. The footprints of existing uses such as agriculture, buildings, commercial and other facilities, maintained lawns, utility lines, and on-site wastewater systems are exempt. A total of 50 feet of riparian area is required on each side of waterbodies. Within this 50 feet, the first 30 feet referred to as Zone 1 is to remain undisturbed with the exception of certain activities; the outer 20 feet referred to as Zone 2 must be vegetated, but certain additional uses are allowed. Specific activities are identified in the rule as “exempt”, “allowable”, “allowable with mitigation” or “prohibited”. Activities identified as “exempt” do not require Division review or approval and include driveway and utility crossings of certain sizes through Zone 1 and 2 and grading and revegetation in Zone 2. “Allowable” and “allowable with mitigation” activities require review by Division staff and include activities such as new ponds in drainage ways and water crossings. The other two buffer rules are the buffer mitigation rule and the buffer program delegation rule. The mitigation rule defines the process applicants would follow to gain approval for activities that are identified in the buffer protection rule as “allowable with mitigation”. It also outlines acceptable mitigation measures. The delegation rule lays out the criteria and process for local governments to obtain authority to implement the buffer rules within their jurisdictions. More information about the Buffer rules are available at: http://portal.ncdenr.org/web/wq/swp/ws/401/riparianbuffers.

### Implementation Results

DWR does not receive any information regarding activities within riparian buffers that are identified as “exempt”. Since implementation of the Tar-Pamlico buffer rule Division staff have issued buffer authorizations and variances (January 1, 2000 to December 31, 2013) impacting approximately 15,628,600 $ft^2$ requiring approximately 6,764,500 $ft^2$ of buffer mitigation. Most of the buffer impacts are the result of activities listed in the table of uses that are approved by a buffer authorization. Buffer variances are a small subset of the overall buffer impacts approved (total variances since the inception of the Tar-Pamlico buffer program are 40 general major, 30 major and 81 minor).

DWR has limited ability to monitor for buffer compliance. DWR often relies on notification from other agencies or citizen reports and therefore, the true number of buffer impacts that exist in NC are difficult to determine. Most site visits that determine the presence of buffer impacts are reported in a DWR Notice of Violation (NOV). There is always the potential for a buffer impact to result in an enforcement case. DWR began tracking buffer enforcement cases in 2005. Records indicate that from 2005 through 2013 there were 16 buffer violation enforcement cases which impacted 491,457 $ft^2$ of riparian buffers, resulting in civil penalty assessments of approximately $142,000. Also during this time, 162 buffer NOVs were reported resulted in approximately 823,000 $ft^2$ of impacted buffers. It is important to recognize that not all NOVs report the length of buffer impacts; therefore, the total length of impacted buffers within these years is difficult to determine. DWR intends to improve the database currently used for tracking buffer compliance to include the length of buffer impacted at each site visit, a description of the type of buffer impact, and impacted buffer location information. These improvements to the database will hopefully allow DWR to better measure the success of the buffer rules on reducing nutrient loading.

Delegation of local authority for implementing the buffer rule was granted to Pitt County in 2006 and their ordinance became effective January 1, 2007.

## Nutrient Management Rule

The nutrient management rule requires people who apply fertilizer in the basin, except residential landowners who apply fertilizer to their own property, to either take state-sponsored nutrient management training or have a nutrient management plan in place for the lands to which they apply fertilizer. The rule applies to fertilizer applicators, people who own or manage fertilized lands, and consultants who provide nutrient management advice. More information about the Nutrient Management rules are available on the DWR Non-Point Source website: http://portal.ncdenr.org/web/wq/ps/nps/tarpamnutrman.

### Implementation Results

Over the winter of 2005 and 2006, 1,969 fertilizer applicators in the Tar-Pamlico River Basin were trained in nutrient management. Training courses were held in 14 counties and applicators attended a 4 hour training and certification program. Trainings are given on an as needed basis. The effectiveness of this program is not known, however expanding this program to include education materials for homeowners is an opportunity to reduce nutrients especially as agricultural land is converted to residential. Recently, in several states, new lawn fertilizer ordinances regulating nitrogen and phosphorus application rates have been adopted at county and municipal levels.

## New Development Stormwater Rule

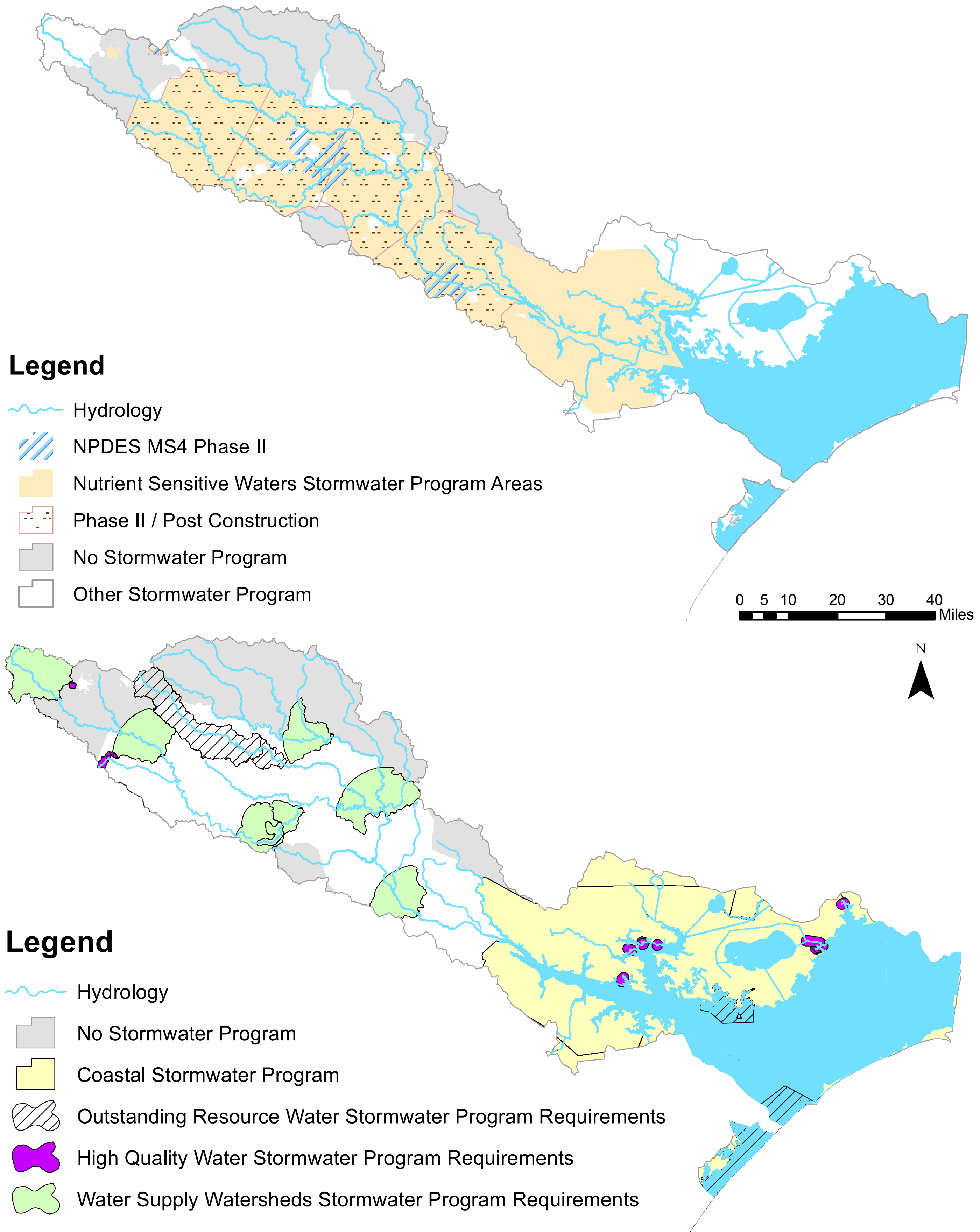
The Tar-Pamlico stormwater rule establishes a nutrient export goal of 4.0 lbs/ac/yr of TN and 0.4 lbs/ac/yr of TP for new residential and commercial development projects within the planning and zoning jurisdictions of six of the largest and fastest-growing local municipalities and five counties within the basin. Each of these local governments has successfully implemented its stormwater program since 2006 and continues to achieve the nutrient export target through a combination of onsite BMPs and off site nutrient offsets. DWR has begun to assess the extent to which the stormwater rule does not address new development activities in the basin. A key factor in this assessment is determining the impact of increases in population and the corresponding growth in residential and commercial development activities in municipalities and counties that are currently not subject to the stormwater rule.

Approximately 55% of the basin is covered by either Phase II or the NSW stormwater rules, 1% is covered by solely ORW or Water Supply Watershed stormwater regulations, 19% by Coastal stormwater rules and 23% of the basin has no stormwater program. Nutrient stormwater controls are in place for only 54% of the basin. Figure 13 shows how the stormwater programs are distributed throughout the basin, a Division of Energy, Mineral and Land Resources (DEMLR) Stormwater Permitting Program interactive **stormwater permitting map viewer** is also available online to help identify which programs apply to any portion of the Tar-Pamlico River watershed.

The requirements of Phase II stormwater regulations and the Tar-Pamlico NSW Stormwater Rule do share some similarities; both include provisions for implementing illicit discharge detection and elimination programs, public outreach and education, and some type post construction stormwater controls. However, there are additional protective measures provided for in the NSW Stormwater Rules that specifically address nutrients (nutrient export goals) that are not present in the Phase II regulations. While Phase II stormwater regulations do not currently address nutrients, DEMLR could consider including nutrient requirements under Phase II programs when existing permits are renewed or future Phase II designations are made. Table 15 details the population growth of the municipalities with a population greater than 500 as of October 2014 and their corresponding stormwater program. All the stormwater programs in Table 15 and Figure 13 include some type of post-construction site runoff controls however, only the NSW stormwater areas specifically addresses reducing nitrogen and phosphorus loading needed to meet the goal of the nutrient reduction strategy.

In addition to the NSW Stormwater rule's geographic coverage limitations, it does not set a quantitative reduction target for nitrogen loading from existing developed lands. According to land cover data collected by the National Resources Inventory (NRI), as of 2011 approximately 7% of the entire basin is considered developed. Since the current nutrient strategy addresses stormwater from new development starting in 2006, the stormwater runoff from these ~200,000 acres, plus any lands developed between 1997 and 2006, and any land developed after 2006 on which a vested development right was established, has not been subject to the rule. The great majority of these lands are not being treated to achieve nutrient reductions. Treating nutrient runoff from existing development through stormwater retrofit BMPs and other load reducing measures, both structural and management oriented, represents a real opportunity to further reduce existing nutrient loads to the basin from this significant source. A rule to address nutrient contributions from stormwater runoff from existing development could provide municipalities opportunities to receive nutrient reduction through practices such as removing existing impervious cover, buffer restoration, street sweeping, and removal of illicit discharges, in addition to structural retrofits.

Figure 13: Stormwater Programs in the Tar-Pamlico River Basin




Revised 2/4/15

## Table 15: Stormwater Programs in Municipalities with Populations* >500

| Municipality | April 2000 | April 2010 | Growth | | Federal Program[1] | Local Stormwater Programs[2] | | State Stormwater Programs[3] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Amount | % | NPDES MS4 Phase II Permit | NSW Stormwater | Water Supply Watershed Stormwater | Coastal Stormwater | Phase II Post Constr[4] | ORW/ HQW Stormwater |
| Aurora | 583 | 520 | -63 | -11 | | | | X | | |
| Belhaven | 1,968 | 1,688 | -280 | -14 | | | | X | | HQW |
| Bethel | 1,760 | 1,577 | -183 | -10 | | | | | X | |
| Chocowinity | 733 | 820 | 87 | 12 | | | | X | | |
| Dortches | 809 | 935 | 126 | 16 | | | | | X | |
| Elm City | 1,412 | 1,298 | -114 | -8 | | | | | | |
| Enfield | 2,370 | 2,532 | 162 | 7 | | | | | | |
| Fountain | 533 | 427 | -106 | -20 | | | | | X | |
| Franklinton | 1,745 | 2,023 | 278 | 16 | | | X (partial) | | X | HQW (partial) |
| Greenville | 61,209 | 84,554 | 23,345 | 38 | X | X | X (partial) | | | |
| Henderson | 16,095 | 15,368 | -727 | -5 | X | X | | | | ORW (partial) |
| Littleton | 692 | 674 | -18 | -3 | | | | | | |
| Louisburg | 3,111 | 3,359 | 248 | 8 | | | X (partial) | | X | |
| Nashville | 4,417 | 5,352 | 935 | 21 | X | | X (partial) | | | |
| Norlina | 1,107 | 1,118 | 11 | 1 | | | | | | |
| Oxford | 8,338 | 8,461 | 123 | 1 | | X | | | | |
| Pinetops | 1,419 | 1,374 | -45 | -3 | | | | | X | |
| Princeville | 940 | 2,082 | 1,142 | 121 | | | | | X | |
| Red Oak | 2,723 | 3,430 | 707 | 26 | X | | | | | ORW (partial) |
| Robersonville | 1,731 | 1,488 | -243 | -14 | | | | | | |
| Rocky Mount | 55,977 | 57,685 | 1,708 | 3 | X | X | X (partial) | | | |
| Scotland Neck | 2,362 | 2,059 | -303 | -13 | | | | | | |
| Sharpsburg | 2,421 | 2,024 | -397 | -16 | | | | | X | |
| Spring Hope | 1,261 | 1,320 | 59 | 5 | | | | | X | |
| Tarboro | 11,138 | 11,415 | 277 | 2 | | X | X (partial) | | X | |
| Warrenton | 811 | 862 | 51 | 6 | | | | | | |
| Washington | 9,619 | 9,744 | 125 | 1 | | X | | X | | |
| Whitakers | 799 | 744 | -55 | -7 | | | | | X | |
| Youngsville | 651 | 1,157 | 506 | 78 | | | X (partial) | | X | HQW (partial) |

*NC Office of State Budget and Management (data pull October 2014) http://www.osbm.state.nc.us/

1 - Federal Stormwater Program administered by the state, NCDENR Division of Energy, Mineral and Land Resources Stormwater Permitting Program. The six minimum measure required by this permit include, 1) Public education and outreach, 2) Public involvement and participation, 3) Illicit discharge detection and elimination, 4) Construction site runoff controls, 5) Post-construction site runoff controls, and 6) pollution prevention and good housekeeping for municipal operations.

2 - Local Stormwater Programs - These are stormwater programs delegated to the local governments. There can be additional local stormwater programs throughout the basin. Please check with the local stormwater departments for details.

3 - State Stormwater Programs - There are multiple state-mandated post-construction stormwater management control programs in place to protect the water resource.

4- Phase II Post-Construction stormwater control requirements for areas beyond cities with NPDES Phase II MS4 permits. These areas include certain tipped counties, unincorporated areas within urbanizing areas (according to the US Census), and municipal spheres of influence (MSIs) around Phase I or II MS4 cities and towns (Session Law 2006-246 and subsequent legislation affecting this law).

There are also potential low cost opportunities to address existing sources of nutrients in runoff from existing development. Existing sources include nutrients from pet waste and over fertilization of turf and landscape areas. Controls could be incorporated into local stormwater programs and ordinances to address these two sources of nutrients. Educational opportunities should be incorporated into established local stormwater programs' public education and outreach requirement. Some local governments in North Carolina already implement pet waste ordinances. Local governments in other parts of the country are beginning to place limitations on home fertilizer use with success as well. One example is the Minnesota phosphorus fertilizer law (18C.60, MN Statutes 2006) which prohibits use of phosphorus lawn fertilizer unless new turf is being established or a soil or tissue test shows need for phosphorus fertilization.

Table 16 lists county population and growth rates. Counties shaded are subject to the Tar-Pamlico NSW Stormwater Rules in the unincorporated areas of the county.

Table 16: County Population Estimates*.

| County | April 2000 Estimate | April 2010 Estimate | Growth Amount | Growth Percent | Projected 2020 Population | Projected 2030 Population |
|---|---|---|---|---|---|---|
| BEAUFORT | 44,958 | 47,770 | 2,812 | 6 | 47,790 | 47,791 |
| CARTERET | 59,386 | 66,469 | 7,083 | 12 | 75,154 | 83,577 |
| DARE | 29,967 | 33,920 | 3,953 | 13 | 36,799 | 38,020 |
| EDGECOMBE | 55,606 | 56,552 | 946 | 2 | 54,935 | 53,667 |
| FRANKLIN | 47,260 | 60,619 | 13,359 | 28 | 67,794 | 75,007 |
| GRANVILLE | 48,498 | 57,532 | 9,034 | 19 | 58,559 | 59,425 |
| HALIFAX | 57,374 | 54,691 | -2,683 | -5 | 51,513 | 48,313 |
| HYDE | 5,826 | 5,810 | -16 | 0 | 6,057 | 6,423 |
| MARTIN | 25,546 | 24,505 | -1,041 | -4 | 22,709 | 21,212 |
| NASH | 87,385 | 95,836 | 8,451 | 10 | 92,557 | 89,388 |
| PAMLICO | 12,934 | 13,144 | 210 | 2 | 13,071 | 13,071 |
| PERSON | 35,623 | 39,464 | 3,841 | 11 | 39,454 | 39,696 |
| PITT | 133,719 | 168,148 | 34,429 | 26 | 184,070 | 198,446 |
| VANCE | 42,952 | 45,419 | 2,467 | 6 | 44,625 | 44,483 |
| WARREN | 19,972 | 20,975 | 1,003 | 5 | 19,940 | 19,602 |
| WILSON | 73,811 | 81,234 | 7,423 | 10 | 87,872 | 94,341 |

*NC Office of State Budget and Management (data pull October 2014) http://www.osbm.state.nc.us/

During the previous basin plan, DWR recognizes that greater oversight of local stormwater programs by the state could provide more assurance of full implementation of the rule as well as provide better data to assess the effectiveness of the rule and its various components. Periodic audits of each individual stormwater program were one method developed for this assessment. The audits would serve to help identify improvements needed in both implementation and reporting. Four local water supply programs (Franklin, Granville, Halifax and Vance Counties) and one Phase II stormwater program (Rocky Mount) audits were completed between 2010 and mid 2014. No major issues or violations were reported. The audits found that implementation of state-administered buffer rules as well as other state stormwater rules (HQW, ORW) improve when the local governments are well informed of the rules and include references to the stormwater rules in either their ordinances or on their permitting forms.

Several recommendation were made as result of the audits and can apply to other stormwater programs in the Tar-Pamlico River basin and throughout the state.

*** _Consider a Unified Development Ordinance (UDO)._**
DWR has found that local governments can benefit from incorporating their watershed and stormwater ordinances into a UDO and streamlining their permitting processes. Development of a UDO also presents an opportunity to review each ordinance, removing inconsistencies and eliminating outdated policies, thereby making it easier for the regulated community to understand the requirements.

*** _Consider revising UDO to strengthen language concerning development in riparian buffer areas._**
DWR recommends revise the watershed protection portion of the UDO to emphasize that development in the local government area may be subject to the Tar-Pamlico River Riparian Buffer Rule (Rule 15A NCAC 02B .0259) in addition to local buffer requirements. You may also consider ordinance language that clarifies that written authorization from DWR may be needed for activities that are proposed to occur within the 50-foot Tar-Pamlico River riparian buffer and that local program approvals do not authorize activities within the Tar-Pamlico River riparian buffer. Lastly, you may consider adding the following language, as appropriate: "Whenever conflicts exist between federal, state, or local laws, ordinances or rules, the more restrictive provision shall apply." While you're not required to make these revisions to your ordinance, we believe these revisions would provide an additional safeguard against potential violations of the Tar-Pamlico Buffer Rule.

*** _Consider requiring that vegetated buffers be recorded on final plats._**
DWR recommends that the local government require that buffers be recorded on final plats. While not required, it may be helpful in ensuring that current and subsequent property owners are aware of the presence of a protected watershed buffer area.

*** _Identify special classified waters on area watershed maps._**
DWR recommends that local governments consider including special classified waters (ORW, HQW, Water Supply watersheds) on local watershed maps. The appropriate GIS data layers can be obtained from www.nconemap.com.

## Agriculture Rule

The progress achieved by the agriculture sector in implementing the Tar-Pamlico Agriculture Rule is well documented in the Annual Agricultural Progress Reports submitted to the EMC every fall since 2003. As of 2002, the agriculture sector exceeded its collective 30% nutrient reduction goal and in 2013 reported a 43% reduction in estimated nitrogen loss to the basin through a combination of BMP implementation, crop shifts, fertilization rate reductions, and loss of overall cropland acres. During implementation, improvements have been made to the accounting of these reductions as more research and data becomes available concerning the effectiveness of agriculture BMPs. Opportunities remain for further improvement to the accounting process and fuller accounting of contributing agricultural sources. For yearly agricultural reports and annual progress tracking see Tar-Pamlico: Tracking Progress website.

DWR staff will continue to consult with university researchers and Division of Soil and Water Conservation staff as more data becomes available concerning the efficiencies of agricultural BMPs and how this information can be used to further refine the nutrient reduction credits applied under the current program. In addition to revisiting BMP efficiencies, DWR plans to continue collaborating with an interagency workgroup to identify methods to better track land use changes. Specifically, staff will be working to develop a “whole basin” land accounting strategy that will work to ensure that accounting for land that goes out of agriculture does not result in double counting of nutrient reductions.

The agricultural Basin Oversight Committee (BOC) was established to oversee the required agricultural nutrient reductions in the Tar-Pamlico basin in response to the NSW strategy. The Agricultural Nutrient Control Strategy (15A NCAC 02B. 0256) describes the role and expectations of the BOC and the Local Advisory Committees (LACs). The BOC develops and approves an annual report based on information provided by the LACs, summarizing local nitrogen and phosphorus loadings and estimated nutrient reductions based on implemented BMPs in the watershed. According to the rule, the accounting methodology shall provide for quantification of changes in nutrient loading due to changes in agricultural land use, modifications in agricultural activity, or changes in atmospheric nitrogen loading to the extent allowed by advances in technical understanding (15A NCAC 02B. 0256. (f)(3)(E)) and this should be done with sufficient detail to allow for compliance monitoring at the farm level. However, the approved accounting methodology supports aggregated county-wide nutrient accounting in the annual reports. Given the requirements of the agricultural rule, it is recommended that the BOC incorporate in their annual accounting estimates adjusted N rates from ammonia deposition and second year N availability contributions, when the data are available.

One potential limitation of the agriculture rule involves pastured livestock nitrogen contributions. Nutrient loading from pasture-based livestock operations has not been well characterized generally, including in NC, and the accounting tool used for rule compliance does not include the ability to quantify the effects of livestock management on nitrogen loading. Additional research is still needed to better quantify the nutrient benefits of various pasture management practices like fencing out livestock, pasture renovation and restoring riparian buffers. Encouraging the use pasture BMPs could represent an opportunity to achieve additional nutrient reductions.

In addition to better potential nutrient loading from pastures, staff also recognizes the need to better understand the role that artificial drainage, such as subsurface tile drains, plays in contributing nutrient loads to the basin. The interception of shallow groundwater beneath agricultural fields through tile drains to ditches can increase nitrogen and phosphorus loading into receiving streams by allowing the runoff to bypass BMP treatment (Harden and Spruill, 2008; Smith et al., 2014; King et al., 2014; Williams et al., 2015).

There is also a need to better understand the potential magnitude of nutrient loading from animal housing, holding, waste storage facilities and sprayfields used by confined animal feeding operations (CAFOs), such as dairies, hog farms, and poultry operations. Subsurface seepage from waste lagoons and ammonia emissions from CAFOs are also not captured under the NSW agriculture rule, but are to some degree addressed under other state rules and programs addressing animal operations. The location of hog and cattle CAFOs are known due to the fact that an NPDES permit is required by DWR. While their direct nutrient contribution is not currently well understood, knowing that these sources exist in the watershed can help water quality managers to better understand the available water quality data and make better regulatory recommendations and decisions.

Due to a hog farm moratorium put in place in 1997 and a new law passed in 2007 prohibiting the construction of new hog waste lagoons and sprayfields as the primary method of waste management (SB 1465), nutrient contributions from hog operations have remained fairly constant over the last several years. However, the continued growth in the poultry industry in the coastal plain of NC is adding to the current nutrient loading from non-point sources. Most poultry operations produce a dry litter by-product which is not monitored. The locations of poultry operations and the disposal of their waste is not known to environmental regulators due to the fact that they are deemed permitted, making it very difficult to get a complete picture of the possible non-point sources contributions within a specific watershed. This makes managing and protecting water quality more challenging.

The **USDA census data** indicates in 2012 there were 8,508,279 chickens in the Tar-Pamlico basin. The number of chickens has increased by at least another 4.75 million totaling over 13,000,000 this is over a 100% increase since 2002. The increase in poultry operations are likely having an impact on the water quality in the Tar-Pamlico River Basin and other coastal basins.

Model estimates for the 1994 basin plan estimated 45% agriculture contribution of total nitrogen to the basin, while a more recent USGS study of nutrient source shares and loads estimates 70% of the nitrogen load to the Pamlico and Pungo River Estuaries is from manure or fertilizer (Moorman et al. 2014). The nitrogen load calculated by the SPARROW model to the Pamlico Sound attributed to manure or fertilizer is 75% (Moorman et al. 2014). Updated watershed modeling is needed to manage for nutrient reductions given the shifts in agricultural practices and intensification.

## Wastewater Point Sources

WWTP effluent discharge contains organic (eg., proteins, amino acids, urea, amino sugars, and humic substances) and inorganic (eg., ammonium ($NH_4$+), nitrite ($NO_2$-) and nitrate ($NO_3$-)) nitrogen forms. New research is indicating the organic nitrogen may not be as recalcitrant as previously thought (Yu, 2012). This organic nitrogen is released as either dissolved organic nitrogen (DON) or particulate organic nitrogen (PON). One study of found DON to make up 20% of total nitrogen effluent (Yu, 2012). Additional research is needed to understand if changes in WWTP technologies to reduce total nitrogen loads are also leading to an increase in organic nitrogen loads that may or may not be biologically available.

Aging WWTP infrastructure may also be contributing to unaccounted nutrient contributions to surface waters via groundwater. Several seasonal comparisons of WWTP flow indicate that inflow and infiltration (I & I) issues may lead to wastewater exfiltration during the dry seasons; this wastewater contaminates the groundwater. During drier times baseflow is a major component of stream volume.

Upgrades and maintenance of wastewater infrastructure is important to protect human health, protect water quality and to prevent monetary fines and costs associated with a system overload. Sanitary sewer overflows are often a result of blocked or broken pipes, infiltration and inflow from leaky pipes, equipment failure or an overload of the system's capacity. Many SSO's can be prevented with infrastructure inspections, monitoring and maintenance programs, structural improvements, and employee and public education. Inspections are import to ensure WWTP facilities are in compliance with their permits; data indicating compliance have increased may just be the result of a decrease in the number of inspections due to limited staffing resources.

Based on DWR reports the total SSOs, from 2009-2014, for the Tar-Pamlico Basin counties of Beaufort, Edgecombe, Franklin, Granville, Halifax, Hyde, Nash, Pitt, Vance and Warren was 3,486,051 Gallons. Using an estimate average of TN 35.8mg/l and TP 5.35mg/l for raw sewage influent data, estimates were calculated for TN and TP loading as a result of the spills. Total Nitrogen for all above counties is approximately 1,042lbs. Total Phosphorus for all above counties is approximately 156lbs.

Even though the point sources are meeting their yearly cumulative cap limits, efforts should be focused on achieving Best Available Technology levels within their facilities. The 2014 permit renewal process included individual permit limits for the first time (Table 9).

## Nutrient Contributions from Land Application Sources of Waste

Indirect nutrient loads from point sources and agriculture through groundwater is likely a significant source of nutrient loading to the Pamlico River Estuary. There is a limited amount of research available that quantifies changes and the amount of nutrient contributions from groundwater to surface waters in the basin. Initial research indicates that land application of treated wastewater, biosolids from municipal wastewater treatment systems, and animal waste from confined animal feeding operations (CAFOs) are all considered likely sources of nutrients found in groundwater in the Tar-Pamlico River Basin.

The predominant wastewater treatment systems used at swine CAFOs are lagoons and sprayfields, in which waste is flushed from confined animal housing units into large waste lagoons and then periodically sprayed onto agricultural fields. Similarly, municipal wastewater treatment plants commonly land apply the sludge that is a by-product of the treatment process to agriculture fields as a means of disposal. In both cases the nitrogen contained in the land-applied products will either be assimilated by crops, volatilize into the atmosphere, run off into adjacent streams, or infiltrate into the groundwater system and eventually discharge into streams in the basin (Paerl et al., 2002).

### *Point sources*

As the demand for wastewater treatment increases with population growth, the dischargers will still have to comply with the nutrient reduction goals. DWR requires new and expanding NPDES permit applicants to consider non-discharge alternatives such as spray irrigation, rapid infiltration basins and drip irrigation systems. Land application of treated wastewater is likely to increase as a means of complying with this rule. Evaluation of the extent that land application may be yielding a net increase in nutrient loading is needed. A better understanding of land application program compliance and compliance criteria is also needed to quantify nutrient loading.

### *High-rate infiltration*

High-rate infiltration systems are a variation of land application systems that have become a growing practice in the coastal plain. These systems are being proposed to address wastewater needs of some new developments where receiving waters would not accommodate direct discharge of treated wastewater and no POTW is available. The new nutrient load from these systems is not captured by the point source rule or other strategy accounting mechanisms. Concerns have been raised about the system's use of landscape features to treat effluent prior to entering the surface waters. Nutrient contributions to surface waters from these systems have not been well quantified. Currently, there is only one high-rate infiltration system, located near Aurora, in the Tar-Pamlico Basin.

### *Biosolids*

Residuals, biosolids or treated sludge are by-products of the wastewater treatment process. After pathogen reduction, vector attraction reductions and metal limits are met, these residuals are disposed in a manner to protect public health and the environment. Disposal sites include land fills, dedicated and non-dedicated residual disposal sites, agricultural land for crops not for human consumption, and distribution to the public for home use. When applied to the land, steps must be taken to assure that residuals are applied at or below agronomic rates based on the soil and crop types present at the disposal site. Class B residuals are monitored by DWR and are applied to fields at agronomic rates. Class A residuals are not monitored by DWR but can also contribute nitrogen and phosphorus loading within the basin which are not currently accounted for. Additional research would be necessary to determine if organic nitrogen from biosolids is contributing to the basinwide increase in organic nitrogen.

An example of how nutrient loading to groundwater can occur from land application of biosolids is the situation at Novozymes in Franklin County. The facility has nitrate-nitrogen groundwater standard exceedances and is likely discharging off-site into local surface waters. The current leaching from the site is a result of past applications >10 years ago and has not been quantified. Novozymes has initiated a groundwater treatment system to address contaminated groundwater. Novozymes' wastewater, now low in nitrogen, is applied to approximately 900 acres of sprayfields. They also have a Class A equivalent biosolids permit for spent biomass (another source of N) from their industry process. These systems provide primary treatment of the wastewater along with some means of disinfection and then they dispose of the treated wastewater on irrigation fields.

While most regulations require that land application not exceed realistic yield-based agronomic rates, studies have shown that nitrate concentrations are higher in groundwater under crop fields sprayed with animal wastes than in groundwater beneath crop fields fertilized with commercial fertilizers (Spruill, 2004). Ideally, nutrient application should be based on crop needs and, for a given crop, there should be no difference in nitrogen loss between nutrient types applied. Given that the use of land application is expected to continue, and in light of the projected increase in human population in the Tar-Pamlico Basin, the continued use of this waste disposal method from such high volume sources highlights the importance of seeking a better understanding of the relative impacts of these practices on nutrient loading to surface waters.

Export of land-applied nutrients to surface waters, whether originating from municipal, commercial, or animal facility is enhanced when the field in question has artificial drainage systems like tile drains. The NLEW accounting tool used for agriculture rule compliance does not capture the effects of drain tiles nor does it reflect the research findings cited above regarding nitrogen concentrations under waste-applied fields.

While not part of the Tar-Pamlico NSW agriculture rule, there are other state rules that regulate land application. These include the 15A NCAC 2T rules, which specify requirements for systems that treat, store and dispose of wastes that are not discharged to surface waters of the state. These regulations do not contain nutrient reduction requirements and were not developed to specifically address the 30% nitrogen reduction goal, the rules do require management practices that could help reduce nutrient inputs in the Tar-Pamlico Basin from land application operations.

In addition, in 2007 the NC General Assembly incorporated the findings of the Smithfield Agreement into Senate Bill 1465 (Session Law 2007, Section 523). Senate Bill 1465 prohibits permitting of a new or expanding swine management system utilizing an anaerobic lagoon and sprayfield as the swine farm's primary method of treatment. Senate Bill 1465 also charged the Environmental Management Commission (EMC) to adopt rules to make the performance standards permanent thus allowing for the construction of innovative swine waste management systems for either new farms or for expansion of existing farms. The swine waste management system performance standards are to:

- Eliminate swine waste discharge to surface water and groundwater through direct discharge, seepage or runoff,
- Substantially eliminate atmospheric emission of ammonia,
- Substantially eliminate odor detectable beyond the swine farm property boundaries,
- Substantially eliminate disease-transmitting vectors and pathogens, and
- Substantially eliminate nutrient and heavy metals in soils and groundwater.



Revised 2/4/15

In 2007, a petition filed by several environmental groups requested monitoring requirements for general permits for animal feeding operations to ensure compliance with non-discharge effluent limitations. The petition resulted in a public stakeholder process that generated draft rules requiring CAFO facilities to develop monitoring plans that would serve to track the performance of the permitted system, verify that the system is protective of surface water standards and document water quality parameter concentrations in adjacent surface waters and compliance with permit discharge limitations. In July 2011, the EMC declined to adopt the proposed CAFO rules and suggested information on the impact of existing animal operations, sampling regimes and parameters is needed prior to adoption of rules for monitoring at animal operations. A collaborative study between the DWR and USGS was initiated in 2011 to generate scientifically based data to address many of the remaining concerns of the EMC. The EMC stated that they "should review the results of the study" and "if the results of the study indicate a need for monitoring, the EMC should direct DWR to reconsider the proposed monitoring rules at that time. The results of the study should be used to determine if monitoring of animal operations is needed, and if so, the type and frequency on monitoring to be performed" (NC DWQ July 2011 Hearing Officers Report for Monitoring Rules for Animal Feeding Operations). The USGS study was designed to characterize stream water quality conditions in coastal plain watersheds to document whether swine CAFOs have a measurable effect on surface water nutrient concentrations. USGS has a website with study related information available at nc.water.usgs.gov/projects/cafo/. The USGS final report for the CAFO study is due to be released in 2015. Although, this monitoring is not directly related to the 30% nitrogen reduction goal, the information collected will provide valuable information that will be useful in identifying high priority areas of nutrient inputs from animal waste land application sites.

## Nutrient Contributions from Onsite Wastewater Systems

Onsite wastwater treatment systems (OTWS) rely on nitrogen removal through landscape processes, primarily denitrification and plant uptake. These processes are believed to remove the vast majority of nitrogen generated by onsite systems before it reaches surface waters. However, such landscape processes are variable in nature, and a question requiring additional study is quantifying the extent to which such ground absorption systems may increase N loading to streams as compared to centralized collection of wastewater, and under what landscape conditions. A second question, which is discussed in the following section, involves understanding the temporal pattern of nitrogen movement through groundwater to surface water toward better understanding the relationship between population increases and nitrogen delivery to streams.

In addition to land application of waste as a potential nutrient source, initial evidence suggests that residential on-site wastewater systems (OSTS) may be a source of nutrients in the basin. A study conducted by researchers at the NCSU Department of Soil Science provided potential nitrogen loading numbers generated by households in the basin that use onsite wastewater systems. It estimates that approximately 49% of households in the Tar-Pamlico River Basin use onsite systems, and the cumulative nitrogen load generated by these systems is 1.76 million lbs N/yr (Pradham, 2007). While the study is somewhat limited in that it used 1990 Census data, were this magnitude of loading delivered directly to streams it would rival that delivered to the Pamlico estuary by all other sources combined. Another study of 10 septic tanks along NC's coast found an average of 80mg/L of dissolved organic nitrogen (DON) (Humphrey 2009). Additional research suggests this DON is mobile and may be more bioavailable than previously thought and contributes to the overall total dissolved nitrogen loads being distributed to the surface water via groundwater (Berman and Bronk, 2003 & O'Driscoll et al., 2014). The elevated dissolved organic nitrogen concentrations were more common during the wet periods (O'Driscoll et al., 2014).

A joint effort between the North Carolina Division of Public Health and the United States Geological Survey (USGS) compared the effects of onsite and offsite wastewater treatment on the occurrence of nitrogen in the Upper Neuse River Basin. It concluded that onsite systems contribute slightly more nitrogen to the nutrient load in recharging surface water than the load contributions from similar residences served instead by municipal sewer systems (Grimes & Ferrell, 2005). Another study compared groundwater and surface water phosphorus concentrations between onsite wastewater treatments and municipal wastewater treatments in NC coastal plain watersheds; this study found that groundwater and surface water phosphorous levels were higher in the watersheds with septic systems vs. the municipal treatment systems (Humphrey et al., 2014). In light of these findings it is evident that additional research in this area is needed to better quantify the role on-site wastewater treatment systems play in contributing nutrients to the Tar-Pamlico River Basin.

## Nutrient Loading from Groundwater

An area of growing interest involves improving our understanding of the role of groundwater in nutrient loading to the estuary. Harden and Spruill (2008) reported that in North Carolina's Coastal Plain, shallow groundwater contributes at least 40 percent of the average annual stream flows. The baseflow contribution to the Tar River is estimated 60% of the total discharge (O'Driscoll et al., 2010). Groundwater residence time is estimated to be less than 50 years (Spruill et al. 2005 & O'Driscoll et al. 2010). They have found that nutrient delivery to surface waters via groundwater can be influenced by various environmental, hydrogeological and geochemical factors.

While there are no specific studies for the Tar-Pamlico River Basin, a study published by USGS in 2008, estimates groundwater nitrogen flux into the Neuse River Estuary and reported nutrient fluxes from groundwater to the estuary account for 6% of the nitrogen inputs derived from all sources and approximately 8% of the nitrogen annual inputs from surface-water inflow to the Neuse River Estuary (Spruill and Bratton, 2008). Nutrient contributions from groundwater is needed for a comprehensive assessment of nutrient loading to the Pamlico River Estuary and to help determine contributions from sources not captured under the current NSW managment strategy.

In 1997, Spruill presented results from the U.S. Geological Survey's National Water Quality Assessment study indicating that groundwater was also a significant source of phosphorus loading in Coastal Plain streams of the Albemarle-Pamlico drainage basin. He reported that the concentrations of phosphorus were significantly higher in discharging groundwater (median = 0.23 mg/L) than in surface water (median = 0.07 mg/L) and that shallow groundwater typically had lower concentrations (median = ≤ 0.01 mg/L) than deeper groundwater (median = 0.2-0.3 mg/L) (Spruill, 1997).

Nurtient groundwater data is very limited in NC and usually is only monitored for the human health drinking water standard of Nitrate 10mg/l. Most groundwater nutrient studies also just evaluate the nitrate levels. The denitrification processes was shown to be the most significant factor responsible for decreasing groundwater nitrate concentrations. Additional factors influencing the groundwater nitrate concentrations included soil drainage, presence or absence of riparian buffers, evapotranspiration, fertilizer use, groundwater recharge rates and residence times, aquifer properties, subsurface tile drainage, sources and amount of organic matter and hyporheic processes (Harden and Spruill, 2008). They also reported that in the NC Coastal Plain, the nitrate reducing capacity of the buffer and hyporheic zones combined, substantially lowered the amount of groundwater nitrate discharged to streams from agricultural settings. However, the beneficial effects from these denitrification zones was greatly diminished by the presence of subsurface tile drainage that allows groundwater to bypass these natural streamside buffers and organic carbon-rich streambed (Harden and Spruill, 2008).

The nitrogen and phosphorus loads delivered by groundwater were not identified as part of the Tar-Pamlico TMDL, nor assigned a reduction requirement. This was in part because quantitative knowledge was limited at the time on either direct groundwater flux into the estuary or the makeup of groundwater's contribution to loading into basin streams. In addition, from a management standpoint DWR views groundwater primarily as a pathway rather than a source, and currently we look to manage inputs to this pathway rather than considering treatment of groundwater itself. Over sufficient time, the groundwater nitrogen flux should respond to reductions in landscape inputs. Research is increasingly showing that deeper groundwater flow paths may take on the order of decades to express themselves as surface discharges. This raises several questions including:

- Can we characterize the temporal pattern of groundwater nitrogen delivery to streams?
- Can we reliably monitor changes to both stream and estuary nitrogen inputs over time?
- To what extent have the Tar-Pamlico nutrient rules and other regulations resulted in reductions to landscape N and P inputs?

To begin answering these questions, we recognize that the set of landscape activities that add nitrogen to groundwater are primarily the variety of human and animal waste disposal and crop fertilization activities mentioned in sections above. An additional contribution is the overlay of atmospheric deposition of nitrogen across the landscape, as described in the following section. Much of these groundwater additions occur under the practice of agriculture. The agriculture rule focuses on surface water and does not require reduction of groundwater N inputs by 30%. Certain practices used to meet the agriculture rule, primarily decreasing N fertilization rates, should decrease groundwater N concentrations. Applying the 30% goal to N application would be problematic since the business of growing crops relies on certain application rates, and crops have inherent N use efficiencies that result in the loss of a fraction of that N, often on the order of half, to groundwater. But we believe that actions taken by producers to comply with the Tar-Pamlico agriculture rule should yield decreases in cropland N contributions to groundwater. Similarly, as detailed in the previous section, other regulations should result in decreased groundwater N inputs. The state CAFO regulations initiated in the mid-1990's have yielded significant decreases in waste N land application rates. Changes to residuals application included in the 2T rules should yield similar reductions to application rates for this activity.

The other questions will require us to pursue knowledge improvements by seeking additional monitoring and research into groundwater-to-surface water N dynamics. It will be important to assess the magnitude of contributions through this pathway over years and decades.

Currently, DWR's groundwater quality monitoring is very limited; expansion of the monitoring program to include water quality samples from established wells that currently only measure quantity would help gather the data the needed to analyze nutrient contributions from groundwater. The Chicod Creek watershed is a highly agricultural watershed, that contributes a significant nutrient load to the Tar River, despite the nutrient loading trends that show a decrease from the mid-1990s. Groundwater monitoring in this watershed would be helpful to understand if and how nutrients are moving from groundwater to surface waters. It is recommended that Chicod Creek be used as a pilot study area to initiate expansion of DWR's groundwater quality monitoring.

# Nutrient Loading from Atmospheric Deposition

Atmospheric deposition of nitrogen oxides ($NO_x$) and ammonia ($NH_3$) is a significant source of nitrogen input into North Carolina's coastal nutrient sensitive estuaries and sounds (Whitall and Paerl, 2001; Whitall et al., 2003; Costanza et al., 2008). However due to lack of available data at the time, contributions through atmospheric deposition were vastly underestimated in developing the Tar-Pamlico TMDL, nor was it assigned a reduction requirement. Much like groundwater contributions, this was in part because quantitative knowledge was limited at the time on the magnitude of either direct deposition to the surface of the estuary or its contribution to N loading to basin streams. From a management standpoint, atmospheric deposition was viewed primarily as a pathway rather than a source, and currently we look to manage inputs to this pathway rather than considering treatment of atmospheric nitrogen itself. Over sufficient time, atmospheric N deposition rates should respond to reductions by emissions sources. As with groundwater, this raises several questions including:

- To what extent are air quality regulations resulting in reductions to atmospheric N emissions?
- Can we characterize the relationship between reductions in N emissions and reductions in N deposition?
- Can we reliably monitor changes to nitrogen deposition over time?

While the scientific understanding of atmospheric deposition continues to evolve, some general observations can be made about atmospheric deposition as a source of nitrogen input into North Carolina's estuaries. Atmospheric inputs can be divided into two main types:

Direct: those that fall directly into the estuary and
Indirect: those that are deposited on various land surfaces throughout the basin, some portion of which is transported into streams and eventually delivered to the estuary.

As the population grows in the airshed of the Tar-Pamlico River Basin, an increase in $NO_X$ emissions from increased fossil fuel combustion is likely to occur. Ammonia also contributes to atmospheric nitrogen. The majority of atmospheric ammonia in the coastal plan volatilizes from confined animal operations, but sewage treatment plants and fertilizers applied to the land also contribute small amounts (Whitall et al., 2003; Walker et al., 2004). In North Carolina, animal agriculture is responsible for over 90 percent of all ammonia emissions; in turn, ammonia comprises more than 40 percent of the total estimated nitrogen emissions from all sources (Aneja et al., 1998).

In April 1989, the Division of Environmental Management, Water Quality Section reported that 18.6% percent of the nitrogen budget originated from atmospheric sources (NCDEM, 1989; USEPA 1993). The 1994 Tar-Pamlico River Basin Plan noted atmospheric deposition was one of the main cultural sources of nutrients in the estuary along with agricultural runoff, wastewater treatment plants and forestry.

While there are no recent studies indicating the overall amount of atmospheric deposition of nitrogen to the entire Tar-Pamlico River Basin, there are studies that suggest that up to 40 percent of the nitrogen entering the Albemarle-Pamlico Sound comes from atmospheric sources (DENR-DAQ, 1999; Costanza et al., 2008). A modeling study on the potential geographic distribution of atmospheric nitrogen deposition from CAFOs in NC reported that due to the high number of CAFO lagoons in the coastal plain and the prevailing southwest wind direction for 10 months of the year, the highest nitrogen depositional rates from CAFOs are in Neuse and Tar-Pamlico watersheds (Costanza et al., 2008). They also reported that between 24 and 47 percent of the Sound receives 50 percent of the atmospheric deposition from these CAFO lagoons (Costanza et al., 2008).

Studies have been conducted to assess the direct and indirect contribution from wet atmospheric N deposition to the Neuse River Basin. The results of one such study completed in 2003 indicates that atmospheric contributions of nitrogen vary seasonally and spatially within the watershed but that overall it accounts for approximately 24% of the total nitrogen load to the Neuse River Estuary, and these contributions have risen over the last twenty years (Whitall et al., 2003). It is likely that these results are similar for the Pamlico River Estuary.

While some of the land-based portion of this loading is addressed through stormwater rules and adjustments to crop fertilization rates, attaining the 30% reduction in nitrogen load to the Pamlico River Estuary may be challenging without first quantifying atmospheric contributions to the watershed more accurately, and eventually seeking appropriate management measures on all significant emission sources.

There is very little data available on the concentrations of dry nitrogen deposition. As with wet deposition, dry deposition rates are expected to vary across the basin depending on the proximity to the source. Initial research by the NC DAQ and EPA suggest that the amount of nitrogen contributed to an area from dry deposition is likely to be at least comparable to if not greater than that contributed through wet deposition.

Emissions from concentrated animal operations comprise the great majority of atmospheric ammonia emissions (Aneja et al., 1998). Currently, these outputs are not directly regulated. However, one recent improvement addresses new and expanding operations. In 2007, the NC legislature enacted a new law (SB 1465) requiring animal waste systems that serve new and expanding swine farms to meet or exceed five performance standards. One of the standards requires such farms to "substantially eliminate atmospheric emission of ammonia." This performance standard specifically requires that "ammonia emissions from the swine farm must not exceed an annual average of 0.9 kg $NH_3$ /wk/1,000 kg of steady state live weight" (15A NCAC 02T .1307 (2) (C)). This new regulation may be expected to substantially cap $NH_3$ emissions from swine farms at current levels. However, it does not require reductions from existing operations, nor does it apply to other types of CAFOs, such as cattle and poultry operations. Thus $NH_3$ emissions from existing CAFOs remain the largest unregulated source of atmospheric nitrogen emissions.

Additional research and monitoring is needed to obtain a complete understanding of the magnitude and variability of all atmospheric nitrogen inputs into the Pamlico River Estuary. Due to the dynamic nature of the airshed, it is also necessary to develop a better understanding of the relationship between emission levels and deposition rates of atmospheric nitrogen. DWR is working with DAQ staff to identify research opportunities. One such opportunity comes from DAQ modeling work using Community Multi-scale Air Quality modeling system (CMAQ) to conduct emissions modeling. The CMAQ modeling system simulates various chemical and physical processes that are thought to be important for understanding atmospheric trace gas transformations and distributions. The modeling system contains three types of modeling components: a meteorological modeling system for the description of atmospheric states and motions, emission models for man-made and natural emissions that are injected into the atmosphere, and a chemistry-transport modeling system for simulation of the chemical transformation and fate. It is possible that the use of an add-on tool to this model in the future may make it possible to use the output of this model to develop estimates of projected atmospheric nitrogen deposition rates.

## Phosphorus Reductions

Phosphorus loading to the estuary decreased significantly as a result of two events. Effective January 1, 1988, the NC General Assembly adopted a statewide phosphate detergent ban, which resulted in significant drops in stream phosphorus concentrations statewide, however this ban does not include dishwasher detergent. Also, in the fall of 1992, PCS Phosphate, located on the Pamlico River estuary in Aurora, began a wastewater recycling program that reduced its phosphorus discharge by about 97 percent. Opportunities to further reduce phosphorus loading include eliminating phosphorus in lawn fertilizers and automatic dishwasher detergent. Several other states have taken this easy step to reduce eutrophication including New York State's recent law amendment to limit the amount of phosphorus in dishwashing detergent and limit the use of lawn fertilizer's containing phosphorus.

## Estuary Dynamics

Climatic variability also plays an important role in the mobilization, processing, and delivery of nutrients and subsequent chlorophyll *a* response in the Pamlico River Estuary. Conditions in Pamlico River and Sound are more influenced by wind driven tides than the lunar cycle, where climate conditions such as hurricanes and drought impact both nutrient loading and cycling within the estuary. Estuary improvement is a generally complex nature of estuary dynamics; more specifically the potential for continual release of stored nutrients in sediments while water column nutrient concentrations decrease. Water residence time varies between 10 days and 2 months, with an average of 24 days in the Pamlico (Stanley, 1992). However, little is known about the residence time and recycling of nutrients within the estuary. A study is needed to gauge the extent to which purging of estuary sediments may be expected to delay improvements in estuary productivity response.

## Summary & Necessary Actions

Full implementation of the nutrient reduction strategy has been a measured process and was finally reached in 2006. Point sources continually have met their targeted nutrient loading caps from the early 1990's. The agriculture community has reduced their estimated nitrogen loss from cropland and pasture land by an average 46%, since 2002 (2002-2013). Almost 2,000 fertilizer applicators have received nutrient management training and the six local governments covered under the stepped Stormwater Rule have all adopted and implemented local stormwater programs to limit nitrogen and phosphorus inputs from stormwater runoff resulting from new development. Despite this successful implementation, the goal of a 30% reduction in instream nitrogen loading and no net increase in phosphorus loading since 1991 does not appear to have been met, and the Pamlico River Estuary remains impaired.

The estuary is a very complex and dynamic system. Climatic variability plays an important role in the mobilization, processing, and delivery of nutrients to the Pamlico River Estuary. The estuarine water quality response is affected by climatic events and this variability obscures clear trends in nutrient loading and the estuary's response to these loads, despite efforts to reduce point and non-point source loads. It is important to note that the water quality is assessed every two years in the estuary; each assessment represents data from a specific 5-year data window. The latest 2014 assessment includes data from 2008-2012, which included an extended drought period throughout much of the basin. Due to the decades of chronic overloading, the time lag required for nonpoint source input reductions to be fully expressed, and the likelihood of nutrient cycling within the estuary, it may be some time before current reductions in nutrient loading will reflect in improved water quality, and before a definitive assessment of the effect of the strategy on the estuary can be made.

DWR staff will continue to evaluate the limitations of the current strategies and work towards identifying opportunities to develop a better understanding of the nutrient dynamics for both the Tar-Pamlico and Neuse River systems. While we believe that further analysis of existing data and additional years of data collection will provide greater certainty as to the effect of the strategies on the estuaries, we also recognize the existing strategy limitations and other basin factors contribute to estuarine conditions. Listed below are the more overarching recommendations and research needs identified in this report which will be pursued during this next basin plan cycle. The basin plan will be updated as research and additional watershed assessments are completed as well as when other recommendations and basin needs are identified.

### *Source Assessment and Trends*

- Identify information needed for development of a watershed model
    - Explore opportunities to update loading goals and reductions needed to meet water quality standards in the estuary under current conditions.
    - Identify the need for additional monitoring locations and parameters to better characterize basin nutrient sources and relative contributions.
    - Calculate baseflow contributions of nitrogen to surface water.
    - Develop a more detailed analysis of current and historic data in order to better quantify the status of nutrient loading to the estuary; conduct additional trend and loading analysis upstream of the Pamlico River Estuary focusing on smaller watersheds with dominant land use types. This will allow staff to better gauge the effectiveness and progress of strategy implementation.

•Coordinate efforts with the Division of Air Quality to assess atmospheric nitrogen contributions to the watershed and develop recommendations on better ongoing characterization of atmospheric nitrogen deposition and emission source regulatory considerations.

- Specifically address better characterization of the contribution of ammonia emissions from CAFO operations.

•Work with Division of Soil and Water Conservation and Basin Oversight Committee to achieve the following:

- Identify additional opportunities to offset new or increased sources of nutrients from agricultural operations.

- Increase the focus on local nutrient control strategies that specify the numbers and types of all agricultural operations within their areas, numbers of BMPs that will be implemented by enrolled operations and acres to be affected by those BMPs, estimated nitrogen and phosphorus reductions and schedule for BMP implementation and efficacy. (In accordance to the Agricultural Nutrient Control Strategy Rule 15A NCAC 02B .0256).

- Better quantification of BMP effectiveness (agricultural and stormwater BMPs); improve accounting tools; support BMP development.

### *Stormwater Needs*

•Develop a full assessment and recommendations on stormwater programmatic coverage gaps and need to meet nutrient strategy goals on new development activities. Include recommendations on most appropriate regulatory approach.

•Work with DEMLR on the assessment of stormwater Phase II and Tar-Pamlico stormwater permitting programs. Make recommendations on how to strengthen the current program to be more environmentally protective. Need to address hydrologic, sediment and nutrient issues.

•Continue to audit local stormwater programs for effectiveness and work with local governments to strengthen their implementation.

•Evaluate the magnitude of nitrogen loading in runoff from existing development areas and develop recommendations on the need to address this source under the strategy.

•Work with DEMLR to assess compliance and enforcement needs for stormwater and sediment and erosion control activities in the basin.





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## *Identified Research Needs*

•Develop monitoring to better characterize the nature, magnitude and trends in atmospheric and groundwater derived nutrient contributions to the Tar-Pamlico River Estuary.

•Identify organic nitrogen sources that are contributing the TN loads at Grimesland (e.g., legacy sediments, beaver ponds, wetlands, septic systems).

•Assess nutrient residence time in the estuary.

•Characterize the location, geographic extent and functionality of tile drains under agricultural fields.

•Quantify the potential magnitude of nutrient loading from sprayfields, directly from animal housing and holding, and waste storage facilities on CAFOs.

•Characterize the geographic extent and quantify the potential magnitude of nutrient loading from dry litter poultry facilities, animal housing and waste storage.

•Characterize the potential for groundwater contamination and transport of nutrients from biosolids and wastewater land application fields to the surface waters of the Tar-Pamlico Basin.

•Assess whether the change in WWTP technology results in a transfer of nitrogen species leading to increased organic nitrogen loads.

•Quantify the nitrogen contributions from conventional on-site wastewater treatment systems to surface waters of the Tar-Pamlico Basin.

•Characterize nutrient loading from various pasture management practices which leads to a better understanding of pasture's nutrient contributions and the value of different management options.

•Assess impacts of fish farms on the water quality and determine their relative nutrient contributions and include them in the basin accounting of progress towards meeting the nutrient reduction goals.

•Assess Tar-Pamlico Buffer compliance.

•Identify the local Drainage Districts and understand their current role in controlling water flow and drainage issues. Work with the Districts to develop recommendations on how to protect water quality in these areas.

## *Voluntary Opportunities*

•Develop of a Unified Development Ordinance (UDO).
•Consider requiring vegetated buffers on final development plats.
•Require stormwater best management practices for existing and new development.
•Develop, strengthen and enforce riparian buffer ordinances.
•Identify special classification waters on local government area watershed maps.
•Develop and enforce local erosion control ordinances.
•Implement pet waste and residential fertilizer reduction ordinances.
•Work with local resource agencies to install appropriate BMPs in order to reduce the contribution of nutrient, sediment, bacteria and toxicants as well as addresses stormwater volume and velocity issues.

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# Appendix I

## Trend Analysis

### Introduction

DWR's Modeling and Assessment Branch used multiple trend and loading estimation tools to assess the progress towards meeting the NSW strategy goals. The trend analysis of annual nutrient concentrations for TN, TP, Total Kjeldahl Nitrogen (TKN), ammonia ($NH_3$-N), and nitrite+nitrate ($NO_x$-N) was conducted. TN is not directly measured, but is calculated as $NO_x$ plus TKN. The trend analyses focused on data from the ambient monitoring station O6500000, between 1991–2013, to evaluate progress towards meeting NSW reduction goals. This station is located at Grimesland, which is approximately 7 miles upstream of Washington. Trend analyses were also completed for an additional four waterbodies within the watershed that drain to the Grimesland compliance point (Table 17 and Figure 14). These additional analyses will help the division to understand what impact the nutrient reduction strategy has had in these smaller watersheds and where additional attention is needed to help meet the reduction goals.

Table 17: Ambient and USGS Gage Stations Used to Assess Tar-Pamlico River Basin Trends Analyses

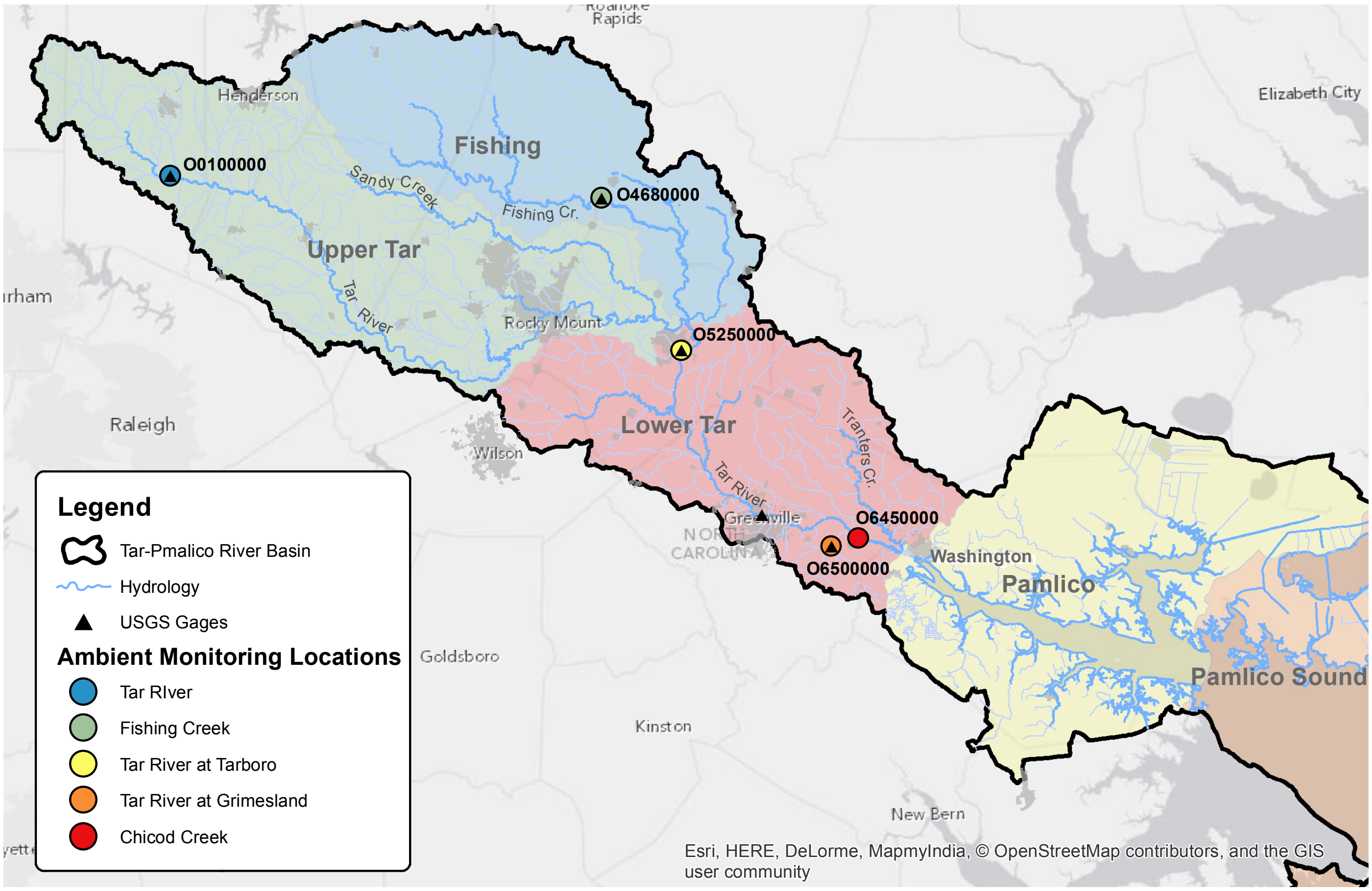
| River | Station Number | Station Location | USGS Flow Gage | Watershed Drainage Size ($mi^2$) | Trend Years |
|---|---|---|---|---|---|
| Tar River (Upper Portion) | O0100000 | Tar River at NC 96 near Tar River | 02081500 | 166.5 | 1991-2013 |
| Fishing Creek | O4680000 | Fishing Creek at US 301 near Enfield | 02083000 | 529.7 | 1991-2013 |
| Tar River (Middle Portion) | O5250000 | Tar River near Tarboro | 02083500 | 2,224.2 | 1991-2013 |
| Chicod Creek | O6450000 | Chicod Creek at SR 1960 near Simpson | 02084160 | 44.0 | 1993-2013 |
| Tar River (Lower Portion) | O6500000* | Tar River at SR 1565 near Grimesland | 02084000^ | 2,897.0 | 1991-2013 |

* Tar-River station O6500000 at Grimesland is used as the NSW compliance point because this station is close the City of Washington at the head of the estuary but is generally out of the tidal influence in the estuary which interferes with flow estimates.
^Greenville USGS gage station (02084000) is the closest upstream gage (~13 miles).

The purpose of any statistical trend testing is to determine whether a set of data that arise from a particular probability distribution represent a detectable increase or decrease over time (or space). There are a wide variety of trend testing techniques, all of which have certain assumptions that must be met for the analysis to be valid.

Detecting trends in a water quality data series is not as simple as drawing a line of best fit and measuring the slope. There are likely to be multiple factors contributing to variation in water quality over time, many of which can hide or exaggerate trend components in the data. Changes in water quality brought about by human activity will usually be superimposed on natural sources of variation such as flow and season. Identification and separation of these components is one of the most important tasks in trend testing. In the current trends analysis, the flow-adjusted concentration is estimated based on regression of concentration on some function of discharge to overcome the flow relatedness. The flow-adjusted concentration is then tested for a trend by using the Seasonal Kendall test to overcome seasonality.

FIGURE 14: TAR-PAMLICO RIVER BASIN MAP SHOWING THE AMBIENT AND USGS GAGE STATIONS USED FOR TREND ANALYSIS.




Pollutant loads, which are calculated as concentration multiplied by streamflow, have a large weather-dependent variance component and as a result discerning pollutant reduction using loads estimates is difficult. For this reason, the Modeling and Assessment Branch does not recommend performing trend analysis on load because the confounding effects of naturally variable flow (i.e. precipitation). A trend analysis of load will not, in fact, directly evaluate compliance towards meeting a nutrient load reduction goal because the dominant influence of precipitation, which is an uncontrollable variable, cannot be removed. Therefore, trend in flow-adjusted concentrations are performed to remove the component of variation related to flow. It has been demonstrated by many studies that removing flow variability has advantages for evaluating the ability of TMDLs to achieve reductions in both pollutant inputs and associated concentrations (Hirsch, 2012; Hirsch et al., 2010; Lebo et al., 2011; and Sprague et al., 2011).

Human impacts, such as those achieved through implementation of best management practices or point source controls, would be captured by changes in concentration. Therefore, it is appropriate to evaluate concentration when conducting trend analyses. This provides insight into whether or not management actions have resulted in long-term changes in water quality.

While the Seasonal Kendall nutrient loading trend analysis is not recommended, an alternative flow-normalized load estimates are designed to remove the effect of random stream flow-driven variations and are ideal for evaluating progress towards nutrient reduction goals (Sprague et al., 2011). Recent studies have demonstrated the use of flow-normalized loading assessments to evaluate effectiveness of management actions to reduce nutrients (Hirsch, 2012; Hirsch et al., 2010, Hirsch et al., 1991, Lebo et al., 2011; and Sprague et al., 2011). While some of these studies employed rigorous statistical methods for their analyses, the approach proposed by Lebo et al., (2011) used a simpler method and was selected for the current study. Lebo et al. (2011) used this approach to evaluate progress in achieving the Neuse TMDL reduction goal as well as changes in N fractions associated with different flow regimes.

Modeling and Assessment Branch also ran a USGS loading estimation (LOADEST) program which estimates constituent loads in streams and rivers. This assessment was completed for total nitrogen and total phosphorus at each station and provides a time series of annual load estimates for general comparison purposes over the study period.

## Trend and Load Estimation Methodologies

### *Flow Estimation*

All water quality monitoring stations used for this analysis except Grimesland have collocated USGS gage stations to measure daily flow (Table 17). Due to the lack of a stream gage at Grimesland, flow data were generated by multiplying flow from the closest upstream gage, which is approximately 13 miles upstream at Greenville (USGS 02084000), by a drainage area (DA) ratio of 1.07 (Grimesland DA divided by Greenville DA).

### *Flow-Adjusted Nutrient Concentration Trend Analysis*

The Water Quality / Hydrology Graphics / Analysis System (WQHYDRO) software was used to evaluate trends for the selected Tar-Pamlico River Basin stations. The software is a multi-faceted computer program, which is capable of computing flow-adjusted concentration and the Seasonal Kendall test. The model removes the concentration variation related to streamflow with flow-adjusted data by using a robust smoothing technique called Locally Weighted Scatterpot Smooth (LOWESS). The technique describes the relationship between concentration (Y) and flow (X) without assuming linearity or normality. The resulting residuals are considered flow-adjusted concentrations. The Seasonal Kendall test was applied to test a null hypothesis of no trend in NH3-N, NOx-N, TKN, TN, and TP concentrations. Upward trend (positive slope ↑) indicates degradation of water quality, whereas downward trend (negative slope↓) indicates improvement of water quality. The hypothesis was tested at 95% confidence level.

### *Flow-Normalized Trend Analysis*

Assessment of trends in annual nutrient loads were performed using flow-normalized (FN) concentrations and loads computed for flow intervals representing low, medium, and high flows. A spreadsheet-based tool was used for this analysis.

This analysis was designed to replicate the same approach used in the Neuse River Basin by Lebo et al. (2011) for the five selected stations in the Tar Pamlico River Basin. Nutrient concentrations were estimated from the mean of available data and flow-weighted average concentrations. Nutrient loads for the long-term flow distribution were computed from the average concentration and the average flow volume calculated from the low, medium, and high flow intervals over the assessment period of record (Table 18). A detailed description of this approach is presented in a peer-reviewed article by Lebo et al., (2011).

Table 18: Flow-Normalized Interval Information for Monitoring Locations Evaluated.

| Watershed | DWR Station Number | USGS Flow Gage | Flow Record Used | Flow Averages (cfs) | | | Flow Record Average |
|---|---|---|---|---|---|---|---|
| | | | | Low | Middle | High | |
| Tar River at Tar River | O0100000 | 02081500 | 1991-2013 | 4 | 37 | 371 | 138 |
| Fishing Creek | O4680000 | 02083000 | 1991-2013 | 62 | 235 | 121 | 422 |
| Tar River at Tarboro | O5250000 | 02083500 | 1991-2013 | 281 | 1,090 | 4,707 | 2,023 |
| Chicod Creek | O6450000 | 02084160 | 1993-2013 | 2 | 17 | 148 | 55 |
| Tar River at Grimesland | O6500000 | 02084000* | 1997-2013 | 373 | 1,417 | 5,809 | 2,530 |
| Average flows are listed for the three flow intervals used to group nutrient concentration data. Intervals bases on tertiles of long-term flow data at each location.<br>*Greenville USGS gage station (02084000) is the closest upstream gage (~13 miles). | | | | | | | |

## USGS LOAD ESTimator Analysis

LOAD ESTimator (LOADEST) is a publicly available FORTRAN program developed by the USGS for estimating constituent loads in streams and rivers. Given a time series of streamflow, additional data variables, and constituent concentration, LOADEST assists the user in developing a regression model for the estimation of constituent load. For specific information on this program and the analysis, go to the USGS website (http://water.usgs.gov/software/loadest/). This analysis was completed for total nitrogen and total phosphorus at each of the five watersheds selected. Unit area Loading was also determined by dividing the estimated annual load by the drainage area to get the relative load per unit area (lbs/$mi^2$/yr).

## Trend Analysis Results

### *Flow-Adjusted Concentration at Grimesland -TMDL watershed compliance point*

The results of the Seasonal Kendall test for flow-adjusted concentrations of TP, TN, TKN, $NH_3$-N, and $NO_x$-N at station O6500000 (Grimesland) are provided in Table 5. The results indicate that there were statistically significant concentration trends for TN, $NH_3$-N, $NO_x$-N, and TKN (Table 19). There was not a statistically significant trend for TP. TN and TKN showed increasing trends in concentration, while both $NH_3$-N and $NO_x$-N showed decreasing trends.

The downward or upward trend slope in flow-adjusted concentration represents the median rate of change in flow-adjusted concentration for each statistically significant parameter. The trend slope can be expressed as a combined percentage over the study period. This was calculated by dividing the trend slope by the base median concentration (first year median, 1991), and multiplying by 22 years (study period, 1992-2013) and then 100 to convert it to a percentage. Accordingly, reductions in the base median $NH_3$-N and $NO_x$-N through 2013 are estimated to be 33% and 22%, respectively; and increases in TN and TKN are estimated to be 11% and 55%, respectively (Table 19). The rate of change over the last three trends analysis are listed in Table 20 and are likely to change over time as more data is available, which increases confidence in a trends assessment, as well as due to the implementation of the NSW strategy, along with changing weather patterns that directly affect the rate of nutrient inputs or dilution effects in the system. The data over time (Table 20) is showing a continued increase in the organic nitrogen (TKN minus $NH_3$-N) component of TN. Identifying the source of the organic nitrogen

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appears to be crucial in understanding how to control the increasing TN concentration and to achieve the required reductions needed throughout the Tar-Pamlico basin.

Table 19: Results of Seasonal Kendall Trend Analysis for Flow-adjusted Concentrations at Grimesland O6500000

| Water Quality Constituents (mg/L) | Seasonal Sen Trend Slope (mg/L per year) | Significant Trend at 95% | 1991 Median | Estimated % Change in Median from 1991 - 2013 |
|---|---|---|---|---|
| NH3-N | -0.00106 | Yes ↓ | 0.07 | - 33% |
| NOx-N | -0.00756 | Yes ↓ | 0.77 | - 22% |
| TKN | +0.01259 | Yes ↑ | 0.50 | + 55% |
| TN | +0.00627 | Yes ↑ | 1.27 | + 11% |
| TP | | No | 0.16 | |

Minus - Denotes constituent concentration declining and water quality improving;
Plus - Denotes constituent concentration increasing and water quality declining.

Table 20: Trend Results Comparison of the Seasonal Kendall Trend Analysis for Flow-adjusted Concentrations at Grimseland O6500000

| Water Quality Constituents (mg/L) | 1991 | 1991-2002 | | 1991-2008 | | 1991-2013 | |
|---|---|---|---|---|---|---|---|
| | Median | Trend* | % Change[1] | Trend* | % Change[1] | Trend* | % Change[1] |
| NH3-N | 0.07 | na | na | Yes ↓ | - 45% | Yes ↓ | - 33% |
| NOx-N | 0.77 | na | na | Yes ↓ | - 28% | Yes ↓ | - 22% |
| TKN | 0.50 | na | na | Yes ↑ | + 32% | Yes ↑ | + 55% |
| TN | 1.27 | Yes ↓ | - 18% | No | | Yes ↑ | + 11% |
| TP | 0.16 | Yes ↓ | - 33% | No | | No | |

* Significant Trend at 95% Confidence;
1 - Estimated percent change from the 1991 median.;
na - The trend assessment did not include an analysis for this constituent;
Minus - Denotes constituent concentration declining and water quality improving;
Plus - Denotes constituent concentration increasing and water quality declining.

### *Concentration Trends Results for the Remaining Four Tar-Pamlico Watershed Stations.*

Four additional watershed stations were chosen for assessment of nutrient concentration trends similar to those completed above for Grimesland (O6500000), the Tar-Pamlico River Basin NSW nutrient compliance point. These four ambient monitoring stations were chosen as result of their proximity to a USGS flow gages which allow for the most accurate assessment (Table 17). These stations are spread throughout the basin (Figure 14) and provide additional insight as to what and where nutrient loading is coming from and will help the division understand differences between different watershed contributions based on, the amount of or changes in, agriculture and forestry practices, development densities, permit types (point and nonpoint), and biosolid applications. This information can help focus limited resources to those areas that might result in the greatest improvement in water quality. A summary of the estimated changes in concentration for those that are statistically significant from 1991 baseline are in Table 21.

Table 21: Percent change for Seasonal Kendall Trend Analysis for Flow-adjusted Concentration at all Stations

| Water Quality Constituents (mg/L) | 00100000 Tar River (Tar River) | 04680000 Fishing Creek | 05250000 Tar River (Tarboro) | 06450000 Chicod Creek | 06500000 Tar River (Grimesland) |
|---|---|---|---|---|---|
| **Trend Years** | 1991-2013 | 1991-2013 | 1991-2013 | 1991-2013 | 1991-2013 |
| **Basinline Year** | 1991 | 1991 | 1991 | 1991 | 1991 |
| $NH_3$-N | | - 39% | - 41% | - 38% | - 33% |
| $NO_x$-N | - 160% | - 58% | - 42% | - 57% | - 22% |
| TKN | + 37% | + 60% | + 44% | | + 55% |
| TN | | + 36% | | | + 11% |
| TP | + 36% | | | | |

Data provided for only those found to be statistically significant;
Minus - Denotes constituent concentration declining and water quality improving;
Plus - Denotes constituent concentration increasing and water quality declining

All watersheds draining to these stations except the upper Tar River at station 00100000 are experiencing a reduction in $NH_3$-N concentration. All watersheds assessed also showed a decreasing trend in $NO_x$-N concentration ranging from 160% decline in the upper Tar River (00100000) to a minimum decline of 22% at Grimesland (06500000). All watersheds except Chicod Creek (06450000), a heavily agricultural watershed (40.48% Ag), showed a significant increasing trend in organic nitrogen concentration (TKN is comprised of $NH_3$-N and organic nitrogen. Since $NH_3$-N is decreasing in most of these watersheds, the increasing component of TKN is the organic fraction). The significant increases ranged between 37 and 60 % of the original instream concentrations.

Significant increases in TN concentrations were found at Fishing Creek (04680000) (36%) and at Tar River at Grimesland (06500000)(11%). TN concentration is determined by adding TKN plus $NO_x$. The reductions in the $NO_x$-N concentration at all the stations tested in the watershed are offset by increases in TKN (organic nitrogen fraction) at almost all the stations in the watershed. Only the upper Tar River watershed (00100000) has a significant increase in TP concentration of 36%)

As described above, the majority of the instream concentrations declined with the exception of TKN concentrations. The yearly average flow at the USGS Tar River gage at Tarboro (02083500) during the 2014 IR period was 1,294 cfs, only slightly higher than the 1991 baseline period average flow of 1,249 cfs. Given the similarities in flow, Table 22 provides the 1991 and 2014 IR period (2008-2012) median instream concentrations and the stream flows for comparison. The concentrations that are higher for the 2014 IR period are denoted in red. TKN stands out as the constituent that is substantially higher than the 1991 concentrations. This would indicate that with the exception of a few stations and the increase in TKN, the instream concentrations are lower during the most recent 2014 IR assessment period. It is important to note that data was not available for Chicod Creek until 1993. The average flow for the USGS Tar River gage at Tarboro was 2,258 cfs in 1993, significantly higher than the extreme low flow of 1991. It is possible that the 1991 concentrations in Chicod Creek were lower than those reported in 1993, however the flows are comparable for 1993 and the 2014 IR period (Table 22).

### Table 22: Median 1991 Nutrient Concentration all Stations with Associated Flow and Drainage Area

| Water Quality Constituents (mg/L) | 00100000 Tar River (Tar River) | | 04680000 Fishing Creek | | 05250000 Tar River (Tarboro) | | 06450000 Chicod Creek | | 06500000 Tar River (Grimesland) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1991 | 2008-2012 | 1991 | 2008-2012 | 1991 | 2008-2012 | 1993 | 2008-2012 | 1991 | 2008-2012 |
| $NH_3$-N | 0.035 | 0.02 | 0.04 | 0.02 | 0.05 | 0.02 | 0.31 | 0.02 | 0.07 | 0.04 |
| $NO_x$-N | 0.04 | 0.06 | 0.12 | 0.12 | 0.47 | 0.29 | 0.8 | 0.08 | 0.77 | 0.45 |
| TKN | 0.40 | 0.59 | 0.30 | 0.42 | 0.40 | 0.58 | 1.0 | 0.84 | 0.50 | 0.65 |
| TN | 0.49 | 0.65 | 0.44 | 0.54 | 0.96 | 0.87 | 1.9 | 0.92 | 1.27 | 1.10 |
| TP | 0.035 | 0.06 | 0.05 | 0.06 | 0.13 | 0.10 | 0.42 | 0.19 | 0.16 | 0.13 |
| Mean Flow (cfs) | 95 | 94 | 273 | 248 | 1,249 | 1,294 | 51 | 50 | NA | 1,600 |
| Mean Flow (1991-2013) (cfs) | 138 | | 422 | | 2,023 | | 56 | | 2,536 | |
| Watershed Drainage Area (Miles$^2$) | 166.5 | | 529.7 | | 2,224.2 | | 44.0 | | 2,897.0 | |

1991 is the TMDL baseline year
2008-2012 is the latest IR (2014) assessment period, which tended to have lower flows than the previous IR periods; Red values denotes concentrations that are higher during the 2014IR period.

## Additional Concentration Trends

Additional discussions with DWR staff and stakeholders resulted in a reevaluation of the Seasonal Kendall concentration trends assessment to include an adjustment of the baseline period from 12 months (1991) to 24 months (1991-1992) to allow for a more normalized baseline dataset and to specifically look at trends from 2002-2013 with a two year baseline of 2002-03. This resulted in two additional Seasonal Kendall trend analyses for flow-adjusted concentrations at all five stations to be able to evaluate how these trends might differ from the overall compliance trend analyses (1991-2013). Reviewing the last decade can help us understand the most current watershed issues and determine how these are affecting the overall compliance of the NSW strategy. An additional trend analysis from 1991-2001 is pending.

The concentration trends from 2002-2013, indicate that TKN continues to rise while NOx-N appears to have stabilized. The overall increase in TN at Grimesland may account for the rise in TKN and NOx-N that was previously declining. The NOx-N reductions were likely a result of the implementation of the NSW strategy as WWTP dischargers reduced their TN loads. The other parameter of interest within the last decade is the increase in TP; this may be related to the increase in TP loads from WWTPs within the last decade since their initial decline in TP loading or may be related to other land use activities that mobilize the soils.

The tables below show the percent change in concentration for each parameter that were found to be statistically significant; a minus - denotes constituent concentration declining and water quality improving and a plus + denotes constituent concentration increasing and water quality declining.

| Table 23: Percent change for Seasonal Kendall Trend Analysis for Flow-adjusted Concentration at all Stations from 1991-2013 with Adjusted Baseline Period | | | | | |
|---|---|---|---|---|---|
| | 00100000 Tar River (Tar River) | 04680000 Fishing Creek | 05250000 Tar River (Tarboro) | 06450000 Chicod Creek | 06500000 Tar River (Grimesland) |
| Trend Years | 1991-2013 | 1991-2013 | 1991-2013 | 1991-2013 | 1991-2013 |
| Basinline Years | 1991 & 1992 | 1991 & 1992 | 1991 & 1992 | 1991 & 1992 | 1991 & 1992 |
| $NH_3$-N | | - 39% | - 41% | - 36% | - 25% |
| $NO_x$-N | - 80% | - 41% | - 43% | - 52% | - 26% |
| TKN | + 37% | + 60% | + 44% | | + 55% |
| TN | | + 32% | | | + 12% |
| TP | + 25% | | | | |

| Table 24: Percent change for Seasonal Kendall Trend Analysis for Flow-adjusted Concentration at all Stations From 2002-2013 with Adjusted Baseline Period | | | | | |
|---|---|---|---|---|---|
| | 00100000 Tar River (Tar River) | 04680000 Fishing Creek | 05250000 Tar River (Tarboro) | 06450000 Chicod Creek | 06500000 Tar River (Grimesland) |
| Trend Years | 2002-2013 | 2002-2013 | 2002-2013 | 2002-2013 | 2002-2013 |
| Basinline Years | 2002 & 2003 | 2002 & 2003 | 2002 & 2003 | 2002 & 2003 | 2002 & 2003 |
| $NH_3$-N | | | | - 30% | |
| $NO_x$-N | | | | | |
| TKN | | + 61% | + 39% | | + 43% |
| TN | | + 38% | + 21% | | + 24% |
| TP | | + 28% | | | + 31% |

| Table 25: Percent change for Seasonal Kendall Trend Analysis for Flow-adjusted Concentration at all Stations from 1991-2001 with Adjusted Baseline Period | | | | | |
|---|---|---|---|---|---|
| | 00100000 Tar River (Tar River) | 04680000 Fishing Creek | 05250000 Tar River (Tarboro) | 06450000 Chicod Creek | 06500000 Tar River (Grimesland) |
| Trend Years | 1991-2001 | 1991-2001 | 1991-2001 | 1991-2001 | 1991-2001 |
| Basinline Years | 1991 & 1992 | 1991 & 1992 | 1991 & 1992 | 1991 & 1992 | 1991 & 1992 |
| $NH_3$-N | PENDING | | | | |
| $NO_x$-N | | | | | |
| TKN | | | | | |
| TN | | | | | |
| TP | | | | | |



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### *Annual and Flow-Normal Load Estimation Results*

Annual nutrient load assessments were calculated using flow-weighted average concentrations. The 1991-2013 flow records were used for each station to develop flow thresholds that were used to group nutrient data by low (0-33%), middle (34-66%), and high (67-100%) flow regimes. This approach allows for the determination of which flow interval delivers the largest portion of the overall load to the Tar-Pamlico system. The data in Table 23 and Figure 15 clearly show that the largest contribution of nutrients occur during the high flow events at Grimesland and throughout the system. The average TN contribution at Grimesland from low, middle, and high flow intervals were 6, 20 and 74% respectively and for TP contribution was 6, 19, and 75% respectively. The contribution of TN and TP from high flows throughout the Tar-Pamlico River watershed ranged between 77 to 92.8% (Table 23). The average flows at each station for each flow interval are reported in Table 18. For tables presenting the average concentration of TN, TKN, NOx-N and TP by five-year periods and flow intervals for all stations see Appendix II at the end of this document.

Table 26: Average TN and TP Percent Contribution from Flow Intervals (1991-2013).

| Flow Interval | Tar River at Tar River 00100000 | | Fishing Cr. 04680000 | | Tar River at Tarboro 05250000 | | Chicod Cr. 04650000 | | Tar River Grimesland 06500000 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | TN (%) | TP (%) | TN (%) | TP (%) | TN (%) | TP (%) | TN (%) | TP (%) | TN (%) | TP (%) |
| Low | 1 | 0.6 | 5 | 4 | 5 | 4.4 | 1 | 2 | 6 | 6 |
| Medium | 7 | 6.6 | 16 | 19 | 18 | 16.2 | 7 | 9 | 20 | 19 |
| High | 92 | 92.8 | 79 | 77 | 77 | 79.4 | 92 | 89 | 74 | 75 |

Over the 1991-2013 assessment period, annual TN loads at Grimesland ranged between 2.2 to 9.3 x $10^6$ lbs/yr with a mean value of 4,700,000 lbs/yr and TP loads ranged between 0.24 to 1.27 x $10^6$ lbs/yr with a mean value of 567,000 lbs/yr (Table 24 and Figure 15). Figure 15 shows the annual load for TN (A) and TP (B) for the Tar River at Grimesland (06500000), for the other 4 watershed stations see Appendix III. The load of TN and TP at the Tar River at Tarboro is approximately 61.5% of the load at Grimesland (Table 24). This indicates that about 38.5% of the load to Grimesland is being delivered from the 03020103 (Lower Tar River) watershed.

### 1991-2013 TN and TP Annual Loading Estimates at Each Watershed Station.

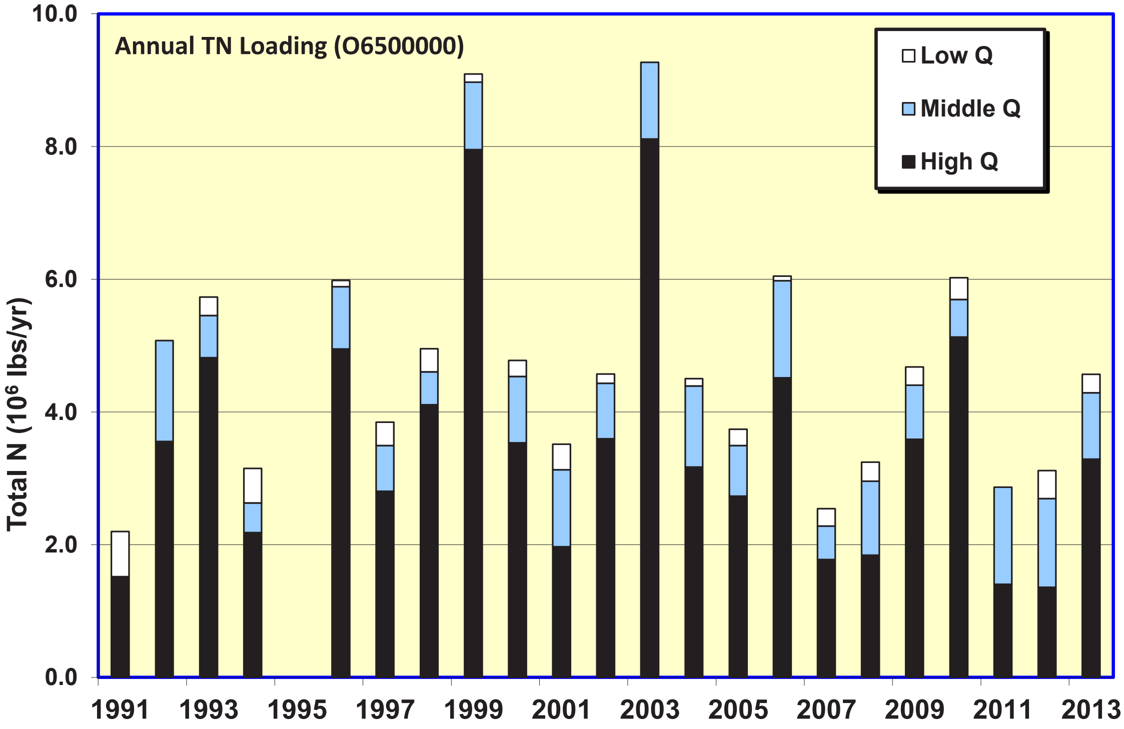
| Watershed | Station Number | TN Loading Range 1991-2013 (lbs/yr) | TN Mean Value (lbs/yr) | % of Load* | TP Loading Range 1991-2013 (lbs/yr) | TP Mean Value (lbs/yr) | % of Load* |
|---|---|---|---|---|---|---|---|
| Tar River at Tar River | O0100000 | 0.1 to 4.4 x $10^5$ | 190,000 | 4.0% | 0.06 to 0.7 x $10^5$ | 23,000 | 4.1% |
| Fishing Cr. | O4680000 | 0.65 to 9.6 x $10^5$ | 409,000 | 8.7% | 0.1 to 1.2 x $10^5$ | 47,000 | 8.3 |
| Tar River at Tarboro | O5250000 | 0.74 to 6.2 x $10^6$ | 2,892,000 | 61.5% | 0.5 to 8.9 x $10^5$ | 361,000 | 63.7% |
| Chicod Cr. | O6450000 | 0.12 to 3.34 x $10^5$ | 142,800 | 3.0% | 0.04 to 0.67 x $10^5$ | 25,700 | 4.5% |
| Tar River at Grimesland | O6500000 | 2.2 to 9.3 x $10^6$ | 4,700,000 | | 0.24 to 1.27 x $10^6$ | 567,000 | |

* Percent of total load to Tar River at Grimesland station O6500000, NSW nutrient compliance point;
The NSW Tar River TN target at Washington is 3,000,491 lbs/yr (1,361,000 kg/yr) or less and the TP target is not to exceed 396,832 lbs/yr (180,000 kg/yr).

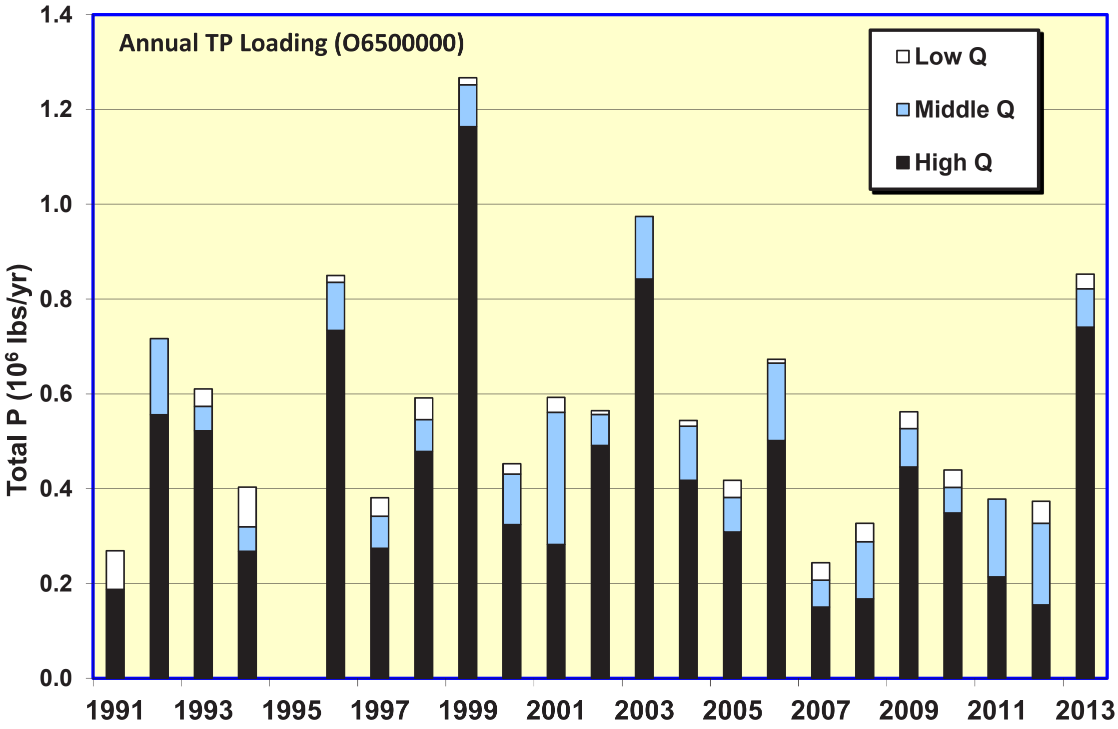
In order to evaluate progress in achieving the nutrient reduction goal set by the Tar Pamlico River Basin NSW Strategy, Flow-Normalized (FN) load estimated under long-term average flow conditions were compared to the average load for the 1991-1995 period. Five-year moving averages of $NO_x$-N, TKN, TN and TP loads were computed and compared with the corresponding value for the 1991–1995 period (Figure 16 and Figure 17).

## Figure 15: Loading at Tar River Grimesland Station O6500000.

### A) Total Nitrogen Loads




### B) Total Phosphorus Loads




Q is a symbol for volumetric flow rate (cubic feet per second).

Figure 16: Relative Flow-Normalized TN Load Reduction Comparison to 1991-1995 at Tar River Grimesland Station O6500000.

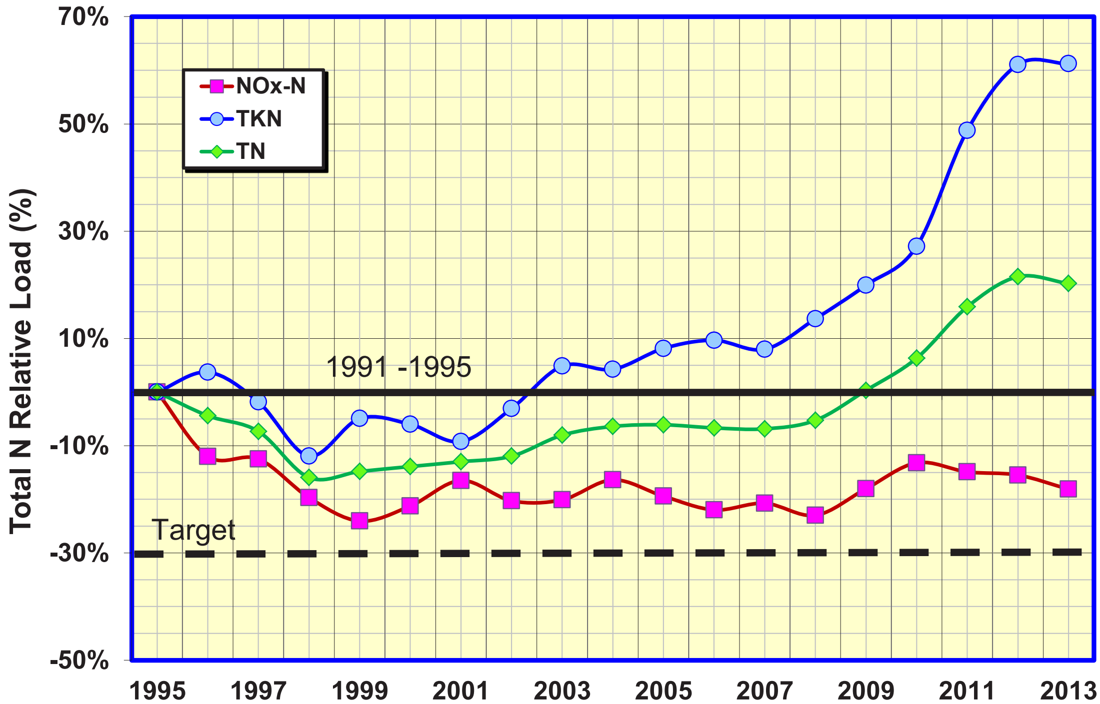
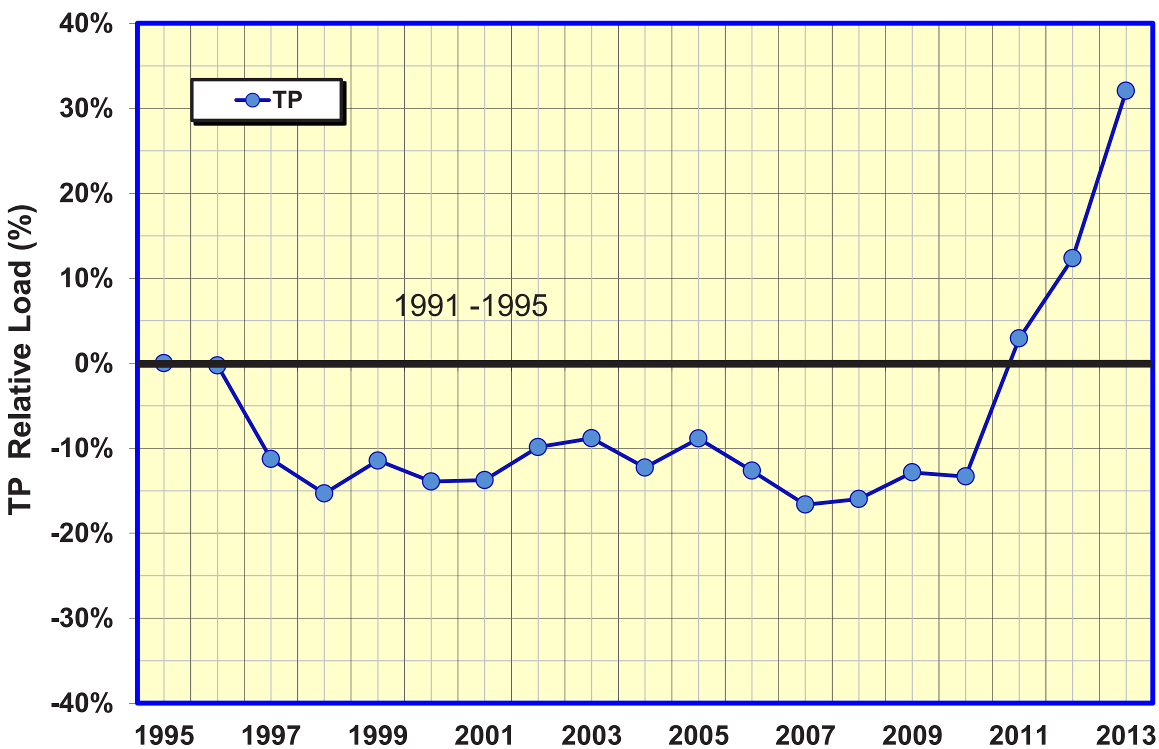



Figure 17: Relative Flow-Normalized TP Load Reduction Comparison to 1991-1995 at Tar River Grimesland Station O6500000.



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Similar to the concentration trend analysis at Grimesland, the results of the FN loading analysis indicates a reduction in FN NOx-N loading along with an increase in TKN (organic nitrogen) loading (Figure 16). Flow-normalized NOx-N loading gradually decreased from the 1991-1995 period to the end of the study period. It reached a minimum value of -24.1% in the 1995–1999 time period. The average reduction achieved was approximately 18% for all periods beginning with 1992–1996. Flow-normalized TKN loading decreased from the baseline period and reached the minimum values of -12.0% in the 1994-1998 period and increased substantially afterwards. Flow-normalized TKN loading has been consistently higher than the 1991–1995 period throughout the past 11 five-year periods and increased to greater than 60% for the last five-year periods ending in 2013. Since Ammonia loading declined over the same time period, the increase in TKN loading was primarily due to an increase in the organic nitrogen fraction. The flow-normalized TN loading decreased to a minimum value of -15.9% in the 1994-1998 period and increased gradually afterwards in response to the increasing TKN (Organic fraction).

Flow-normalized TP loading at Grimesland has been consistently lower than the corresponding 1991-1995 loading until the 2007-2011 period when the load began to increase and has climbed to approximately 30% greater than the 1991-1995 load (Figure 17). The increase in TKN and TP over the last three to four, five-year periods need further investigation in order to determine the cause of such a drastic shift in the loading of these two nutrient parameters. The data range for this shift is about 2006 to 2013. There was an extended low flow period during this time frame which should have resulted in lower loading if in fact the highest loads come from high flow events as described earlier. It will take some time to understand all of the possible contributing factors that have led to these results. As information becomes available, this section of the plan will be updated to reflect new information and research results.

Similar FN trends were seen at the other watershed stations assessed with the exception of Chicod Creek (all Flow-Normalized graphs provided in Appendix IV). The results of the FN loading analysis for Chicod Creek indicate reductions in FN TN, NOx-N, TKN and TP loadings relative to the 1993-1997 period. It is important to remember that the Chicod Creek assessment is relative to 1993-1997 instead of 1991-1995 like the rest of the stations. Data is not available for Chicod Creek prior to 1993. By using 1993 instead of 1991 as the baseline in Chicod Creek, which according to the annual loading graph in the Appendix III, was a high loading year for Chicod Creek watershed, the reduction needed to fall below this threshold is not as difficult to achieve. Since the 2004-2008 five-year period, TN, NOx-N and TKN have all increased but are still below the 1993-1997 initial loading period.

### *LOADEST TN and TP Estimated Annual Load Time Series and Unit Area Loading Results*

The USGS LOAD ESTimator (LOADEST) tool for estimating constituent loads in streams and rivers is being used to produce the TN and TP annual load time series. This provides a visual assessment of how loads vary but are highly impacted by precipitation as can be seen in 1999 (hurricane Floyd) and 2003 (unusually wet year). This is used to see the general pattern of loading compared to the 1991 baseline year. It is important to remember that 1991 was a very dry, low stream flow year which affected the overall loading for both nitrogen and phosphorus.

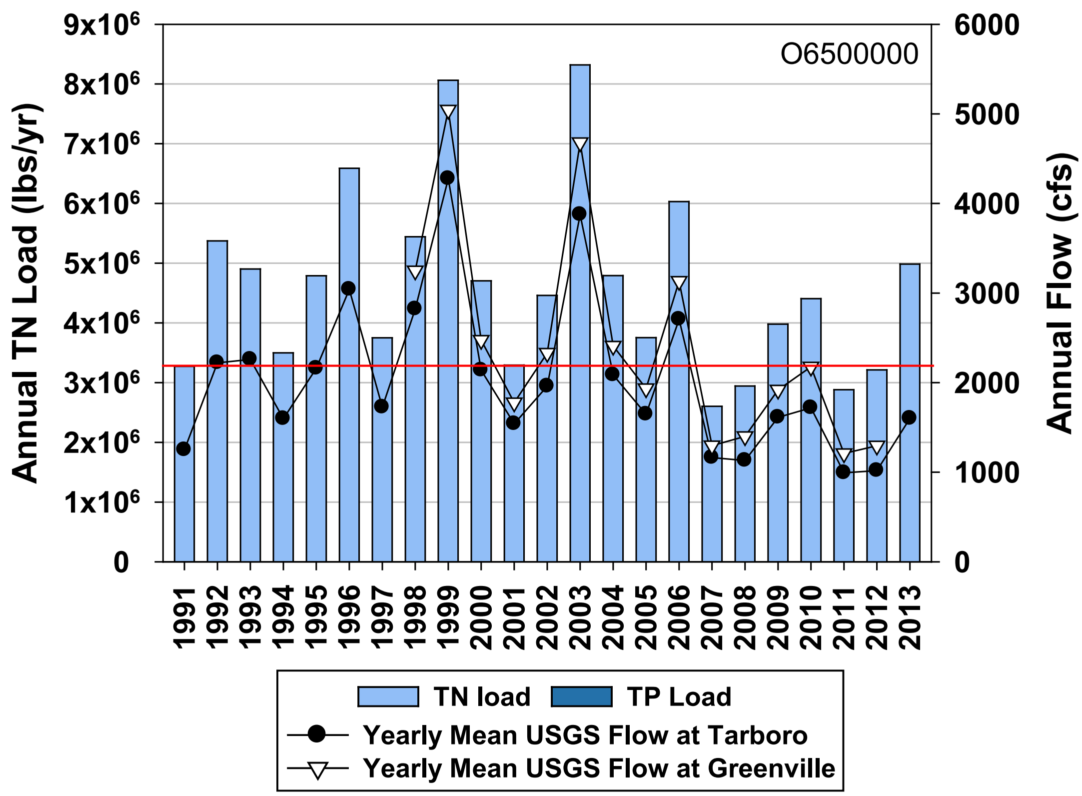
The NSW Tar River TN load target at Washington is 3,000,491 lbs/yr (1,361,000 kg/yr) or less and the TP target is not to exceed 396,832 lbs/yr (180,000 kg/yr). Tar-River station O6500000 at Grimesland is used as the NSW compliance point because this station is close to the City of Washington at the head of the estuary but is generally out of the tidal influence in the estuary which interferes with flow estimates used in loading analysis.

The LOADEST TN annual load time series is provided below is Figure 18(A). The red line in Figure 18 denotes the 1991 estimated load. The only years that fell below the 1991 estimated load was 2007, 2008, 2011 and 2012. The yearly mean and median instream concentrations are provided in Table 25 for comparison of the concentration levels between the high and low loading years. The mean instream concentration are generally higher in the low loading years but account for a lower overall load because less is being delivered as result of the lower stream flows.

The TP annual load time series is provided in Figure 18(B). Similar to the TN loading summary, the only years with estimated total TP loads less than the 1991 baseline are 2007, 2008 and 2011. The instream mean TP concentrations were also higher during these three low loading years. It should be noted that 2007, 2008, 2011 and parts of 2012 were impacted by drought conditions. This implies that the total load is being driven more by the amount of precipitation, which drives flow, than by nutrient concentrations. Having higher instream concentrations during the low flow periods indicates that the source of the pollutant is likely point source or possibly groundwater contribution. The majority of the base flow in a stream during low flow periods in often driven by groundwater contributions. In a stream with a large municipal source, wastewater can also be a large portion of the stream flow during low flow periods. There is very little groundwater monitoring done throughout this basin to support this assertion other than monitoring done for new groundwater drinking wells. This is an area identified for possible research and if resources become available DWR should participate in understanding this issue further.

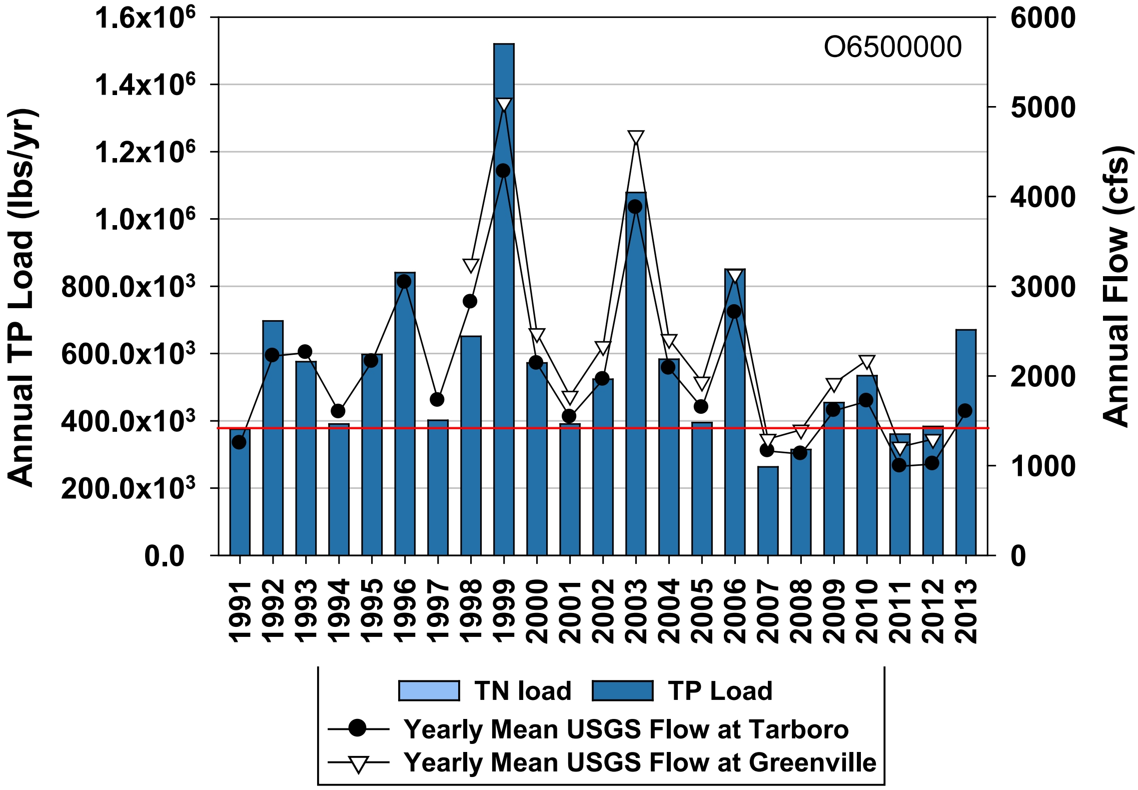
Figure 18: LOADEST Time Series of Annual Load of TN and TP (lbs/yr) at Grimesland O6500000 with Mean Flow at Tarboro and Grimesland USGS Tar River Gages.

A) TN Estimated Annual Load Series




Red Line Denotes 1991 Estimated Load.

### B) TP Estimated Annual Load Series




Red Line Denotes 1991 Estimated Load.

### Table 27: Nutrient Yearly Mean and Median Concentrations (mg/L) for Tar River Grimesland Station O6500000 for 2002-2012.

| Year | TN | | TKN | | $NO_x$-N | | $NH_3$-N | | TP | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Mean | Median |
| 2002 | 0.894 | 0.910 | 0.496 | 0.485 | 0.398 | 0.350 | 0.065 | 0.055 | 0.094 | 0.090 |
| 2003 | 0.993 | 0.950 | 0.518 | 0.510 | 0.475 | 0.435 | 0.044 | 0.045 | 0.106 | 0.115 |
| 2004 | 0.901 | 0.870 | 0.503 | 0.460 | 0.398 | 0.435 | 0.040 | 0.030 | 0.103 | 0.105 |
| 2005 | 0.997 | 1.060 | 0.517 | 0.530 | 0.480 | 0.460 | 0.045 | 0.040 | 0.122 | 0.120 |
| 2006 | 0.959 | 0.960 | 0.539 | 0.530 | 0.420 | 0.440 | 0.048 | 0.040 | 0.108 | 0.100 |
| 2007 | 1.057 | 0.985 | 0.557 | 0.590 | 0.500 | 0.510 | 0.047 | 0.040 | 0.128 | 0.115 |
| 2008 | 1.078 | 1.035 | 0.663 | 0.650 | 0.414 | 0.425 | 0.049 | 0.045 | 0.123 | 0.135 |
| 2009 | 1.146 | 1.145 | 0.621 | 0.585 | 0.525 | 0.530 | 0.043 | 0.040 | 0.131 | 0.130 |
| 2010 | 1.147 | 1.170 | 0.653 | 0.645 | 0.494 | 0.575 | 0.048 | 0.040 | 0.115 | 0.120 |
| 2011 | 1.257 | 1.135 | 0.853 | 0.780 | 0.404 | 0.445 | 0.076 | 0.030 | 0.164 | 0.145 |
| 2012 | 1.135 | 1.140 | 0.665 | 0.685 | 0.470 | 0.445 | 0.050 | 0.050 | 0.135 | 0.140 |

LOADEST TN and TP annual load estimations were also done for the four additional watersheds throughout the basin in order to understand the loads coming from each and how they contribute to the overall loading at the Grimesland compliance point (Figure 14). Each of the total TN and TP loading time series graphs are split into two sets, one for the smaller watersheds (Upper Tar River at Tar River, Fishing Creek and Chicod Creek) and the second for the larger watersheds (Middle Tar River at Tarboro and Grimesland) due to total loading scale differences (Figure 19, Figure 20, Figure 21, and Figure 22). It is important to remember that the total loading at Tarboro is derived from the two subbasins upstream (Upper Tar - 03020101 and Fishing Creek - 03020102) and that Grimesland loading is from essentially the entire watershed above the City of Washington with the exception of Tranters Creek watershed (Figure 14). The estimated TN and TP unit area loading were also calculated and presented in Figure 23 and Figure 24. This helps to understand what level of loading is being delivered per square mile and to help understand the amount of loading that might be expected from a specific type of land use.

The estimated TN loading in the upper Tar River at Tar River (O0100000) fell below the 1991 baseline load in 4 of the 22 years post 1991 (Table 7; Figure 19). The 23 year estimated mean loading was 300,929 lbs/yr with an estimated unit area loading of 1,807 lbs/mi$^2$/yr (Table 7, Figure 23). The mean estimated TP loading at the upper Tar River station was 39,105 lbs/yr and fell below the 1991 loading in 3 of the 22 years. The estimated mean unit area TP loading was 234 lbs/mi$^2$/yr (Table 8; Figure 24). The upper Tar River has a relatively high level loading for a head water region that is mostly forested. Additional research is needed in order to determine the source of the high loading in this small headwater portion of the upper Tar River watershed.

The estimated mean TN loading in Fishing Creek was 160,918 lbs/yr with a unit area loading of 304 lbs/mi$^2$/yr (Table 7). The estimated mean TP loading was 19,264 lbs/yr with a unit area loading of 36.4 lbs/mi$^2$/yr (Table 8). Fishing Creek had the lowest area unit loading of all the watersheds tested. The TN and TP area unit loading is 5.2 time and 5.6 times higher at Grimesland than in Fishing Creek. The yearly estimated TN and TP loading was lower in 10 and 9 of the 22 years post the 1991 baseline loads respectively (Table 7 and Table 8). It appears that the controls in place are likely working well to control loading from the sources in this watershed. Additional research is needed to determine what land use changes have occurred and what nutrient reduction controls have been utilized to help protect this watershed.

The estimated mean TN loading in Tar River at Tarboro was 3,161,774 lbs/yr with a unit area loading mean of 1,422 lbs/mi$^2$/yr (Table 7). The estimated mean TP loading was 393,712 lbs/yr with a unit area loading of 177 lbs/mi$^2$/yr (Table 8). The TN and TP area unit loading is 1.12 and 1.13 times higher at Grimesland than in the Tar River at Tarboro. The yearly estimated TN and TP loading was lower in 5 and 4 of the 22 years post the 1991 baseline loads respectively. The loading at this point represents what is coming into this station from the two upstream subbasins. The area unit loading is fairly equivalent to that at Grimesland.

The estimated mean TN loading in Chicod Creek was 188,112 lbs/yr with a unit area loading mean of 4,275 lbs/mi$^2$/yr (Table 7). The estimated mean TP loading was 32,110 lbs/yr with a unit area loading of 730 lbs/mi$^2$/yr (Table 8). The TN and TP area unit loading is 2.7 time and 3.7 times higher from the Chicod Creek watershed than at the Tar River at Grimesland station. The yearly estimated TN and TP loading was lower in 15 and 13 of the 20 years post the 1993 baseline loads respectively. The unit area loading from Chicod Creek is substantially higher than all the other watersheds assessed. Chicod Creek is a small 44 square mile agricultural based watershed but is located in close proximity to Grimesland and the estuary. Chicod Creek watershed only accounts for 1.5% of the overall Grimesland watershed but accounts for 4.1% of the overall estimated mean load. While it appears that the loads are lower than the 1993 baseline load, it is considerably high and the sources of nutrients in this watershed should be identified. DWR should work closely with the Soil and Water Conservation District to determine what BMP has been utilized and if additional practices are likely to help reduce the high instream concentrations and overall load.

The range in TN and TP annual and unit area loading are also provided in Table 7 and Table 8 respectively. The NSW TN loading target at Grimesland in 3,000,491 lbs/yr. The estimated annual TN loading range at Grimesland was 2,603,728 to 8,319,762 lbs/yr with a mean of 4,593,624 (Table 7). The target falls within the loading range seen at Grimesland but has only fallen below the target in 2007, 2008 and 2011, all of which were very low flow years. The NSW TP target is not greater than 396,832 lbs/yr. The estimated annual TP loading range at Grimesland was 263,069 to 1,520,328 lbs/yr with a mean of 579,692 lbs/yr. The target for TP loading also fell within the range of loading delivered to Grimesland in 7 of the 22 years post the 1991 baseline period (1994, 2001, 2005, 2007, 2008, 2011 and 2012), again these were all low flow periods. LOADEST estimated annual TN and TP loading graphs are included in the Appendix V for all individual stations.

Figure 19: LOADEST Annual TN Load Estimates for Upper Tar River at Tar River, Fishing Creek and Chicod Creek with USGS Tar River at Tarboro Annual Mean Flow (1991-2013).

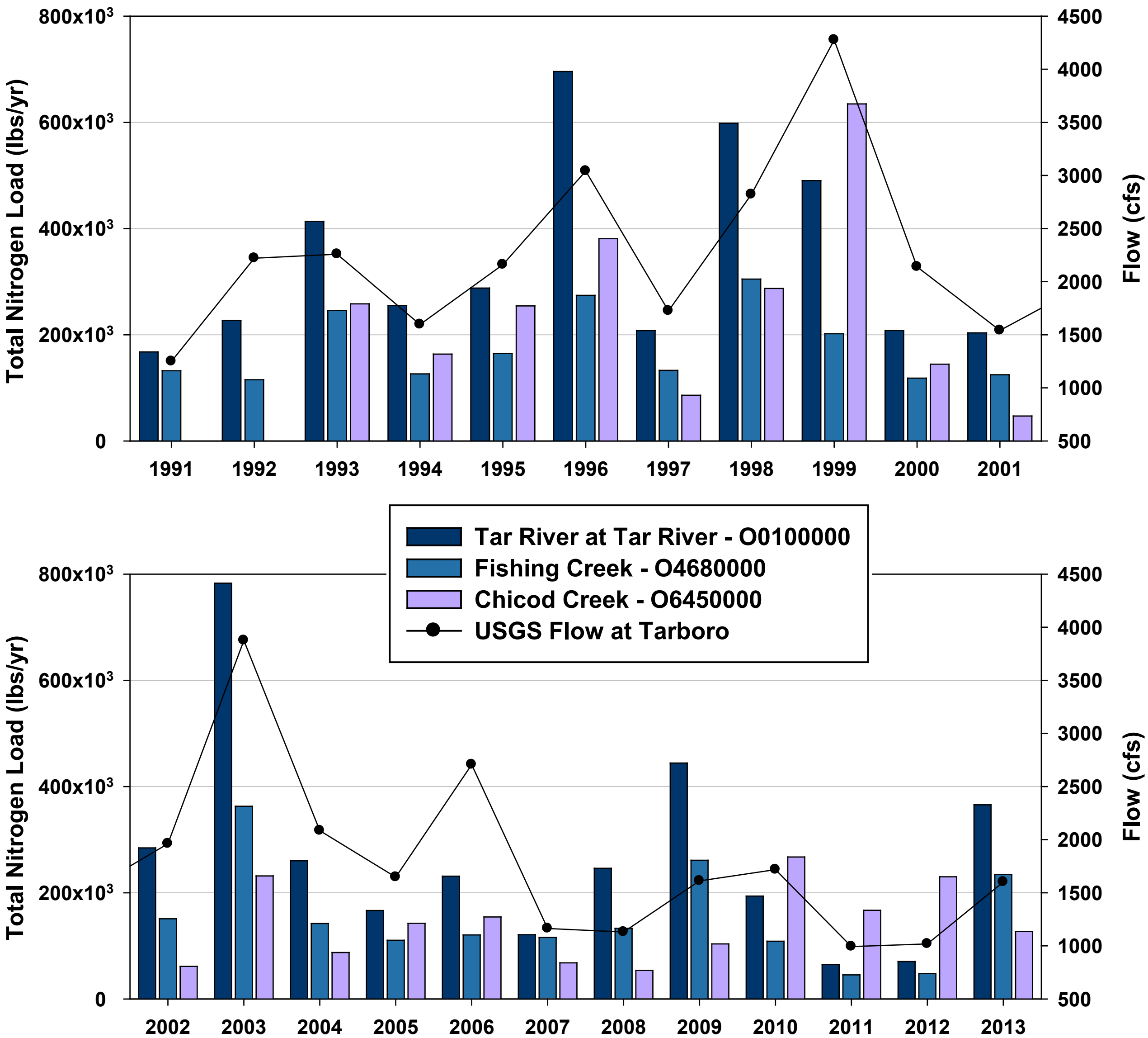
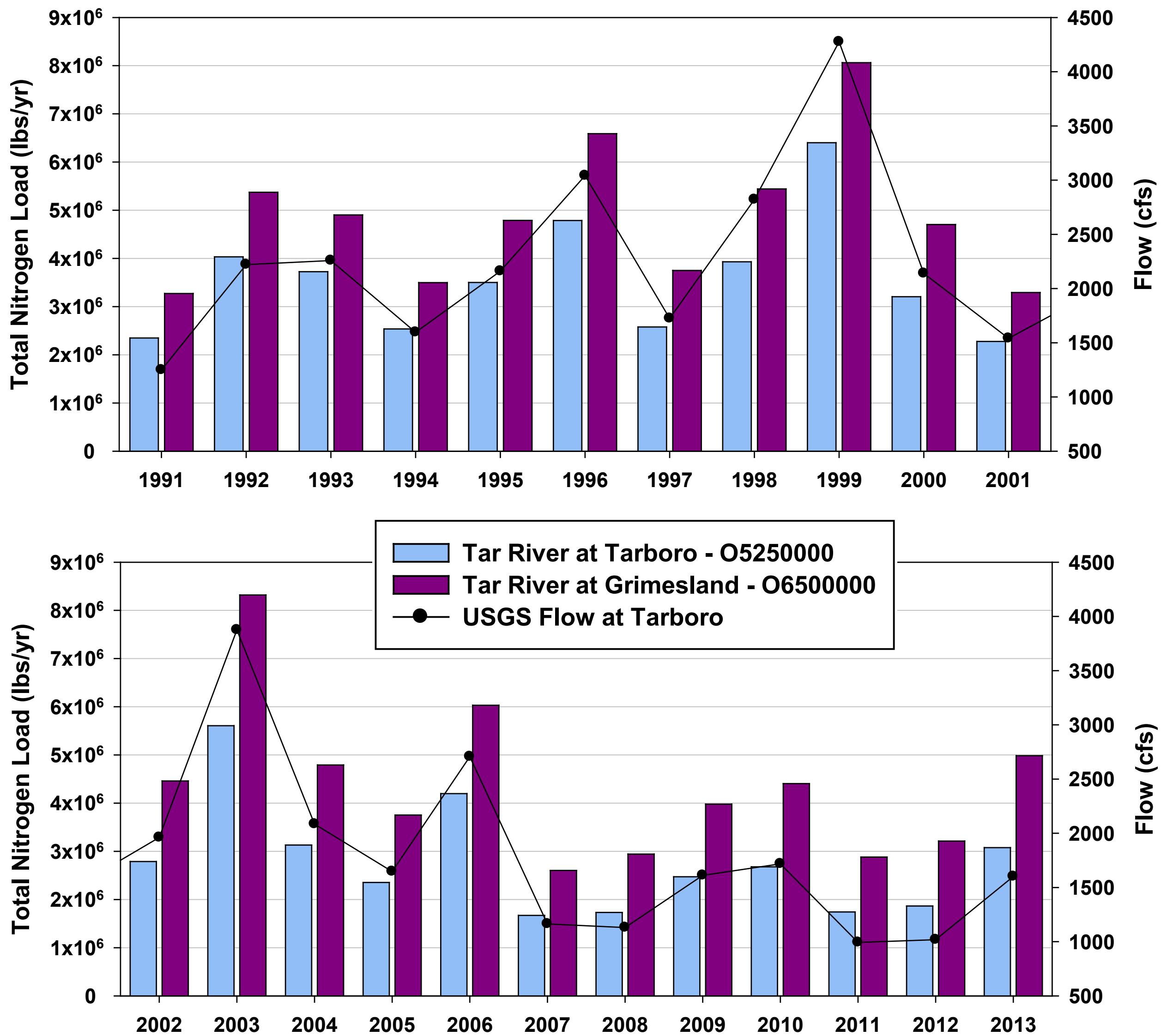


FIGURE 20: LOADEST ANNUAL TN LOAD ESTIMATES FOR MIDDLE TAR RIVER AT TARBORO AND TAR RIVER AT GRIMESLAND WITH USGS TAR RIVER AT TARBORO ANNUAL MEAN FLOW (1991-2013).



## Figure 21: LOADEST Annual TP Load Estimates for Upper Tar River at Tar River, Fishing Creek and Chicod Creek with USGS Tar River at Tarboro Annual Mean Flow (1991-2013).

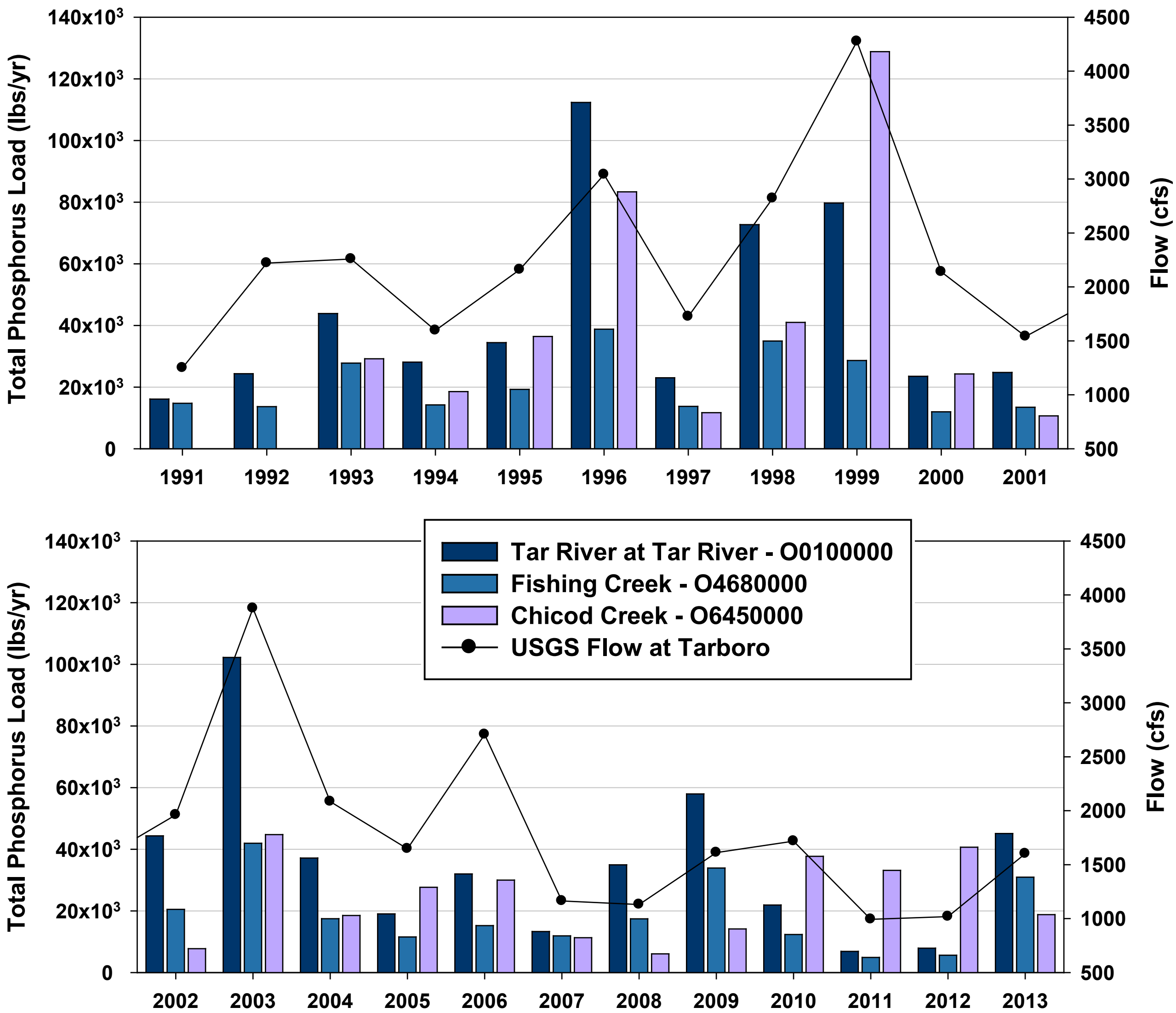
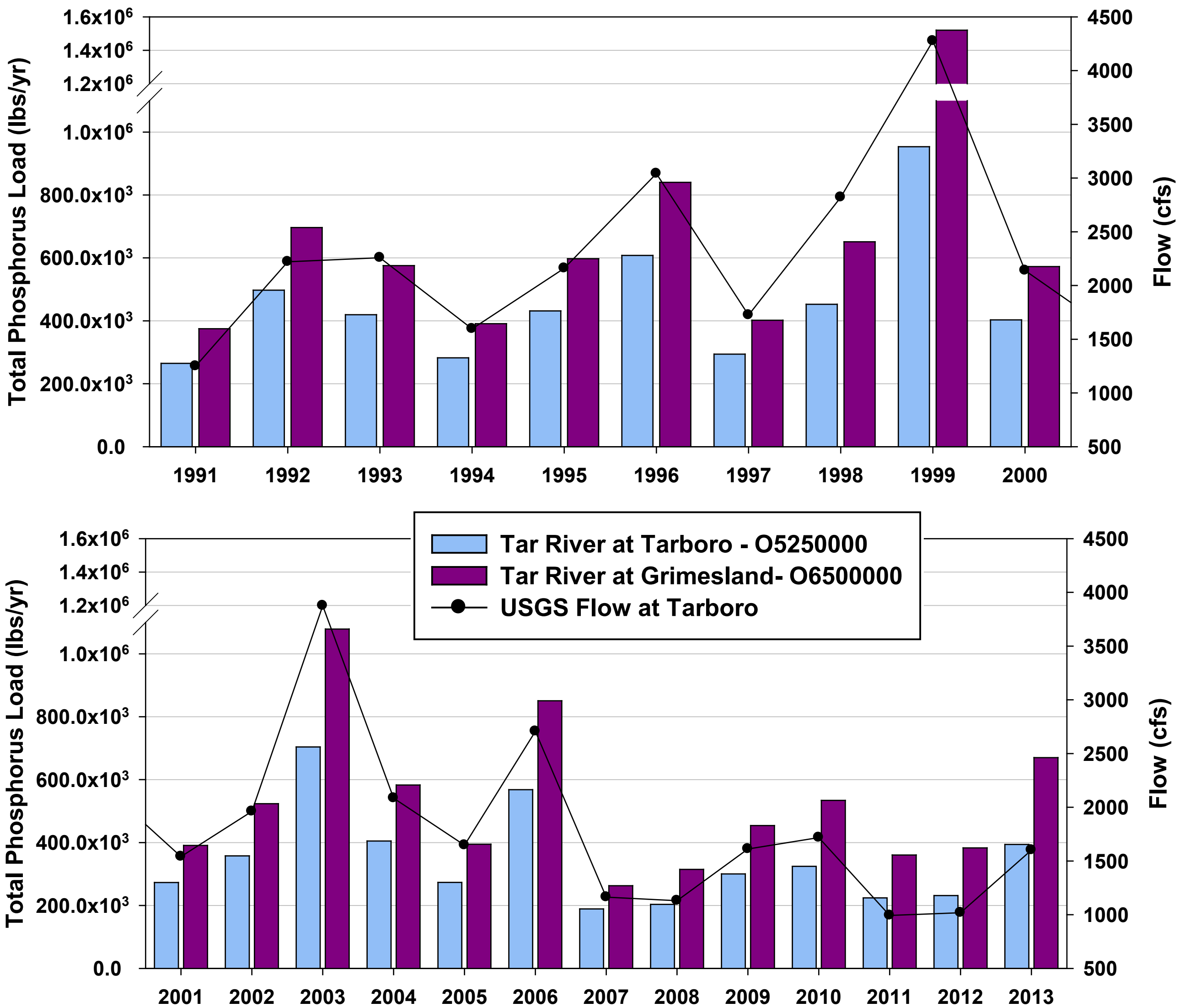
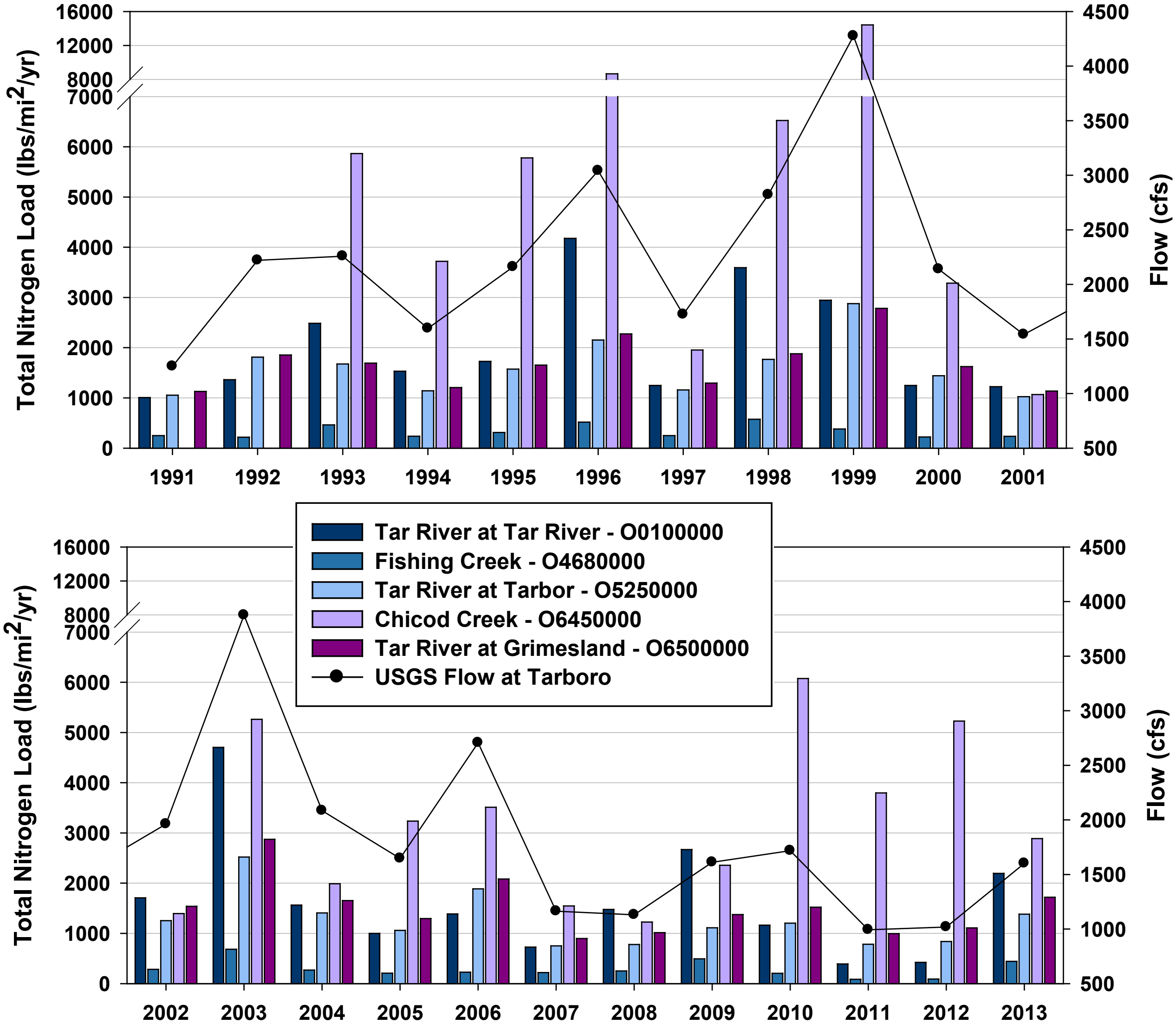


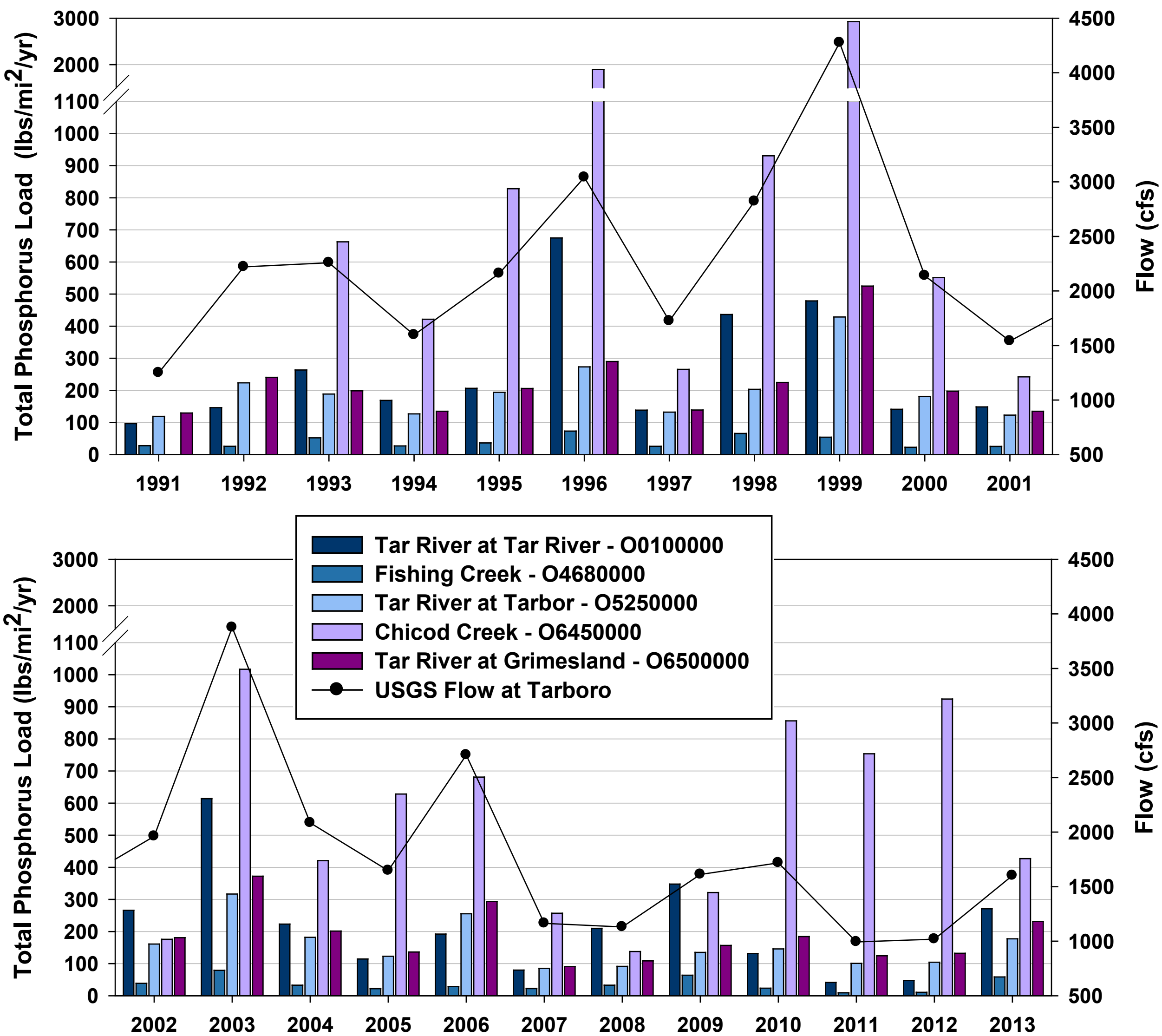
FIGURE 22: LOADEST ANNUAL TP LOAD ESTIMATES FOR MIDDLE TAR RIVER AT TARBORO AND TAR RIVER AT GRIMESLAND WITH USGS TAR RIVER AT TARBORO ANNUAL MEAN FLOW (1991-2013)



## Figure 23: LOADEST TN Unit Area Load Estimates for all Watershed Assessed with USGS Tar River at Tarboro Annual Mean Flow (1991-2013)



## Figure 24: LOADEST TP Unit Area Load Estimates for all Watershed Assessed with USGS Tar River at Tarboro Annual Mean Flow (1991-2013)




# Trend Analysis Discussion & Next Steps

Based on the trend analyses the TN 30% loading reduction goal has not been reached and the TP load has exceeded the 1991 maintenance level. There is also no decrease in TN or TP concentrations trends. Reevaluation of the TMDL is justified when the 30% TN instream load reduction has been achieved and chlorophyll *a* standards are still not being met.

Even though significant efforts have been taken by point sources and the agricultural community to reduce their collective nutrient loading, the implementation of the NSW strategy has thus far not resulted in meeting water quality standards in the Pamlico River Estuary. The decrease in annual loads of TP and TN below the baseline levels as shown in Figure 8 (low flow years) suggest that nutrient loading to the estuary is likely a result of nonpoint source contributions. However, the fact that the instream nutrient concentrations are higher during the low flow periods also indicates that the source of nutrients during these periods is possibly coming from groundwater. Groundwater makes up the majority of the base flow in streams during low flow periods. Groundwater contribution was also likely reduced during the drought of the late 2000's as the drought extended over several years and impacted groundwater levels as well. This is an area of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research that is needed to help understand the effects and nutrient contributions of groundwater in the Tar-Pamlico River system.

The NSW strategy accounts for aspects of agriculture and stormwater nonpoint source contributions however, it is recognized that some nonpoint sources may have not been accounted for or are exceeding the original source contributions. Specifically, looking at the different forms of nitrogen, organic nitrogen has increased and thus warrants identifying sources and reducing inputs of organic nitrogen throughout the basin.

By expanding the analysis outside of the TMDL compliance point and focusing on specific watersheds with dominant land use types, staff may be able to better gauge the effectiveness and progress of strategy implementation. For this reason DWR's Modeling and Assessment Branch conducted additional trend analyses on tributaries within the basin that represent predominately agriculture and urban watersheds. Additional analysis is needed to tease out the impacts of the different land use practices. The data clearly show a substantial nutrient contribution from the agricultural watershed assessed in this study (Chicod Creek). The unit area loading for Chicod Creek was the highest in the basin with the mean 2.7 times higher than that of the whole watershed (Grimesland). The need to understand if the nutrient loads are getting into the system through runoff or through groundwater contributions is needed. Work with the local Soil and Water Conservation District staff is necessary to help understand the practices that are occurring in this watershed and what additional areas can be address to help focus limited resources to best improve water quality throughout agricultural watersheds. The flow-normalized annual loading assessment for the Lower Tar subbasin 03020103 (a heavily agricultural watershed) accounts for approximately 39% of the annual mean load but only accounts for 23% of the watershed area draining to Grimesland. Taking what is learned from the Chicod Creek assessment and applying them to other agricultural watersheds could help improve the water quality in those areas as well.

Additional analysis is needed to better understand the process occurring for the other watershed as well. There is a need to understand the sources of TKN and TP loading in the upper Tar River at Tar River in order to understand this headwater area and why the load is relatively high for this headwater watershed. It is also important to understanding what is happening in the Fishing Creek watershed to decipher why the loading is lower in this watershed. While the loading is lower relative to the other watersheds, there has been a significant increase in the TKN and TN instream concentrations over the baseline period, therefore additional reductions are needed in the Fishing Creek watershed as well.

While we believe that further analyses of existing data and additional years of data collection will provide greater certainty as to the effect of the strategy on the estuary, we also recognize other basin factors (e.g., groundwater, atmospheric deposition, nutrient recycling) may contribute to the results seen in these analyses and conditions in the estuary.

Additional trends analysis at other flow gages throughout the basin could help decipher changing waters quality patterns as the NSW strategy is implemented. Ambient nutrient monitoring is needed at flow gages throughout the state to help in these types of analysis as we move forward.

# Five Year Period Flow Interval Tables

**Average NOx-N, TKN, TN, and TP concentrations (mg/L) by five-year period and flow interval.**

**Tar River at Tar River (O0100000)**

| Constituent | Period | Low Flow (mg/l) | Middle Flow (mg/l) | High Flow (mg/l) |
|---|---|---|---|---|
| NOx-N | 1991-1995 | 0.064 | 0.159 | 0.215 |
| NOx-N | 1996-2000 | 0.058 | 0.148 | 0.222 |
| NOx-N | 2001-2005 | 0.050 | 0.120 | 0.157 |
| NOx-N | 2006-2010 | 0.044 | 0.071 | 0.124 |
| NOx-N | 2009-2013 | 0.025 | 0.140 | 0.147 |
| TKN | 1991-1995 | 0.386 | 0.392 | 0.462 |
| TKN | 1996-2000 | 0.368 | 0.289 | 0.474 |
| TKN | 2001-2005 | 0.423 | 0.441 | 0.609 |
| TKN | 2006-2010 | 0.469 | 0.461 | 0.699 |
| TKN | 2009-2013 | 0.412 | 0.555 | 0.663 |
| TN | 1991-1995 | 0.450 | 0.551 | 0.677 |
| TN | 1996-2000 | 0.426 | 0.437 | 0.695 |
| TN | 2001-2005 | 0.473 | 0.561 | 0.766 |
| TN | 2006-2010 | 0.513 | 0.532 | 0.823 |
| TN | 2009-2013 | 0.437 | 0.695 | 0.810 |
| TP | 1991-1995 | 0.050 | 0.046 | 0.079 |
| TP | 1996-2000 | 0.047 | 0.034 | 0.060 |
| TP | 2001-2005 | 0.047 | 0.094 | 0.111 |
| TP | 2006-2010 | 0.057 | 0.057 | 0.098 |
| TP | 2009-2013 | 0.039 | 0.070 | 0.090 |
| | | | | |



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**Average NOx-N, TKN, TN, and TP concentrations (mg/L) by five-year period and flow interval.**

**Fishing Creek (O4680000)**

| Constituent | Period | Low Flow (mg/l) | Middle Flow (mg/l) | High Flow (mg/l) |
|---|---|---|---|---|
| NOx-N | 1991-1995 | 0.148 | 0.182 | 0.231 |
| NOx-N | 1996-2000 | 0.153 | 0.172 | 0.140 |
| NOx-N | 2001-2005 | 0.344 | 0.118 | 0.138 |
| NOx-N | 2006-2010 | 0.163 | 0.112 | 0.253 |
| NOx-N | 2009-2013 | 0.098 | 0.119 | 0.165 |
| TKN | 1991-1995 | 0.269 | 0.324 | 0.362 |
| TKN | 1996-2000 | 0.277 | 0.295 | 0.388 |
| TKN | 2001-2005 | 0.456 | 0.409 | 0.382 |
| TKN | 2006-2010 | 0.405 | 0.382 | 0.413 |
| TKN | 2009-2013 | 0.396 | 0.409 | 0.624 |
| TN | 1991-1995 | 0.417 | 0.506 | 0.592 |
| TN | 1996-2000 | 0.430 | 0.467 | 0.527 |
| TN | 2001-2005 | 0.800 | 0.528 | 0.520 |
| TN | 2006-2010 | 0.568 | 0.494 | 0.620 |
| TN | 2009-2013 | 0.495 | 0.528 | 0.788 |
| TP | 1991-1995 | 0.056 | 0.052 | 0.059 |
| TP | 1996-2000 | 0.037 | 0.043 | 0.057 |
| TP | 2001-2005 | 0.067 | 0.111 | 0.064 |
| TP | 2006-2010 | 0.055 | 0.057 | 0.074 |
| TP | 2009-2013 | 0.053 | 0.059 | 0.085 |

Average NOx-N, TKN, TN, and TP concentrations (mg/L) by five-year period and flow interval.

Tar River at Tarboro (O5250000)

| Constituent | Period | Low Flow (mg/l) | Middle Flow (mg/l) | High Flow (mg/l) |
|---|---|---|---|---|
| NOx-N | 1991-1995 | 0.550 | 0.404 | 0.327 |
| NOx-N | 1996-2000 | 0.507 | 0.443 | 0.266 |
| NOx-N | 2001-2005 | 0.295 | 0.301 | 0.269 |
| NOx-N | 2006-2010 | 0.401 | 0.255 | 0.229 |
| NOx-N | 2009-2013 | 0.437 | 0.276 | 0.263 |
| TKN | 1991-1995 | 0.39 | 0.53 | 0.49 |
| TKN | 1996-2000 | 0.30 | 0.38 | 0.42 |
| TKN | 2001-2005 | 0.43 | 0.45 | 0.52 |
| TKN | 2006-2010 | 0.50 | 0.54 | 0.57 |
| TKN | 2009-2013 | 0.47 | 0.56 | 0.71 |
| TN | 1991-1995 | 0.94 | 0.93 | 0.81 |
| TN | 1996-2000 | 0.81 | 0.82 | 0.69 |
| TN | 2001-2005 | 0.72 | 0.75 | 0.79 |
| TN | 2006-2010 | 0.90 | 0.80 | 0.80 |
| TN | 2009-2013 | 0.910 | 0.841 | 0.969 |
| TP | 1991-1995 | 0.119 | 0.105 | 0.089 |
| TP | 1996-2000 | 0.078 | 0.079 | 0.090 |
| TP | 2001-2005 | 0.090 | 0.081 | 0.129 |
| TP | 2006-2010 | 0.108 | 0.104 | 0.095 |
| TP | 2009-2013 | 0.087 | 0.100 | 0.117 |





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**Average NOx-N, TKN, TN, and TP concentrations (mg/L) by five-year period* and flow interval.**

**Chicod Creek (O6450000)** ***no data available for 1991 & 1992**

| Constituent | Period | Low Flow (mg/l) | Middle Flow (mg/l) | High Flow (mg/l) |
|---|---|---|---|---|
| NOx-N | 1993-1995 | 0.340 | 0.623 | 0.840 |
| NOx-N | 1996-2000 | 0.160 | 0.213 | 0.708 |
| NOx-N | 2001-2005 | 0.104 | 0.194 | 0.404 |
| NOx-N | 2006-2010 | 0.037 | 0.204 | 0.492 |
| NOx-N | 2009-2013 | 0.040 | 0.201 | 0.487 |
| TKN | 1993-1995 | 0.853 | 0.703 | 0.940 |
| TKN | 1996-2000 | 0.751 | 0.609 | 0.593 |
| TKN | 2001-2005 | 0.948 | 0.745 | 0.697 |
| TKN | 2006-2010 | 1.127 | 0.858 | 0.808 |
| TKN | 2009-2013 | 1.010 | 0.868 | 0.801 |
| TN | 1993-1995 | 1.207 | 1.340 | 1.789 |
| TN | 1996-2000 | 0.911 | 0.821 | 1.293 |
| TN | 2001-2005 | 1.052 | 0.939 | 1.102 |
| TN | 2006-2010 | 1.163 | 1.061 | 1.299 |
| TN | 2009-2013 | 1.050 | 1.069 | 1.288 |
| TP | 1993-1995 | 0.575 | 0.264 | 0.283 |
| TP | 1996-2000 | 0.280 | 0.235 | 0.216 |
| TP | 2001-2005 | 0.319 | 0.266 | 0.244 |
| TP | 2006-2010 | 0.306 | 0.214 | 0.182 |
| TP | 2009-2013 | 0.324 | 0.231 | 0.179 |

**Average NOx-N, TKN, TN, and TP concentrations (mg/L) by five-year period and flow interval.**

**Tar River near Grimesland (O6500000)**

| Constituent | Period | Low Flow (mg/l) | Middle Flow (mg/l) | High Flow (mg/l) |
|---|---|---|---|---|
| NOx-N | 1991-1995 | 0.732 | 0.621 | 0.469 |
| NOx-N | 1996-2000 | 0.590 | 0.562 | 0.351 |
| NOx-N | 2001-2005 | 0.542 | 0.503 | 0.381 |
| NOx-N | 2006-2010 | 0.486 | 0.480 | 0.431 |
| NOx-N | 2009-2013 | 0.573 | 0.466 | 0.396 |
| TKN | 1991-1995 | 0.466 | 0.485 | 0.477 |
| TKN | 1996-2000 | 0.394 | 0.379 | 0.470 |
| TKN | 2001-2005 | 0.502 | 0.506 | 0.520 |
| TKN | 2006-2010 | 0.657 | 0.549 | 0.618 |
| TKN | 2009-2013 | 0.646 | 0.611 | 0.817 |
| TN | 1991-1995 | 1.198 | 1.105 | 0.946 |
| TN | 1996-2000 | 0.984 | 0.941 | 0.820 |
| TN | 2001-2005 | 1.044 | 1.008 | 0.901 |
| TN | 2006-2010 | 1.143 | 1.030 | 1.050 |
| TN | 2009-2013 | 1.219 | 1.078 | 1.213 |
| TP | 1991-1995 | 0.161 | 0.112 | 0.123 |
| TP | 1996-2000 | 0.116 | 0.100 | 0.107 |
| TP | 2001-2005 | 0.111 | 0.117 | 0.111 |
| TP | 2006-2010 | 0.147 | 0.107 | 0.104 |
| TP | 2009-2013 | 0.139 | 0.114 | 0.176 |





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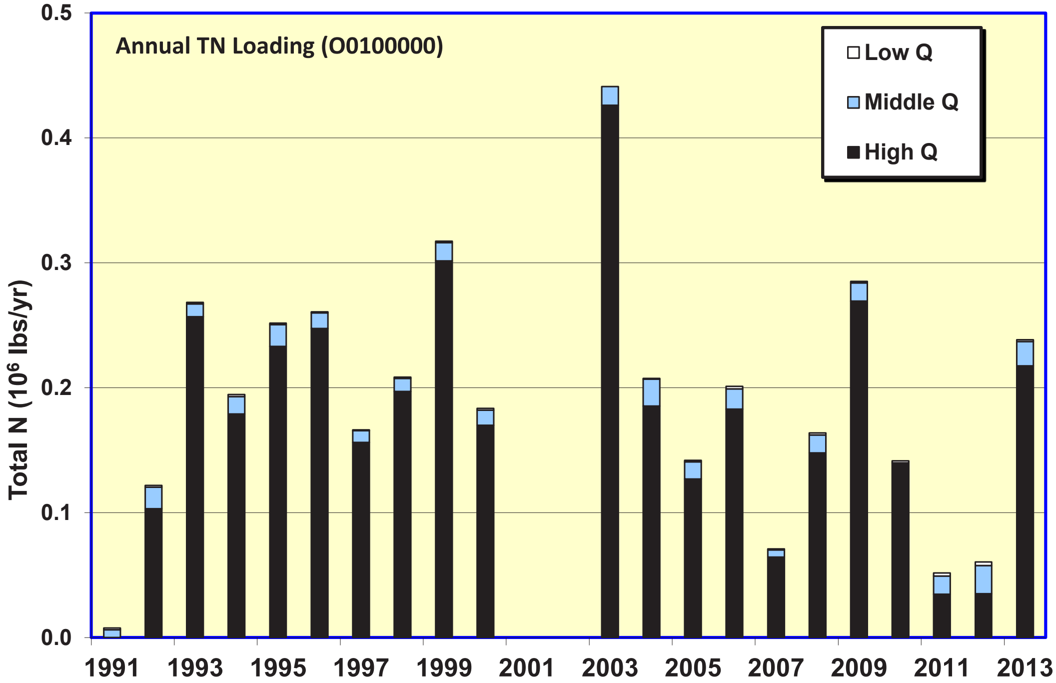
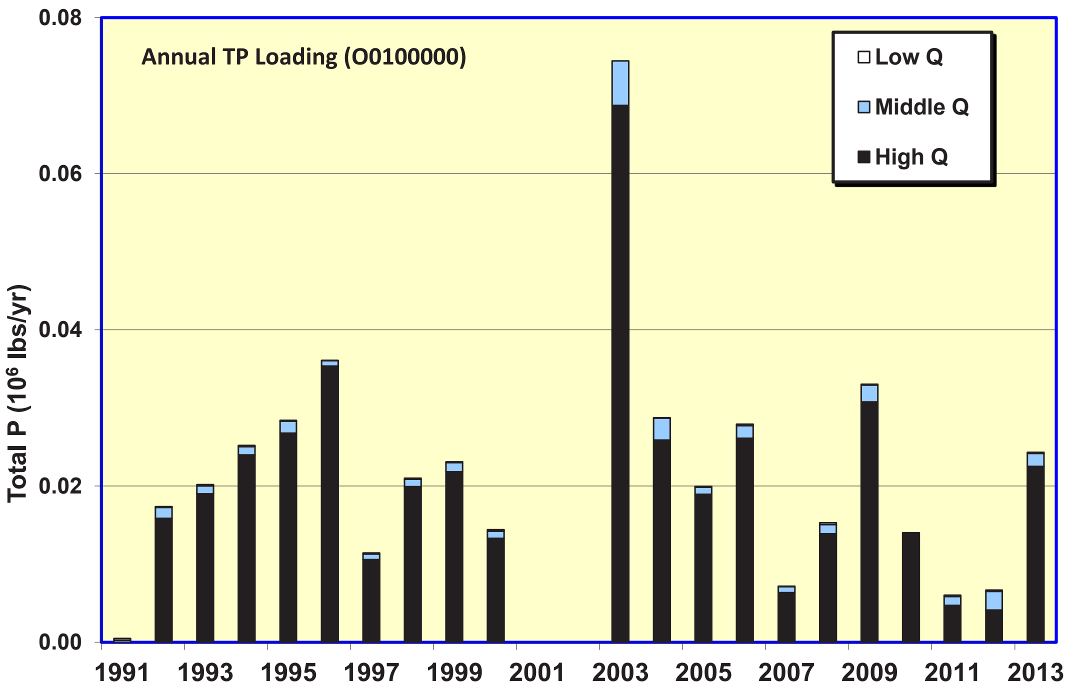
# Flow-Normalized TN and TP Annual Time Series Loading

## Total Nitrogen and Total Phosphorus Annual Loading

Q is a symbol for volumetric flow rate (cubic feet per second).

### Tar River at Tar River (O0100000)

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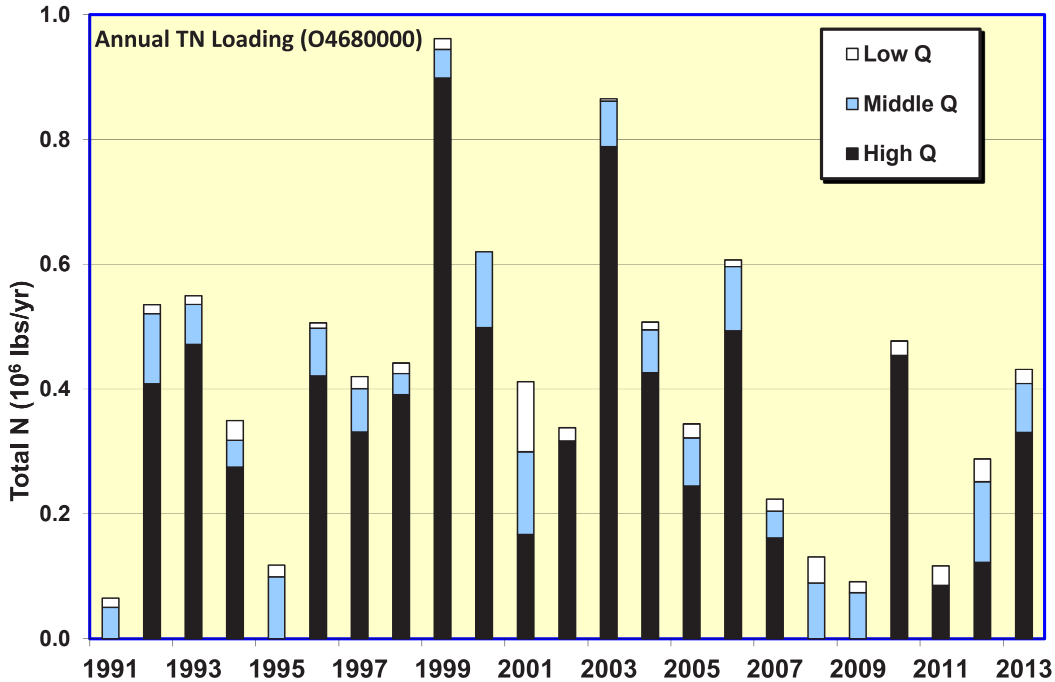
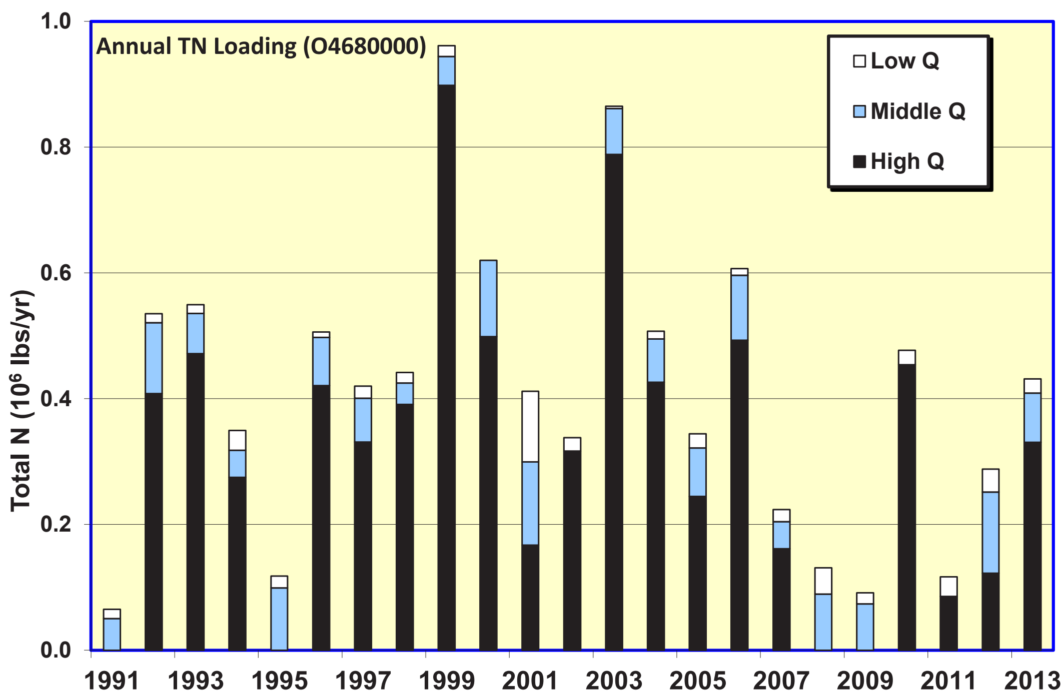
## Total Nitrogen and Total Phosphorus Annual Loading

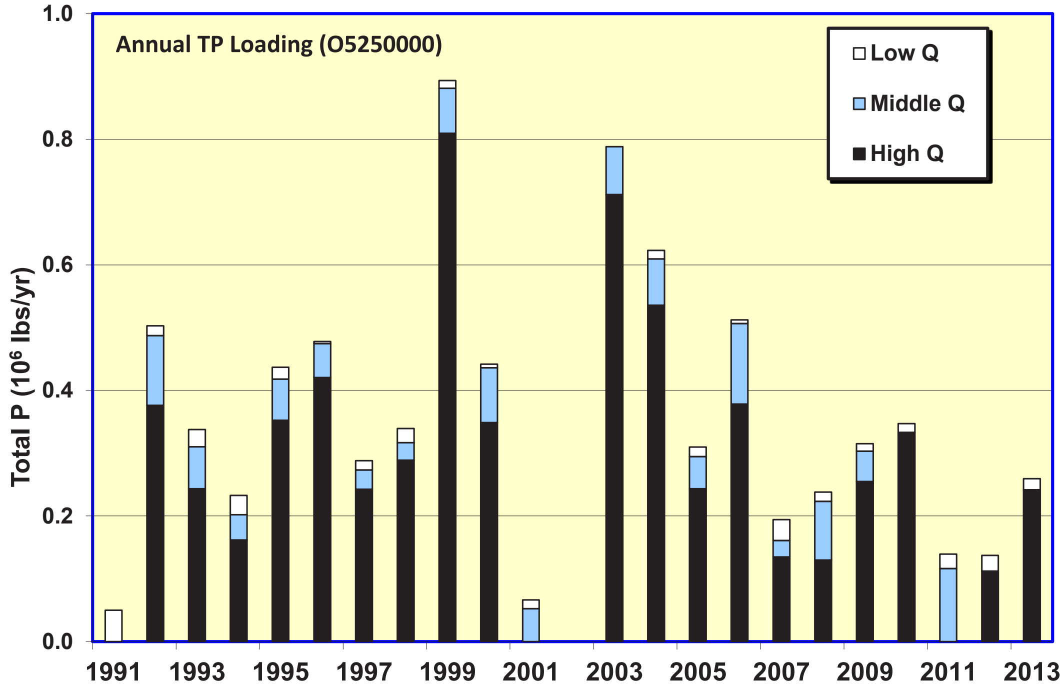
## Fishing Creek (O4680000)

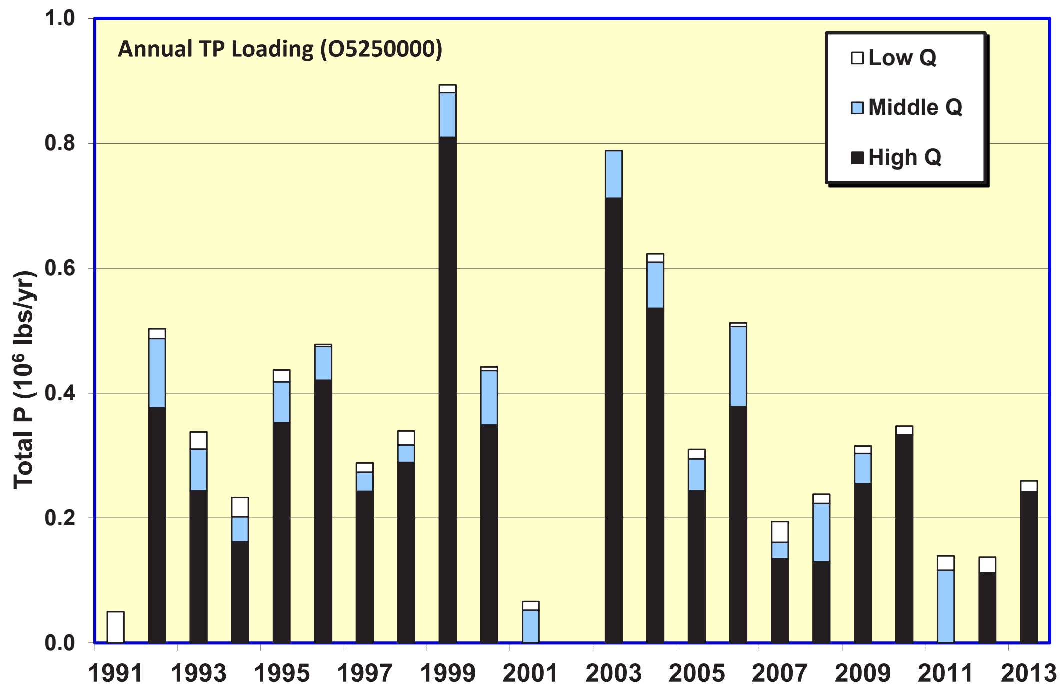


Total Nitrogen and Total Phosphorus Annual Loading

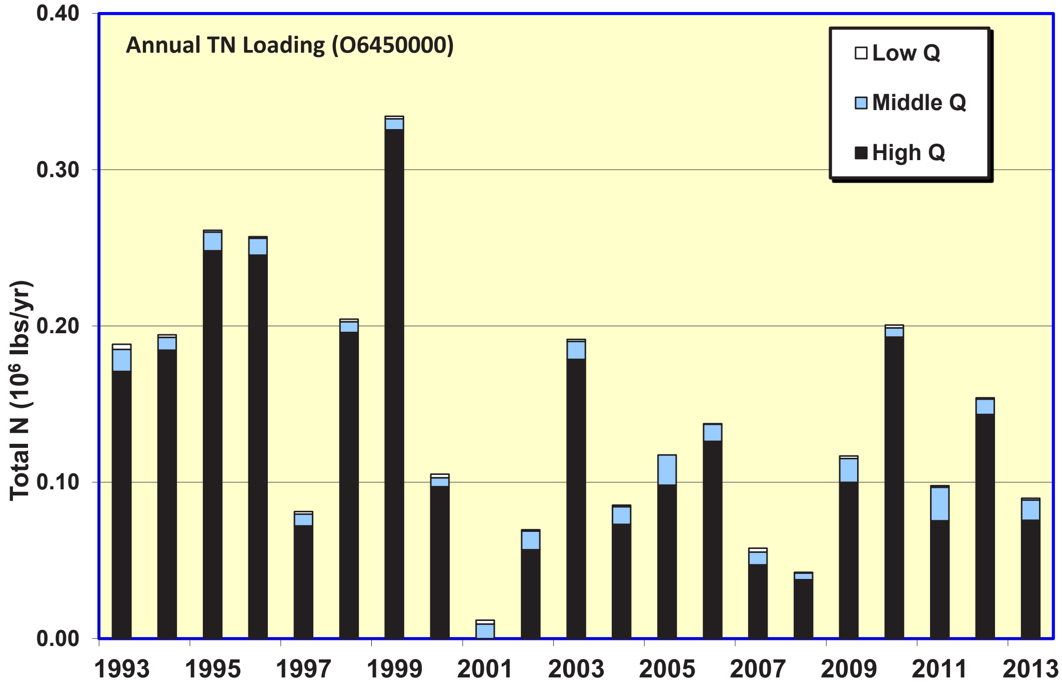
Tar River at Tarboro (05250000)

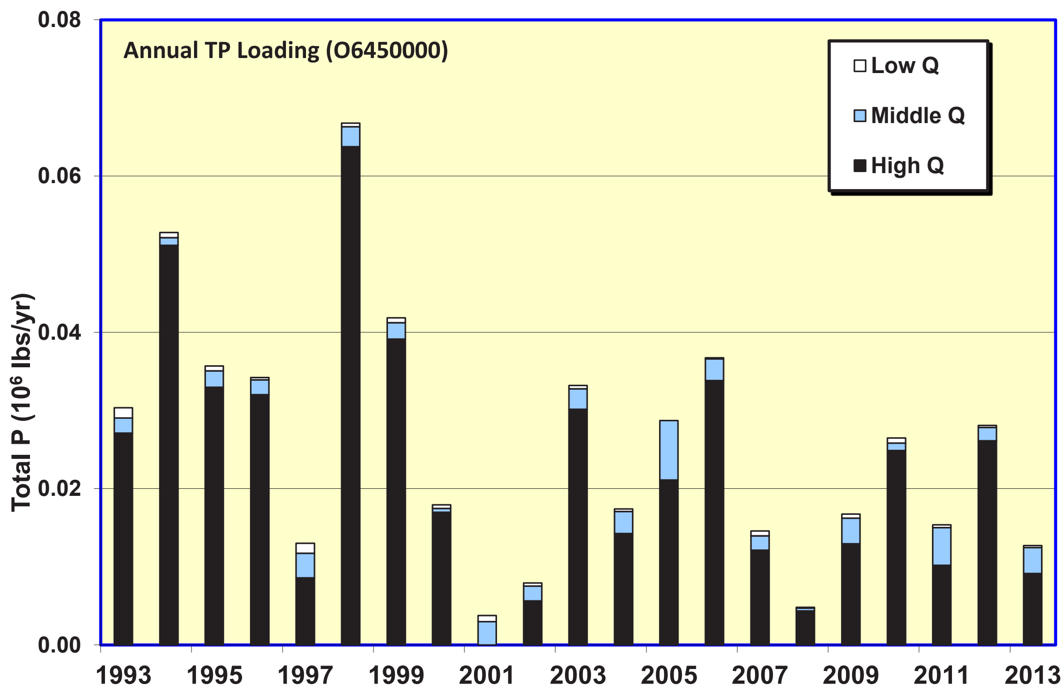


## Total Nitrogen and Total Phosphorus Annual Loading

## Chicod Creek (O6450000)





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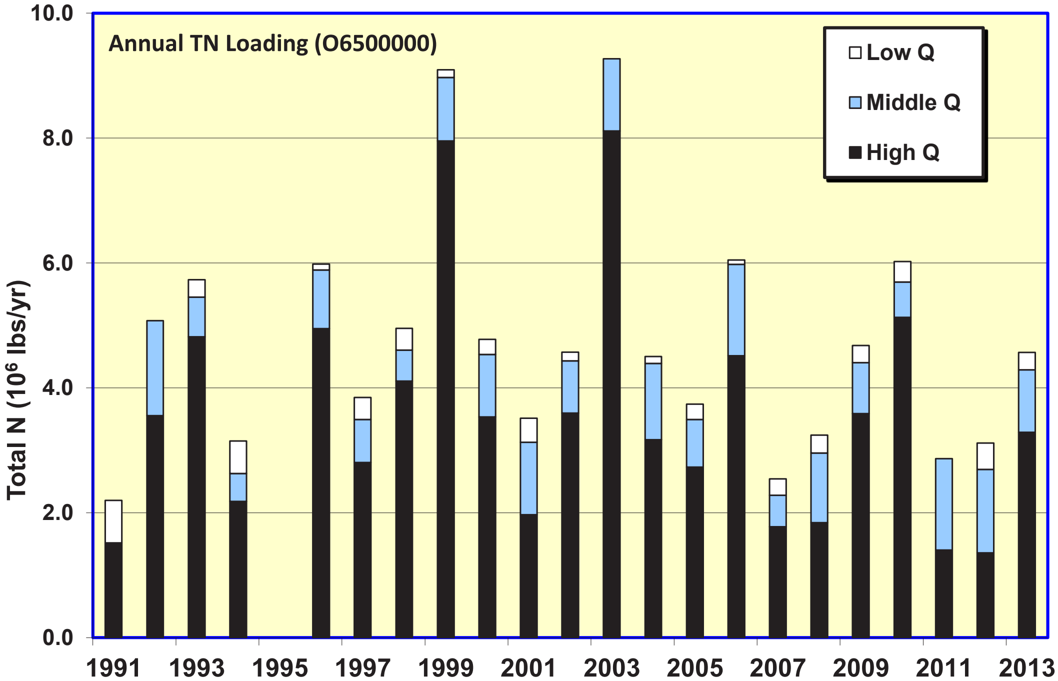
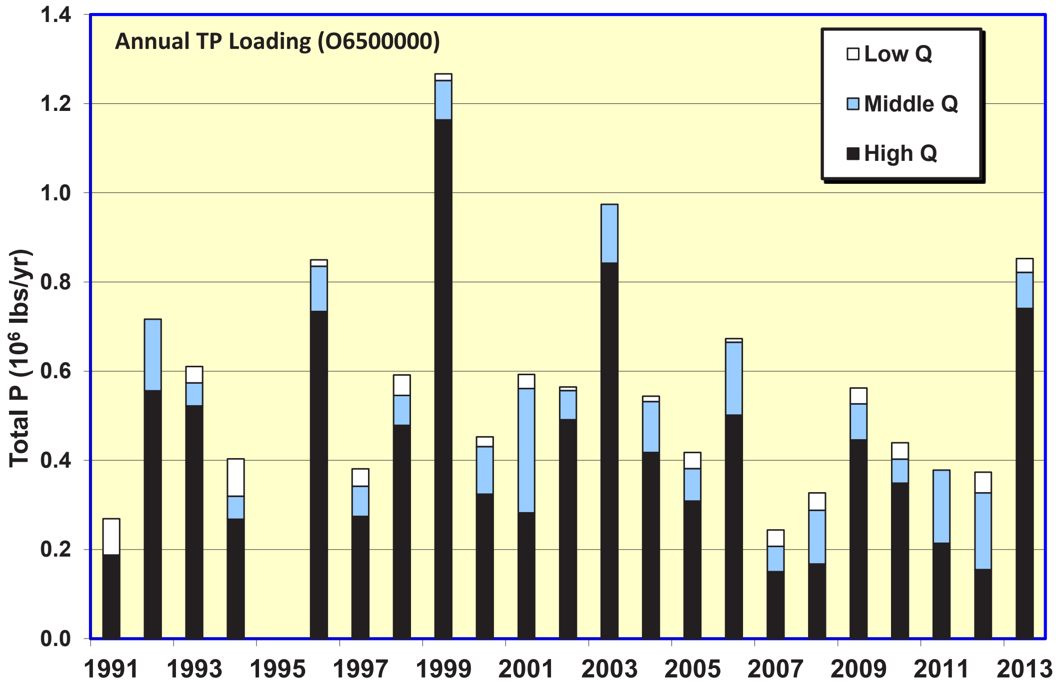
## Total Nitrogen and Total Phosphorus Annual Loading

## Tar River at Grimesland (O5250000)



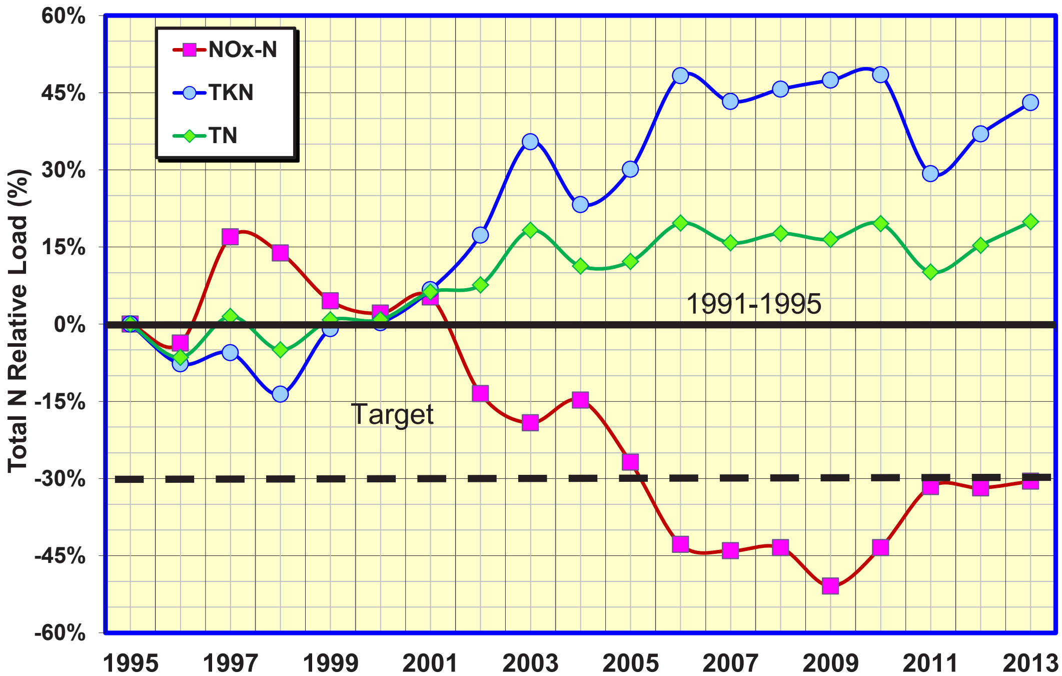



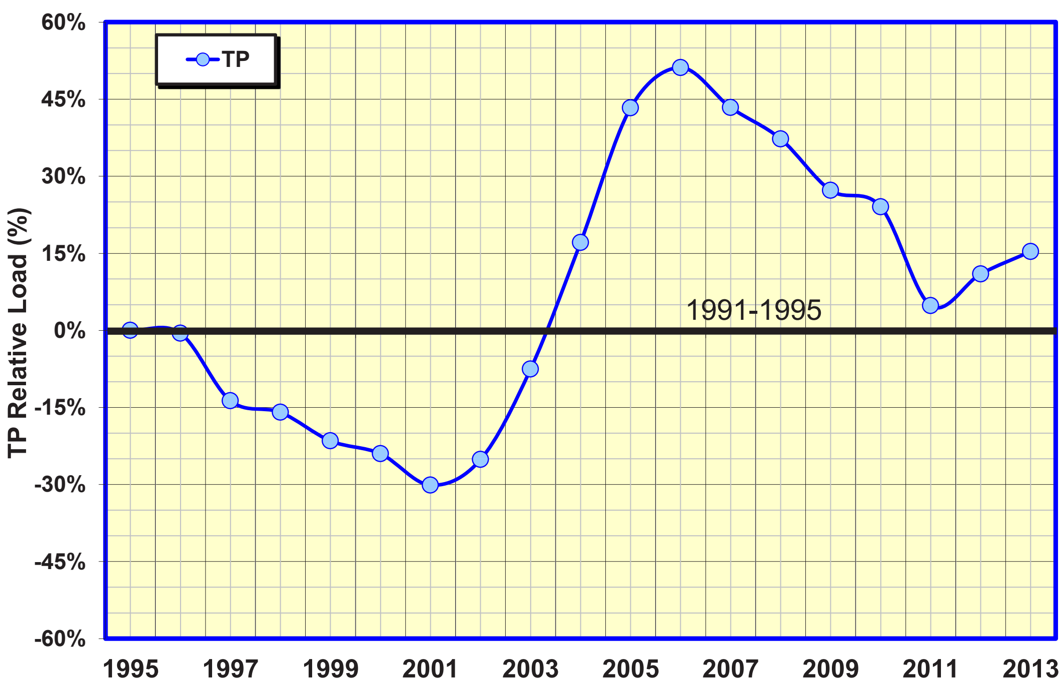
# Appendix III

## Flow-Normalized Relative TN and TP Load Reduction - Comparison to 1991-1995

**Total Nitrogen and Total Phosphorus Relative Load Reductions Over Time Compared to 1991-2013.**

**Tar River at Tar River (O0100000)**



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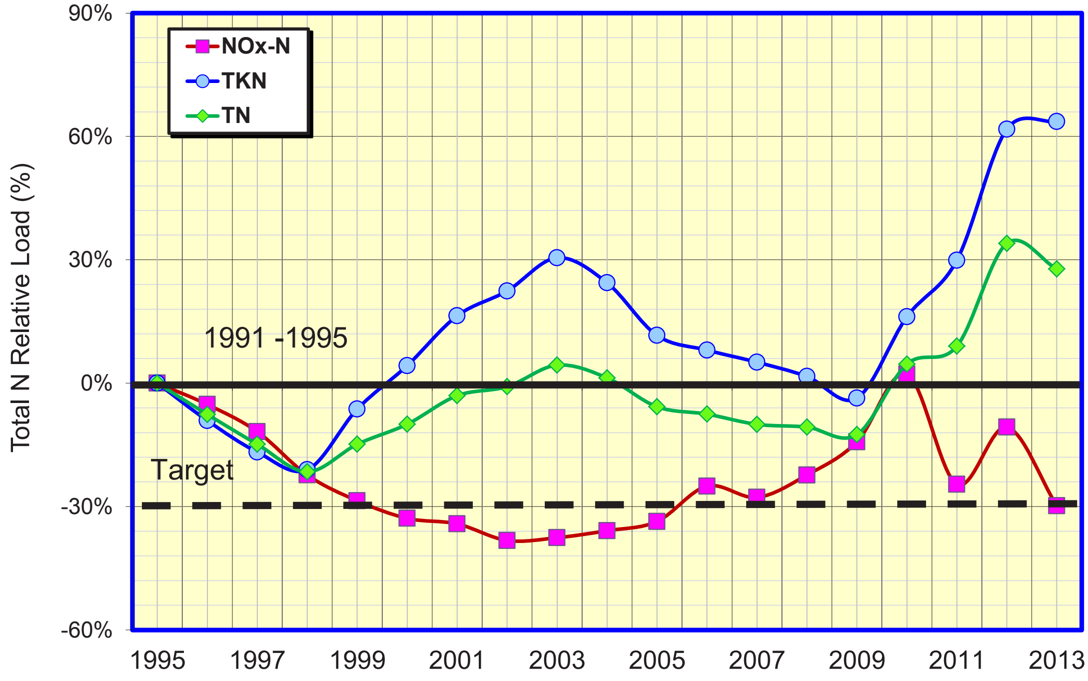
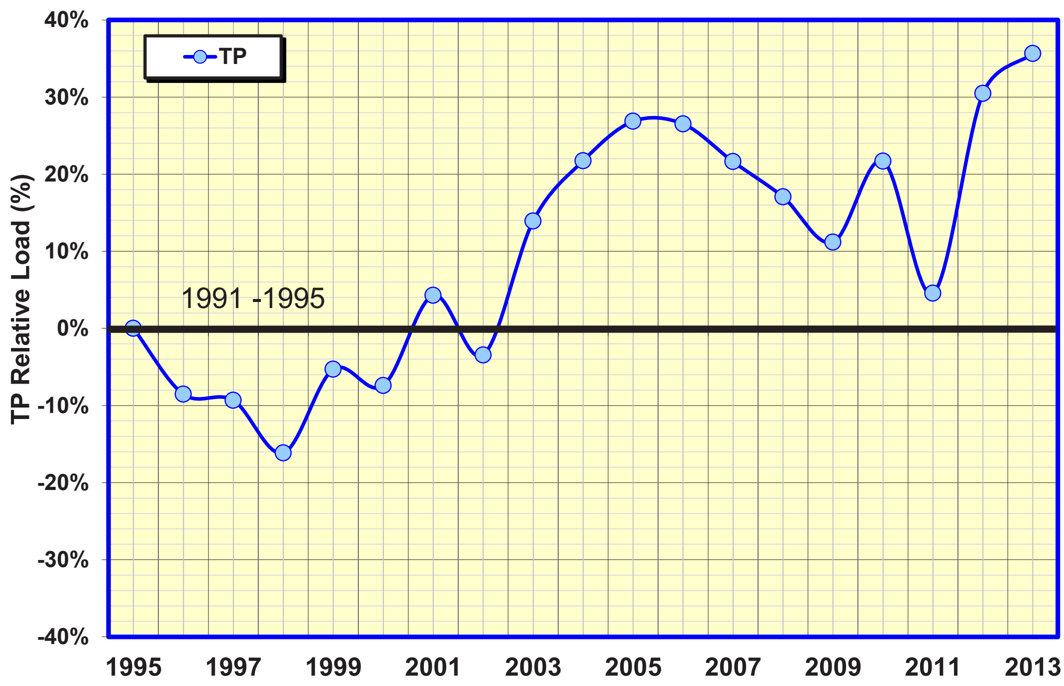
**Total Nitrogen and Total Phosphorus Relative Load Reductions Over Time Compared to 1991-2013.**

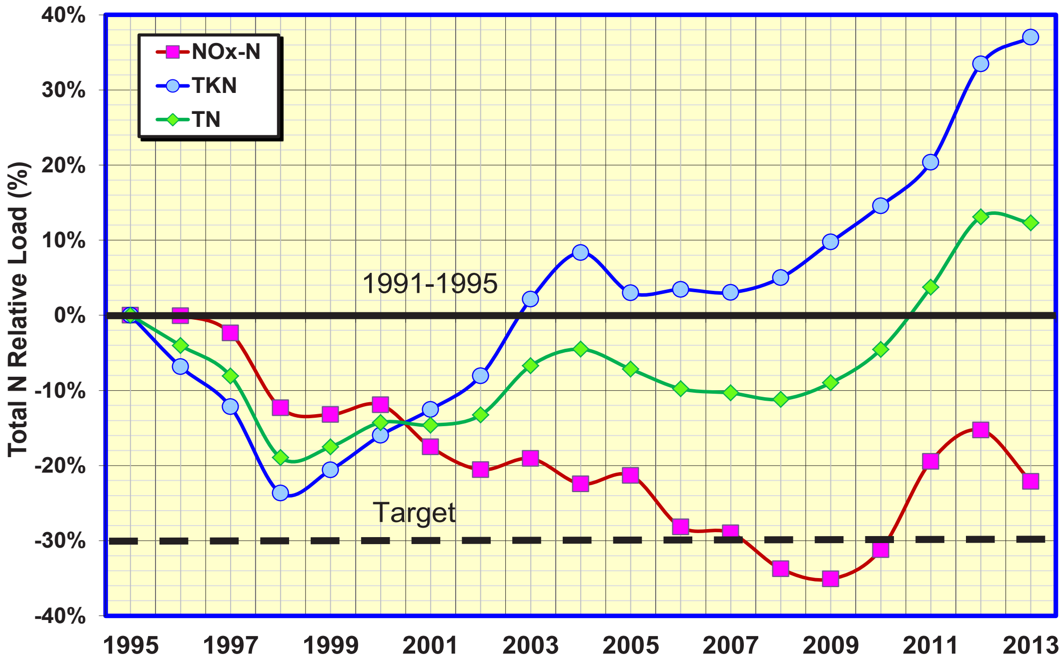
**Fishing Creek (O4680000)**

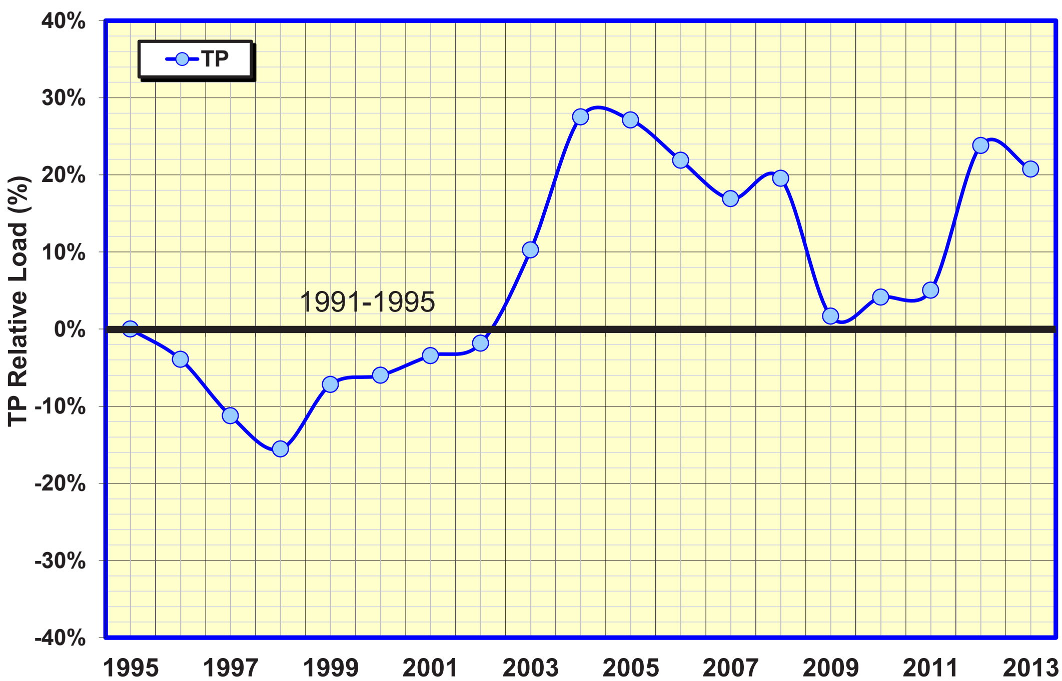


**Total Nitrogen and Total Phosphorus Relative Load Reductions Over Time Compared to 1991-2013.**

**Tar River at Tarboro (O5250000)**





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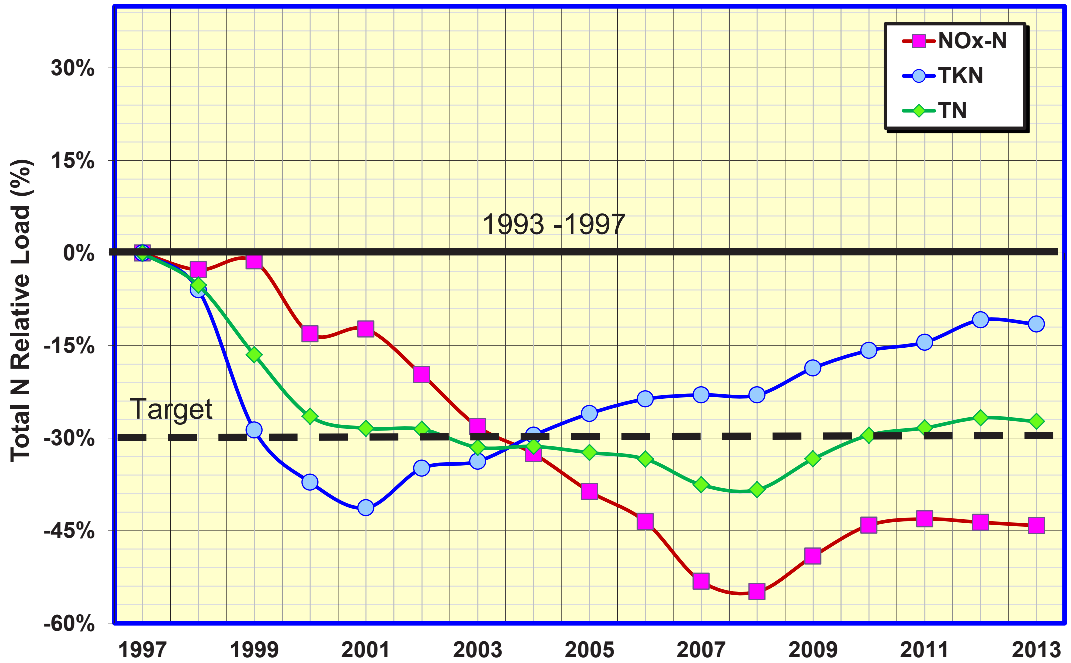
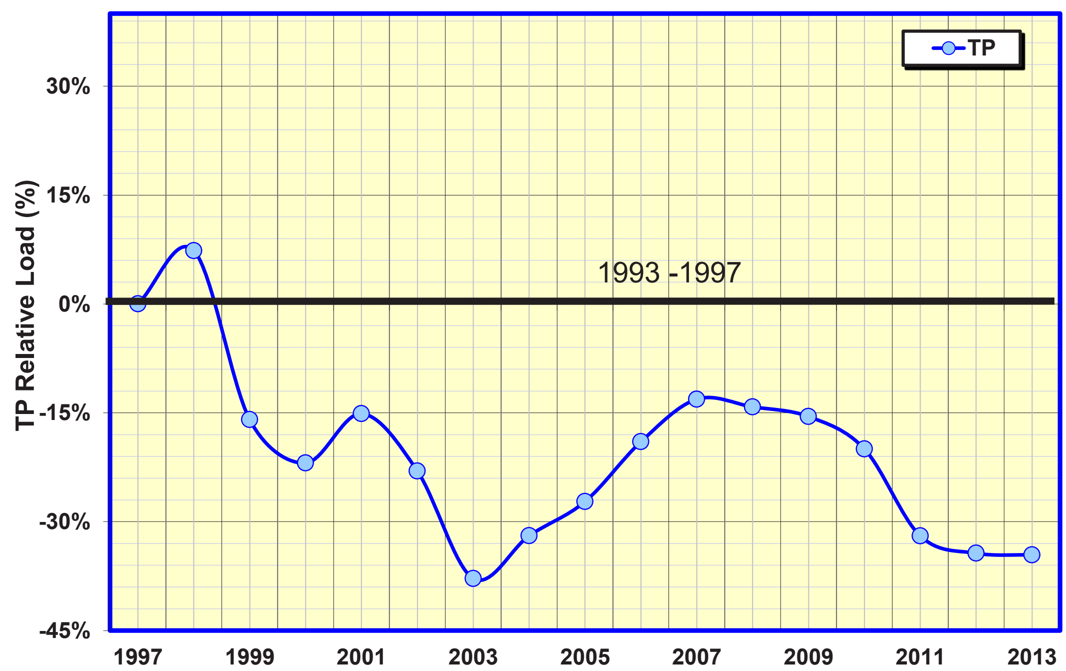
**Total Nitrogen and Total Phosphorus Relative Load Reductions Over Time Compared to 1991-2013.**

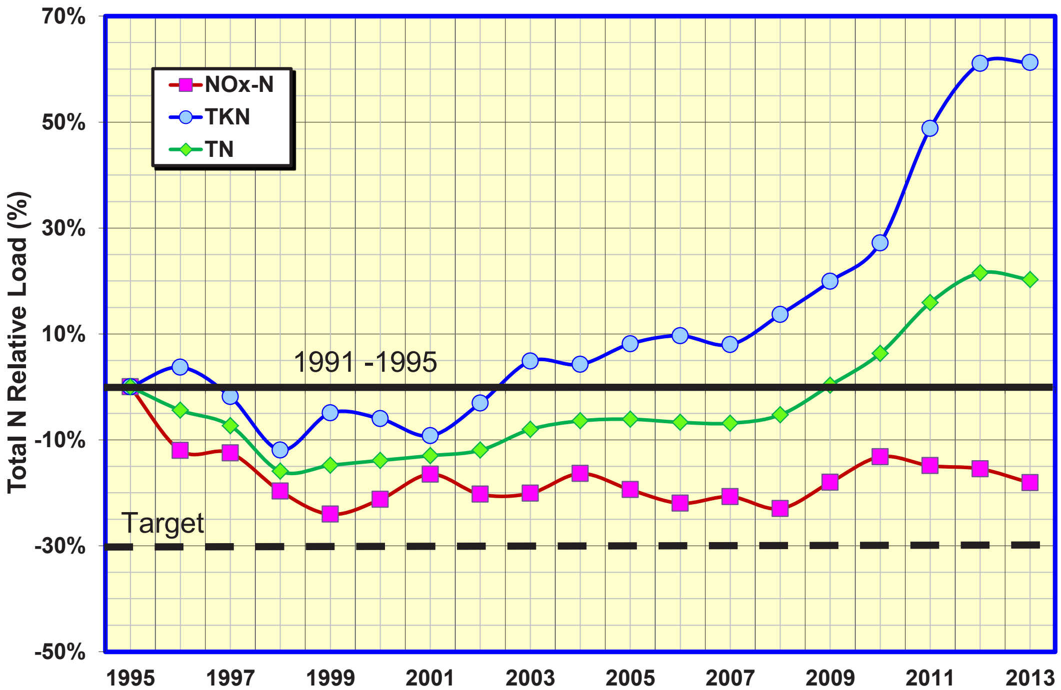
**Chicod Creek (O6450000)**

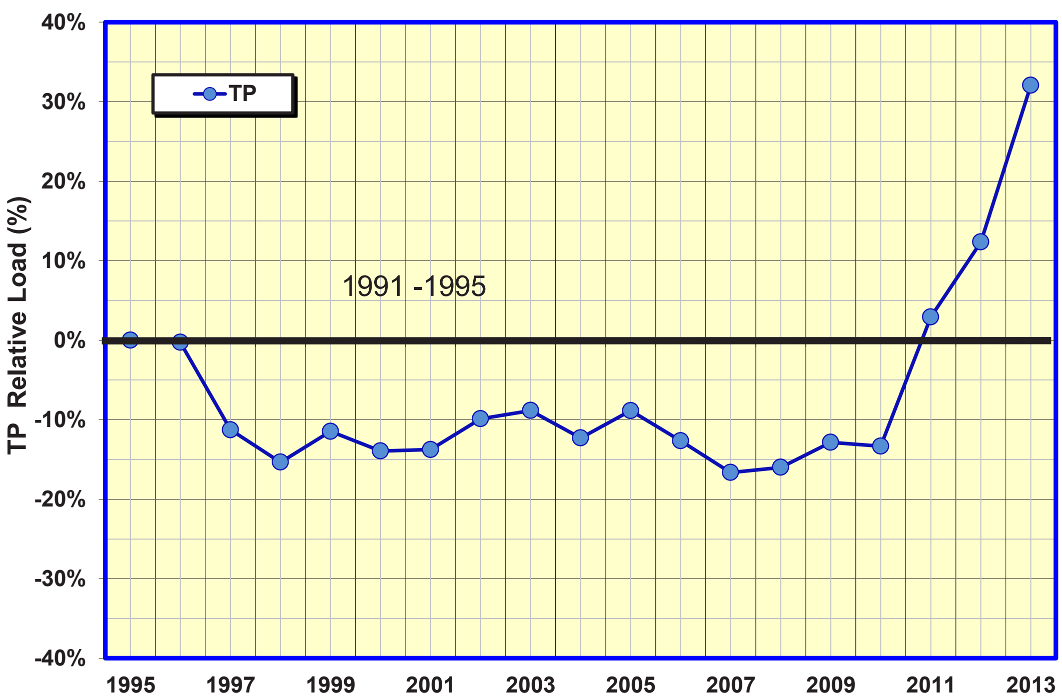


**Total Nitrogen and Total Phosphorus Relative Load Reductions Over Time Compared to 1991-2013.**

**Tar River at Grimesland (O6500000)**





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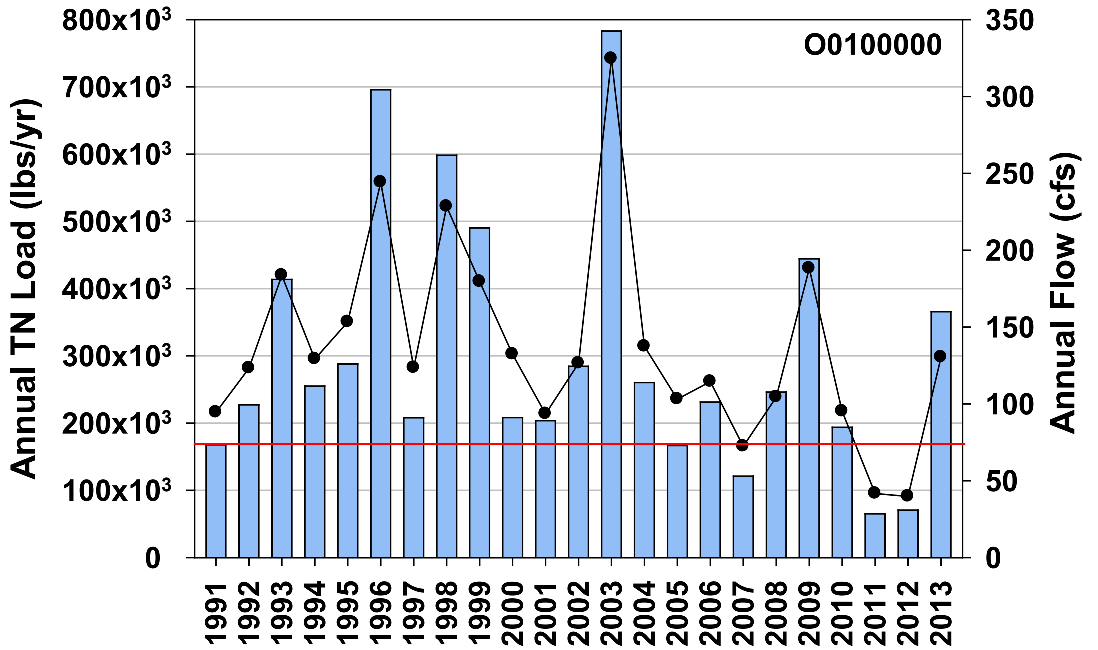
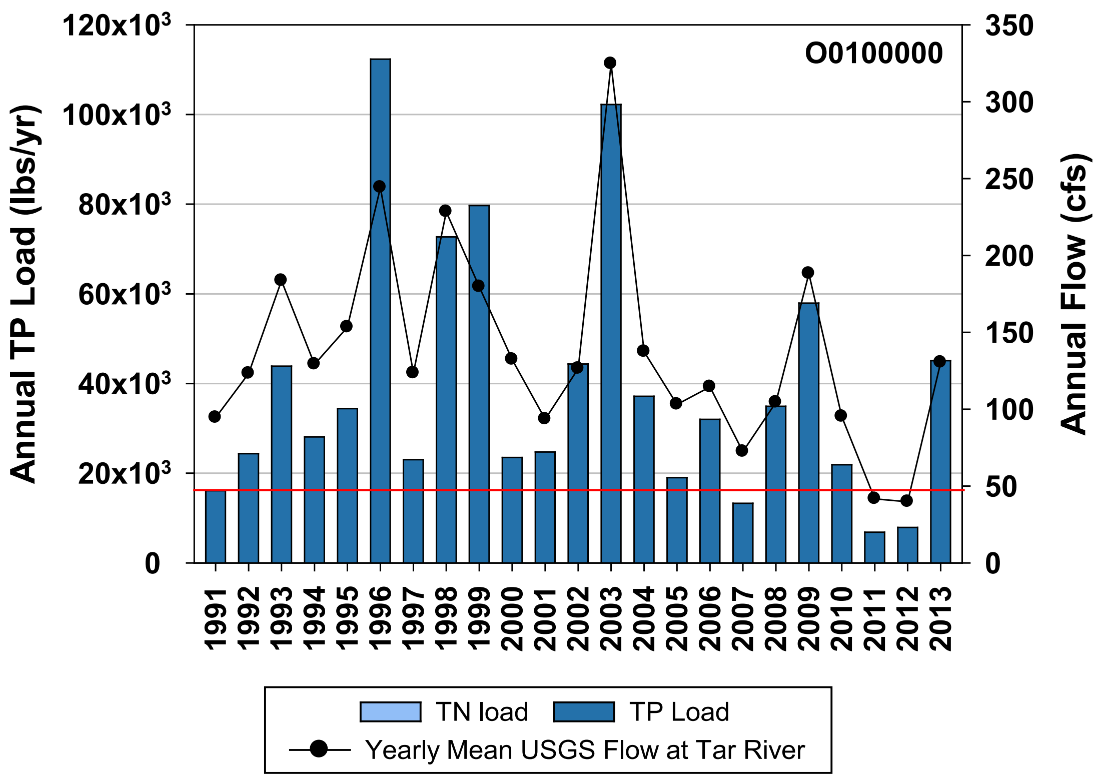
## LOADEST TN and TP Estimated Annual Loading.

Total Nitrogen and Total Phosphorus LOADEST Annual Load.
Red Line Denotes 1991 Baseline Load.

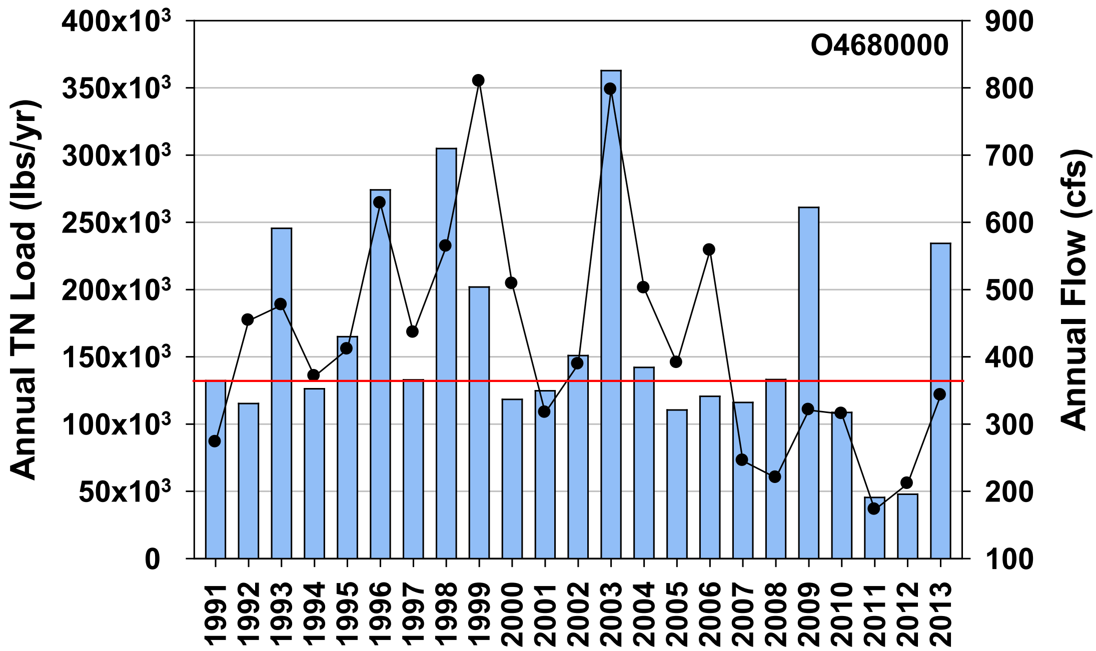
**Tar River at Tar River (O0100000) with flow at Tar River USGS gage 02081500.**

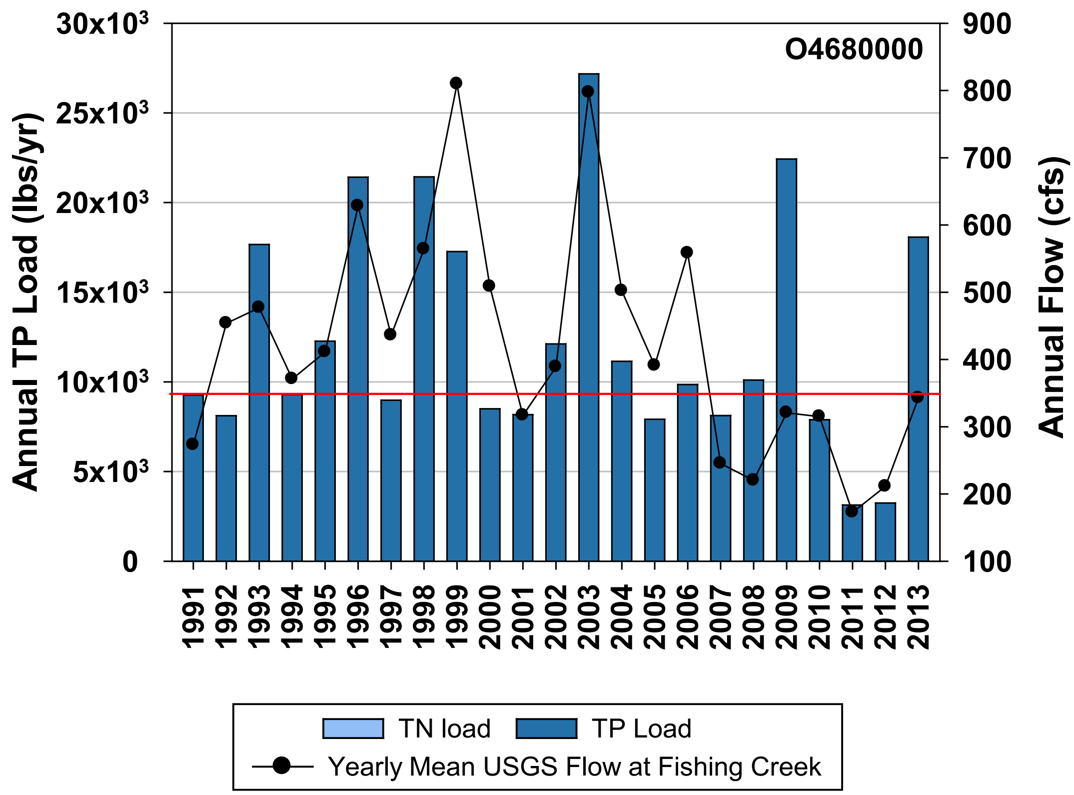


**Total Nitrogen and Total Phosphorus LOADEST Annual Load.**
Red Line Denotes 1991 Baseline Load.

**Fishing Creek (O4680000) with flow at Fishing Creek USGS gage 02083000.**



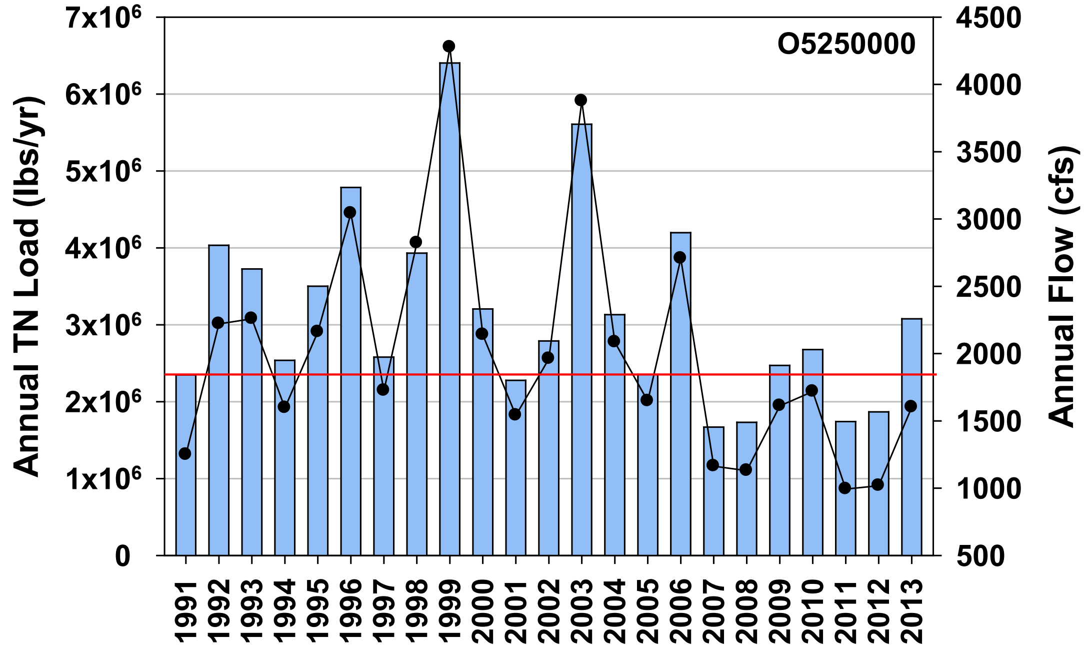



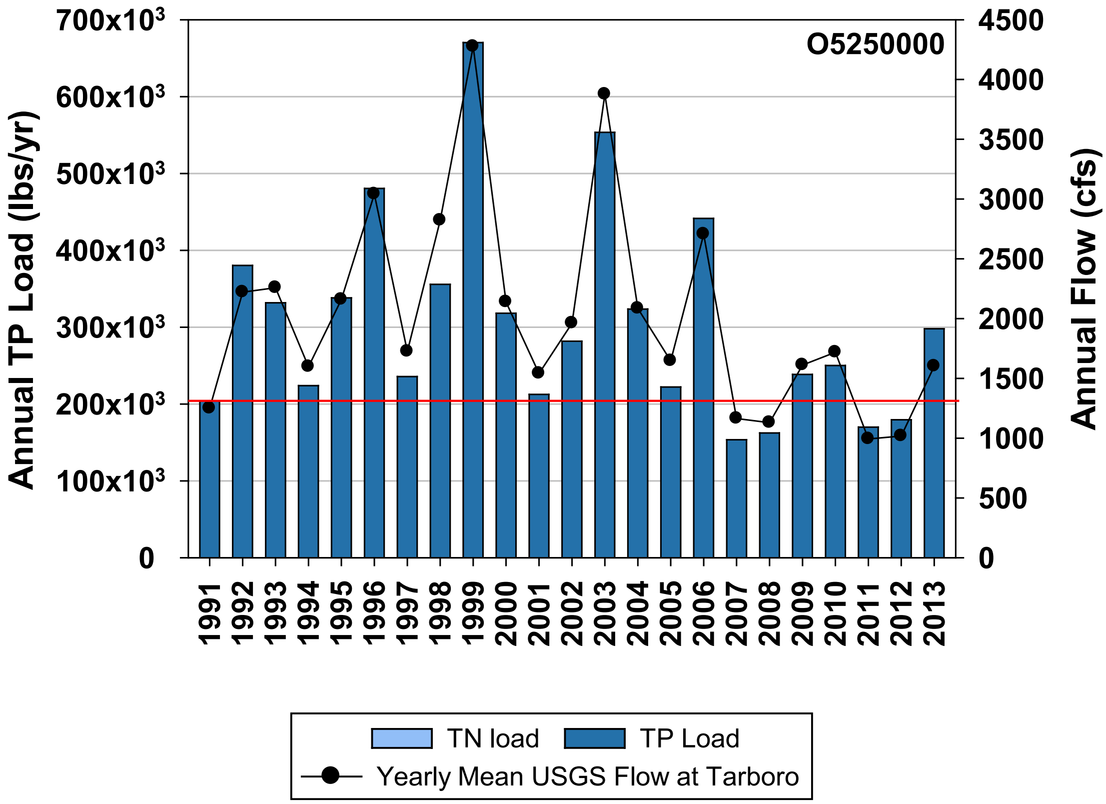



Revised 2/4/15

Total Nitrogen and Total Phosphorus LOADEST Annual Load.
Red Line Denotes 1991 Baseline Load.

Tar River at Tarboro (O5250000) with flow at Tar River at Tarboro USGS gage 02083500.



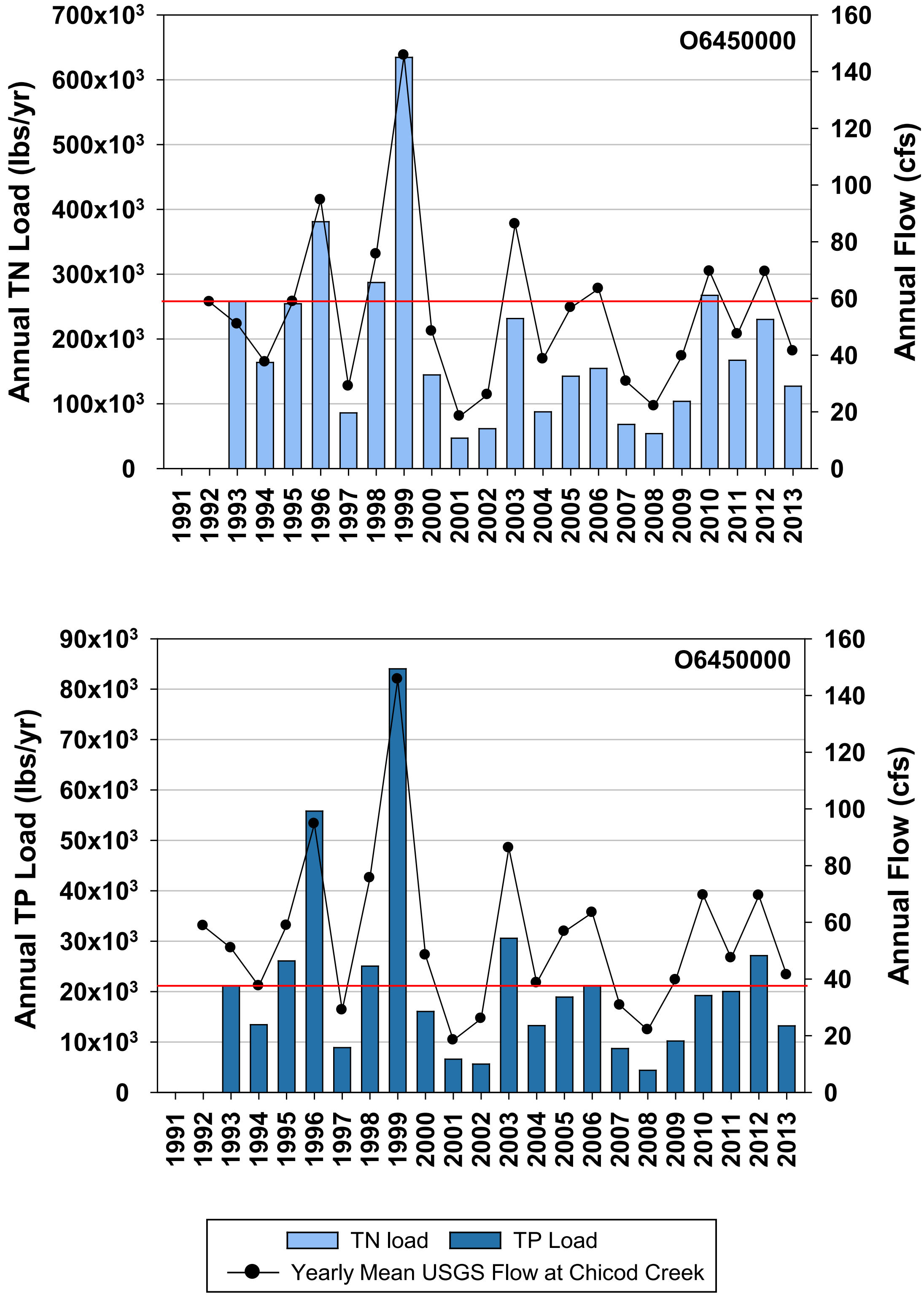






Revised 2/4/15

**Total Nitrogen and Total Phosphorus LOADEST Annual Load.**
Red Line Denotes 1991 Baseline Load.

**Chicod Creek (O6450000) with flow at Chicod Creek USGS gage 02084160.**






Revised 2/4/15

Total Nitrogen and Total Phosphorus LOADEST Annual Load.
Red Line Denotes 1991 Baseline Load.

Tar River at Grimesland (O6500000) with flow at Grimesland USGS gage 02084000.