# Appendix J
# Model Configuration, Calibration and Validation

## Basin: Tar and Neuse Rivers (TarNeu)

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# Watershed Background

The Tar and Neuse River basins, within the Albemarle-Pamlico NAWQA study area, were selected as one of the 15 non-pilot application watersheds for the 20 Watershed study. Watershed modeling for the non-pilot areas is accomplished using the SWAT model only, and model calibration and validation results are presented in abbreviated form.

The Tar and Neuse River drainages are located entirely within North Carolina (Figure 1) and drain to two important estuaries (Pamlico and Neuse Estuaries) that have been impacted by excess nutrient loads. The watershed covers an area of 9,972 $mi^2$ in 8 HUC8s, all within HUC 0302. The watershed is divided between the Piedmont, and Coastal Plain physiographic provinces. Land-surface elevations range from about 885 feet above sea level in the Piedmont northwest of Durham to sea level in the eastern Coastal Plain (McMahon and Lloyd, 1995). Streams descend through the Piedmont province to the Coastal Plain Province (Spruill et al. 1998).

The watershed as a whole is dominated by forested (34 percent) and agricultural crop and pasture land (29 percent). Agricultural land in the study area is used primarily for growing crops (soybeans, corn, wheat, peanuts, tobacco, and cotton) and raising livestock (chickens, turkeys, hogs, and cattle.)

Less than 10 percent of the watershed consists of developed land, primarily in and around the cities of Raleigh, Durham, and Greenville, NC are prominent in the eastern third of the watershed and occupy 13 percent of the study area.

Average annual temperatures in the watershed range from about 58 °F in the western headwaters to slightly more than 62° F along Pamlico Sound in the eastern part of the Coastal Plain. Average annual precipitation ranges from about 44 to about 55 inches per year, but can be much greater in years impacted by tropical storms. The highest average monthly streamflow typically occurs during the months that include the non-growing season when temperatures are low and evapotranspiration rates are low. The lowest average monthly streamflow occurs during the growing season when evapotranspiration rates are high. Groundwater is a significant component of the total water discharged to the Albemarle-Pamlico estuarine system.

The greatest uses of surface water in the Tar and Neuse River drainage basin are for public water supplies and thermoelectric power. Domestic groundwater use and agricultural surface water use are comparable in size, and both are slightly less than groundwater use for public water supplies. Surface water use is highest in areas with large urban populations served by surface water diversions for public water supplies (e.g., Neuse River basin) and in areas with large commercial, industrial, or mining water users (e.g., the Tar-Pamlico River basin). Groundwater use is generally highest in the Coastal Plain.

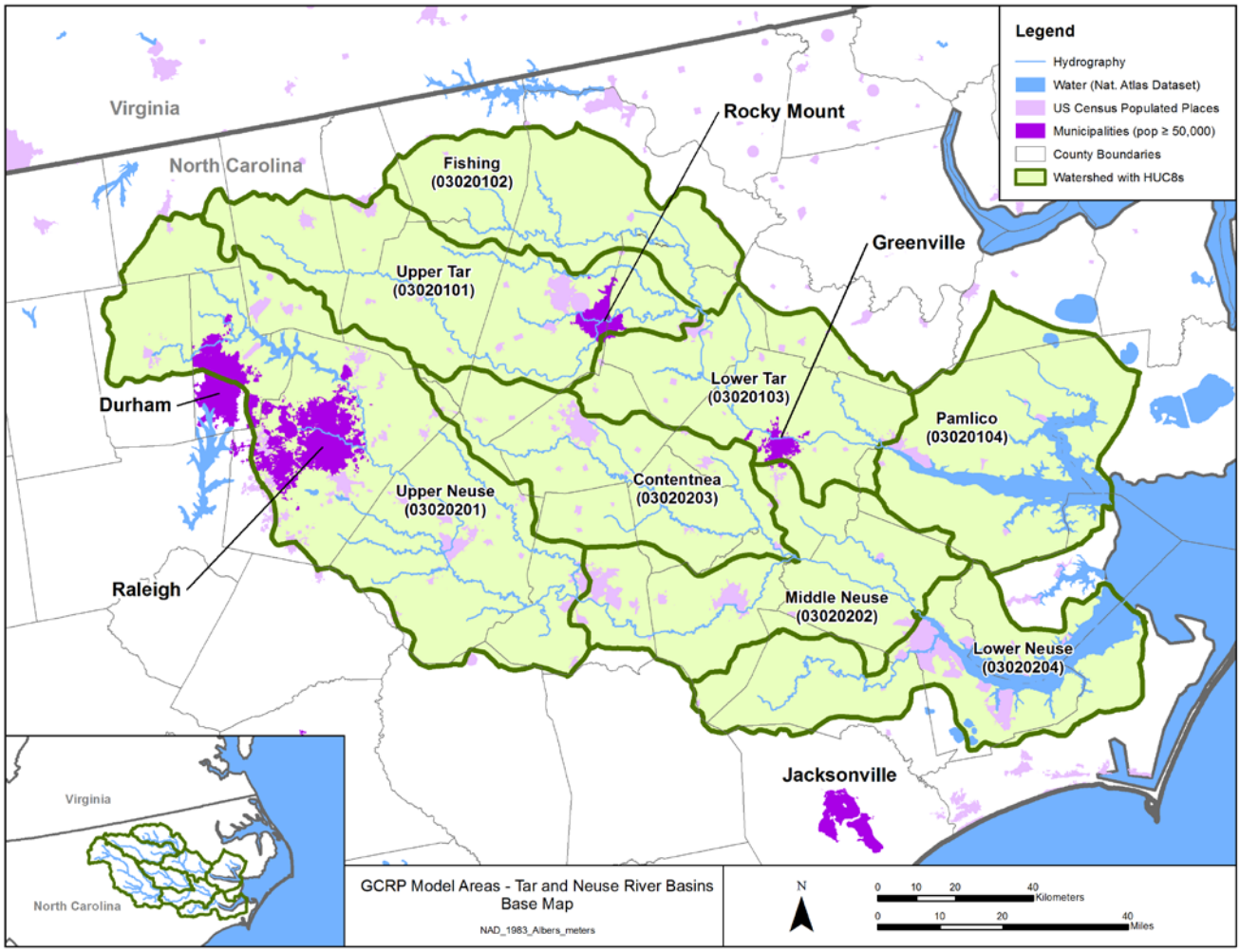


**Figure 1. Location of the Tar and Neuse River basins.**

## Soil Characteristics

Soils in the watershed are described in STATSGO soil surveys. SWAT uses information drawn directly from the soils data layer to populate the model.

## Land Use Representation

Land use/cover in the watershed is based on the 2001 National Land Cover Database (NLCD) coverage (Figure 2). NLCD land cover classes were aggregated according to the scheme shown in Table 1 for representation in the 20 Watershed model. SWAT uses the built-in hydrologic response unit (HRU) overlay mechanism in the ArcSWAT interface. SWAT HRUs are formed from an intersection of land use and SSURGO major soils. The distribution of land use in the watershed is summarized in Table 2.

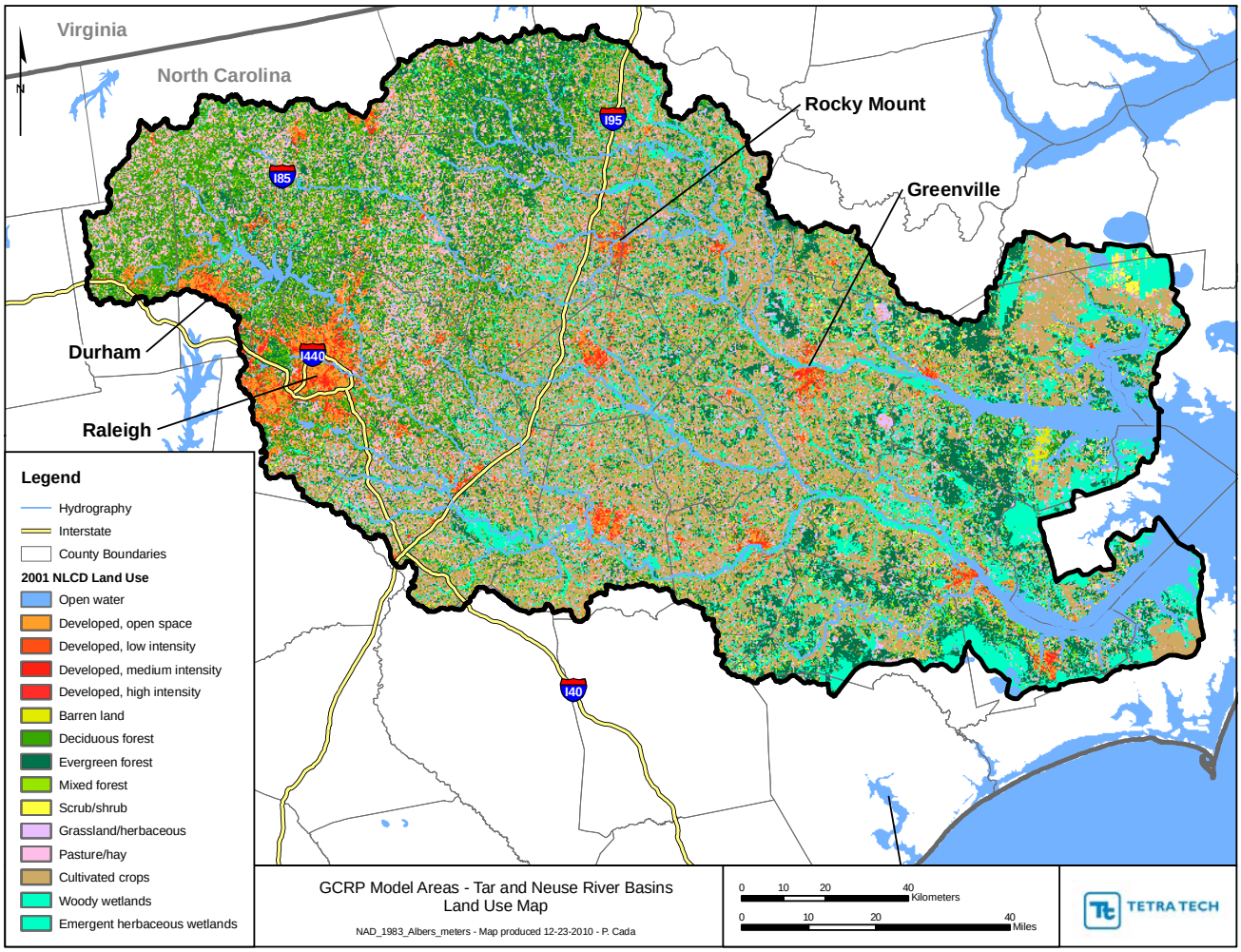


**Figure 2. Land use in the Tar and Neuse River basin.**

**Table 1. Aggregation of NLCD land cover classes**

| NLCD class | Comments | SWAT class |
|---|---|---|
| 11 Water | Water surface area usually accounted for as reach area | WATR |
| 12 Perennial ice/snow | | WATR |
| 21 Developed open space | | URLD |
| 22 Dev. Low Intensity | | URMD |
| 23 Dev. Med. Intensity | | URHD |
| 24 Dev. High Intensity | | UIDU |
| 31 Barren Land | | SWRN |
| 41 Forest | Deciduous | FRSD |
| 42 Forest | Evergreen | FRSE |
| 43 Forest | Mixed | FRST |
| 51-52 Shrubland | | RNGB |

| NLCD class | Comments | SWAT class |
|---|---|---|
| 71-74 Herbaceous Upland | | RNGE |
| 81 Pasture/Hay | | HAY |
| 82 Cultivated | | AGRR |
| 91-97 Wetland | Emergent & woody wetlands | WETF, WETL, WETN |
| 98-99 Wetland | Aquatic bed wetlands (not emergent) | WATR |

**Table 2. Land use distribution for the Albemarle-Pamlico basin (2001 NLCD) ($mi^2$)**

| HUC 8 watershed | Open water | Developed[a] | | | | Barren land | Forest | Shrubland | Pasture/Hay | Cultivated | Wetland | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Open space | Low density | Medium density | High density | | | | | | | |
| Upper Tar 03020101 | 11.6 | 84.5 | 22.8 | 7.9 | 2.8 | 2.5 | 599.6 | 115.3 | 212.9 | 157.1 | 87.7 | 1,304.8 |
| Fishing 03020102 | 2.7 | 42.1 | 4.6 | 0.6 | 0.1 | 1.8 | 448.3 | 76.1 | 75.7 | 153.7 | 88.4 | 894.0 |
| Lower Tar 03020103 | 6.5 | 53.0 | 17.3 | 6.4 | 2.0 | 0.4 | 257.4 | 125.6 | 27.0 | 330.5 | 134.1 | 960.2 |
| Pamlico 03020104 | 184.5 | 37.9 | 6.3 | 1.3 | 0.2 | 9.7 | 259.5 | 129.0 | 6.6 | 262.4 | 277.7 | 1,175.2 |
| Upper Neuse 03020201 | 40.1 | 244.9 | 96.2 | 37.0 | 9.4 | 4.4 | 908.0 | 200.2 | 288.6 | 287.0 | 156.4 | 2,272.1 |
| Middle Neuse 03020202 | 10.2 | 59.7 | 19.0 | 6.5 | 2.2 | 0.8 | 276.7 | 126.9 | 28.6 | 332.0 | 202.9 | 1,065.4 |
| Contentnea 03020203 | 10.2 | 69.8 | 21.8 | 6.8 | 1.9 | 1.0 | 274.6 | 105.5 | 82.3 | 412.1 | 156.6 | 1,142.6 |
| Lower Neuse 03020204 | 182.6 | 47.5 | 14.0 | 4.3 | 1.5 | 0.4 | 312.6 | 114.0 | 4.9 | 170.7 | 305.6 | 1,158.1 |
| Total | 448.3 | 639.4 | 201.9 | 70.7 | 20.3 | 21.0 | 3,336.6 | 992.6 | 726.4 | 2,105.4 | 1,409.6 | 9,972.4 |

[a]The percent imperviousness applied to each of the developed land uses is as follows: open space (7.17%), low density (30.90%), medium density (61.05%), and high density (87.31%).

## Point Sources

There are numerous point source discharges in the watershed. Only the major dischargers, generally defined as those with a design flow greater than 1 MGD are included in the simulation (Table 3). The major dischargers are represented at long-term average flows, without accounting for changes over time or seasonal variations.

**Table 3. Major point source discharges in the Tar and Neuse River basin**

| NPDES ID | Name | Design flow (MGD) | Observed flow (MGD) (1991-2006 average) |
|---|---|---|---|
| NC0001881 | PHILLIPS PLATING COMPANY INC | 0.10 | 0.02 |
| NC0003191 | WEYERHAEUSER N R CO NEW BERN C | 32.00 | 19.74 |
| NC0003255 | PCS PHOSPHATE CO INC AURORA MI | NA | 62.83 |
| NC0003417 | CP&L CO DBA PROG ENRG CAROLINA | 1.40 | 2.38 |
| NC0003760 | E I DUPONT DE NEMOURS E I DUPO | 3.60 | 1.58 |
| NC0003816 | US MCAS CHERRY PT MCALF ATLANT | 3.50 | 1.99 |
| NC0020231 | LOUISBURG WWTP | 1.37 | 0.79 |
| NC0020389 | BENSON WWTP | 1.50 | 1.50 |
| NC0020605 | TARBORO WWTP | 5.00 | 2.10 |
| NC0020648 | WASHINGTON WWTP | 3.65 | 1.76 |
| NC0020834 | WARRENTON WWTP | 2.00 | 0.36 |
| NC0023841 | DURHAM NORTH DURHAM WRF | 20.00 | 5.90 |
| NC0023906 | WILSON WWTP | 14.00 | 10.52 |
| NC0023931 | GREENVILLE UTIL COMMISSION GUC | 17.50 | 9.08 |
| NC0024236 | KINSTON REG WTR RECLAMATION FA | 11.85 | 1.73 |
| NC0025054 | OXFORD WWTP | 3.50 | 1.30 |
| NC0025348 | NEW BERN WWTP | 7.00 | 3.26 |
| NC0025453 | CLAYTON LITTLE CREEK WWTP | 2.50 | 1.10 |
| NC0026042 | ROBERSONVILLE WWTP | 1.80 | 1.22 |
| NC0026433 | HILLSBOROUGH WWTP | 3.00 | 1.15 |
| NC0029033 | RALEIGH NEUSE RIVER WWTP | 75.00 | 47.24 |
| NC0029572 | FARMVILLE WWTP | 3.50 | 2.05 |
| NC0030317 | ROCKY MOUNT TAR RIVER REG WWTP | 21.00 | 11.76 |
| NC0030716 | JOHNSTON CO DEPARTMENT OF PUBL | 7.00 | 4.15 |
| NC0030759 | RALEIGH SMITH CREEK WWTP | 2.40 | 0.87 |
| NC0032077 | CONTENTNEA METRO SWRG DIS CONT | 2.85 | 1.49 |
| NC0048879 | CARY NORTH CARY WRF | 12.00 | 2.45 |

| NPDES ID | Name | Design flow (MGD) | Observed flow (MGD) (1991-2006 average) |
|---|---|---|---|
| NC0064050 | APEX WATER RECLAMATION FAC | 3.60 | 4.58 |
| NC0065102 | CARY SOUTH CARY WRF | 12.80 | 7.69 |
| NC0066516 | FUQUAY VARINA TERRIBLE CRK WWT | 1.00 | 0.18 |
| NC0069311 | FRANKLIN CO PUBLIC UTIL FRANKL | 1.00 | 0.41 |

Most of these point sources have reasonably complete monitoring for total phosphorus and total suspended solids (TSS). Many dischargers in the Tar and Neuse River basin also report total nitrogen (unlike other study areas) because of concerns over nitrogen impacts on the coastal estuaries. The point sources were initially represented in the model with the median of reported values for total phosphorus, TSS and total nitrogen.

## Meteorological Data

The required meteorological time series for the 20 Watershed SWAT simulations are precipitation and air temperature. The 20 Watershed simulations do not include water temperature and uses a degree-day method for snowmelt. SWAT estimates Penmann-Monteith potential evapotranspiration using a statistical weather generator for inputs other than temperature and precipitation. These meteorological time series are drawn from the BASINS4 Meteorological Database (USEPA 2008), which provides a consistent, quality-assured set of nationwide data with gaps filled and records disaggregated. Scenario application requires simulation over 30 years, so the available stations are those with a common 30-year period of record (or one that can be filled from an approximately co-located station) that covers the year 2001. A total of 40 precipitation stations were identified for use in the Tar and Neuse River watershed model with a common period of record of 10/1/1973-9/30/2004 (Table 4). Temperature records are sparser; where these are absent temperature is taken from nearby stations with an elevation correction.

**Table 4. Precipitation stations for the Tar and Neuse River watershed model**

| COOP ID | Latitude | Longitude | Temperature | Elevation (m) |
|---|---|---|---|---|
| NC310241 | 36.2912 | -77.9822 | x | 101 |
| NC310576 | 35.1500 | -76.7167 | x | 3 |
| NC310674 | 35.4993 | -76.6864 | | 2 |
| NC311241 | 36.1279 | -79.4068 | | 195 |
| NC311285 | 36.1414 | -78.7736 | | 108 |
| NC311606 | 34.9833 | -76.2999 | x | 2 |
| NC311677 | 35.9086 | -79.0794 | x | 152 |
| NC311820 | 35.6408 | -78.4633 | x | 91 |
| NC311881 | 35.0248 | -78.2758 | x | 48 |
| NC312500 | 35.3247 | -78.6881 | x | 61 |
| NC312515 | 36.0425 | -78.9625 | | 122 |
| NC312827 | 36.1686 | -77.6749 | | 34 |
| NC313232 | 36.1050 | -78.4591 | | 114 |
| NC313510 | 35.3445 | -77.9646 | x | 33 |
| NC313555 | 36.0504 | -79.3727 | | 201 |
| NC313638 | 35.6401 | -77.3983 | x | 10 |
| NC313969 | 36.3482 | -78.4119 | x | 146 |
| NC314684 | 35.1967 | -77.5433 | x | 7 |
| NC314689 | 35.2975 | -77.5721 | x | 18 |
| NC314962 | 36.1326 | -77.1707 | x | 15 |
| NC315123 | 36.1029 | -78.3038 | x | 79 |
| NC315830 | 34.7337 | -76.7357 | x | 3 |
| NC316108 | 35.0667 | -77.0499 | x | 5 |
| NC316135 | 35.4486 | -76.2108 | x | 1 |
| NC316853 | 35.8722 | -76.6591 | x | 6 |
| NC317069 | 35.8707 | -78.7864 | x | 127 |
| NC317074 | 35.7283 | -78.6843 | x | 128 |
| NC317079 | 35.7945 | -78.6988 | x | 122 |
| NC317319 | 36.4783 | -77.6717 | x | 64 |
| NC317395 | 35.9100 | -77.8892 | | 40 |
| NC317400 | 35.8936 | -77.6805 | | 34 |
| NC317499 | 36.2119 | -78.8568 | | 165 |
| NC317516 | 36.3469 | -78.8858 | x | 216 |
| NC317994 | 35.5164 | -78.3457 | x | 46 |
| NC318500 | 35.8848 | -77.5386 | x | 11 |
| NC318706 | 35.0667 | -77.3499 | | 9 |
| NC319100 | 35.5554 | -77.0721 | | 3 |
| NC319440 | 35.8529 | -77.0306 | x | 6 |
| NC319476 | 35.6939 | -77.9455 | x | 34 |
| VA444414 | 36.6003 | -78.3011 | x | 76 |

## Watershed Segmentation

The Tar and Neuse River basin was divided into 71 subwatersheds for the purposes of modeling (Figure 3). The initial calibration watershed (Contentnea Creek) is highlighted. The model encompasses the complete watershed and does not require specification of any upstream boundary conditions for application.

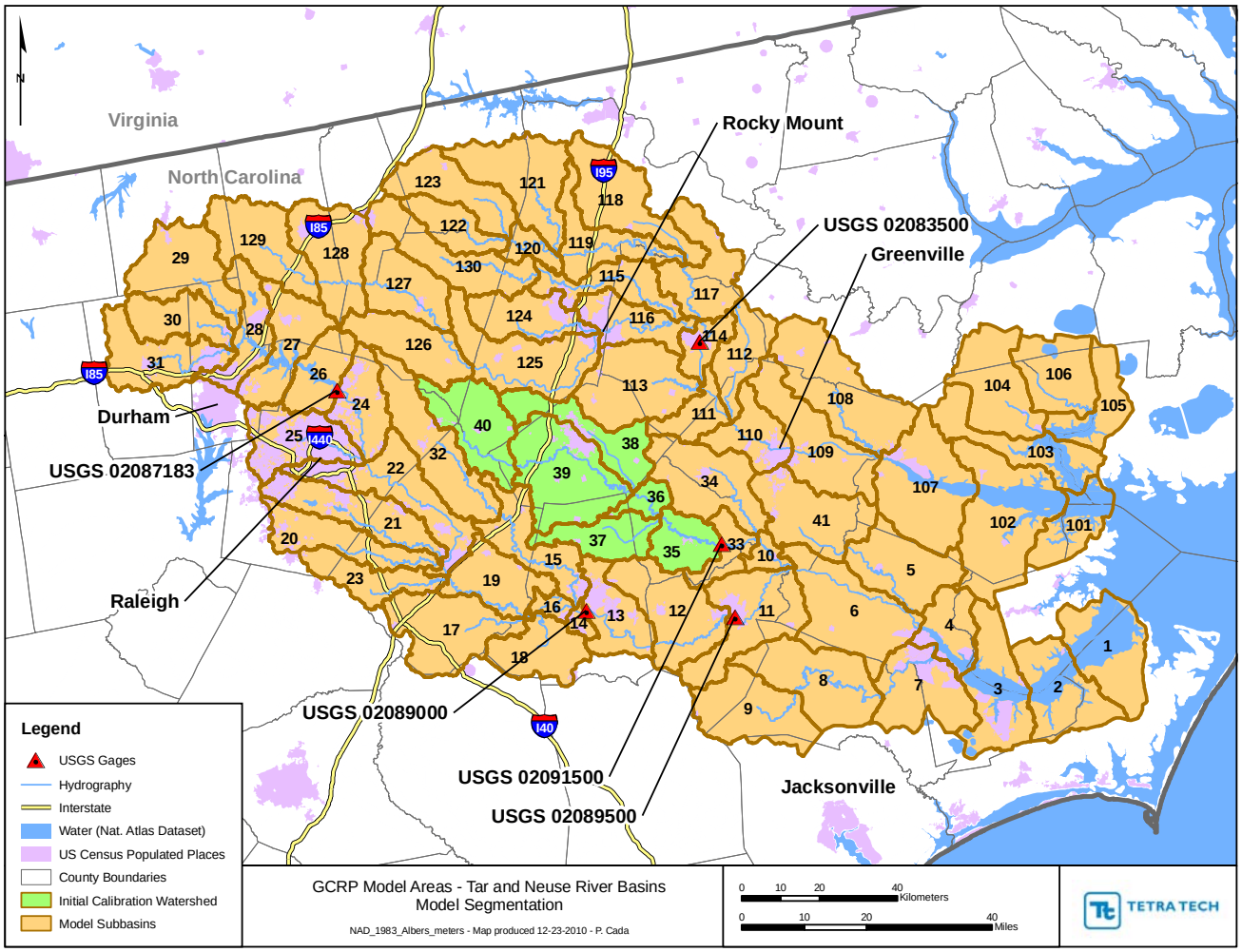


**Figure 3. Model segmentation and USGS stations utilized for the Tar and Neuse River basin.**

## Calibration Data and Locations

The specific site chosen for initial calibration was the Contentnea Creek near Hookerton (USGS 02091500), a flow and water quality monitoring location that approximately coincides with the mouth of an 8-digit HUC at its outflow to the Neuse River. The Contentnea Creek watershed was selected because there is a good set of flow and water quality data available and the watershed lacks major point sources and impoundments. Additional calibration and validation was pursued at multiple locations (Table 5). Parameters derived on the Contentnea Creek were not fully transferable to other portions of the Tar and Neuse River basin, and additional calibration was conducted at multiple gage locations.

**Table 5. Calibration and validation locations in the Tar and Neuse River basin**

| Station name | USGS ID | Drainage area ($mi^2$) | Hydrology calibration | Water quality calibration |
|---|---|---|---|---|
| Contentnea Creek near Hookerton, NC | 02091500 | 733 | X | X |
| Neuse River near Falls, NC | 02087183 | 771 | X | |
| Neuse River near Goldsboro, NC | 02089000 | 2399 | X | |
| Neuse River at Kinston, NC | 02089500 | 2692 | X | X |
| Tar River at Tarboro, NC | 02083500 | 2183 | X | X |

The model hydrology calibration period was set to Water Years 1993-2003 (within the 32-year period of record for modeling). Hydrologic validation was then performed on Water Years 1983-1993. Water quality calibration used calendar years 1993-2003, while validation used 1983-1993.

# SWAT Modeling

## Assumptions

Falls Lake reservoir is the major impoundment in the Tar and Neuse River study area that was sufficiently large enough to represent in the model. It is located on the Neuse River. Pertinent reservoir information including surface area and storage at principal (normal) and emergency spillway levels for the reservoir was obtained from the US Army Corps of Engineers. The SWAT model provides four options to simulate reservoir outflow: measured daily outflow, measured monthly outflow, average annual release rate for uncontrolled reservoir, and controlled outflow with target release. Keeping in view the 20 Watershed climate change impact evaluation application to future climate scenarios, it was assumed that the best representation of the reservoir was to simulate it without supplying time series of outflow records. Therefore, the target release approach was used in the GCRP-SWAT model.

## Hydrology Calibration

A spatial calibration approach was adopted for GCRP-SWAT modeling for the Tar and Neuse River basin. A systematic adjustment of parameters has been adopted and some adjustments are applied throughout the basin. Most of the calibration efforts were geared towards getting a closer match between simulated and observed flows at the outlet of calibration focus area.

### Land Use/Soil/Slope Definition

A 5/10/5 percent threshold was used for land use/soil/slope in the SWAT model while defining the HRUs. Urban land use classes were exempted from the HRU overlay thresholds.

The calibration focus area (Contentnea Creek) includes five subwatersheds and is generally representative of the general land use characteristics of the overall watershed with the exception of a higher percentage of cultivated lands. The parameters were adjusted within the practical range to obtain reasonable fit between the simulated and measured flows in terms of Nash-Sutcliffe modeling efficiency and the high flow and low flow components as well as the seasonal flows.

The water balance of the whole Tar and Neuse River basin predicted by the SWAT model over the 32-year simulation period is as follows:

```
PRECIP =   1234.6 MM
SNOW FALL =   40.57 MM
SNOW MELT =    40.17 MM
SUBLIMATION =     0.39 MM
SURFACE RUNOFF Q =   170.61 MM
LATERAL SOIL Q =   18.20 MM
TILE Q =     0.00 MM
GROUNDWATER (SHAL AQ) Q =   223.76 MM
REVAP (SHAL AQ => SOIL/PLANTS) =   40.29 MM
DEEP AQ RECHARGE =    13.90 MM
TOTAL AQ RECHARGE = 277.94 MM
TOTAL WATER YLD =   410.46 MM
PERCOLATION OUT OF SOIL = 276.02 MM
ET =    763.0 MM
PET =   1433.2MM
TRANSMISSION LOSSES =     2.10 MM
```

Hydrologic calibration adjustments focused on the following parameters:

- CN2 (initial SCS runoff curve number for moisture condition II)
- ESCO (soil evaporation compensation factor)
- SURLAG (surface runoff lag coefficient)
- SOL_AWC (available water capacity of the soil layer, mm water/mm of soil)
- ALPHA_BF (baseflow alpha factor, days)
- GW_DELAY (groundwater delay time, days)
- GWQMIN (threshold depth of water in the shallow aquifer required for return flow to occur, mm)
- GW_REVAP (groundwater "revap" coefficient)
- CH_N2 (Manning's "n" value for main channels)

Calibration results for the Contentnea Creek are summarized in Figure 4, Figure 5, Figure 6, Figure 7 and Table 6.

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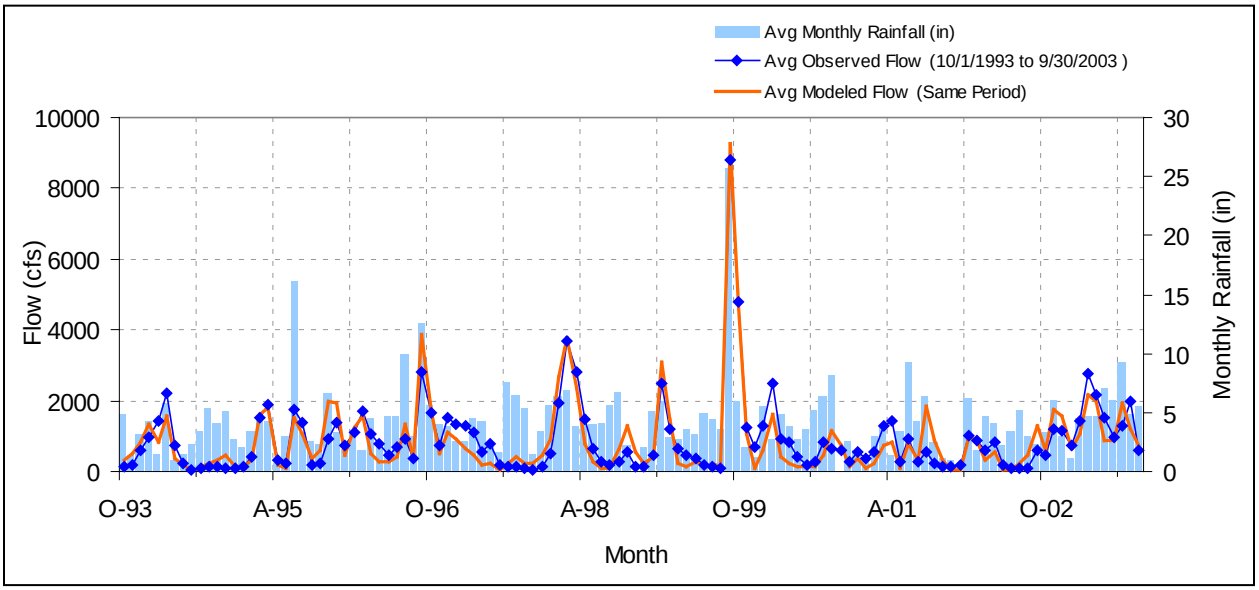


**Figure 4. Mean monthly flow at USGS 02091500 Contentnea Creek near Hookerton, NC – calibration period.**

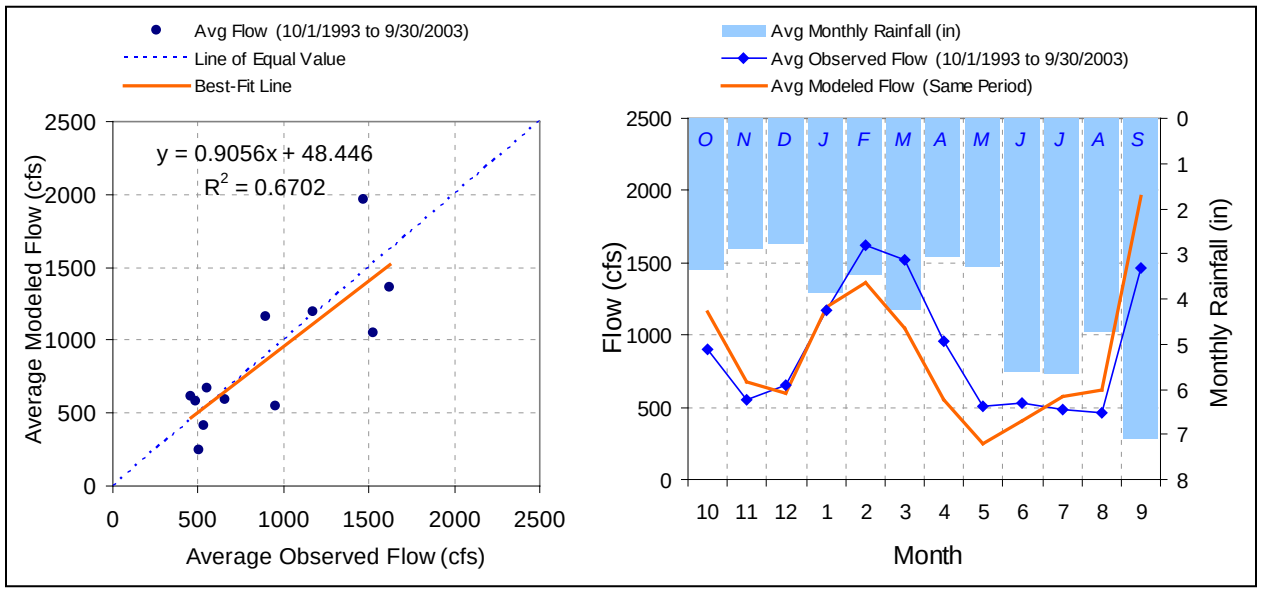


**Figure 5. Seasonal regression and temporal aggregate at USGS 02091500 Contentnea Creek near Hookerton, NC – calibration period.**

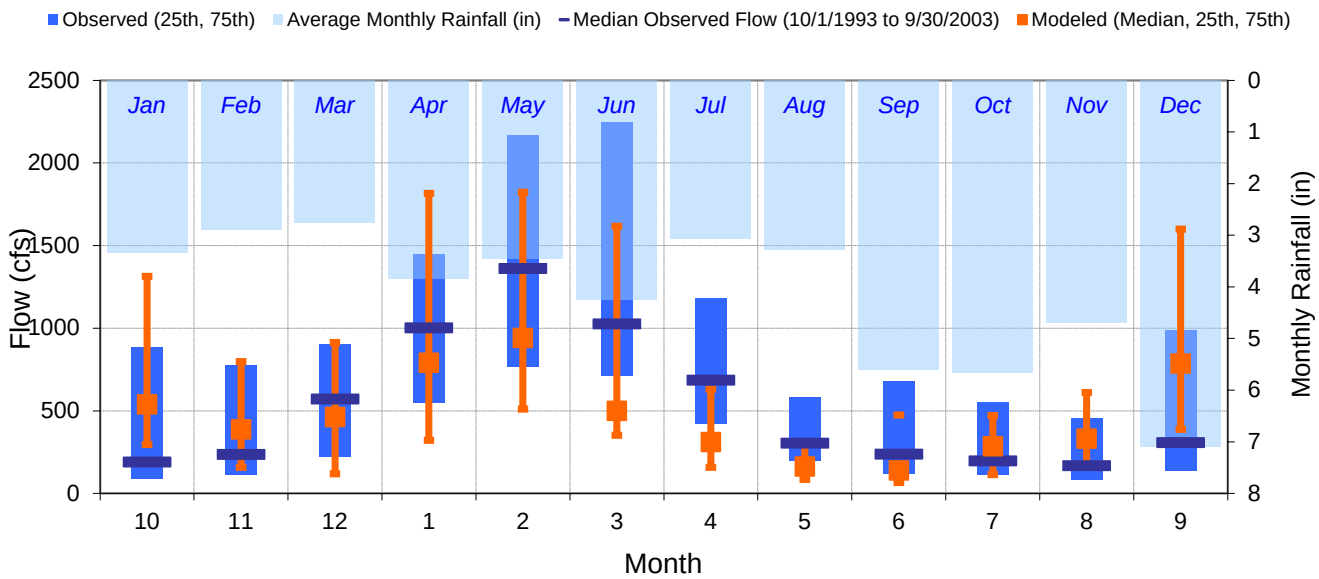


**Figure 6. Seasonal medians and ranges at USGS 02091500 Contentnea Creek near Hookerton, NC – calibration period.**

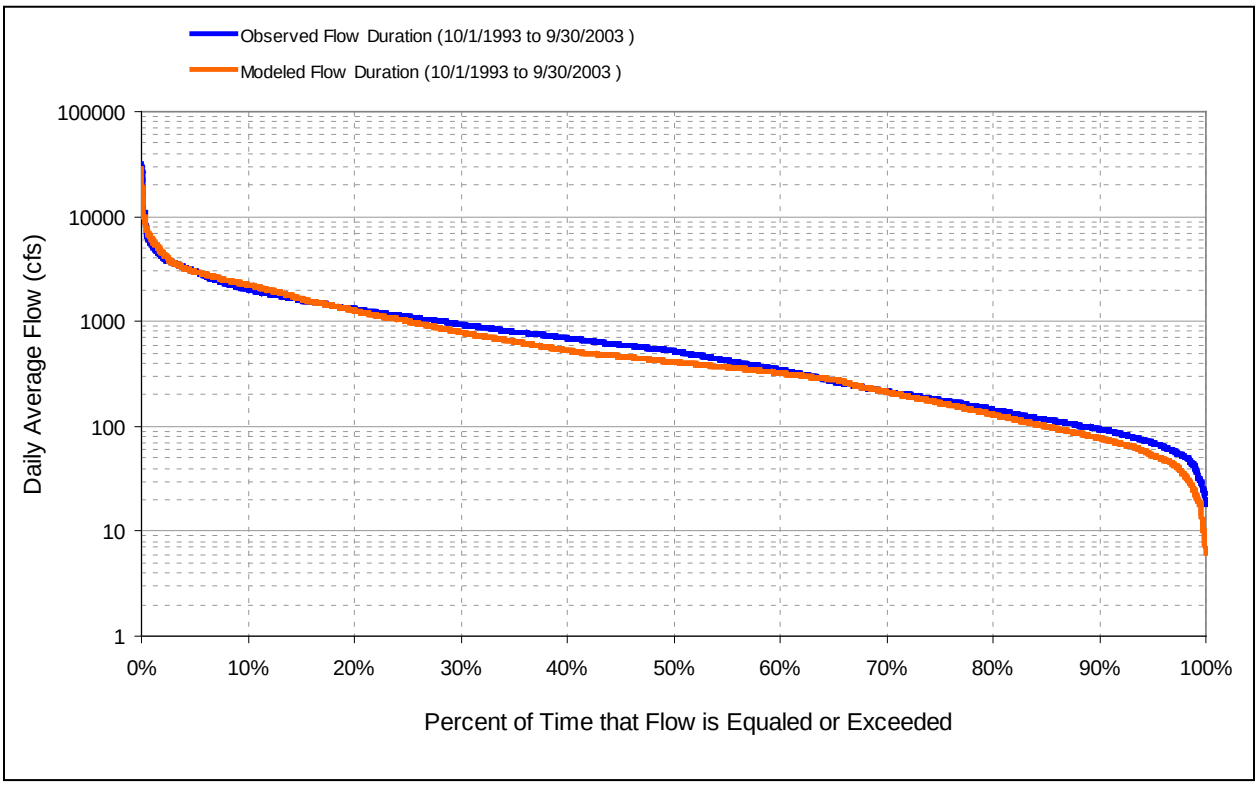


**Figure 7. Flow exceedance at USGS 02091500 Contentnea Creek near Hookerton, NC – calibration period.**

**Table 6. Summary statistics at USGS 02091500 Contentnea Creek near Hookerton, NC – calibration period**

| SWAT Simulated Flow | | Observed Flow Gage | |
|---|---|---|---|
| REACH OUTFLOW FROM OUTLET 35<br><br>10-Year Analysis Period: 10/1/1993 - 9/30/2003<br>Flow volumes are (inches/year) for upstream drainage area | | USGS 02091500 CONTENTNEA CREEK AT HOOKERTON, NC<br><br>Hydrologic Unit Code: 3020203<br>Latitude: 35.42888889<br>Longitude: -77.5825<br>Drainage Area (sq-mi): 733 | |
| Total Simulated In-stream Flow: | **15.98** | Total Observed In-stream Flow: | **16.64** |
| Total of simulated highest 10% flows: | **7.16** | Total of Observed highest 10% flows: | **7.01** |
| Total of Simulated lowest 50% flows: | **1.78** | Total of Observed Lowest 50% flows: | **1.97** |
| Simulated Summer Flow Volume (months 7-9): | **4.86** | Observed Summer Flow Volume (7-9): | **3.72** |
| Simulated Fall Flow Volume (months 10-12): | **3.79** | Observed Fall Flow Volume (10-12): | **3.29** |
| Simulated Winter Flow Volume (months 1-3): | **5.48** | Observed Winter Flow Volume (1-3): | **6.56** |
| Simulated Spring Flow Volume (months 4-6): | **1.85** | Observed Spring Flow Volume (4-6): | **3.06** |
| Total Simulated Storm Volume: | **3.81** | Total Observed Storm Volume: | **4.35** |
| Simulated Summer Storm Volume (7-9): | **1.51** | Observed Summer Storm Volume (7-9): | **1.48** |
| *Errors (Simulated-Observed)* | *Error Statistics* | *Recommended Criteria* | |
| Error in total volume: | -3.98 | 10 | |
| Error in 50% lowest flows: | -9.98 | 10 | |
| Error in 10% highest flows: | 2.15 | 15 | |
| **Seasonal volume error - Summer:** | **30.50** | **30** | |
| Seasonal volume error - Fall: | 15.05 >> | 30 | Clear |
| Seasonal volume error - Winter: | -16.48 | 30 | |
| **Seasonal volume error - Spring:** | **-39.56** | **30** | |
| Error in storm volumes: | -12.39 | 20 | |
| Error in summer storm volumes: | 2.17 | 50 | |
| Nash-Sutcliffe Coefficient of Efficiency, E: | 0.678 | Model accuracy increases as E or E' approaches 1.0 | |
| Baseline adjusted coefficient (Garrick), E': | 0.459 | | |
| Monthly NSE | 0.859 | | |

## Hydrology Validation

Hydrology validation for Contentnea Creek was performed for the period 10/1/1983 through 9/30/1993. Results are presented in Figures 8 through 11 and Table 7. The validation achieves a moderately high coefficient of model fit efficiency, but is over on 10 percent highest flow volume, and summer and fall seasonal volumes (Figure 8, Figure 9, Figure 10, Figure 11 and Table 7).

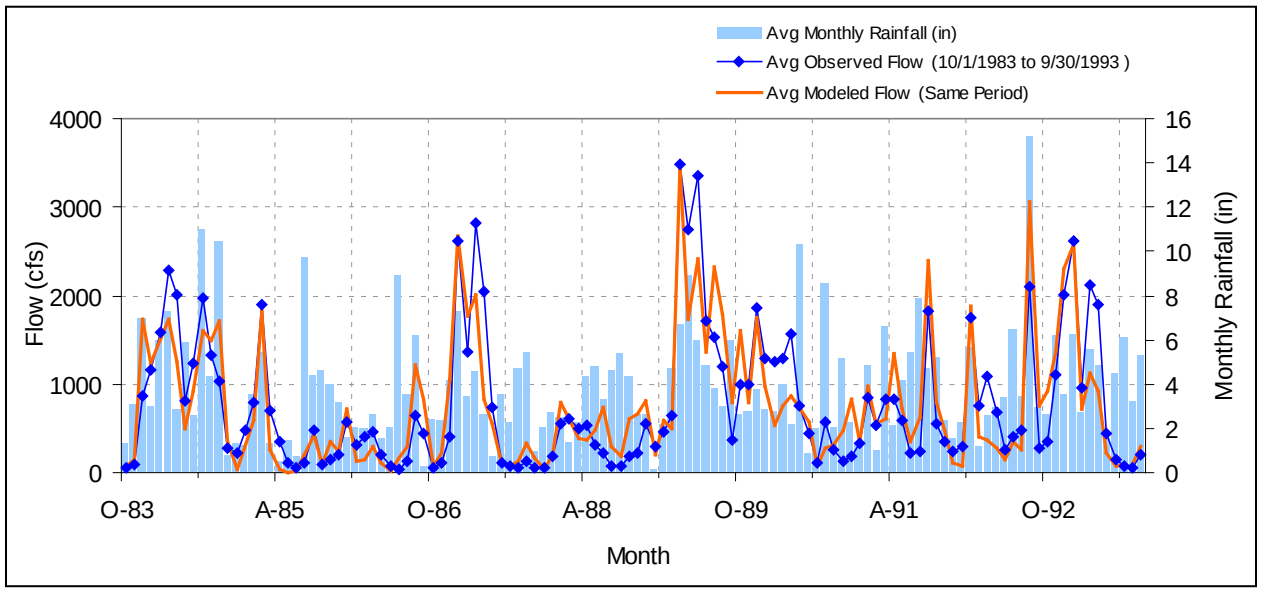


**Figure 8. Mean monthly flow at USGS 02091500 Contentnea Creek near Hookerton, NC – validation period.**

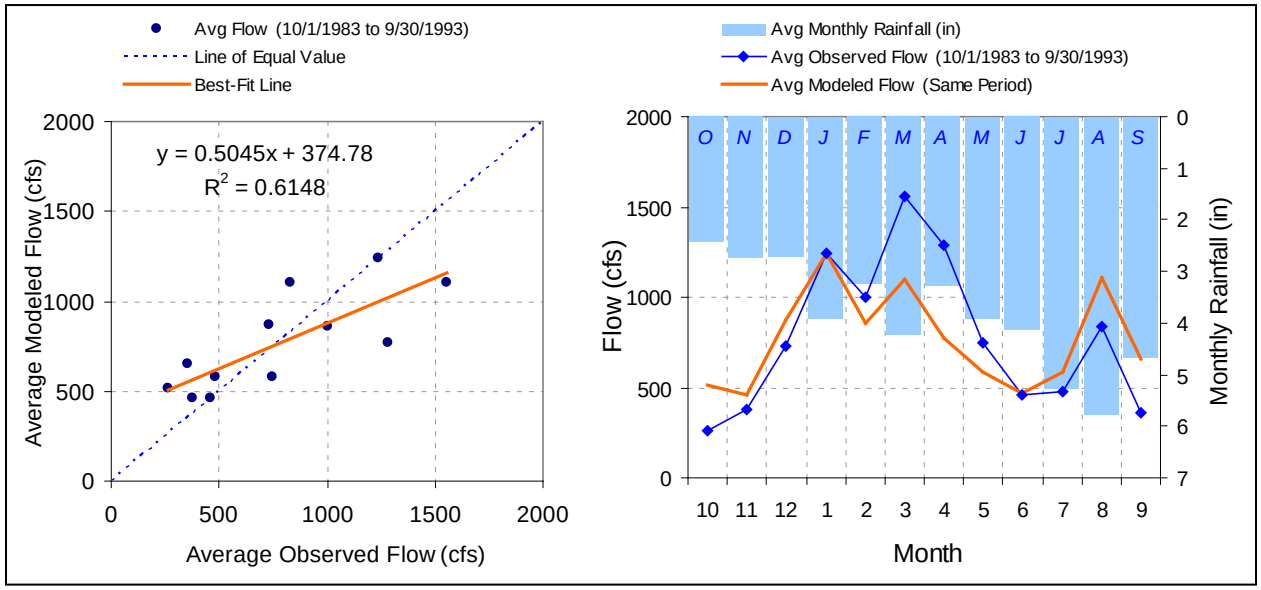


**Figure 9. Seasonal regression and temporal aggregate at USGS 02091500 Contentnea Creek near Hookerton, NC – validation period.**

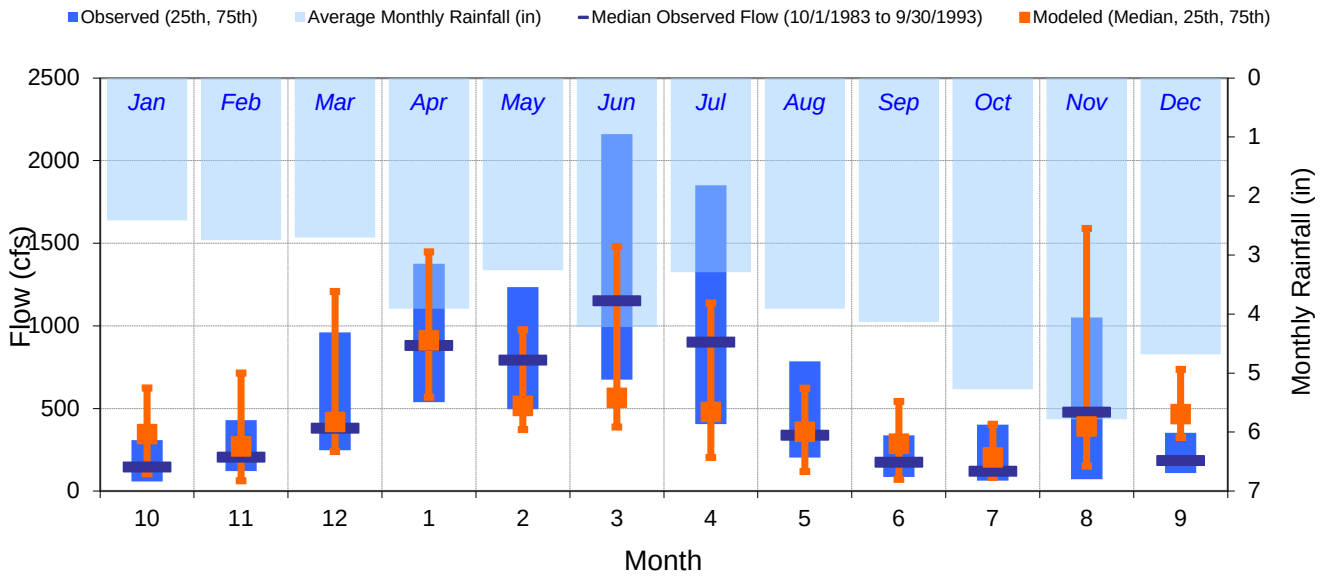


**Figure 10. Seasonal medians and ranges at USGS 02091500 Contentnea Creek near Hookerton, NC – validation period.**

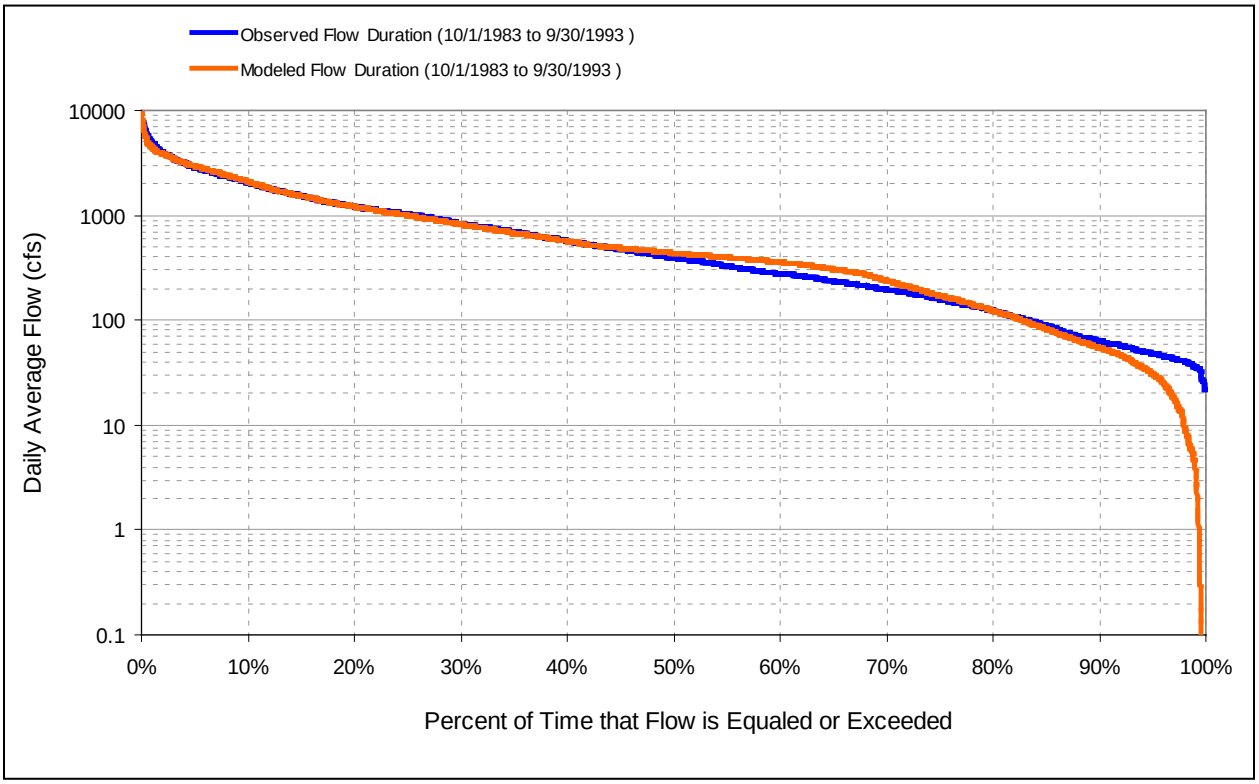


**Figure 11. Flow exceedance at USGS 02091500 Contentnea Creek near Hookerton, NC – validation period.**

**Table 7. Summary statistics at USGS 02091500 Contentnea Creek near Hookerton, NC – validation period**

| SWAT Simulated Flow | | Observed Flow Gage | |
|---|---|---|---|
| REACH OUTFLOW FROM OUTLET 35<br>10-Year Analysis Period: 10/1/1983 - 9/30/1993<br>Flow volumes are (inches/year) for upstream drainage area | | USGS 02091500 CONTENTNEA CREEK AT HOOKERTON, NC<br>Hydrologic Unit Code: 3020203<br>Latitude: 35.42888889<br>Longitude: -77.5825<br>Drainage Area (sq-mi): 733 | |
| Total Simulated In-stream Flow: | **14.24** | Total Observed In-stream Flow: | **14.41** |
| Total of simulated highest 10% flows: | **5.76** | Total of Observed highest 10% flows: | **5.97** |
| Total of Simulated lowest 50% flows: | **1.79** | Total of Observed Lowest 50% flows: | **1.59** |
| Simulated Summer Flow Volume (months 7-9): | **3.65** | Observed Summer Flow Volume (7-9): | **2.61** |
| Simulated Fall Flow Volume (months 10-12): | **2.88** | Observed Fall Flow Volume (10-12): | **2.13** |
| Simulated Winter Flow Volume (months 1-3): | **4.91** | Observed Winter Flow Volume (1-3): | **5.84** |
| Simulated Spring Flow Volume (months 4-6): | **2.80** | Observed Spring Flow Volume (4-6): | **3.83** |
| Total Simulated Storm Volume: | **3.19** | Total Observed Storm Volume: | **3.66** |
| Simulated Summer Storm Volume (7-9): | **0.99** | Observed Summer Storm Volume (7-9): | **0.96** |
| *Errors (Simulated-Observed)* | *Error Statistics* | *Recommended Criteria* | |
| Error in total volume: | -1.18 | 10 | |
| **Error in 50% lowest flows:** | **12.17** | **10** | |
| Error in 10% highest flows: | -3.49 | 15 | |
| **Seasonal volume error - Summer:** | **39.76** | **30** | |
| **Seasonal volume error - Fall:** | **35.01** >> | **30** | Clear |
| Seasonal volume error - Winter: | -15.83 | 30 | |
| Seasonal volume error - Spring: | -26.94 | 30 | |
| Error in storm volumes: | -13.04 | 20 | |
| Error in summer storm volumes: | 2.93 | 50 | |
| Nash-Sutcliffe Coefficient of Efficiency, E: | 0.635 | Model accuracy increases as E or E' approaches 1.0 | |
| Baseline adjusted coefficient (Garrick), E': | 0.479 | | |
| Monthly NSE | 0.742 | | |

## Hydrology Results for Larger Watershed

As described above, parameters determined for the gage at Contentnea Creek were initially transferred to other gages in the watershed. However, changes to subbasin level parameter were required to fit the model to the observed flows. In all, calibration and validation was pursued at a total of five gages throughout the watershed, including one gage at the outlet of an 8-digit HUC, one gage at the outfall of the Falls Lake reservoir and three gages on the mainstem. Results of the calibration and validation exercise are summarized in Table 8 and Table 9, respectively. Calibration and validation results were acceptable at most gages.

**Table 8. Summary statistics (percent error): all stations - calibration period**

| Station | 02091500 Contentnea Creek near Hookerton, NC | 02087183 Neuse River near Falls Lake, NC | 02089000 Neuse River near Goldsboro, NC | 02089500 Neuse River at Kinston, NC | 02083500 Tar River at Tarboro, NC |
|---|---|---|---|---|---|
| Error in total volume: | -3.98 | 5.36 | -3.95 | -3.00 | 0.23 |
| Error in 50% lowest flows: | -9.98 | -11.43 | -2.44 | -0.14 | 0.92 |
| Error in 10% highest flows: | 2.15 | -11.68 | -1.26 | 1.23 | -6.55 |
| Seasonal volume error - Summer: | 30.50 | 30.71 | 20.87 | 22.20 | 18.69 |
| Seasonal volume error - Fall: | 15.05 | 21.62 | 7.54 | 8.74 | 29.36 |
| Seasonal volume error - Winter: | -16.48 | 3.54 | -11.38 | -9.95 | -11.81 |
| Seasonal volume error - Spring: | -39.56 | -20.48 | -26.07 | -26.52 | -21.93 |
| Error in storm volumes: | -12.39 | -61.90 | -14.75 | -10.38 | -33.68 |
| Error in summer storm volumes: | 2.17 | -29.11 | 3.89 | 2.19 | -15.34 |
| Daily Nash-Sutcliffe Coefficient of Efficiency, E: | 0.678 | 0.417 | 0.736 | 0.732 | 0.754 |
| Monthly Nash-Sutcliffe Coefficient | 0.859 | 0.719 | 0.864 | 0.859 | 0.894 |

**Table 9. Summary Statistics (percent error): All Stations - Validation Period**

| Station | 02091500 Contentnea Creek near Hookerton, NC | 02087183 Neuse River near Falls Lake, NC | 02089000 Neuse River near Goldsboro, NC | 02089500 Neuse River at Kinston, NC | 02083500 Tar River at Tarboro, NC |
|---|---|---|---|---|---|
| Error in total volume: | -1.18 | -1.02 | -7.60 | -8.55 | -4.88 |
| Error in 50% lowest flows: | 12.17 | -29.70 | 0.60 | -2.55 | -9.07 |
| Error in 10% highest flows: | -3.49 | -26.58 | -20.17 | -20.42 | -20.23 |
| Seasonal volume error - Summer: | 39.76 | 5.54 | 14.56 | 14.73 | 39.72 |
| Seasonal volume error - Fall: | 35.01 | 29.41 | 16.15 | 12.09 | 26.83 |
| Seasonal volume error - Winter: | -15.83 | -7.93 | -14.24 | -14.46 | -16.29 |
| Seasonal volume error - Spring: | -26.94 | -7.10 | -22.37 | -24.12 | -22.16 |
| Error in storm volumes: | -13.04 | -63.68 | -28.64 | -27.30 | -37.61 |
| Error in summer storm volumes: | 2.93 | -46.92 | -22.43 | -20.82 | -7.61 |
| Daily Nash-Sutcliffe Coefficient of Efficiency, E: | 0.635 | 0.620 | 0.775 | 0.767 | 0.688 |
| Monthly Nash-Sutcliffe Coefficient | 0.742 | 0.845 | 0.849 | 0.832 | 0.808 |

## Water Quality Calibration and Validation

Initial calibration and validation of water quality was done on the Contentnea Creek (USGS 02091500), using 1993-2003 for calibration and 1983-1993 for validation. As with hydrology, water quality calibration was performed on the later period as this better reflects the land use included in the model.

Calibration adjustments for sediment focused on the following parameters:

- SPCON (linear parameter for estimating maximum amount of sediment that can be re-entrained during channel sediment routing)
- SPEXP (exponential parameter for estimating maximum amount of sediment that can be re-entrained during channel sediment routing)
- CH_COV (channel cover factor)
- CH_EROD (channel erodibility factor)
- USLE_P (USLE support practice factor)

Simulated and estimated sediment loads at the Contentnea Creek station for both the calibration and validation periods are shown in Figure 12 and statistics for the two periods are provided separately in Table 10. The key statistic in Table 10 is the relative percent error, which shows the error in the prediction of monthly load normalized to the estimated load. Table 10 also shows the relative average absolute error, which is the average of the relative magnitude of errors in individual monthly load predictions. This number is inflated by outlier months in which the simulated and estimated loads differ by large amounts (which may be as easily due to uncertainty in the estimated load due to limited data as to problems with the model) and the third statistic, the relative median absolute error, is likely more relevant and shows better agreement.

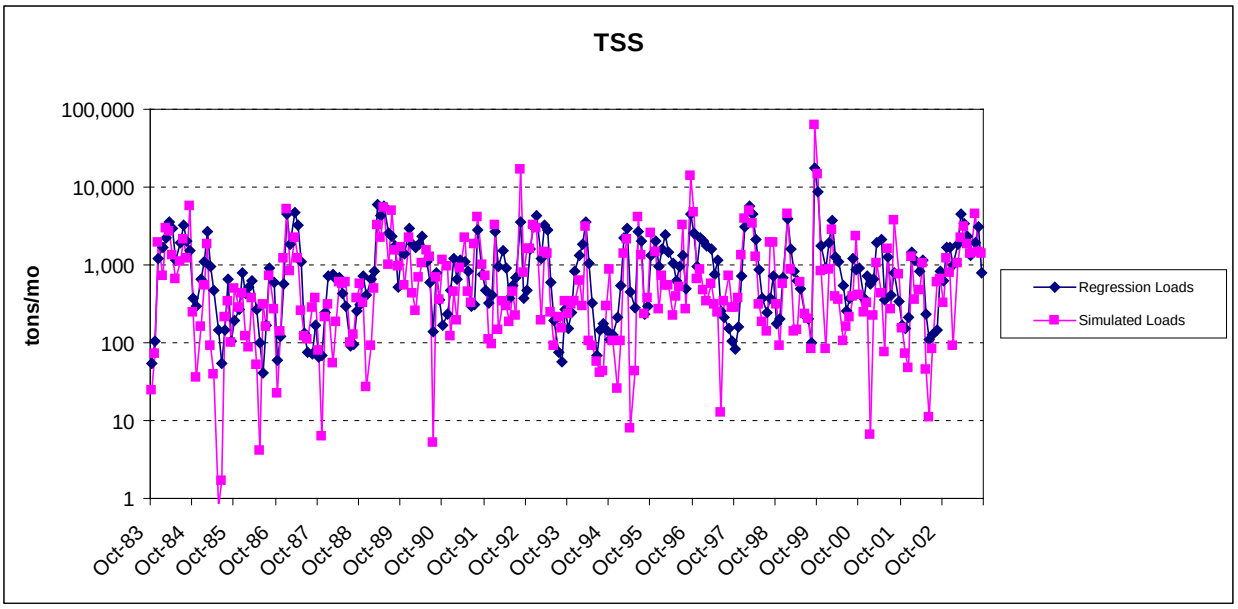


**Figure 12. Fit for monthly load of TSS at USGS 02091500 Contentnea Creek near Hookerton, NC.**

**Table 10. Model fit statistics (observed minus predicted) for monthly sediment loads using stratified regression at USGS 02091500 Contentnea Creek near Hookerton, NC**

| Statistic | Calibration period (1993-2003) | Validation period (1983-1993) |
|---|---|---|
| Relative Percent Error | -19.9% | 9.9% |
| Relative Average Absolute Error | 81% | 61% |
| Relative Median Absolute Error | 34.7% | 33.1% |

Calibration adjustments for total phosphorus and total nitrogen focused on the following parameters:

- RHOQ (algal respiration rate at $20^{O}$ C)
- PHOSKD (phosphorus soil partitioning coefficient)
- PSP (phosphorus availability index)
- RS2 (benthic source rate for dissolved P in the reach at $20^{O}$ C)
- RS5 (organic P settling rate in the reach at $20^{O}$ C)
- BC4 (rate constant for mineralization of organic P to dissolved P in the reach at $20^{O}$ C)
- RS4 (rate coefficient for organic N settling in the reach at $20^{O}$ C)

Results for the phosphorus simulation are shown in Figure 13 and Table 11. Results for the nitrogen simulation are shown in Figure 14 and Table 12. The model fit is generally acceptable.

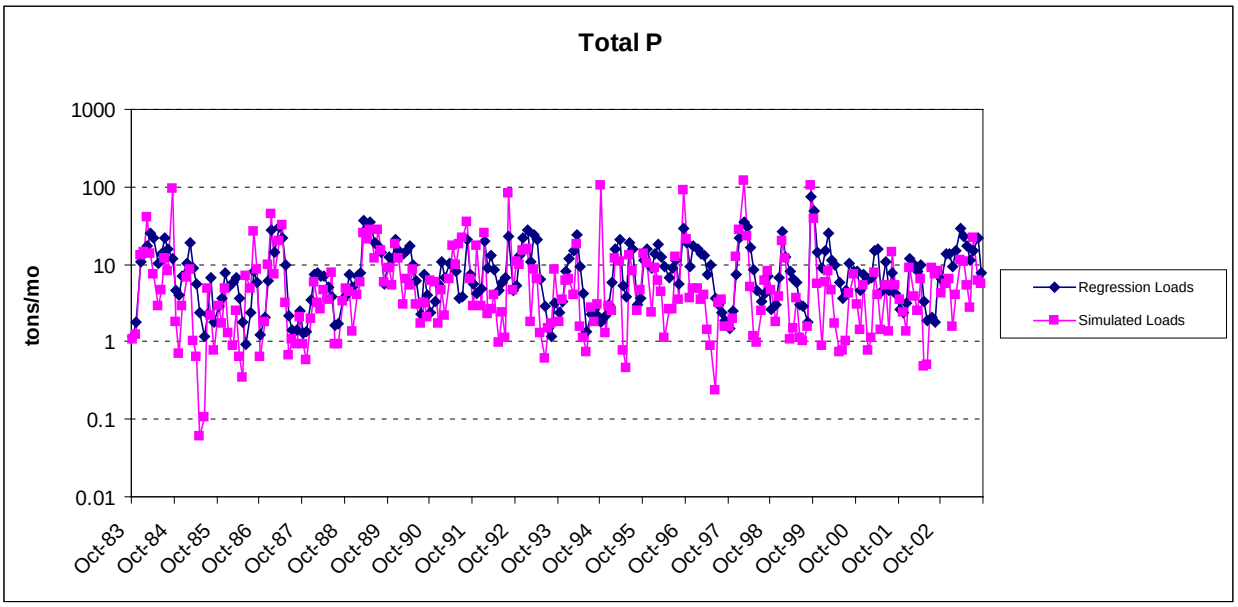


**Figure 13. Fit for monthly load of total phosphorus at USGS 02091500 Contentnea Creek near Hookerton, NC.**

**Table 11. Model fit statistics (observed minus predicted) for monthly phosphorus loads using stratified regression at USGS 02091500 Contentnea Creek near Hookerton, NC**

| Statistic | Calibration period (1993-2003) | Validation period (1983-1993) |
|---|---|---|
| Relative Percent Error | 15.9% | 5.3% |
| Average Absolute Error | 69% | 66% |
| Median Absolute Error | 49.3% | 39.3% |

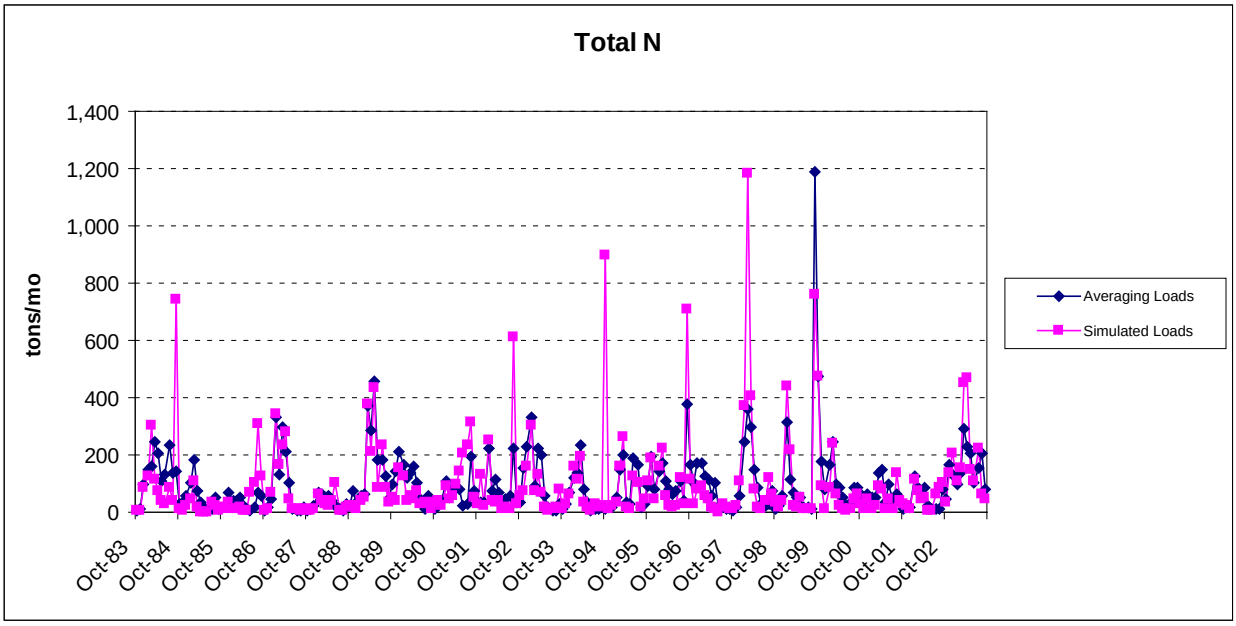


**Figure 14. Fit for monthly load of total nitrogen at USGS 02091500 Contentnea Creek near Hookerton, NC.**

**Table 12. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator at USGS 02091500 Contentnea Creek near Hookerton, NC**

| Statistic | Calibration period (1993-2003) | Validation period (1983-1993) |
|---|---|---|
| Relative Percent Error | -5.6% | 5.3% |
| Average Absolute Error | 56% | 57% |
| Median Absolute Error | 24.3% | 31.6% |

## Water Quality Results for Larger Watershed

As with hydrology, a spatial calibration approach was adopted. Contentnea Creek watershed SWAT model parameters for water quality were transferred to other portions of the watershed with necessary changes to subwatershed level parameters. Summary statistics for the SWAT water quality calibration and validation at other stations in the watershed are provided in Table 13 and Table 14.

**Table 13. Summary statistics for water quality at all stations – calibration period 1993-2003**

| Station | 02091500 Contentnea Creek near Hookerton, NC | 02089500 Neuse River at Kinston, NC | 02083500 Tar River at Tarboro, NC |
|---|---|---|---|
| Relative Percent Error TSS Load | -19.9% | -6.7% | -5.1% |
| Relative Percent Error TP Load | 15.9% | -10.5% | -0.4% |
| Relative Percent Error TN Load | -5.6% | -15% | -33.8% |

**Table 14. Summary statistics for water quality at all stations – validation period 1983-1993**

| Station | 02091500 Contentnea Creek near Hookerton, NC | 02089500 Neuse River at Kinston, NC | 02083500 Tar River at Tarboro, NC |
|---|---|---|---|
| Relative Percent Error TSS Load | 9.9% | 17.3% | 22.9% |
| Relative Percent Error TP Load | 5.3% | 2.5% | 13.1% |
| Relative Percent Error TN Load | 5.3% | 6.7% | 13.5% |

# References

Spruill, T.B., D.A. Harned, P.M. Ruhl, J.L. Eimers, G. McMahon, K.E. Smith, D.R. Galeone, and M.D. Woodside. 1998. Water Quality in the Albemarle-Pamlico Drainage Basin, North Carolina and Virginia, 1992-95. Circular 1157. U.S. Geological Survey, Denver, CO.

USEPA. 2008. Using the BASINS Meteorological Database (Version 2006). BASINS Technical Note 10. Office of Water, U.S. Environmental Protection Agency, Washington, DC. http://water.epa.gov/scitech/datait/models/basins/upload/2009_04_13_BASINSs_tecnote10.pdf (Accessed June, 2009).