# Appendix M
# Model Configuration, Calibration and Validation

## Basin: Georgia-Florida Coastal

## Contents

**Watershed Background** ..... **1**
Water Body Characteristics ..... 1
Soil Characteristics ..... 3
Land Use Representation ..... 3
Point Sources ..... 7
Meteorological Data ..... 8
Watershed Segmentation ..... 10
Calibration Data and Locations ..... 12
**SWAT Modeling** ..... **13**
Assumptions ..... 13
Hydrology Calibration ..... 13
Hydrology Validation ..... 17
Hydrology Results for Larger Watershed ..... 20
Water Quality Calibration and Validation ..... 22
Water Quality Results for Larger Watershed ..... 25
**References** ..... **27**

## Tables


Table 1. Aggregation of NLCD land cover classes ....5
Table 2. Land use distribution for the Georgia-Florida Coastal basin (2001 NLCD) ($mi^2$) ....6
Table 3. Major point source discharges in the Georgia-Florida Coastal basin ....7
Table 4. Precipitation stations for the Georgia-Florida Coastal watershed model ....8
Table 5. Calibration and validation locations in the Georgia-Florida Coastal basin ....12
Table 6. Summary statistics at USGS 02329000 Ochlockonee River at Havana, FL – calibration period ..17
Table 7. Summary statistics at USGS 02329000 Ochlockonee River at Havana, FL – validation period ...20
Table 8. Summary statistics (percent error): all stations - calibration period ....21
Table 9. Summary statistics (percent error): all stations - validation period ....21
Table 10. Model fit statistics (observed minus predicted) for monthly sediment loads using stratified regression at USGS 02329000 Ochlockonee River at Havana, FL ....23
Table 11. Model fit statistics (observed minus predicted) for monthly phosphorus loads using stratified regression at USGS 02329000 Ochlockonee River at Havana, FL ....24
Table 12. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator at USGS 02329000 Ochlockonee River at Havana, FL ....25
Table 13. Summary statistics for water quality at all stations – calibration period 1992-2002 ....26
Table 14. Summary statistics for water quality at all stations – validation period 1982-1992 ....26


## Figures


Figure 1. Location of the Georgia-Florida Coastal basin. ....2
Figure 2. Land use in the Georgia-Florida Coastal basin. ....4
Figure 3. Model segmentation and USGS stations utilized for the Georgia-Florida Coastal basin ....11
Figure 4. Mean monthly flow at USGS 02329000 Ochlockonee River at Havana, FL – calibration period.14
Figure 5. Seasonal regression and temporal aggregate at USGS 02329000 Ochlockonee River at Havana, FL – calibration period. ....15
Figure 6. Seasonal medians and ranges at USGS 02329000 Ochlockonee River at Havana, FL – calibration period. ....15
Figure 7. Flow exceedance at USGS 02329000 Ochlockonee River at Havana, FL – calibration period ....16
Figure 8. Mean monthly flow at USGS 02329000 Ochlockonee River at Havana, FL – validation period..18
Figure 9. Seasonal regression and temporal aggregate at USGS 02329000 Ochlockonee River at Havana, FL – validation period. ....18
Figure 10. Seasonal medians and ranges at USGS 02329000 Ochlockonee River at Havana, FL – validation period. ....19
Figure 11. Flow exceedance at USGS 02329000 Ochlockonee River at Havana, FL – validation period ....19
Figure 12. Fit for monthly load of TSS at USGS 02329000 Ochlockonee River at Havana, FL. ....23
Figure 13. Fit for monthly load of total phosphorus at USGS 02329000 Ochlockonee River at Havana, FL.24
Figure 14. Fit for monthly load of total nitrogen at USGS 02329000 Ochlockonee River at Havana, FL. ....24

# Watershed Background

The Georgia-Florida Coastal basin was 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.

## Water Body Characteristics

The Georgia-Florida Coastal Plain study unit is located on the southeastern coast of the United States. Most of the study area is in the Coastal Plain physiographic province with a small part in the north in the Piedmont physiographic province.

The study area includes all or parts of seven hydrologic subregions, including the Ogeechee-Savannah, the Altamaha-St.Marys, the Suwannee, the Ochlockonee, the St. Johns, the Peace-Tampa Bay, and the Southern Florida hydrologic subregions. Only the Ogeechee River is included in the Georgia-Florida Coastal Plain from the Ogeechee-Savannah subregion and only the Withlacoochee (south), Hillsborough, and Alafia River are in the study area from the Peace-Tampa Bay hydrologic subregion.

The study area has a climatic range from temperate in the north to subtropical in the south and along the Gulf Coast. The land uses of significance within the study area include forest, agriculture (citrus and row crops), wetlands, urban, and rangeland. Forested areas, much of which is in silviculture, cover approximately 48 percent of the study area. Much of the forest lands are softwood pines used to manufacture paper products (facial tissue, toilet paper, hand towels, bags, and boxes). Agricultural areas account for nearly 28 percent of the study area, are concentrated in several areas, and include growing of field crops, fruits (including citrus), vegetables and cattle, dairy and poultry operations.

20 Watershed models for the Georgia-Florida Coastal basin include 15 HUC8s in two groups, one group draining to Tampa Bay and the remainder in southern Georgia and northwest Florida (Ochlockonee and Suwanee drainages) (Figure 1).

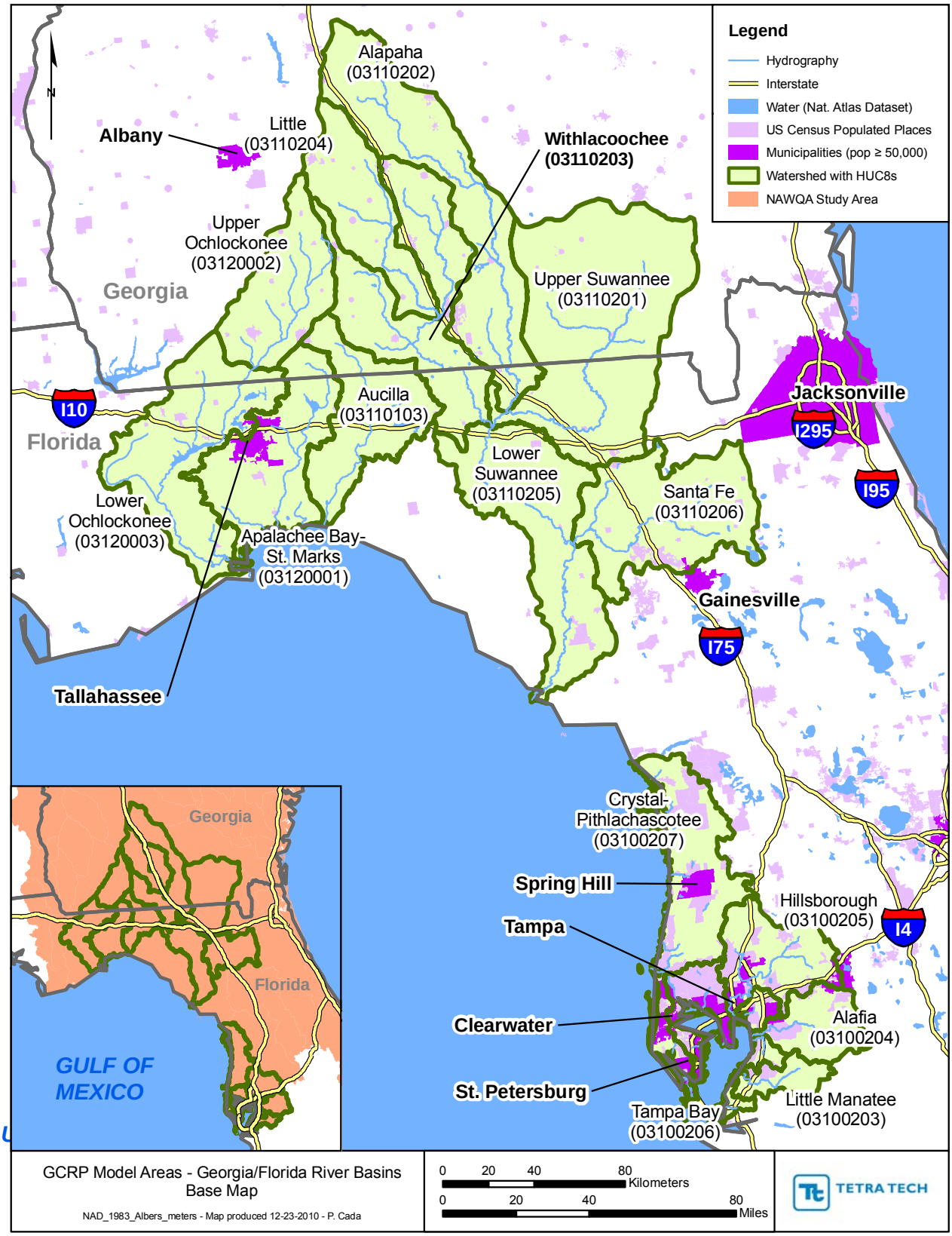


**Figure 1. Location of the Georgia-Florida Coastal basin.**

## 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 STATSGO major soils. The distribution of land use in the watershed is summarized in Table 2.

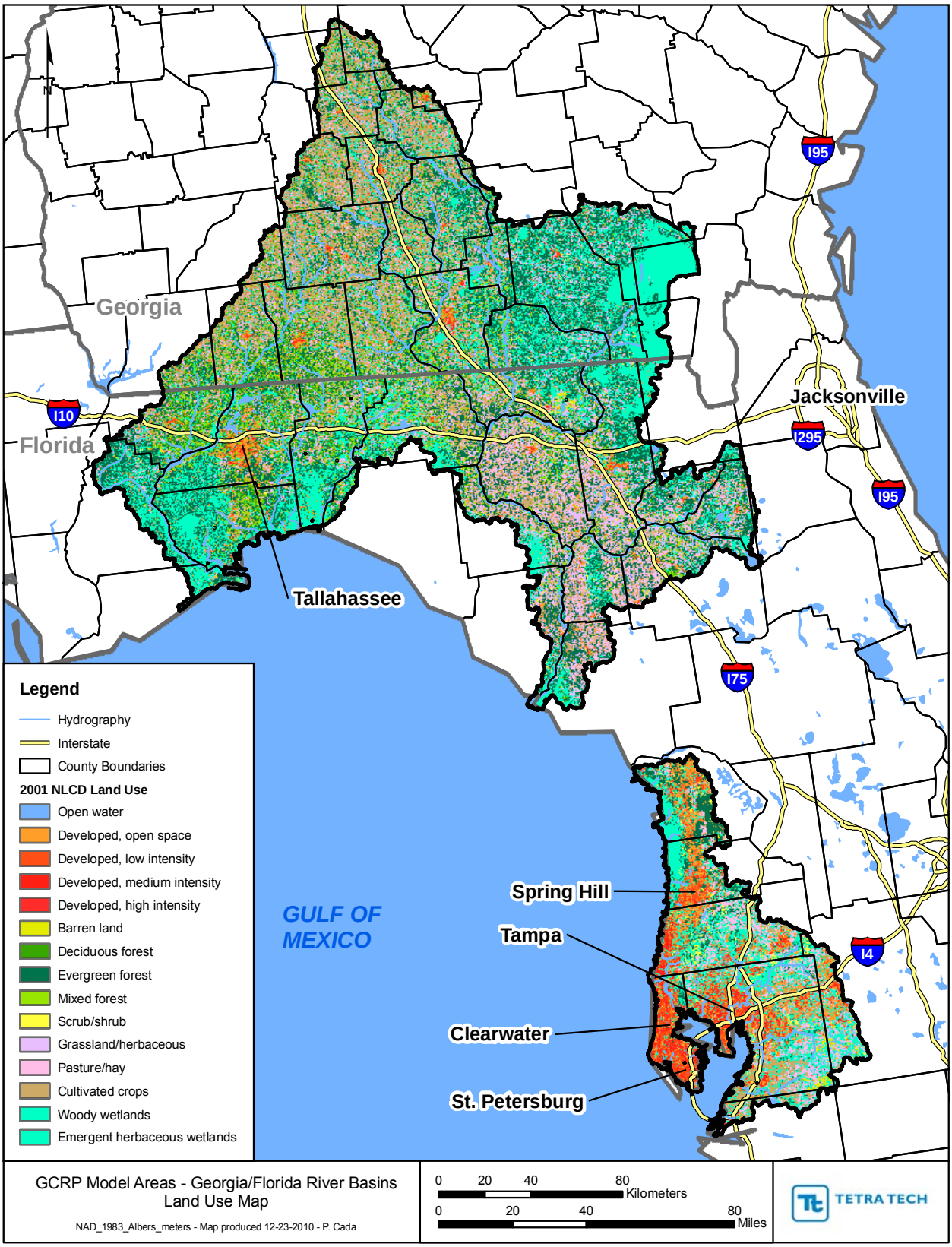


**Figure 2. Land use in the Georgia-Florida Coastal basin.**

**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 |
| 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 Georgia-Florida Coastal 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 | | | | | | | |
| Little Manatee 03100203 | 3.28 | 12.89 | 5.92 | 3.77 | 0.41 | 11.02 | 8.32 | 9.61 | 35.45 | 51.00 | 64.58 | 206.25 |
| Alafia 03100204 | 14.54 | 57.09 | 20.05 | 8.94 | 1.69 | 18.31 | 16.32 | 63.67 | 42.11 | 19.43 | 154.34 | 416.49 |
| Hillsborough 03100205 | 6.95 | 109.61 | 52.21 | 30.46 | 9.82 | 1.53 | 36.32 | 30.35 | 115.04 | 15.32 | 238.80 | 646.41 |
| Tampa Bay 03100206 | 14.74 | 85.28 | 97.65 | 66.80 | 23.62 | 0.60 | 16.16 | 17.35 | 22.23 | 30.04 | 115.03 | 489.49 |
| Crystal-Pithlachascotee 03100207 | 13.46 | 171.27 | 155.40 | 66.08 | 14.78 | 2.96 | 193.61 | 49.35 | 78.46 | 2.07 | 304.20 | 1,051.64 |
| Aucilla 03110103 | 2.56 | 37.36 | 4.58 | 0.88 | 0.40 | 0.87 | 407.91 | 80.61 | 48.99 | 79.08 | 301.57 | 964.81 |
| Upper Suwannee 03110201 | 8.51 | 92.49 | 21.25 | 2.83 | 1.05 | 9.98 | 930.65 | 304.63 | 51.51 | 40.42 | 1,144.83 | 2,608.16 |
| Alapaha 03110202 | 11.15 | 83.39 | 22.97 | 5.34 | 3.31 | 1.38 | 648.83 | 141.50 | 110.92 | 390.06 | 364.90 | 1,783.76 |
| Withlacoochee 03110203 | 7.96 | 82.00 | 22.55 | 6.45 | 3.29 | 0.95 | 565.93 | 133.57 | 115.66 | 362.75 | 209.62 | 1,510.74 |
| Little 03110204 | 6.22 | 38.31 | 13.15 | 2.53 | 1.09 | 0.88 | 263.72 | 57.54 | 83.81 | 282.16 | 126.03 | 875.42 |
| Lower Suwannee 03110205 | 8.63 | 85.64 | 16.23 | 1.66 | 0.35 | 2.02 | 536.15 | 295.65 | 204.14 | 158.13 | 193.62 | 1,502.22 |
| Santa Fe 03110206 | 19.51 | 70.92 | 15.33 | 3.41 | 0.97 | 4.47 | 534.92 | 268.37 | 166.54 | 68.38 | 202.26 | 1,355.07 |
| Apalachee Bay-St. Marks 03120001 | 4.47 | 91.70 | 19.32 | 7.09 | 2.23 | 2.36 | 560.43 | 90.09 | 33.53 | 33.62 | 295.04 | 1,139.88 |
| Upper Ochlockonee 03120002 | 5.53 | 42.28 | 13.04 | 2.11 | 1.11 | 1.11 | 328.10 | 67.64 | 62.55 | 264.89 | 113.10 | 901.45 |
| Lower Ochlockonee 03120003 | 18.55 | 70.17 | 12.40 | 2.08 | 0.69 | 3.27 | 679.84 | 91.14 | 37.14 | 76.99 | 490.00 | 1,482.26 |
| Total | 121.29 | 950.82 | 413.86 | 167.24 | 52.89 | 30.87 | 5,666.23 | 1,597.45 | 1,015.47 | 1,788.59 | 3,860.20 | 15,664.90 |

[a]The percent imperviousness applied to each of the developed land uses is as follows: open space (7.20%), low density (31.87%), medium density (60.14%), and high density (87.47%).

## 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 Georgia-Florida Coastal basin**

| NPDES ID | Name | Design flow (MGD) | Observed flow (MGD) (1991-2006 average) |
|---|---|---|---|
| FL0029033 | CITY OF QUINCY WWTP | 1.5 | 1.0 |
| FL0025518 | ARVAH B. HOPKINS GENERATING | 1.9 | 0.3 |
| GA0001279 | AFFINITY FOODS OF GA | | 0.5 |
| GA0024082 | THOMASVILLE WPCP | 6.5 | 3.7 |
| GA0001678 | ENGELHARD CORPORATION | | 1.1 |
| FL0001465 | GOLDKIST INC - LIVE OAK PROCES | 1.5 | 1.3 |
| GA0024911 | ADEL WPCP | 2.5 | 1.3 |
| GA0000124 | TIFTON ALUMUNUM CO | | 0.3 |
| FL0027880 | JASPER-WWTP | 1.2 | 0.7 |
| GA0020222 | VALDOSTA (MUD CREEK WPCP) | 3.2 | 2.1 |
| GA0025852 | ASHBURN (WPCP) | 1.2 | 0.9 |
| FL0028126 | STARKE-MUNICIPAL STP | 1.7 | 1.7 |
| FL0002518 | ST. MARKS POWDER, INC. | 0.8 | 21.4 |
| FL0025526 | SAM O. PURDOM GEN STATION | | 21.0 |
| FL0027839 | MONTICELLO-STP | 1.0 | 10.7 |
| FL0026557 | PLANT CITY STP | 8.0 | 3.6 |
| FL0040983 | HILLSBOROUGH CTY VALRICO WWTP | 6.0 | 5.2 |
| FL0029653 | AOC, LLC | | 0.1 |
| FL0000523 | CF INDUSTRIES - BARTOW PHOS. | | 4.0 |
| FL0001589 | MOSAIC FERTILIZER, LLC - BARTO | | 1.7 |
| FL0034657 | CORONET INDUSTRIES INC | | 62.7 |
| FL0043869 | TAMPA ELEC-POLK POWER STATION | | 2.7 |
| FL0028061 | HILLSBOROUGH CO-SOUTHWEST WTP | 4.0 | 1.6 |
| FL0030406 | TARPON SPRINGS STP | 4.0 | 3.2 |
| FL0021326 | DUNEDIN-MAINLAND STP | 6.0 | 5.8 |
| FL0021857 | CLEARWATER-MARSHALL ST STP | 10.0 | 6.7 |
| FL0034789 | MID-COUNTY SERVICES, INC | 0.9 | 1.1 |
| FL0000159 | PROGRESS ENERGY CRYSTAL RIVER | 0.7 | 0.0 |

| | | | |
|---|---|---|---|
| FL0036366 | PROGRESS ENERGY CRYSTAL R 4&5 | 99.0 | 4.0 |
| FL0027821 | RIVER OAKS AWWTP | 10.0 | 8.0 |
| FL0021865 | CLEARWATER-EAST WWTF | 4.3 | 10.2 |
| FL0026603 | LARGO, CITY OF | 15.0 | 9.1 |
| FL0000264 | IMC-AGRICO CO - PORT SUTTON | 0.5 | 3.1 |
| FL0000809 | TAMPA ELEC COMPANY-FJ GANNON | | 0.2 |
| FL0020940 | HOWARD F CURREN AWTP | 96.0 | 148.8 |
| FL0040614 | HILLSBORO CO - FALKENBURG RD A | 6.0 | 9.3 |
| FL0027651 | CITY OF OLDSMAR | 2.3 | 1.2 |
| FL0041670 | NORTHWEST REGIONAL WRF | 5.0 | 3.5 |

Most of these point sources have reasonably complete monitoring for total phosphorus and total suspended solids (TSS). In the Georgia-Florida Coastal basin more dischargers also report total nitrogen (unlike other study areas) due to 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, total suspended solids 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 2002. A total of 51 precipitation stations were identified for use in the Georgia-Florida Coastal watershed model with a common period of record of 10/1/1971-9/30/2002 (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 Georgia-Florida Coastal watershed model**

| COOP ID | Name | Latitude | Longitude | Temperature | Elevation (m) |
|---|---|---|---|---|---|
| 097276 | QUITMAN 2 NW | 30.7836 | -83.5691 | x | 56 |
| 098666 | THOMASVILLE 3 NE | 30.8673 | -83.9318 | x | 79 |
| 090140 | ALBANY 3 SE | 31.5339 | -84.1488 | x | 55 |
| 098703 | TIFTON | 31.4462 | -83.4766 | x | 116 |
| 096087 | MOULTRIE 2 ESE | 31.1769 | -83.7492 | x | 104 |
| 080478 | BARTOW | 27.8986 | -81.8432 | x | 38 |
| 081046 | BROOKSVILLE CHIN HILL | 28.6164 | -82.3657 | x | 73 |
| 084731 | LAKE CITY 2 E | 30.1854 | -82.5942 | x | 59 |
| 085275 | MADISON | 30.4517 | -83.4119 | x | 37 |
| 087205 | PLANT CITY | 28.0236 | -82.1422 | x | 37 |

| COOP ID | Name | Latitude | Longitude | Temperature | Elevation (m) |
|---|---|---|---|---|---|
| 087851 | SAINT LEO | 28.3379 | -82.2600 | x | 58 |
| 099186 | WAYCROSS 4 NE | 31.2515 | -82.3127 | x | 44 |
| 084273 | INGLIS 3 E | 29.0254 | -82.6157 | | 9 |
| 084797 | LAKELAND | 28.0207 | -81.9218 | | 44 |
| 080975 | BRANFORD | 29.9625 | -82.9107 | | 9 |
| 082391 | DOWLING PARK 1 W | 30.2498 | -83.2593 | | 16 |
| 088758 | TALLAHASSEE WSO AP | 30.3932 | -84.3533 | x | 17 |
| 088788 | TAMPA WSCMO AP | 27.9615 | -82.5403 | x | 6 |
| 090586 | BAINBRIDGE INTL PAPER C | 30.8229 | -84.6175 | | 58 |
| 093312 | FARGO | 30.6908 | -82.5632 | | 35 |
| 096879 | PEARSON | 31.2928 | -82.8422 | | 62 |
| 082008 | CROSS CITY 2 WNW | 29.6497 | -83.1663 | x | 13 |
| 083956 | HIGH SPRINGS | 29.8287 | -82.5972 | x | 20 |
| 084289 | INVERNESS 3 SE | 28.8032 | -82.3124 | x | 12 |
| 085879 | MONTICELLO WTP | 30.4923 | -83.7832 | x | 30 |
| 087025 | PERRY | 30.0987 | -83.5742 | x | 14 |
| 087886 | ST PETERSBURG | 27.7632 | -82.6272 | x | 2 |
| 088824 | TARPON SPRINGS SWG PLNT | 28.1500 | -82.7500 | x | 2 |
| 090010 | ABBEVILLE 4 S | 31.9381 | -83.3078 | | 73 |
| 091500 | CAMILLA 3 SE | 31.1904 | -84.2035 | x | 53 |
| 092266 | CORDELE | 31.9848 | -83.7758 | x | 94 |
| 092783 | DOUGLAS | 31.4890 | -82.8205 | x | 71 |
| 093386 | FITZGERALD | 31.7108 | -83.2516 | x | 113 |
| 093460 | FOLKSTON 3 SW | 30.7987 | -82.0181 | | 9 |
| 083986 | HILLSBOROUGH RVR ST PK | 28.1429 | -82.2269 | | 16 |
| 086880 | PARRISH | 27.6089 | -82.3478 | x | 18 |
| 093465 | FOLKSTON 9 SW | 30.7400 | -82.1277 | x | 37 |
| 087440 | RAIFORD STATE PRISON | 30.0678 | -82.1928 | x | 37 |
| 085539 | MAYO | 30.0565 | -83.1818 | x | 20 |
| 085099 | LIVE OAK | 30.2890 | -82.9650 | x | 37 |
| 084394 | JASPER | 30.5229 | -82.9446 | x | 45 |
| 098974 | VALDOSTA 2 S | 30.8056 | -83.2736 | | 81 |
| 083153 | FORT GREEN 12 WSW | 27.5706 | -82.1377 | | 34 |
| 089795 | WOODRUFF DAM | 30.7220 | -84.8742 | | 33 |

| COOP ID | Name | Latitude | Longitude | Temperature | Elevation (m) |
|---|---|---|---|---|---|
| 089120 | USHER TOWER | 29.4084 | -82.8186 | x | 10 |
| 094429 | HOMERVILLE 5 N | 31.0767 | -82.8002 | x | 57 |
| 090406 | ASHBURN 3 ENE | 31.7003 | -83.6230 | x | 133 |
| 080945 | BRADENTON 5 ESE | 27.4467 | -82.5014 | x | 6 |
| 087429 | QUINCY 3 SSW | 30.6001 | -84.5499 | x | 75 |
| 089430 | WEEKI WACHEE | 28.5175 | -82.5755 | x | 6 |

## Watershed Segmentation

The Georgia-Florida Coastal basin was divided into 108 subwatersheds for the purposes of modeling (Figure 3). Ochlockonee River at USGS 02329000 was chosen for initial calibration. The model encompasses the complete watershed and does not require specification of any upstream boundary conditions for application.

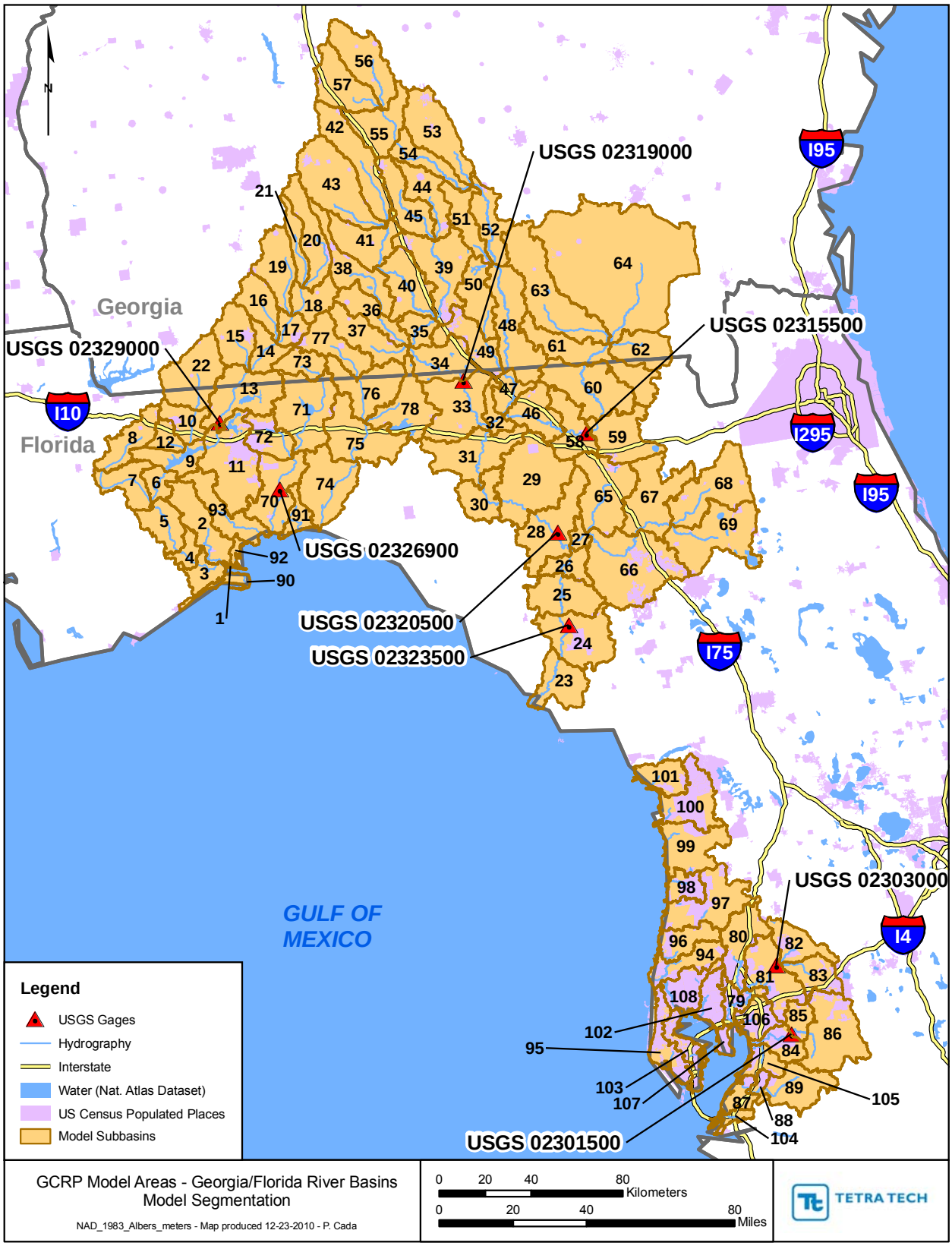


**Figure 3. Model segmentation and USGS stations utilized for the Georgia-Florida Coastal basin.**

## Calibration Data and Locations

The specific site chosen for initial calibration was the Ochlockonee River at Havana, FL, a flow and water quality monitoring location that approximately coincides with the mouth of an 8-digit HUC at its outflow to the Ochlockonee River. The Ochlockonee River 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 Ochlockonee River were not fully transferable to other portions of the Georgia-Florida Coastal basin, and additional calibration was conducted at multiple gage locations.

**Table 5. Calibration and validation locations in the Georgia-Florida Coastal basin**

| Station name | USGS ID | Drainage area ($mi^2$) | Hydrology calibration | Water quality calibration |
|---|---|---|---|---|
| Alafia River at Lithia, FL | 02301500 | 335 | x | x |
| Hillsborough River near Zephyrhills, FL | 02303000 | 220 | x | x |
| Suwanee River at White Springs, FL | 02315500 | 2430 | x | |
| Withlacoochee River near Pinetta, FL | 02319000 | 2120 | x | |
| Suwanee River near Branford, FL | 02320500 | 7880 | x | x |
| Suwanee River near Wilcox, FL | 02323500 | 9640 | x | |
| St. Marks River near Newport, FL | 02326900 | 535 | x | |
| Ochlockonee River at Havana, FL | 02329000 | 1140 | x | x |

The model hydrology calibration period was set to Water Years 1992-2002 (within the 32-year period of record for modeling). Hydrologic validation was then performed on Water Years 1982-1992. Water quality calibration used calendar years 1992-2002, while validation used 1982-1992.

# SWAT Modeling

## Assumptions

## Hydrology Calibration

A spatial calibration approach was adopted for GCRP-SWAT modeling for the Georgia-Florida Coastal basin. A systematic adjustment of parameters was adopted and some adjustments were 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 (Ochlockonee River) includes nine subwatersheds and is generally representative of the general land use characteristics of the overall watershed. 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 upper portion of the Georgia-Florida Coastal basin predicted by the SWAT model over the 32-year simulation period is as follows:

```
PRECIP =   1323.6 MM
SNOW FALL =    1.53 MM
SNOW MELT =     1.52 MM
SUBLIMATION =     0.01 MM
SURFACE RUNOFF Q =   167.16 MM
LATERAL SOIL Q =   18.39 MM
TILE Q =     0.00 MM
GROUNDWATER (SHAL AQ) Q =   223.44 MM
REVAP (SHAL AQ => SOIL/PLANTS) =  104.93 MM
DEEP AQ RECHARGE =    44.75 MM
TOTAL AQ RECHARGE =  374.05 MM
TOTAL WATER YLD =   397.68 MM
PERCOLATION OUT OF SOIL =  369.14 MM
ET =    766.5 MM
PET =   1576.8MM
TRANSMISSION LOSSES =    11.31 MM
```

The water balance of the lower portion of the Georgia-Florida Coastal basin predicted by the SWAT model over the 32-year simulation period is as follows:

```
PRECIP =   1314.8 MM
SNOW FALL =    0.10 MM
SNOW MELT =     0.10 MM
SUBLIMATION =     0.00 MM
SURFACE RUNOFF Q =   169.83 MM
```

```
LATERAL SOIL Q =   31.62 MM
TILE Q =     0.00 MM
GROUNDWATER (SHAL AQ) Q =   143.04 MM
REVAP (SHAL AQ => SOIL/PLANTS) =  100.62 MM
DEEP AQ RECHARGE =   162.45 MM
TOTAL AQ RECHARGE =  406.12 MM
TOTAL WATER YLD =   344.49 MM
PERCOLATION OUT OF SOIL =  409.81 MM
ET =    701.1 MM
PET =   1678.8MM
TRANSMISSION LOSSES =     0.00 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_N1 (Manning's "n" value for tributary channels)
- CH_N2 (Manning's "n" value for main channels)

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

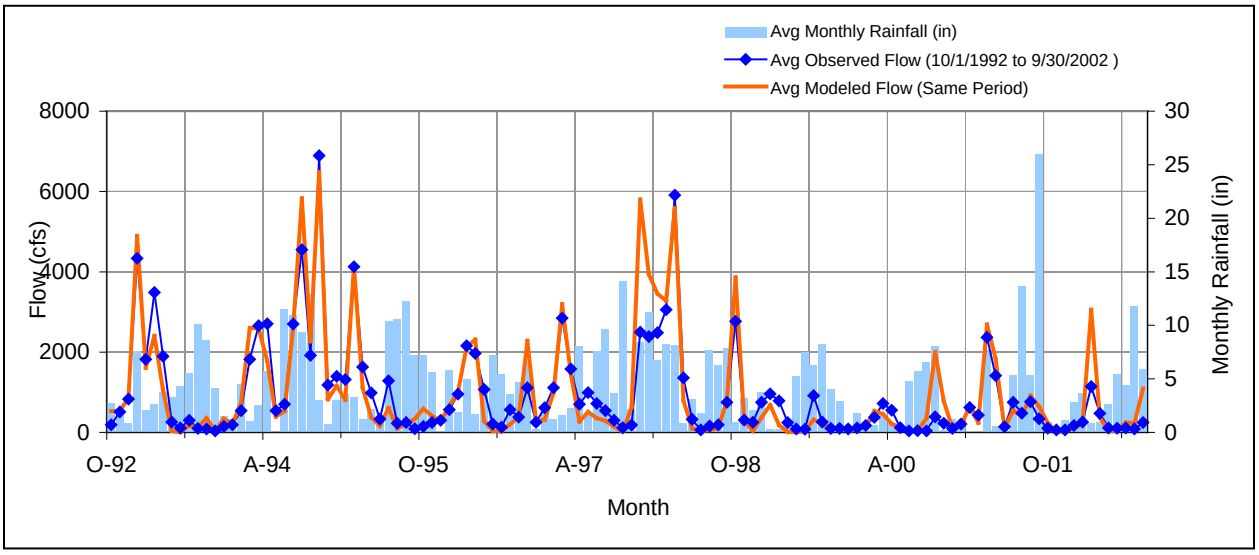


**Figure 4. Mean monthly flow at USGS 02329000 Ochlockonee River at Havana, FL – calibration period.**

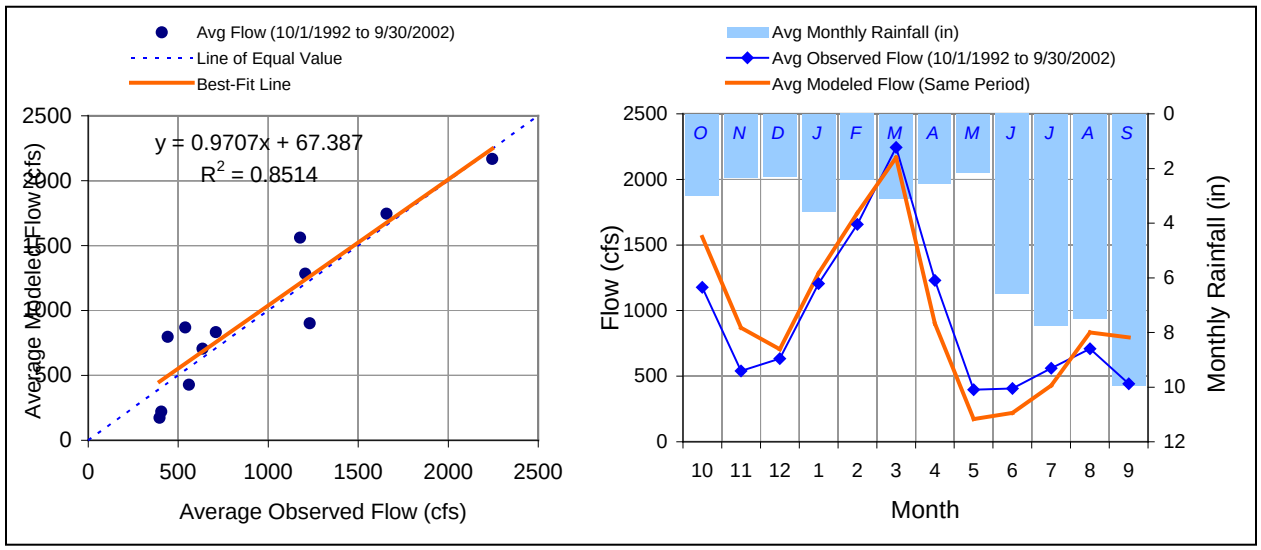


**Figure 5. Seasonal regression and temporal aggregate at USGS 02329000 Ochlockonee River at Havana, FL – calibration period.**

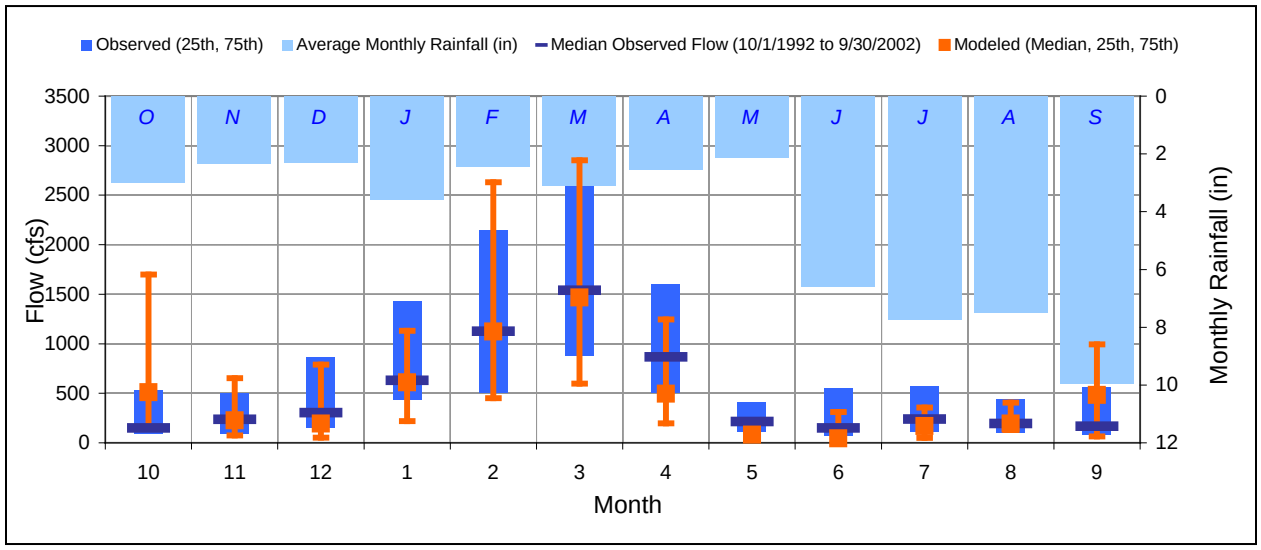


**Figure 6. Seasonal medians and ranges at USGS 02329000 Ochlockonee River at Havana, FL – calibration period.**

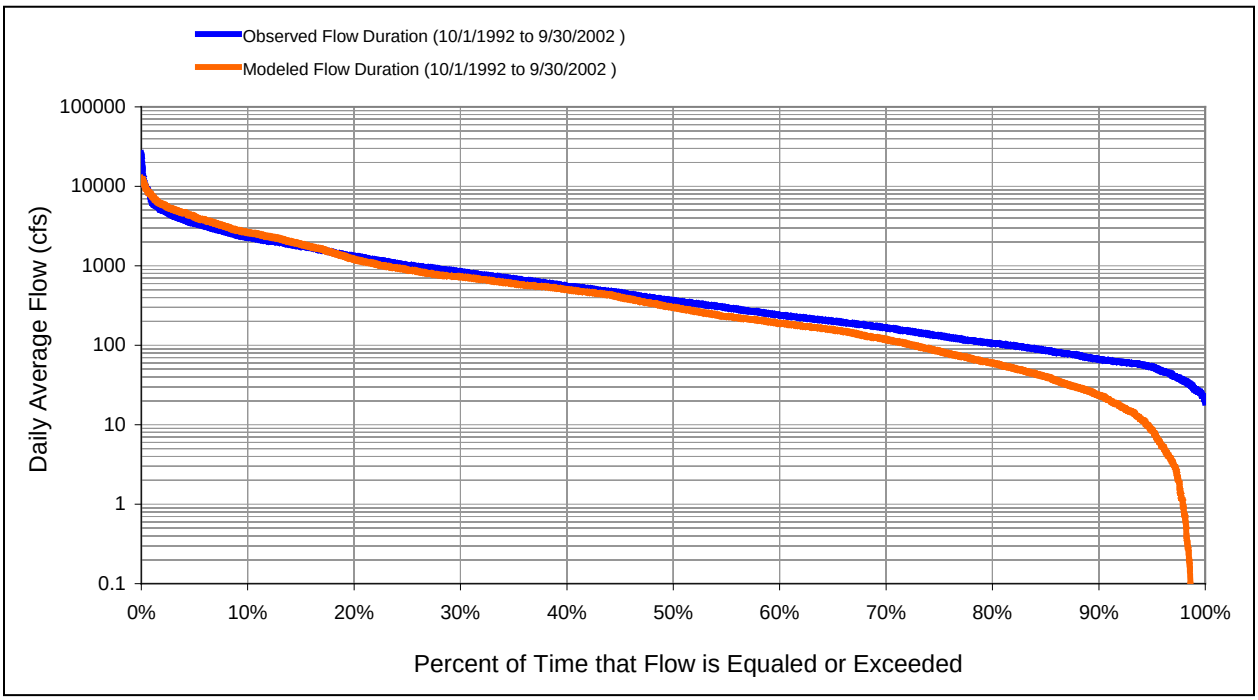


**Figure 7. Flow exceedance at USGS 02329000 Ochlockonee River at Havana, FL – calibration period.**

**Table 6. Summary statistics at USGS 02329000 Ochlockonee River at Havana, FL – calibration period**

| SWAT Simulated Flow | | Observed Flow Gage | |
|---|---|---|---|
| REACH OUTFLOW FROM OUTLET 13<br><br>10-Year Analysis Period: 10/1/1992 - 9/30/2002<br>Flow volumes are (inches/year) for upstream drainage area | | USGS 02329000 OCHLOCKONEE RIVER NR HAVANA, FLA.<br><br>Hydrologic Unit Code: 3120003<br>Latitude: 30.55408644<br>Longitude: -84.3840715<br>Drainage Area (sq-mi): 1140 | |
| Total Simulated In-stream Flow: | **11.57** | Total Observed In-stream Flow: | **11.10** |
| | | | |
| Total of simulated highest 10% flows: | **6.08** | Total of Observed highest 10% flows: | **5.32** |
| Total of Simulated lowest 50% flows: | **0.66** | Total of Observed Lowest 50% flows: | **0.93** |
| | | | |
| Simulated Summer Flow Volume (months 7-9): | **2.06** | Observed Summer Flow Volume (7-9): | **1.72** |
| Simulated Fall Flow Volume (months 10-12): | **3.14** | Observed Fall Flow Volume (10-12): | **2.36** |
| Simulated Winter Flow Volume (months 1-3): | **5.10** | Observed Winter Flow Volume (1-3): | **5.01** |
| Simulated Spring Flow Volume (months 4-6): | **1.27** | Observed Spring Flow Volume (4-6): | **2.00** |
| | | | |
| Total Simulated Storm Volume: | **3.36** | Total Observed Storm Volume: | **3.51** |
| Simulated Summer Storm Volume (7-9): | **0.58** | Observed Summer Storm Volume (7-9): | **0.53** |
| *Errors (Simulated-Observed)* | *Error Statistics* | *Recommended Criteria* | |
| Error in total volume: | 4.25 | 10 | |
| **Error in 50% lowest flows:** | **-28.91** | **10** | |
| Error in 10% highest flows: | 14.27 | 15 | |
| Seasonal volume error - Summer: | 19.83 | 30 | |
| **Seasonal volume error - Fall:** | **33.10** | **30** | |
| Seasonal volume error - Winter: | 1.60 | 30 | |
| **Seasonal volume error - Spring:** | **-36.43** | **30** | |
| Error in storm volumes: | -4.28 | 20 | |
| Error in summer storm volumes: | 10.50 | 50 | |
| Nash-Sutcliffe Coefficient of Efficiency, E: | 0.711 | Model accuracy increases | |
| Baseline adjusted coefficient (Garrick), E': | 0.539 | as E or E' approaches 1.0 | |

## Hydrology Validation

Hydrology validation for Ochlockonee River was performed for the period 10/1/1982 through 9/30/1992. 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).

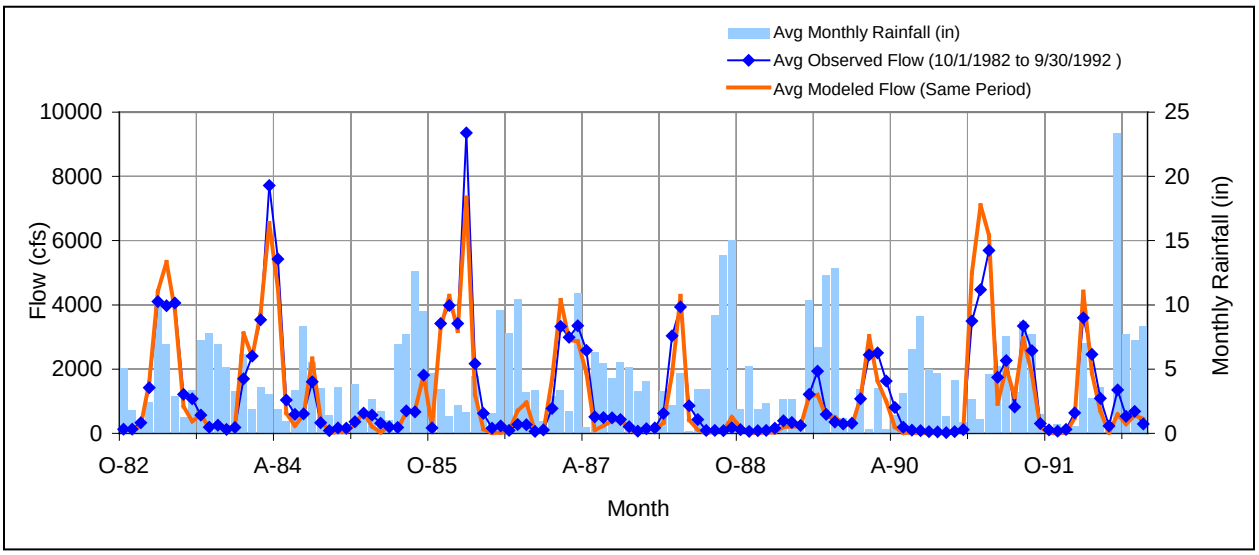


**Figure 8. Mean monthly flow at USGS 02329000 Ochlockonee River at Havana, FL – validation period.**

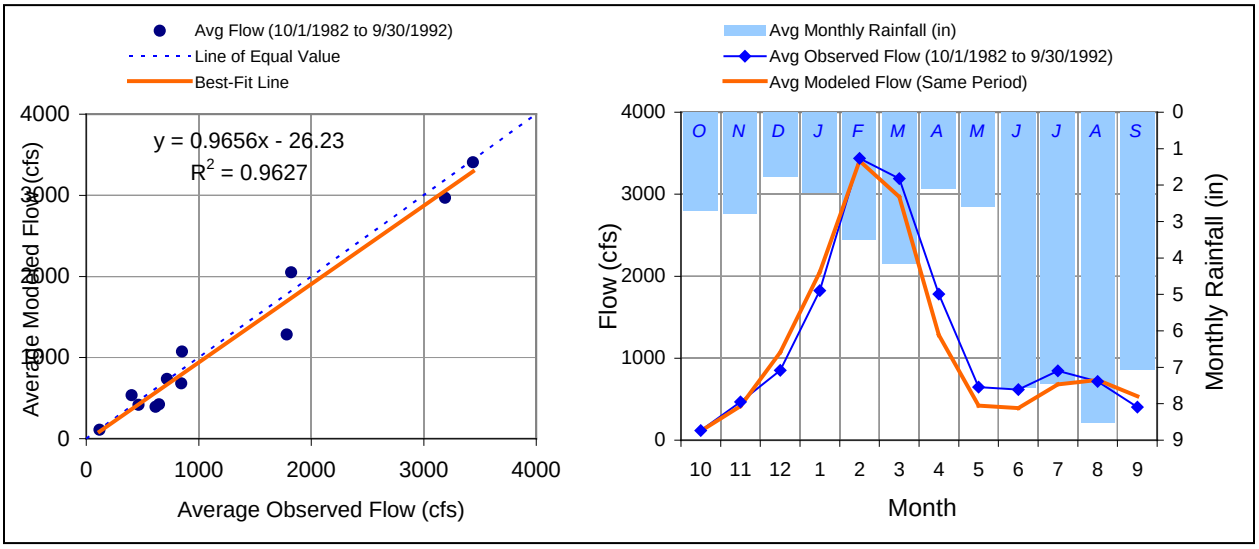


**Figure 9. Seasonal regression and temporal aggregate at USGS 02329000 Ochlockonee River at Havana, FL – validation period.**

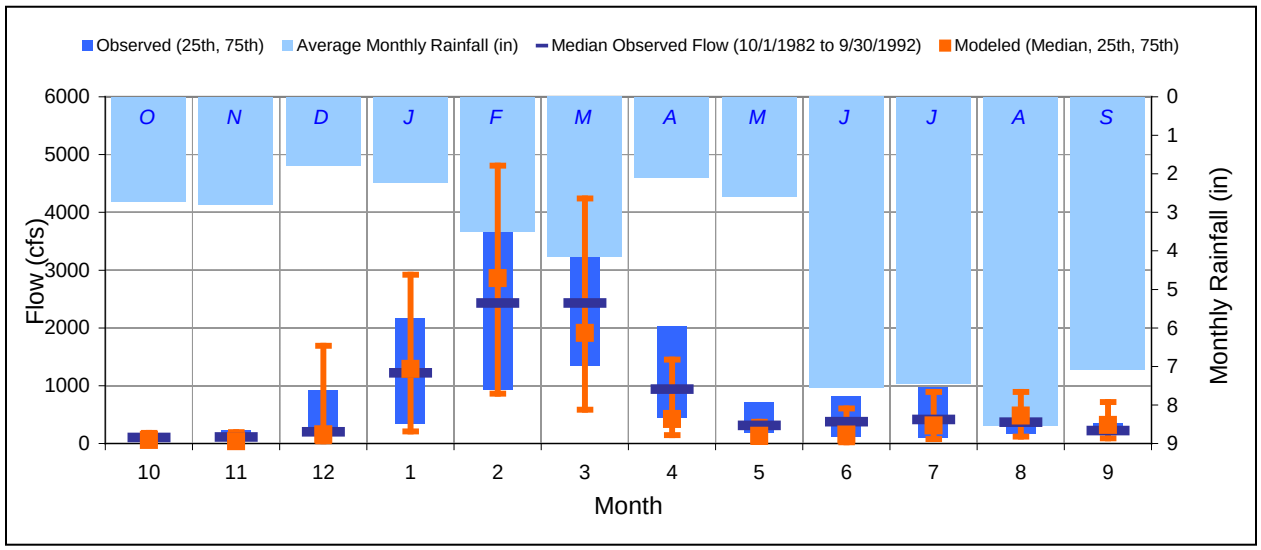


**Figure 10. Seasonal medians and ranges at USGS 02329000 Ochlockonee River at Havana, FL – validation period.**

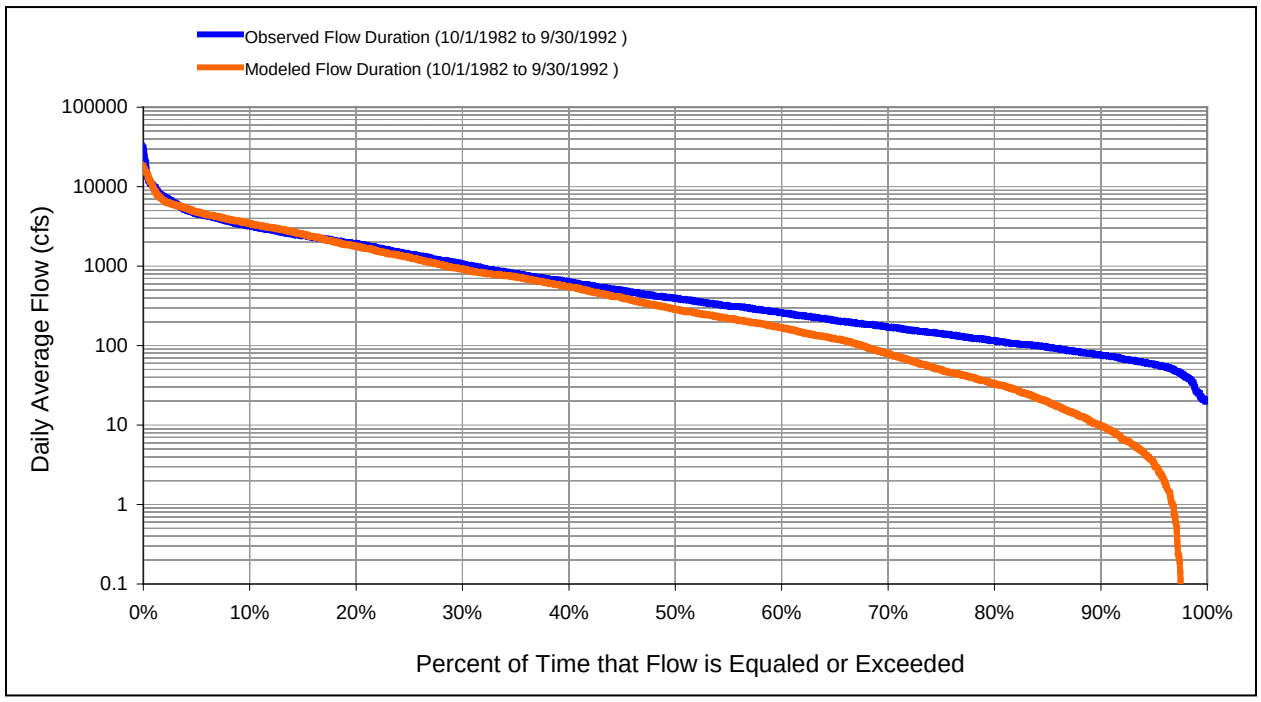


**Figure 11. Flow exceedance at USGS 02329000 Ochlockonee River at Havana, FL – validation period.**

**Table 7. Summary statistics at USGS 02329000 Ochlockonee River at Havana, FL – validation period**

| SWAT Simulated Flow | | Observed Flow Gage | |
|---|---|---|---|
| REACH OUTFLOW FROM OUTLET 13<br><br>10-Year Analysis Period: 10/1/1982 - 9/30/1992<br>Flow volumes are (inches/year) for upstream drainage area | | USGS 02329000 OCHLOCKONEE RIVER NR HAVANA, FLA.<br><br>Hydrologic Unit Code: 3120003<br>Latitude: 30.55408644<br>Longitude: -84.3840715<br>Drainage Area (sq-mi): 1140 | |
| Total Simulated In-stream Flow: | **13.85** | Total Observed In-stream Flow: | **14.66** |
| | | | |
| Total of simulated highest 10% flows: | **7.22** | Total of Observed highest 10% flows: | **7.36** |
| Total of Simulated lowest 50% flows: | **0.51** | Total of Observed Lowest 50% flows: | **0.99** |
| | | | |
| Simulated Summer Flow Volume (months 7-9): | **1.95** | Observed Summer Flow Volume (7-9): | **1.97** |
| Simulated Fall Flow Volume (months 10-12): | **1.60** | Observed Fall Flow Volume (10-12): | **1.44** |
| Simulated Winter Flow Volume (months 1-3): | **8.22** | Observed Winter Flow Volume (1-3): | **8.24** |
| Simulated Spring Flow Volume (months 4-6): | **2.07** | Observed Spring Flow Volume (4-6): | **3.00** |
| | | | |
| Total Simulated Storm Volume: | **4.01** | Total Observed Storm Volume: | **4.94** |
| Simulated Summer Storm Volume (7-9): | **0.53** | Observed Summer Storm Volume (7-9): | **0.61** |
| *Errors (Simulated-Observed)* | *Error Statistics* | *Recommended Criteria* | |
| Error in total volume: | -5.54 | 10 | |
| **Error in 50% lowest flows:** | **-48.00** | **10** | |
| Error in 10% highest flows: | -1.84 | 15 | |
| Seasonal volume error - Summer: | -1.04 | 30 | |
| Seasonal volume error - Fall: | 11.57 | 30 | |
| Seasonal volume error - Winter: | -0.26 | 30 | |
| **Seasonal volume error - Spring:** | **-31.19** | **30** | |
| Error in storm volumes: | -18.85 | 20 | |
| Error in summer storm volumes: | -12.44 | 50 | |
| Nash-Sutcliffe Coefficient of Efficiency, E: | 0.799 | Model accuracy increases | |
| Baseline adjusted coefficient (Garrick), E': | 0.649 | as E or E' approaches 1.0 | |

## Hydrology Results for Larger Watershed

As described above, parameters determined for the gage at Ochlockonee River were initially transferred to other gages in the watershed. However, changes to subwatershed level parameters were required to fit the model to the observed flows. In all, calibration and validation was pursued at a total of eight gages throughout the watershed. 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 | 02301500 | 02303000 | 02315500 | 02319000 | 02320500 | 02323500 | 02326900 | 02329000 |
|---|---|---|---|---|---|---|---|---|
| Error in total volume: | -4.77 | -0.21 | -8.07 | -1.91 | 2.22 | 3.45 | 4.32 | 4.25 |
| Error in 50% lowest flows: | 32.79 | 8.10 | 55.83 | 9.25 | 14.34 | 11.46 | 15.97 | -28.91 |
| Error in 10% highest flows: | -10.46 | -12.69 | -14.74 | -9.20 | -3.57 | 1.83 | 0.32 | 14.27 |
| Seasonal volume error - Summer: | 5.48 | 8.36 | 28.40 | 41.01 | 10.89 | 20.53 | -6.54 | 19.83 |
| Seasonal volume error - Fall: | 0.84 | -2.28 | 14.11 | 23.55 | 19.48 | 18.31 | 22.26 | 33.10 |
| Seasonal volume error - Winter: | -26.89 | -17.54 | -21.36 | -15.83 | -7.80 | -7.73 | 1.85 | 1.60 |
| Seasonal volume error - Spring: | -5.58 | 13.71 | -21.16 | -19.73 | -2.98 | -6.27 | 3.42 | -36.43 |
| Error in storm volumes: | -28.50 | -9.30 | -12.16 | -34.73 | 19.91 | -17.80 | 18.67 | -4.28 |
| Error in summer storm volumes: | -18.37 | 0.77 | 0.31 | -10.47 | 48.43 | -12.89 | -12.42 | 10.50 |
| Nash-Sutcliffe Coefficient of Efficiency, E: | 0.727 | 0.675 | 0.823 | 0.756 | 0.821 | 0.802 | 0.623 | 0.711 |
| Baseline adjusted coefficient (Garrick), E': | 0.527 | 0.495 | 0.588 | 0.572 | 0.599 | 0.545 | 0.412 | 0.539 |

**Table 9. Summary statistics (percent error): all stations - validation period**

| Station | 02301500 | 02303000 | 02315500 | 02319000 | 02320500 | 02323500 | 02326900 | 02329000 |
|---|---|---|---|---|---|---|---|---|
| Error in total volume: | 1.39 | 3.17 | -7.80 | -2.51 | -11.68 | -17.18 | -2.87 | -5.54 |
| Error in 50% lowest flows: | 8.63 | -3.25 | 42.55 | -36.60 | -22.56 | -32.66 | -4.93 | -48.00 |
| Error in 10% highest flows: | -3.36 | -4.80 | -19.13 | -0.51 | -6.19 | -4.00 | 2.96 | -1.84 |
| Seasonal volume error - Summer: | 3.79 | 9.87 | 6.07 | -14.33 | -20.22 | -19.58 | -12.90 | -1.04 |
| Seasonal volume error - Fall: | 54.39 | 7.84 | 97.49 | 29.83 | -3.66 | -17.71 | -3.76 | 11.57 |
| Seasonal volume error - Winter: | -35.46 | -14.76 | -13.63 | 1.90 | -6.19 | -10.92 | 1.01 | -0.26 |
| Seasonal volume error - Spring: | -7.98 | 6.66 | -30.57 | -21.71 | -17.18 | -22.74 | 3.05 | -31.19 |
| Error in storm volumes: | -19.86 | 3.38 | -7.60 | -35.83 | 26.96 | -6.77 | 11.11 | -18.85 |
| Error in summer storm volumes: | -22.13 | -3.79 | -12.02 | -36.70 | -0.67 | -23.61 | -19.59 | -12.44 |

| Station | 02301500 | 02303000 | 02315500 | 02319000 | 02320500 | 02323500 | 02326900 | 02329000 |
|---|---|---|---|---|---|---|---|---|
| Nash-Sutcliffe Coefficient of Efficiency, E: | 0.416 | 0.720 | 0.722 | 0.801 | 0.850 | 0.788 | 0.584 | 0.799 |
| Baseline adjusted coefficient (Garrick), E': | 0.334 | 0.448 | 0.613 | 0.636 | 0.658 | 0.536 | 0.292 | 0.649 |

## Water Quality Calibration and Validation

Initial calibration and validation of water quality was done on the Ochlockonee River (USGS 02329000), using 1992-2002 for calibration and 1982-1992 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 Ochlockonee River 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.

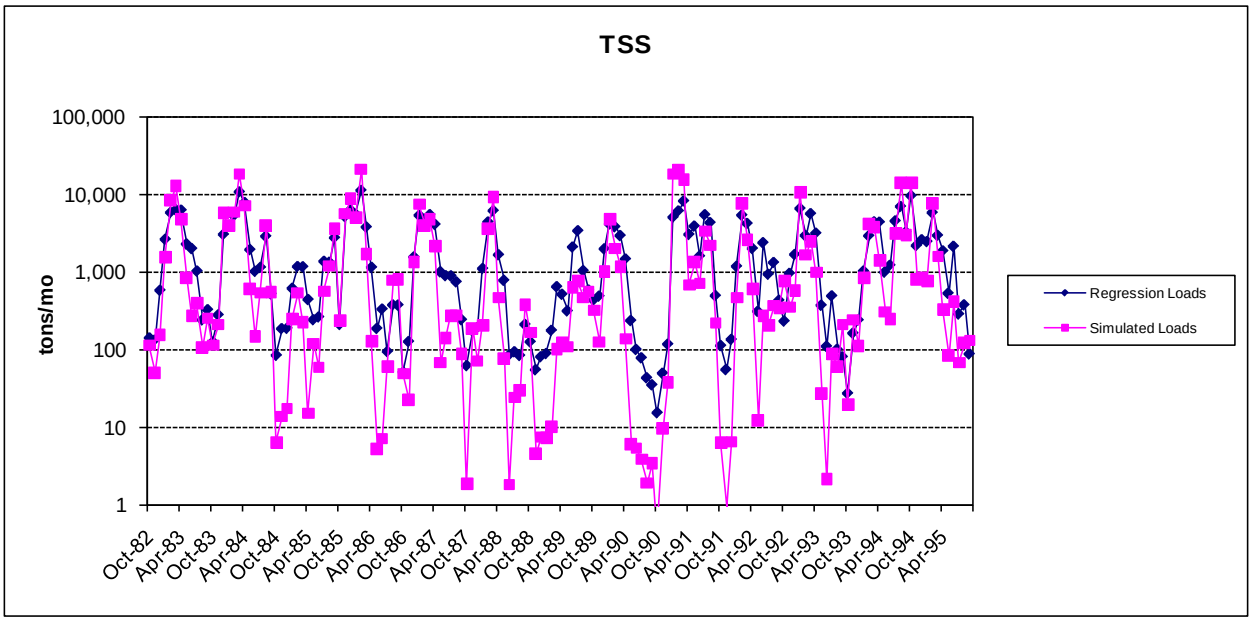


**Figure 12. Fit for monthly load of TSS at USGS 02329000 Ochlockonee River at Havana, FL.**

**Table 10. Model fit statistics (observed minus predicted) for monthly sediment loads using stratified regression at USGS 02329000 Ochlockonee River at Havana, FL**

| Statistic | Calibration period (1992-1995) | Validation period (1982-1992) |
|---|---|---|
| Relative Percent Error | 9.5% | -6.6% |
| Relative Average Absolute Error | 55.5% | 59.4% |
| Relative Median Absolute Error | 36.7% | 24.4% |

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.

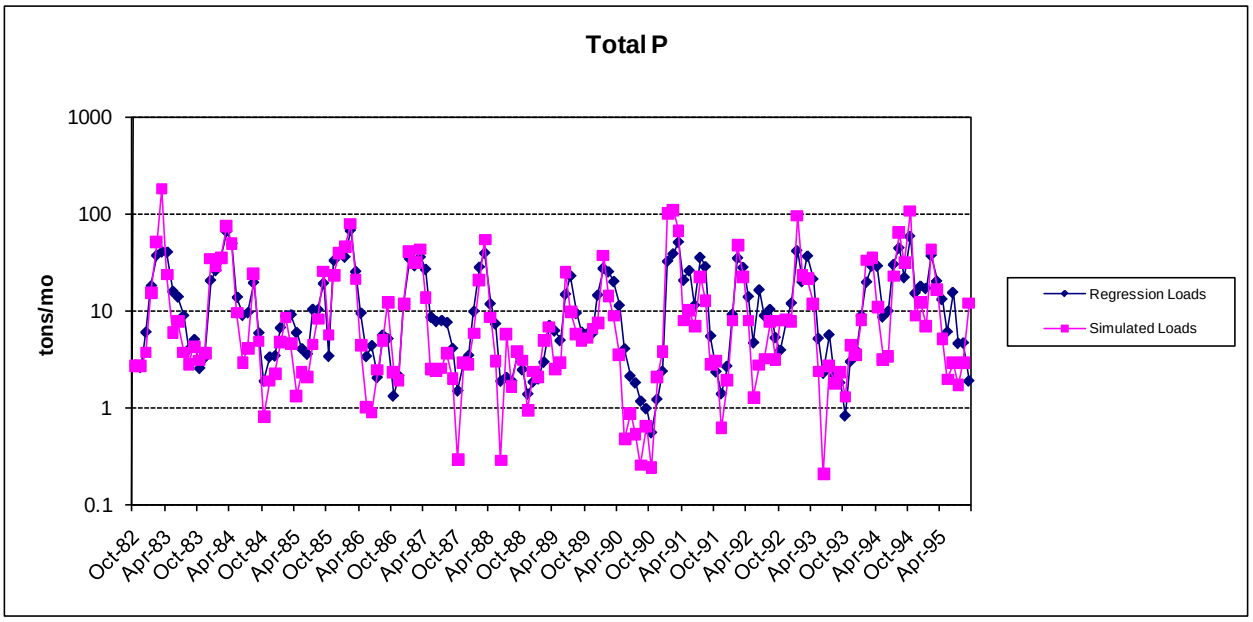


**Figure 13. Fit for monthly load of total phosphorus at USGS 02329000 Ochlockonee River at Havana, FL.**

**Table 11. Model fit statistics (observed minus predicted) for monthly phosphorus loads using stratified regression at USGS 02329000 Ochlockonee River at Havana, FL**

| Statistic | Calibration period (1992-1995) | Validation period (1982-1992) |
|---|---|---|
| Relative Percent Error | -7.4% | -5.8% |
| Average Absolute Error | 48.3% | 52.4% |
| Median Absolute Error | 22.8% | 34.2% |

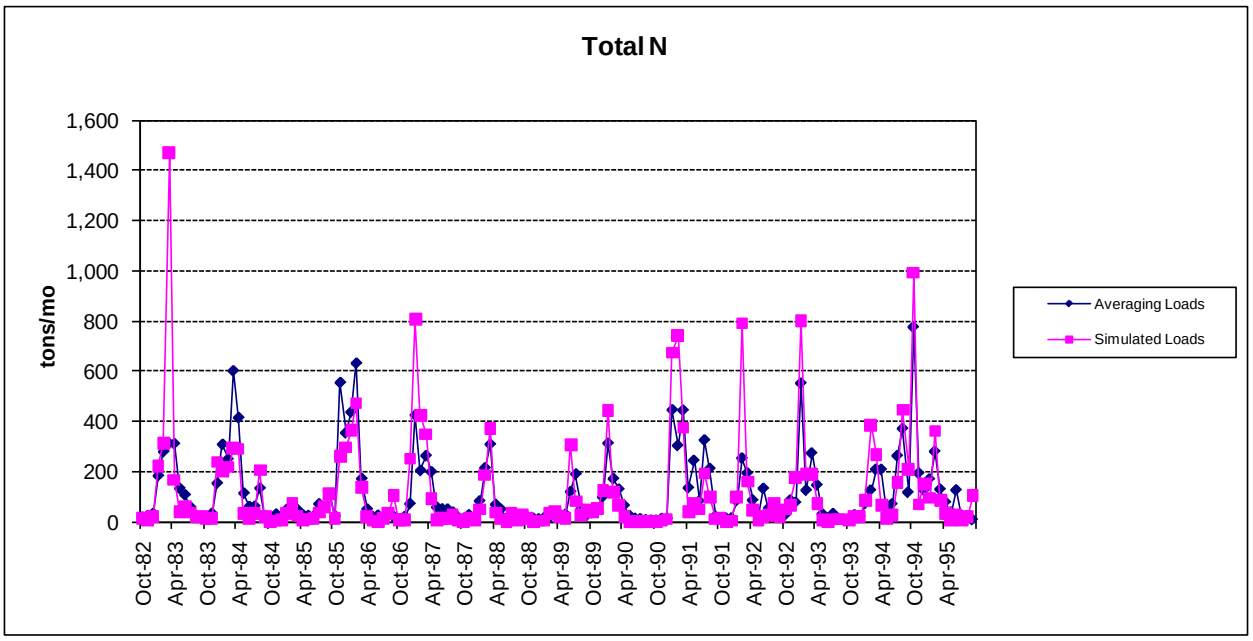


**Figure 14. Fit for monthly load of total nitrogen at USGS 02329000 Ochlockonee River at Havana, FL.**

**Table 12. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator at USGS 02329000 Ochlockonee River at Havana, FL**

| Statistic | Calibration period (1992-1995) | Validation period (1982-1992) |
|---|---|---|
| Relative Percent Error | -8.0% | -5.0% |
| Average Absolute Error | 49.2% | 58.6% |
| Median Absolute Error | 32.9% | 21.0% |

## Water Quality Results for Larger Watershed

As with hydrology, a spatial calibration approach was adopted. Ochlockonee River watershed SWAT model parameters for water quality were transferred to other portions of the watershed with necessary changes to subbasin 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 1992-2002**

| Station | 02301500 | 02303000 | 02320500 | 02329000 |
|---|---|---|---|---|
| Relative Percent Error TSS Load | 21.4% | 10.0% | -12.5% | 9.5% |
| Relative Percent Error TP Load | 16.5% | 27.1% | 6.6% | -7.4% |
| Relative Percent Error TN Load | 24.1% | -4.8% | 9.2% | -8.0% |

**Table 14. Summary statistics for water quality at all stations – validation period 1982-1992**

| Station | 02301500 | 02303000 | 02320500 | 02329000 |
|---|---|---|---|---|
| Relative Percent Error TSS Load | -11.1% | -7.8% | 18.1% | -6.6% |
| Relative Percent Error TP Load | -1.9% | 4.2% | 10.9% | -5.8% |
| Relative Percent Error TN Load | -26.1% | -20.2% | 15.5% | -5.0% |

# References

USEPA. 2008. Using the BASINS Meteorological Database (Version 2006). BASINS Technical Note 10. Office of Water, U.S. Environmental Protection Agency, Washington, DC.