Modeling Report

Lake Talquin – Including Ochlockonee River and Little River Nutrients

September 1, 2021

Version 5

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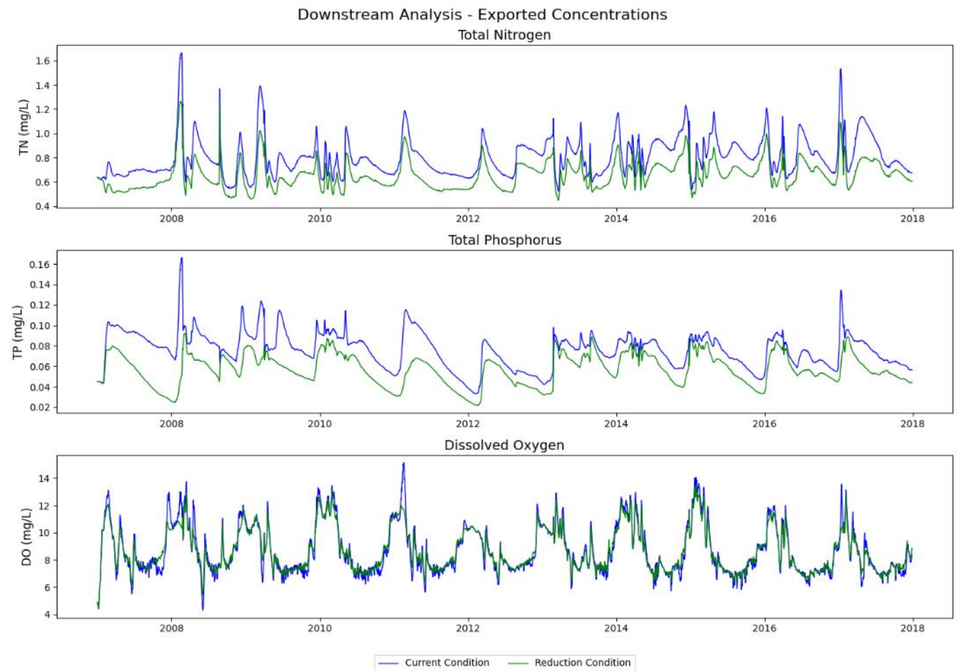
Downstream Analysis - Exported Concentrations
Total Nitrogen
TN (mg/L)
Total Phosphorus
TP (mg/L)
Dissolved Oxygen
DO (mg/L)
Current Condition
Reduction Condition

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Changes from Version 4 to 5

Calibrated Model Input Files

- No Changes

Model Report

- Updated watershed model application nutrient loading section, more discussion on event mean concentration adjustments during calibration process.

Appendix D Scenarios

- Updated the EMC section to include the results of the USGS LOADEST comparison between the prior model and the current model.

Changes from Version 3 to 4

Calibrated Model Input Files

- No Changes

Modeled Scenario Development

- Natural Condition Scenario
- Advanced Waste Water Treatment
- Low Flow Sensitivity Analysis
- See Appendix D Scenarios

Model Report

- Divided into three documents

Changes from Version 2 to 3

Lake Talquin Water Quality Model (WASP Version 8.32)

- Updated Little River and Ochlockonee River Boundaries for phosphorus, had mistakenly left boundary scale factor in distributed inputs which was used for a sensitivity run.
- Provided segment info file which adds meta data to Lake Talquin BMD2 file which makes it easier to calculate annual geometric means.

Modeling Report

- Corrected Zone Geomean table, fixed bad reference to cells

Changes from Version 1 to 2

Watershed Model

- Event Mean Concentrations changed for calibration

Ochlockonee River Model (WASP Version 8.32)

- Boundary concentrations updated due to watershed model adjustments
- Point Source discharge data updated based upon information provided by GAEPD
- Water Quality Model Changes for Calibration
  - 3.0000 Phytoplankton Maximum Growth Rate Constant @20 C (1/day)
  - 0.0800 Phytoplankton Death Rate Constant (Non-Zoo Predation) (1/day)
  - 0.5000 Detritus & Solids Light Extinction Multiplier 1/m/(mg/L)
  - 0.5000 DOC Light Extinction Multiplier (Values Below Modify Global Value)

Little River Model (WASP Version 8.32)

- Boundary concentrations updated due to watershed model adjustments

Lake Talquin Model (WASP Version 8.32)

- Boundary concentrations updated due to watershed model adjustments
- Updated Hopkins Power Plant loads for 2013 thru 2017. Information was provided by the City of Tallahassee

EFDC - Hydrodynamic

- No changes

WASP - Water Quality (WASP Version 8.32)

- Boundary concentrations updated due to watershed model adjustments
- Updated Hopkins Power Plant loads for 2013 thru 2017. Information was provided by the City of Tallahassee
- Water Quality Model Changes for Calibration
  - 0.0500 Nitrification Rate Constant @20 degree C (1/day)
  - 100.0000 Ammonia Partition Coefficient to Water Column Solids (L/kg)
  - 1000.0000 Orthophosphate Partition Coefficient to Water Column Solids (L/kg)

  - 0.0500 Dissolved Organic Nitrogen Mineralization Rate Constant @20 C (1/day)
  - 0.0500 CBOD Decay Rate Constant @20 C (1/day) (Watershed BOD)
  - 0.2000 CBOD Decay Rate Constant @20 C (1/day) (Biotic BOD)
  - 2.8000 Phytoplankton Maximum Growth Rate Constant @20 C (1/day) (Summer)
  - 2.6000 Phytoplankton Maximum Growth Rate Constant @20 C (1/day) (Spring)
  - 2.6000 Phytoplankton Maximum Growth Rate Constant @20 C (1/day)(Fall)
  - 75.0000 Phytoplankton Carbon to Chlorophyll Ratio (mg C/mg Chl) (Summer)
  - 14.0000 Optimal Temperature for Growth (C) (Spring)
  - 22.0000 Optimal Temperature for Growth (C) (Fall)
  - 0.0500 Shape parameter for below optimal temperatures (Spring)
  - 0.0500 Shape parameter for below optimal temperatures (Fall)
  - 0.0500 Shape parameter for above optimal temperatures (Spring)
  - 0.0500 Shape parameter for above optimal temperatures (Fall)
  - 0.0400 Phytoplankton Death Rate Constant (Non-Zoo Predation) (1/day) (Summer)
  - 0.0400 Phytoplankton Death Rate Constant (Non-Zoo Predation) (1/day) (Spring)
  - 0.0400 Phytoplankton Death Rate Constant (Non-Zoo Predation) (1/day)(Fall)
  - 220.0000 Phytoplankton Optimal Light Saturation as PAR (watts/m2) (Summer)
  - 0.0800 Detritus & Solids Light Extinction Multiplier 1/m/(mg/L)
  - 0.0800 DOC Light Extinction Multiplier (Values Below Modify Global Value)

Water Resources Database

- Updated NPDES database to reflect data from GAEPD and City of Tallahassee

Reduction Scenario Development

Model Changes (August 2021)

For the development of the reduction scenario that forms the basis to the TMDL on two model inputs were manipulated.

EFDC – Hydrodynamic

- The Lake Talquin QSER file was updated to accommodate the Ochlockonee River NPDES discharges operating at maximum permitted flows. The discharge from the dam was updated proportionally with the increase in dischargers flows.

Lake Talquin Water Quality Model (LT_Reduction_Scenario.wif)

- Using the above mentioned EFDC model, the calibrated current condition Lake Talquin water quality loadings at the 11 boundaries were reduced until the TMDL target was achieved

Watershed Description

Lake Talquin is located west of Tallahassee, Florida approximately 15 miles south of the Florida-Georgia state line. The Lake Talquin Watershed encompasses over 1,577 square miles and includes portions of the following counties in Georgia: Worth, Mitchell, Colquitt, Decatur, Grady and Thomas, along with Gadsden and Leon Counties in Florida (Figure 1). Lake Talquin receives water from both the Little River and the Ochlockonee River. The following creeks drain to Little River: Quincy Creek, Willacoochee Creek, Attapulgus Creek, and Swamp Creek, along with several smaller and/or unnamed tributaries. The following creeks drain to Ochlockonee River: Turkey Creek, Lees Creek, Barnett's Creek (both east and west branches), Lost Creek, Big Creek, Little Creek, and Bridge Creek, along with several smaller and/or unnamed tributaries.

Approximately 41% of the watershed is forested or clear-cut and 16% of the watershed is wetlands. Agricultural land uses (crop and pasture) comprise 33% with a greater percentage located in Georgia. About 6% of the watershed is urban land use (Figure 2).

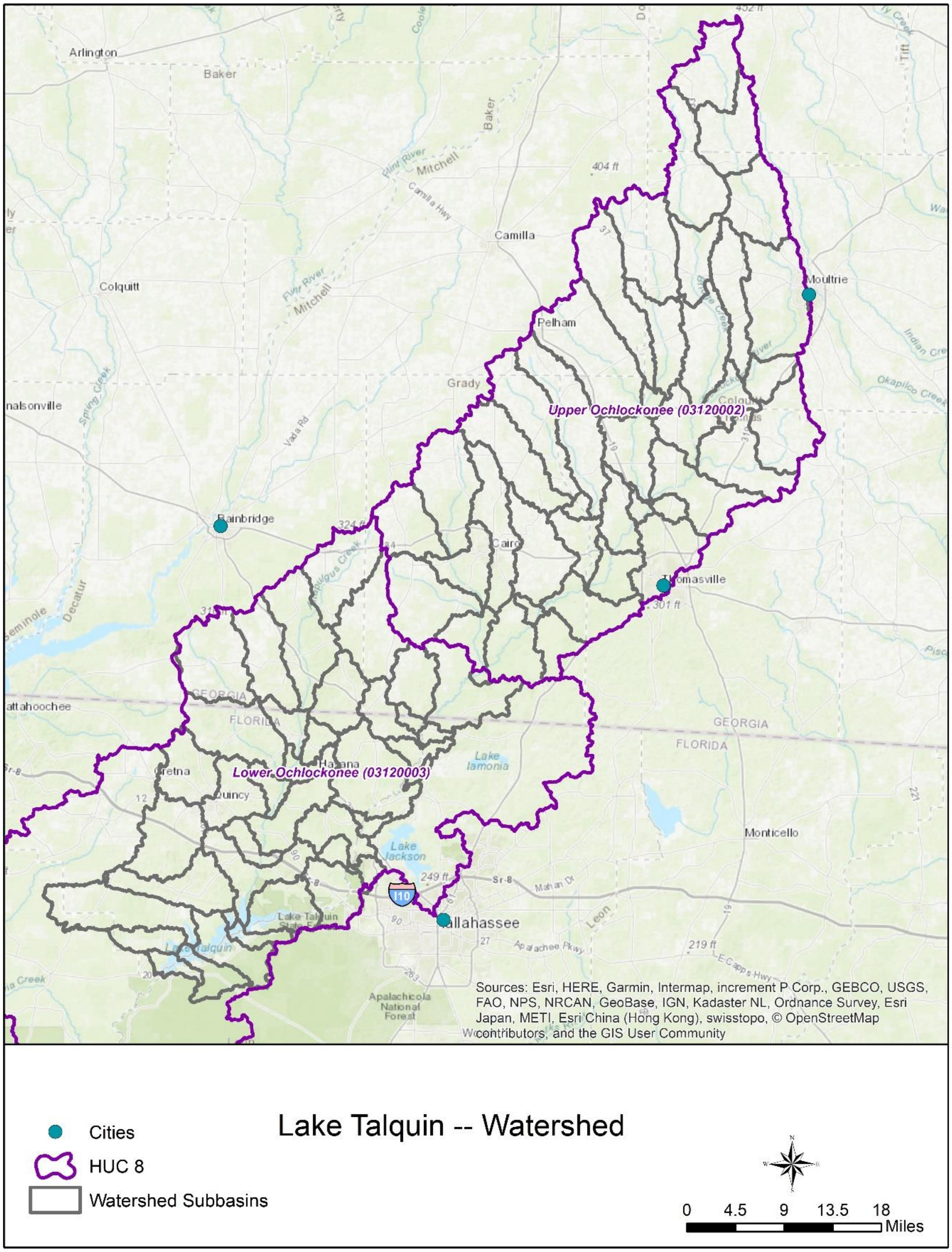

Figure 1 Location of the Lake Talquin Watershed

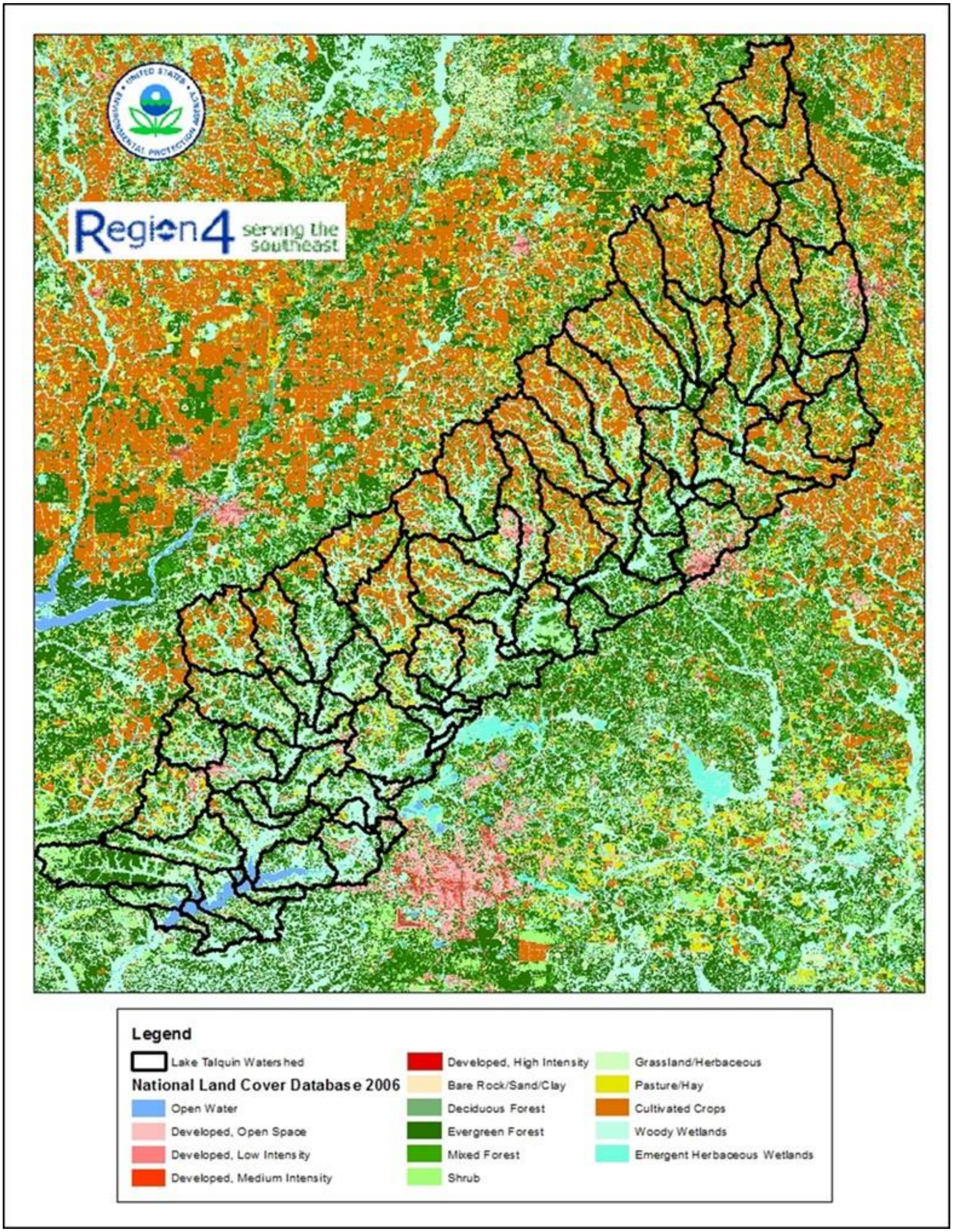

Figure 2 Lake Talquin Watershed Landuse Data

Modeling Approach

The modeling approach used for the development of the nutrient water quality model for Lake Talquin (including Little River and Ochlockonee River) considers 10 years of meteorological and flow conditions (2008-2017). The selection of a longer-term continuous simulation insures that average, wet and dry conditions are included in the model. The modeling approach uses a dynamic watershed model that predicts surface and subsurface runoff of pollutants (total nitrogen [TN], total phosphorus [TP], biochemical oxygen demand [BOD], and total suspended solids [TSS]) and flow as a function of land use and meteorological conditions. The ten-year simulation of watershed loadings and flow were then forwarded into a water quality models, along with point source discharge data, to predict the impacts of the loadings and flow on water quality in Lake Talquin. The water quality model predicts: dissolved oxygen (DO), nitrogen (ammonia (NH4/NH3), nitrate (NO3O2), and organic nitrogen (dissolved (DOP) and particulate (POP)), phosphorus (dissolved inorganic phosphorus (DIP), organic phosphorus (dissolved (DOP) and particulate (POP)), chlorophyll a (3-Seasonal Species (summer, fall, winter) and biochemical oxygen demand (CBOD) as a function of loads and flows from the watershed and point source dischargers.

Because of the size and complexity of the watershed and TMDL/nutrient criteria decisions both a watershed and water quality model were used to model the Ochlockonee River watershed and Lake Talquin. Based on a range of parameters, the watershed model simulated surface and subsurface runoff for each of the watershed subbasins. This runoff was calculated based on meteorological conditions, landuse and soil type, percent imperviousness, spatial extent of sinkholes, and septic tank densities for each subbasin. In addition, flows and concentrations originating from sanitary sewer overflows (SSOs) were incorporated into the watershed model.

Simulated surface and subsurface runoff from the watershed model, both flows and concentrations, were subsequently linked to the water quality model. Because the watershed model only generated concentrations of total nitrogen (TN) and total phosphorus (TP) for nutrient runoff, we had to partition these total concentrations into their respective subspecies prior to routing them into the water quality model. For this partitioning, we used measured values at the various water quality monitoring stations. First, we calculated subspecies percent composition for each sample.

Because certain subspecies concentrations were calculated based on their constituents (e.g., ORGN = TKN – NH_3), negative compositions were sometimes generated. Those records were excluded prior to averaging. We then calculated average subspecies percentages that were used to partition the LSPC generated TN and TP runoff into their respective constituent concentrations (Ammonia 4.1%, Nitrate 36.3%, Dissolved Organic Nitrogen 40%, Particulate Organic Nitrogen 19.6% of Total Nitrogen. For Total Phosphorus: Dissolved Inorganic Phosphorus 43.6%, Dissolved Organic Phosphorus 43%, Particulate Organic Phosphorus 13.7%).

LSPC Watershed Model

The Loading Simulation Program C++ (LSPC version 4.1) model is a lumped parameter, semi-physical watershed hydrology and water quality model. Model parameterization is grouped by hydrologic response units (HRUs) within sub-basins, and the model domain is delineated based on soil type and land use, as opposed to a distributed and cell-based parameterization. It is a semi-physical model with the physical processes of the hydrologic cycle represented; however, the physics behind each of the processes are solved empirically and/or conceptually. For example, soil water flow is not modeled by solving the physical theory of unsaturated-saturated flow as represented by one dimensional (1-D) Richard's equation (Richard, 1931). Soil water flow in LSPC is 'bucket-hydrology' - a water balance approach where the soil column is divided into two zones and water flows from one zone to the other when the nominal storages are met. This method does not address upward flows in the soil column.

The LSPC streamflow hydraulics are simplified using a kinematic approximation to the 1-D Saint Venant dynamic equation (Cunge et al., 1980; Yeh et al., 1995). The kinematic wave approximation is a water balance-storage routing where the momentum equation is simplified with the Manning's equation (Manning, 1891). With the kinematic wave assumption, inertial forces are neglected, and hydraulics are dominated by gravity waves with one-directional downstream wave flow. LSPC cannot address backwater effects and attenuation of flow due to in-stream structures like culverts. The overland flow hydraulics also use the storage routing approach and do not solve the overland flow equation as represented by the equivalent 2-D Saint Venant dynamic equation (Cunge et al., 1980; Yeh et al., 1995). The LSPC surface runoff generation is predominantly Hortonian where water flows horizontally across land surfaces when rainfall has exceeded infiltration capacity and depression storage capacity (Horton, 1933). This contrasts with saturation excess surface runoff models, where surface runoff is generated when the groundwater table rises to the surface, as in lowland areas. When evaluating the calibration results, one should take into consideration the above physical basis of the model and the intended purpose of the model.

Despite the simplified processes discussed above, the LSPC meets the requirements of this specific modeling project and has also been successfully applied to a range of similar projects on a national basis. Although more detailed watershed models are available and may be applicable, it is a best management practice to choose the simplest model that meets the needs of a modeling project. The more comprehensive the model, the more model parameterization is required.

WASP Water Quality Model

Water Quality Analysis Simulation Program (WASP 8.32) (USEPA, 2018) is one of the most widely used water quality models. It is currently developed and maintained by USEPA Region 4. WASP8 is a dynamic compartment (or segment)-modeling program for aquatic systems, including both the water column and the underlying benthos. WASP can be linked to free surface hydrodynamic models (e.g., EFDC) to allow the user to investigate water quality dynamics in 1, 2, and 3 dimensional systems (streams, rivers, lakes and estuaries). The hydrodynamic models provide WASP information related to flows, depths, velocities, temperature and salinity. The constituents that can be modeled by WASP include conventional water quality variables (nitrogen, phosphorus, dissolved oxygen, biological oxygen demand, sediment oxygen demand, algae and periphyton), organic chemicals, metals, mercury, pathogens and temperature. WASP can also be linked with watershed models, which allows for multi-year analysis under varying meteorological and environmental conditions. a generalized framework for modeling contaminant fate and transport in surface waters. The Advanced Eutrophication Module of WASP was used for Lake Talquin. Figure 3 provides a schematic of the state variables considered by the module.

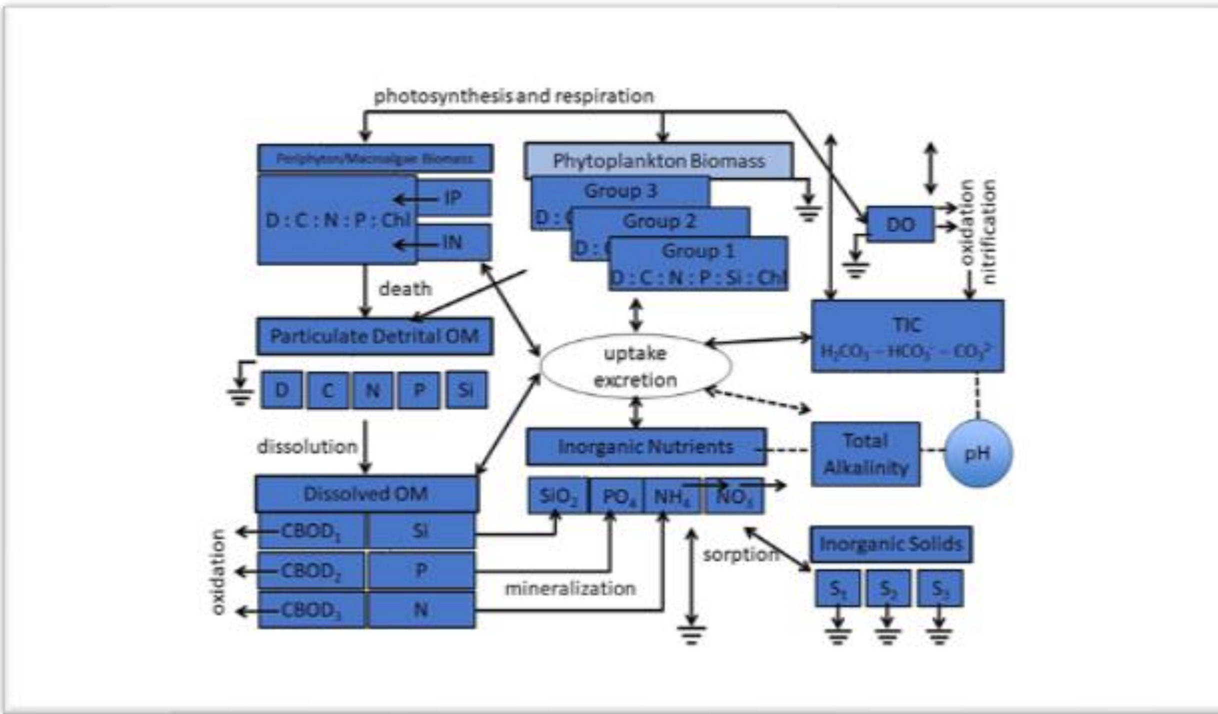

Figure 3 WASP 8.2 Advanced Eutrophication State Variables

The WASP model integrates the predicted flows and loads from the LSPC model to simulate water quality responses in: nitrogen, phosphorus, chlorophyll a and dissolved oxygen. Both LSPC and WASP were calibrated to current conditions. For this application, WASP is the receiving water quality model for both Lake Talquin and its major tributaries (Ochlockonee River and Little River). The Lake Talquin WASP model uses the same model state variables as the Ochlockonee and Little River models with one exception. The Lake Talquin WASP model simulates three phytoplankton groups which is standard practice for reservoirs, lakes and estuaries. When species specific assemblage data is available the multiple phytoplankton state variables could represent diatoms, greens and blue/green algae. In the case of Lake Talquin, seasonal assemblages are being used: Summer, Spring and Fall. Summer higher light and temperature tolerance for growth, Spring lower light and lower water temperature tolerance for growth and Fall lower light warm to cool water temperature tolerance for growth.

EFDC Hydrodynamic Model

The Environmental Fluid Dynamics Code (EFDC) is a public domain, open source, linked hydrodynamic and water modeling system, which also includes modules for sediment transport and fate and transport of toxic contaminants fully integrated in a single source code. Model simulations can be fully coupled where hydrodynamics, sediment, and contaminant transport are executed simultaneously or be done using saved hydrodynamic transport data. EFDC can represent water bodies in one, two and three dimensions using a finite difference methodology. Model cells are represented using a curvilinear or Cartesian grid with two options for vertical cell spacing: Sigma-z or GVC (general vertical coordinate). Water column transport includes 3-dimensional advection and vertical and horizontal turbulent diffusions. For this application, a three-dimensional EFDC grid was developed for Lake Talquin to provide necessary hydrodynamic inputs to WASP, the advanced receiving water quality model. EFDC uses stretched or sigma vertical coordinates and Cartesian or curvilinear, orthogonal horizontal coordinates to represent the physical characteristics of a waterbody. It solves three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable-density fluid. Dynamically-coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved.

Model Domains

Because of the size and complexity of the watershed and the TMDL/nutrient criteria decision that will be made a set of nested models were developed. Figure 4 depicts the model network for the five models. The gray polygons define the areas that were simulated for the Ochlockonee River watershed. Results from the LSPC model, both flows and concentration were used by all the WASP models. The red line segments represent the WASP water quality model for the Ochlockonee River. This model incorporates the flows and concentrations from the watershed model plus the 7 NPDES dischargers to determine the fate and transport to Lake Talquin. The green line segments represent the WASP water quality model for the Attapulgus River (Georgia)/Little River (Florida). This model incorporates the flows and concentrations from the watershed model plus the 2 NPDES dischargers to determine the fate and transport to Lake Talquin. The purple grid represents the hydrodynamic and water quality model for Lake Talquin. The EFDC hydrodynamic and water quality model receives flows and loads from the mainstem river WASP models (Ochlockonee and Attapulgus/Little River) and the surrounding watershed model subbasins that drain directly to the lake.

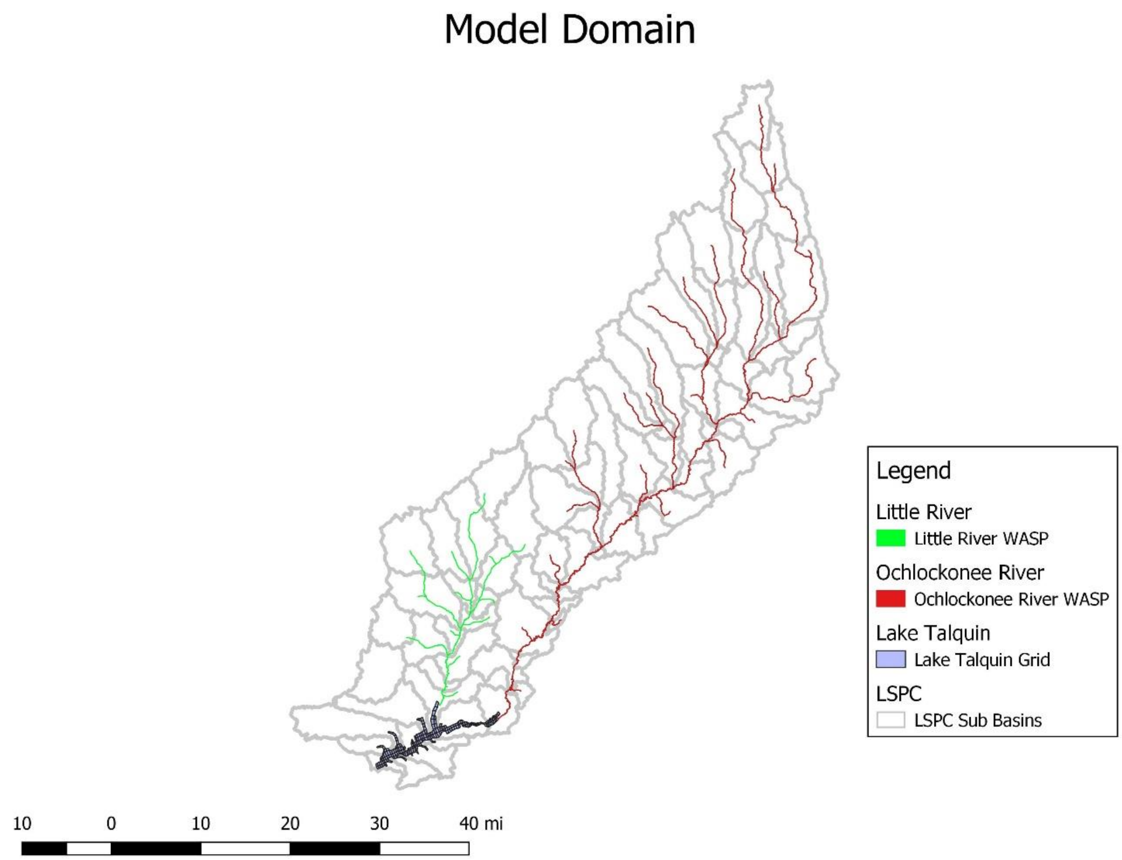

Figure 4 LPSC Watersheds and WASP Segments

Watershed Model Application

The watershed model was applied to the Lake Talquin watershed for the simulation period of 2007 through 2017. The 2007 year was used to equilibrate the initial conditions in the watershed model (soil moisture, buildup and washoff). The period from 2008 through 2017 was used to predict flows and loads under current conditions which were passed onto the WASP water quality models.

Watershed Delineation and Landuse

Watersheds that drain directly to Lake Talquin, and those draining to Little River and Ochlockonee River, were included in the LSPC watershed model. The watershed was delineated into 85 sub basins (Figure 5). Sixteen subbasins drained to the Little River, 59 subbasins drained to Ochlockonee River, and 13 sub basins drained directly to Lake Talquin (Figure 5). The LSPC model predicts flow and pollutant concentrations from each of these sub basins into Little River, Ochlockonee River, and Lake Talquin.

The initial model setup and parameterization for Lake Talquin watershed model was based on EPA's LSPC model used for the purposes of nutrient criteria development and from the Apalachee basin model developed by Tetra-Tech for the State of Georgia (Tetra-Tech, 2011). The initial model was further refined and calibrated to all water quality and flow data that were available in the watershed.

The watershed model uses land use data as the basis for representing hydrology and nonpoint source loadings. The Georgia Land Use Trends (GLUT), FDEP Level III Florida Land Use, and the National Landuse Coverage Dataset (NLCD) were used to develop the watershed land use representations. The GLUT 2008 was used as the primary coverage in the Georgia portion of the watershed and FDEP and NLCD 2006 data were used to complete the land use coverage in Florida where there was no GLUT 2008 data. The coverages utilized a variety of land use classes. The FDEP coverages were grouped and reclassified into 18 land use categories: beaches/dune/mud, open water, utility swaths, developed open space, developed low intensity, developed medium intensity, developed high intensity, clear-cut/sparse, quarries/strip mines, deciduous forest, evergreen forest, mixed forest, golf courses, pasture, row crop, forested wetland, non-forested wetland (salt/brackish), and non-forested wetland (freshwater). The GLUT and NLCD datasets were reclassified into the same land use categories. For the LSPC simulation, similar land use classes were grouped together reduce the land uses to 15 modeling categories. Deciduous forest, evergreen forest and mixed forest were grouped into a land use category named forest.

The LSPC model requires division of land uses in each sub-watershed into separate pervious and impervious land units. The GLUT impervious cover was intersected with the GLUT land use-land cover. Any impervious areas associated with utility swaths, developed open space, and developed low intensity, were grouped together and placed into a new category of low intensity developed impervious cover. Impervious areas associated with medium intensity development and high intensity development, were kept separate and placed into two categories of medium intensity developed impervious and high intensity developed impervious cover, respectively. Finally, any impervious area not already accounted for in the three developed impervious cover categories, were grouped together into a fourth category.

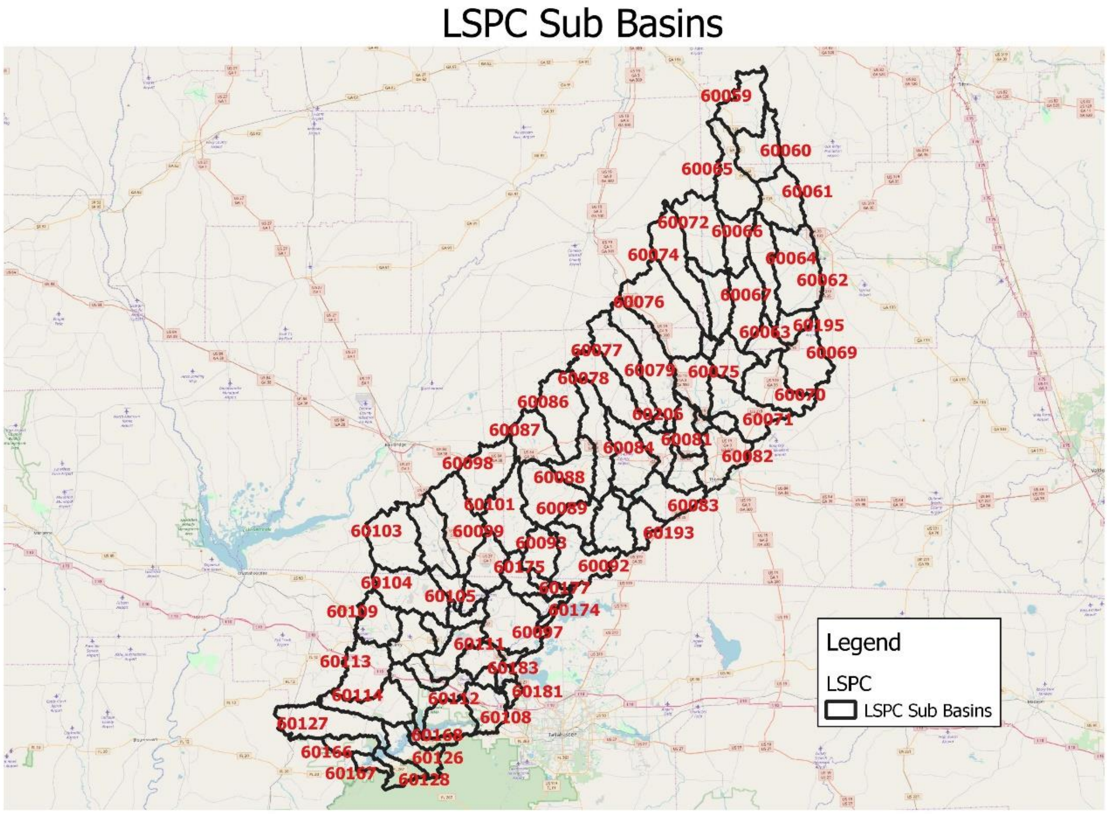

Figure 5 Lake Talquin Watershed Delineation

Meteorological Information

Non-point source loadings and hydrological conditions are dependent on weather conditions. The North American Land Data Assimilation System (NLDAS) meteorological dataset was used to augment the hourly rainfall and meteorological inputs for the watershed model. NLDAS hourly rainfall in combination with the atmospheric data from the National Climate Data Center (NCDC) stations were used for 2007-2017. Figure 6 depicts the location and station names of the NLDAS and NCDC weather stations used in the watershed model.

Hourly data from NCDC and NLDAS weather stations within the boundaries of, or near the sub-watersheds were used in the watershed model. An ASCII file (*.air) was generated for each meteorological and precipitation station. Each station file contains atmospheric data including precipitation, air temperature, dew point temperature, wind speed, cloud cover, evaporation, and solar radiation. These data were used directly or calculated from the observed data from other stations such as solar radiation.

Text files using the American Standard Code for Information Interchange (ASCII files) were generated for each NLDAS grid center with the “.air” extension and were used for hydrologic generation in LSPC (i.e,air-file). The six parameters obtained from the NCDC stations were selected based on distances to each sub-basin in the model and added to the corresponding ASCII file. Not all stations collect all parameters in which cases data were used from nearby stations to fill in those gaps. For example, the Kingston Spring station does not provide dew point, wind speed, cloud cover or solar radiation data for the modeling period. Therefore, the air-file utilizing Kingston Springs for PET and air temperature would have another nearby station's records filled in for solar, dew point, cloud cover, and wind speed. This method of grouping weather data from multiple stations provides the most reliable PET and precipitation data, which are the major driving forces in watershed modeling, and results in numerous combinations of stations in air-file.

Ochlockonee Watershed Meteorological Stations

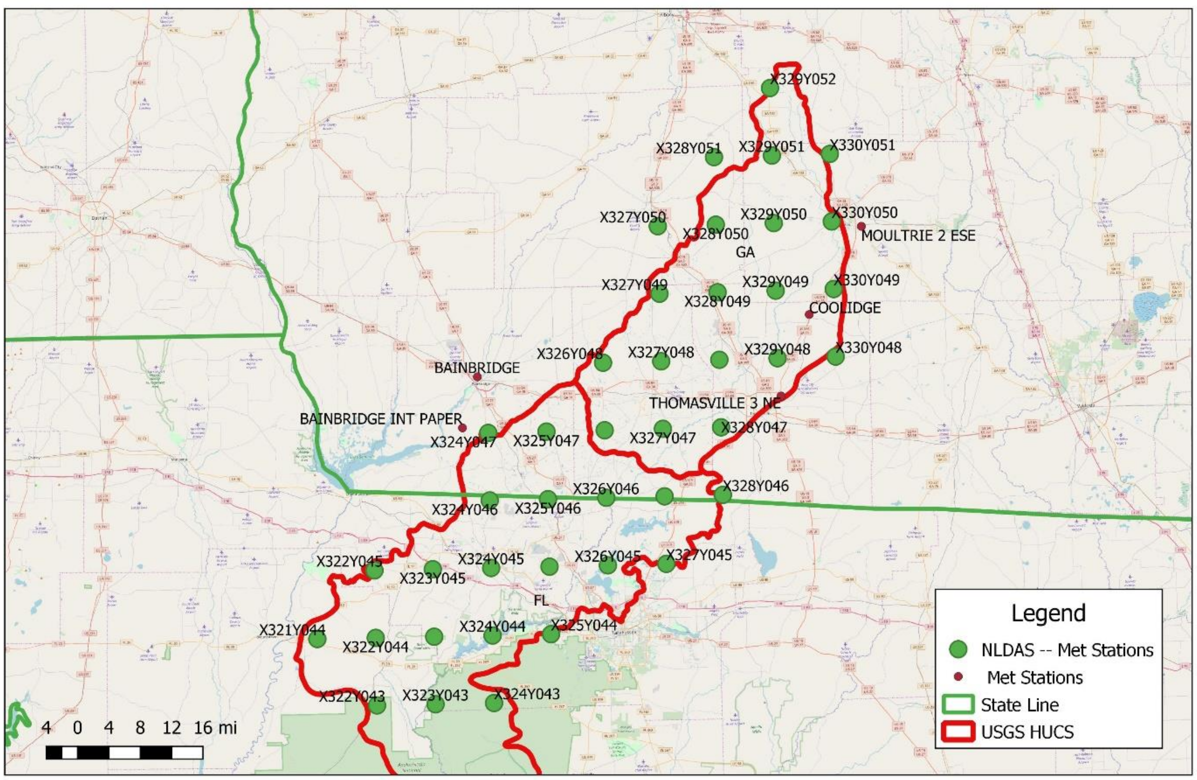

Figure 6 Meteorological Station Locations

Table 1 provides a summary of the annual rainfall for each of the 43 meteorological stations used in the watershed model simulation.

Table 1 Annual Rainfall for Simulation Period

Station	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
088758	35.63	63.26	60.63	49.56	39.95	51.04	67.35	67.12	49.71	62.16	54.12
X323Y044_FL087429_FL08742	34.32	68.33	64.65	52.76	39.63	48.80	68.85	74.23	55.51	63.50	54.14
X323Y045_FL087429_FL08742	34.73	66.60	60.96	47.31	36.87	50.25	68.34	72.21	53.51	60.84	49.01
X324Y044_FL087429_FL08742	34.30	68.13	64.65	53.64	40.90	51.88	68.83	73.95	56.19	63.81	55.94
X324Y044_FL088758_FL08875	34.30	68.13	64.65	53.64	40.90	51.88	68.83	73.95	56.19	63.81	55.94
X324Y045_FL087429_FL08742	34.01	68.42	60.56	49.34	38.59	52.07	69.68	73.01	54.61	61.02	50.95
X324Y046_FL087429_FL08742	34.05	66.24	58.28	44.98	35.72	50.56	68.44	69.48	52.39	55.51	43.21
X324Y047_FL087429_FL08742	33.34	62.11	56.79	43.23	36.47	49.55	63.52	66.00	51.09	52.70	40.74
X324Y047_GA090581_GA09058	33.34	62.11	56.79	43.23	36.47	49.55	63.52	66.00	51.09	52.70	40.74
X325Y044_FL088758_FL08875	35.75	66.31	64.85	53.56	40.76	54.28	66.81	71.76	55.89	62.67	56.01
X325Y045_FL087429_FL08742	34.30	66.78	60.31	49.28	39.62	53.13	68.20	71.63	54.10	61.28	52.90
X325Y045_FL088758_FL08875	34.30	66.78	60.31	49.28	39.62	53.13	68.20	71.63	54.10	61.28	52.90
X325Y046_FL087429_FL08742	32.55	64.82	58.93	46.35	38.56	50.82	66.88	68.51	51.28	56.90	45.80
X325Y047_GA090581_GA09058	33.37	61.76	56.83	44.34	36.25	48.65	62.95	64.44	49.32	54.24	42.26
X326Y045_FL087429_FL08742	33.86	65.46	61.15	49.88	40.41	52.38	66.78	69.23	52.08	61.69	53.94
X326Y045_FL088758_FL08875	33.86	65.46	61.15	49.88	40.41	52.38	66.78	69.23	52.08	61.69	53.94
X326Y046_FL087429_FL08742	32.62	64.85	57.09	48.02	39.01	48.19	65.50	66.47	48.98	60.06	49.79
X326Y046_GA091463_GA09146	32.62	64.85	57.09	48.02	39.01	48.19	65.50	66.47	48.98	60.06	49.79
X326Y047_GA091463_GA09146	32.37	63.01	56.18	44.63	37.66	45.92	63.49	64.05	47.63	58.99	47.13
X326Y048_GA091463_GA09146	35.24	60.35	56.75	43.09	35.97	41.88	61.85	60.43	47.17	57.88	43.31
X327Y046_FL088758_FL08875	33.45	64.47	59.22	47.51	39.40	47.35	65.98	65.39	47.78	62.72	52.04
X327Y046_GA091463_GA09146	33.45	64.47	59.22	47.51	39.40	47.35	65.98	65.39	47.78	62.72	52.04
X327Y047_GA091463_GA09146	32.56	62.20	57.88	44.41	40.01	45.80	65.08	64.79	47.62	63.22	50.54
X327Y048_GA091463_GA09146	33.97	62.63	57.68	44.10	37.92	42.57	64.03	62.94	47.48	61.71	47.52
X327Y049_GA091463_GA09146	35.52	55.99	56.61	42.63	35.35	38.33	62.63	61.17	48.03	59.42	43.68
X328Y047_GA091463_GA09146	33.73	58.65	57.15	44.41	39.75	46.95	66.12	64.81	47.84	64.44	51.40
X328Y047_GA098666_GA09866	33.73	58.65	57.15	44.41	39.75	46.95	66.12	64.81	47.84	64.44	51.40
X328Y048_GA091463_GA09146	35.60	59.47	55.82	43.59	39.01	44.27	65.05	63.83	47.26	62.98	49.47
X328Y048_GA098666_GA09866	35.60	59.47	55.82	43.59	39.01	44.27	65.05	63.83	47.26	62.98	49.47
X328Y049_GA091463_GA09146	35.20	58.07	57.33	42.06	36.22	40.16	63.55	62.91	47.44	60.23	45.62
X328Y049_GA091500_GA09150	35.20	58.07	57.33	42.06	36.22	40.16	63.55	62.91	47.44	60.23	45.62
X328Y050_GA091500_GA09150	35.42	51.74	57.43	41.75	36.00	36.95	61.49	60.35	48.32	56.97	42.51
X329Y048_GA098666_GA09866	34.81	57.48	54.87	41.76	39.05	45.40	64.95	63.33	46.03	61.09	49.75
X329Y048_GA098666_GA09866	34.64	55.38	55.49	41.96	38.55	41.96	64.34	64.14	45.93	58.30	47.73
X329Y049_GA096087_GA09608	34.64	55.38	55.49	41.96	38.55	41.96	64.34	64.14	45.93	58.30	47.73
X329Y049_GA098666_GA09866	34.64	55.38	55.49	41.96	38.55	41.96	64.34	64.14	45.93	58.30	47.73
X329Y050_GA091500_GA09150	35.04	53.71	54.66	41.75	36.23	39.31	63.17	62.76	46.72	55.85	45.81
X329Y050_GA096087_GA09608	35.04	53.71	54.66	41.75	36.23	39.31	63.17	62.76	46.72	55.85	45.81
X329Y051_GA096087_GA09608	35.20	51.20	56.81	40.93	35.51	38.44	62.00	59.37	48.08	53.11	44.55
X329Y052_GA096087_GA09608	35.05	48.41	56.26	39.58	34.74	41.08	62.38	56.42	49.25	47.70	45.31
X330Y049_GA096087_GA09608	34.07	53.50	56.16	40.40	39.36	42.09	64.26	63.92	44.50	54.57	47.95
X330Y050_GA096087_GA09608	33.49	51.81	55.36	41.50	38.11	40.63	63.69	62.92	44.85	53.38	47.97
X330Y051_GA096087_GA09608	34.54	49.26	55.70	40.89	35.66	40.54	63.65	60.42	46.27	52.32	47.75
Average	34.27	60.53	58.10	45.27	38.17	46.01	65.24	65.75	49.40	59.15	48.65

Figure 7 depicts the hourly rainfall for the Tallahassee WSO AP (WBAN 088758) meteorological station. The period of record being simulated during this TMDL development contains average, wet and dry years.

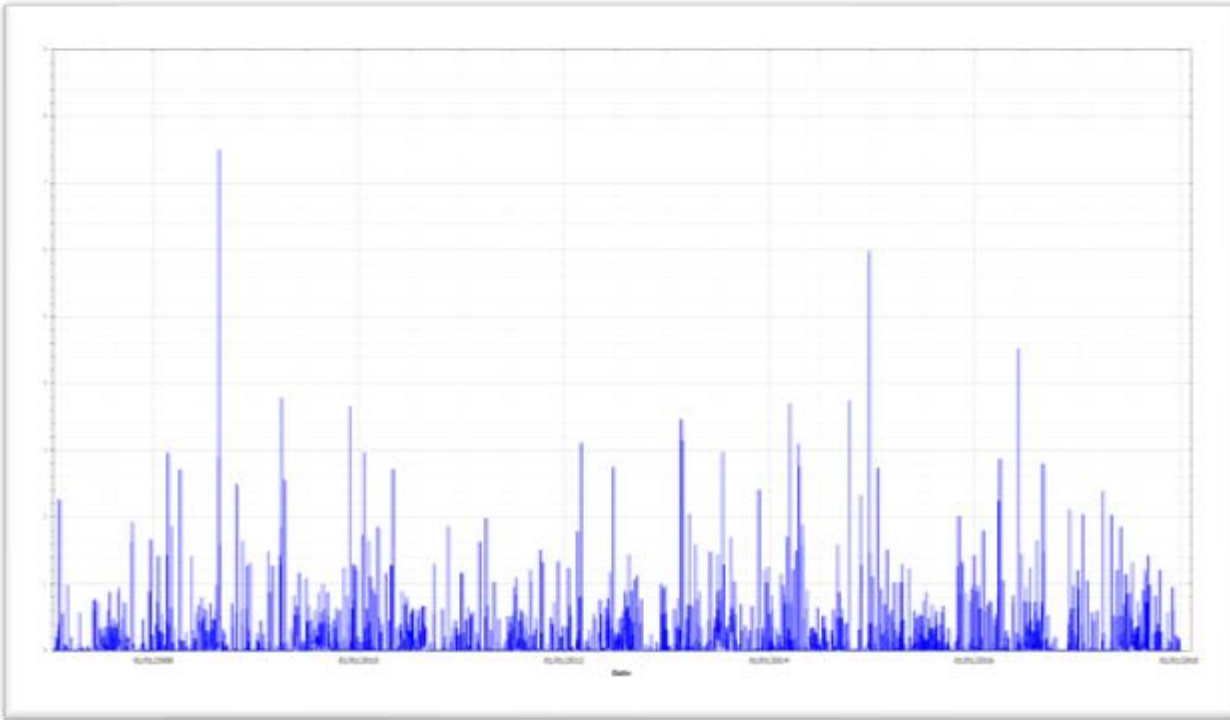

Figure 7 Hourly Rainfall Station 0088758

Nutrient Loadings

Watershed loadings were generated using event mean concentrations (EMC) for total nitrogen, total phosphorus, and BOD (Table 2). The initial EMC values were derived for each landuse category from a study by Harper and Baker (2007). Wetland EMCs were derived from the study of Reiss et.al (2009 that summarizes the available literature on nutrient concentrations and hydrology for wetlands in Florida. It should be noted that these initial EMC values are a starting point in the calibration process. EMC pollutant concentrations vary greatly by landuse, watershed and geographical area and are very difficult to measure and quantify. Harper and Baker's study was conducted in the central peninsula of Florida where there is greater mix of anthropogenically influenced landuses than in the Ochlockonee basin. During both the watershed (LSPC) and the water quality model (WASP) calibration process the simulated loadings will be compared with measured data to ensure the EMCs used in the watershed model adequately represent the current loadings. The USGS's LOADEST statistical tool (https://water.usgs.gov/software/loadest/) will be used to compare loadings calculated from measured total nitrogen, total phosphorous concentrations and flows and the corresponding predictions from the model(s) at the same location as the data. The results of the loading comparison can be reviewed in Appendix D.

All EMC values that are used in the final watershed model are within range of other published studies from other watersheds (District Department of Environment, 2014).

Table 2 represents the EMCs used in the final calibrated model.

Table 2 Event Mean Concentration (mg/l) for Landuse Classifications

Landuse	TN	TP	BOD
Beach	2.89	0.06	1.93
Water	2.10	0.02	1.93
LowIntDevPerv	2.89	0.06	7.86
LowIntDevImperv	1.65	0.03	7.60
MedIntDevPerv	2.89	0.06	7.86
MedIntDevImperv	2.89	0.06	7.86
HighIntDevPerv	3.24	0.08	11.28
HighIntDevImperv	3.36	0.05	11.30
Barren	2.89	0.06	1.35
Forest	1.61	0.02	1.35
Golf	4.86	0.09	5.62
Pasture	4.86	0.09	8.24
Crop	3.70	0.13	5.62
Wetland	4.03	0.10	1.93
AllOtherImperv	2.90	0.06	7.27

Model Calibration Objectives

The overall objective of the model calibration process was to produce a final model that provided robust predictions of measured values, while exhibiting the flexibility necessary to effectively extrapolate values under a range of environmental conditions. The final model resulting from this calibration process could be subsequently used to inform management decisions based on various modeling scenarios.

Model Bias and Variance Trade-off

When calibrating a watershed or water quality model, there is an inherent trade-off between a model's bias and variance. Specifically, including additional parameters in a model and increasing its complexity can increase model variance, but decrease model bias. Model variance is the variability of individual simulated values relative to the true value of a field measurement. Model bias is how well the model predicts, on average, the true measured value. For instance, if the model building process was repeated ten times with separate subsets of the field measurement data, bias assesses how accurately, on average, the true measured value is predicted by the simulated values generated by the ten models. Model variance assesses variability in the simulated values across the ten models. When trained to different subsets of calibration data, a model with high bias and low variance, would result in a consistently tight cluster of simulated values that, on average, may not be accurate predictions of the true measured value.

Effective model calibration requires a balance between bias and variance, as increasing model complexity can cause the model to find patterns in random noise (natural variation) in field measurements. This can lead to an overfitted model that has an excellent ability to predict measured values under environmental conditions represented by the current set of field observations. However, when the model is applied to new conditions that may fall outside of the range of original field measurements or conditions, the model may not provide robust predictions. Thus, the model performs poorly and is considered overfitted to the environmental conditions represented by the original field measurements.

A well-calibrated model is a model that has balanced bias and variance error. It will be able to capture regular patterns in the calibration data and exhibit relatively low variance compared to individual measurements, while possessing the flexibility to extrapolate to novel scenarios that may contain conditions and data that were not part of the original calibration data.

Weight of Evidence Approach

Due to limitations of any single metric's ability to effectively assess model calibration and performance, Region 4 EPA implements a 'weight of evidence' approach. Specifically, model calibration and performance are assessed through a combination of quantitative (e.g., calibration statistics) and qualitative (e.g., visual inspection of calibration graphs) methods. This approach integrates multiple metrics, leveraging the strengths of each individual test while helping to acknowledge their limitations. This can provide a broader assessment of model performance across the full range of environmental conditions observed during the simulation period. Moreover, it improves the robustness of a model's predictions and ability to extrapolate values when the model is applied to novel model scenarios.

When applying the 'weight of evidence' approach, Region 4 EPA makes pairwise comparisons of simulated and observed values at stations that possess monitoring data. To be included in the process, a station requires a minimum number of field observations. This minimum is determined based on an assessment of the frequency, timing, and variability of measured data. Stations with too few measured data cannot effectively assess model performance or constrain model calibration. Although all stations that met the minimum number of field observations were used for calibration, additional consideration was given to stations located in the lower basin, as they presumably integrated changes throughout the entire basin. When a tributary had multiple stations located on it, the model was calibrated based on all stations; however, additional consideration was given to downstream stations and those stations with greater number of field observations.

Quantitative

Quantitative analysis of model fit was assessed using several widely used goodness of fit statistics (Moriasi et al. 2007) that were calculated in R (v3.5.1) using the HydroGOF package (Zambrano-Bigiarini 2017). We assessed overall model fit based on the following statistical comparisons:

- Arithmetic Mean ($\bar{x}$) – On average, assesses how well the simulated values represent observed values. For both the observed and simulated dataset, an arithmetic mean is calculated for each parameter across the entire model simulation period.

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

- Percentiles – This verifies the model is reasonably predicting extreme values in the observed data. Entails inspection of the 10th and 90th percentiles of both observed and simulated data.

- Mean Error (ME) – For each pair of measured and simulated values, measures the average difference (i.e., error) between observed and simulated data. Does not indicate if the simulated value is over or underpredicting the observed value and does not consider the natural variation in the observed data. For each paired observed and simulated record, the difference of the observed and simulated value is calculated, and subsequently averaged.

$$\mathrm{ME} = \frac{1}{N}\sum_{i\,=\,1}^{N} (S_i - O_i)$$

- Mean Absolute Error (MAE) – Measures the average magnitude of the difference (i.e., error) between observed and simulated data. It does not consider the direction of those differences (i.e., whether the model is over or underpredicting) or natural variation in the observed data. Calculated similarly to Mean Error, but the absolute value of the difference is taken.

$$\mathrm{MAE} = \frac{1}{N}\sum_{i\,=\,1}^{N} |S_i - O_i|$$

- Root Mean Square Error (RMSE) – Measures the difference (i.e., error) between observed and simulated data. This metric provides assurance that the model is matching the frequency, magnitude, and duration of water quality changes. However, it does not account for natural variability in observed data. Values of RMSE range from 0 to 1, with RMSE = 1 indicating a perfect match and a value of 0 indicating no agreement between observed and simulated data.

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i\,=\,1}^{N} (S_i - O_i)^2}$$

- Coefficient of determination (R^2) – Assesses the strength of the linear relationship between observed and simulated data. Describes the proportion of variation in the observed data that is explained by a simple linear regression relating observed and simulated data. Values of R^2 range from 0 to 1, with better fitting models possessing higher R^2 values.

$$R^2 = \left[\frac{\sum_{i=1}^{N}(O_i - \overline{O})(P_i - \overline{P})}{\sqrt{\sum_{i=1}^{N}(O_i - \overline{O})^2} \times \sqrt{\sum_{i=1}^{N}(P_i - \overline{P})^2}}\right]^2$$

- Spearman Rank Correlation Coefficient (r) – Conceptually, similar to simple linear regression, but the relationship between simulated and observed values is assessed based on their rank value (i.e., highest value given a rank of 1). As the comparison is nonparametric, data do not need to meet assumptions of normality and equal variance. Values range from -1 to 1, with r = -1 indicating a perfect negative relationship between simulated and observed data and r =1 indicating a perfect positive relationship.

- Percent Bias (PBIAS) – Provides a measure of whether a model, on average, tends to over- or underestimate observed values. The magnitude of the difference in observed and simulated data is calculated relative to the mean of observed data. Values range from -100% to 100%, with more accurate models exhibiting PBIAS that approach 0%. Values of PBIAS > 0% indicates that the model is overestimating observed values, while PBIAS < 0% indicates the model is underestimating them.

$$\text{PBIAS\%} = 100 \times \frac{\sum_{i=1}^{N}(S_i - O_i)}{\sum_{i=1}^{N} O_i}$$

- Nash-Sutcliffe Coefficient (NSE) – Assesses the magnitude of the difference in observed and simulated data relative to residual variance (i.e., natural variation) of observed data. This indicates how well the linear fit of observed versus simulated data fits a 1:1 line. Values range from -Infinity to 1, whereby NSE = 1 represents a perfect match of simulated and observed data, NSE = 0 indicates that model predictions are as accurate as the mean of observed data, while NSE = -Infinity indicates that the mean of observed values is a better predictor than simulated data.

$$\text{NSE} = 1 - \frac{\sum_{i=1}^{N}(S_i - O_i)^2}{\sum_{i=1}^{N}(O_i - \bar{O})^2}$$

- Index of Agreement (d) – Provides a measure of model error relative to natural variability (i.e., error). Values range from 0 to 1, with an index of agreement = 1 indicating a perfect fit of simulated and observed data, and a value of 0 indicating no agreement between them.

$$\text{d} = 1 - \frac{\sum_{i=1}^{N}(S_i - O_i)^2}{\sum_{i=1}^{N}(|S_i - \overline{O}| + |O_i - \overline{O}|)^2}$$

Qualitative

Inspection of calibration figures is an additional method for assessing model calibration. They are typically x/y plots of observed and simulated parameters. Such plots can help identify systematic bias in model results that may not be easily discernable from quantitative statistics alone. Their examination can help inform specific model parameters that may be adjusted during calibration.

Four commonly used graphs are included in this report:

- Time Series Plot – Simple x/y plot comparing model predictions to observed data. This plot allows visual inspection to assess if the model is predicting the range and frequency of the data, and the timing of extreme events.
- Cumulative Probability Distribution Plot – This plot helps assess whether the model is predicting the range and frequency of observed data, including extreme and median values.
- Observed vs. Simulated Plot – This plot helps identify the range of values that are best predicted by the model and evaluates whether the model is over- or underpredicting observed values. Data points above the 1:1 line indicate that the model is overpredicting observed values, while data points below this line suggest underprediction. Better fitting models have linear regressions lines that are closer to the 1:1 line.
- Box Plot with Overlaid Scatter Plot – Similar to the cumulative probability plot, this plot illustrates the degree of overlap in the distribution of simulated and observed data. Observed data are plotted as individual data points, with their respective average represented by open red squares. Simulated data are plotted as box and whisker plots, with whiskers indicating the range, boxes representing the 25th and 75th percentiles, solid blue lines indicating the median (50th percentile), and green circles indicating the average of simulated data.

Calibration

The calibration process for the riverine models (Ochlockonee & Little River) was a twostep process. The flows and water quality are initially calibrated within the watershed model to the available monitoring data. This entails entering point source discharge data into the LPSC model, execute, and then compare. Most effort is spent on parameterizing the hydrology and getting the water balance correct. Once the watershed model has been parameterized, its simulation results are passed onto the water quality model. The water quality has many more computational elements for the river channel than the watershed and requires slight adjustments to better match time of travel. The water quality model than incorporates the flows and non-point source loads from the watershed with point source dischargers and water transport (flow) to simulate the fate and transport to Lake Talquin.

The calibration statistics and plot presented in these sections are generated from the river water quality models, not the watershed model. This best represents the flows and loads going into the Lake Talquin hydrodynamic and water quality models.

Ochlockonee River Watershed and Water Quality Model

Watershed Model Correspondence

The simulated flows and loads from the watershed model subbasins are passed (linked) to one or more water quality model segments for fate and transport. For the Ochlockonee River there were 56 watershed subbasins that provided daily loads and flows to the water quality model (Figure 8).

The number of LSPC subbasins does not directly correlate to the number of WASP segments, which required mapping of LSPC results to WASP segment inputs (i.e., boundaries). When a single WASP segment overlapped several LSPC subbasins, we merged flows and concentrations from the LSPC subbasins prior to routing. On the other hand, when multiple WASP segments were in a single LSPC subbasin, flows and concentrations from that LSPC subbasin were routed as a boundary to only one of the WASP segments.

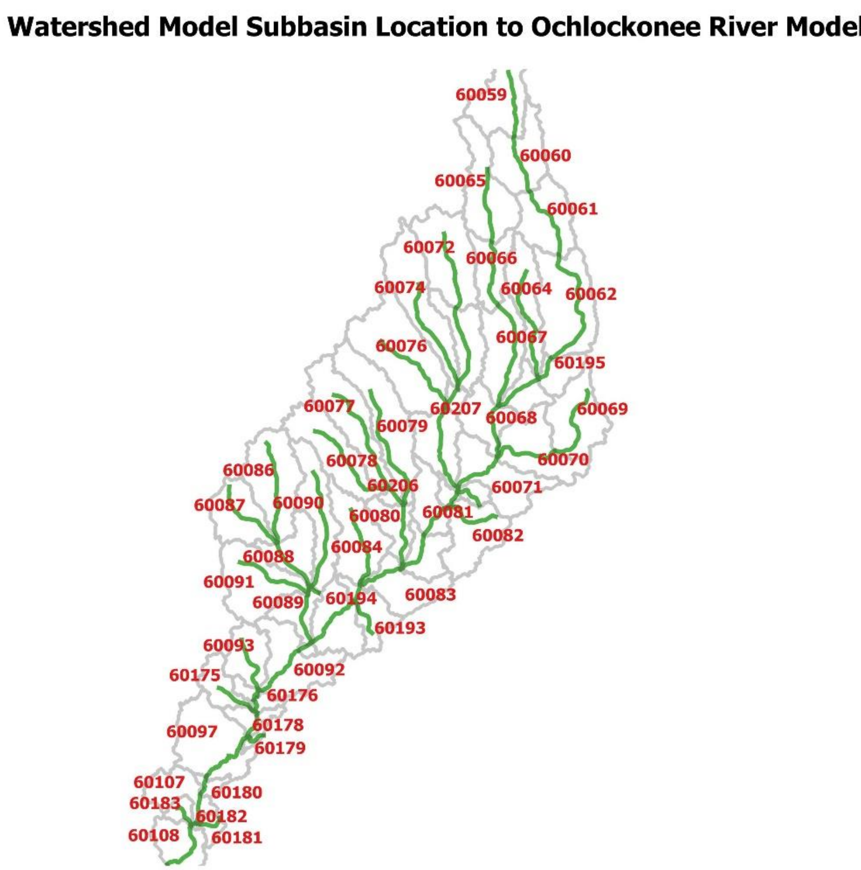

Figure 8 Watershed Model Subbasins draining to Ochlockonee River Water Quality Model

When a WASP segment included a LSPC subbasin as its boundary, the segment name begins with 'LSPC' followed by the subbasin number. When multiple subbasins were merged prior to routing to WASP, multiple subbasins are listed. Segment names ending in 'RO' and 'PERO' indicate the type of LSPC runoff values that were used for routing. Segments without an LSPC boundary were named based on their relative geographic location and subwatershed. Table 3 indicates how LSPC subbasins were routed to WASP segments and the routing method used.

Table 3 LSPC to WASP Correspondence – Ochlockonee River

LSPC Basin	PERO/RO	WASP Segment
60108	PERO	3
60183	PERO	5
60107	PERO	7
60180	PERO	8
60178	PERO	17
60175	PERO	18
60176	PERO	19
60177	PERO	20
60092	PERO	23
60205	PERO	26
60085	PERO	29
60079	RO	152
60194	PERO	32
60204	PERO	36
60192	PERO	39
60081	PERO	42
60190	PERO	43
60191	PERO	44
60068	PERO	51
60063	PERO	55
60195	PERO	57
60061	PERO	66
60059	RO	74
60060	PERO	76
60062	PERO	77
60064	RO	82
60067	PERO	85
60066	PERO	90
60065	RO	96
60070	PERO	99
60069	RO	104
60071	PERO	105
60207	PERO	111
60073	PERO	114

60072	RO	117
60074	RO	123
60076	RO	130
60075	PERO	131
60082	RO	134
60080	PERO	137
60206	PERO	140
60077	RO	143
60078	RO	146
60083	PERO	155
60084	RO	158
60193	RO	159
60089	PERO	161
60088	PERO	166
60086	RO	171
60087	RO	172
60091	RO	176
60093	RO	180
60179	PERO	181
60097	PERO	182
60181	PERO	183
60079	RO	152

Point Source Dischargers

The Ochlockonee River WASP model includes six municipal wastewater treatment plants (WWTP) and one food processing facility as point sources (Figure 9). All parameters associated with the point sources were added into the Ochlockonee River WASP model as concentration boundary inputs with separate surface flow functions.

Ochlockonee River Point Sources

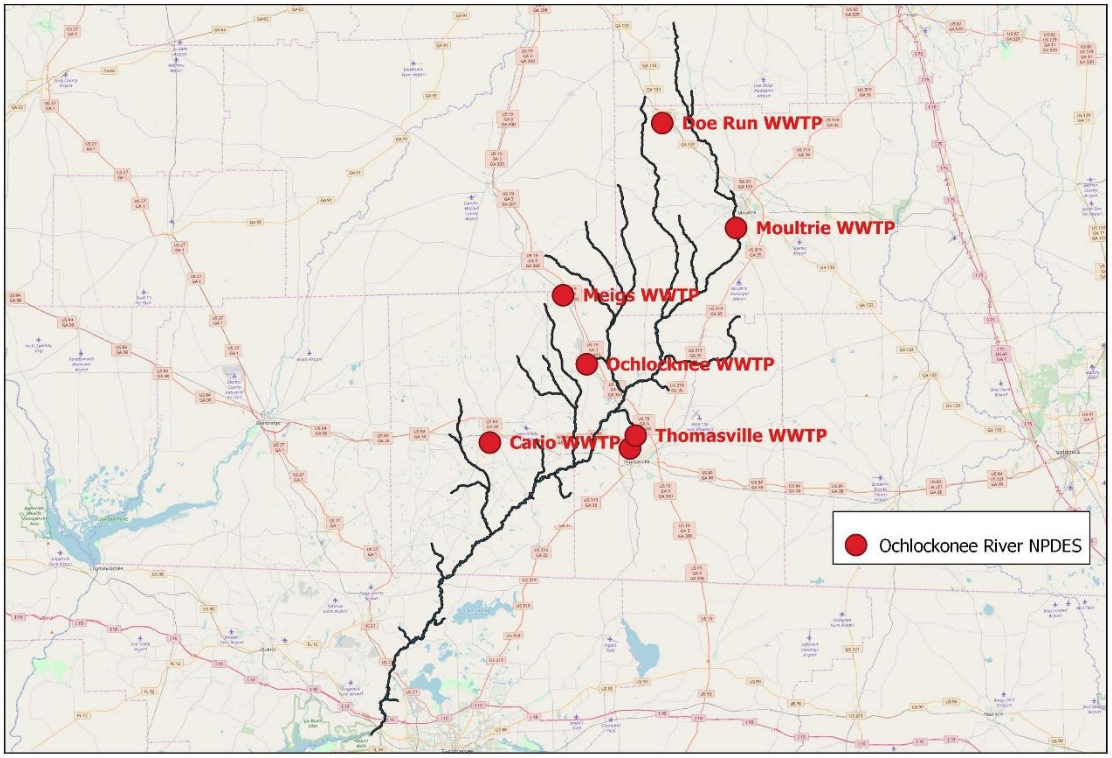

Figure 9 NPDES Dischargers to Ochlockonee River Water Quality Model

The following paragraphs discuss each point source individually.

Thomasville WPCP – Permit #GA0024082

DMR data stored on PCS and ICIS was used for the BOD, flow, and ammonia monthly input values. However, no data was identified in PCS or ICIS for TP (PO_4 and Organic P) or NOx and Organic N (Table 4). All of these parameters are needed in order to run the WASP model. A review of EPA's file for this facility located two permit applications and some limited TKN sampling data from 2012. This data was used to calculate an average ratio for Ammonia/TN, NOx/TN, and Organic N/TN. These ratios were used to calculate NOx and Organic N based on the Ammonia concentrations provided in DMR. Due to spikes in NOx concentrations when ammonia concentrations were high, a maximum TN target of 20.60 (the maximum of the two TN values presented in the permits applications) was added to the model. The average TP value was also calculated by using the permit applications. Due to no additional data available, a percentage allotment of 70% PO4 and 30% Organic P was assumed.

Table 4 Thomasville DMR Data

PCode	Parameter Name	Units	No. Obs.	Mean	Min	Max	First Date	Last Date
BOD	Biochemical Oxygen Demand	mg/L	132	5.466	1	12	1/2/2007 0:00	12/31/2017 0:00
DIP	Dissolved Inorganic Phosphorus	mg/L	132	1.833	0.6	7	1/2/2007 0:00	12/31/2017 0:00
DO	Dissolved Oxygen	mg/L	132	6.798	4.6	8.7	1/31/2007 0:00	12/31/2017 0:00
DON	Dissolved Organic Nitrogen	mg/L	132	0.985	0.2	4.92	1/2/2007 0:00	12/31/2017 0:00
DOP	Dissolved Organic Phosphorus	mg/L	132	0.639	0	15.8	1/2/2007 0:00	12/31/2017 0:00
FLOWCMS	Flow	cms	132	0.163	0	0.399	1/2/2007 0:00	12/31/2017 0:00
NH3	Ammonia	mg/L	132	0.365	0	2	1/2/2007 0:00	12/31/2017 0:00
NO3O2	Nitrate/Nitrite	mg/L	132	14.639	5.5	35	1/2/2007 0:00	12/31/2017 0:00
TEMP	Water Temperature	Deg C	3	20	20	20	1/1/2007 0:00	12/31/2017 0:00

Moultrie WPCP – Permit # GA0024660

DMR data stored on PCS and ICIS was used for the BOD, flow, and ammonia monthly input values. However, no data was identified in PCS or ICIS for TP (PO_4 and Organic P) or NOx and Organic N (Table 5). All these parameters are needed in order to run the WASP model. A review of EPA's file for this facility located two permit applications. This data was used to calculate an average ratio for Ammonia/TN, NOx/TN, and Organic N/TN. These ratios were used to calculate NOx and Organic N based on the Ammonia concentrations provided in DMR. Due to spikes in NOx concentrations when ammonia concentrations were high, a maximum TN target of 22.7 (the maximum of the two TN values presented in the permits applications) was added to the model. The average TP value was also calculated by using the permit applications. Due to no additional data available, a percentage allotment of 70% PO4 and 30% Organic P was assumed.

Table 5 Moultrie DMR Data

PCode	Parameter Name	Units	No. Obs.	Mean	Min	Max	First Date	Last Date
BOD	Biochemical Oxygen Demand	mg/L	132	4.449	1	13	1/2/2007 0:00	12/31/2017 0:00
DIP	Dissolved Inorganic Phosphorus	mg/L	132	3.35	0.7	9	1/2/2007 0:00	12/31/2017 0:00
DO	Dissolved Oxygen	mg/L	132	7.436	3.3	10.1	1/31/2007 0:00	12/31/2017 0:00
DON	Dissolved Organic Nitrogen	mg/L	132	2.513	0	16.16	1/2/2007 0:00	12/31/2017 0:00
DOP	Dissolved Organic Phosphorus	mg/L	132	0.253	0	1.5	1/2/2007 0:00	12/31/2017 0:00
FLOWCMS	Flow	cms	132	0.12	0.057	0.291	1/2/2007 0:00	12/31/2017 0:00
NH3	Ammonia	mg/L	132	0.723	0	7	1/2/2007 0:00	12/31/2017 0:00
NO3O2	Nitrate/Nitrite	mg/L	132	16.385	1.56	32.2	1/2/2007 0:00	12/31/2017 0:00

Cairo WPCP – Permit # GA0025771

DMR data stored on PCS and ICIS was used for the BOD, flow, and ammonia monthly input values (Table 6). However, Cairo was not discharging to a stream during from 1998 until 2006. Cairo was operating under a land application permit at that time. For this model, a zero discharge (i.e. load) was assumed during those years. GAEPD provided the BOD, flow and ammonia monthly values for 2006. However, no data was identified in PCS or ICIS, or available from GAEPD, for NOx and Organic N. These parameters are needed in order to run the WASP model. A review of EPA's file for this facility located a permit application. This data was used to calculate an average ratio for Ammonia/TN, NOx/TN, and Organic N/TN. GAEPD provided the TP and Ortho P data for the years 2006 through 2012. This data was used as the monthly input values for phosphorus.

Table 6 Cairo DMR Data

PCode	Parameter Name	Units	No. Obs.	Mean	Min	Max	First Date	Last Date
BOD	Biochemical Oxygen Demand	mg/L	132	5.501	2	10	1/1/2007 0:00	12/31/2017 0:00
DIP	Dissolved Inorganic Phosphorus	mg/L	132	0.246	0	3.2	1/1/2007 0:00	12/31/2017 0:00
DO	Dissolved Oxygen	mg/L	132	6.997	3	12	1/31/2007 0:00	12/31/2017 0:00
DON	Dissolved Organic Nitrogen	mg/L	132	1.266	0	7	1/1/2007 0:00	12/31/2017 0:00
DOP	Dissolved Organic Phosphorus	mg/L	135	0.219	0	0.7	1/1/2007 0:00	12/31/2017 0:00
FLOWCMS	Flow	cms	192	0.099	0	0.399	1/1/2007 0:00	12/31/2017 0:00
NH3	Ammonia	mg/L	132	0.53	0	2.1	1/1/2007 0:00	12/31/2017 0:00
NO3O2	Nitrate/Nitrite	mg/L	132	3.532	0	10.5	1/1/2007 0:00	12/31/2017 0:00
TEMP	Water Temperature	Deg C	1	20	20	20	12/31/2012 0:00	12/31/2012 0:00

Doerun WPCP – Permit # GA0021717

This facility is a minor wastewater treatment plant and therefore, no DMR data was available. A review of EPA's file for this facility located a permit application. The permit application contained sampling results for ammonia, NOx, TKN and phosphorus. Since this was the only data available it was used as the monthly data inputs in the WASP model. Additionally, the permit provided permit limits for BOD and flow. These limits were used in the model.

Table 7 Doe Run DMR Data

PCode	Parameter Name	Units	No. Obs.	Mean	Min	Max	First Date	Last Date
BOD	Biochemical Oxygen Demand	mg/L	120	9.803	0.4	38	1/31/2008 0:00	12/31/2017 0:00
DIP	Dissolved Inorganic Phosphorus	mg/L	62	0.595	0.595	0.595	1/1/2007 0:00	12/31/2017 0:00
DO	Dissolved Oxygen	mg/L	2	5	5	5	1/1/2007 0:00	12/31/2017 0:00
DON	Dissolved Organic Nitrogen	mg/L	62	3.73	3.73	3.73	1/1/2007 0:00	12/31/2017 0:00
DOP	Dissolved Organic Phosphorus	mg/L	62	0.255	0.255	0.255	1/1/2007 0:00	12/31/2017 0:00
FLOWCMS	Flow	cms	120	0.004	0	0.012	1/31/2008 0:00	12/31/2017 0:00
NH3	Ammonia	mg/L	62	3.1	3.1	3.1	1/1/2007 0:00	12/31/2017 0:00
NO3O2	Nitrate/Nitrite	mg/L	62	0.407	0.407	0.407	1/1/2007 0:00	12/31/2017 0:00

Sunnyland (aka Genesis Project/Affinity) Permit # GA001279

This facility is a frozen food plant. The DMR data stored on PCS and ICIS was used for the monthly BOD, flow and ammonia input values (Table 8). Several gaps in data were present in the databases. A search of the PCS website indicated that the gaps in data occurred whenever there was no discharge from the facility. Therefore, in the WASP model, whenever no flow was listed a zero flow and concentration was assumed for that time period. No data was found regarding phosphorus in PCS, ICIS or during a file review. Therefore, a phosphorus load was not added to the model for this point source.

Table 8 Sunnyland DMR Data

PCode	Parameter Name	Units	No. Obs.	Mean	Min	Max	First Date	Last Date
BOD	Biochemical Oxygen Demand	mg/L	132	9.268	0	481.656	1/2/2007 0:00	12/31/2017 0:00
DIP	Dissolved Inorganic Phosphorus	mg/L	132	0.887	0	13	1/2/2007 0:00	12/31/2017 0:00
DO	Dissolved Oxygen	mg/L	132	1.563	0	11	1/31/2007 0:00	12/31/2017 0:00
DON	Dissolved Organic Nitrogen	mg/L	3	0	0	0	1/1/2007 0:00	12/31/2017 0:00
DOP	Dissolved Organic Phosphorus	mg/L	132	0.136	0	1.725	1/2/2007 0:00	12/31/2017 0:00
FLOWCMS	Flow	cms	117	0	0	0.005	1/2/2007 0:00	9/30/2016 0:00
NH3	Ammonia	mg/L	130	0.573	0	12.233	1/2/2007 0:00	12/31/2017 0:00
NO3O2	Nitrate/Nitrite	mg/L	132	0.946	0	56	1/2/2007 0:00	12/31/2017 0:00
TEMP	Water Temperature	Deg C	3	20	20	20	1/1/2007 0:00	12/31/2017 0:00

Ochlocknee Permit # GA0046370

This is small municipal discharger to a tributary of the Ochlockonee River. The DMR data stored on PCS and ICIS was used for the monthly BOD, flow and nitrogen and phosphorus input values (Table 9).

Table 9 Ochlocknee, GA DMR Data

PCode	Parameter Name	Units	No. Obs.	Mean	Min	Max	First Date	Last Date
BOD	Biochemical Oxygen Demand	mg/L	124	4.9	2	16	1/1/2007 0:00	12/15/2017 0:00
DIP	Dissolved Inorganic Phosphorus	mg/L	133	1.506	0.05	3	1/1/2007 0:00	12/15/2017 0:00
DON	Dissolved Organic Nitrogen	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2007 0:00
DOP	Dissolved Organic Phosphorus	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2007 0:00
FLOWCMS	Flow	cms	132	0.001	0	0.004	1/15/2007 0:00	12/15/2017 0:00
NH3	Ammonia	mg/L	133	3.983	0.21	18.6	1/1/2007 0:00	12/15/2017 0:00
NO3O2	Nitrate/Nitrite	mg/L	112	0.307	0.01	1.6	1/1/2007 0:00	12/15/2017 0:00
PON	Particulate Organic Nitrogen	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2007 0:00
POP	Particulate Organic Phosphorus	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2007 0:00
TEMP	Water Temperature	Deg C	2	15	15	15	1/1/2007 0:00	12/31/2007 0:00

Meigs, GA Permit # GA0048178

This is small municipal discharger to a tributary of the Ochlockonee River. DMR data stored on PCS and ICIS was used for the monthly BOD, flow and ammonia and phosphorus input values (Table 10).

Table 10 Meigs, GA DMR Data

PCode	Parameter Name	Units	No. Obs.	Mean	Min	Max	First Date	Last Date
BOD	Biochemical Oxygen Demand	mg/L	68	6.007	0.2	19	1/1/2007 0:00	12/15/2017 0:00
DIP	Dissolved Inorganic Phosphorus	mg/L	2	2.5	2.5	2.5	1/1/2007 0:00	12/31/2017 0:00
DO	Dissolved Oxygen	mg/L	70	5.86	1.3	10.1	1/15/2010 0:00	12/15/2017 0:00
DON	Dissolved Organic Nitrogen	mg/L	1	0	0	0	1/1/2007 0:00	1/1/2007 0:00
DOP	Dissolved Organic Phosphorus	mg/L	2	2.5	2.5	2.5	1/1/2007 0:00	12/31/2017 0:00
FLOWCMS	Flow	cms	100	0.004	0	0.011	2/15/2007 0:00	12/15/2017 0:00
NH3	Ammonia	mg/L	102	2.89	0.07	18	2/15/2007 0:00	12/15/2017 0:00
NO3O2	Nitrate/Nitrite	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2017 0:00
PON	Particulate Organic Nitrogen	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2017 0:00
POP	Particulate Organic Phosphorus	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2017 0:00
TEMP	Water Temperature	Deg C	1	15	15	15	12/31/2017 0:00	12/31/2017 0:00

Facilities Not Included in the Model

The following permitted facilities were not included in this model:

- Pelham WPCP – Permit # GA0025518 – This facility was a minor wastewater treatment plant. According to GAEPD, the facility closed out their permit in the 1990s. Therefore, it was not included in the WASP model.

- W.B. Roddenbery Company – Permit # GA0001660 – According to the PCS data, this facility was first permitted in 1997. A review of the EPA's files on this facility determined all production ceased on July 2002. Since the facility was only active for five years, TN and TP were not regulated by the permit, and it was only a minor permitted facility, it was not included in the WASP model.

The remaining permits are for mining facilities (Permits # GA0047503, GA0047511, GA0047520, and GA0032409) and three of the four permits are no longer active. Additionally, none of the mining permits have limits for TN or TP. For these reasons, the mining permits were not included in the WASP model.

Water Withdrawals from Ochlockonee River

There are over 140 groundwater wells and 700 surface water withdrawals (Figure 10) in the upper Ochlockonee River used for agriculture and industrial purposes. While these are permitted facilities, water withdrawal quantities are only available on an annual basis for some of the facilities. It is impossible to account for these water withdrawals within the watershed or water quality model. The flow balancing methodology employed for the hydrodynamic model inflows to Lake Talquin will implicitly account for these sinks of water.

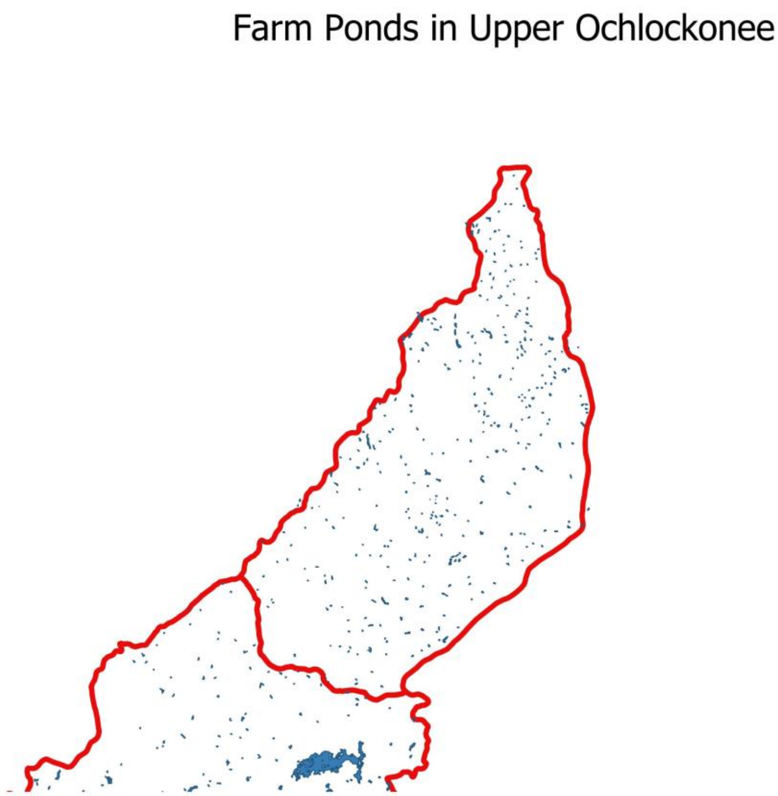

Figure 10 Farm Ponds in Upper Ochlockonee Watershed

Hydraulic Calibration

The watershed and water quality model were calibrated for flow by comparing the predicted flows to three USGS gages located within the Ochlockonee River. Figure 11 provides a map of the location of the USGS flow gages used in the flow calibration.

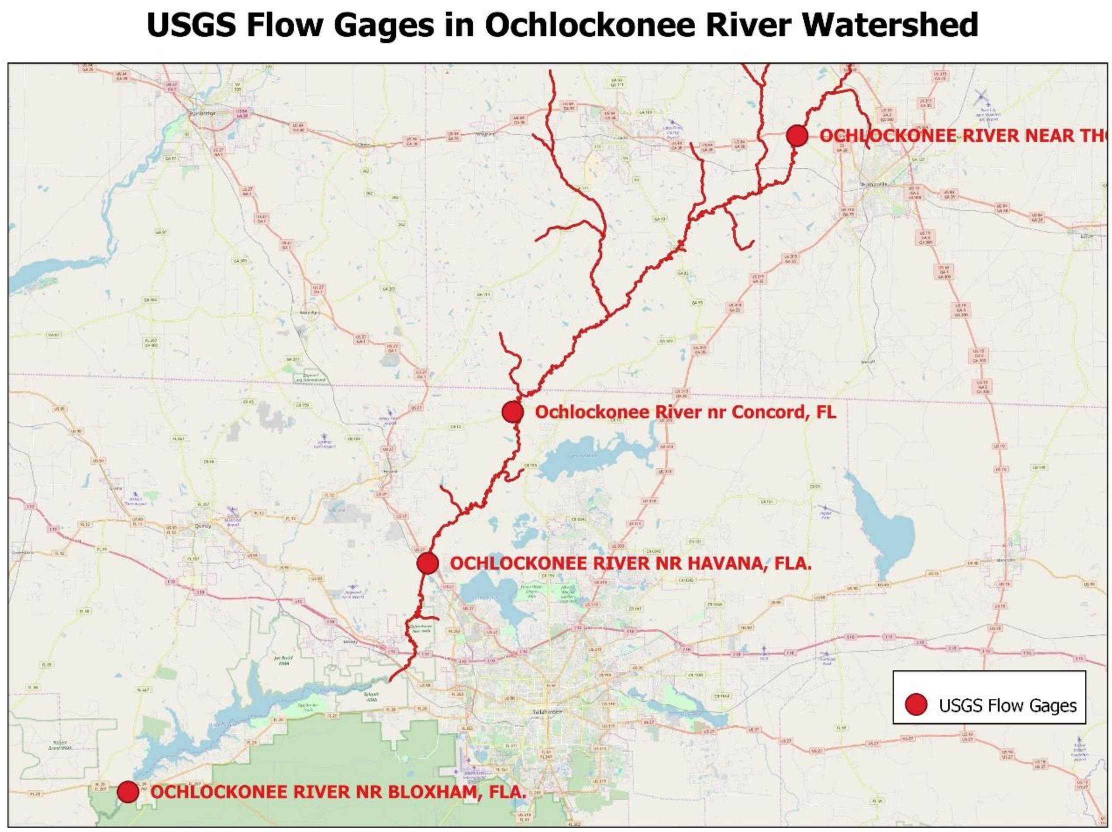

Figure 11 USGS Flow Gages used for Calibration on Ochlockonee River

Flow

Table 11 and Figure 12 provide a comparison of the flow simulated by the watershed/water quality model and the daily average flows at the USGS flow gage in the Ochlockonee River. Both the qualitative and quantitative comparison show very good correlation with the measured data.

Table 11 Quantitative Statistical Analysis for Flow – USGS Flow Gages Ochlockonee River

Metric	USGS HAVANA GAGE	USGS CONCORD GAGE	USGS THOMASVILLE GAGE	Average
Number Obs	3652	3652	3652	3652
Observed Mean	26.4197	26.6291	14.7418	22.5969
Observed Variance	3432.1774	4645.4067	1748.5451	3275.3764
Simulation Mean	26.1926	24.3167	14.1882	21.5658
Simulation Variance	3087.8848	2727.712	894.6024	2236.7331
Mean Error	-0.2271	-2.3124	-0.5536	-1.031
Mean Absolute Error	13.7217	12.5937	7.2593	11.1916
RMSE	28.6905	28.6892	20.6127	25.9975
R2	0.7655	0.8478	0.7866	0.8
Spearman Coeff.	0.7735	0.803	0.8012	0.7926
PBias	-0.9	-8.7	-3.8	-4.4667
Nash	0.7601	0.8228	0.7569	0.7799
Index of Agreement	0.933	0.9411	0.9128	0.929
Levene Test p-value	0.09623	0.00162	0.00308	0.0336
Mann-Whitney U p-value	0	0	0	0

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

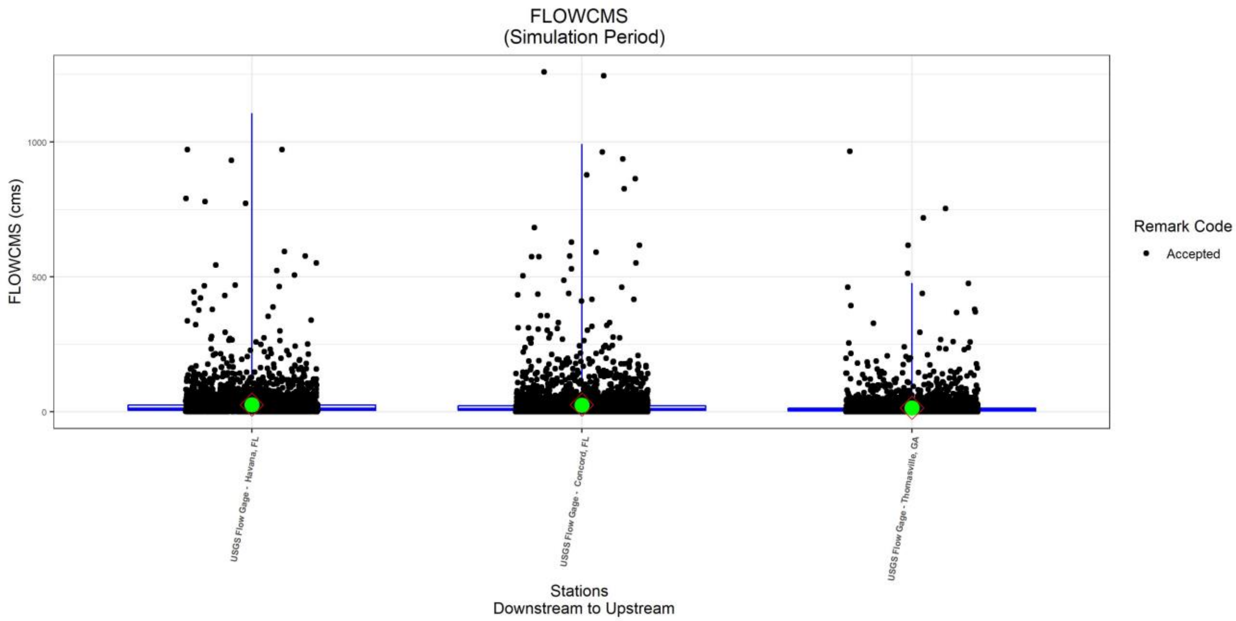

Figure 12 Flow Calibration Box Plot for Ochlockonee River

Water Quality Model Calibration

There are 19 water quality monitoring stations used for watershed/water quality model calibration for the Ochlockonee River water quality model. The monitoring data was obtained from FDEP's Impaired Waters Rule Database (Version 55) and data provided directly from GAEPD for the stations in Georgia. Figure 13 depicts the name and location of the water quality monitoring stations. For a Station/Water Quality Parameter to be considered in the quantitative and qualitative calculations and plots the station must have more than 9 observations during the simulation period.

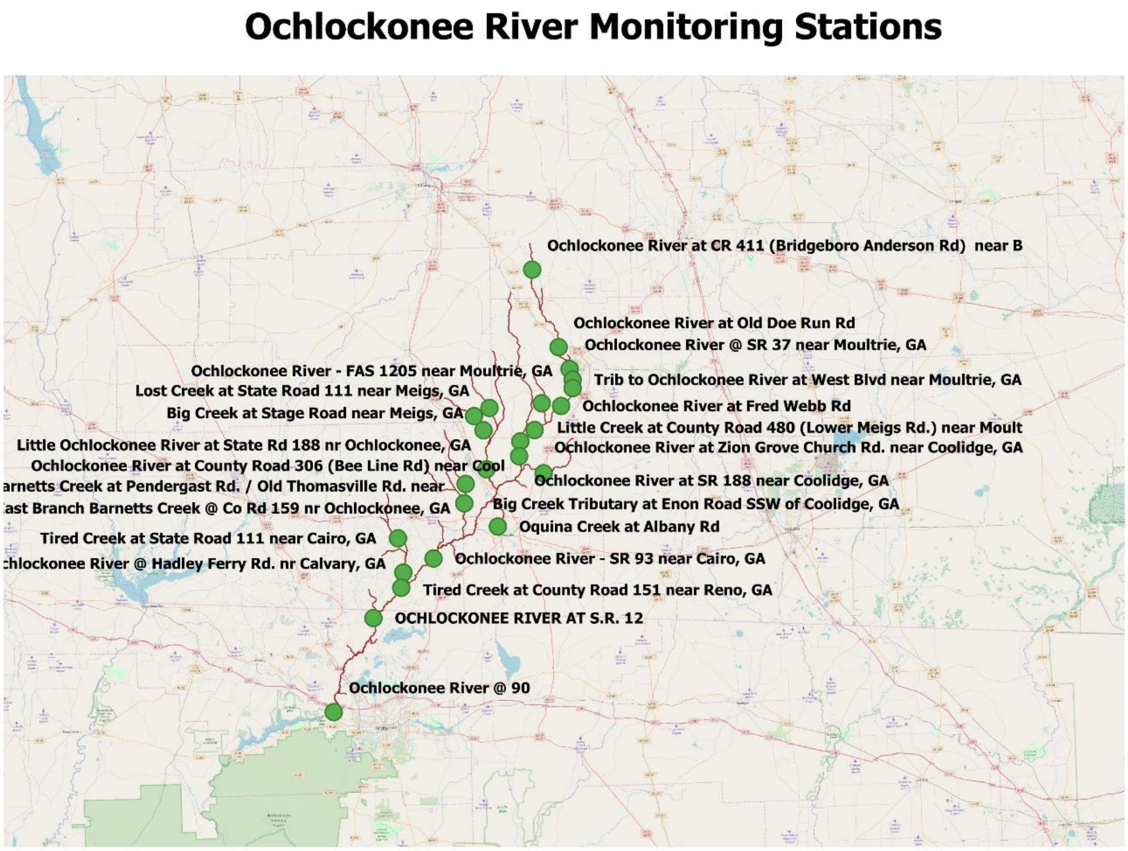

Figure 13 Ochlockonee River Water Quality Monitoring Locations

Table 12 provides a summary of measured parameters at each station that will be used for comparison with the simulated values from the water quality model.

Table 12 Summary of Ochlockonee River Monitoring Stations and Parameters Measured

Plot_Title	Metric	BOD	CHLAC	DO	NH4	NO3O2	PORD	TEMP	TN	TP
OR @ Highway 90, FL	Number Obs-Total	38	36	78	38	38			38	38
OR @ State Route 12, FL	Number Obs-Total		126	231	126	126	21	231	126	126
Tired Creek @ CR 151 nr Reno, GA	Number Obs-Total			59	24	24		59	12	50
OR @ Hadley Ferry Rd, GA	Number Obs-Total	14		275	93	157	73	275	47	157
OR @ SR 93 nr Cairo, GA	Number Obs-Total	12		23		11	12	23	11	12
Tired Creek @ SR 111 nr Cairo, GA	Number Obs-Total			11		11		11		11
E Branch Barnetts Creek @ Co Rd 159, GA	Number Obs-Total			19	10	18		20		18
Barnetts Creek @ Pendergast Rd, GA	Number Obs-Total	12		23				23		12
OR @ County Road 306, GA	Number Obs-Total			12		11		13		11
Big Creek @ Stage Rd nr Meigs, GA	Number Obs-Total	12		23				23	12	12
OR @ FAS 1205 nr Moultrie, GA	Number Obs-Total			65	33	56	29	65		56
OR @ Zion Grove Church Rd, GA	Number Obs-Total	14		38	10	24	23	39	12	24
OR @ Fred Webb Rd, GA	Number Obs-Total			32		16	16	32		16
OR @ SR 188 nr Coolidge, GA	Number Obs-Total	14		46	13	33	12	46		36
Little OR @ State Rd 188, GA	Number Obs-Total	12		23			10	23		12
Trib to OR @ at West Blvd, GA	Number Obs-Total			13		11		13		14
OR @SR 37 nr Moultrie, GA	Number Obs-Total			10				10		10
Global_Avg	Number Obs-Total	16	81	57.7059	43.375	41.2308	24.5	56.625	36.8571	36.1765

Total Nitrogen

Table 13 and Figure 14 provide a comparison of total nitrogen simulated by the watershed/water quality model and the measured values at 7 water quality monitoring stations.

Table 13 Quantitative Statistical Analysis for Total Nitrogen – Ochlockonee River Stations

Metric	OR @ Highway 90, FL	OR @ State Route 12, FL	Tired Creek @ CR 151 nr Reno, GA	OR @ Hadley Ferry Rd, GA	OR @ SR 93 nr Cairo, GA	Big Creek @ Stage Rd nr Meigs, GA	OR @ Zion Grove Church Rd, GA	Average
Number Obs-Total	38	126	12	47	11	12	12	36.8571
Number Obs-Accepted	38	126	12	47	11	12	12	36.8571
Observed Mean	1.013	1.235	2.973	1.347	1.285	0.728	1.42	1.4287
Observed Variance	0.141	0.312	3.645	0.326	0.094	0.022	0.466	0.7151
Simulation Mean	1.224	1.429	0.498	1.593	1.796	0.638	2.381	1.3656
Simulation Variance	0.341	1.243	0.032	1.522	2.314	0.147	2.558	1.1653
Mean Error	0.2115	0.1943	-2.4749	0.2462	0.5118	-0.0896	0.9614	-0.0628
Mean Absolute Error	0.5884	0.6461	2.4749	0.5886	0.7904	0.3591	1.3019	0.9642
RMSE	0.7962	1.1744	3.1042	1.0026	1.4667	0.4271	1.911	1.4117
NRMSE %	41.1	23.5	66.2	36.5	148.1	77.6	74.4	66.7714
R^2	0.0795	0.0265	0.051	0.3928	0.1253	0.0329	0.0005	0.1012
Spearman Coeff.	-0.2863	0.4334	-0.2587	0.5864	0.2636	0.1053	-0.1471	0.0995
PBias	20.9	15.7	-83.2	18.3	39.8	-12.3	67.7	9.5571
Nash	-3.6208	-3.4493	-1.8837	-2.1555	-24.2238	-7.9764	-7.5568	-7.2666
Index of Agreement	0.1283	0.3155	0.4672	0.6478	0.2608	0.257	0.2906	0.3382
Kling-Gupta Effic. Modified	-0.33	-0.1173	-0.5468	0.0734	-1.6621	-1.2748	-0.2543	-0.5874
Kling-Gupta Pear. Coeff.	-0.282	0.1629	-0.2257	0.6267	0.3539	-0.1814	0.0219	0.068
Kling-Gupta Beta (Ratio Means)	1.2088	1.1574	0.1677	1.1828	1.3984	0.8769	1.6771	1.0956
Kling-Gupta Gamma (Ratio CV)	1.2863	1.7231	0.5557	1.8282	3.5516	2.94	1.3976	1.8975

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

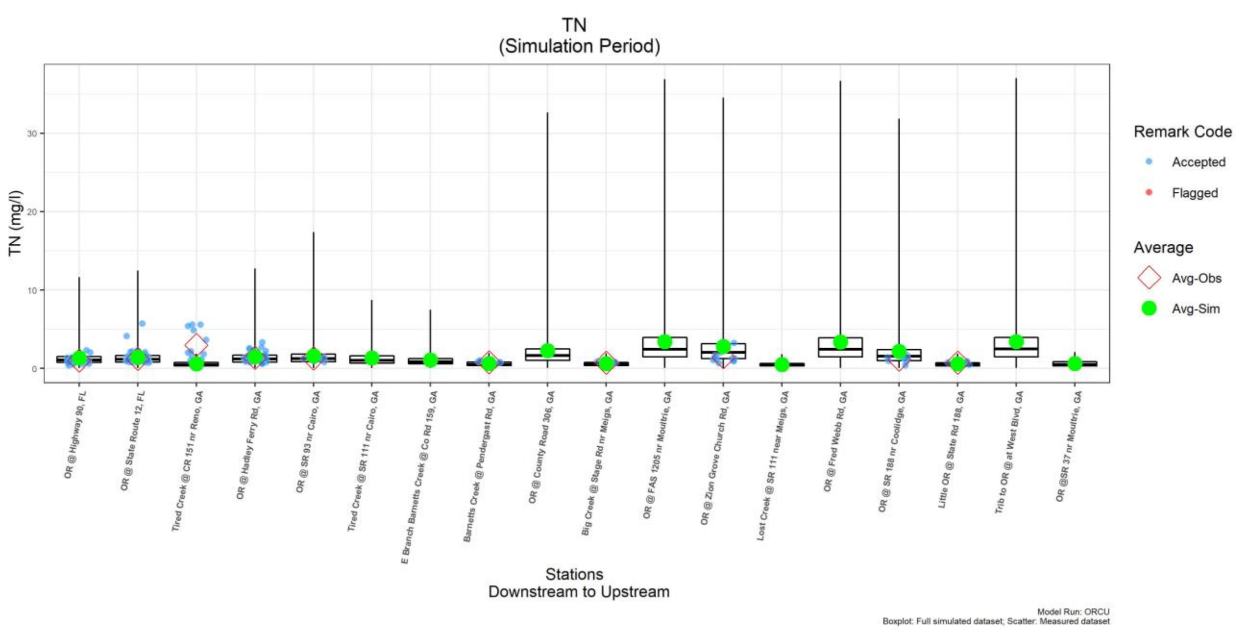

Figure 14 Total Nitrogen Box Plot for Ochlockonee River

Table 14 and Figure 15 provide a comparison of ammonia simulated by the watershed/water quality model and the measured values at 8 water quality monitoring stations.

Table 14 Quantitative Statistical Analysis for Ammonia – Ochlockonee River Stations

Metric	OR @ Highway 90, FL	OR @ State Route 12, FL	Tired Creek @ CR 151 nr Reno, GA	OR @ Hadley Ferry Rd, GA	E Branch Barnetts Creek @ Co Rd 159, GA	OR @ FAS 1205 nr Moultrie, GA	OR @ Zion Grove Church Rd, GA	OR @ SR 188 nr Coolidge, GA	Average
Number Obs-Total	38	126	24	93	10	33	10	13	43.375
Number Obs-Accepted	28	122	24	93	10	33	10	13	41.625
Observed Mean	0.059	0.056	0.138	0.056	0.058	0.103	0.058	0.043	0.0714
Observed Variance	0.002	0.01	0.045	0.001	0.001	0.01	0.004	0	0.0091
Simulation Mean	0.074	0.075	0.031	0.076	0.062	0.115	0.061	0.078	0.0715
Simulation Variance	0.001	0.002	0	0.002	0.001	0.006	0.001	0.001	0.0018
Mean Error	0.0155	0.0184	-0.1069	0.0191	0.0039	0.0122	0.0035	0.0349	0.0001
Mean Absolute Error	0.0384	0.0456	0.1125	0.0368	0.0245	0.0738	0.0415	0.0403	0.0517
RMSE	0.0531	0.1085	0.2363	0.0509	0.0307	0.1062	0.0665	0.0488	0.0876
NRMSE %	26.6	9.9	24.4	33.9	43.9	27.2	31.7	162.6	45.025
R^2	0.0001	0.0011	0.0045	0.0237	0.0249	0.084	0	0.001	0.0174
Spearman Coeff.	0.2116	0.3407	-0.0377	0.1111	0.0681	0.219	0.6356	-0.0945	0.1817
PBias	26.4	32.8	-77.7	33.9	6.7	11.9	6	80.9	15.1125
Nash	-0.6735	-0.1642	-0.286	-1.4217	-0.697	-0.1303	-0.1836	-23.2171	-3.3467
Index of Agreement	0.2987	0.135	0.3313	0.4163	0.5494	0.5413	0.1682	0.2295	0.3337
Kling-Gupta Effic. Modified	-0.1074	-0.239	-0.4332	0.0831	0.1522	0.2031	-0.1644	-0.515	-0.1276
Kling-Gupta Pear. Coeff.	0.0086	0.033	-0.0671	0.154	0.1578	0.2899	0.0023	0.0309	0.0762
Kling-Gupta Beta (Ratio Means)	1.2642	1.328	0.2228	1.3388	1.0668	1.1187	1.0599	1.8092	1.151
Kling-Gupta Gamma (Ratio CV)	0.5834	0.2982	0.442	0.8997	0.9293	0.6583	0.4028	1.8374	0.7564

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

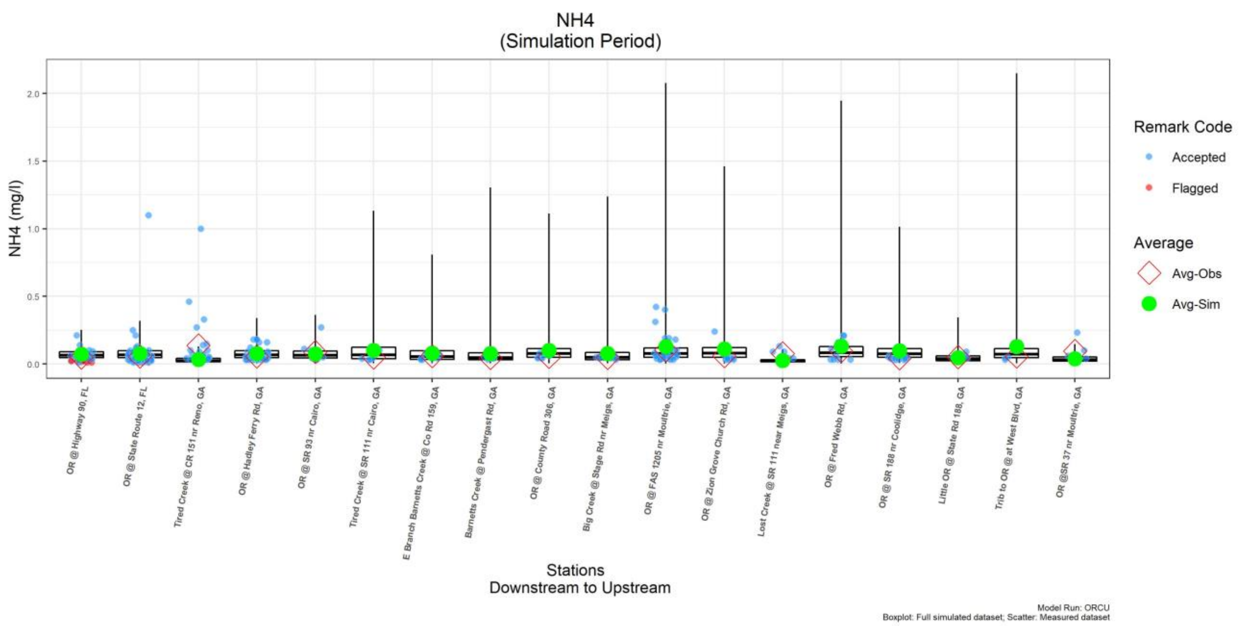

Figure 15 Ammonia Box Plot for Ochlockonee River

Nitrate

Table 15 and Figure 16 provide a comparison of nitrate simulated by the watershed/water quality model and the measured values at 13 water quality monitoring stations.

Table 15 Quantitative Statistical Analysis for Nitrate – Ochlockonee River Stations

Metric	OR @ Highway 90, FL	OR @ State Route 12, FL	Tired Creek @ CR 151 nr Reno, GA	OR @ Hadley Ferry Rd, GA	OR @ SR 93 nr Cairo, GA	Tired Creek @ SR 111 nr Cairo, GA	E Branch Barnetts Creek @ Co Rd 159, GA	OR @ County Road 306, GA	OR @ FAS 1205 nr Moultrie, GA	OR @ Zion Grove Church Rd, GA	OR @ Fred Webb Rd, GA	OR @ SR 188 nr Coolidge, GA	Trib to OR @ at West Blvd, GA	Average
Number Obs-Total	38	126	24	157	11	11	18	11	56	24	16	33	11	41.2308
Number Obs-Accepted	37	125	24	157	11	11	18	11	56	24	16	33	11	41.0769
Observed Mean	0.373	0.544	1.152	0.643	0.517	0.475	0.181	0.915	6.943	1.894	3.866	0.509	0.162	1.398
Observed Variance	0.063	0.14	0.941	0.301	0.118	0.187	0.013	0.529	40.351	4.81	8.628	0.739	0.03	4.3731
Simulation Mean	0.842	1.055	0.247	1.034	1.36	0.561	0.352	1.675	2.922	2.276	3.188	0.949	1.468	1.3792
Simulation Variance	0.303	1.071	0.025	1.424	2.028	0.063	0.026	3.825	16.153	3.721	22.259	0.411	0.753	4.0048
Mean Error	0.4696	0.5116	-0.9047	0.3912	0.843	0.0856	0.1712	0.7591	-4.0207	0.3826	-0.6779	0.4403	1.3061	-0.0187
Mean Absolute Error	0.5296	0.5685	0.9482	0.5136	0.9516	0.4619	0.2054	1.1771	4.234	1.5653	1.9907	0.803	1.3061	1.1735
RMSE	0.7528	1.0551	1.2995	1.0572	1.5246	0.5699	0.2539	1.8217	6.1145	2.1129	2.9475	1.1211	1.6062	1.7105
NRMSE %	50.5	39.4	32.6	32.8	151	39.9	72.5	80.3	29.6	23.7	26.2	25	321.2	71.1308
R^2	0.0013	0.2077	0.0361	0.3317	0.1435	0.2097	0.002	0.2211	0.4671	0.2264	0.6364	0.0024	0.3464	0.2178
Spearman Coeff.	0.2453	0.6873	0.0884	0.7806	0.5513	-0.41	0.0496	0.2818	0.7444	0.5207	0.6176	-0.1465	-0.6758	0.2565
PBias	126	94.1	-78.6	60.8	163	18	94.5	82.9	-57.9	20.2	-17.5	86.5	807.2	107.6308
Nash	-8.3136	-7.0138	-0.8719	-2.7387	-20.7272	-0.9083	-4.2615	-5.8983	0.0566	0.0315	-0.0741	-0.7538	-92.5476	-11.0785
Index of Agreement	0.2563	0.4218	0.4373	0.5817	0.2458	0.1141	0.3491	0.4833	0.7173	0.6695	0.8367	0.3332	0.0597	0.4235
Kling-Gupta Effic. Modified	-0.5862	-0.1671	-0.154	0.1789	-0.8375	-0.5548	-0.3717	-0.0904	0.1701	0.3774	0.0152	-0.4189	-7.2388	-0.7444
Kling-Gupta Pear. Coeff.	0.0364	0.4558	0.19	0.5759	0.3788	-0.4579	0.0444	0.4702	0.6834	0.4758	0.7977	0.0492	-0.5885	0.2393
Kling-Gupta Beta (Ratio Means)	2.2598	1.9408	0.2144	1.6083	2.6297	1.18	1.9452	1.8293	0.4209	1.202	0.8246	1.8654	9.0717	2.0763
Kling-Gupta Gamma (Ratio CV)	0.9745	1.4253	0.7579	1.3526	1.5784	0.4906	0.7262	1.4698	1.5032	0.7318	1.9478	0.3999	0.5492	1.0698

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

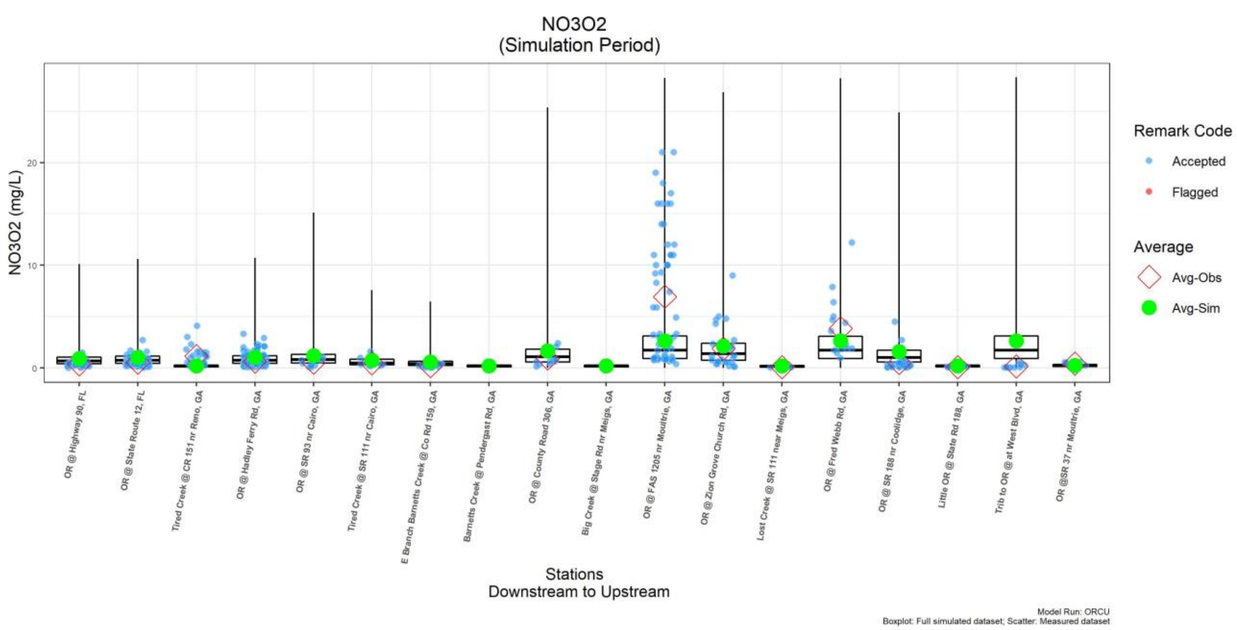

Figure 16 Nitrate Box Plot for Ochlockonee River

Total Phosphorus

Table 16 and Figure 17 provide a comparison of Total Phosphorus simulated by the watershed/water quality model and the measured values at 17 water quality monitoring stations.

Table 16 Quantitative Statistical Analysis for Total Phosphorus – Ochlockonee River Station

Metric	OR @ Highway 90, FL	OR @ State Route 12, FL	Tired Creek @ CR 151 nr Reno, GA	OR @ Hadley Ferry Rd, GA	OR @ SR 93 nr Cairo, GA	Tired Creek @ SR 111 nr Cairo, GA	E Branch Barnetts Creek @ Co Rd 159, GA	Barnetts Creek @ Pendergast Rd, GA	OR @ County Road 306, GA
Number Obs-Total	38	126	50	157	12	11	18	12	11
Number Obs-Accepted	38	125	50	157	12	11	18	12	11
Observed Mean	0.113	0.157	0.157	0.158	0.209	0.11	0.07	0.099	0.797
Observed Variance	0.001	0.027	0.002	0.003	0.003	0.002	0.001	0.003	0.516
Simulation Mean	0.198	0.242	0.103	0.238	0.301	0.137	0.107	0.129	0.858
Simulation Variance	0.023	0.034	0.001	0.046	0.048	0.005	0.002	0.002	0.884
Mean Error	0.0854	0.0853	-0.0543	0.0797	0.0921	0.0269	0.0371	0.03	0.0605
Mean Absolute Error	0.1043	0.1365	0.063	0.1153	0.111	0.0781	0.0612	0.0575	0.4059
RMSE	0.182	0.2618	0.0818	0.2286	0.2173	0.1048	0.0782	0.0742	0.5958
NRMSE %	110.3	14.3	35.6	53.2	144.9	80.6	65.2	39	32.7
R^2	0.0526	0.0003	0.1762	0.018	0.1278	0.7122	0.3592	0.0246	0.5629
Spearman Coeff.	-0.1883	0.1087	-0.4221	0.2445	0.5644	-0.8174	-0.7472	0.0495	0.8929
PBias	75.7	54.4	-34.6	50.4	44	24.5	53	30.3	7.6
Nash	-23.1012	-1.5942	-1.9054	-16.6952	-17.1093	-5.8669	-3.3711	-1.3161	0.2437
Index of Agreement	0.1181	0.1213	0.3507	0.2114	0.2515	0.0166	0.1232	0.1731	0.8426
Kling-Gupta Effic. Modified	-0.9254	-0.1851	-0.4868	-0.9102	-1.0029	-0.8858	-0.713	-0.2512	0.6612
Kling-Gupta Pear. Coeff.	-0.2293	-0.0183	-0.4198	0.1343	0.3575	-0.8439	-0.5993	-0.1568	0.7503
Kling-Gupta Beta (Ratio Means)	1.7574	1.5438	0.6539	1.5039	1.4401	1.245	1.5303	1.3029	1.0758
Kling-Gupta Gamma (Ratio CV)	2.2736	0.7321	0.7263	2.6266	2.8453	1.3101	0.6913	0.6319	1.2161

Metric	Big Creek @ Stage Rd nr Meigs, GA	OR @ FAS 1205 nr Moultrie, GA	OR @ Zion Grove Church Rd, GA	OR @ Fred Webb Rd, GA	OR @ SR 188 nr Coolidge, GA	Little OR @ State Rd 188, GA	Trib to OR @ at West Blvd, GA	OR @SR 37 nr Moultrie, GA	Average
Number Obs-Total	12	56	24	16	36	12	14	10	36.1765
Number Obs-Accepted	12	56	24	16	36	12	14	10	36.1176
Observed Mean	0.145	1.276	0.842	1.555	0.438	0.104	0.043	0.116	0.3758
Observed Variance	0.003	0.974	0.639	1.942	0.17	0.001	0	0.005	0.2525
Simulation Mean	0.13	0.452	0.48	0.507	0.288	0.106	0.509	0.098	0.2872
Simulation Variance	0.002	0.184	0.122	0.289	0.037	0.001	0.352	0	0.1195
Mean Error	-0.0153	-0.8236	-0.3617	-1.0481	-0.1503	0.0014	0.4664	-0.0181	-0.0886
Mean Absolute Error	0.0545	0.8634	0.4695	1.0481	0.2359	0.0336	0.4664	0.0698	0.2573
RMSE	0.067	1.1272	0.7504	1.5174	0.384	0.0371	0.7447	0.0828	0.3844
NRMSE %	39.4	35.4	21.4	34.7	18.3	46.4	1063.9	43.6	110.5235
R^2	0.0127	0.4299	0.3077	0.3995	0.2447	0.0913	0.1833	0.4249	0.2428
Spearman Coeff.	0.0106	0.7039	0.6096	0.5401	0.412	-0.2338	-0.2694	-0.7256	0.0431
PBias	-10.6	-64.6	-43	-67.4	-34.3	1.3	1088.2	-15.6	68.1941
Nash	-0.5154	-0.3277	0.0803	-0.2646	0.107	-1.3942	-1364.6959	-0.4897	-84.6009
Index of Agreement	0.462	0.617	0.5677	0.5569	0.5796	0.1799	0.0098	0.1274	0.3123
Kling-Gupta Effic. Modified	0.0978	0.234	0.3385	0.2108	0.3231	-0.3058	-10.063	-0.7947	-0.8623
Kling-Gupta Pear. Coeff.	0.1128	0.6557	0.5547	0.632	0.4947	-0.3021	-0.4281	-0.6518	0.0025
Kling-Gupta Beta (Ratio Means)	0.8942	0.3544	0.5703	0.326	0.6571	1.0134	11.8823	0.844	1.682
Kling-Gupta Gamma (Ratio CV)	0.8752	1.2266	0.7663	1.1823	0.7081	0.9032	2.3875	0.3158	1.2599

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

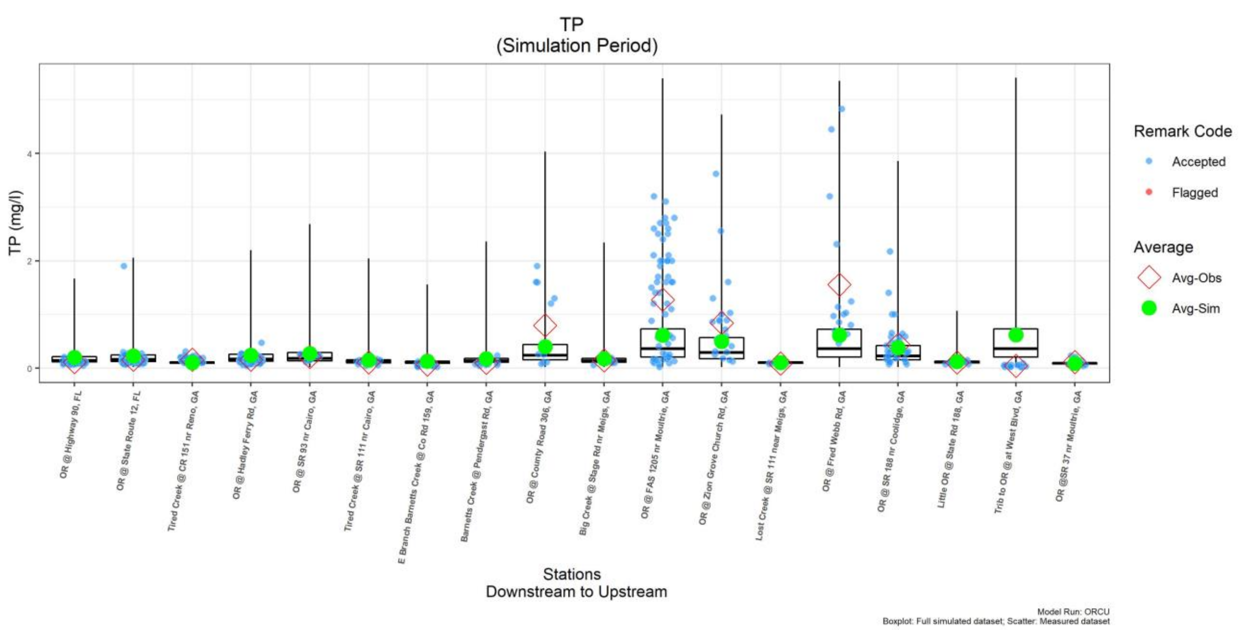

Figure 17 Total Phosphorus Box Plot for Ochlockonee River

Dissolved Inorganic Phosphorus

Table 17 and Figure 18 provide a comparison of chlorophyll a simulated by the watershed/water quality model and the measured values at 7 water quality monitoring stations.

Table 17 Quantitative Statistical Analysis for Dissolved Inorganic Phosphorus – Ochlockonee River Stations

Metric	OR @ State Route 12, FL	OR @ Hadley Ferry Rd, GA	OR @ SR 93 nr Cairo, GA	OR @ FAS 1205 nr Moultrie, GA	OR @ Zion Grove Church Rd, GA	OR @ Fred Webb Rd, GA	OR @ SR 188 nr Coolidge, GA	Little OR @ State Rd 188, GA	Average
Number Obs-Total	21	73	12	29	23	16	12	10	24.5
Number Obs-Accepted	21	73	12	29	23	16	12	10	24.5
Observed Mean	0.096	0.066	0.117	0.954	0.751	1.498	0.431	0.033	0.4932
Observed Variance	0.002	0.001	0.002	0.851	0.492	1.784	0.269	0	0.4251
Simulation Mean	0.277	0.174	0.226	0.385	0.425	0.457	0.368	0.049	0.2951
Simulation Variance	0.043	0.033	0.049	0.28	0.117	0.276	0.056	0	0.1068
Mean Error	0.1809	0.1078	0.1093	-0.5696	-0.3259	-1.0405	-0.0625	0.0157	-0.1981
Mean Absolute Error	0.187	0.1121	0.1333	0.6091	0.439	1.0405	0.2039	0.0188	0.343
RMSE	0.2596	0.2095	0.242	0.8602	0.6584	1.4618	0.396	0.023	0.5138
NRMSE %	153.6	116.4	134.4	31.3	23.1	33.3	20.4	76.7	73.65
R^2	0.1901	0.0072	0.0002	0.5154	0.3091	0.4446	0.4152	0.1434	0.2532
Spearman Coeff.	0.4013	0.2841	0.2222	0.672	0.6298	0.6047	0.807	-0.4259	0.3994
PBias	187.5	162.2	93.7	-59.7	-43.4	-69.5	-14.5	47.6	37.9875
Nash	-27.9773	-51.822	-24.9647	0.0999	0.0789	-0.2773	0.3634	-5.5434	-13.7553
Index of Agreement	0.2813	0.1173	0.1294	0.7161	0.5972	0.5676	0.6538	0.2492	0.414
Kling-Gupta Effic. Modified	-1.0107	-1.3173	-0.8797	0.217	0.3643	0.177	0.3945	-0.4671	-0.3152
Kling-Gupta Pear. Coeff.	0.436	0.085	0.0131	0.7179	0.556	0.6668	0.6444	-0.3787	0.3426
Kling-Gupta Beta (Ratio Means)	2.8749	2.6221	1.9366	0.4033	0.5662	0.3052	0.8548	1.4764	1.3799
Kling-Gupta Gamma (Ratio CV)	1.4577	2.3789	2.297	1.4213	0.8628	1.289	0.5319	0.843	1.3852

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

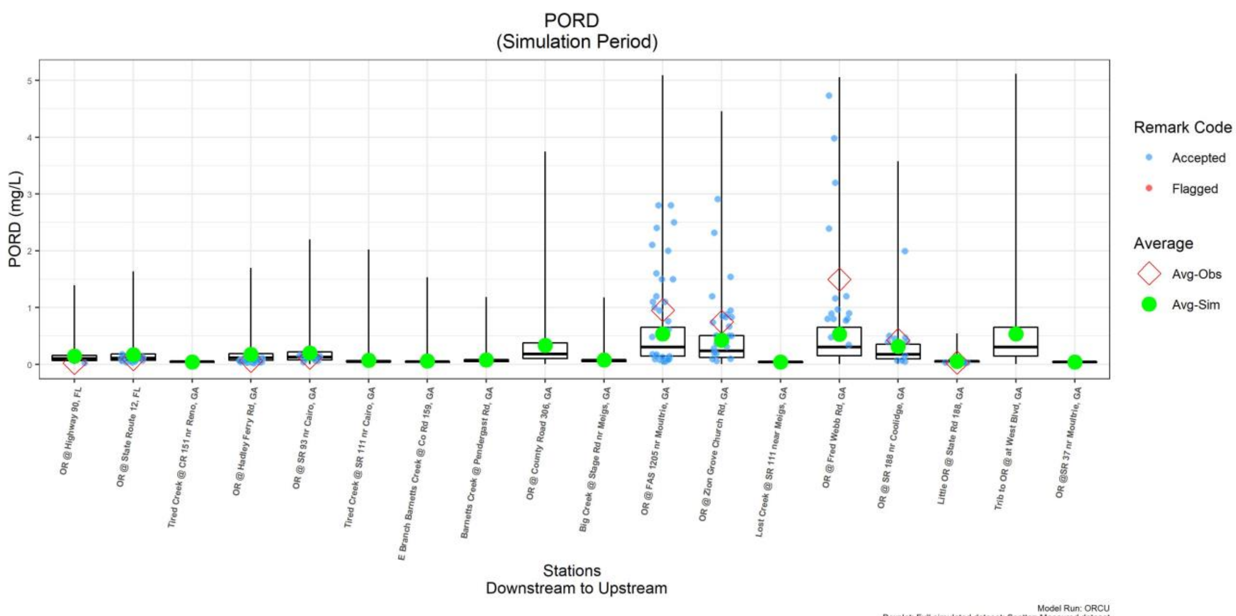

Figure 18 Dissolved Inorganic Phosphorus Box Plot for Ochlockonee River

Chlorophyll a

Table 18 and Figure 19 provide a comparison of chlorophyll a simulated by the watershed/water quality model and the measured values at 2 water quality monitoring stations.

Table 18 Quantitative Statistical Analysis for Chlorophyll a – Ochlockonee River Stations

Metric	OR @ Highway 90, FL	OR @ State Route 12, FL	Average
Number Obs-Total	36	126	81
Number Obs-Accepted	29	121	75
Observed Mean	8.748	5.007	6.8775
Observed Variance	97.795	60.645	79.22
Simulation Mean	0.443	0.717	0.58
Simulation Variance	0.642	2.46	1.551
Mean Error	-8.3048	-4.2894	-6.2971
Mean Absolute Error	8.3048	4.4107	6.3578
RMSE	12.6389	8.6049	10.6219
NRMSE %	33.2	12.4	22.8
R^2	0.0779	0.082	0.0799
Spearman Coeff.	0.2269	0.33	0.2784
PBias	-94.9	-85.7	-90.3
Nash	-0.6918	-0.2311	-0.4614
Index of Agreement	0.4246	0.3125	0.3686
Kling-Gupta Effic. Modified	-0.3339	-0.1867	-0.2603
Kling-Gupta Pear. Coeff.	0.279	0.2864	0.2827
Kling-Gupta Beta (Ratio Means)	0.0507	0.1433	0.097
Kling-Gupta Gamma (Ratio CV)	1.5986	1.406	1.5023

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

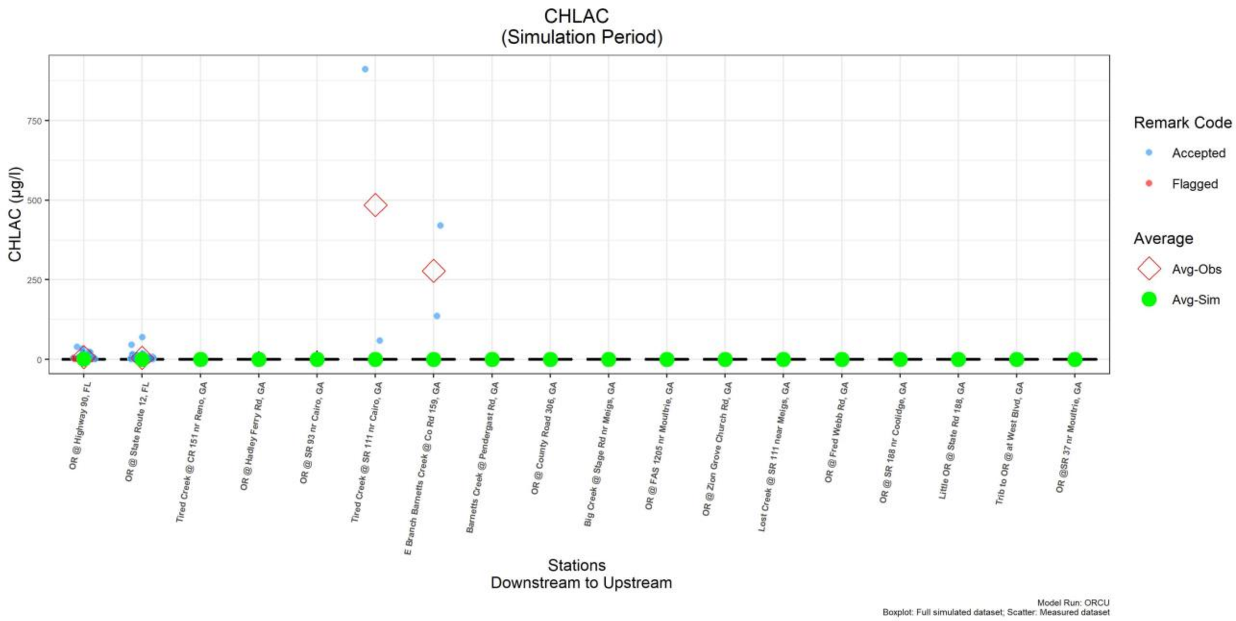

Figure 19 Chlorophyll a Box Plot for Ochlockonee River

Dissolved Oxygen

Table 19 and Figure 20 provide a comparison of dissolved oxygen simulated by the watershed/water quality model and the measured values at 14 water quality monitoring stations.

Table 19 Quantitative Statistical Analysis for Dissolved Oxygen – Ochlockonee River Stations

Metric	OR @ Highway 90, FL	OR @ State Route 12, FL	Tired Creek @ CR 151 nr Reno, GA	OR @ Hadley Ferry Rd, GA	OR @ SR 93 nr Cairo, GA	Tired Creek @ SR 111 nr Cairo, GA	E Branch Barnetts Creek @ Co Rd 159, GA	Barnetts Creek @ Pendergast Rd, GA	OR @ County Road 306, GA	Big Creek @ Stage Rd nr Meigs, GA	OR @ FAS 1205 nr Moultrie, GA	OR @ Zion Grove Church Rd, GA	OR @ Fred Webb Rd, GA	OR @ SR 188 nr Coolidge, GA	Little OR @ State Rd 188, GA	Trib to OR @ at West Blvd, GA	OR @SR 37 nr Moultrie, GA	Average
Number Obs-Total	78	231	59	275	23	11	19	23	12	23	65	38	32	46	23	13	10	57.7059
Number Obs-Accepted	78	231	59	275	23	11	19	23	12	23	65	38	32	46	23	13	10	57.7059
Observed Mean	6.995	7.646	7.758	7.336	6.786	6.404	6.917	7.849	6.597	7.982	6.08	6.528	6.124	6.275	6.867	7.36	5.894	6.9058
Observed Variance	4.046	3.756	2.108	3.548	2.374	3.125	3.619	2.97	9.369	1.956	2.791	2.374	2.239	4.297	5.417	6.39	12.738	4.301
Simulation Mean	7.962	7.973	8.306	7.783	7.824	7.851	7.873	8.421	7.061	8.208	7.303	7.462	6.415	7.62	7.964	7.431	7.995	7.7325
Simulation Variance	1.573	1.658	3.248	1.868	1.865	2.361	2.378	2.523	1.496	2.845	2.026	1.234	0.682	1.496	2.869	2.297	2.285	2.0414
Mean Error	0.9677	0.3273	0.5482	0.4472	1.0382	1.4475	0.9564	0.5719	0.4639	0.2262	1.2227	0.9339	0.2909	1.3457	1.0968	0.0711	2.101	0.8269
Mean Absolute Error	1.3562	0.8859	0.8649	1.0404	1.3126	1.4846	1.1627	0.7788	1.477	0.7037	1.4981	1.2126	1.2045	1.5059	1.1984	1.3325	2.3757	1.2585
RMSE	1.732	1.1254	1.078	1.3066	1.661	1.8998	1.5021	0.9751	2.035	0.8842	1.7688	1.518	1.4836	1.8187	1.5587	1.806	3.0152	1.5981
NRMSE %	16.2	10.2	17.7	11.9	29	31.6	22.6	14.8	17.9	17.4	23.8	19.5	24.2	19.7	18.4	20.2	29.8	20.2882
R^2	0.4892	0.7251	0.7327	0.5747	0.3478	0.4946	0.6095	0.7818	0.7727	0.7322	0.4409	0.3896	0.0887	0.7067	0.7891	0.4533	0.8293	0.5858
Spearman Coeff.	0.714	0.8546	0.8409	0.7414	0.4605	0.7364	0.7526	0.8745	0.7811	0.8488	0.5919	0.61	-0.0119	0.8511	0.8864	0.6593	0.9152	0.7122
PBias	13.8	4.3	7.1	6.1	15.3	22.6	13.8	7.3	7	2.8	20.1	14.3	4.8	21.4	16	1	35.6	12.5471
Nash	0.249	0.6614	0.4393	0.5171	-0.2149	-0.2707	0.3419	0.6653	0.5178	0.5821	-0.1384	0.0028	-0.0147	0.2131	0.5312	0.447	0.207	0.2786
Index of Agreement	0.7173	0.872	0.8848	0.8287	0.6944	0.6977	0.8088	0.9091	0.7474	0.909	0.7078	0.6902	0.5362	0.7476	0.8534	0.7557	0.7091	0.7688
Kling-Gupta Effic. Modified	0.4396	0.6055	0.774	0.5973	0.5048	0.5269	0.6126	0.8036	0.358	0.773	0.5124	0.454	0.1519	0.4206	0.5796	0.4786	0.2202	0.5184
Kling-Gupta Pear. Coeff.	0.6994	0.8515	0.856	0.7581	0.5897	0.7032	0.7807	0.8842	0.8791	0.8557	0.664	0.6242	0.2979	0.8407	0.8883	0.6733	0.9107	0.7504
Kling-Gupta Beta (Ratio Means)	1.1383	1.0428	1.0707	1.061	1.153	1.226	1.1383	1.0729	1.0703	1.0283	1.2011	1.1431	1.0475	1.2145	1.1597	1.0097	1.3565	1.1255
Kling-Gupta Gamma (Ratio CV)	0.5477	0.637	1.1592	0.6839	0.7687	0.709	0.7121	0.8591	0.3734	1.1729	0.7094	0.6307	0.5267	0.4859	0.6275	0.5938	0.3123	0.677

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

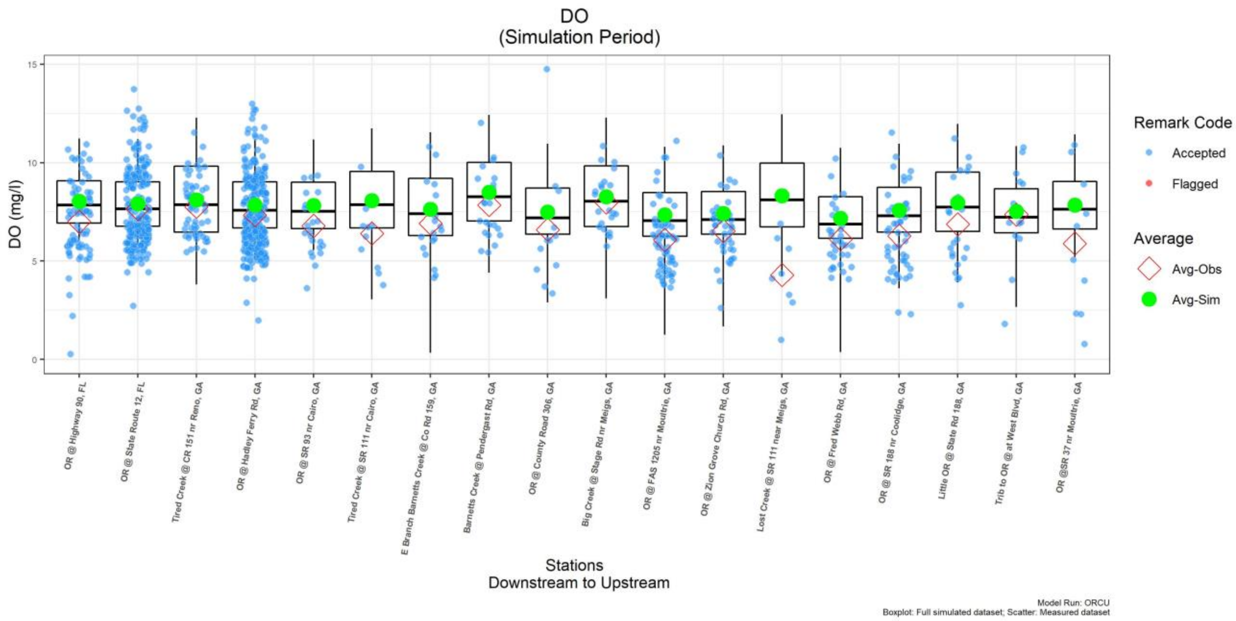

Figure 20 Dissolved Oxygen Box Plot for Ochlockonee River

Carbonaceous Biochemical Oxygen Demand

Table 20 and Figure 21 provide a comparison of CBOD simulated by the watershed/water quality model and the measured values at 7 water quality monitoring stations.

Table 20 Quantitative Statistical Analysis for Biochemical Oxygen Demand – Ochlockonee River Stations

Metric	OR @ Highway 90, FL	OR @ Hadley Ferry Rd, GA	OR @ SR 93 nr Cairo, GA	Barnetts Creek @ Pendergast Rd, GA	Big Creek @ Stage Rd nr Meigs, GA	OR @ Zion Grove Church Rd, GA	OR @ SR 188 nr Coolidge, GA	Little OR @ State Rd 188, GA	Average
Number Obs-Total	38	14	12	12	12	14	14	12	16
Number Obs-Accepted	7	14	12	12	12	14	14	12	12.125
Observed Mean	3.643	2.06	1.86	1.732	1.431	1.491	1.606	1.673	1.937
Observed Variance	2.206	0.314	0.884	0.44	0.156	0.217	0.259	0.178	0.5818
Simulation Mean	1.637	2.236	1.903	3.11	3.038	2.324	2.308	2.673	2.4036
Simulation Variance	0.253	0.388	0.466	1.764	1.747	1.152	0.788	1.111	0.9586
Mean Error	-2.006	0.1759	0.0434	1.3782	1.6074	0.8328	0.7016	0.9996	0.4666
Mean Absolute Error	2.0157	0.5279	0.825	1.3782	1.6074	0.9003	0.7519	1.0561	1.1328
RMSE	2.4328	0.619	1.1036	1.7742	2.0095	1.361	1.1351	1.5519	1.4984
NRMSE %	60.8	38.7	32.7	71.5	189.6	95.2	66.4	126.2	85.1375
R^2	0.0278	0.2142	0.0003	0.2286	0.0923	0.0147	0.0441	0.0784	0.0876
Spearman Coeff.	0.1441	0.4956	0.3636	0.4965	0.3958	0.1716	0.2879	-0.0981	0.2821
PBias	-55.1	8.5	2.3	79.6	112.3	55.9	43.7	59.7	38.3625
Nash	-2.1298	-0.3123	-0.5032	-6.7963	-27.2686	-8.2021	-4.3583	-13.7795	-7.9188
Index of Agreement	0.4679	0.6672	0.3355	0.4236	0.2357	0.2811	0.3921	0.1307	0.3667
Kling-Gupta Effic. Modified	-0.0285	0.4555	-0.0243	0.0414	-0.4422	-0.1463	0.0722	-0.5212	-0.0742
Kling-Gupta Pear. Coeff.	0.1668	0.4628	0.0181	0.4781	0.3037	0.1212	0.21	-0.2799	0.1851
Kling-Gupta Beta (Ratio Means)	0.4493	1.0854	1.0233	1.7959	2.1234	1.5587	1.4368	1.5973	1.3838
Kling-Gupta Gamma (Ratio CV)	0.7543	1.0239	0.7095	1.1144	1.577	1.4791	1.2143	1.565	1.1797

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

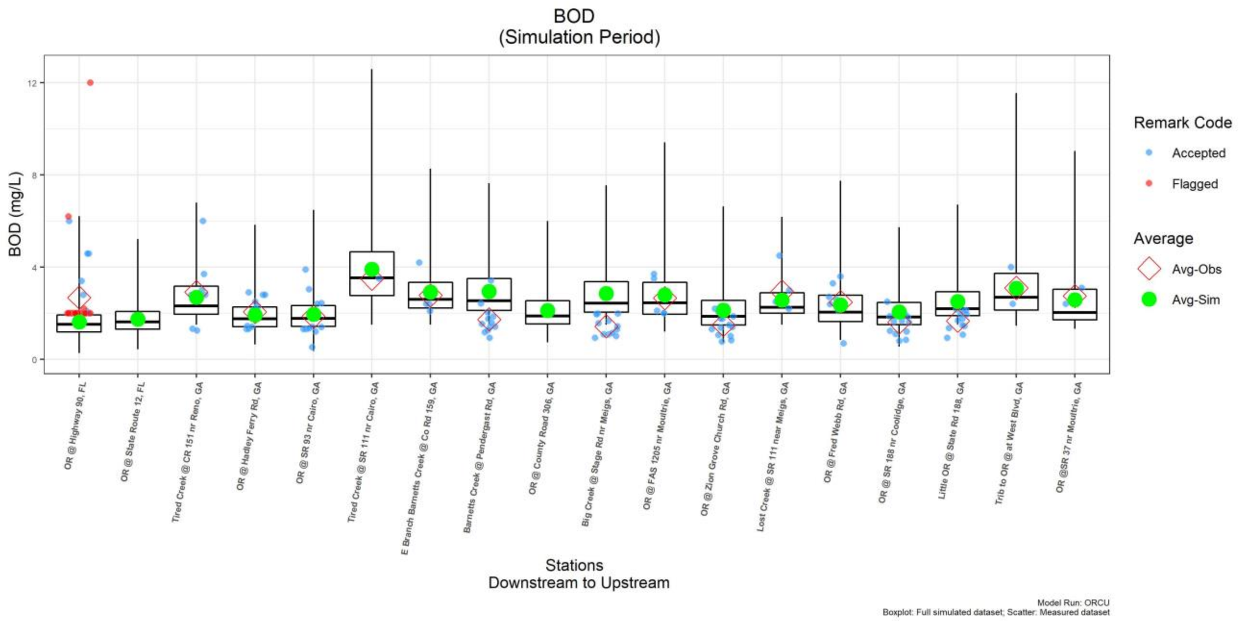

Figure 21 CBOD Box Plot for Ochlockonee River

Total Suspended Solids

Table 21 and Figure 22 provide a comparison of total suspended solids simulated by the watershed/water quality model and the measured values at 12 water quality monitoring stations.

Table 21 Quantitative Statistical Analysis for Total Suspended Solids – Ochlockonee River Stations

Metric	OR @ Highway 90, FL	OR @ State Route 12, FL	Tired Creek @ CR 151 nr Reno, GA	OR @ Hadley Ferry Rd, GA	OR @ SR 93 nr Cairo, GA	Tired Creek @ SR 111 nr Cairo, GA	E Branch Barnetts Creek @ Co Rd 159, GA	OR @ County Road 306, GA	OR @ FAS 1205 nr Moultrie, GA	OR @ Zion Grove Church Rd, GA	OR @ Fred Webb Rd, GA	OR @ SR 188 nr Coolidge, GA	Trib to OR @ at West Blvd, GA	OR @SR 37 nr Moultrie, GA	Average
Number Obs-Total	39	126	36	157	10	11	19	10	48	13	16	27	13	10	38.2143
Number Obs-Accepted	22	121	36	157	10	11	19	10	48	13	16	27	13	10	36.6429
Observed Mean	9.086	7.529	11.172	11.251	10.388	6.364	9.132	6.05	2.944	4.577	5.612	3.574	7.731	4.34	7.125
Observed Variance	9.459	8.151	85.887	98.699	88.281	55.499	55.317	49.527	1.891	7.957	10.958	10.188	128.687	2.82	43.8086
Simulation Mean	7.823	7.79	7.939	7.845	7.647	8.054	8.143	7.741	7.794	8.055	6.963	7.921	7.6	7.995	7.8079
Simulation Variance	1.482	1.798	1.751	1.836	2.094	1.221	1.861	2.732	2.145	2.212	1.114	1.973	2.291	2.285	1.9139
Mean Error	-1.2635	0.2612	-3.2335	-3.4057	-2.7405	1.6904	-0.9888	1.6912	4.8507	3.4784	1.3505	4.347	-0.1312	3.655	0.6829
Mean Absolute Error	2.4459	2.7044	6.6135	5.722	5.8137	5.1308	4.6683	5.8578	4.8507	4.1952	3.0685	4.8214	7.309	3.655	4.7754
RMSE	3.347	3.3542	9.9094	10.8362	9.0887	7.1355	7.3318	6.9207	5.1567	4.7195	3.5146	5.2642	10.5528	4.6408	6.5552
NRMSE %	29.1	24	25.9	12.5	33	26.9	25.5	32	79.3	48.2	30.3	43.9	31.1	94.7	38.3143
R^2	0.0137	0.03	0.0113	0.0491	0.0651	0.0548	0.0052	0.0091	0.0509	0.0103	0.0145	0.1125	0.0909	0.6146	0.0809
Spearman Coeff.	0.2026	-0.2229	-0.2123	-0.3504	0.383	-0.1636	-0.0501	0.6242	0.2808	0.0882	0.1948	0.322	-0.2253	-0.7295	0.0101
PBias	-13.9	3.5	-28.9	-30.3	-26.4	26.6	-10.8	28	164.8	76	24.1	121.6	-1.7	84.2	29.7714
Nash	-0.2407	-0.3917	-0.176	-0.1973	-0.0397	-0.0092	-0.0258	-0.0745	-13.3613	-2.0326	-0.2023	-1.8246	0.0625	-7.4846	-1.857
Index of Agreement	0.4022	0.2623	0.2896	0.2123	0.3466	0.3177	0.2022	0.2647	0.302	0.381	0.3699	0.4593	0.2118	0.2538	0.3054
Kling-Gupta Effic. Modified	-0.0442	-0.2947	-0.3951	-0.4937	-0.118	-0.1985	-0.2261	-0.2502	-0.9163	-0.5106	-0.1763	-0.601	-0.1114	-1.038	-0.3839
Kling-Gupta Pear. Coeff.	0.1172	-0.1733	-0.1064	-0.2217	0.2551	0.2342	0.0723	0.0954	0.2255	-0.1017	0.1205	0.3354	0.3015	-0.784	0.0264
Kling-Gupta Beta (Ratio Means)	0.8609	1.0347	0.7106	0.6973	0.7362	1.2656	0.8917	1.2795	2.6478	1.76	1.2406	2.2163	0.983	1.8422	1.2976
Kling-Gupta Gamma (Ratio CV)	0.4598	0.4539	0.2009	0.1956	0.2092	0.1172	0.2057	0.1835	0.4022	0.2996	0.257	0.1986	0.1357	0.4886	0.272

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

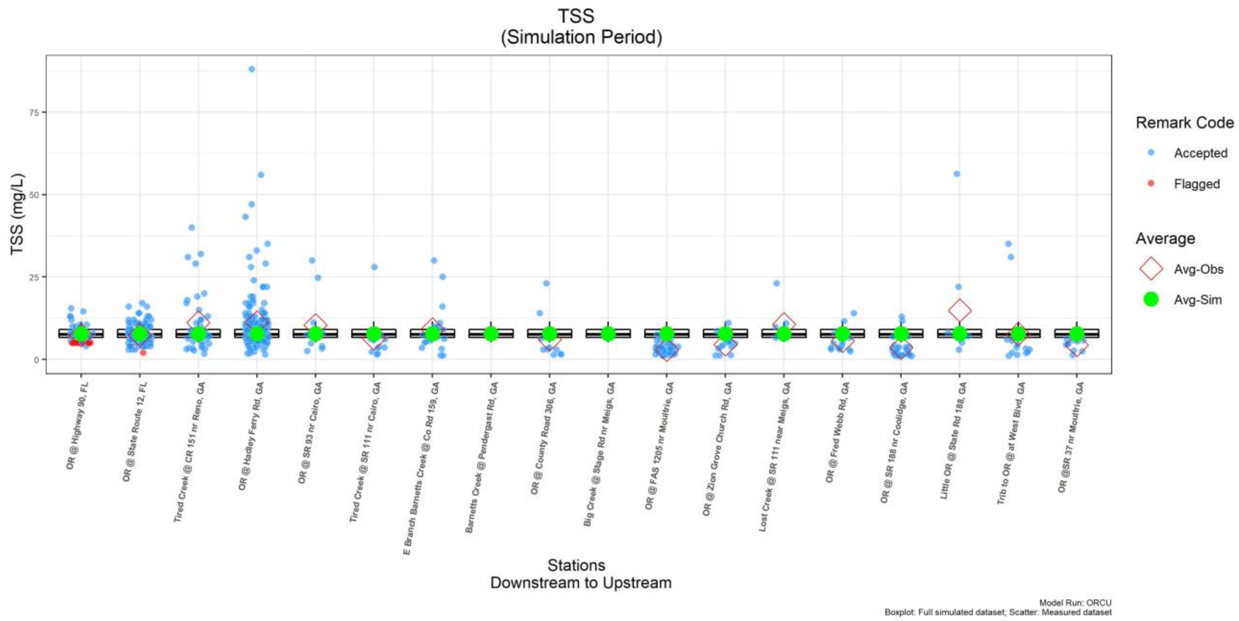

Figure 22 Total Suspended Solids Box Plot for Ochlockonee River

Water Temperature

Table 22 and Figure 23 provide a comparison of water temperature simulated by the watershed/water quality model and the measured values at 13 water quality monitoring stations.

Table 22 Quantitative Statistical Analysis for Water Temperature – Ochlockonee River Stations

Metric	OR @ State Route 12, FL	Tired Creek @ CR 151 nr Reno, GA	OR @ Hadley Ferry Rd, GA	OR @ SR 93 nr Cairo, GA	Tired Creek @ SR 111 nr Cairo, GA	E Branch Barnetts Creek @ Co Rd 159, GA	Barnetts Creek @ Pendergast Rd, GA	OR @ County Road 306, GA	Big Creek @ Stage Rd nr Meigs, GA	OR @ FAS 1205 nr Moultrie, GA	OR @ Zion Grove Church Rd, GA	OR @ Fred Webb Rd, GA	OR @ SR 188 nr Coolidge, GA	Little OR @ State Rd 188, GA	Trib to OR @ at West Blvd, GA	OR @SR 37 nr Moultrie, GA	Average
Number Obs-Total	231	59	275	23	11	20	23	13	23	65	39	32	46	23	13	10	56.625
Number Obs-Accepted	231	59	275	23	11	20	23	13	23	65	39	32	46	23	13	10	56.625
Observed Mean	19.864	18.265	19.961	20.052	19.725	18.907	18.715	17.559	18.48	19.66	19.641	23.646	19.114	18.922	22.266	17.638	19.5259
Observed Variance	42.76	34.739	44.617	47.471	33.936	57.913	35.121	69.929	30.061	36.483	32.954	13.519	36.483	36.545	42.036	35.951	39.4074
Simulation Mean	20.436	19.484	20.868	20.151	21.649	20.472	20.32	19.384	20.498	18.238	19.762	24.341	20.222	20.229	18.165	19.71	20.2456
Simulation Variance	50.921	60.319	50.405	47.663	47.333	60.64	48.134	81.833	49.274	44.056	36.419	19.067	39.793	45.067	62.972	46.377	49.3921
Mean Error	0.572	1.2188	0.9062	0.0993	1.9249	1.5652	1.6051	1.8245	2.0186	-1.422	0.1206	0.6947	1.1076	1.3067	-4.1013	2.072	0.7196
Mean Absolute Error	1.3313	2.4473	1.4217	0.9634	2.3406	2.1866	2.106	2.1731	2.6209	2.3978	1.2623	1.8687	1.4885	1.6617	4.7692	2.3811	2.0888
RMSE	1.6331	2.9661	1.8066	1.2018	2.657	2.4752	2.6217	2.7376	3.0692	3.2544	1.5565	2.3471	1.9092	2.0505	6.3817	2.9057	2.5983
NRMSE %	6.2	13.8	6.7	5.6	14.2	10.4	13.8	12.2	18.2	11.9	7.9	12	8.8	11	32.9	16.8	12.65
R^2	0.9577	0.9159	0.9526	0.9687	0.9367	0.9363	0.9174	0.9472	0.9179	0.8027	0.9323	0.728	0.938	0.9474	0.5911	0.9056	0.8935
Spearman Coeff.	0.9725	0.9443	0.9619	0.9713	0.9727	0.9489	0.9417	0.9298	0.9427	0.9194	0.9521	0.7277	0.9611	0.9644	0.8462	0.9758	0.9333
PBias	2.9	6.7	4.5	0.5	9.8	8.3	8.6	10.4	10.9	-7.2	0.6	2.9	5.8	6.9	-18.4	11.7	4.0563
Nash	0.9374	0.7424	0.9266	0.9682	0.7712	0.8886	0.7954	0.8839	0.6724	0.7052	0.9246	0.5794	0.8979	0.8797	-0.0496	0.7391	0.7664
Index of Agreement	0.9856	0.9515	0.9826	0.992	0.9524	0.9727	0.9566	0.9732	0.9379	0.9315	0.9818	0.9074	0.9754	0.9731	0.8075	0.9431	0.9515
Kling-Gupta Effic. Modified	0.9295	0.7517	0.946	0.9832	0.8722	0.8955	0.8765	0.8909	0.8064	0.7761	0.9431	0.7855	0.9328	0.9164	0.4189	0.8719	0.8498
Kling-Gupta Pear. Coeff.	0.9786	0.9571	0.976	0.9842	0.9678	0.9676	0.9578	0.9733	0.9581	0.8959	0.9656	0.8532	0.9685	0.9733	0.7688	0.9517	0.9436
Kling-Gupta Beta (Ratio Means)	1.0288	1.0667	1.0454	1.005	1.0976	1.0828	1.0858	1.1039	1.1092	0.9277	1.0061	1.0294	1.0579	1.0691	0.8158	1.1175	1.0405
Kling-Gupta Gamma (Ratio CV)	1.0607	1.2353	1.0167	0.9971	1.076	0.945	1.0782	0.9799	1.1542	1.1846	1.0448	1.1537	0.9872	1.0388	1.5003	1.0164	1.0918

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

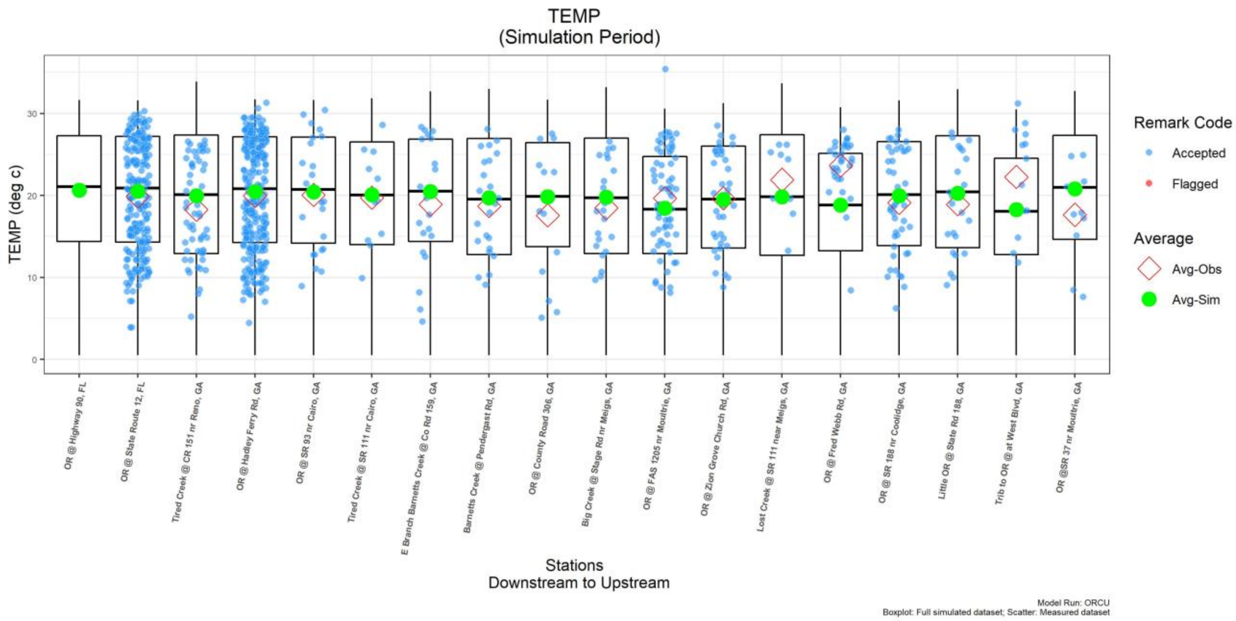

Figure 23 Water Temperautre Box Plot for Ochlockonee River

Little River Watershed and Water Quality Model

Watershed Model Correspondence

The simulated flows and loads from the watershed model subbasins are passed (linked) to one or more water quality model segments for fate and transport. For the Little River there were 16 watershed subbasins that provided daily loads and flows to the water quality model (Figure 24).

The number of LSPC subbasins does not directly correlate to the number of WASP segments, which required mapping of LSPC results to WASP segment inputs (i.e., boundaries). When a single WASP segment overlapped several LSPC subbasins, we merged flows and concentrations from the LSPC subbasins prior to routing. On the other hand, when multiple WASP segments were in a single LSPC subbasin, flows and concentrations from that LSPC subbasin were routed as a boundary to only one of the WASP segments.

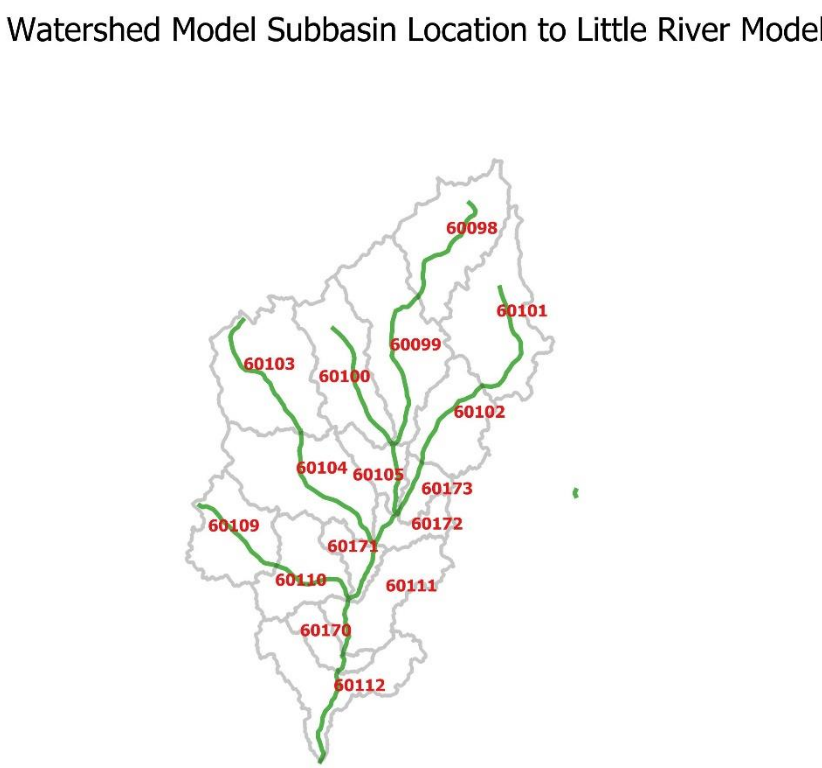

Figure 24 Watershed Model Subbasins draining to Little River Water Quality Model

When a WASP segment included a LSPC subbasin as its boundary, the segment name begins with 'LSPC' followed by the subbasin number. When multiple subbasins were merged prior to routing to WASP, multiple subbasins are listed. Segment names ending in 'RO' and 'PERO' indicate the type of LSPC runoff values that were used for routing. Segments without an LSPC boundary were named based on their relative geographic location and subwatershed. Table 23 indicates how LSPC subbasins were routed to WASP segments and the routing method used.

Table 23 LSPC to WASP Correspondence – Little River

LSPC Output File	PERO/RO	WASP Segment
60099	PERO	42
60098	RO	52
60101	RO	70
60173	PERO	71
60102	PERO	72
60100	RO	79
60105	PERO	83
60172	PERO	89
60110	PERO	96
60109	RO	100

60103	RO	120
60104	PERO	121
60171	PERO	124
60111	PERO	128
60170	PERO	129
60112	PERO	132

Point Sources

The Little River model includes two significant point sources: Quincy WPCP and BASF Attapulgus Plant (Figure 25). Quincy is a major domestic wastewater treatment plant while BASF is a major industrial discharger.

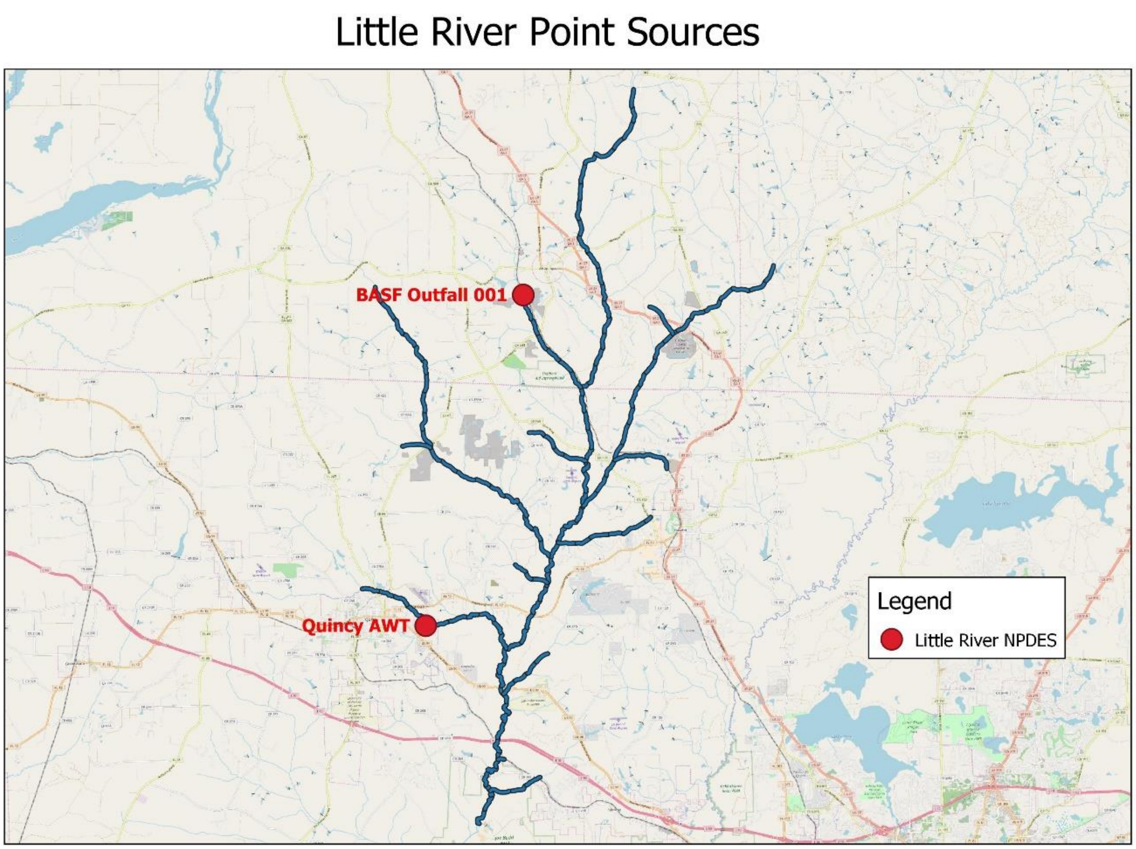

Figure 25 – Little River Simulated NPDES Dischargers

The following paragraphs discuss each point source.

Quincy WPCP – Permit # FL0029033

This facility discharges out of a single outfall (001) (Table 24). Monthly DMR data retrieved from ICIS and PCS are used to load effluent flows and pollutant concentrations for total nitrogen, total phosphorus and BOD5. Data for the period 1996 through 2012 are available. For individual nutrient speciation, limited PO4, TKN and NH3 data from the facility's most recent permit application is used to estimate nutrient fractions. These values compare reasonably well with ambient and observed nutrient fractions such that the ambient speciation applied to LSPC output was also used for this facilitate for efficiency (3% NH3, 23% NO3NO2, 74% Org N, 40% PO4, 60% Org P). Reported monthly dissolved oxygen concentrations are put directly into the model. Stepwise interpolations are used in the model to emulate the DMR monthly values.

Table 24 Quincy DMR Data

Parameter Name	Units	No. Obs.	Mean	Min	Max	First Date	Last Date
Biochemical Oxygen Demand	mg/L	324	2.102	1	4.6	1/1/2007 0:00	12/26/2017 0:00
Dissolved Inorganic Phosphorus	mg/L	362	0.222	0	2.4	1/1/2007 0:00	7/31/2018 0:00
Dissolved Oxygen	mg/L	259	7.507	6	9.9	12/31/2012 0:00	12/26/2017 0:00
Dissolved Organic Nitrogen	mg/L	323	0.746	0.203	1.74	1/1/2007 0:00	12/26/2017 0:00
Dissolved Organic Phosphorus	mg/L	323	0.209	0.02	2.155	1/1/2007 0:00	12/26/2017 0:00
Flow	cms	388	0.041	0.026	0.105	1/1/2007 0:00	12/31/2017 0:00
Ammonia	mg/L	323	0.18	0.049	0.42	1/1/2007 0:00	12/26/2017 0:00
Nitrate/Nitrite	mg/L	323	1.647	0.448	3.84	1/1/2007 0:00	12/26/2017 0:00
Total Nitrogen	mg/L	250	2.64	0.7	6	3/4/2013 0:00	12/26/2017 0:00
Total Phosphorus	mg/L	250	0.45	0.04	4.31	3/4/2013 0:00	12/26/2017 0:00

BASF Attapulgus Plant – Permit # GA0001678

The BASF facility maintains two permitted outfalls (001 and 002) (Table 25 & Table 26). Monthly DMR data was processed to parameterize the inputs to the model. A summary of the data is provided in the tables below for each of the outfalls.

Table 25 BASF001 DMR

Parameter Name	Units	No. Obs.	Mean	Min	Max	First Date	Last Date
Biochemical Oxygen Demand	mg/L	631	4.147	0	57.03	1/1/2007 0:00	12/31/2017 23:59
Dissolved Inorganic Phosphorus	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2017 23:59
Dissolved Oxygen	mg/L	1,550	7.557	0	11.6	1/1/2007 0:00	12/31/2017 23:59
Dissolved Organic Nitrogen	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2017 23:59
Dissolved Organic Phosphorus	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2017 23:59
Flow	cms	4,017	0.031	0	0.215	1/1/2007 0:00	12/30/2017 0:00
Ammonia	mg/L	1,394	33.927	0.025	160.096	1/1/2007 0:00	12/28/2017 0:00
Nitrate/Nitrite	mg/L	1,380	179.74	0.263	700.42	1/1/2007 0:00	12/28/2017 0:00

Table 26 BASF002 DMR

Parameter Name	Units	No. Obs.	Mean	Min	Max	First Date	Last Date
Biochemical Oxygen Demand	mg/L	174	5.317	0	63.346	1/1/2013 0:00	12/12/2017 0:00
Dissolved Inorganic Phosphorus	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2017 23:59
Dissolved Oxygen	mg/L	174	5.57	5	12.6	1/1/2013 0:00	12/12/2017 0:00
Dissolved Organic Nitrogen	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2017 23:59
Dissolved Organic Phosphorus	mg/L	2	0	0	0	1/1/2007 0:00	12/31/2017 23:59
Flow	cms	2,366	0.006	0	0.2	1/1/2007 0:00	12/12/2017 0:00
Ammonia	mg/L	202	2.071	0	29.6	5/16/2008 0:00	12/12/2017 0:00
Nitrate/Nitrite	mg/L	203	8.599	0	180	5/16/2008 0:00	12/12/2017 0:00

Hydraulic Calibration

The watershed and water quality model were calibrated for flow by comparing the predicted flows to three USGS gages located within the Little River. Figure 26 provides a map of the location of the USGS flow gages used in the flow calibration.

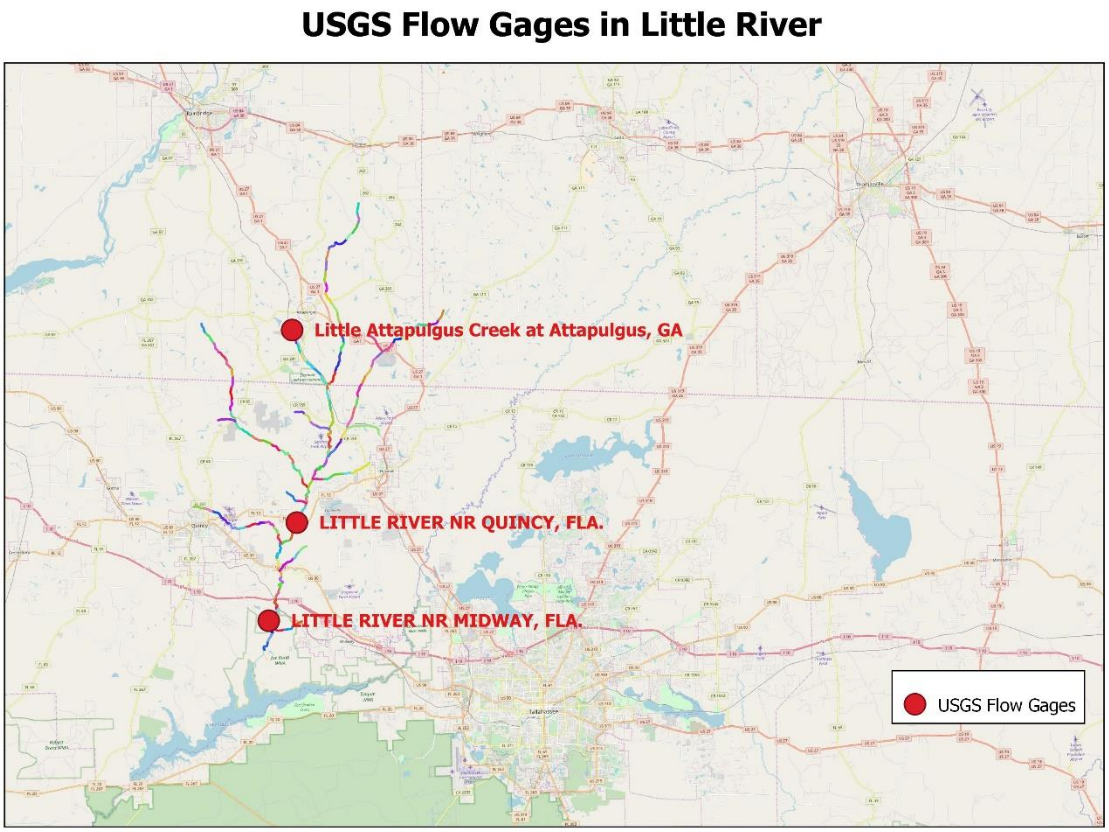

Figure 26 USGS Flow Gages used for Calibration on Little River

Flow

Table 27 and Figure 27 provide a comparison of the flow simulated by the watershed/water quality model and the daily average flows at the USGS flow gage in the Little River. Both the qualitative and quantitative comparison show very good correlation with the measured data.

Table 27 Quantitative Statistical Analysis for Flow – USGS Flow Gages Little River

Metric	Little River nr Midway, FL	Little River nr Quincy, FL	Little Attapulgus Creek at Attapulgus, GA	Average
Number Obs	3652	2121	3603	3125.3333
Observed Mean	9.0645	6.4188	0.3869	5.2901
Observed Variance	540.8963	228.0996	0.1477	256.3812
Simulation Mean	8.6905	6.4313	0.6898	5.2705
Simulation Variance	310.7488	129.6874	1.0627	147.1663
Mean Error	-0.374	0.0125	0.3029	-0.0195
Mean Absolute Error	3.8221	2.8029	0.3848	2.3366
RMSE	11.4973	8.6553	0.8633	7.0053
R2	0.7701	0.6761	0.4936	0.6466
Spearman Coeff.	0.7935	0.8202	0.7612	0.7916
PBias	-4.1	0.2	78.3	24.8
Nash	0.7555	0.6714	-4.0482	-0.8738
Index of Agreement	0.916	0.8832	0.6026	0.8006
Levene Test p-value	0.81007	0.8831	0	0.5644
Mann-Whitney U p-value	0.19302	0.90414	0	0.3657

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix A.

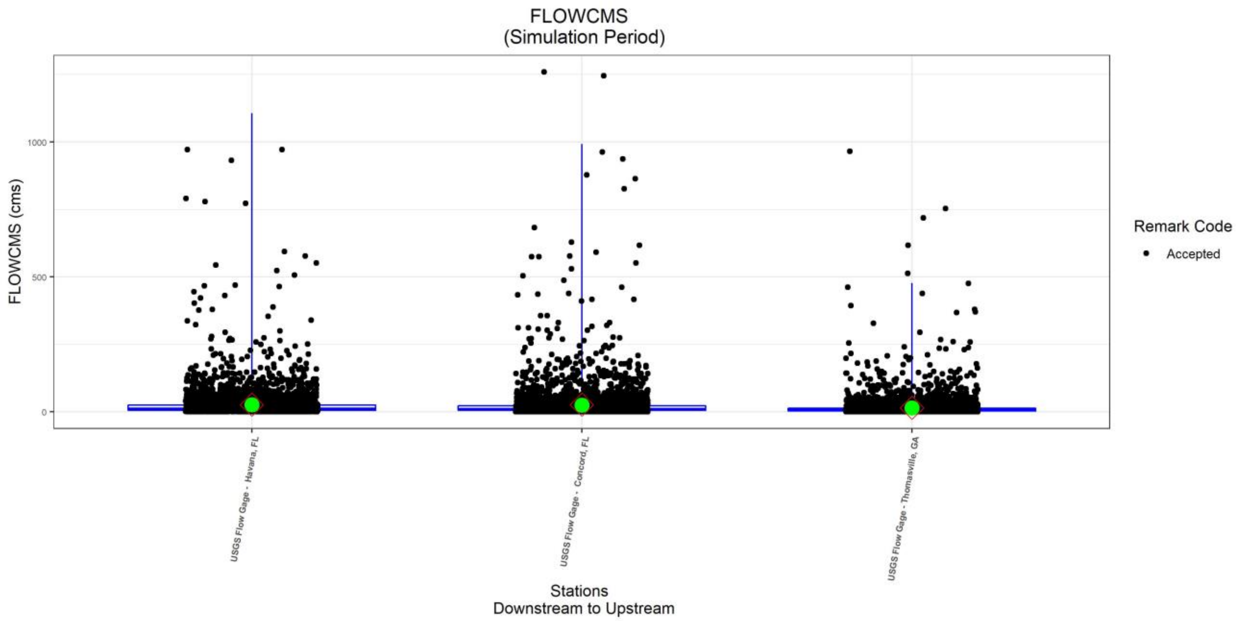

Figure 27 Flow Calibration Box Plot for Little River

Water Quality Model Calibration

There are 5 water quality monitoring stations used for watershed/water quality model calibration for the Little River water quality model. The monitoring data was obtained from FDEP's Impaired Waters Rule Database (Version 55) and data provided directly from GAEPD for the stations in Georgia. Figure 28 depicts the name and location of the water quality monitoring stations. For a Station/Water Quality Parameter to be considered in the quantitative and qualitative calculations and plots the station must have more than 9 observations during the simulation period.

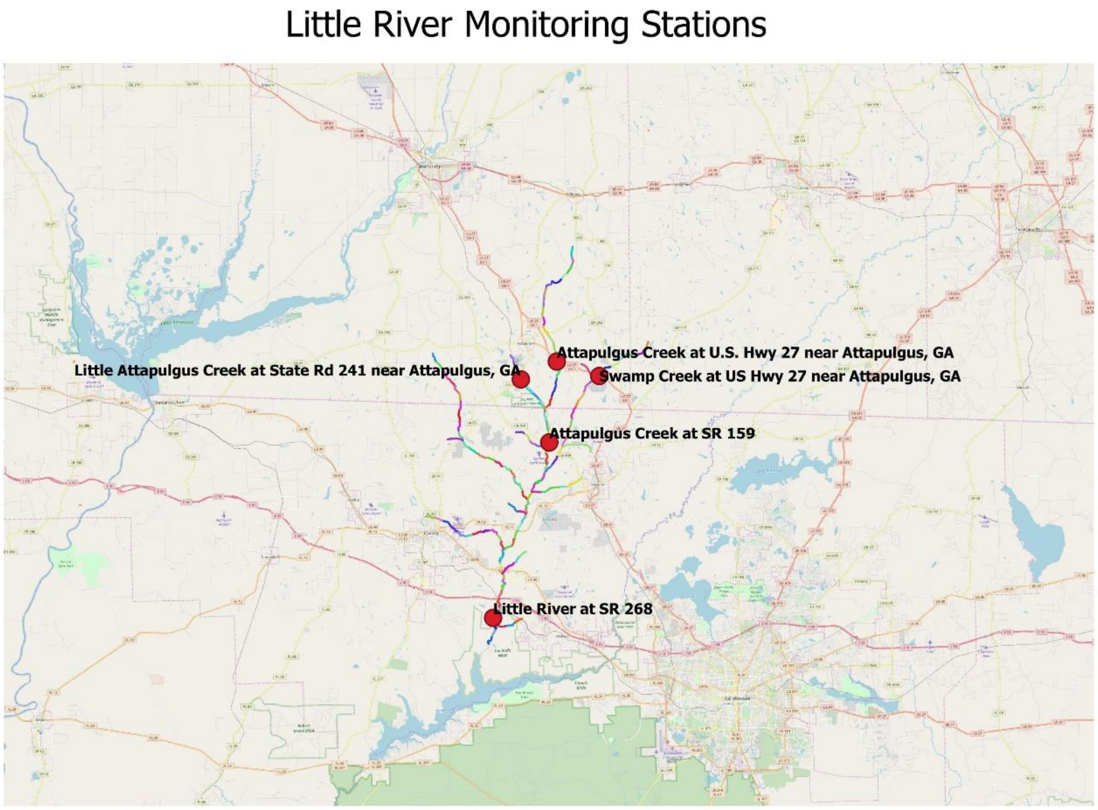

Figure 28 Little River Water Quality Monitoring Locations

Table 28 provides a summary of measured parameters at each station that will be used for comparison with the simulated values from the water quality model.

Table 28 Summary of Little River Monitoring Stations and Parameters Measured

Plot_Title	Metric	BOD	CHLAC	DO	NH4	NO3O2	TEMP	TN
AC @ U.S. Hwy 27 near Attapulgus, GA	Number Obs-Total	11		80	29	62	81	12
SC @ US Hwy 27 near Attapulgus, GA	Number Obs-Total	6		58	28	53	59	
Little AC @ State Rd 241 near Attapulgus, GA	Number Obs-Total	14	4	56	44	49	57	
Global_Avg	Number Obs-Total	10.3333	4	64.6667	33.6667	54.6667	65.6667	12

Total Nitrogen

Table 29 and Figure 29 provide a comparison of total nitrogen simulated by the watershed/water quality model and the measured values at 3 water quality monitoring stations.

Table 29 Quantitative Statistical Analysis for Total Nitrogen – Little River Stations

Metric	AC @ U.S. Hwy 27 near Attapulgus, GA	Average
Number Obs-Total	12	12
Number Obs-Accepted	12	12
Observed Mean	0.802	0.802
Observed Variance	0.023	0.023
Simulation Mean	0.45	0.45
Simulation Variance	0.044	0.044
Mean Error	-0.3525	-0.3525
Mean Absolute Error	0.4223	0.4223
RMSE	0.4489	0.4489
NRMSE %	93.5	93.5
R^2	0.0732	0.0732
Spearman Coeff.	-0.1016	-0.1016
PBias	-43.9	-43.9
Nash	-8.4072	-8.4072
Index of Agreement	0.2704	0.2704
Kling-Gupta Effic. Modified	-0.9676	-0.9676
Kling-Gupta Pear. Coeff.	-0.2705	-0.2705
Kling-Gupta Beta (Ratio Means)	0.5608	0.5608
Kling-Gupta Gamma (Ratio CV)	2.4367	2.4367

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix B.

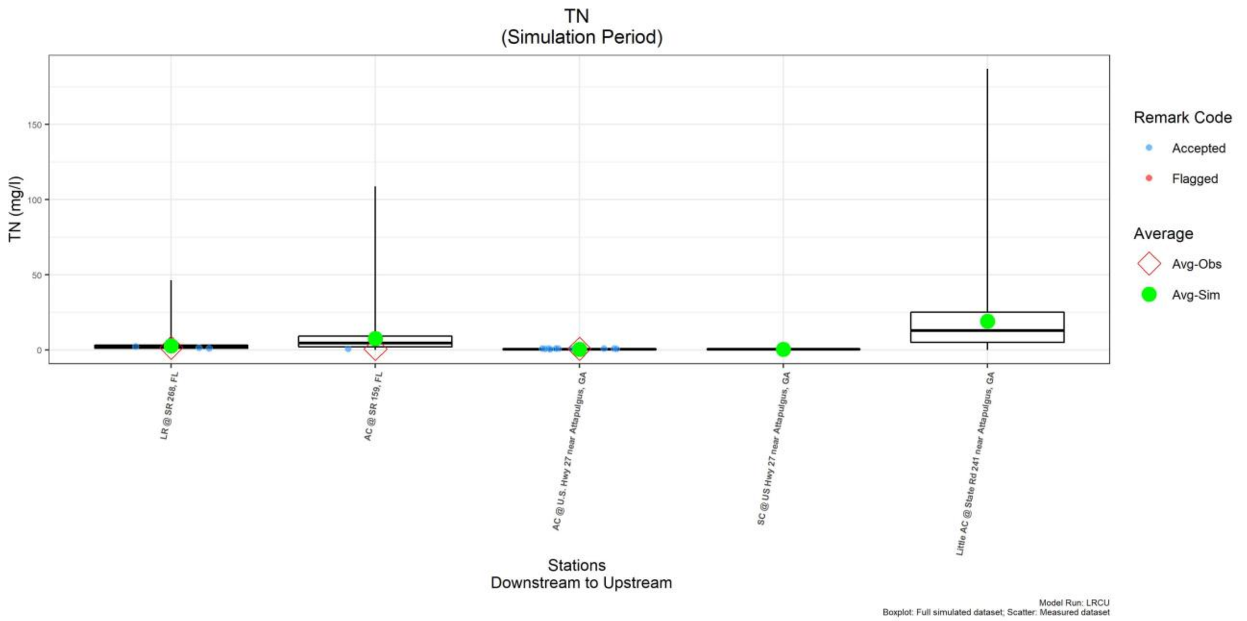

Figure 29 Total Nitrogen Box Plot for Little River

Ammonia

Table 30 and Figure 30 provide a comparison of ammonia simulated by the watershed/water quality model and the measured values at 4 water quality monitoring stations.

Table 30 Quantitative Statistical Analysis for Ammonia – Little River Stations

Metric	AC @ U.S. Hwy 27 near Attapulgus, GA	SC @ US Hwy 27 near Attapulgus, GA	Little AC @ State Rd 241 near Attapulgus, GA	Average
Number Obs-Total	29	28	44	33.6667
Number Obs-Accepted	29	28	44	33.6667
Observed Mean	0.048	0.064	2.332	0.8147
Observed Variance	0	0.001	8.355	2.7853
Simulation Mean	0.018	0.019	2.848	0.9617
Simulation Variance	0	0	9.476	3.1587
Mean Error	-0.0301	-0.0449	0.5166	0.1472
Mean Absolute Error	0.0308	0.0449	1.9328	0.6695
RMSE	0.0378	0.0555	3.1692	1.0875
NRMSE %	45.5	42.7	26.5	38.2333
R^2	0.0485	0.3593	0.1934	0.2004
Spearman Coeff.	-0.2316	0.2025	0.5958	0.1889
PBias	-63.2	-70.6	22.2	-37.2
Nash	-2.8598	-1.1603	-0.2301	-1.4167
Index of Agreement	0.3775	0.4652	0.6778	0.5068
Kling-Gupta Effic. Modified	-0.3929	0.1857	0.3841	0.059
Kling-Gupta Pear. Coeff.	-0.2203	0.5994	0.4398	0.273
Kling-Gupta Beta (Ratio Means)	0.3684	0.2943	1.2215	0.6281
Kling-Gupta Gamma (Ratio CV)	1.2286	0.9323	0.8718	1.0109

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix B.

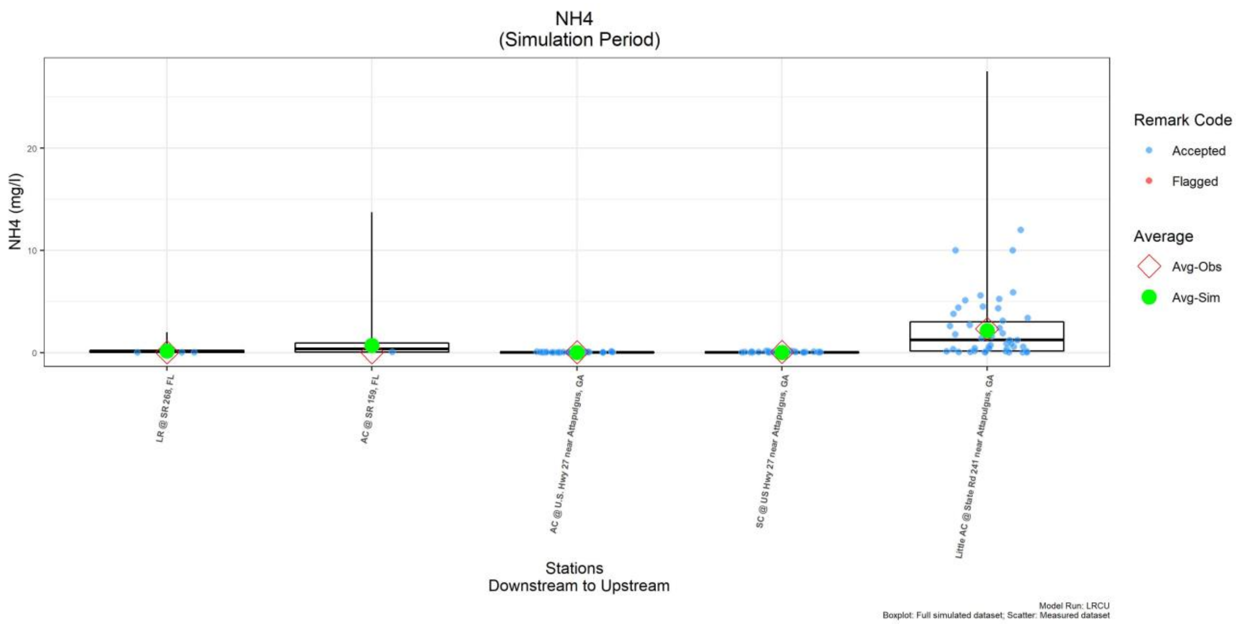

Figure 30 Ammonia Box Plot for Little River

Nitrate

Table 31 and Figure 31 provide a comparison of nitrate simulated by the watershed/water quality model and the measured values at 5 water quality monitoring stations.

Table 31 Quantitative Statistical Analysis for Nitrate – Little River Stations

Metric	AC @ U.S. Hwy 27 near Attapulgus, GA	SC @ US Hwy 27 near Attapulgus, GA	Little AC @ State Rd 241 near Attapulgus, GA	Average
Number Obs-Total	62	53	49	54.6667
Number Obs-Accepted	62	52	49	54.3333
Observed Mean	0.309	0.123	13.703	4.7117
Observed Variance	0.057	0.005	80.753	26.9383
Simulation Mean	0.184	0.182	17.1	5.822
Simulation Variance	0.009	0.009	256.099	85.3723
Mean Error	-0.1253	0.0588	3.3973	1.1103
Mean Absolute Error	0.2078	0.1039	8.1546	2.8221
RMSE	0.2827	0.1397	12.9426	4.455
NRMSE %	17.9	43.7	42.5	34.7
R^2	0.0001	0.0159	0.3814	0.1325
Spearman Coeff.	-0.1578	0.0339	0.6754	0.1838
PBias	-40.5	47.8	24.8	10.7
Nash	-0.4369	-2.7239	-1.1176	-1.4261
Index of Agreement	0.3525	0.1864	0.7089	0.4159
Kling-Gupta Effic. Modified	-0.1188	-0.2282	0.3755	0.0095
Kling-Gupta Pear. Coeff.	0.0087	-0.126	0.6176	0.1668
Kling-Gupta Beta (Ratio Means)	0.5946	1.4781	1.2479	1.1069
Kling-Gupta Gamma (Ratio CV)	0.6764	0.8904	1.427	0.9979

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix B.

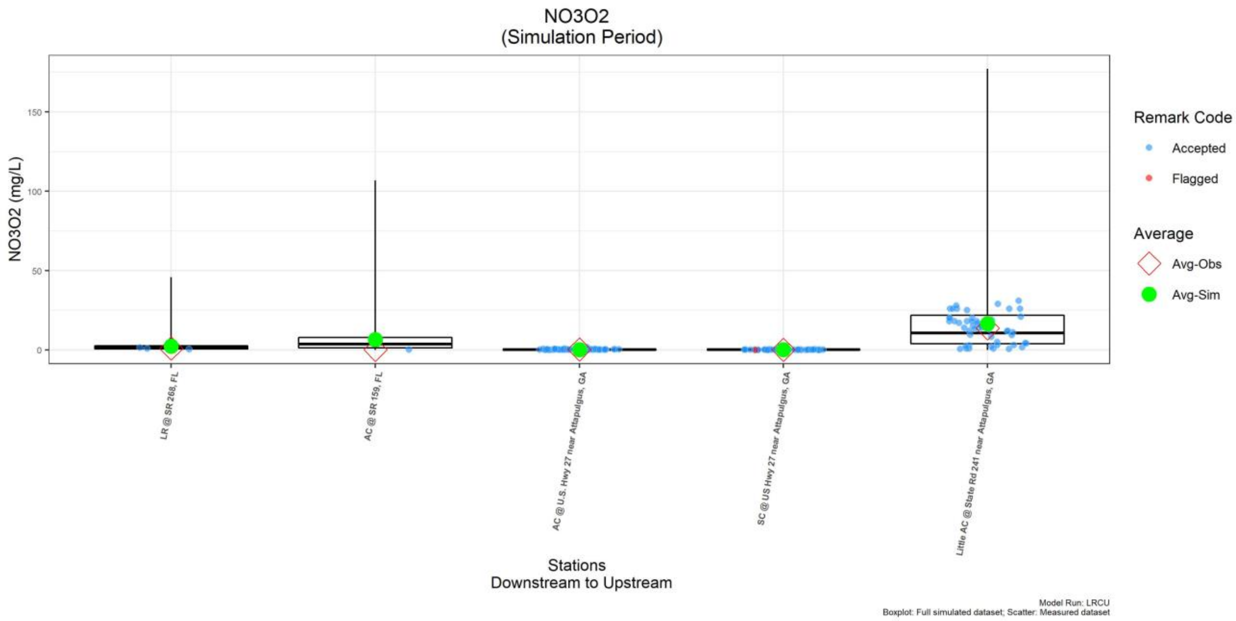

Figure 31 Nitrate Box Plot for Little River

Total Phosphorus

Table 32 and Figure 32 provide a comparison of total phosphorus simulated by the watershed/water quality model and the measured values at 4 water quality monitoring stations.

Table 32 Quantitative Statistical Analysis for Total Phosphorus – Little River Stations

Metric	AC @ U.S. Hwy 27 near Attapulgus, GA	SC @ US Hwy 27 near Attapulgus, GA	Little AC @ State Rd 241 near Attapulgus, GA	Average
Number Obs-Total	71	52	48	57
Number Obs-Accepted	71	52	48	57
Observed Mean	0.079	0.12	0.121	0.1067
Observed Variance	0.001	0.001	0.009	0.0037
Simulation Mean	0.078	0.096	0.081	0.085
Simulation Variance	0	0	0	0
Mean Error	-0.0012	-0.0246	-0.0402	-0.022
Mean Absolute Error	0.0258	0.0425	0.0532	0.0405
RMSE	0.0344	0.0525	0.1026	0.0632
NRMSE %	20.2	27.6	20.1	22.6333
R^2	0.0168	0.2723	0.0443	0.1111
Spearman Coeff.	-0.1636	-0.5542	-0.1227	-0.2802
PBias	-1.5	-20.4	-33.3	-18.4
Nash	-0.3244	-1.102	-0.2607	-0.5624
Index of Agreement	0.2599	0.2112	0.2954	0.2555
Kling-Gupta Effic. Modified	-0.2521	-0.6014	-0.4967	-0.4501
Kling-Gupta Pear. Coeff.	-0.1297	-0.5218	-0.2104	-0.2873
Kling-Gupta Beta (Ratio Means)	0.9849	0.7959	0.6673	0.816
Kling-Gupta Gamma (Ratio CV)	0.4601	0.5451	0.1849	0.3967

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix B.

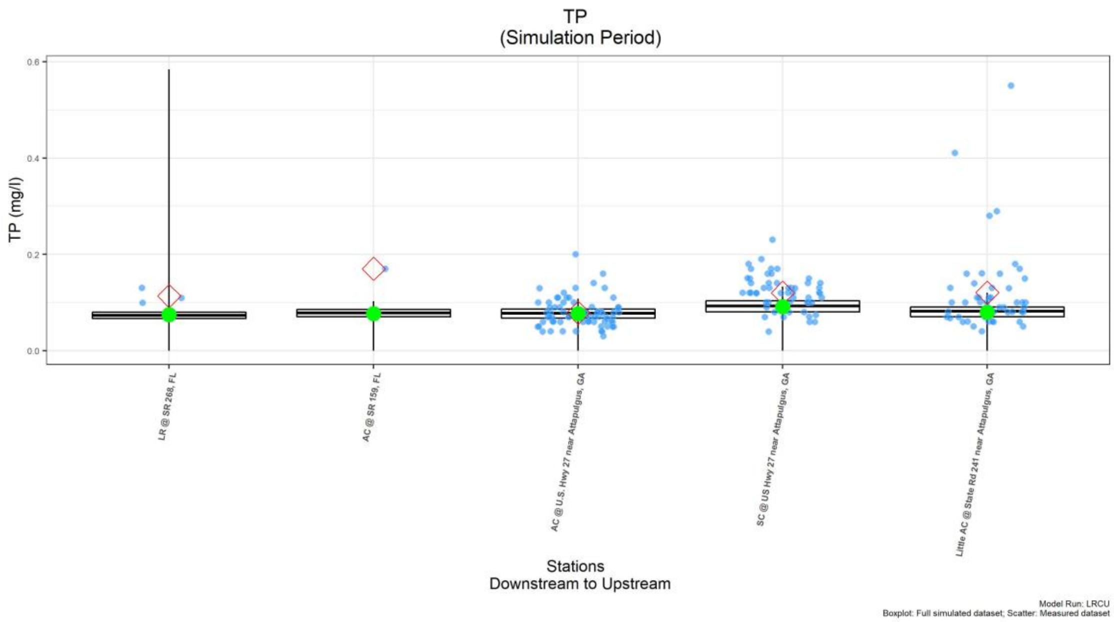

Figure 32 Total Phosphorus Box Plot for Little River

Chlorophyll a

Table 33 and Figure 33 provide a comparison of chlorophyll a simulated by the watershed/water quality model and the measured values at 2 water quality monitoring stations.

Table 33 Quantitative Statistical Analysis for Chlorophyll a – Little River Stations

Metric	Little AC @ State Rd 241 near Attapulgus, GA	Average
Number Obs-Total	4	4
Number Obs-Accepted	4	4
Observed Mean	66	66
Observed Variance	153.337	153.337
Simulation Mean	0.508	0.508
Simulation Variance	0	0
Mean Error	-65.4918	-65.4918
Mean Absolute Error	65.4918	65.4918
RMSE	66.3649	66.3649
NRMSE %	261.6	261.6
R^2	0.248	0.248
Spearman Coeff.	-0.8	-0.8
PBias	-99.2	-99.2
Nash	-37.2973	-37.2973
Index of Agreement	0.2163	0.2163
Kling-Gupta Effic. Modified	-0.9909	-0.9909
Kling-Gupta Pear. Coeff.	-0.498	-0.498
Kling-Gupta Beta (Ratio Means)	0.0077	0.0077
Kling-Gupta Gamma (Ratio CV)	0.1427	0.1427

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix B.

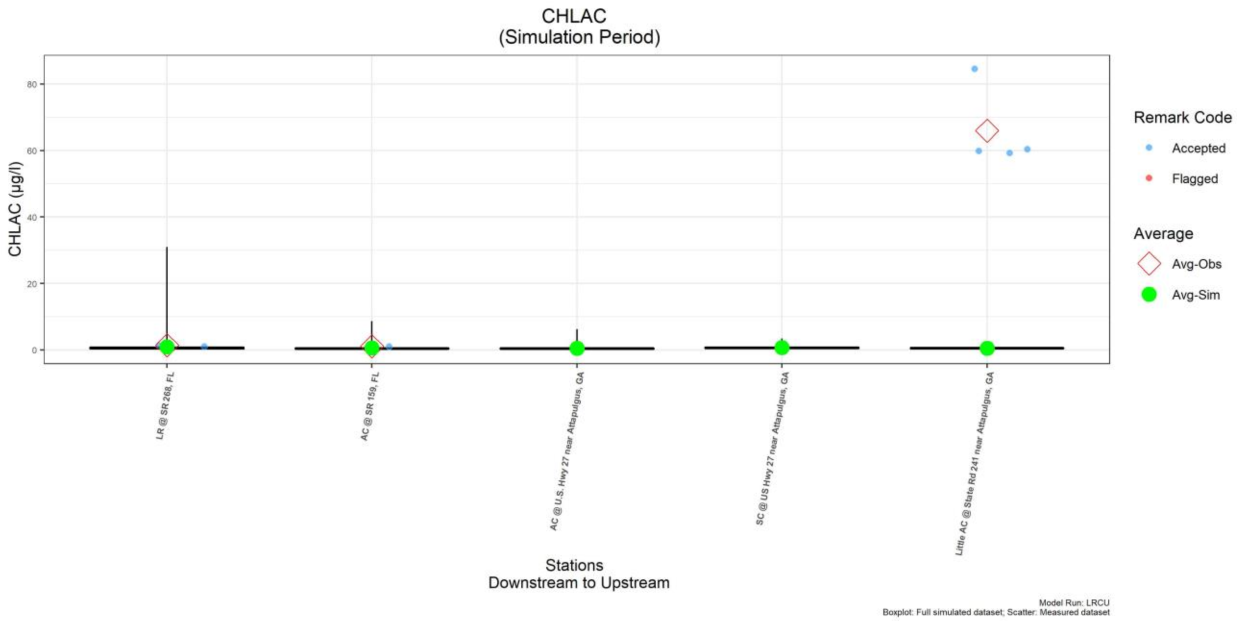

Figure 33 Chlorophyll a Box Plot for Little River

Dissolved Oxygen

Table 34 and Figure 34 provide a comparison of dissolved oxygen simulated by the watershed/water quality model and the measured values at 4 water quality monitoring stations.

Table 34 Quantitative Statistical Analysis for Dissolved Oxygen – Little River Stations

Metric	AC @ U.S. Hwy 27 near Attapulgus, GA	SC @ US Hwy 27 near Attapulgus, GA	Little AC @ State Rd 241 near Attapulgus, GA	Average
Number Obs-Total	80	58	56	64.6667
Number Obs-Accepted	80	58	56	64.6667
Observed Mean	7.569	6.35	7.714	7.211
Observed Variance	2.612	4.84	1.891	3.1143
Simulation Mean	9.03	8.94	8.43	8.8
Simulation Variance	1.971	2.108	2.373	2.1507
Mean Error	1.4612	2.5898	0.7163	1.5891
Mean Absolute Error	1.465	2.5898	0.8135	1.6228
RMSE	1.6438	3.0423	1.0005	1.8955
NRMSE %	20.6	29.5	19.4	23.1667
R^2	0.7804	0.4648	0.7907	0.6786
Spearman Coeff.	0.8822	0.7043	0.9146	0.8337
PBias	19.3	40.8	9.3	23.1333
Nash	-0.0476	-0.9457	0.4609	-0.1775
Index of Agreement	0.7641	0.5963	0.884	0.7481
Kling-Gupta Effic. Modified	0.6467	0.2585	0.8533	0.5862
Kling-Gupta Pear. Coeff.	0.8834	0.6817	0.8892	0.8181
Kling-Gupta Beta (Ratio Means)	1.1931	1.4078	1.0929	1.2313
Kling-Gupta Gamma (Ratio CV)	0.7281	0.4687	1.0251	0.7406

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box

represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix B.

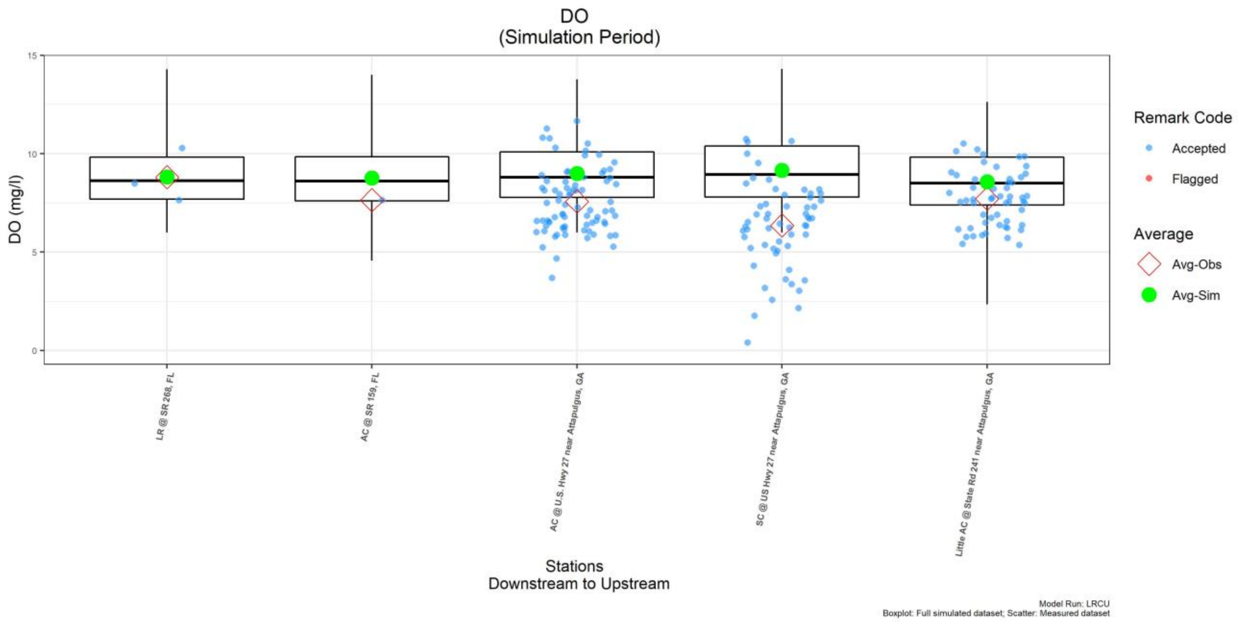

Figure 34 Dissolved Oxygen Box Plot for Little River

Carbonaceous Biochemical Oxygen Demand

Table 35 and Figure 35 provide a comparison of CBOD simulated by the watershed/water quality model and the measured values at 4 water quality monitoring stations.

Table 35 Quantitative Statistical Analysis for Biochemical Oxygen Demand – Little River Stations

[illegible]	[illegible]	[illegible]	[illegible]

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix B.

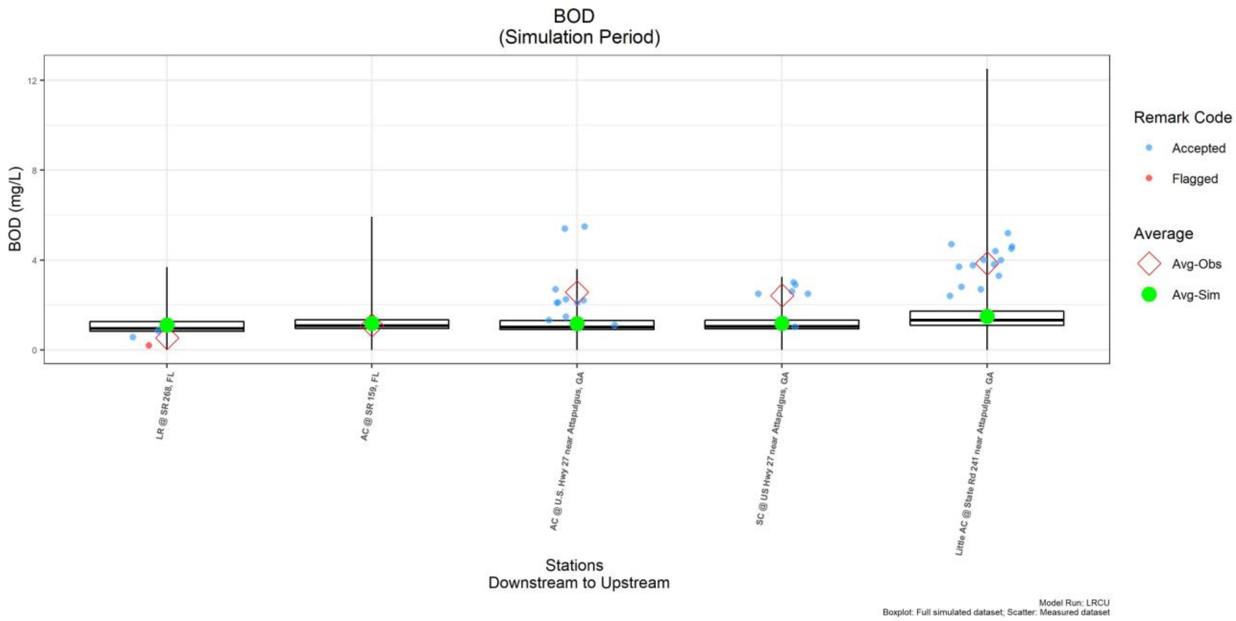

Figure 35 CBOD Box Plot for Little River

Total Suspended Solids

Table 36 and Figure 36 provide a comparison of total suspended solids simulated by the watershed/water quality model and the measured values at 5 water quality monitoring stations.

Table 36 Quantitative Statistical Analysis for Total Suspended Solids – Little River Stations

Metric	AC @ U.S. Hwy 27 near Attapulgus, GA	SC @ US Hwy 27 near Attapulgus, GA	Little AC @ State Rd 241 near Attapulgus, GA	Average
Number Obs-Total	61	53	48	54
Number Obs-Accepted	61	53	48	54
Observed Mean	10.025	9.96	15.398	11.7943
Observed Variance	44.075	63.464	431.061	179.5333
Simulation Mean	8.284	8.426	8.539	8.4163
Simulation Variance	2.536	2.2	2.364	2.3667
Mean Error	-1.741	-1.5342	-6.8591	-3.3781
Mean Absolute Error	5.1589	5.2097	10.3091	6.8926
RMSE	7.183	8.1134	21.7043	12.3336
NRMSE %	21	21	20.1	20.7
R^2	0.0171	0.0017	0	0.0063
Spearman Coeff.	-0.2606	-0.0239	-0.2014	-0.162
PBias	-17.4	-15.4	-44.5	-25.7667
Nash	-0.1902	-0.0572	-0.1161	-0.1212
Index of Agreement	0.1849	0.2205	0.2637	0.223
Kling-Gupta Effic. Modified	-0.3462	-0.2456	-0.3919	-0.3279
Kling-Gupta Pear. Coeff.	-0.1307	0.041	0.0059	-0.0279
Kling-Gupta Beta (Ratio Means)	0.8263	0.846	0.5545	0.7423
Kling-Gupta Gamma (Ratio CV)	0.2903	0.2201	0.1335	0.2146

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix B.

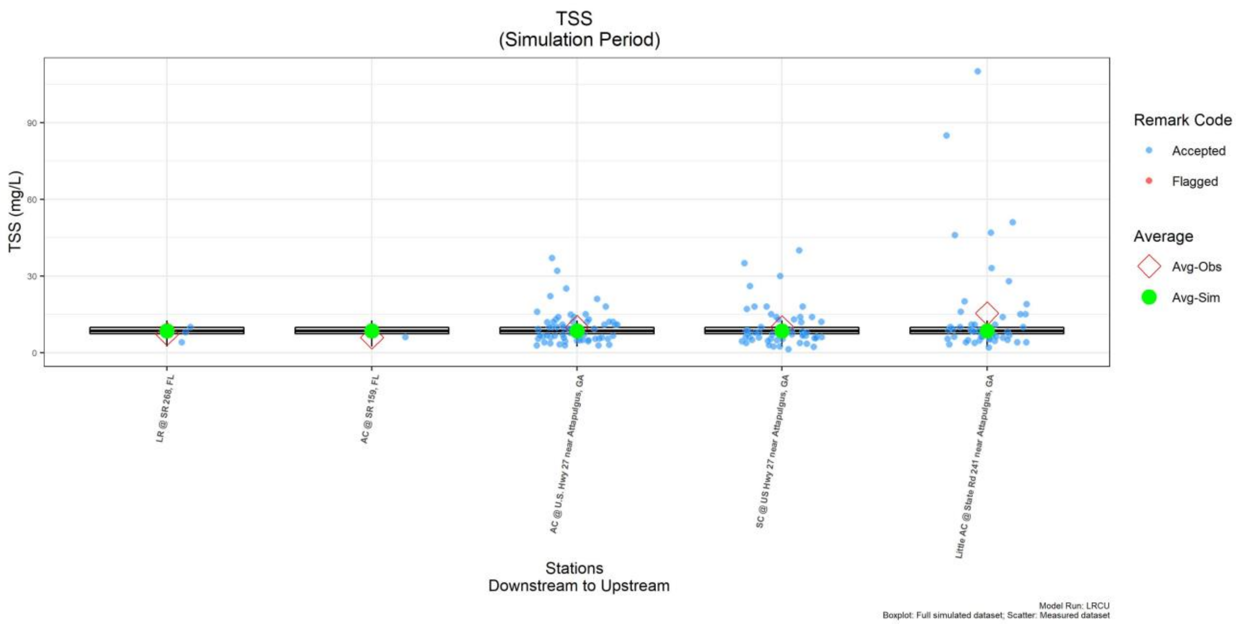

Figure 36 Total Suspended Solids Box Plot for Little River

Water Temperature

Table 37 and Figure 37 provide a comparison of water temperature simulated by the watershed/water quality model and the measured values at 4 water quality monitoring stations.

Table 37 Quantitative Statistical Analysis for Water Temperature – Little River Stations

Metric	AC @ U.S. Hwy 27 near Attapulgus, GA	SC @ US Hwy 27 near Attapulgus, GA	Little AC @ State Rd 241 near Attapulgus, GA	Average
Number Obs-Total	81	59	57	65.6667
Number Obs-Accepted	81	59	57	65.6667
Observed Mean	18.034	18.921	19.871	18.942
Observed Variance	37.632	33.337	26.09	32.353
Simulation Mean	21.675	22.53	21.75	21.985
Simulation Variance	56.928	58.865	46.32	54.0377
Mean Error	3.6415	3.6088	1.8782	3.0428
Mean Absolute Error	3.9087	4.0388	2.734	3.5605
RMSE	4.5362	4.8965	3.2744	4.2357
NRMSE %	19.7	22.6	19.6	20.6333
R^2	0.8864	0.8371	0.8764	0.8666
Spearman Coeff.	0.9369	0.8985	0.9404	0.9253
PBias	20.2	19.1	9.5	16.2667
Nash	0.4464	0.2684	0.5817	0.4322
Index of Agreement	0.8942	0.8711	0.923	0.8961
Kling-Gupta Effic. Modified	0.7885	0.7611	0.7545	0.768
Kling-Gupta Pear. Coeff.	0.9415	0.9149	0.9361	0.9308
Kling-Gupta Beta (Ratio Means)	1.2019	1.1907	1.0945	1.1624
Kling-Gupta Gamma (Ratio CV)	1.0233	1.116	1.2174	1.1189

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix B.

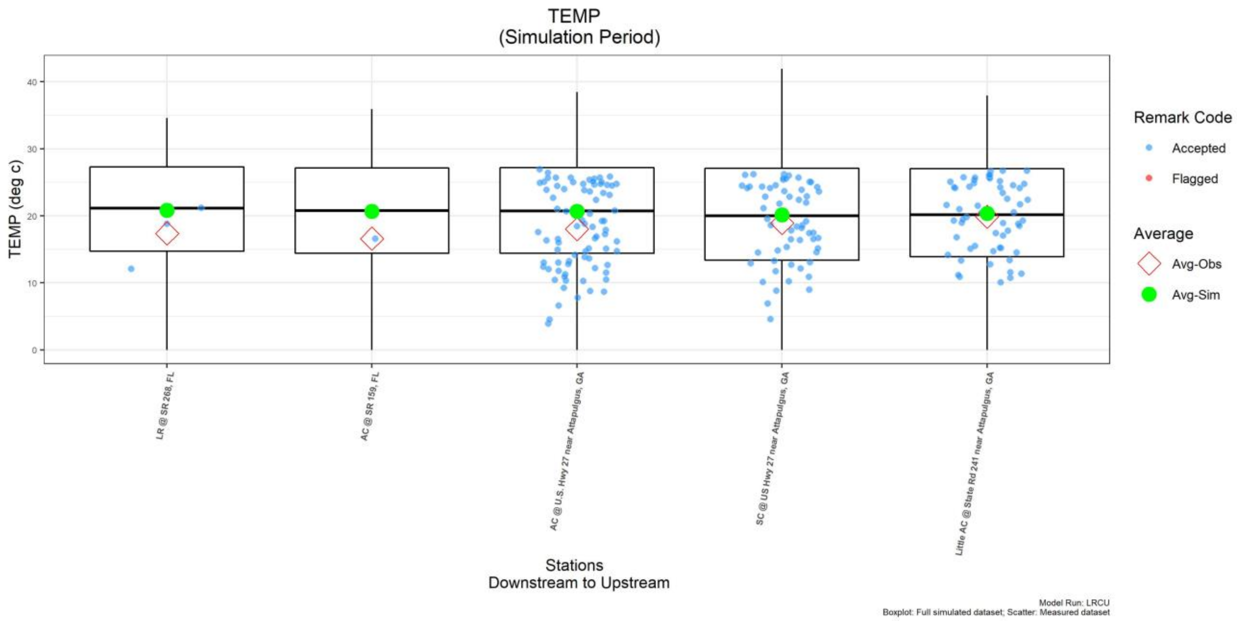

Figure 37 Water Temperautre Box Plot for Little River

Lake Talquin Hydrodynamic and Water Quality Model

Watershed Model Correspondence

The simulated flows and loads from the watershed that drains directly to Lake Talquin are provided by the LSPC watershed model. For the Lake Talquin there 10 watershed subbasins that provided daily loads and flows to the water quality model (Figure 38).

The number of LSPC subbasins does not directly correlate to the number of WASP segments, which required mapping of LSPC results to WASP segment inputs (i.e., boundaries). When a single WASP segment overlapped several LSPC subbasins, we merged flows and concentrations from the LSPC subbasins prior to routing. On the other hand, when multiple WASP segments were in a single LSPC subbasin, flows and concentrations from that LSPC subbasin were routed as a boundary to only one of the WASP segments.

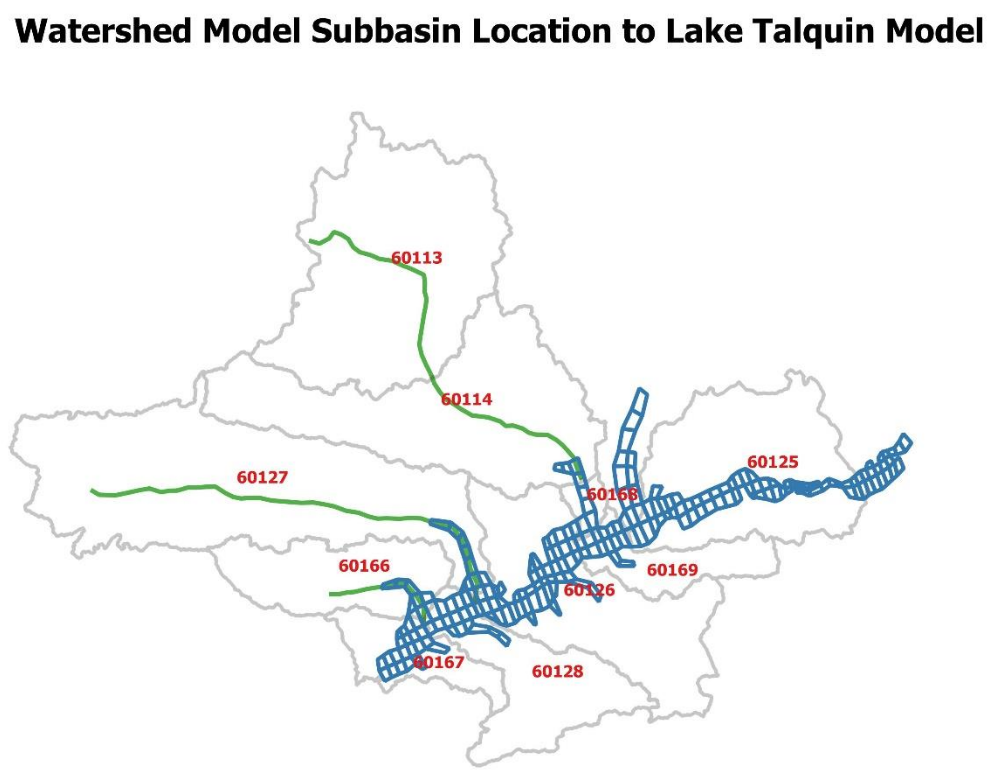

Figure 38 Watershed Model Subbasins draining to Lake Talquin Water Quality Model

When a WASP segment included a LSPC subbasin as its boundary, the segment name begins with 'LSPC' followed by the subbasin number. When multiple subbasins were merged prior to routing to WASP, multiple subbasins are listed. Segment names ending in 'RO' and 'PERO' indicate the type of LSPC runoff values that were used for routing. Segments without an LSPC boundary were named based on their relative geographic location and subwatershed. Table 38 indicates how LSPC subbasins were routed to WASP segments and the routing method used.

Table 38 LSPC to WASP Correspondence – Lake Talquin

LSPC Basin	PERO/RO	WASP Segment
60168	PERO	201
60114	RO	210
60127	RO	207
60166	RO	199
60128	PERO	1
60126	PERO	22
60169	PERO	58
60125	PERO	150
60167	PERO	2
60168	PERO	413
60114	RO	422
60127	RO	419
60166	RO	411
60128	PERO	213
60126	PERO	234
60169	PERO	270
60125	PERO	362
60167	PERO	214

Point Source Dischargers

The Lake Talquin WASP model includes one NPDES discharger (Figure 9). All parameters associated with the point sources were added into the Lake Talquin WASP model as load.

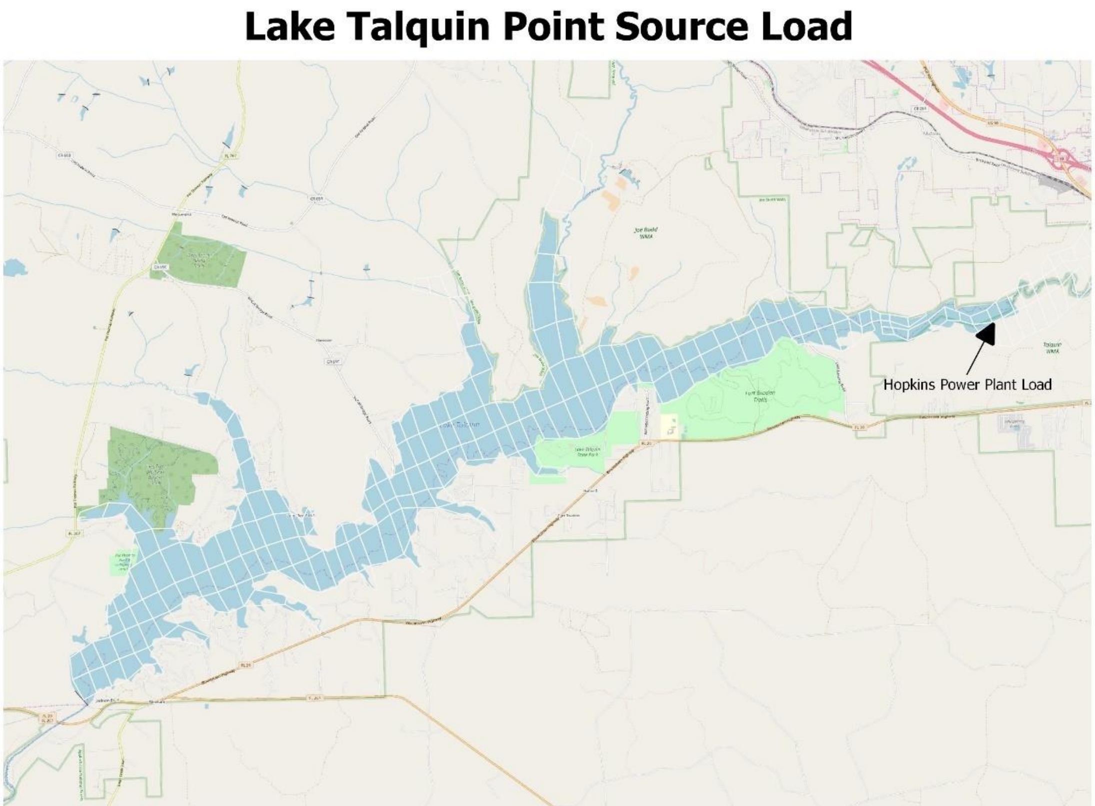

Figure 39 NPDES Discharger to Lake Talquin Water Quality Model

AB Hopkins, City of Tallahassee – Permit # FL0025518

DMR data was used to calculate the loadings to Lake Talquin from the AB Hopkins power plant (Table 39). While the power plant discharges to a tributary (Beaver Creek), the loading approach assumes all loads from the power plant go directly into Lake Talquin. This approach does not consider attenuation of loadings within Beaver Creek and surrounding wetlands.

Table 39 Hopkins Estimates of Loads to Lake Talquin

Parameter Name	Units	No. Obs.	Mean	Min	Max	First Date	Last Date
Dissolved Orgnanic Nitrogen	kg/Day	4,015	0.632	0	3.972	1/1/2007 0:00	12/31/2017 0:00
Dissolved Orgamic Phosphorus	kg/day	4,015	1.942	0	12.2	1/1/2007 0:00	12/31/2017 0:00
Flow	mgd	4,015	1.194	0	7.5	1/1/2007 0:00	12/31/2017 0:00
Ammonia	kg/Day	4,015	0.045	0	0.284	1/1/2007 0:00	12/31/2017 0:00
Nitrate	kg/Day	4,015	0.316	0	1.986	1/1/2007 0:00	12/31/2017 0:00
Dissolved Inorganic Phosphorus	kg/Day	4,015	0.542	0	3.405	1/1/2007 0:00	12/31/2017 0:00

Flow Balance Approach for Lake Talquin

This section provides the methodology used in balancing inflows to Lake Talquin to match the measured water surface elevation. Flow balancing is an essential step in applying a hydrodynamic model to a lake or a reservoir and is an important process to ensure that appropriate lake volumes and retention times are being represented to the water quality model. In the case of the Lake Talquin model, which is simulating a very large upstream watershed for a 10-year simulation period, it would not be possible to predict all inflows and water losses from the lake to accurately match the measured water surface elevation. Because there is only one water outlet from Lake Talquin (over/through the dam) and that flow is measured downstream at a USGS gaging station (Bloxham), the flow balancing approach will only adjust inflows to the lake.

Several utility programs have been developed to implement the flow balancing approach being used for Lake Talquin. These utilities and documentation are provided below.

Flows Considered in Balance

The flow balance equation used for Lake Talquin uses three sets of data to define inflows and outflows of water plus the measured evaporation rates:

- Predicted Flows from the Watershed LSPC Model
- Measured Outflows downstream of the Dam
- Point Source Flows from Ochlockonee & Little Rivers

Inflow/Out Flows

The USGS gages on the Ochlockonee near Havana, FL, and Little River near Midway, FL, were used to calibrate the flows predicted by the watershed model (LSPC) to Lake Talquin. The watershed model flow calibration was compared to two different gages (Ochlockonee River near Havana and Little River near Midway). These same gages will be used for comparison of the adjusted inflows, after flow balancing to Lake Talquin water surface elevations.

Figure 40 (top graph) illustrates the total inflows time series coming into Lake Talquin. It is the sum of the flows from the watershed model, predicted flows that drain directly to Lake Talquin, and the flows routed by the Ochlockonee and Little River WASP models.

Figure 40 (lower graph) illustrates the flows measured just downstream of the dam at the USGS Bloxham gage. Because these flows were measured, the flow balance approach will not manipulate these flows to achieve the measured water surface elevation of Lake Talquin.

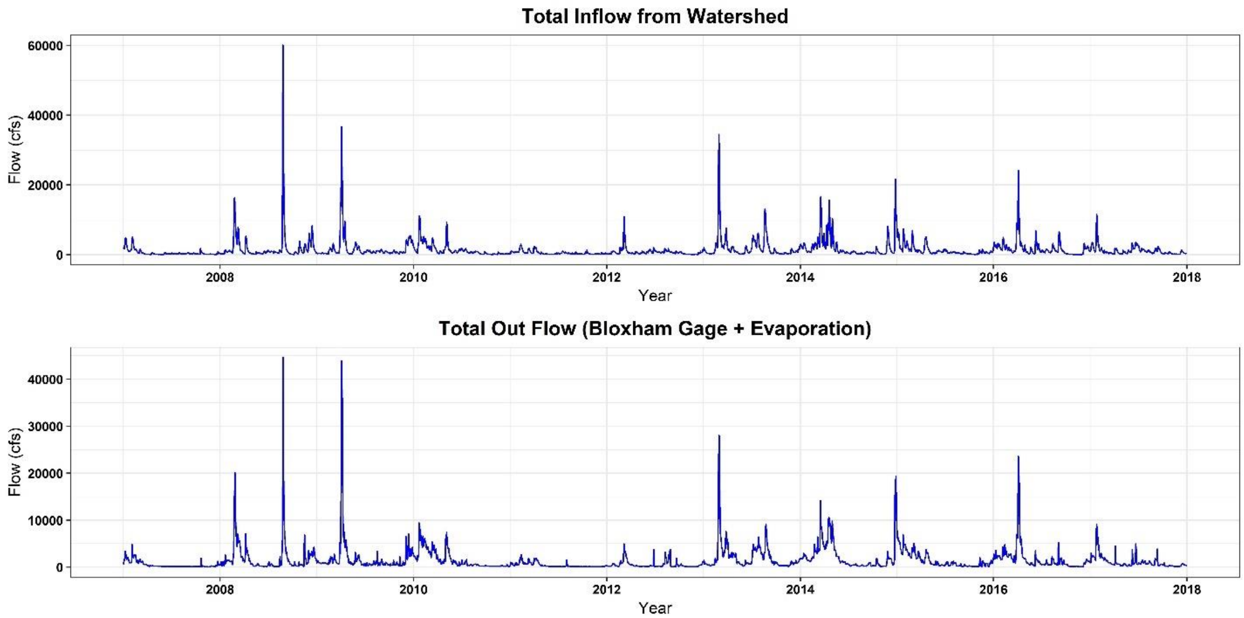

Figure 40 Inflow and Out Flows for Lake Talquin used in Flow Balance Equation

Point Source Flows

The point source flow contributions are handled separately from the flows associated with watershed runoff. The point source flows are considered in the calculation of the flow balance for Lake Talquin but are not subjected to the flow balancing algorithm.

The point source flow contributions were calculated by executing the Ochlockonee and Little River WASP models with and without the point source flows. The difference between the flows at the inlets from the Ochlockonee and Little Rivers to Lake Talquin are the point sources and shown below.

Figure 41 provides the flow contribution time series from the NPDES facilities considered. These flows were not scaled during the flow balancing exercise because these flows are based upon reported measurements.

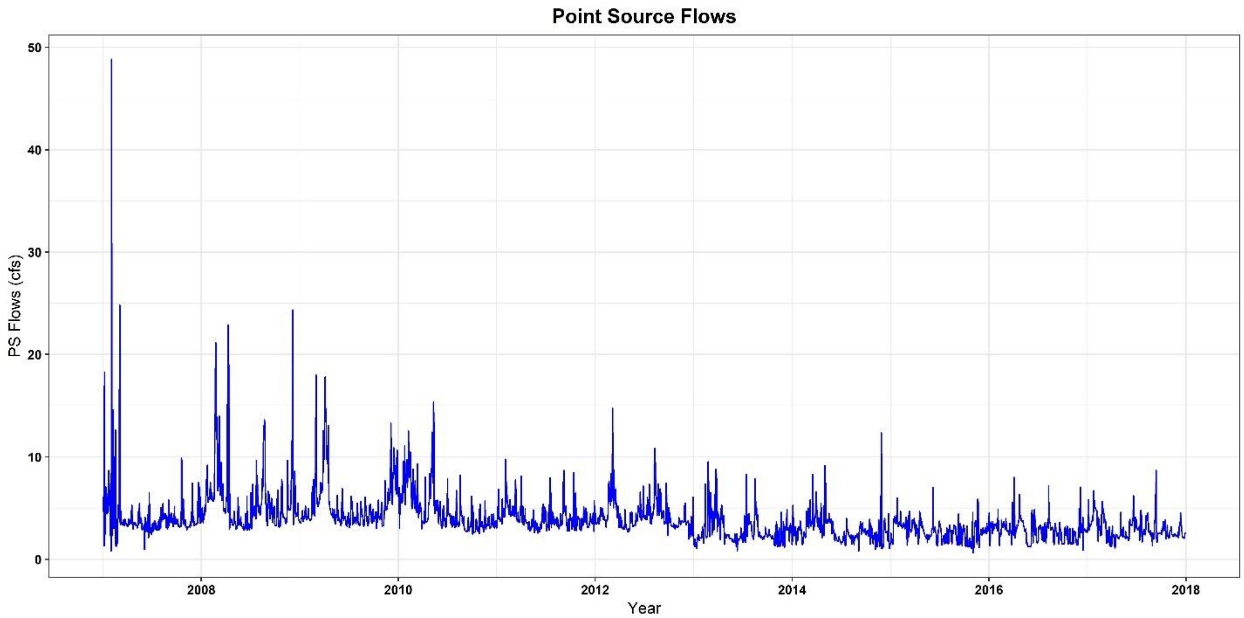

Figure 41 Point Source Flow Contribution

Evaporation

To account for the water loss of from Lake Talquin due to evaporation, measured evaporation rates were obtained from a meteorological station (the Florida Automated Weather Network (FAWN) station at Quincy, FL). These evaporation rates were used as input into the hydrodynamic model. The hydrodynamic model can calculate evaporation as part of its heat balance algorithms, or the user can directly enter the evaporation rates. Because of the sensitivity of the flow balance to small evaporation changes, the measured evaporation rates were entered in to the model.

Figure 42 presents a time series of both the measured evaporation rate and the calculated evaporative loss as flow. The equation for calculating the evaporative loss is given below.

$$Evaporative\ Loss\ (cfs) = \text{(Evaporation Rate (in/day)/12 in/ft) * Lake Area (ft}^2\text{)/3600 sec/hr/24 hr/day}$$

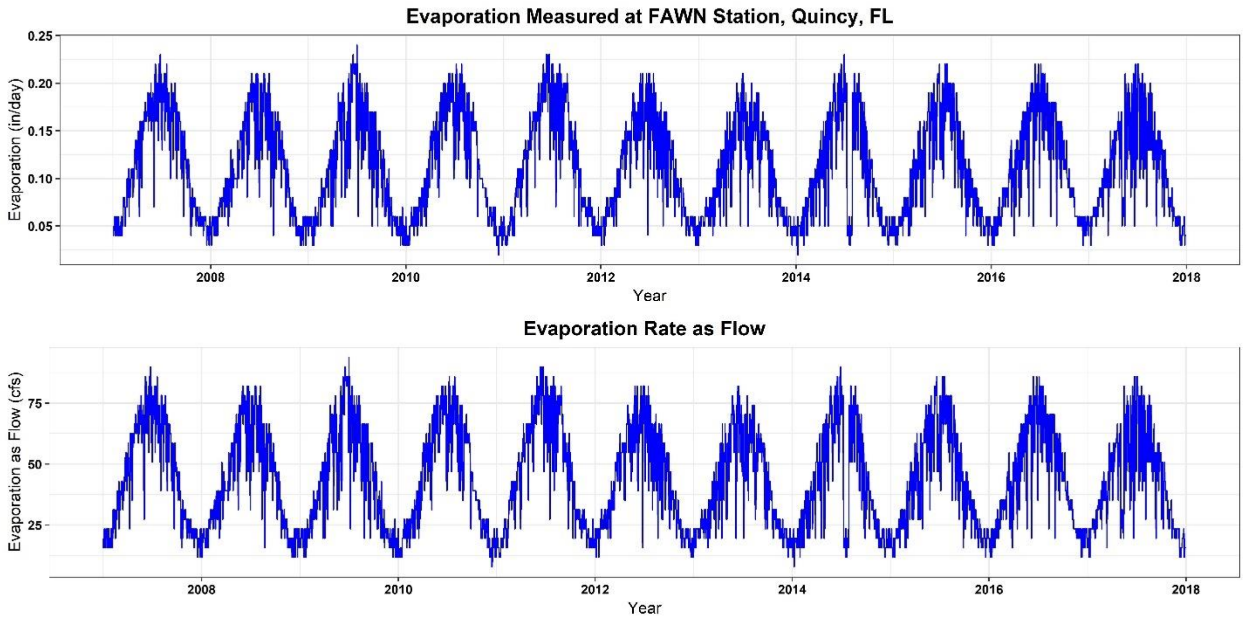

Figure 42 Evaporation Data used in Flow Balance Equation

The total water outflow from Lake Talquin used in the flow balance equation is the sum of the downstream dam gage measurements and the calculated evaporative loss.

Flow Balance Equation

The flow balance approach uses an iterative process to calculate a Flow Multiplier for the Total Inflow into Lake Talquin to achieve a water surface elevation consistent with the measured water surface elevation within a user-specified threshold. The flow balance algorithm has the ability to smooth the measured water surface elevation by calculating a X-day running average, which can be used to determine the Flow Multiplier. The equation for calculating the water surface elevation is given below.

$$Calculated\ WSE = Previous\ Day\ WSE + \frac{((Flow\ In * Flow\ Multiplier) + PS\ Flow) - Flow\ Out}{Lake\ Surface\ Area}$$

The iterative process is controlled by a FORTRAN program that reads inflow, outflow, evaporation, and measured water surface elevation time series, as well as EFDC's DX/DY file that contains information needed to calculate Lake Talquin's surface area. The user specifies a threshold to be considered during the iterative process when comparing calculated water surface elevations to measured water surface elevations. An example of this threshold is +/- 0.2 feet. The iterative process will start with a Flow Multiplier of 1.0, calculate the water surface elevation for the given day, once the calculated water surface elevation has been determined, it is compared to the measured water surface elevation. If the calculated water surface elevation is higher than the measured water surface elevation, the Flow Multiplier is iteratively reduced until the calculated water surface elevation minus the threshold matches the measured water surface elevation. If the calculated water surface elevation is less than the measured water surface elevation, the Flow

Multiplier is iteratively increase until the calculated water surface elevation plus the threshold matches the measured water surface elevation.

It is difficult to remove and/or filter the effects of wind on lake fetch that is part of the measured water surface elevation. Therefore, after running the FORTRAN program to initially determine the daily Flow Multiplier, a spreadsheet tool is used to manually smooth some of the sudden changes in the multiplier. This step is needed to keep the initial flow balancing algorithm from correcting the inflow for a change in water surface elevation that is not based on a flow event.

Results of Flow Balance

The results of the flow balancing algorithm prior to running the results through the hydrodynamic model are shown in the following figures. Slight modifications to the inflows need to be made within EFDC to ensure stability and to match measured water surface elevations within the bounds of the threshold.

Water Surface Elevation

Figure 43 (top graph) shows a time series plot of the calculated water surface elevation compared to the measured water surface with flow balancing threshold of 0.2 feet. The second graph provides a one to one comparison and shows good R^2 and the root mean square of 0.12 is less than the flow balancing threshold.

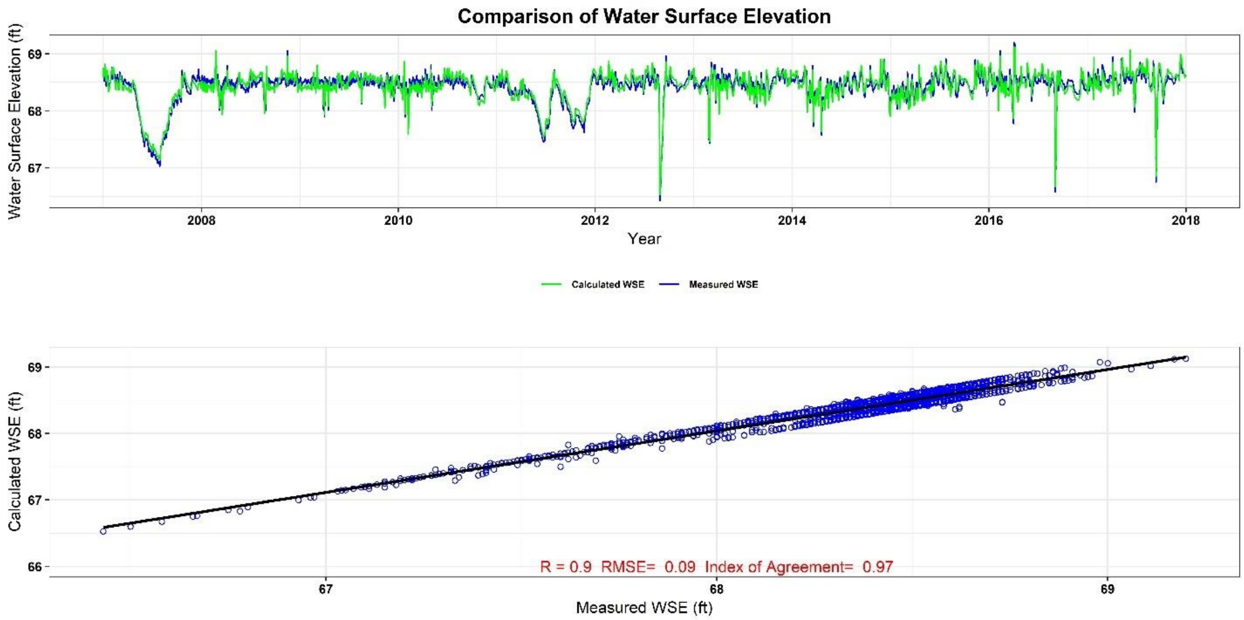

Figure 43 Water Surface Elevation Comparison (Measured vs. Calculated)

Flow Adjustment

Figure 44 shows the calculated total inflow adjustments to Lake Talquin as a function of applying the flow balancing approach. This flow adjustment is applied to the inflows only. In the case of a negative adjusted flow, that amount of water flowing in is scaled back. In the case of a positive adjusted flow, the amount of water flowing in is scaled up.

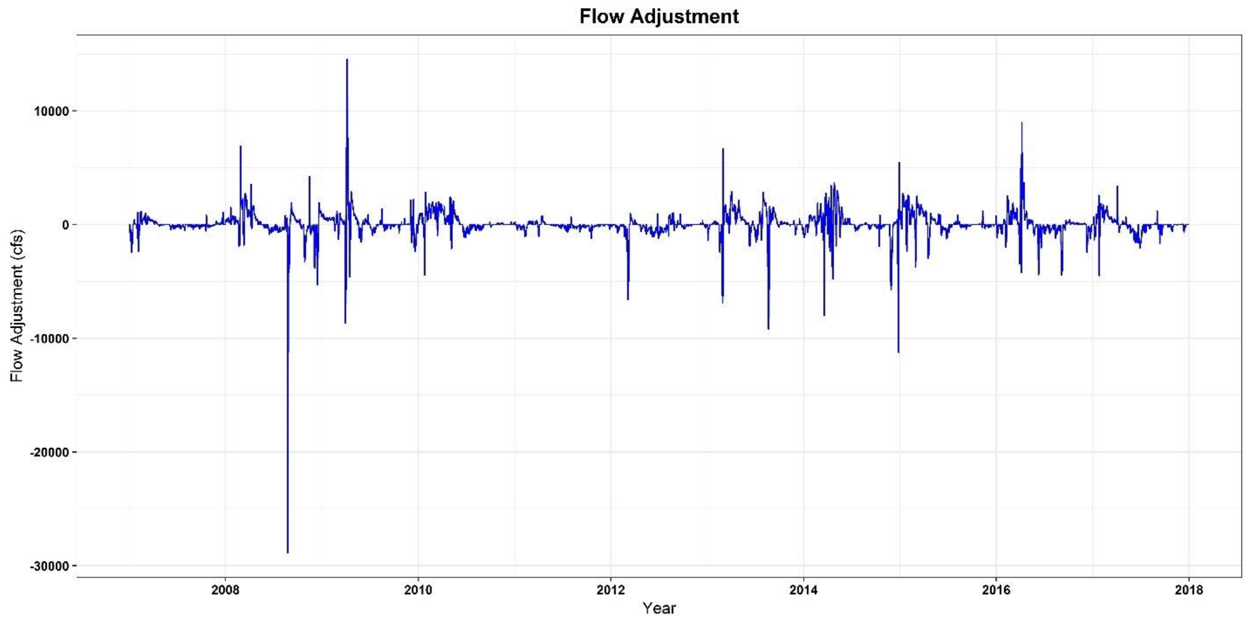

Figure 44 Calculated Flow Correction by Day

Figure 45 provides a comparison of the calculated flow adjustment to daily rainfall measured at the Tallahassee Airport.

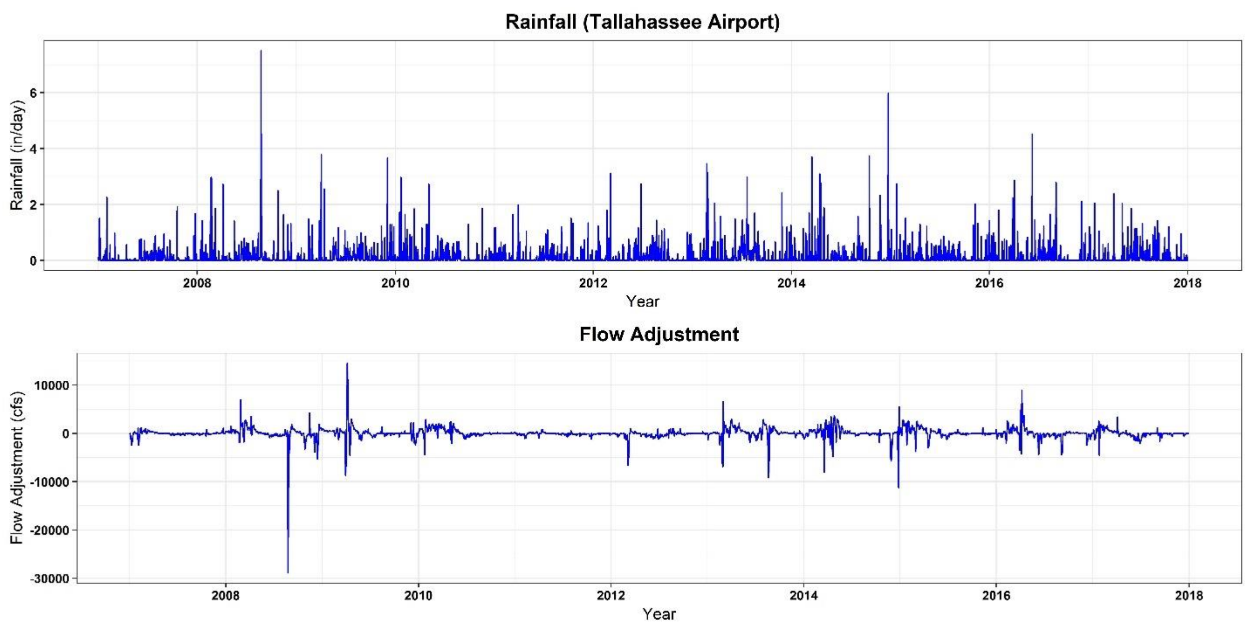

Figure 45 Comparison of Rainfall to Flow Adjustment

Figure 46 provides a comparison of the simulated and adjusted total inflows to the total gaged inflows to Lake Talquin. The lowest USGS gages on the Little River (Midway, FL) and Ochlockonee River (Havana, FL) were used to calculate a representative total gaged inflow to Lake Talquin. A drainage area multiplier was used to scale the measured USGS gage flows to account for the ungaged area that direct drains to Lake Talquin and the area below the gages on two rivers.

The first graph compares the simulated inflows with the area weighted inflows. A statistical comparison of the simulated flows with total gaged inflows shows a very good correlation, both the R^2 (0.86) and the Index of Agreement (0.96) are well within acceptable limits.

The second graph compares the adjusted total inflow with the area weighted flow gages. After applying the flow correction there is an improvement in the statistical comparison of adjusted total inflows compared to the with total gaged inflows. The R^2 improved (0.94), as well as the Index of Agreement to (0.98).

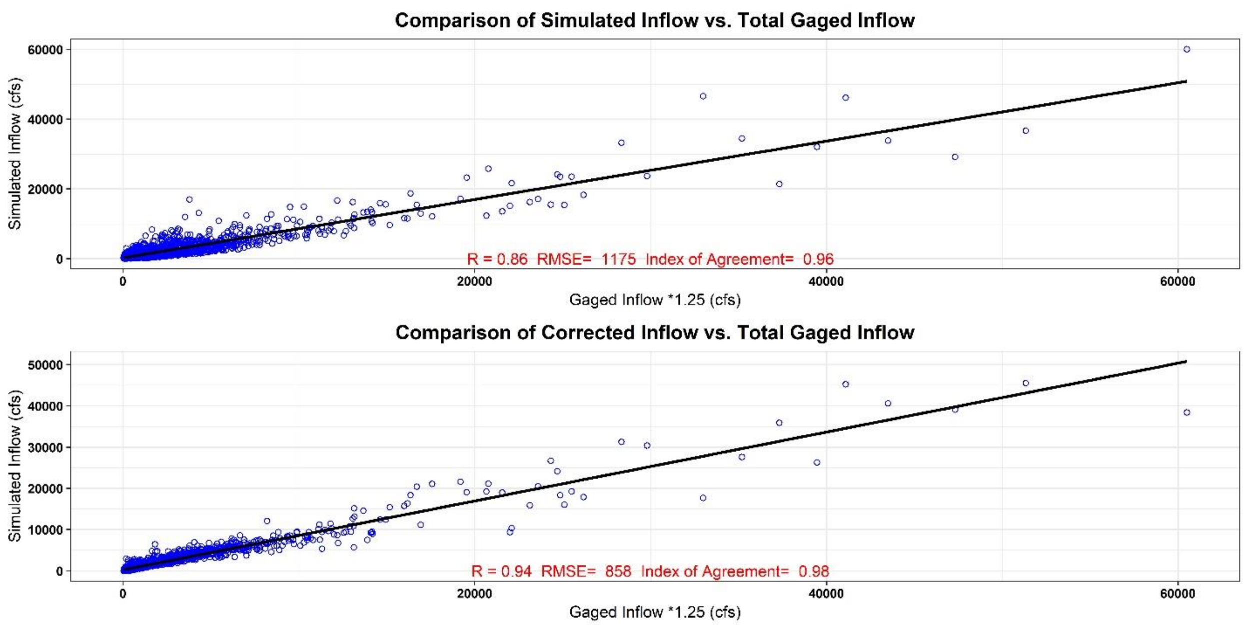

Figure 46 Comparison of the Total Inflows to Total Gaged Flows

Figure 47 provides a comparison between the outflow time series used in the hydrodynamic model at the Lake Talquin Dam to the downstream USGS gage at Bloxham, FL.

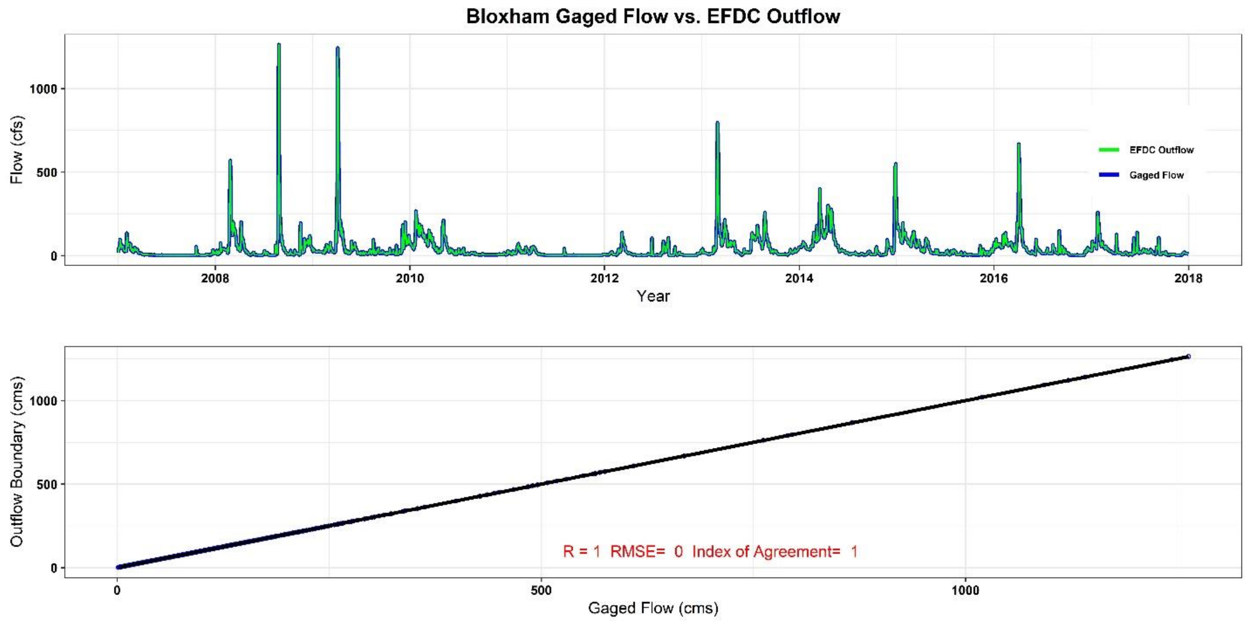

Figure 47 Comparison of Model Specified Outflows from Dam to USGS Bloxham Gage Downstream

Figure 48 provides a comparison of the flow adjusted model time series for the Ochlockonee River to the USGS measured flows at the Havana, FL gage.

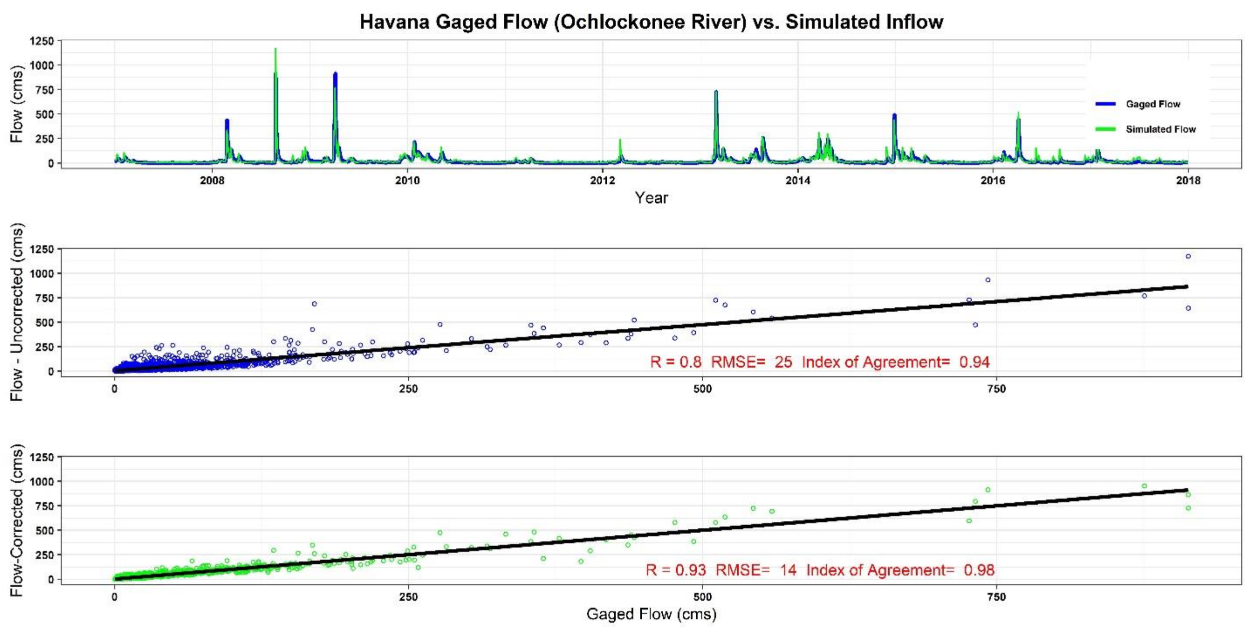

Figure 48 Comparison of Model Specified Inflows from Ochlockonee River to USGS Havana Gage

Figure 49 provides a comparison of the flow adjusted model time series for the Little River to the USGS measured flows at the Midway, FL gage.

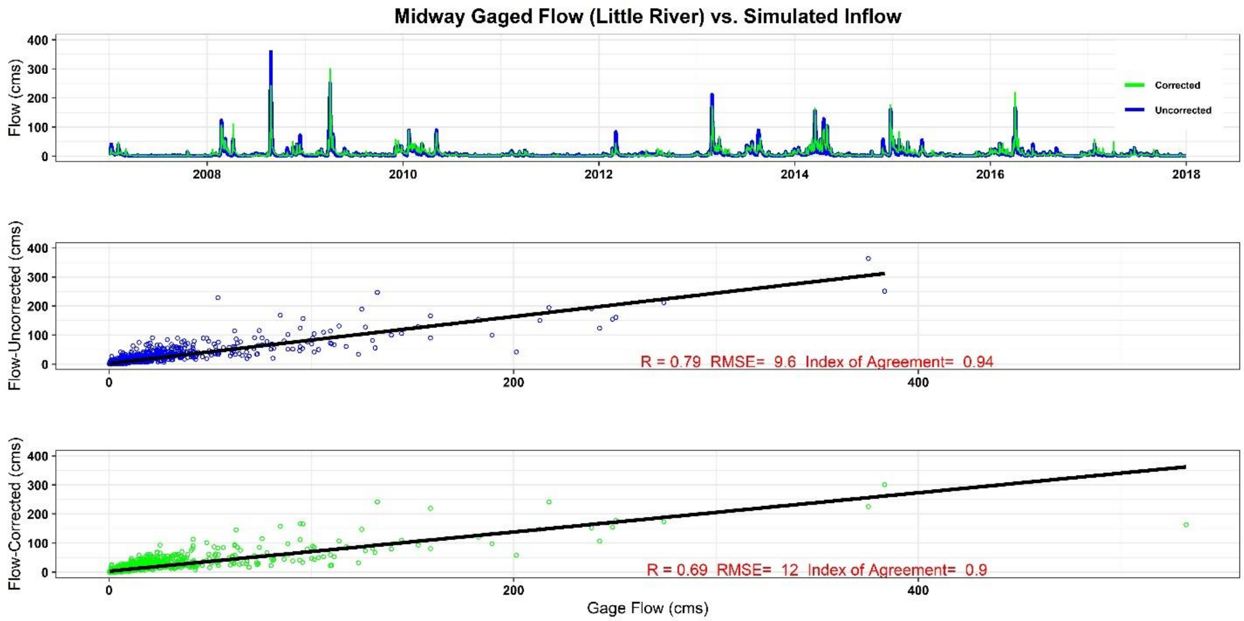

Figure 49 Comparison of Model Specified Inflows from Little River to USGS Midway Gage

Figure 50 top graph provides a comparison of cumulative inflow (simulated & adjusted) with total outflow (Bloxham gage + Evaporation). The bottom graph compares the cumulative adjusted inflow against the total outflow.

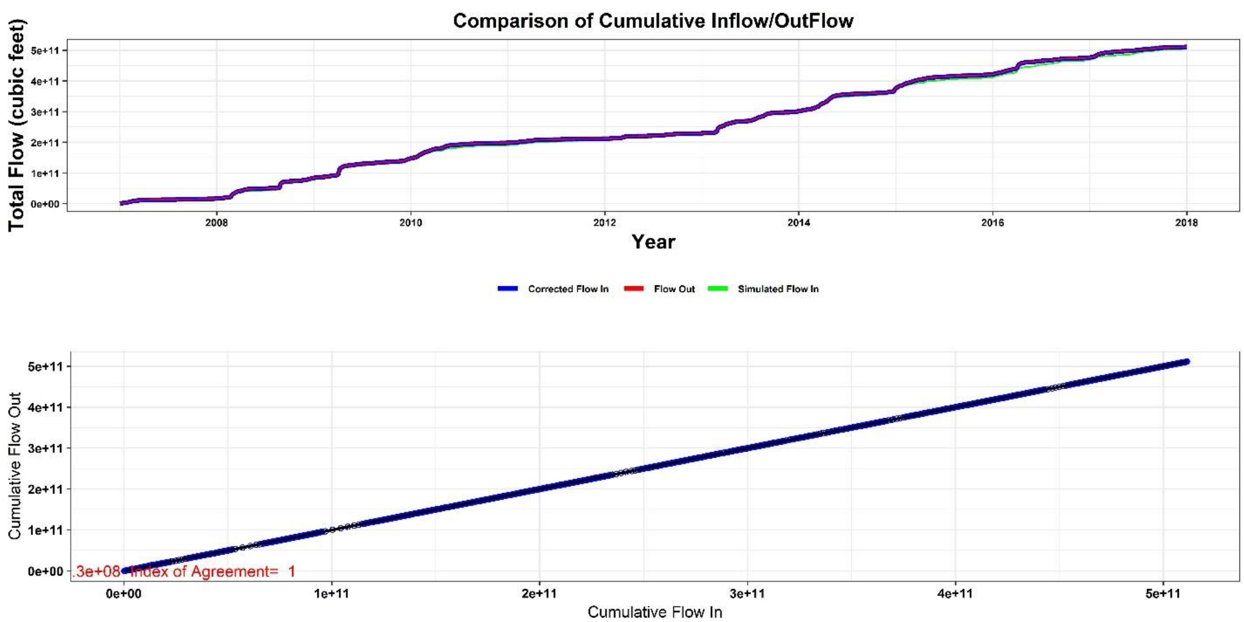

Figure 50 Comparison of the Cumulative Inflows and Outflow

Figure 51 shows a comparison of the cumulative flows simulated by the models compared to the balanced flows from the algorithm. The average difference between the flows is just over 1% over the 10-year simulation period.

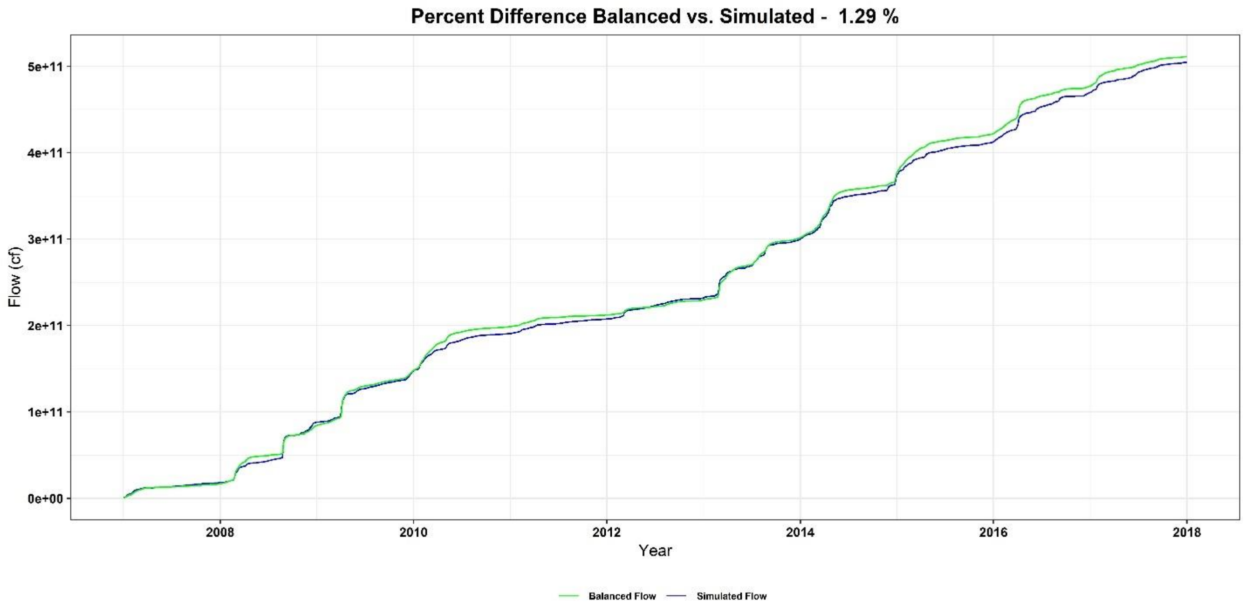

Figure 51 Cumulative Flow Comparison between Simulated (unbalanced flows) and the Adjusted Flow

Figure 52 Comparison of the Inflow Correction shows a time series and cumulative flow plots of the corrective inflow and outflow after the flow balancing approach is completed.

Because the difference between the total simulated inflow and total corrected inflow are within 1% after 10 years, it is clear the flow correction algorithm is correcting timing of water coming into Lake Talquin. Timing issues are caused by rainfall location and intensity throughout the basin. Timing is also changed during large storm events when the rivers are outside their banks.

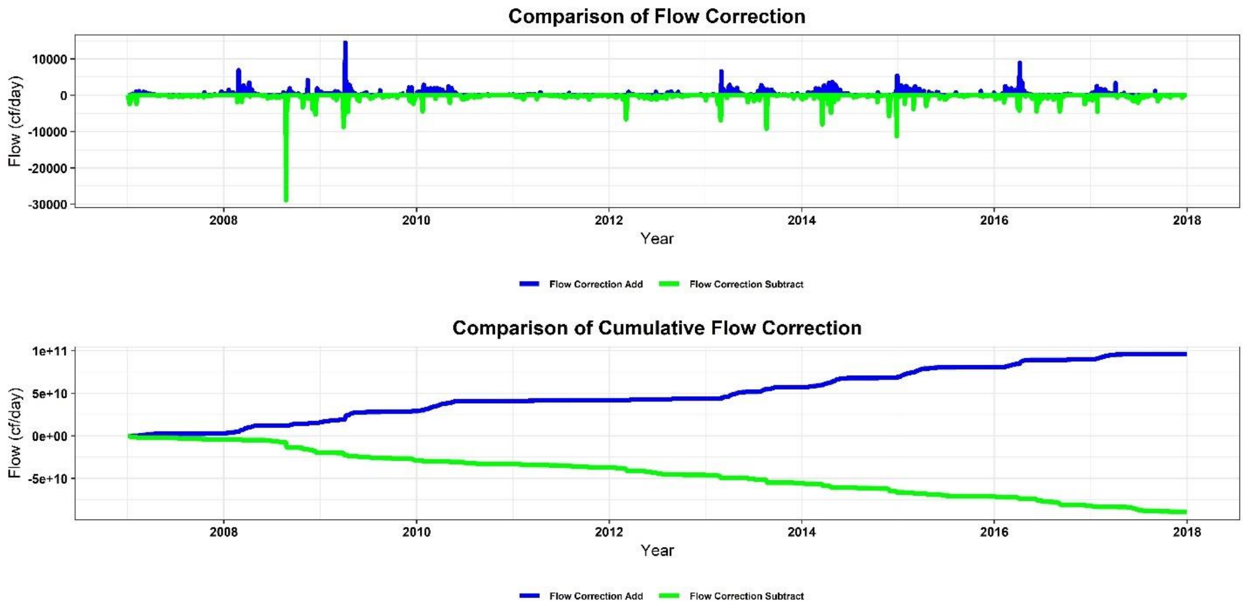

Figure 52 Comparison of the Inflow Correction

Comparison of Loads after Flow Balance

Upon completion of the flow balance process, the daily flow time series that are used in Lake Talquin hydrodynamic and water quality models are slightly altered from the flows simulated by the watershed model (direct drainage to Lake Talquin) and Ochlockonee and Little River water quality models. Because there is no way to apply the flow balance approach to the watershed and riverine water quality models to meet the measured water surface elevation in Lake Talquin, the externally calculated flow balance was applied to the inflows only to Lake Talquin. The predicted concentrations from the watershed model and riverine models were not altered.

As stated above, 1.28% more water was added to Lake Talquin then simulated by the watershed and riverine water quality models. Below is an analysis of the changes in predicted total nitrogen and total phosphorus loads because of the implementation of the flow balance step.

Ochlockonee River

Figure 53 shows a comparison of the predicted daily loads of total nitrogen and total phosphorus for the Ochlockonee River over the simulation period. The time series compares the daily load of the simulated concentrations and flows from water quality model with the daily load after applying the flow balance to flow and using the simulated concentration.

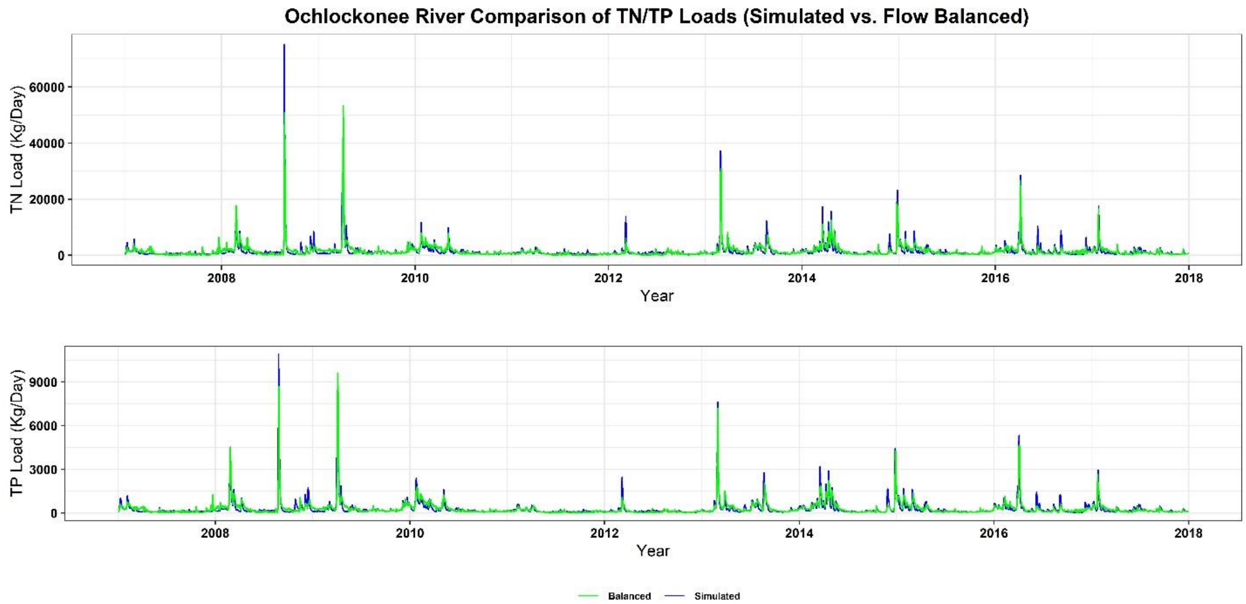

Figure 53 Ochlockonee River Comparison of Total Nitrogen and Total Phosphorus Daily Loads after Flow Balance

Figure 54 compares the cumulative load of total nitrogen and total phosphorus for the Ochlockonee River over the simulation period, with and without the flow balance. After the flow balance the total nitrogen load is increased by 2.36% and total phosphorus by 3.24%.

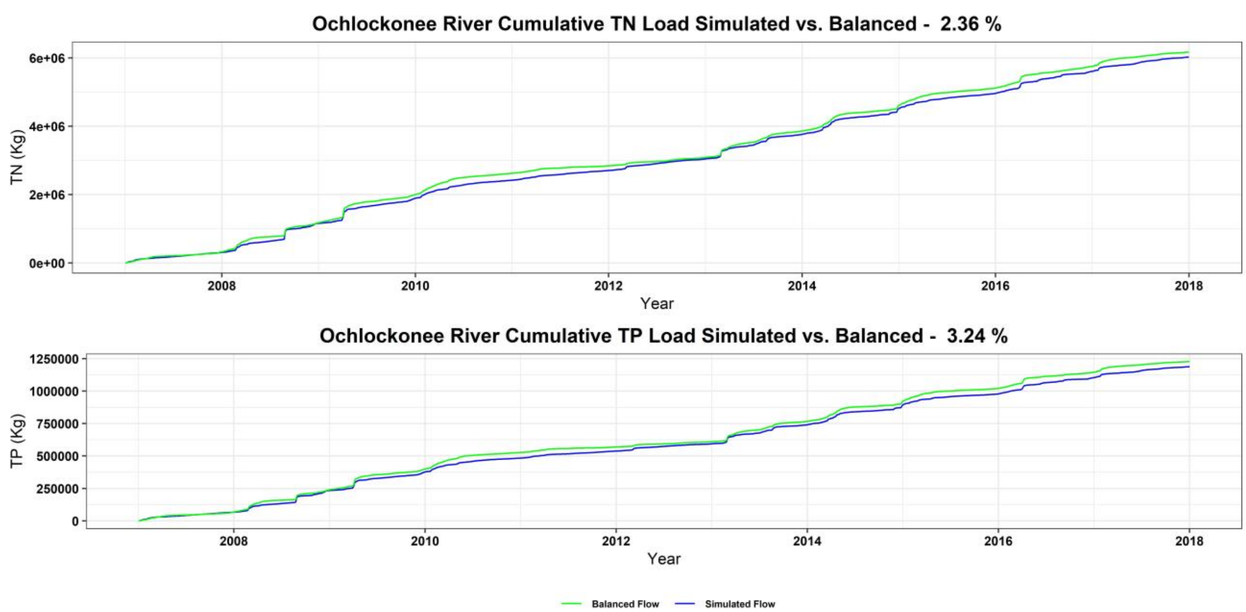

Figure 54 Ochlockonee River Cumulative Load Analysis for Total Nitrogen and Total Phosphorus after Flow Balance

Little River

Figure 55 shows a comparison of the predicted daily loads of total nitrogen and total phosphorus for the Little River over the simulation period. The time series compares the daily load of the simulated concentrations and flows from water quality model with the daily load after applying the flow balance to flow and using the simulated concentration.

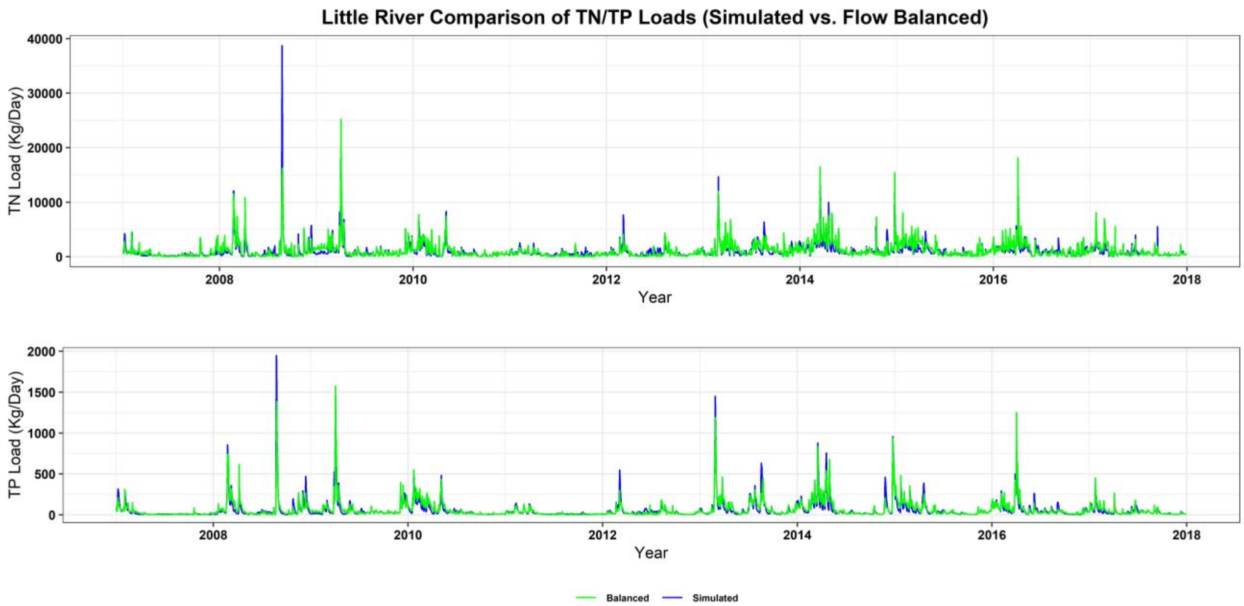

Figure 55 Little River Comparison of Total Nitrogen and Total Phosphorus Daily Loads after Flow Balance

Figure 56 compares the cumulative load of total nitrogen and total phosphorus for the Ochlockonee River over the simulation period, with and without the flow balance. After the flow balance the total nitrogen load is increased by 6.92% and total phosphorus by 0.6%.

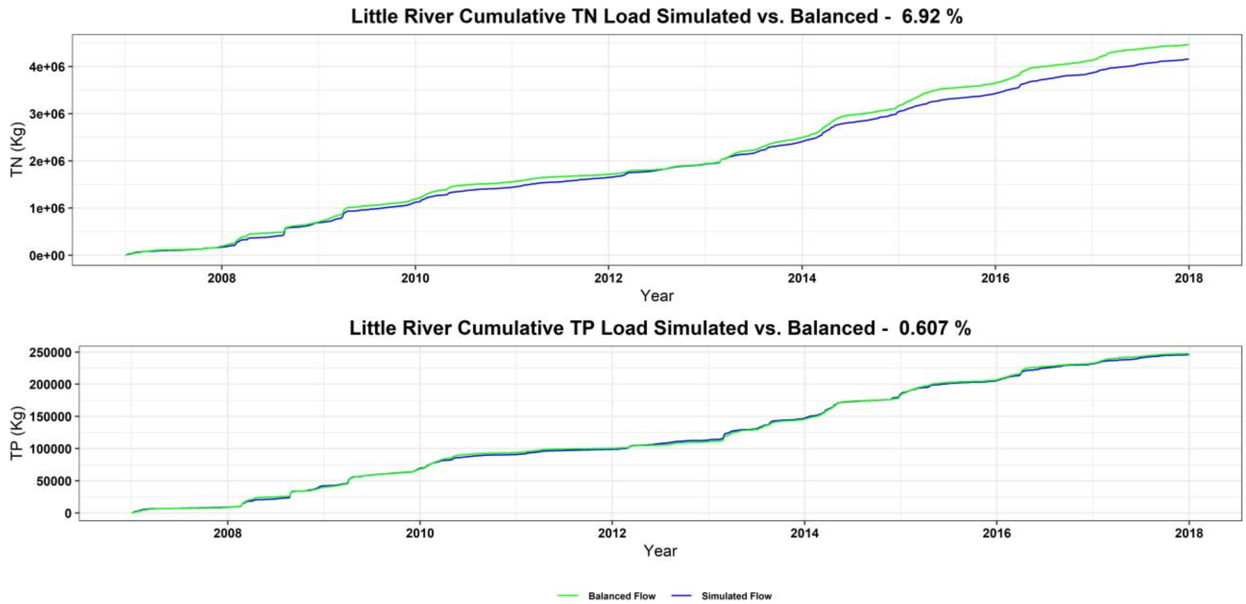

Figure 56 Little River Cumulative Load Analysis for Total Nitrogen and Total Phosphorus after Flow Balance

Hydrodynamic Model Calibration

The hydrodynamic model was calibrated to all available water surface elevation and water temperature data. All inflows to Lake Talquin were calibrated in the watershed and Ochlockonee and Little River water quality models. The inflow calibration was presented in early sections. Outflow from the dam was determined by the USGS flow gage downstream near Bloxham, FL

Water Surface Elevation

Table 40 and Figure 57 provide a comparison of water surface elevation simulated by the hydrodynamic model and the measured values at the USGS Dam Pool Station.

Table 40 Quantitative Statistical Analysis for Water Surface Elevation – USGS Lake Talquin Station

	USGS Lake Talquin Dam Pool	Average
Number Obs	3636	3636
Observed Mean	20.86	20.86
Simulation Mean	20.87	20.87
Mean Error	0.01	0.01
Mean Absolute Error	0.04	0.04
RMSE	0.05	0.05
R2	0.63	0.63
Spearman Coeff.	0.70	0.70
PBias	0.00	0.00
Nash	0.52	0.52
Index of Agreement.	0.88	0.88

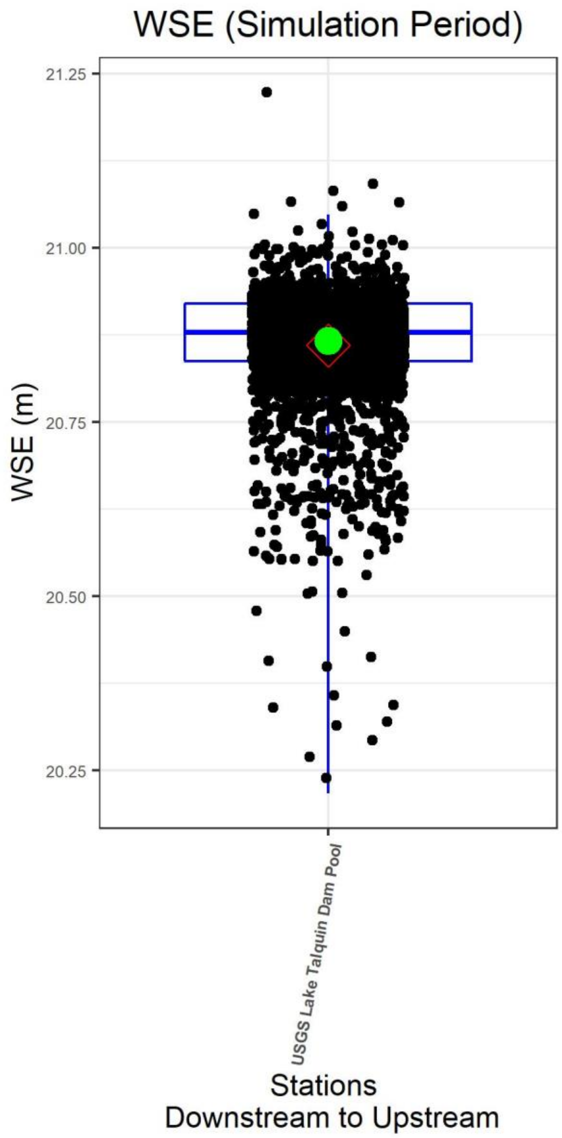

Figure 57 Water Surface Elevation Box Plot for Lake Talquin Station

Dam Outflow

Table 41 and Figure 58 provide a comparison of out flow from lake Talquin to USGS flow gage at Bloxham, FL. This illustrates that the measured flows at Bloxham, FL were not altered or manipulated by the flow balance process.

Table 41 Quantitative Statistical Analysis for Dam Outflow – USGS Bloxham, FL

	USGS Ochlockonee River, Bloxham, FL	Average
Number Obs	3653	3653
Observed Mean	43.13	43.13
Simulation Mean	43.13	43.13
Mean Error	0.00	0.00
Mean Absolute Error	0.00	0.00
RMSE	0.16	0.16
R2	1.00	1.00
Spearman Coeff.	1.00	1.00
PBias	0.00	0.00
Nash	1.00	1.00
Index of Agreement.	1.00	1.00

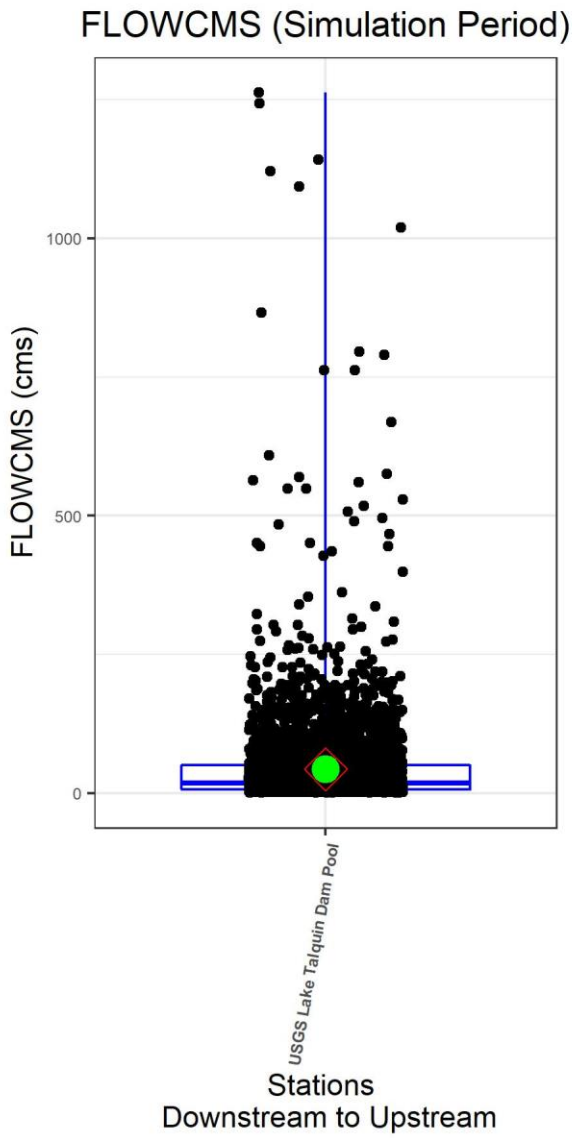

Figure 58 Dam Outflow Box Plot for Lake Talquin Station

Temperature

Table 42 and Figure 59 provide a comparison of water temperature simulated by the hydrodynamic model and the measured values at 6 water quality monitoring stations.

Table 42 Quantitative Statistical Analysis for Water Temperature – Lake Talquin Stations

Metric	Talquin West	Ben Stoutamire	Luther Hall	Talquin Central	Williams Landing	Talquin 4	Average
Number Obs-Total	77	58	53	27	51	24	48.3333
Number Obs-Accepted	77	58	53	27	51	24	48.3333
Observed Mean	22.092	22.069	22.297	23.473	22.837	22.387	22.5258
Observed Variance	42.091	41.161	45.509	46.077	48.382	48.117	45.2228
Simulation Mean	22.654	22.638	22.71	23.94	23.223	22.743	22.9847
Simulation Variance	55.403	55.909	58.169	62.102	68.655	62.68	60.4863
Mean Error	0.5617	0.5686	0.4128	0.4666	0.386	0.3557	0.4586
Mean Absolute Error	1.4184	1.3846	1.324	1.242	1.6371	1.0256	1.3386
RMSE	1.7385	1.6892	1.6308	1.5493	1.9948	1.2595	1.6437
NRMSE %	8.3	8.4	8.6	7.8	9.2	6.2	8.0833
R^2	0.9625	0.97	0.9661	0.98	0.9633	0.9898	0.972
Spearman Coeff.	0.9601	0.96	0.9598	0.8711	0.9642	0.9615	0.9461
PBias	2.5	2.6	1.9	2	1.7	1.6	2.05
Nash	0.9272	0.9295	0.9404	0.9459	0.9161	0.9656	0.9374
Index of Agreement	0.9841	0.9849	0.9868	0.9884	0.9824	0.9925	0.9865
Kling-Gupta Effic. Modified	0.877	0.8606	0.8871	0.8599	0.8268	0.8754	0.8645
Kling-Gupta Pear. Coeff.	0.9811	0.9849	0.9829	0.99	0.9815	0.9949	0.9859
Kling-Gupta Beta (Ratio Means)	1.0254	1.0258	1.0185	1.0199	1.0169	1.0159	1.0204
Kling-Gupta Gamma (Ratio CV)	1.1188	1.1362	1.11	1.1383	1.1714	1.1235	1.133

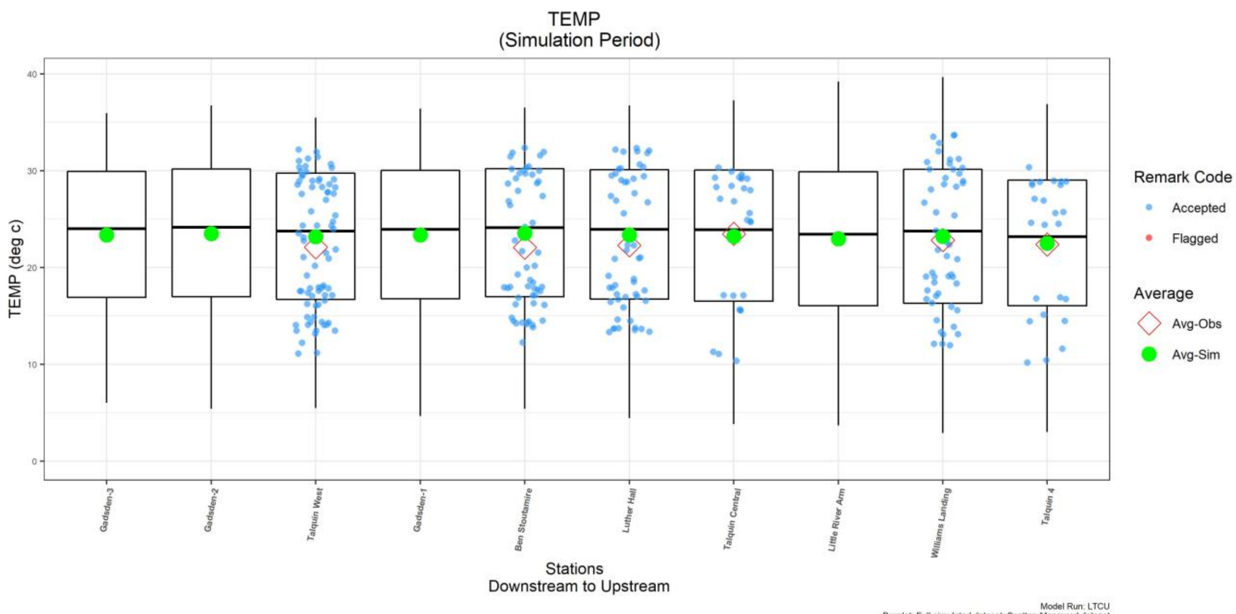

Figure 59 Water Temperature Box Plot for Lake Talquin Stations

Water Quality Model Calibration

There are 13 water quality monitoring stations used for water quality model calibration for the Lake Talquin model. The monitoring data was obtained from FDEP's Impaired Waters Rule Database (Version 55). Figure 60 depicts the name and location of the water quality monitoring stations. For a Station/Water Quality Parameter to be considered in the quantitative and qualitative calculations and plots the station must have more than 10 observations during the simulation period.

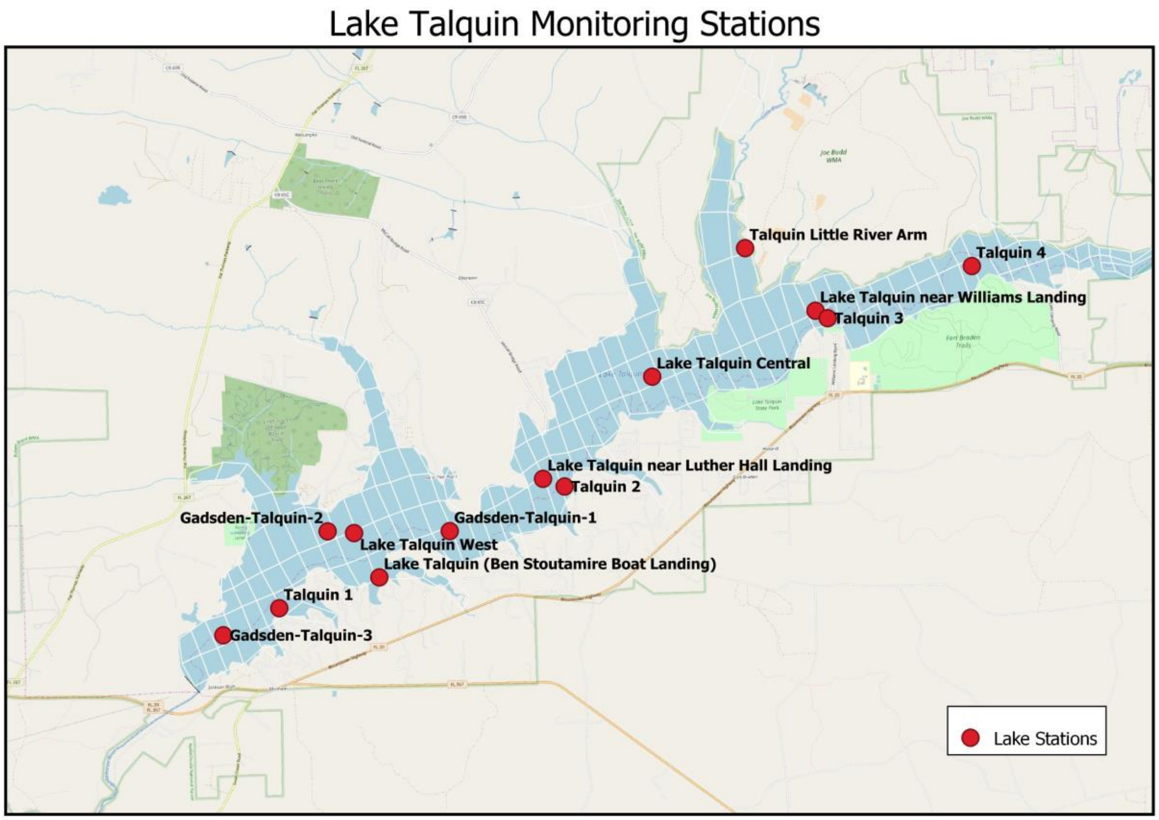

Figure 60 Lake Talquin Water Quality Monitoring Stations

Total Nitrogen

Table 43 and Figure 61 provide a comparison of total nitrogen simulated by the watershed/water quality model and the measured values at 8 water quality monitoring stations.

Table 43 Quantitative Statistical Analysis for Total Nitrogen – Lake Talquin Stations

Metric	Gadsden-3	Gadsden-2	Talquin West	Gadsden-1	Ben Stoutamire	Luther Hall	Little River Arm	Williams Landing	Average
Number Obs-Total	104	105	35	105	38	28	15	28	57.25
Number Obs-Accepted	104	105	35	105	38	28	15	28	57.25
Observed Mean	1.026	1.012	0.791	0.969	0.746	0.818	0.982	0.805	0.8936
Observed Variance	0.084	0.118	0.044	0.072	0.059	0.052	0.076	0.034	0.0674
Simulation Mean	0.828	0.841	0.869	0.877	0.867	0.916	1.452	0.977	0.9534
Simulation Variance	0.031	0.034	0.048	0.035	0.047	0.033	0.195	0.066	0.0611
Mean Error	-0.1978	-0.1717	0.0777	-0.0921	0.1218	0.0986	0.4694	0.1719	0.0597
Mean Absolute Error	0.3164	0.3253	0.2436	0.3062	0.2757	0.2747	0.5093	0.3082	0.3199
RMSE	0.3876	0.4301	0.3202	0.3665	0.3978	0.3504	0.6154	0.3766	0.4056
NRMSE %	27.7	14.8	31.4	29.1	40.8	34.5	61.5	43.5	35.4125
R^2	0.0009	0.0014	0.005	0.0404	0.1512	0.1471	0.1722	0.0272	0.0682
Spearman Coeff.	-0.0728	-0.1824	-0.1712	-0.2438	-0.237	-0.3767	0.3307	-0.0868	-0.13
PBias	-19.3	-17	9.8	-9.5	16.3	12.1	47.8	21.4	7.7
Nash	-0.7982	-0.5802	-1.3727	-0.8914	-1.7511	-1.4525	-4.3556	-3.272	-1.8092
Index of Agreement	0.4303	0.328	0.2915	0.2804	0.2129	0.2178	0.4987	0.2659	0.3157
Kling-Gupta Effic. Modified	-0.0206	-0.1098	-0.0762	-0.2258	-0.4175	-0.4176	0.2399	-0.193	-0.1526
Kling-Gupta Pear. Coeff.	0.0296	-0.038	-0.0705	-0.201	-0.3888	-0.3835	0.415	-0.165	-0.1003
Kling-Gupta Beta (Ratio Means)	0.8072	0.8304	1.0982	0.905	1.1633	1.1206	1.4778	1.2136	1.077
Kling-Gupta Gamma (Ratio CV)	0.7495	0.6459	0.949	0.7739	0.7682	0.7156	1.0849	1.1429	0.8537

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix C.

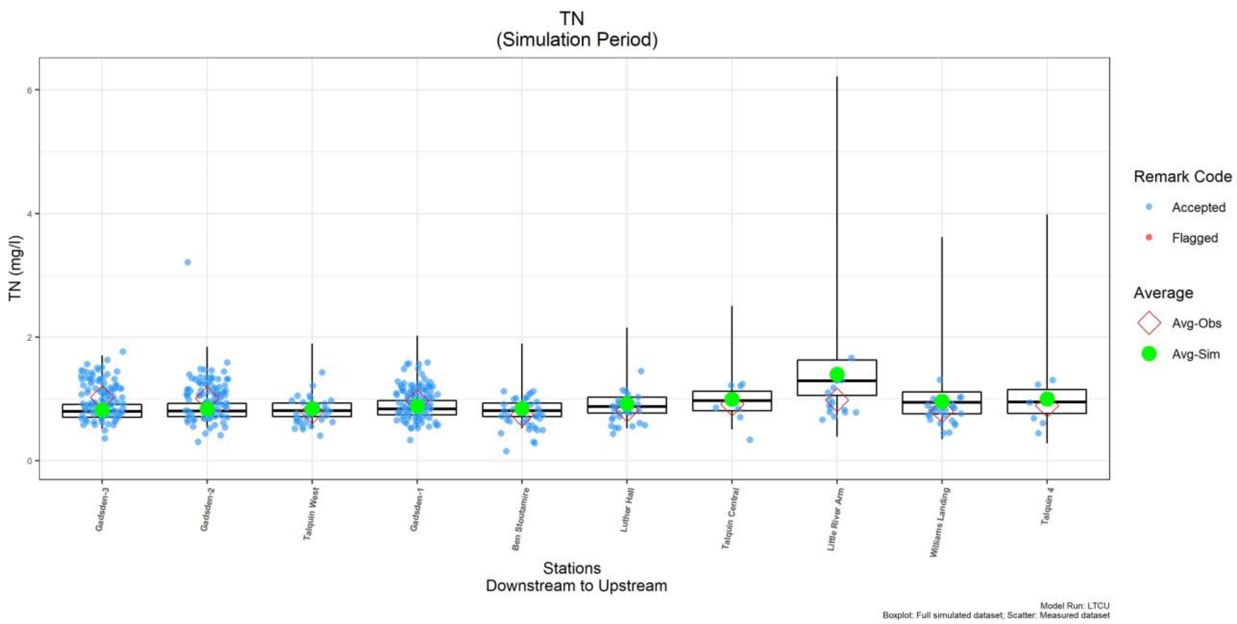

Figure 61 Total Nitrogen Box Plot for Lake Talquin Stations

Ammonia

Table 44 and Figure 62 provide a comparison of ammonia simulated by the watershed/water quality model and the measured values at 5 water quality monitoring stations.

Table 44 Quantitative Statistical Analysis for Ammonia – Lake Talquin Stations

Metric	Talquin West	Ben Stoutamire	Luther Hall	Little River Arm	Williams Landing	Average
Number Obs-Total	35	38	28	15	28	28.8
Number Obs-Accepted	35	38	28	15	28	28.8
Observed Mean	0.032	0.038	0.035	0.035	0.037	0.0354
Observed Variance	0.001	0.007	0	0.001	0.001	0.002
Simulation Mean	0.084	0.08	0.079	0.093	0.05	0.0772
Simulation Variance	0.002	0.002	0.003	0.004	0.002	0.0026
Mean Error	0.0513	0.0421	0.0439	0.0576	0.0137	0.0417
Mean Absolute Error	0.0556	0.0652	0.0506	0.0608	0.0461	0.0557
RMSE	0.0703	0.0969	0.0671	0.0812	0.0606	0.0752
NRMSE %	70.3	18.1	90.6	108.3	50.5	67.56
R^2	0.0327	0.0498	0.048	0.1104	0.0115	0.0505
Spearman Coeff.	0.2566	0.2424	0.1621	0.1735	-0.0407	0.1588
PBias	159	109.6	126.5	163	37.4	119.1
Nash	-7.1822	-0.3293	-9.7695	-11.7882	-3.6897	-6.5518
Index of Agreement	0.3335	0.4041	0.3795	0.384	0.2546	0.3511
Kling-Gupta Effic. Modified	-0.8098	-0.5255	-0.49	-0.7616	-0.2008	-0.5575
Kling-Gupta Pear. Coeff.	0.1808	0.2231	0.2191	0.3322	-0.1071	0.1696
Kling-Gupta Beta (Ratio Means)	2.5899	2.0963	2.2648	2.6301	1.3739	2.191
Kling-Gupta Gamma (Ratio CV)	0.7235	0.2777	1.1036	1.0154	1.2764	0.8793

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix C.

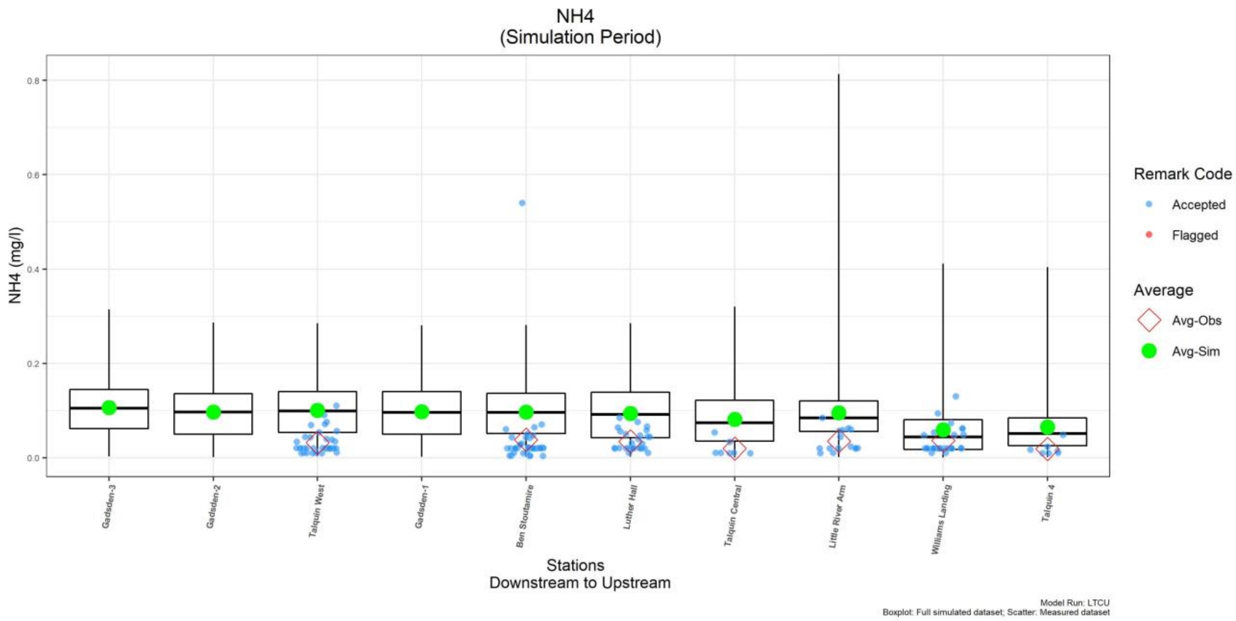

Figure 62 Ammonia Box Plot for Lake Talquin Stations

Nitrate

Table 45 and Figure 63 provide a comparison of nitrate simulated by the watershed/water quality model and the measured values at 5 water quality monitoring stations.

Table 45 Quantitative Statistical Analysis for Nitrate – Lake Talquin Stations

Metric	Talquin West	Ben Stoutamire	Luther Hall	Little River Arm	Williams Landing	Average
Number Obs-Total	35	38	28	15	28	28.8
Number Obs-Accepted	35	38	28	15	28	28.8
Observed Mean	0.086	0.089	0.111	0.255	0.126	0.1334
Observed Variance	0.008	0.008	0.012	0.049	0.009	0.0172
Simulation Mean	0.132	0.132	0.16	0.732	0.148	0.2608
Simulation Variance	0.021	0.022	0.019	0.182	0.019	0.0526
Mean Error	0.0461	0.0426	0.0494	0.4766	0.0217	0.1273
Mean Absolute Error	0.123	0.1362	0.1361	0.4935	0.1372	0.2052
RMSE	0.176	0.1815	0.181	0.5708	0.1595	0.2538
NRMSE %	66.2	51.1	57.2	89.2	53.8	63.5
R^2	0.0003	0.0053	0.0001	0.4397	0.0062	0.0903
Spearman Coeff.	0.0271	-0.0204	-0.0301	0.6393	0.0141	0.126
PBias	53.7	47.8	44.6	186.9	17.2	70.04
Nash	-3.0378	-2.9999	-1.8813	-6.0787	-1.8945	-3.1784
Index of Agreement	0.3542	0.2784	0.4056	0.5198	0.458	0.4032
Kling-Gupta Effic. Modified	-0.1519	-0.1773	-0.1122	-0.928	0.0359	-0.2667
Kling-Gupta Pear. Coeff.	-0.0167	-0.073	-0.0122	0.6631	0.0789	0.128
Kling-Gupta Beta (Ratio Means)	1.5367	1.4779	1.4461	2.8694	1.1722	1.7005
Kling-Gupta Gamma (Ratio CV)	1.0704	1.0797	0.8844	0.6698	1.2268	0.9862

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box

represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix C.

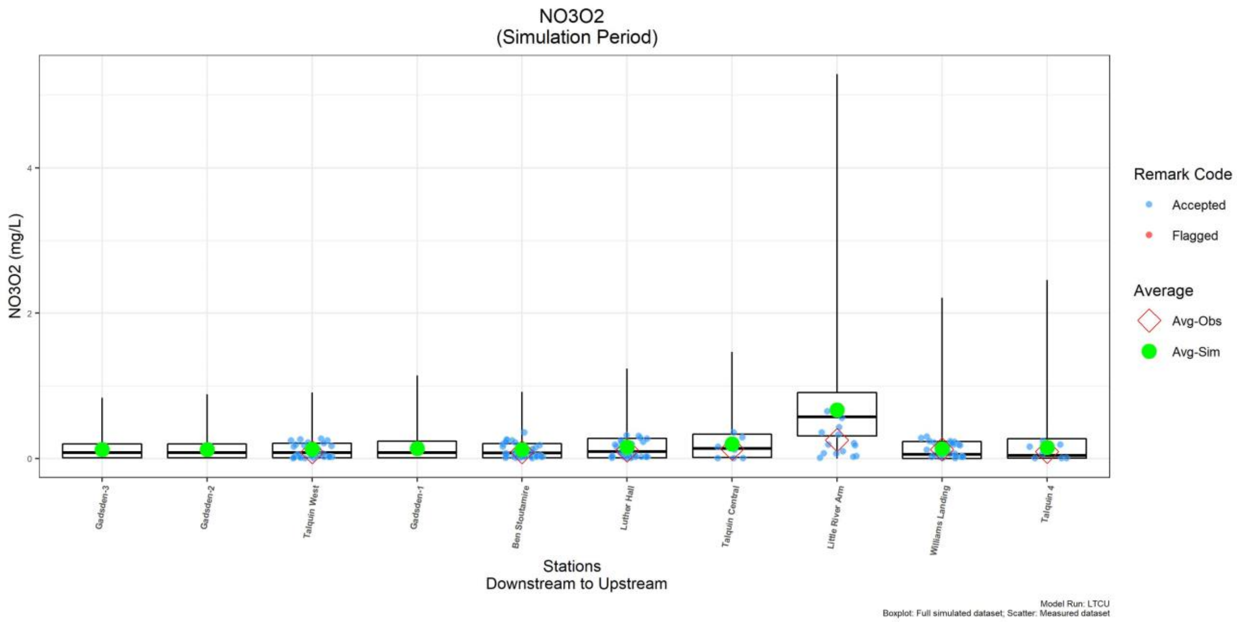

Figure 63 Nitrate Box Plot for Lake Talquin Stations

Total Phosphorus

Table 46 and Figure 64 provide a comparison of total phosphorus simulated by the watershed/water quality model and the measured values at 8 water quality monitoring stations.

Table 46 Quantitative Statistical Analysis for Total Phosphorus – Lake Talquin Stations

Metric	Gadsden-3	Gadsden-2	Talquin West	Gadsden-1	Ben Stoutamire	Luther Hall	Little River Arm	Williams Landing	Average
Number Obs-Total	103	105	35	105	38	28	15	28	57.125
Number Obs-Accepted	103	105	35	105	37	28	15	27	56.875
Observed Mean	0.065	0.061	0.058	0.059	0.057	0.067	0.088	0.072	0.0659
Observed Variance	0	0	0	0	0	0	0.001	0.001	0.0002
Simulation Mean	0.077	0.079	0.083	0.083	0.081	0.083	0.082	0.112	0.085
Simulation Variance	0	0	0.001	0	0.001	0	0	0.001	0.0004
Mean Error	0.0119	0.0172	0.0247	0.0235	0.0232	0.0161	-0.0057	0.0399	0.0188
Mean Absolute Error	0.0164	0.0204	0.0279	0.026	0.0272	0.0203	0.021	0.0399	0.0249
RMSE	0.0213	0.0266	0.0383	0.0325	0.037	0.0244	0.0257	0.0529	0.0323
NRMSE %	30.8	39.2	46.7	41.2	37.4	26.3	39.5	67.8	41.1125
R^2	0.2156	0.1232	0.0332	0.0718	0.0145	0.2724	0.012	0.0201	0.0954
Spearman Coeff.	0.4922	0.4149	0.3144	0.314	0.2711	0.5766	-0.1005	0.0886	0.2964
PBias	18.3	28	42.4	39.7	40.5	24.1	-6.5	55.7	30.275
Nash	-0.6359	-1.6205	-2.6528	-3.0574	-2.3111	-0.4673	-0.2481	-3.8261	-1.8524
Index of Agreement	0.6235	0.5226	0.4114	0.4413	0.4027	0.6231	0.467	0.4468	0.4923
Kling-Gupta Effic. Modified	0.423	0.287	0.072	0.1622	0.0121	0.3767	0.019	-0.0499	0.1628
Kling-Gupta Pear. Coeff.	0.4644	0.351	0.1822	0.268	0.1204	0.5219	0.1094	0.1418	0.2699
Kling-Gupta Beta (Ratio Means)	1.1826	1.2796	1.4238	1.3973	1.4051	1.2412	0.9353	1.557	1.3027
Kling-Gupta Gamma (Ratio CV)	0.8877	0.9053	0.8864	0.9091	0.8047	0.6811	0.5938	0.7644	0.8041

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box

represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix C.

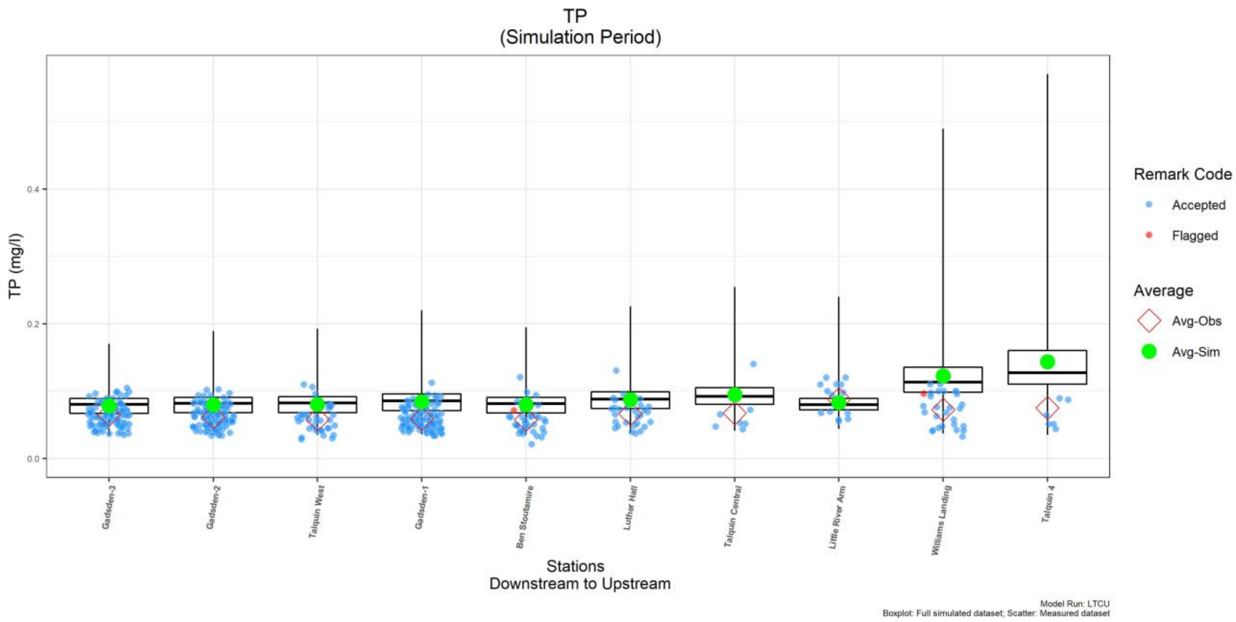

Figure 64 Total Phosphorus Box Plot for Lake Talquin Stations

Chlorophyll a

Table 47 and Figure 65 provide a comparison of chlorophyll a simulated by the watershed/water quality model and the measured values at 8 water quality monitoring stations.

Table 47 Quantitative Statistical Analysis for Chlorophyll a – Lake Talquin Stations

Metric	Gadsden-3	Gadsden-2	Talquin West	Gadsden-1	Ben Stoutamire	Luther Hall	Little River Arm	Williams Landing	Average
Number Obs-Total	61	60	35	59	38	28	14	27	40.25
Number Obs-Accepted	61	60	35	59	35	27	14	27	39.75
Observed Mean	22.23	22.483	25.601	24.39	24.586	26.781	29.4	19.324	24.3494
Observed Variance	186.313	196.695	523.791	201.863	306.442	439.331	479.855	217.138	318.9285
Simulation Mean	21.341	22.546	25.955	22.969	25.443	27.014	21.217	31.583	24.7585
Simulation Variance	46.533	34.825	96.825	39.524	103.254	54.526	152.975	282.096	101.3197
Mean Error	-0.8881	0.0627	0.3534	-1.4209	0.857	0.233	-8.1826	12.2596	0.4093
Mean Absolute Error	12.7801	11.403	18.7553	12.0116	16.5685	16.7721	16.9437	17.1551	15.2987
RMSE	15.6303	14.8461	25.6536	13.9973	20.5612	20.322	20.1766	21.0641	19.0314
NRMSE %	30.6	20.1	22.5	25.4	35.2	29.1	23.9	41.5	28.5375
R^2	0.0063	0.002	0.0159	0.061	0.0048	0.0442	0.2419	0.1545	0.0663
Spearman Coeff.	-0.0823	0.0184	-0.1512	0.1475	-0.1065	0.2751	0.4114	0.4666	0.1224
PBias	-4	0.3	1.4	-5.8	3.5	0.9	-27.8	63.4	3.9875
Nash	-0.3331	-0.1395	-0.2934	0.0127	-0.4202	0.0238	0.0864	-1.122	-0.2732
Index of Agreement	0.3293	0.3541	0.1268	0.4698	0.2362	0.3633	0.5911	0.5533	0.378
Kling-Gupta Effic. Modified	-0.1815	-0.1179	-0.2647	0.0773	-0.1567	-0.0234	0.3811	0.0713	-0.0268
Kling-Gupta Pear. Coeff.	-0.0791	0.0446	-0.1259	0.2471	-0.0696	0.2101	0.4919	0.393	0.139
Kling-Gupta Beta (Ratio Means)	0.9601	1.0028	1.0138	0.9417	1.0349	1.0087	0.7217	1.6344	1.0398
Kling-Gupta Gamma (Ratio CV)	0.5206	0.4196	0.4241	0.4699	0.5609	0.3493	0.7824	0.6974	0.528

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix C.

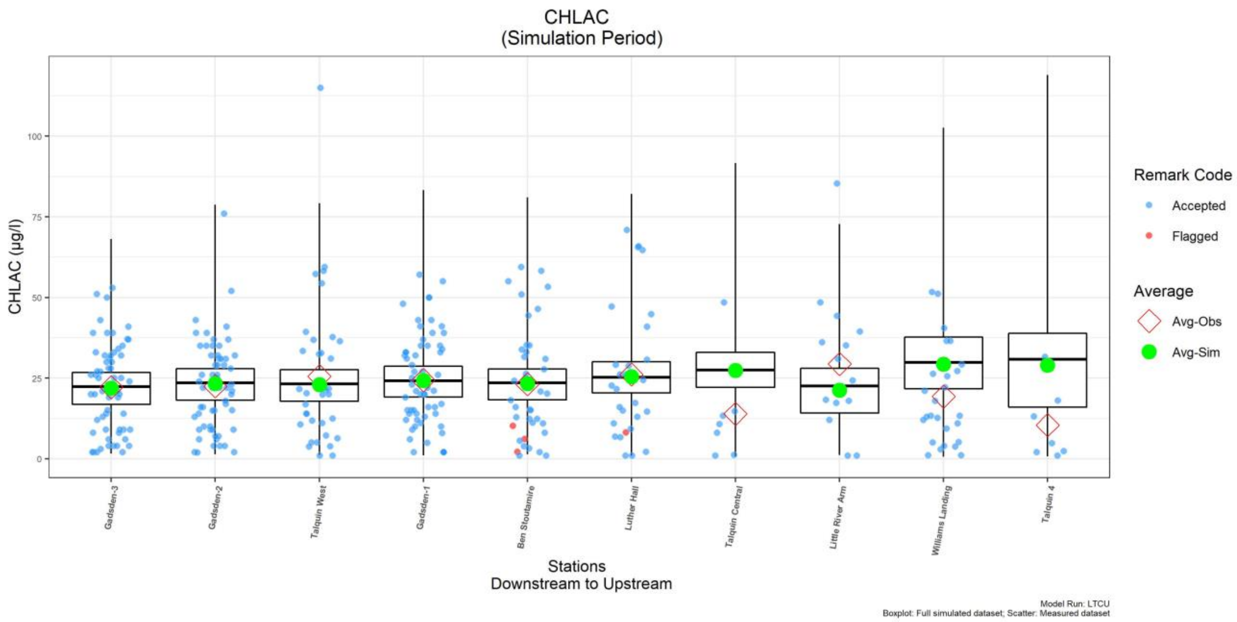

Figure 65 Chlorophyll a Box Plot for Lake Talquin Stations

Carbonaceous Biochemical Oxygen Demand

Table 48 and Figure 66 provide a comparison of total nitrogen simulated by the watershed/water quality model and the measured values at 5 water quality monitoring stations.

Table 48 Quantitative Statistical Analysis for CBOD – Lake Talquin Stations

Metric	Talquin West	Ben Stoutamire	Luther Hall	Little River Arm	Williams Landing	Average
Number Obs-Total	34	39	28	15	28	28.8
Number Obs-Accepted	32	35	23	14	26	26
Observed Mean	2.855	3.2	4.07	3.193	3.585	3.3806
Observed Variance	3.352	6.908	11.455	7.171	8.533	7.4838
Simulation Mean	1.369	1.416	1.46	2.099	2.492	1.7672
Simulation Variance	0.797	1.012	0.634	0.397	1.341	0.8362
Mean Error	-1.4857	-1.784	-2.6091	-1.0935	-1.0929	-1.613
Mean Absolute Error	1.7284	2.126	2.752	1.6447	2.0877	2.0678
RMSE	2.5781	3.3466	4.2265	3.0857	3.2505	3.2975
NRMSE %	25.8	33.5	31.3	30.9	32.5	30.8
R^2	0.0177	0.004	0.0097	0.1714	0.0004	0.0406
Spearman Coeff.	-0.0458	-0.2814	0.002	-0.5609	-0.1487	-0.207
PBias	-52	-55.7	-64.1	-34.2	-30.5	-47.3
Nash	-1.047	-0.6691	-0.6303	-0.4299	-0.2878	-0.6128
Index of Agreement	0.294	0.3233	0.3993	0.2185	0.2939	0.3058
Kling-Gupta Effic. Modified	-0.2468	-0.2079	-0.1587	-0.5903	-0.1136	-0.2635
Kling-Gupta Pear. Coeff.	-0.1329	-0.063	0.0984	-0.414	0.0189	-0.0985
Kling-Gupta Beta (Ratio Means)	0.4796	0.4425	0.3589	0.6575	0.6951	0.5267
Kling-Gupta Gamma (Ratio CV)	1.0165	0.8651	0.6556	0.358	0.5704	0.6931

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix C.

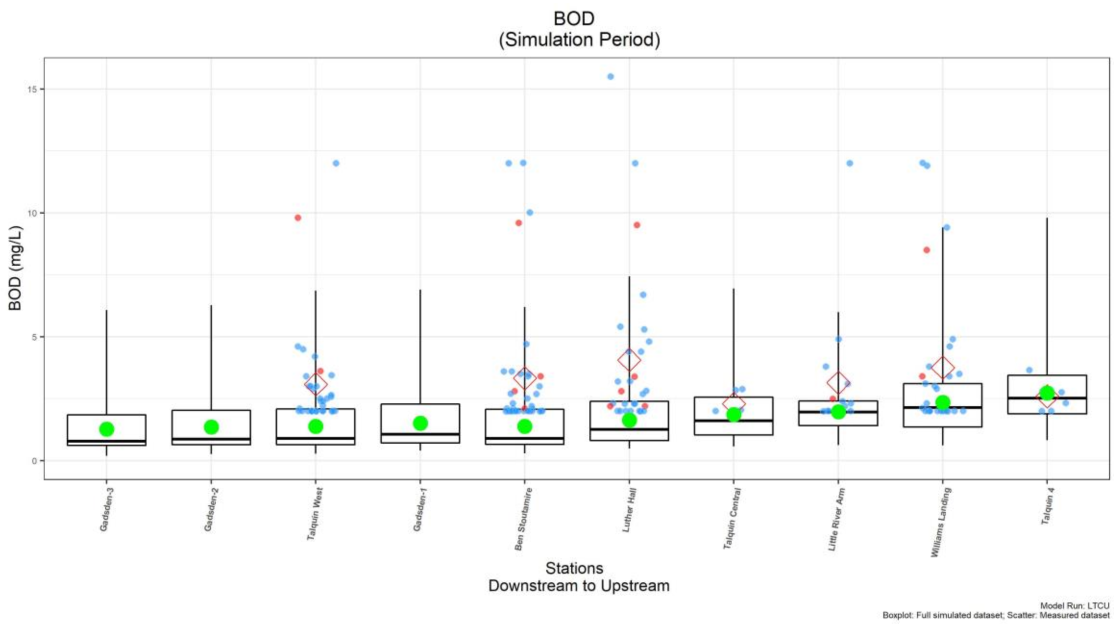

Figure 66 CBOD **Box Plot for Lake Talquin Stations**

Total Suspended Solids

Table 49 and Figure 67 provide a comparison of total suspended solids simulated by the watershed/water quality model and the measured values at 5 water quality monitoring stations.

Table 49 Quantitative Statistical Analysis for Total Suspended Solids – Lake Talquin Stations

Metric	Talquin West	Ben Stoutamire	Luther Hall	Little River Arm	Williams Landing	Average
Number Obs-Total	35	38	28	15	28	28.8
Number Obs-Accepted	35	38	28	15	28	28.8
Observed Mean	5.734	5.955	6.046	8.073	5.696	6.3008
Observed Variance	1.582	10.954	2.179	3.738	1.724	4.0354
Simulation Mean	8.308	8.268	8.79	8.303	10.265	8.7868
Simulation Variance	7.738	7.65	5.206	13.52	23.297	11.4822
Mean Error	2.5735	2.3127	2.7436	0.2293	4.5687	2.4856
Mean Absolute Error	2.9401	3.6809	3.315	2.9991	5.6887	3.7248
RMSE	3.6739	5.4503	3.8762	3.4097	7.0571	4.6934
NRMSE %	56.5	26	55.4	45.5	128.3	62.34
R^2	0.1028	0.1226	0.0034	0.1167	0.1543	0.1
Spearman Coeff.	0.2019	0.0354	0.1512	0.2664	-0.2987	0.0712
PBias	44.9	38.8	45.4	2.8	80.2	42.42
Nash	-7.7811	-1.7852	-6.151	-2.3325	-28.9563	-9.4012
Index of Agreement	0.3859	0.1065	0.2344	0.5261	0.0701	0.2646
Kling-Gupta Effic. Modified	0.0304	-0.4602	-0.1529	-0.075	-0.9143	-0.3144
Kling-Gupta Pear. Coeff.	0.3206	-0.3502	-0.058	0.3417	-0.3928	-0.0277
Kling-Gupta Beta (Ratio Means)	1.4488	1.3883	1.4538	1.0284	1.802	1.4243
Kling-Gupta Gamma (Ratio CV)	1.5264	0.6019	1.0632	1.8493	2.0399	1.4161

The boxplot below provides a comparison of the model performance compared to measured data throughout the simulation period. The green dot represents the simulated average over modeled period, the red diamond represents the measured data's average of modeled period. The blue box represents the 75th and 25th percentiles of simulated results, with the blue whiskers displaying the range of model predictions. The black dots represent the individual measurements. For detailed calibration plots see Appendix C.

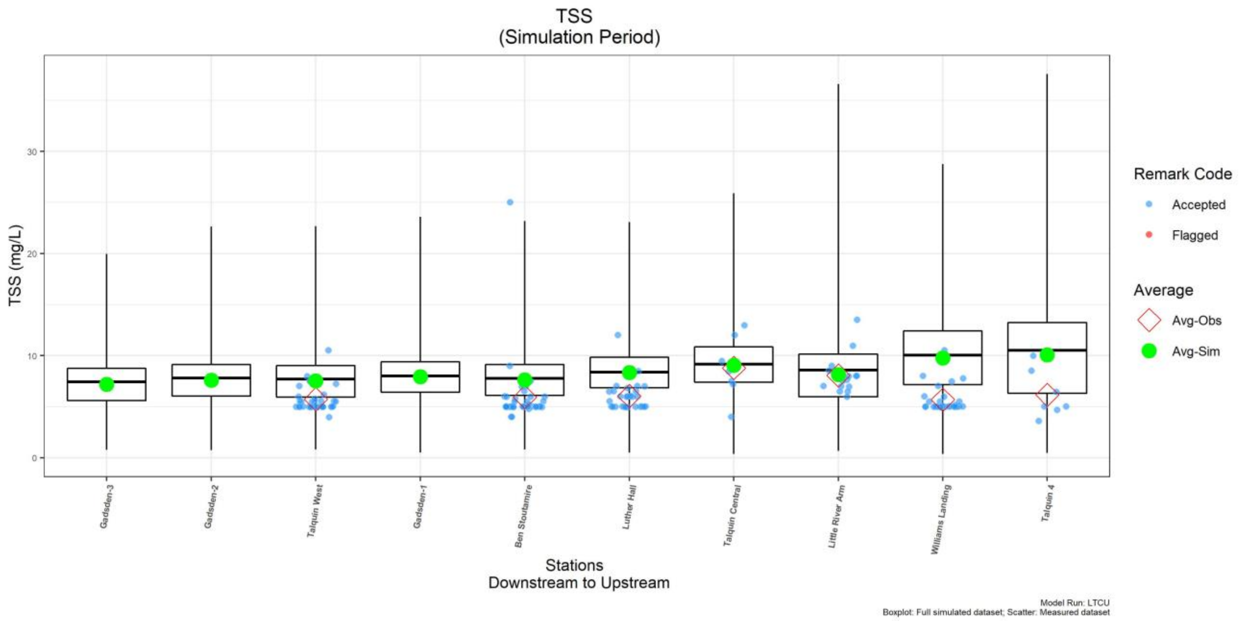

Figure 67 Total Suspended Solids Box Plot for Lake Talquin Station

Lake Talquin Assessment Zones

For assessment and TMDL purpose Lake Talquin was divided into three assessment zones. These zones represent the open water areas of Lake Talquin. The three zones are depicted in Figure 68 and consist of an upper, middle, and lower zone. The areas of Lake Talquin that are shaded in grey are not considered in any zone because they do not represent open lake areas.

For each of the zones an annual geometric mean is calculated for chlorophyll a, total nitrogen and total phosphorus. The target for the TMDL will be to manage nutrient loadings to Lake Talquin to achieve an annual geometric mean of chlorophyll a no greater than 20 µg/L.

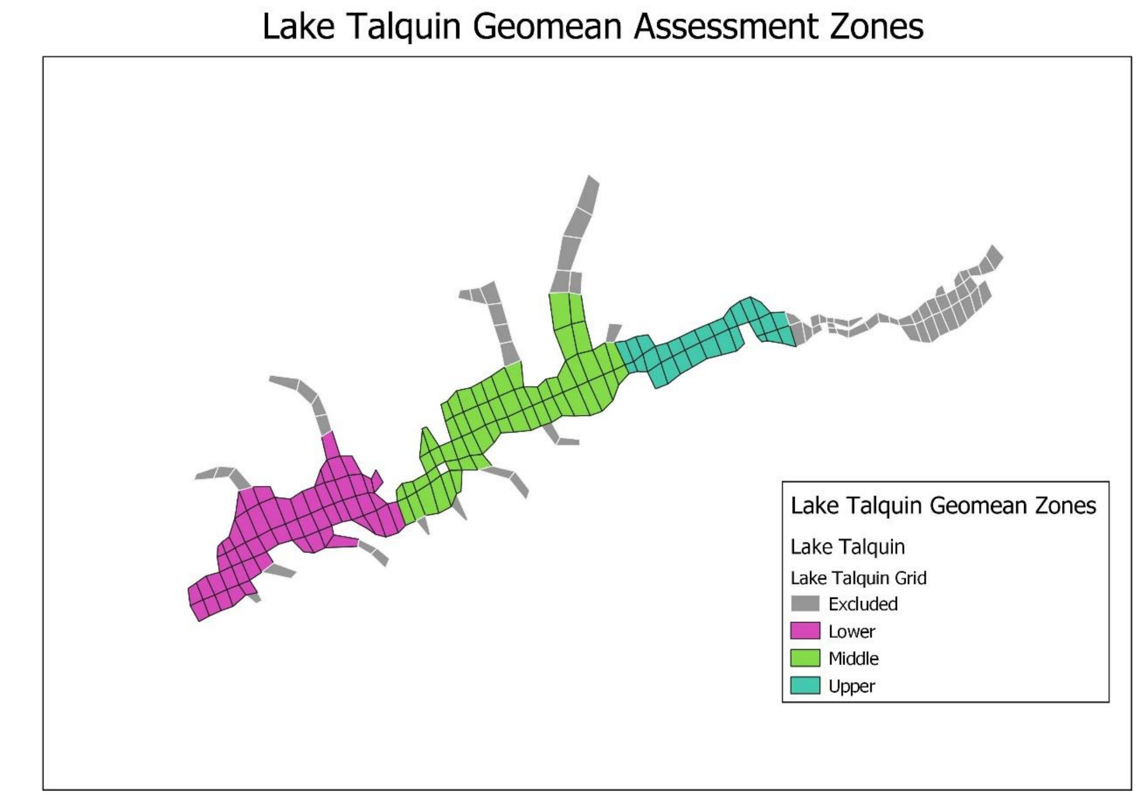

Figure 68 Lake Talquin Three Assessment Zones

Table 50 provides the calculated geometric means for chlorophyll a, total nitrogen and total phosphorus for the current condition calibrated model.

Table 50 Assessment Zone Chlorophyll a, Total Nitrogen and Total Phosphours Annual Geometric Means

	Lower			Middle			Upper		
Year	TN	TP	CHLA	TN	TP	CHLA	TN	TP	CHLA
2008	0.84	0.09	25.22	0.97	0.11	26.07	1.00	0.16	20.60
2009	0.82	0.09	24.04	0.97	0.10	27.37	0.96	0.15	24.48
2010	0.75	0.08	20.24	0.89	0.09	20.12	0.99	0.15	18.32
2011	0.78	0.07	20.45	0.98	0.08	22.99	0.98	0.12	25.82
2012	0.79	0.06	17.19	0.96	0.07	22.46	0.94	0.11	30.30
2013	0.83	0.08	21.67	1.04	0.10	25.79	0.90	0.13	21.17
2014	0.93	0.08	22.11	1.05	0.09	19.94	0.84	0.12	14.43
2015	0.88	0.07	21.92	1.08	0.08	22.26	0.96	0.12	19.91
2016	0.85	0.07	21.26	1.00	0.09	23.72	0.88	0.12	18.70
2017	0.89	0.08	22.23	0.96	0.09	26.13	0.83	0.12	23.15

Load Reduction Scenario

A load reduction scenario was developed that was used to form the basis of the TMDL document. This load reduction scenario was developed by applying scale factors to the 11 discharge points to Lake Talquin (Figure 66). This was an iterative process reducing the loadings until the TMDL target was met in a three assessment zones.

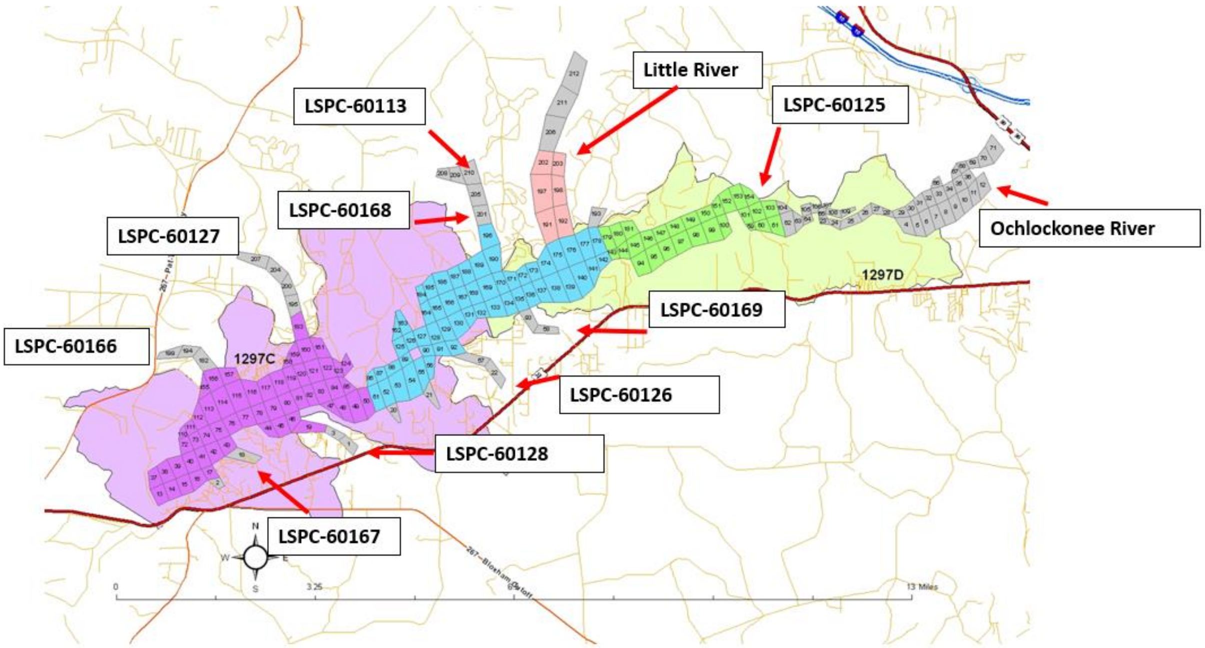

Figure 69 Pore Points to Lake Talquin where load reductions were applied

A summary of the changes in annual loadings for the Ochlockonee River, Little River, and direct discharge to the lake. Figure 70 - Figure 71 compare the annual total nitrogen and total phosphorus between the current and load reduction scenario.

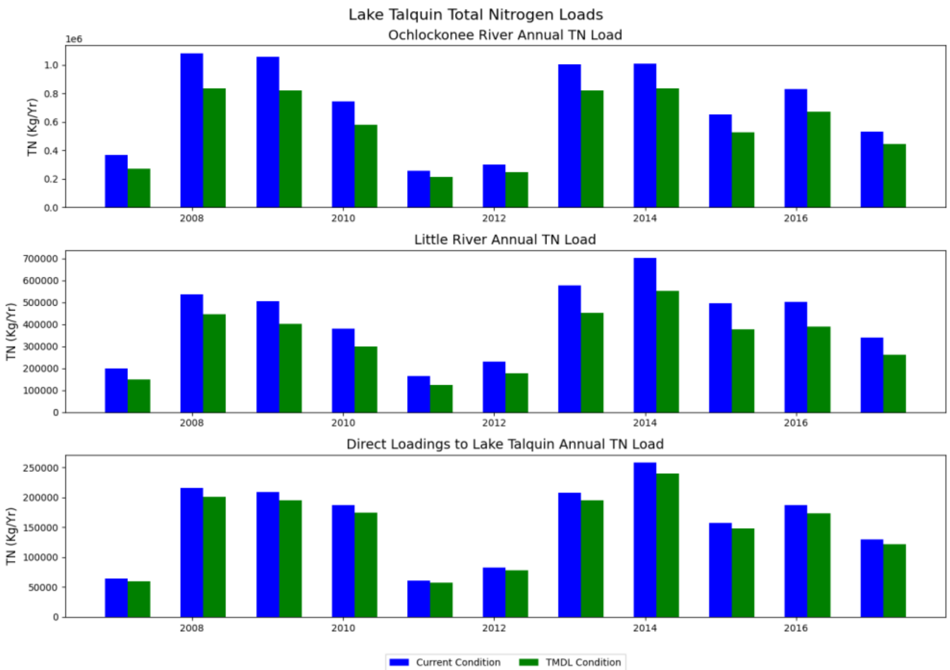

Figure 70 Total Nitrogen Annual Load Comparison between Current and Reduction Scenario

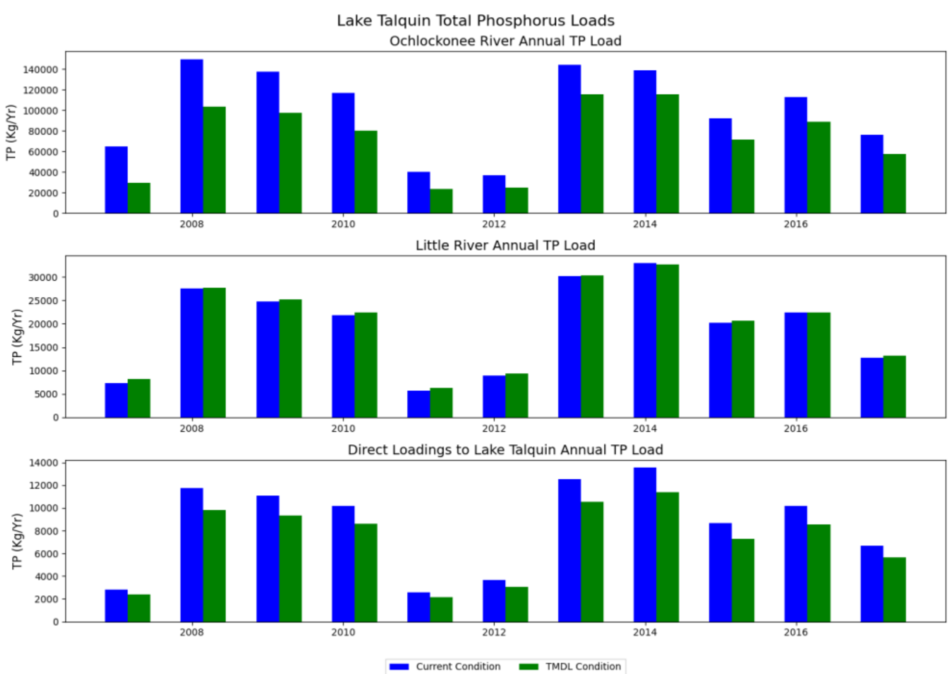

Figure 71 Total Phosphorus Annual Load Comparison between Current and Reduction Scenario

Figure 72 - Figure 73 compares the timeseries of concentrations of total nitrogen and total phosphorus between the current and load reduction scenario.

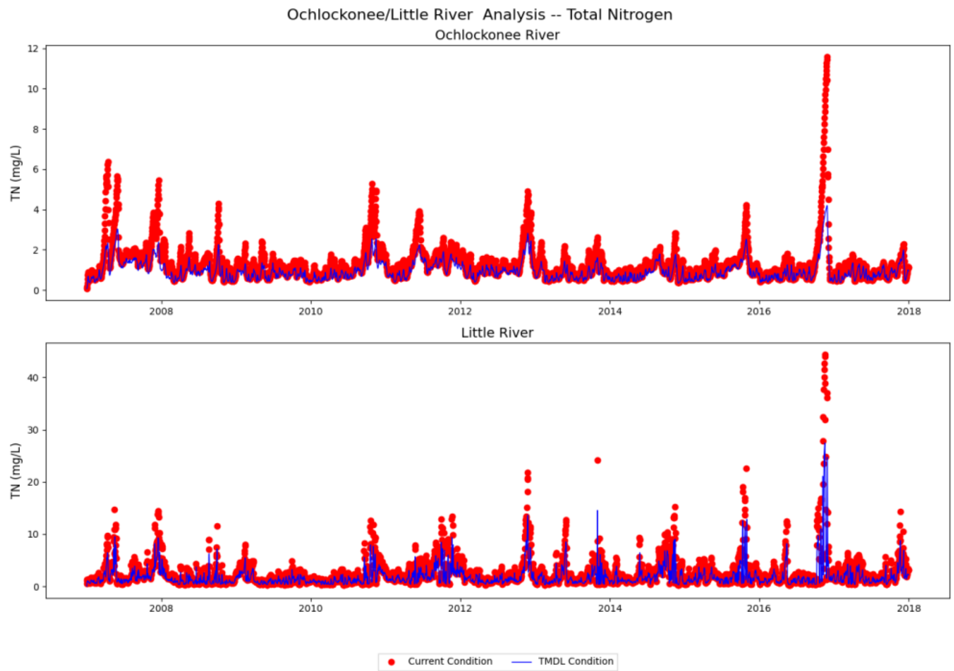

Figure 72 Total Nitrogen Concentration Comparison between Current and Reduction Scenario

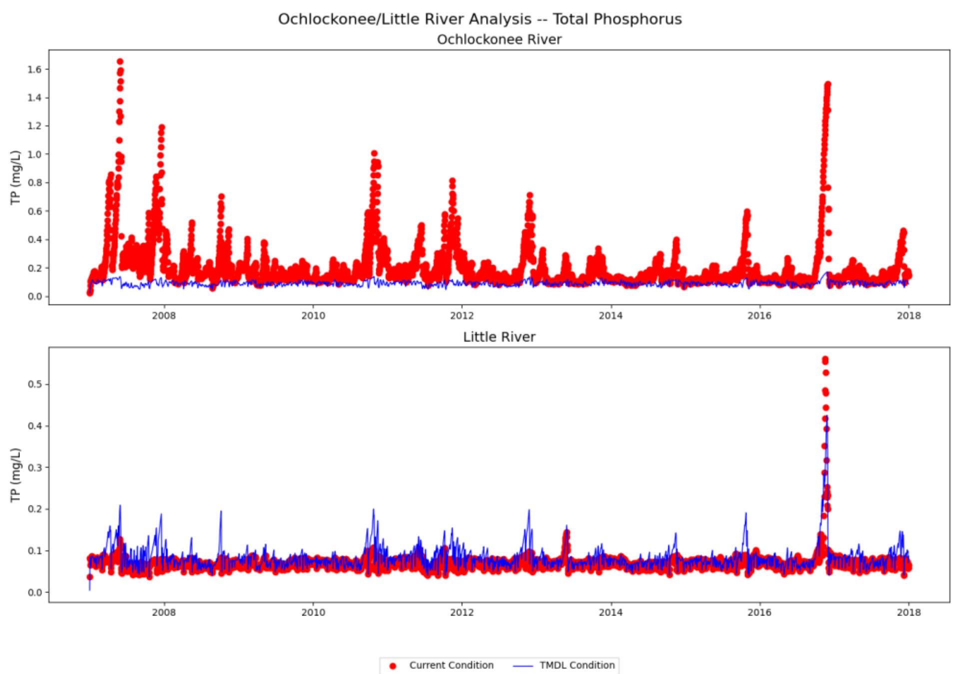

Figure 73 Total Phosphorus Concentration Comparison between Current and Reduction Scenario

The predicted annual geometric means under the reduction scenario for chlorophyll a, total nitrogen, and total phosphorus for the three assessment zones are compared to the current condition. The highest annual geometric mean for chlorophyll a under the reduction scenario is in the middle zone of 19.97 ug/l.

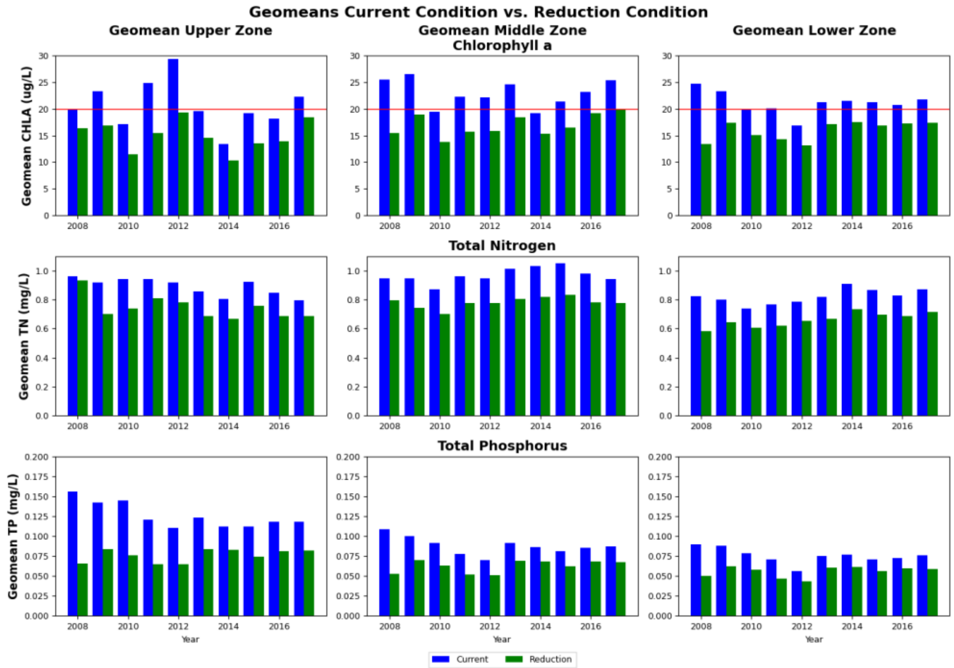

Figure 74 Geomean Comparison between Current and Reduction Scenario

Downstream Impact

An analysis was conducted to determine the impacts of the load reduction scenario on downstream conditions. Figure 75 shows a time series comparison of total nitrogen, total phosphorus, and dissolved oxygen at the current and reduction scenario.

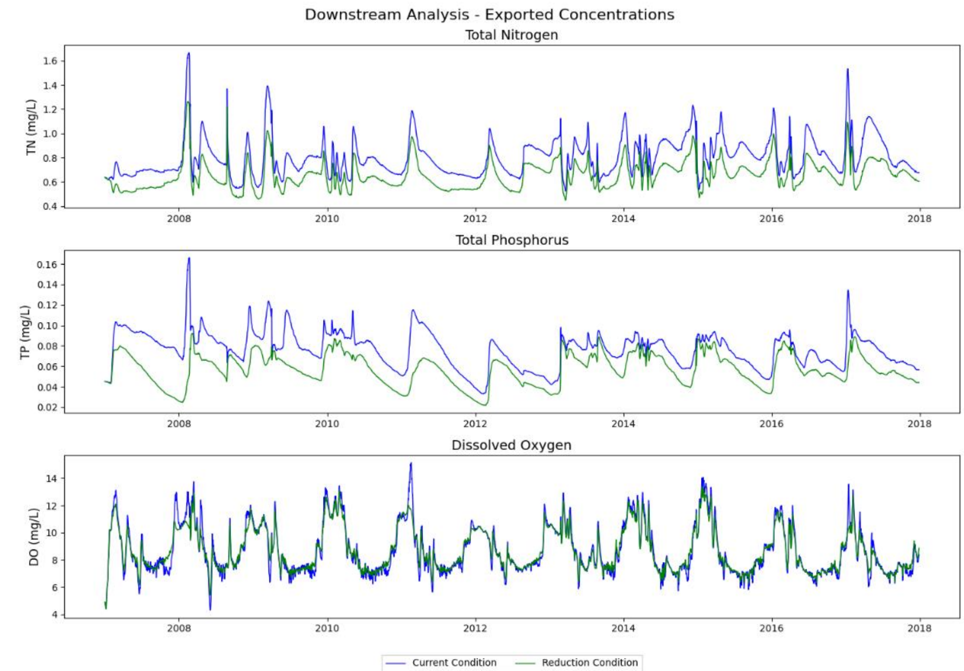

Figure 75 Comparison of change in Total Nitrogen, Total Phosphorus, and Dissolved Oxygen concentrations exported from Lake Talquin

Figure 76 shows the difference in total nitrogen, total phosphorus, and dissolved oxygen loadings to the downstream Ochlockonee River.

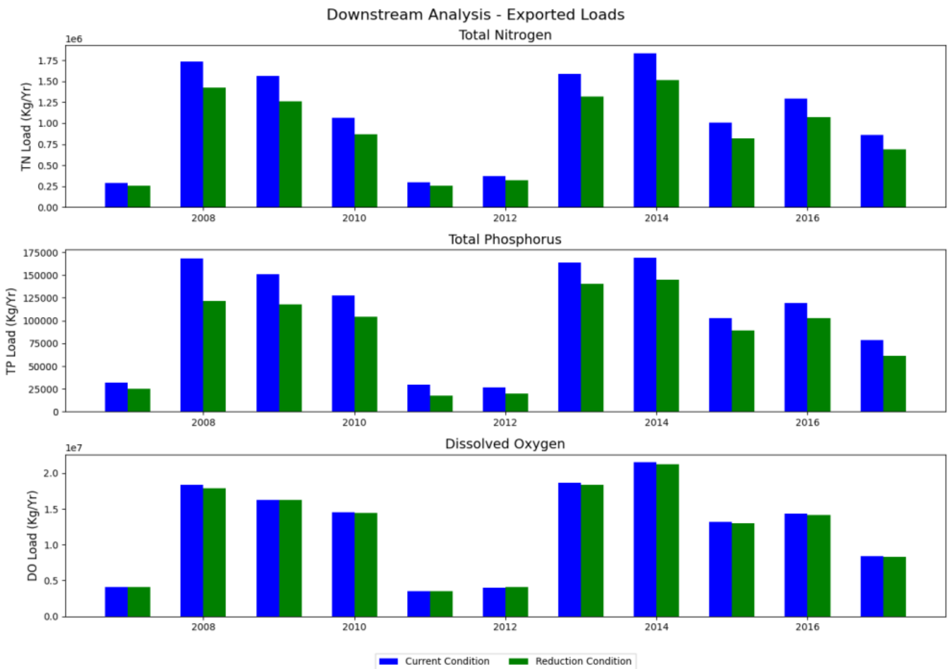

Figure 76 Comparison of change in Total Nitrogen, Total Phosphorus, and Dissolved Oxygen loads exported from Lake Talquin

Figure 77 depicts the difference in outflow from the Lake Talquin under the current gate management.

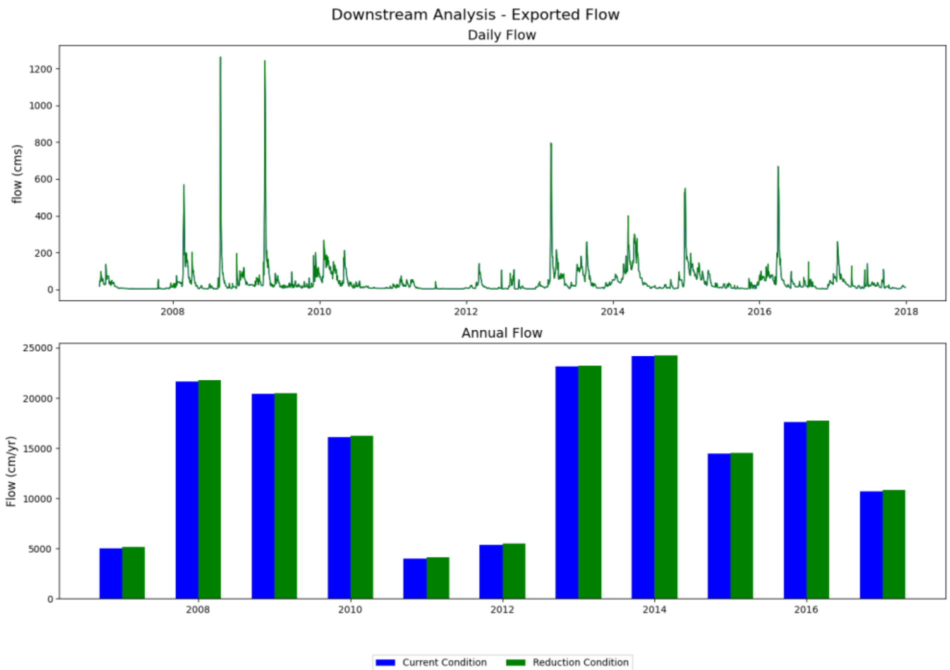

Figure 77 Comparison of Outflow from Lake Talquin dam between current and reduction scenario

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