5.3.5.3 Water Temperature Validation

The **Figures 29-32** show the model-data comparisons for temperatures in the Caloosahatchee model for the validation year of 2004. **Table 8** contains a summary of the RMS (see Section 5.3.2 for a definition) error statistics for temperature. Overall, the model-data comparisons were considered good, though not as good as for the calibration period.

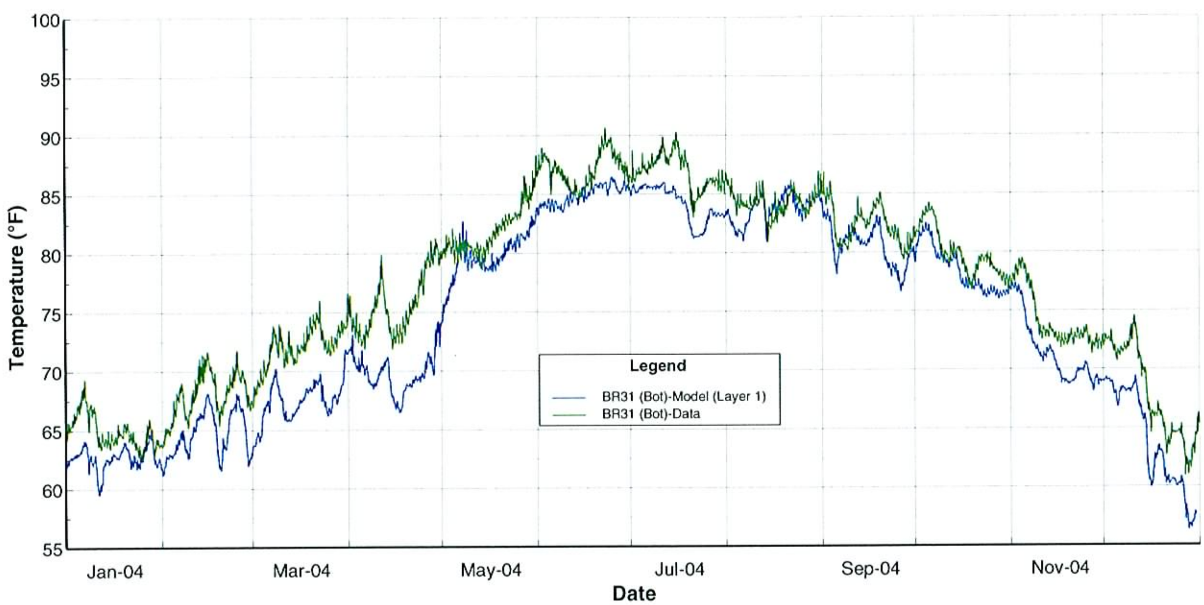

Figure 29 Temperature validation at BR31 – Bottom.

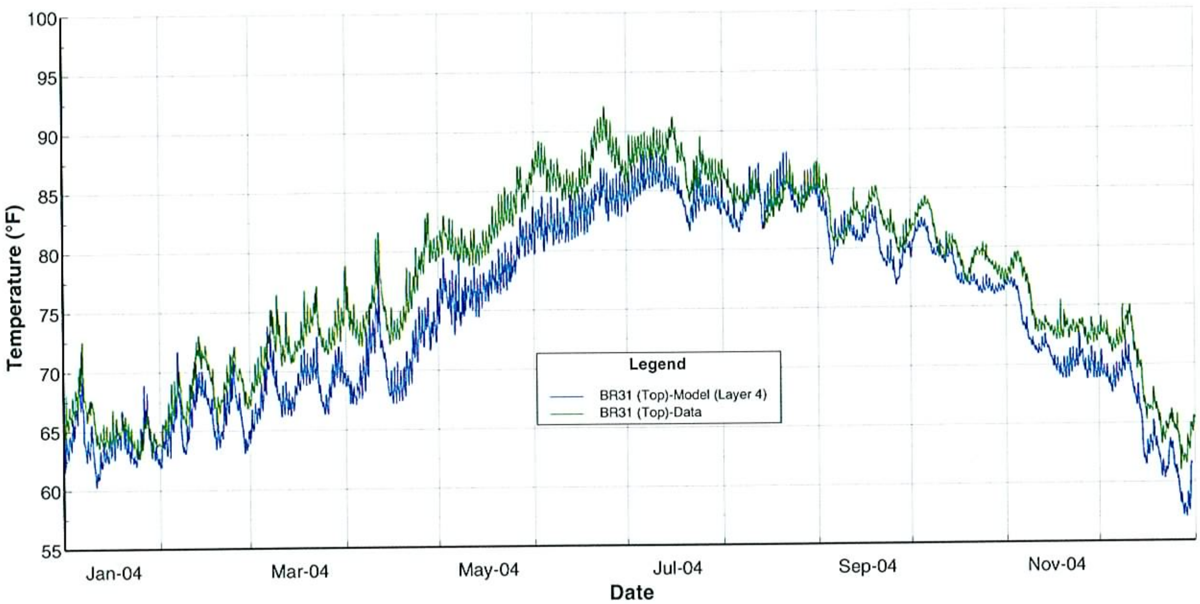

Figure 30 Temperature validation at BR31 – Top.

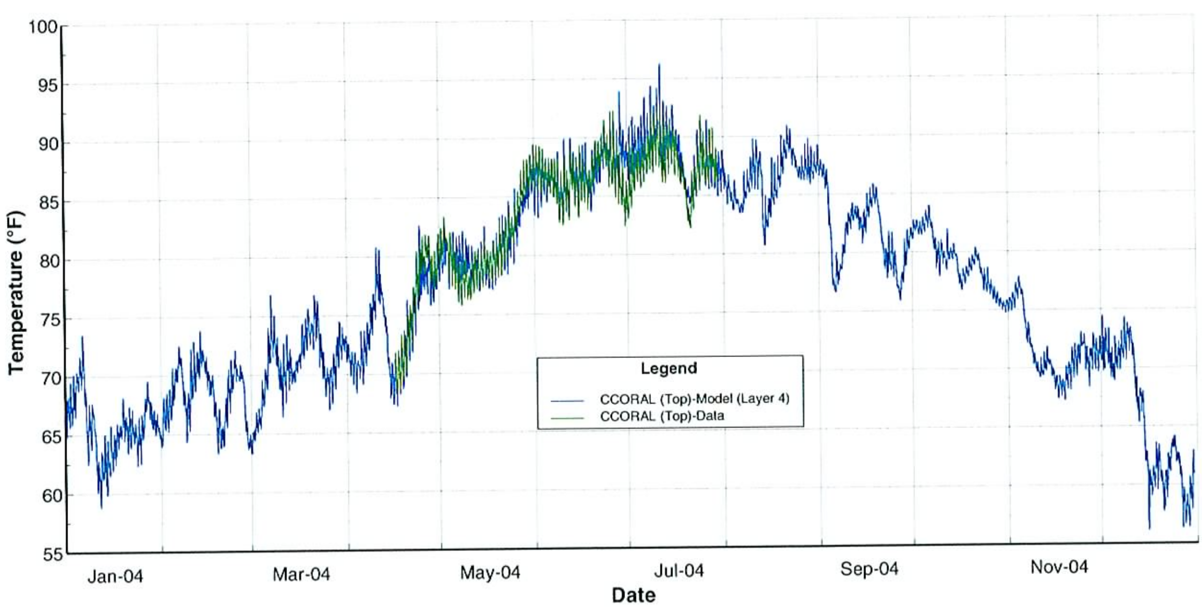

Figure 31 Temperature validation at CCORAL – Top.

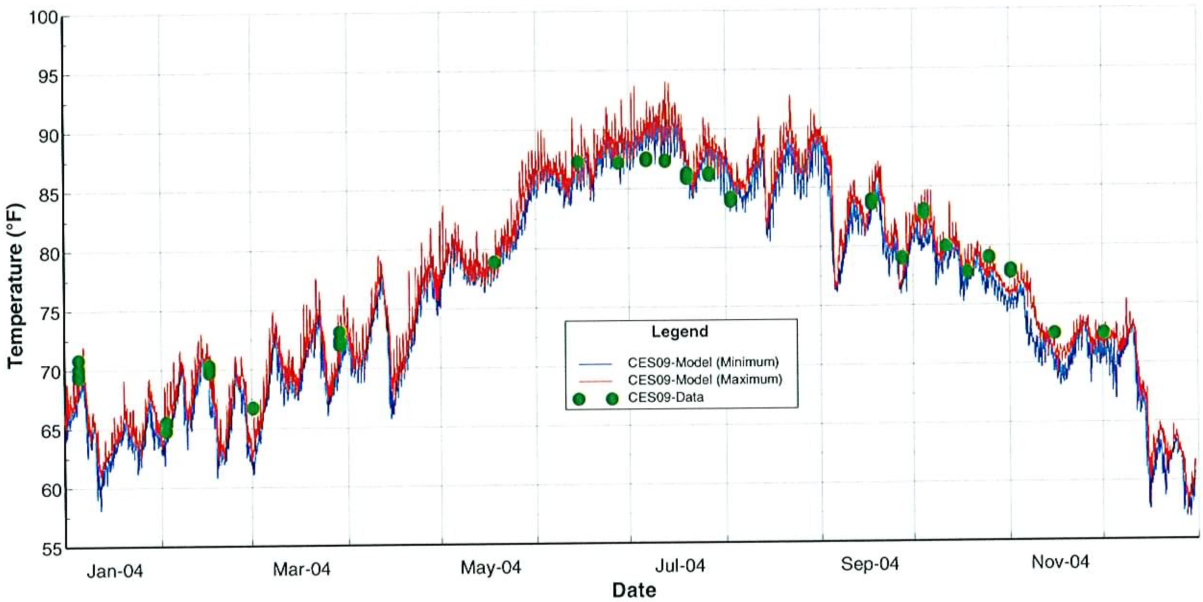

Figure 32 Temperature validation at CES09.

Table 8 Validation period summary statistics for Temperature (°F).

Station ID	Layer/ Type	Starting Date/Time	Ending Date/Time	# Pairs	RMS	Data Average	Model Average
CES09	Minimum	5-Jan-04 11:02	1-Dec-04 09:28	22	1.833	78.702	77.537
CES09	Maximum	5-Jan-04 11:02	1-Dec-04 09:28	22	1.497	79.019	78.479
BR31 (Bot)	Layer 1	1-Jan-04 00:00	30-Dec-04 21:00	8692	3.37	77.133	74.311
BR31 (Top)	Layer 4	1-Jan-04 00:00	30-Dec-04 21:00	8691	3.302	77.494	74.705
CCORAL (Top)	Layer 4	16-Apr-04 13:00	30-Jul-04 01:00	2506	1.452	83.843	84.132
Composite				**19933**	**3.095**		

5.4 WASP Model

5.4.1 Model Development of WASP Model and EFDC/WASP linkage

This section summarizes the preliminary development of the WASP model for application to the Caloosahatchee River tidal estuary. The hydrodynamic element of the Environmental Fluids Dynamics Code (EFDC) model of the Caloosahatchee River tidal estuary was used to "drive" the WASP model by providing volume, flow, velocity, salinity and water temperature data to simulate water quality conditions in the tidal Caloosahatchee River. EFDC is an advanced three-dimensional hydrodynamic model (Hamrick, 1992; 1996) that has often been applied for linkage with the WASP water quality model.

The WASP model includes separate sub-models to simulate surface water transport and fate of (a) water quality (nutrients, algae and dissolved oxygen); (b) toxic chemicals and solids; and (c) mercury. Since WASP does not include an internal three-dimensional sub-model to simulate hydrodynamics, segment geometry, transport and mixing is either (a) specified by the modeler as input data or is (b) provided by external linkage to a hydrodynamic model such as EFDC (USEPA, 2006).

Hydrodynamic linkage from the EFDC model was developed using EFDC_Explorer to generate the hydrodynamics files required for input to run WASP (Version 7.2). EFDC_Explorer is a Windows-based graphic user interface for pre- and post processing of the EFDC model (Craig, 2004). The data generated by the EFDC to WASP linkage automatically defines the spatial and vertical location of each WASP segment by mapping the EFDC grid cells to the WASP segments. In order to develop the input data for the WASP model, it is essential for the modeler to know the spatial location and depth information of each WASP segment that corresponds to the matching EFDC grid cell. The time series modeling results for flow, volume, velocity, salinity and temperature are passed from EFDC to WASP with the hydrodynamic linkage file generated by EFDC. Utilizing this linkage procedure greatly improves the water quality simulation results since it eliminates any potential error from the manual input of numerous temperature and salinity time series generated by EFDC. Computation time for the WASP model is also saved by linkage of the EFDC generated salinity and temperature results since WASP doesn't need to simulate salinity processes. An ArcGIS based post-processing file was also generated during this process to assist in visualizing the spatial distributions of the model results.

5.4.1.1 Model Parameters

Flow volume, velocity, temperature and salinity simulated by the EFDC hydrodynamic model are passed to, and utilized by, the WASP model to provide segment geometry, transport and temperature and salinity data. The water quality sub-model of WASP includes the following state variables:

- Ammonia;
- Nitrate
- Organic Nitrogen
- Organic Phosphate
- Orthophosphate
- Phytoplankton Chl a
- Dissolved Oxygen;
- CBOD1; CBOD2 and CBOD3
- Detrital Carbon;
- Detrital Nitrogen, and;
- Detrital Phosphorous.

In the application of the WASP model to the tidal Caloosahatchee River, the state variables for CBOD2 and CBOD3 are not used (i.e., "bypassed") in the WASP simulation. The WASP state variable for CBOD1 is defined by boundary condition data describing CBOD provided by either wastewater facilities or results generated by the HSPF watershed model.

5.4.1.2 Model Boundary Locations

The domain of the WASP model is shown in Figure 20. The USGS Station S79 and SFWMD Station CES01 monitoring stations are within the upstream river boundary cell at the Franklin Lock & Dam. The upstream boundary conditions for the water quality variables of the WASP model are assigned using time series from these two stations. The yellow grid cells bounded with a red outline identify the open water boundary cells for the south, west and north boundaries where tide stage, temperature and salinity represent that of the Gulf of Mexico (south); Pine Island Sound (west) and Matalacha Pass (north).

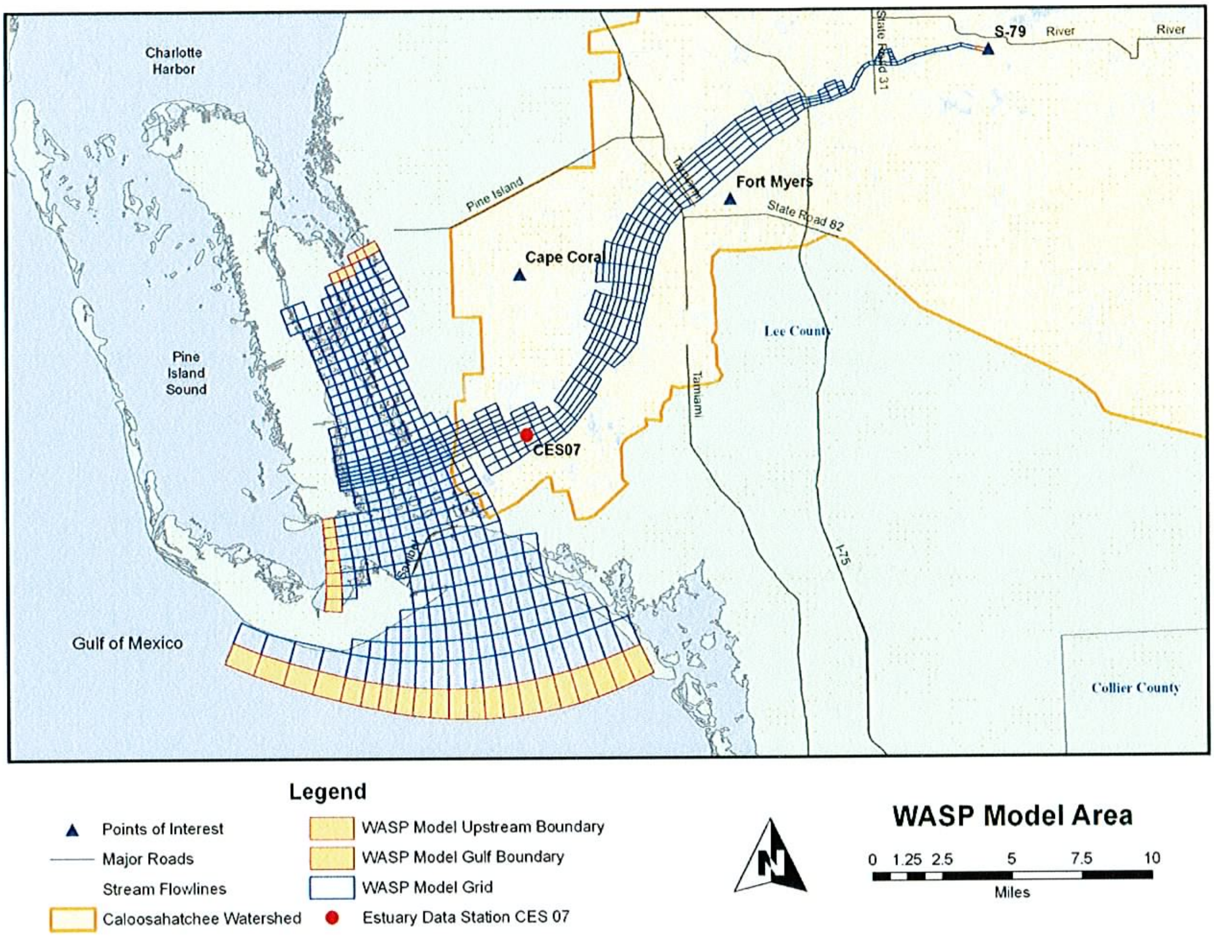

Figure 16 Caloosahatchee River Estuary WASP Modeling boundary location

5.4.1.2.1 Flow, temperature and salinity Boundary Conditions

The EFDC model results were linked to the WASP model for the following model parameters for all the WASP segments: flow, volume, velocity, dispersive mixing, temperature, and salinity.

The EFDC model generates hydrodynamic linkage files that provide temperature, salinity, segment volume and flow information for the boundary segments and all the interior segments of the WASP model. Thus, the WASP model does not need additional input data to describe volume, flow, temperature and salinity for the boundary conditions and the initial conditions of the interior segments.

The EFDC model supplied flow data as boundary conditions to the Caloosahatchee River tidal estuary WASP model for the (a) upstream boundary location at the S79 Franklin Lock & Dam and (b) open water boundaries to the south, west, and north for the Gulf of Mexico, Pine Island

Sound and Matalacha Pass. These flows have been linked to the WASP model for use as boundary conditions for the incoming freshwater Caloosahatchee River and the Gulf of Mexico open water boundary. The use of simulated flows, salinity and temperature are necessary to provide complete temporal and spatial coverage for all of the incoming flows for the simulation periods of interest.

As an example of the EFDC volume information provided as linked input to the WASP model, the Caloosahatchee River upstream location (S79) surface layer volume and temperature for the calibration period of January 2003 to December 2003 is shown in Figures 21 and 22.

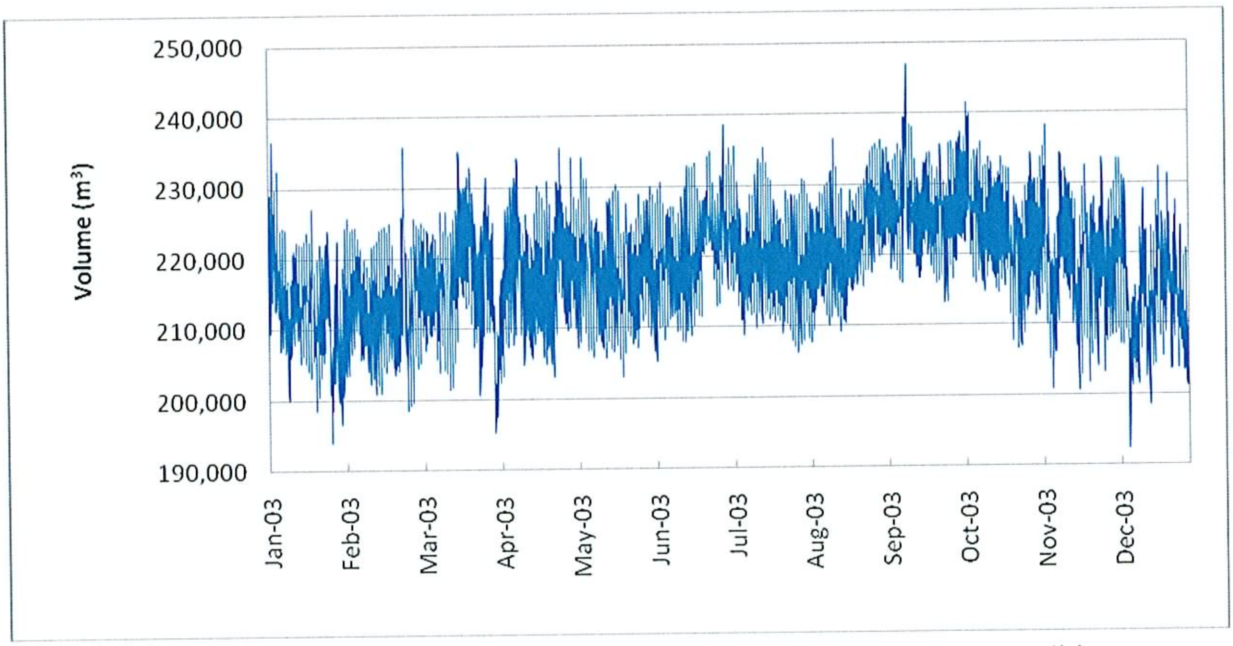

Figure 17 Caloosahatchee River upstream EFDC volume derived boundary conditions

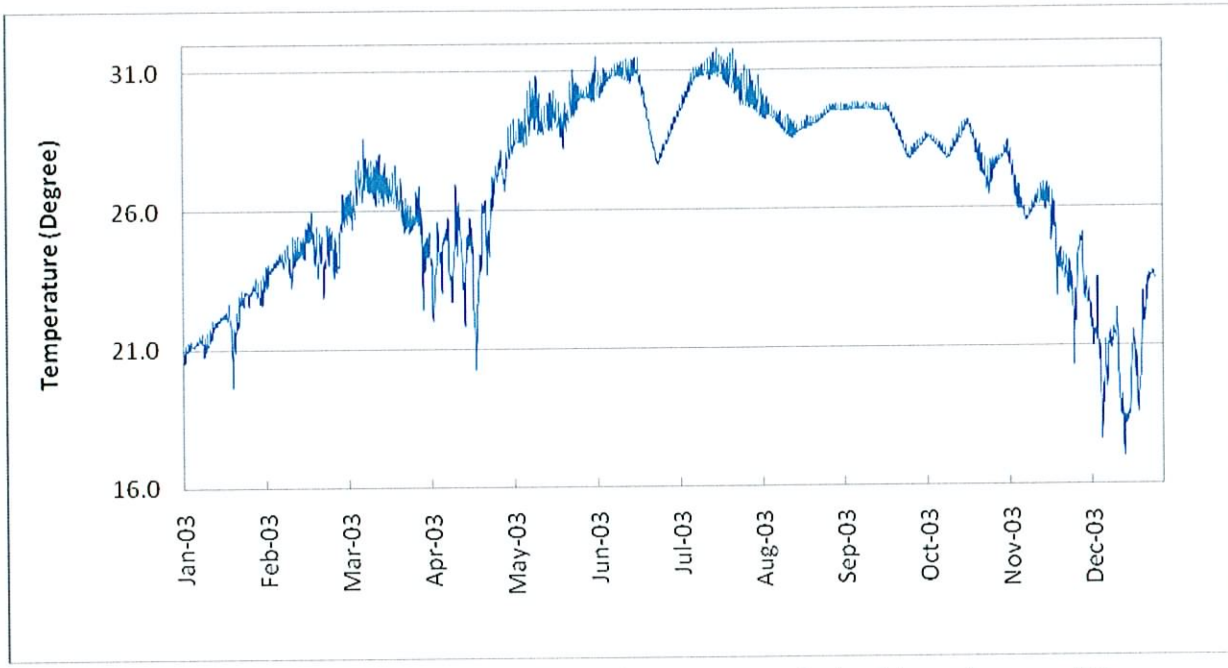

Figure 18 Caloosahatchee River upstream EFDC temperature derived boundary conditions

In addition to the upstream boundary location at S79, the WASP model requires similar boundary conditions for assignment from the EFDC model at the south, west and north open boundaries. Segment volume, temperature, and salinity time series for a surface segment on the South Gulf of Mexico boundary condition are shown in Figures 23, 24, and 25.

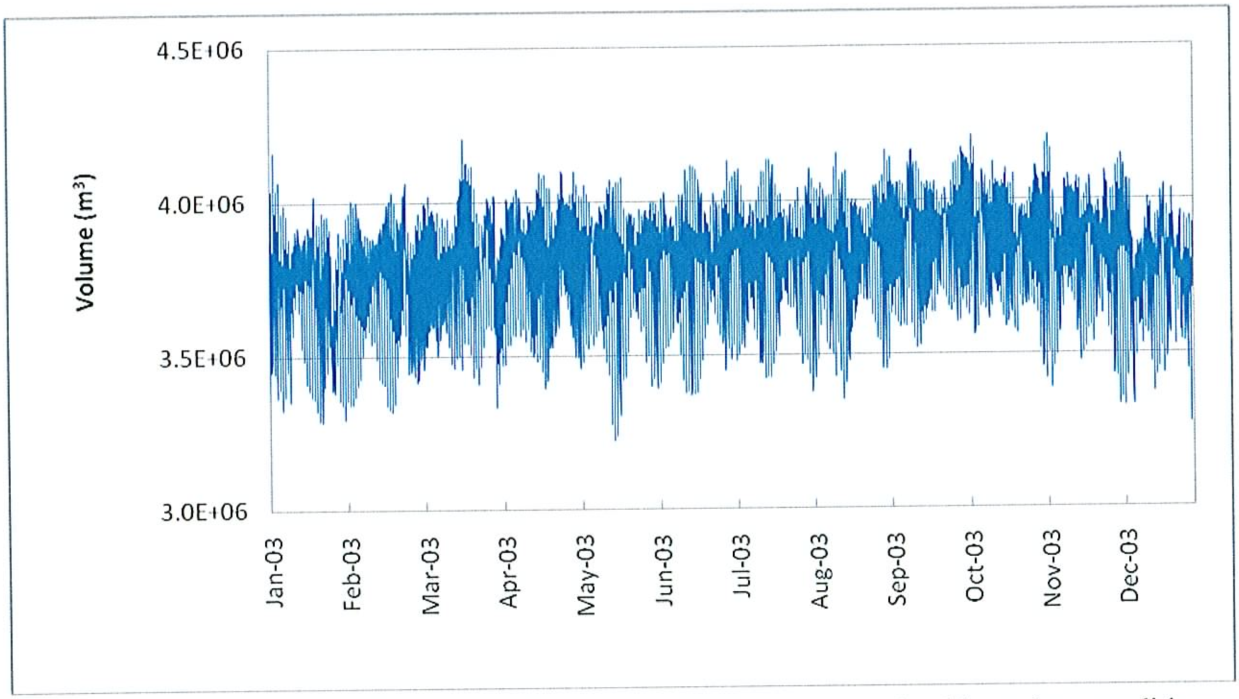

Figure 19 Caloosahatchee River Open Boundary EFDC volume derived boundary conditions

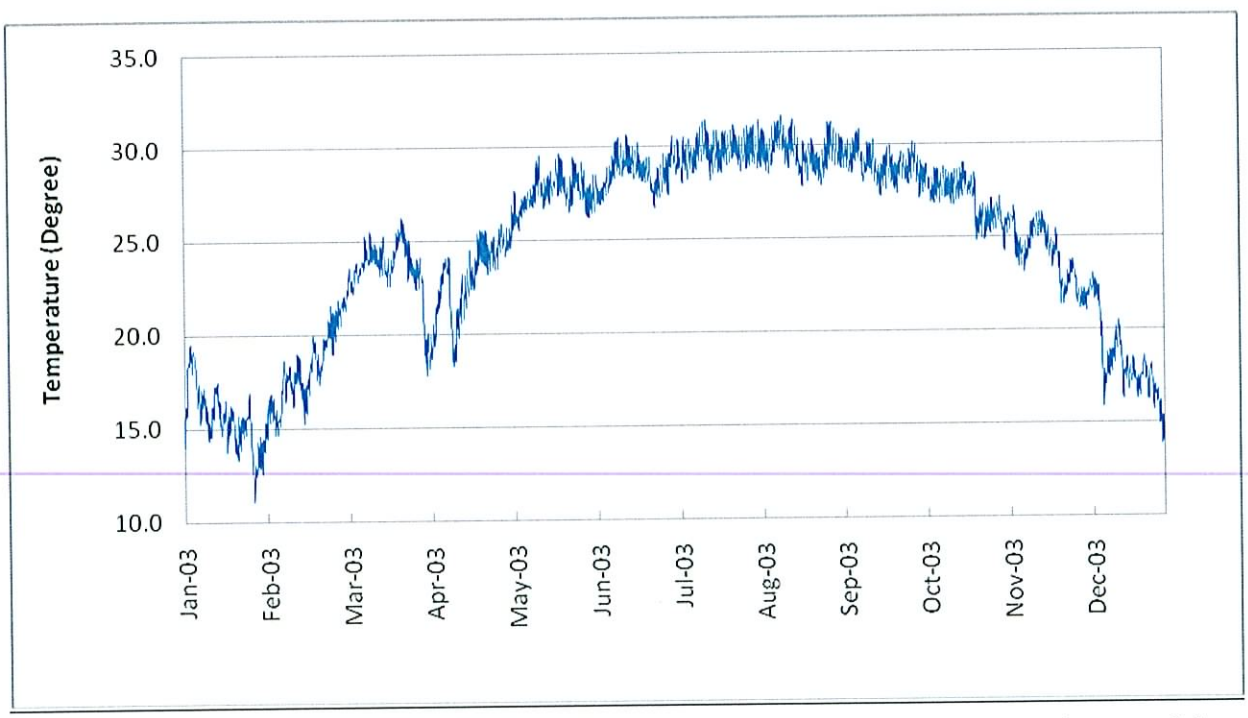

Figure 20 Caloosahatchee River Open Boundary EFDC temperature derived boundary conditions

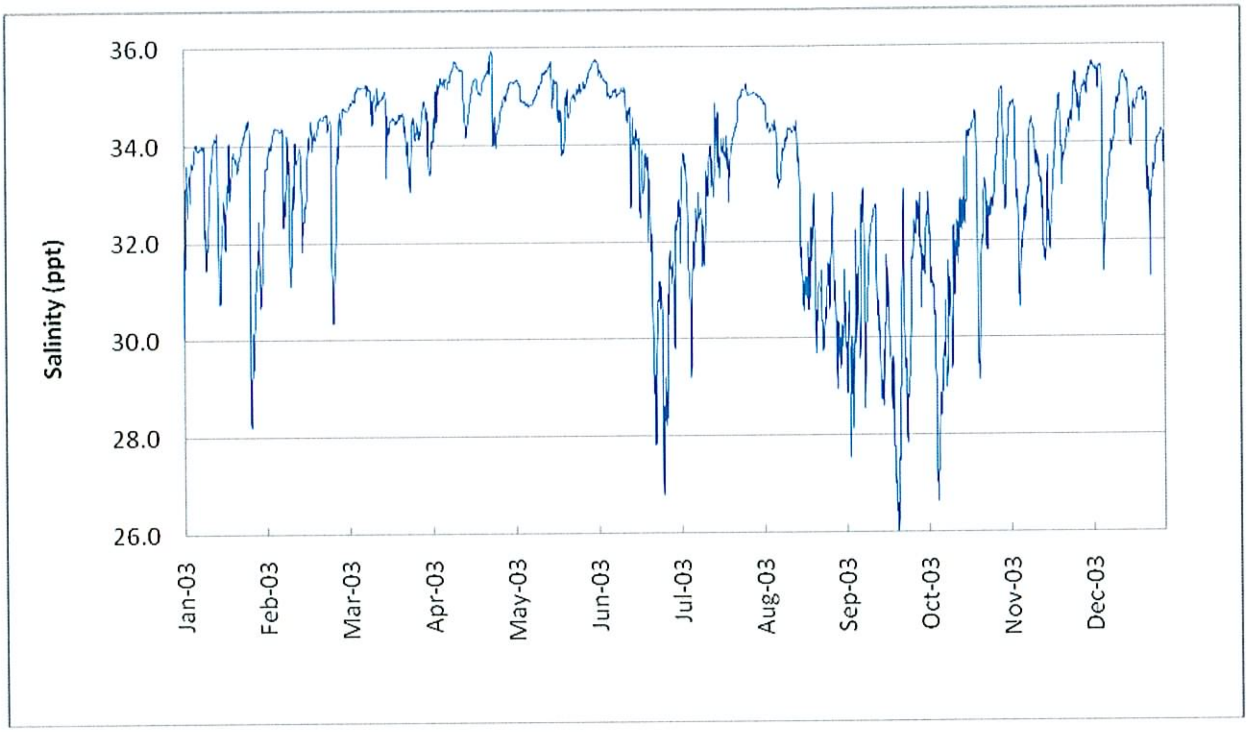

Figure 21 Caloosahatchee River Open Boundary EFDC salinity derived boundary conditions

5.4.1.2.2 Water Quality Boundary Conditions

The water quality boundary information required for input to the WASP model includes time series concentrations of Ammonia, Nitrate, Organic Nitrogen, Organic Phosphate, Orthophosphate, Phytoplankton Chla, Dissolved Oxygen, CBOD1, Detrital Carbon, Detrital Nitrogen, and Detrital Phosphorous. Water quality boundary conditions are assigned for the upstream boundary at the S79 Franklin Lock & Dam and the open water boundary for the Gulf of Mexico, Pine Island Sound and Matalacha Pass.

The Caloosahatchee River tidal estuary WASP model uses the water quality information from both the S79 and CES01 monitoring stations to assign the upstream river boundary conditions. As examples of the WASP upstream boundary inputs, Figures 26 and 27 show the surface layer boundary conditions of Dissolved Oxygen and Nitrate concentrations at the upstream segment at S79.

Figure 22 Caloosahatchee River upstream DO boundary concentration

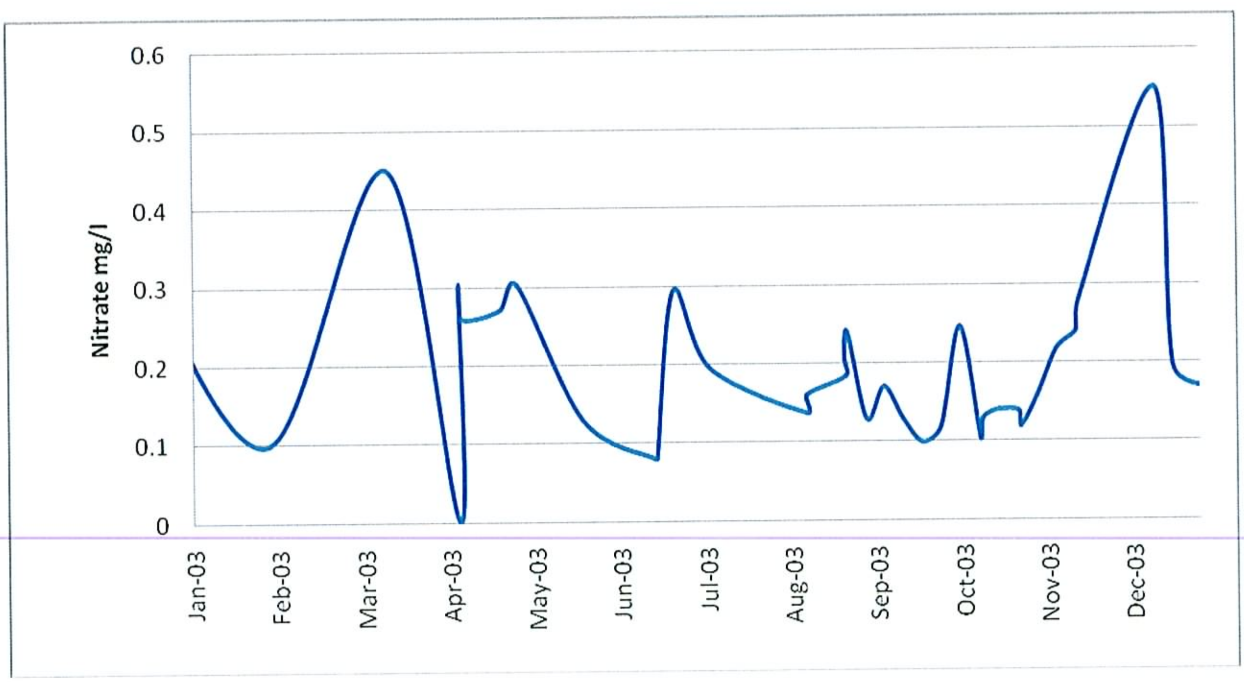

Figure 23 Caloosahatchee River upstream Nitrate boundary concentration

For the coastal open water boundary of the Gulf of Mexico, limited data are available. The water quality boundary information was derived from data extracted from the NOAA NODC World Ocean database (WOD05) for the Gulf of Mexico in the vicinity of the Caloosahatchee estuary (http://www.nodc.noaa.gov/OC5/WOD05/pr_wod05.html). As an example of the open water boundary conditions, the time series concentrations for the calibration period of October 2002 to November 2003 are plotted for Dissolved Oxygen (Figure 28) and Nitrate (Figure 29).

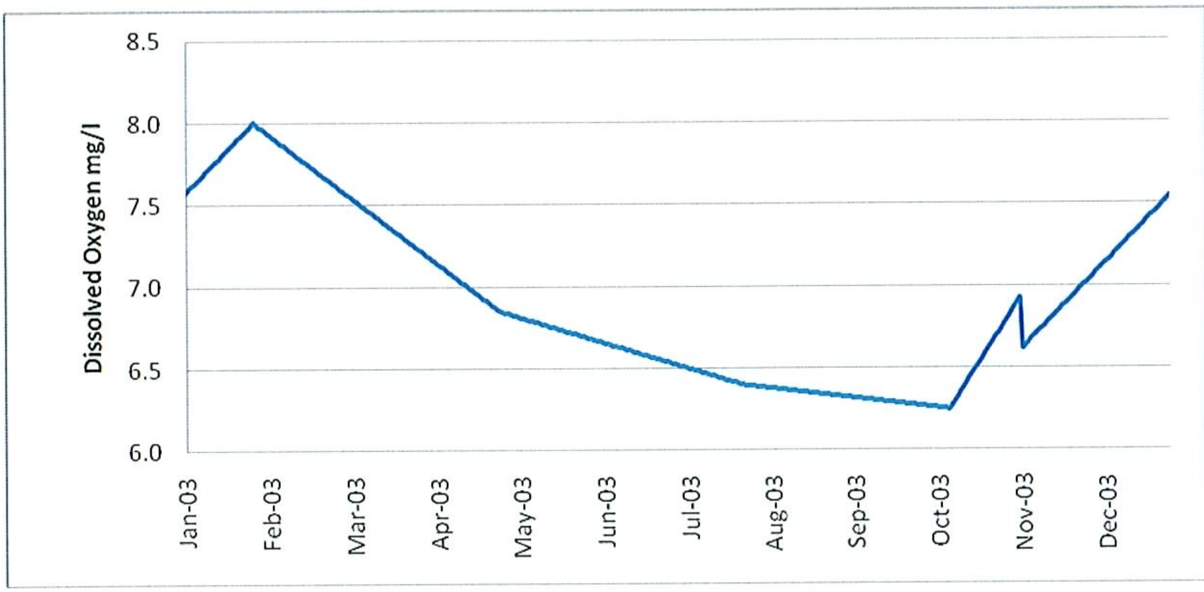

Figure 24 Coastal DO boundary concentration

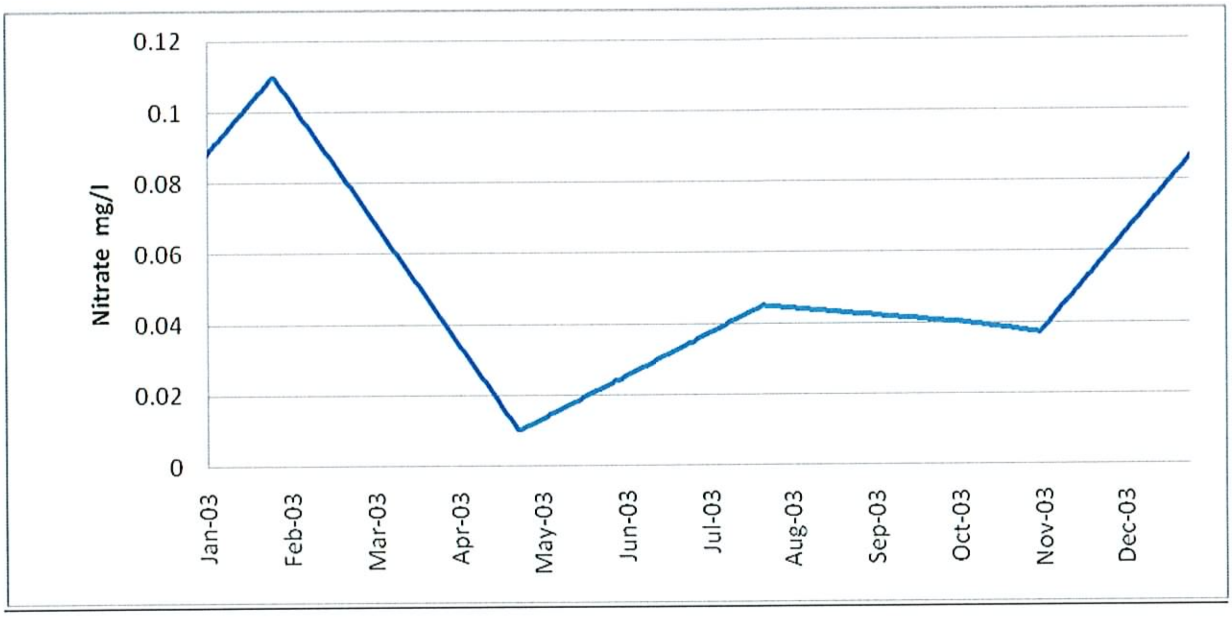

Figure 25 Coastal Nitrate boundary concentration

5.4.1.3 Model Simulation Periods

The period selected for model simulation was from January 1, 2003 to December 31, 2003. During this period there exists a good overlap of all the salinity, temperature, and water quality and meteorology data to define both the initial conditions and boundary conditions. Data are also available for this period to support model calibration.

5.4.2 WASP Model Verification

Initial conditions were set as a fixed constant value for each WASP state variable at all segments in the domain from the upstream boundary to the coastal open water boundary at each layer. The model required several days "spin-up" to allow the initial conditions assigned for all model state variables to become well distributed by circulation processes. A map of the spatial nitrate distribution after one month simulation is presented as Figure 30. The figure shows that a high concentration of upstream water could influence the nutrients and dissolved oxygen concentration in the lower reaches of the estuary. It is very clear that the WASP model is setup and running correctly with the hydrodynamic linkage and water quality forcing from observed data sets. The model responds well to the hydrodynamics and flow boundary information provided by the EFDC linkage. If there is no flow information, the WASP model won't run and the concentration values of all the segments would be the same value for each simulated water quality variable, such as nitrate and Dissolved Oxygen. The spatial distribution of Dissolved Oxygen was also plotted and is presented as Figure 31.

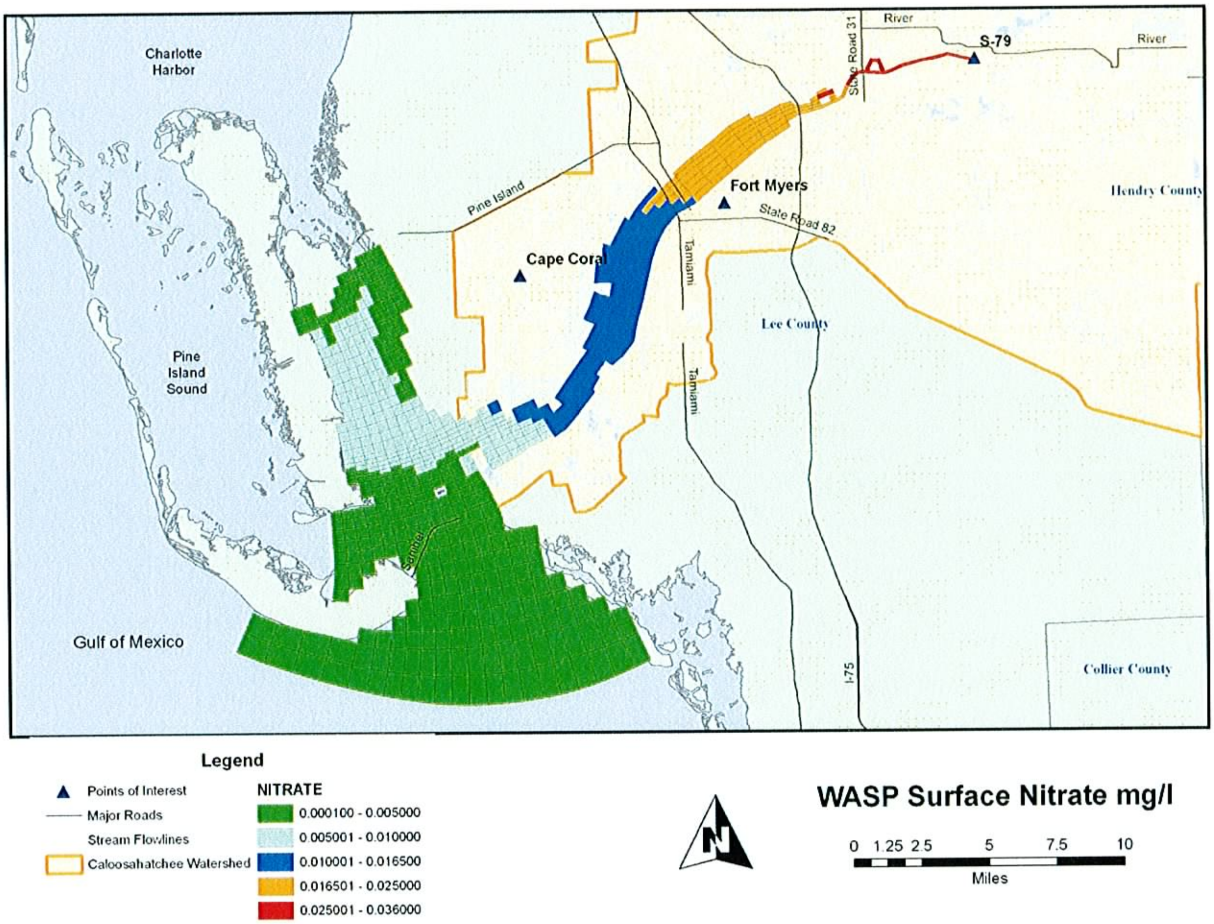

Figure 26 Spatial Nitrate distribution (in mg/l) after 1 month simulation

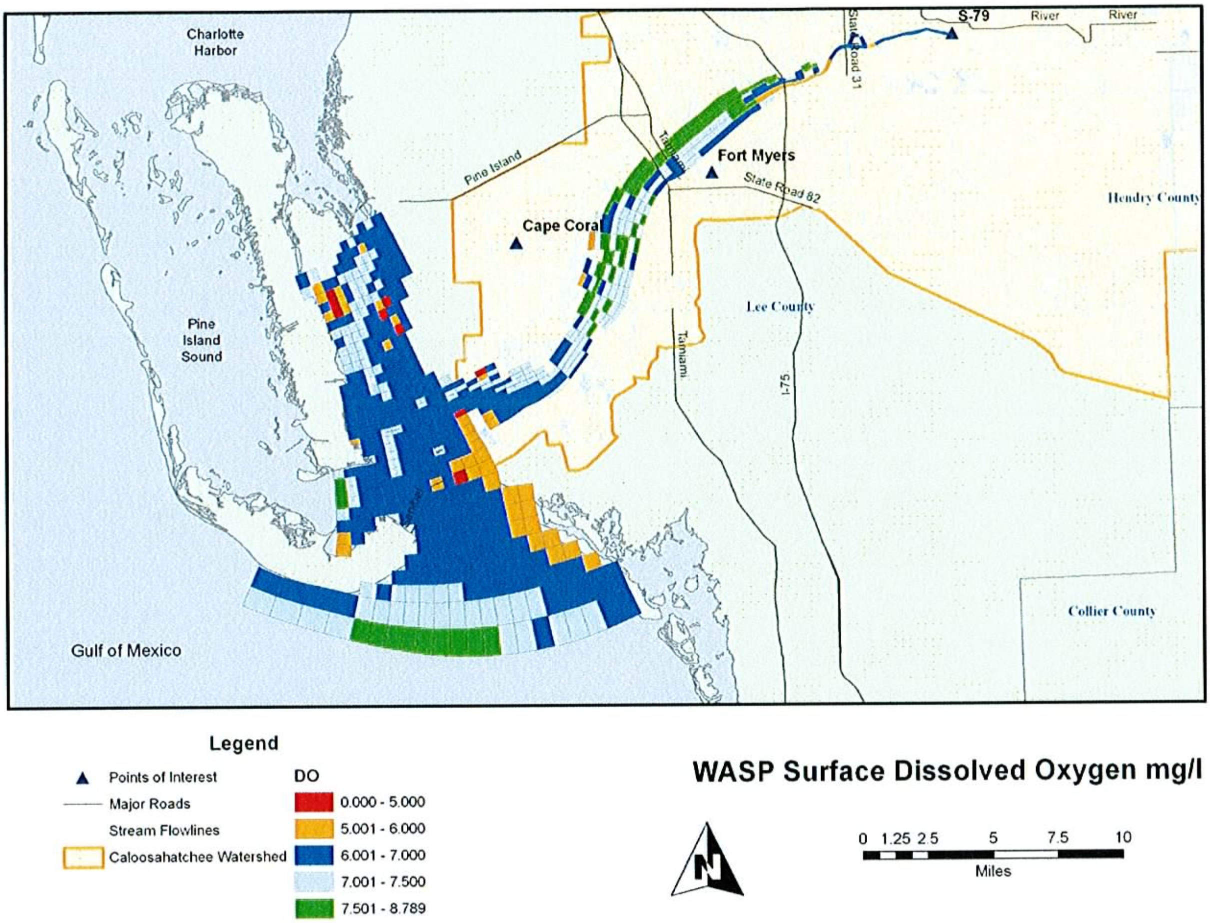

Figure 27 Spatial DO distribution (in mg/l) after 1 month simulation

In addition to the spatial distributions of these constituents shown above, time series plots of Dissolved Oxygen and Nitrate are shown in Figures 32 and 33 for the SFWMD CES-07 monitoring station. The location of CES-07 in the model domain is shown on the map of the entire model grid (see Figure 20). Based on these example time series results generated with the WASP model, it is clear that the WASP model is setup and running correctly with the hydrodynamic linkage and the water quality boundary conditions and other input data required to drive the WASP water quality model. If there were no source or sink terms for nutrients or dissolved oxygen , the time series values for these state variables would continue to decrease continuously with time. The dissolved oxygen values are seen to decrease in the summer and begin to increase again in the fall and winter, which is consistent with typical observations in an estuary such as the Caloosahatchee. The nitrate concentration is seen to fluctuate seasonally and depicts the WASP model responding to the water quality inputs and hydrodynamics forcing. These example spatial maps and time series plots for nitrate and dissolved oxygen demonstrate that that the (a) hydrodynamic information is passing correctly from EFDC to the WASP model and (b) the WASP model is receiving the nutrient and DO input data as expected.

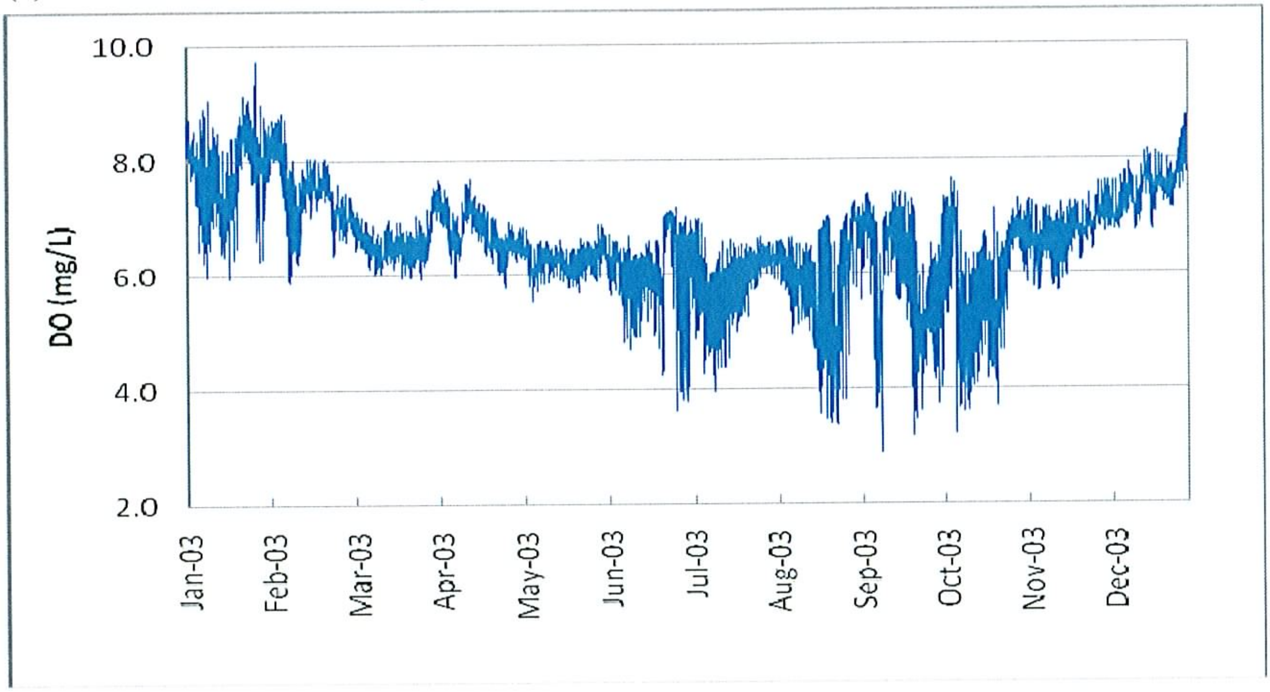

Figure 28 Station CES07 time series DO simulation

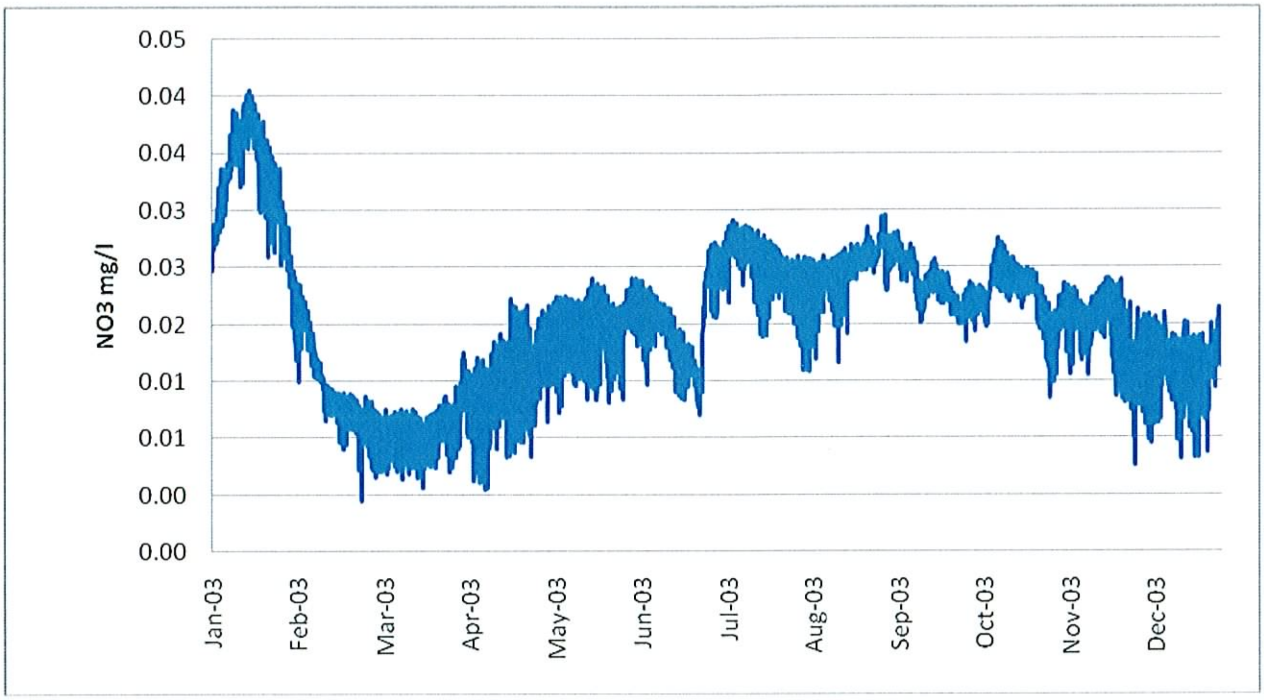

Figure 29 Station CES07 time series Nitrate simulation

5.4.2.1 Conservation of Mass

The hydrodynamic results from the EFDC model provide flow, volume, salinity and temperature data for linked input to the WASP model. Since mass conservation has already been checked for the EFDC model, mass conservation will be also satisfied for the WASP model.

5.4.2.2 Numerical Stability

The computational stability of the numerical solution techniques used in both EFDC and WASP is controlled by (a) the simulated distribution of velocity and dispersive mixing generated by the EFDC hydrodynamic model and (b) the modeler's specifications of the integration time step and the length, width and depth of each grid segment. In building the EFDC model, the integration step was adjusted as needed to achieve a stable solution with the hydrodynamic model.

In the WASP model, numerical stability of the model results are tested by comparison of the model results to "maximum allowed" values assigned by the modeler for each water quality state variable. If the WASP simulation results exceed the "maximum allowed" concentration at any time during the model run, the model stops and a warning message is provided to the modeler to check the setup of the WASP model. If the WASP model results, were, in fact, unstable but simulated concentrations did not exceed the "maximum allowed" concentration for a state variable the model would not stop with a warning message. The time series results for an unstable model would, however, exhibit erratic oscillations with concentrations fluctuating from very high to very low values in the characteristic "sawtooth" pattern indicative of numerical instability.

In the simulations presented here, the maximum concentration for each water quality state variable was set to an arbitrary value of 100 units. As can be seen in the example time series plots, the WASP model is stable for the one year simulation period. The numerical stability is acceptable for a WASP model that has been driven using the hydrodynamic linkage file generated by the EFDC model of the Caloosahatchee estuary.

5.4.3 PRELIMINARY SENSITIVITY ANALYSIS

An initial analysis was conducted to evaluate sensitivity of predicted water quality in the Caloosahatchee to various parameters and loadings. For this preliminary sensitivity analysis, three different sediment oxygen demand (SOD) values were tested. These three cases were for SOD of 0.5 g/square meter/day, SOD of 1 g/square meter/day, and SOD of 2 g/square meter/day. It was found that Phytoplankton Chl a, Ammonia, and Orthophosphate experienced relatively small changes under these three cases. Both nitrate and dissolved oxygen were found to be responsive to varying levels of SOD. Figure 34, below, depicts the model's nitrate concentration response to three SOD settings. DO was found to be very sensitive to variation in the setting of SOD. Figure 35, below, depict this sensitivity.

Recommendations
Model
- levels of detail
- source code

Data
- SOD
- Flow
- Water quality
- cross sections & structures
- BMPs [ag urban
- WWTP DMRs
- soils

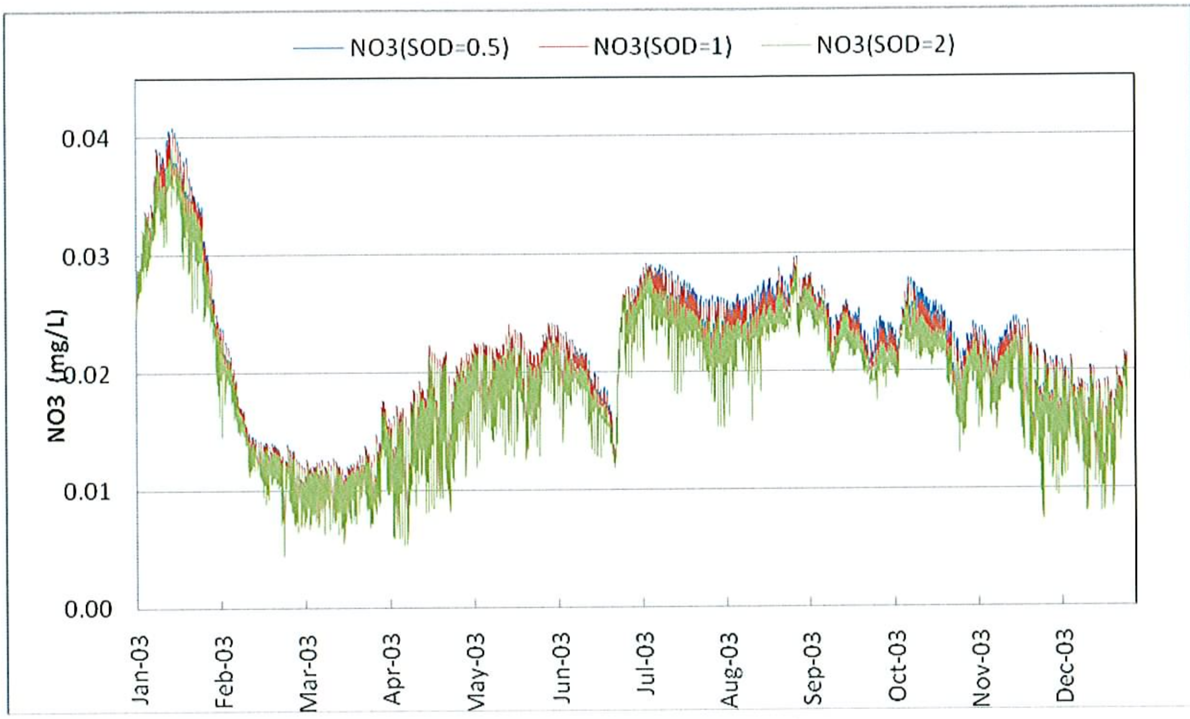

Figure 30 Sensitivity of Nitrate to variations in SOD

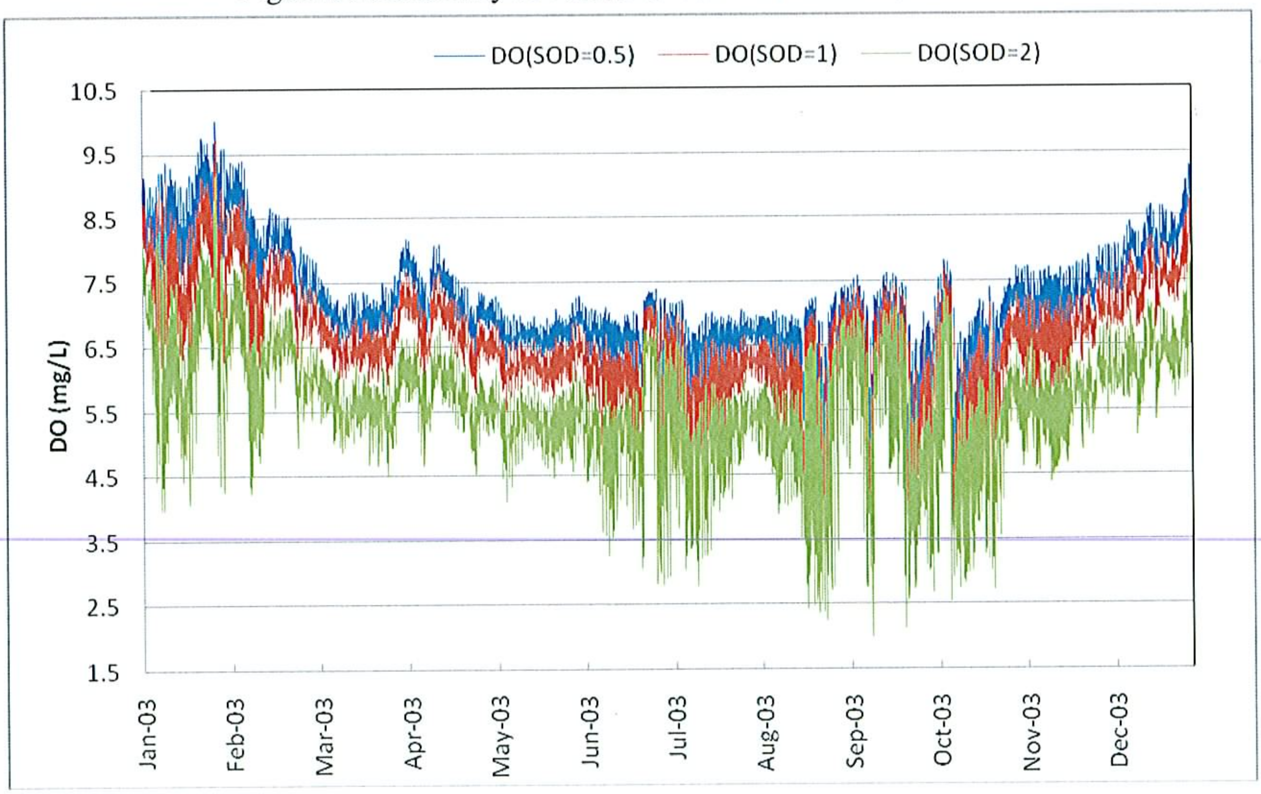

Figure 31 Sensitivity of Dissolved Oxygen to variations in SOD

5.4.4 WASP Model Calibration
- 5.4.4.1 Simulation Period
- 5.4.4.2 Watershed or Receiving Water Variations
- 5.4.4.3 Goodness of Fit Tests
- 5.4.4.4 Sensitivity Analysis

5.4.5 WASP Model Validation
- 5.4.5.1 Simulation Period
- 5.4.5.2 Watershed or Receiving Water Variations
- 5.4.5.3 Goodness of Fit Tests

5.4.6 WASP Model Quality Control

57.

5.5 WMM ~~Model~~ (CDM for this entire section)
- 5.5.1 Model Development Of WMM Model
  - 5.5.1.1 Model Parameters
  - 5.5.1.2 Model Boundary Locations
    - 5.5.1.2.1 Flow, Temperature and Salinity Boundary Conditions
    - 5.5.1.2.2 Water Quality Boundary Conditions
  - 5.5.1.3 Model Simulation Periods
- 5.5.2 WMM Model Verification
  - 5.5.2.1 Conservation Of Mass
  - 5.5.2.2 Numerical Stability
- 5.5.3 Preliminary Sensitivity Analysis
- 5.5.4 WMM Model Calibration (CDM for this entire section)
  - 5.5.4.1 Simulation Period
  - 5.5.4.2 Watershed or Receiving Water Variations
  - 5.5.4.3 Goodness of Fit Tests
  - 5.5.4.4 Sensitivity Analysis
- 5.5.5 WMM Model Validation (CDM for this entire section)
  - 5.5.5.1 Simulation Period
  - 5.5.5.2 Watershed or Receiving Water Variations
  - 5.5.5.3 Goodness of Fit Tests
- 5.5.6 WMM Model Quality Control

5.6 Recommended Data Needs and Model Refinements