Hydrodynamic Model Development, Calibration, and MFL Flow Reduction and Sea Level Rise Simulation for the Tidal Portion of the Econfina River

Econfina River, Florida

Suwannee River Water Management District
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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND AND OBJECTIVES

The Suwannee River Water Management District (SRWMD) is performing a minimum flow and level (MFL) analysis for the Econfina River. A component of the MFL analyses is the evaluation of the impacts to estuarine resources associated with potential reductions in freshwater flow in the Econfina. A key component of the analyses is the change in salinity within the estuarine portions of the river. As such, SRWMD contracted for the development, calibration and application of a hydrodynamic model for the tidal portions of the Econfina River. The model can be used to evaluate the response of isohalines to reductions in freshwater discharge and sea level rise.

The extents of the hydrodynamic model are from offshore in the Gulf of Mexico up to a point above the limit of salinity intrusion under low flow conditions, including a sufficient distance upstream (area of coverage) to account for the magnitude of the tidal prism passing into the systems. The tidal prism represents the total volume of flow that passes a point in the river through the ebb and flood cycle of the tides. For the Econfina, the model extended approximately 3.5 miles upstream of the mouth. Figure 1-1a presents a project location map showing the location of the tidal portions of the Econfina River. Figure 1-1b presents a similar map but with a broader view to include the location of the most-downstream active flow monitoring station presently maintained by the U.S. Geological Survey (USGS 02326000 near Perry, FL). The overall project for the Econfina River included the following components:

1. A comprehensive field data collection program within the tidal portions of the Econfina River.
2. Development and calibration of a hydrodynamic model.
3. Application of the calibrated hydrodynamic model under varying freshwater inflow and sea level rise.

The methodologies and results from the field data collection are presented within a separate report entitled *Hydrodynamic Monitoring of the Tidal Portions of the Econfina River* [Applied Technology and Management, Inc. (ATM), 2015]. The data presented in the report supported the development and calibration of the hydrodynamic model presented herein.

Janicki Environmental, Inc. (2007) developed a hydrodynamic model [the Gulf Coast Shelf Model (GCSM)] under contract with the Southwest Florida Water Management District (SWFWMD). SRWMD contributed funding to support that effort. One purpose of the model was to inform the future development of coastal boundary conditions (water surface elevations and salinity) for more detailed models such as the Econfina River model outlined in this report. The GCSM provided boundary conditions (water level and salinity) for the Econfina River model for the MFL simulations outlined in Section 4. The GCSM model was not utilized for the model calibration because measured data were available to utilize in a boundary matching process. This is discussed further in Section 2.

1.2 REPORT OUTLINE

Following this introduction, the report is broken down into four sections. Section 2 presents the development of the model, including a general description of the Environmental Fluid Dynamics Code (EFDC) hydrodynamic model utilized for this project, the model inputs, the data sources for the model inputs, and the period of the calibration simulation. Section 3 presents the model calibration including the data used in the model calibration, along with graphical and statistical comparisons of the model versus measured data. Section 4 presents the application of the calibrated model under the flow reduction and sea level rise scenarios. Section 5 summarizes the results of the model development and calibration.

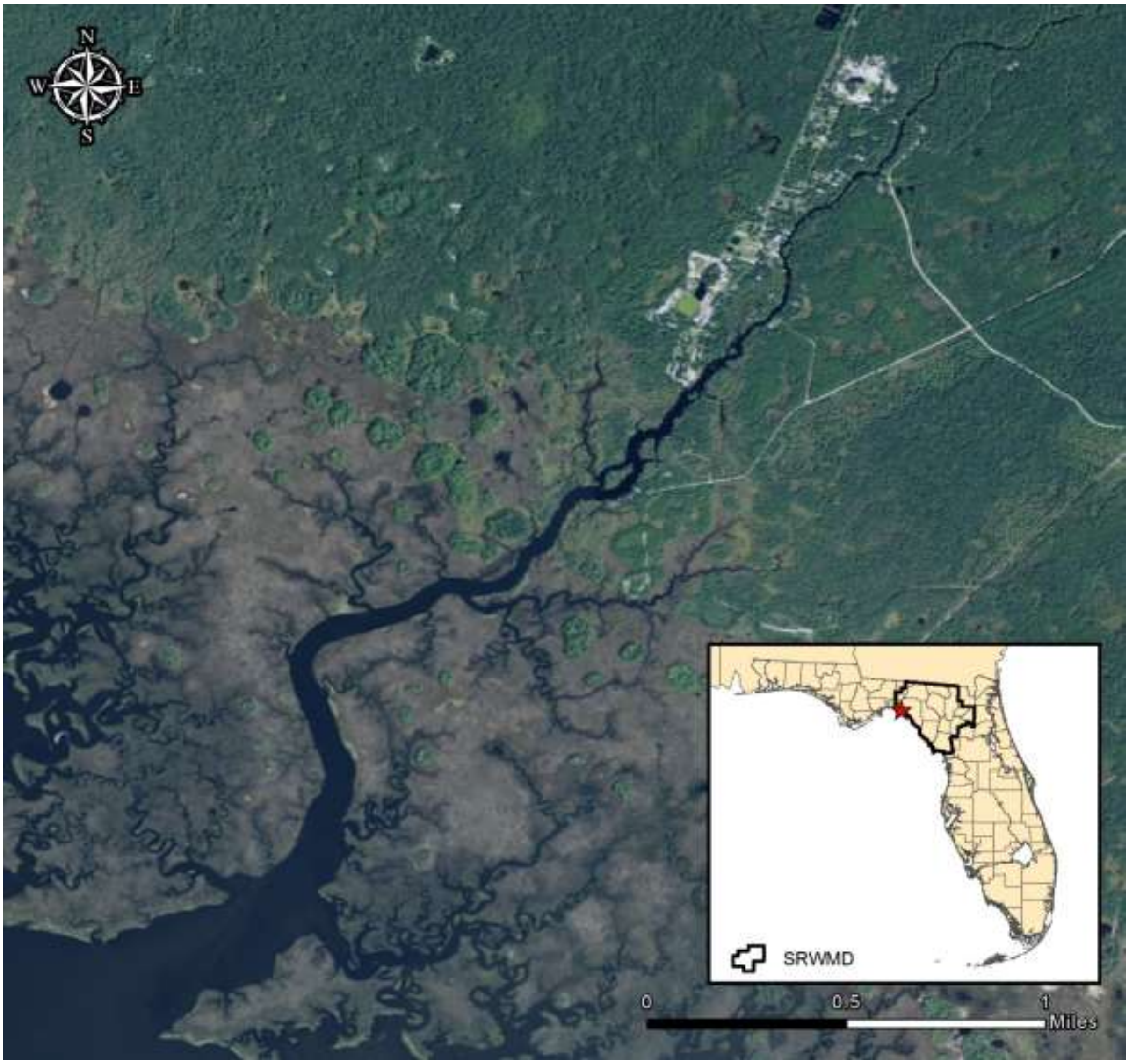

Figure 1-1a. Project Location of the Econfina River and the Extent of the Study Area.

Figure 1-1b. *Project Location of the Econfina River Including USGS Gage 02326000 near Perry, FL.*

2.0 HYDRODYNAMIC MODEL DEVELOPMENT

This section provides a detailed description of the development of the hydrodynamic model for the tidal portions of the Econfina River. As discussed in Section 1, the model extent includes the offshore area (approximately 2 miles out from the mouth, and 1.2 miles in either direction along the coast), the main stem of the Econfina River upstream about 3.5 miles from the mouth, and necessary tidal tributaries and adjacent marsh storage areas connected to the tributaries.

2.1 MODEL DESCRIPTION

The EFDC model used in this project is a general purpose modeling package for simulating two- and three-dimensional flow, transport and biogeochemical processes in surface water systems, including rivers, lakes, estuaries, reservoirs, wetlands, and nearshore to shelf-scale coastal regions. The EFDC model was developed by Dr. John Hamrick at the Virginia Institute of Marine Science and is considered public domain software (Hamrick 1992a, 1992b). EFDC is currently supported by the U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD), EPA Region 4, and EPA Headquarters. A link to the EPA website for the EFDC model is http://www.epa.gov/athens/wwqtsc/html/efdc.html. Additionally, the Florida Department of Environmental Protection (FDEP) and the Water Management Districts (WMDs) throughout the state have used this model extensively. Specific examples of FDEP and the WMD applications of EFDC include the Indian River Lagoon [St. Johns River Water Management District (SJRWMD)], tidal portions of the St. Johns River (SJRWMD), Florida Bay [South Florida Water Management District (SFWMD)], tidal Caloosahatchee River (FDEP), Pensacola and Escambia Bay (FDEP) , and the tidal Suwannee River (USGS for the SRWMD).

The physics of the EFDC model, and many aspects of the computational scheme, are equivalent to the widely used Blumberg-Mellor (1987) model. The EFDC model solves the three-dimensional, vertically hydrostatic, free surface, turbulent-averaged equations of motions for a variable density fluid. Dynamically coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved. The two turbulence parameter transport equations implement the Mellor-Yamada level 2.5

turbulence closure scheme. The EFDC model uses a stretched or sigma vertical coordinate and curvilinear orthogonal horizontal coordinates.

The numerical scheme employed in EFDC to solve the equations of motion uses second-order accurate spatial finite differencing on a staggered or C grid. The model's time integration employs a second-order accurate three-time level, finite difference scheme with an internal-external mode splitting procedure to separate the internal shear or baroclinic mode from the external free surface gravity wave or barotropic mode. The external mode solution is semi-implicit and simultaneously computes the two-dimensional surface elevation field by a preconditioned conjugate gradient procedure. The external solution is completed by the calculation of the depth-average barotropic velocities using the new surface elevation field. The model's semi-implicit external solution allows large time steps that are constrained only by the stability criteria of the explicit central difference or higher order upwind advection scheme used for the nonlinear accelerations. Horizontal boundary conditions for the external mode solution include options for simultaneously specifying the surface elevation only, the characteristic of an incoming wave, free radiation of an outgoing wave or the normal volumetric flux on arbitrary portions of the boundary.

2.2 MODEL GRID AND BATHYMETRY

The first aspect of the hydrodynamic model development is the definition of the model extent or spatial model domain. This is achieved through the development of the model grid. For the Econfina River model grid mesh, the representation of the shoreline used was the light detection and ranging (LiDAR) data that outline elevations from 0.15 feet referenced to the North American Vertical Datum of 1988 (NAVD88) and up. These data, in essence, represent the landforms and the elevations that correspond to the edge of the open water areas for the flow. Figure 2-1 presents a contour plot of these data. For the Econfina model grid, shown in Figure 2-2, the main stem and portions of tributary boundaries from these data were utilized to define the grid extent. The offshore boundary was extended a distance of approximately 2 miles out from the mouth. Additionally, the grid was extended approximately 1.2 miles in either direction laterally from the mouth. The purpose of the grid extension offshore was to provide sufficient area for mixing of the freshwater flowing into the Gulf of Mexico. The grid was extended upstream 3.5 miles from the mouth, upstream of the boat landing. The grid for the Econfina model included 3500 horizontal cells and 6 vertical cells, with minimum sizes on the order of 3 by 8 meters and maximum sizes on the order of 200 by 150 meters.

A key aspect of the model calibration was the need to include representative storage areas along the main stem. As Figure 2-1 demonstrates, there are extensive areas that inundate under different water level conditions (high tides can be up around 2.0 feet NAVD88 at times). As such, to accurately simulate the tidal prism moving through the system, representative storage areas were added (Figure 2-2) that fill through tributary spurs off the main stem model grid. These were roughly based upon the area of inundation shown in Figure 2-1, but were more driven by the simulation of the flow measured at one of the field data collection stations (the mid-river station). These aspects are discussed further in the model calibration section (Section 3).

Figure 2-3 presents the bathymetric conditions in the Econfina model for the simulations. The bathymetry came from a detailed survey of the main stem of the river extending upstream approximately 3.5 miles. All bathymetric conditions were referenced to NAVD88. The bottom elevations for the Econfina River grid were interpolated using a combination of the digital elevation model (DEM) provided by SRWMD and the bathymetry points collected during the river survey. The DEM was first converted from a raster coverage to a point coverage of 10-foot resolution (horizontal). This coverage was modified to remove any DEM point within the river or near a bathymetry data point. The DEM point coverage was combined with the bathymetric point coverage into a single coverage to represent both the land elevations and the bathymetric data. An inverse distance-weighted raster interpolation was performed to create a single raster coverage of the rivers and the surrounding watershed referenced to NAVD88. This coverage was used to find the mean elevation value of each model grid cell, with the mean values of rasters within a cell representing the cell bottom elevation.

USGS created the offshore bathymetry interpolated onto the model grid for the Florida Shelf Habitat (FLaSH) map study in 2007. This was a multi-agency effort that created a compilation dataset of available bathymetry data from the Florida coast to the edge of the Florida shelf. This coverage is a bathymetry point file that was used to create the elevations for the model grid cells offshore in the Gulf of Mexico. Bottom elevations were converted from the vertical datum of the coverage [mean lower low water (MLLW)] to NAVD88. For the offshore bathymetric conditions in the final model grid, adjustments were made for the model to allow progression of the tidal wave to the mouth and facilitate boundary matching at the mouth. This is discussed in more detail in the model inputs section (Section 2.3).

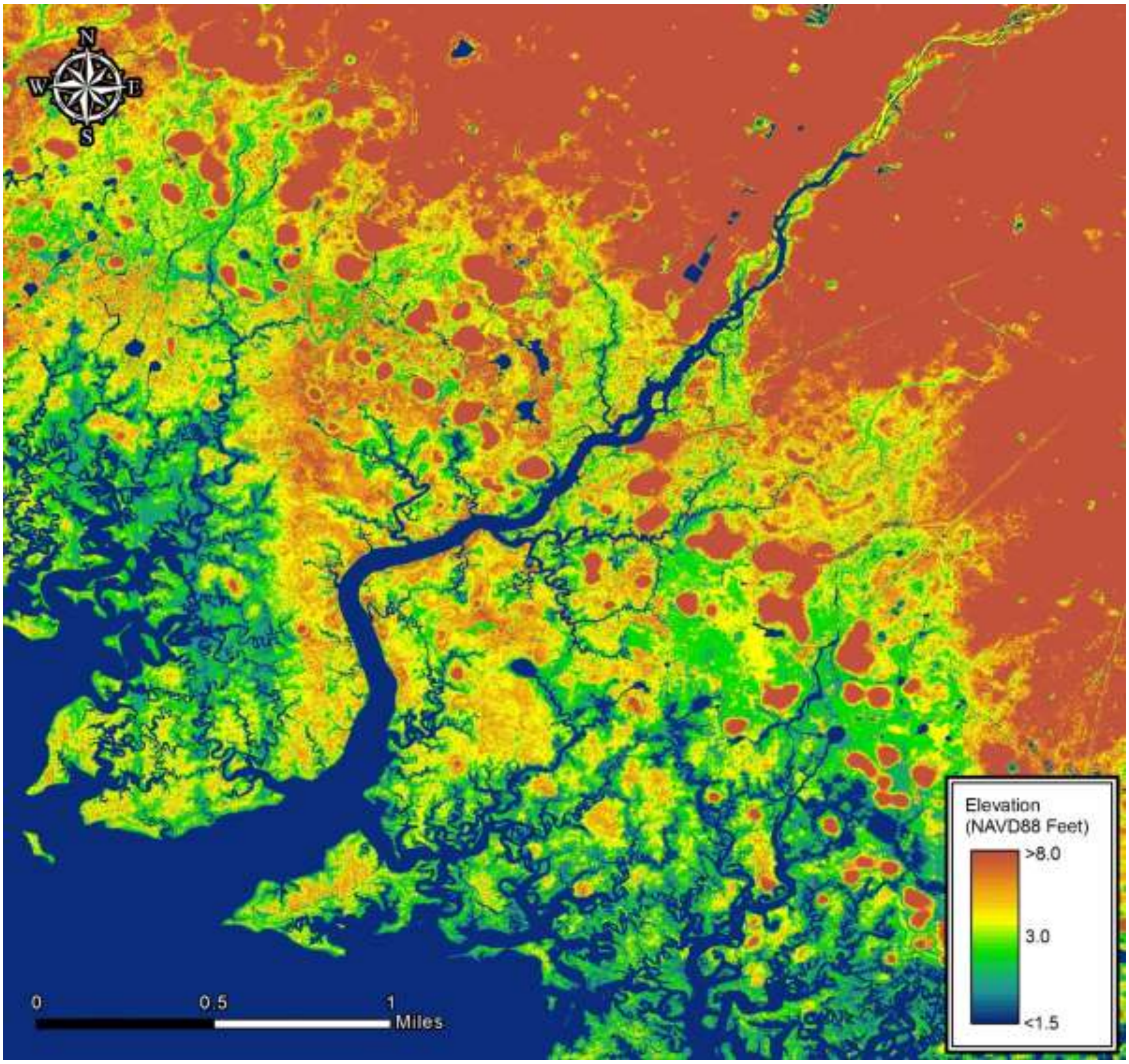

Figure 2-1. Upland Topographic Conditions from LIDAR Data.

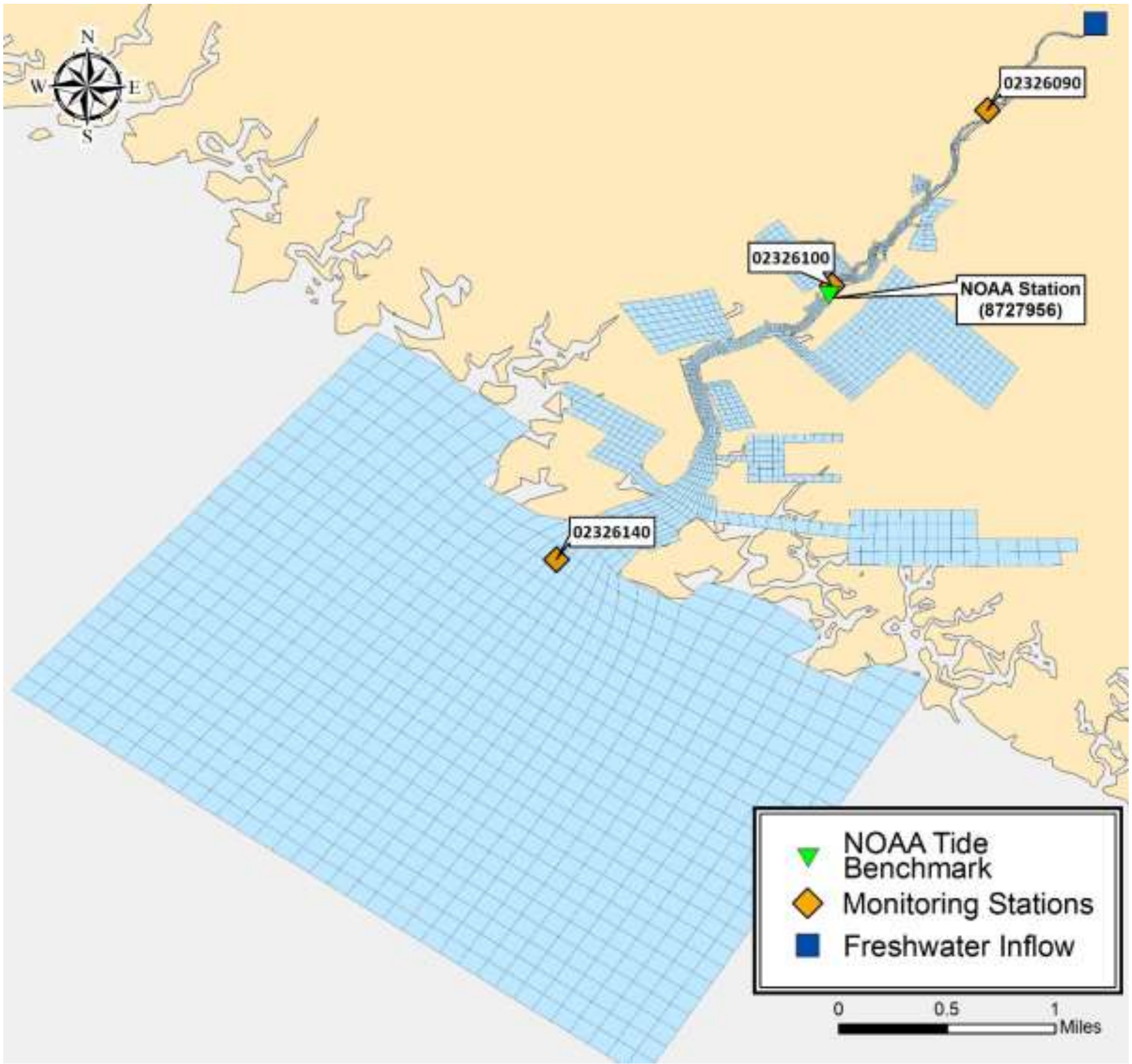

Figure 2-2. Econfina River Model Grid.

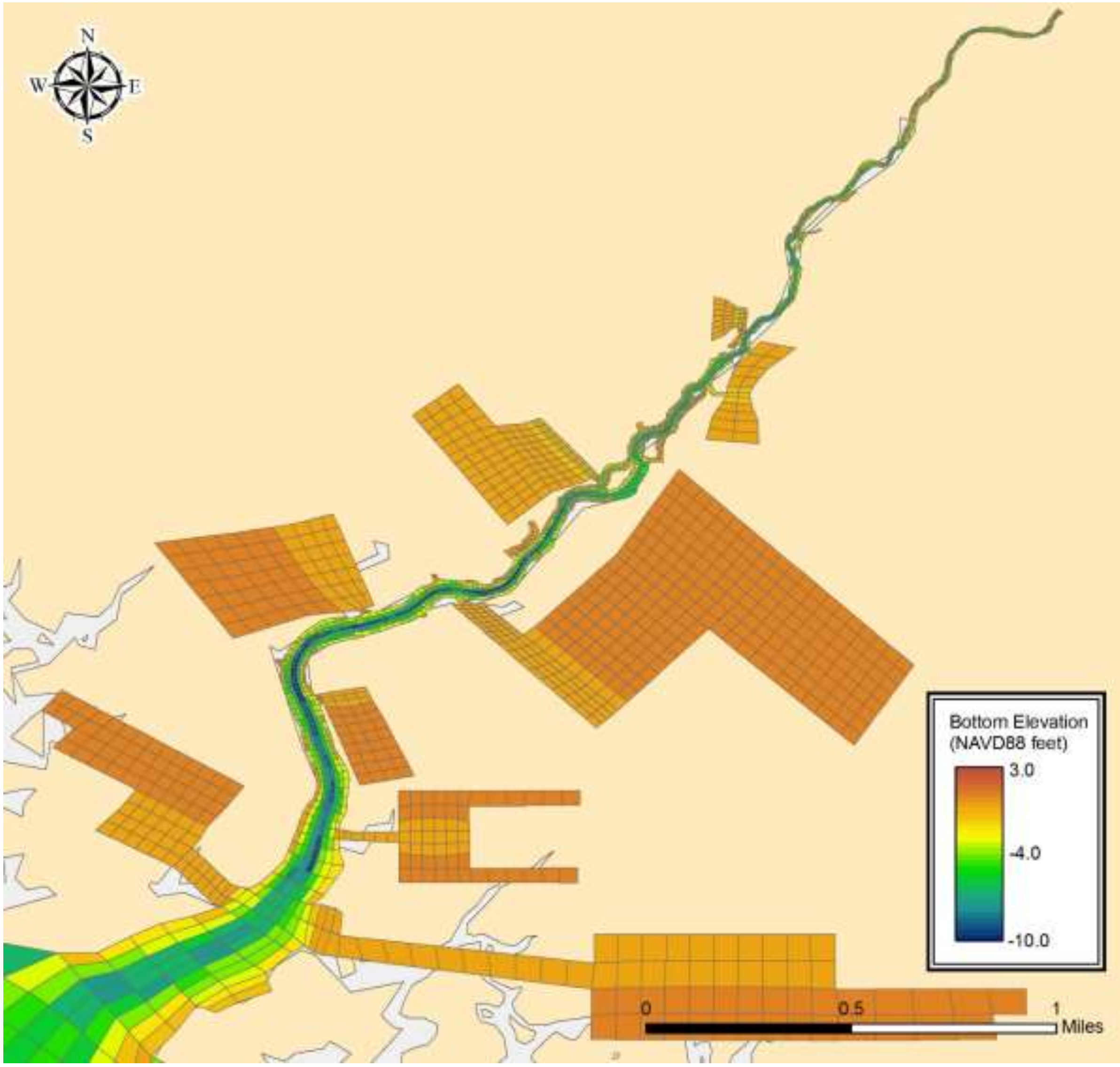

Figure 2-3. Econfina River Model Grid Bathymetry.

2.3 MODEL BOUNDARY FORCINGS AND SIMULATION PERIOD

A number of model inputs were developed for the Econfina River hydrodynamic model. Based on the grid provided in Section 2.2, the specific inputs include:

- Offshore water levels relative to NAVD88
- Offshore salinity
- Upstream freshwater inflow
- Meteorologic inputs (wind speed and direction)

This section provides an overview of the inputs utilized in the model and how they were developed. The simulation period for the Econfina model is from March 1, 2015 through May 31, 2015, with a period of simulation in February to allow the model conditions to reach an equilibrium (spin-up period). The graphs presented reflect the time period following model spin-up.

The model inputs were derived from the field data collected from February through June 2015. These data are presented in detail within the data collection report (ATM, 2015). The data included water levels, salinity and flow.

Prior to the introduction of the boundary conditions, it is important to provide some background on the tidal conditions in the area since tides are a critical forcing mechanism. Table 2-1 presents the elevations of key tidal constants derived for a long-term monitoring station at a location within the estuarine portions of the Econfina. The location of the long-term tidal station is presented in Figure 2-2. The data are referenced to the MLLW at this station and provide the difference between the MLLW and NAVD88, the datum used for the model development. The data show that the astronomic tide range is on the order of 2.5 to 3.2 feet at this location on average. This does not account for mean water level fluctuations in the Gulf of Mexico and freshwater inflows, which also impact the local water levels.

Table 2-1. Econfina Tidal Datums for NOAA Station 8727956 (Econfina River, Inside)

Datum	Elevation (ft)
MHHW	3.19
MHW	2.94
MTL	1.70
MSL	1.53
NAVD88	1.28
MLW	0.45
MLLW	0.00

2.3.1 OFFSHORE WATER LEVEL

For the model calibration period, the water levels used to drive the offshore boundary shown in Figure 2-2 were derived from the measured water levels at the mouth of the Econfina River (Station SRWMD 02326140 in Figure 2-2). The offshore water levels were derived using a process known as boundary matching. The boundary matching process went as follows:

- First, the measured tides at the mouth (SRMWD 02326140) were utilized directly as measured for the offshore forcing function.
- Second, the simulated and measured water levels at the station at the mouth (SRWMD 02326140) were analyzed for phase and amplitude errors.
- Finally, phase and amplitude adjustments were made to the offshore to minimize as much as possible, the errors at the mouth.

For the Econfina model, no phase lag or amplitude adjustments were needed. Figure 2-4 presents a plot of the offshore tides used for the boundary forcing.

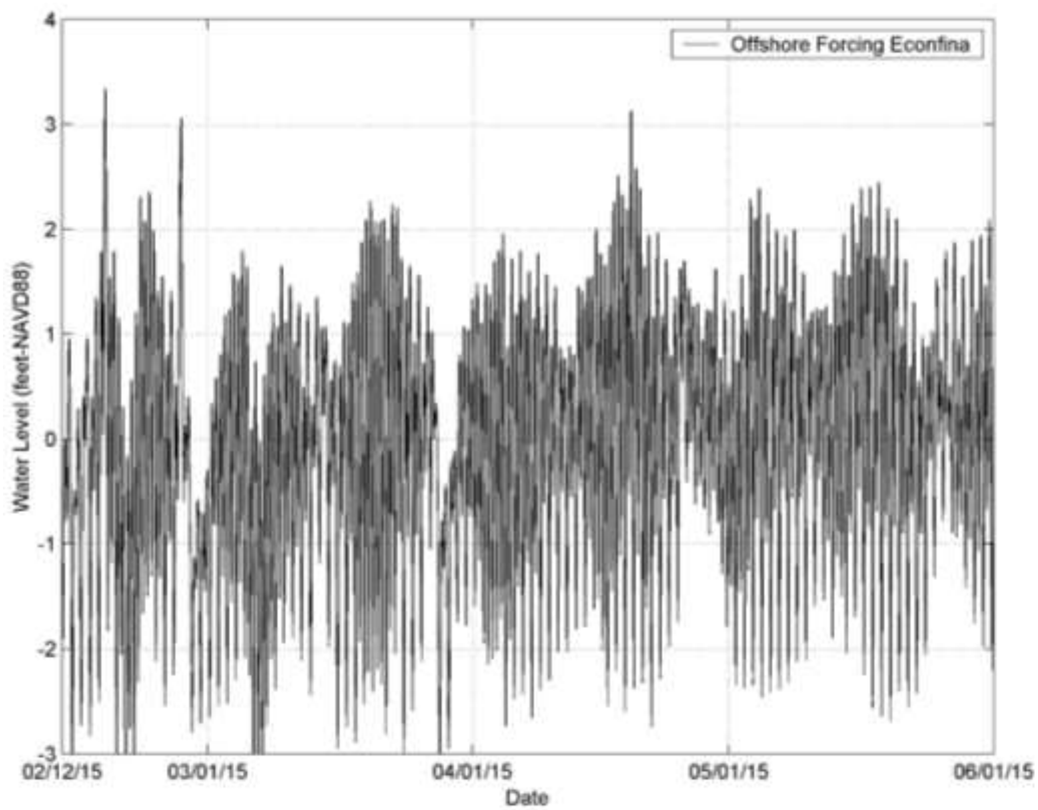

Figure 2-4. Derived Offshore Water Level Boundary Condition.

2.3.2 OFFSHORE SALINITY

The offshore salinity conditions for the Econfina model were derived using a similar approach to that used for the tides, with one difference. For the salinity, the daily maximums measured at the mouth were utilized as the base condition to start the boundary matching process. The reason for using the daily maximums measured at the mouth is that in any one day, the station at the mouth measures the salinity through the ebb and flood cycle (inflow and outflow). At the end of a flood tide cycle (inflowing), water from offshore has moved from the offshore to the mouth to the maximum extent, therefore, the measurements at the end of the flood cycle (when the salinities are at their highest) would best reflect the conditions offshore. The following describes the boundary matching process used to establish the offshore salinity.

- First, the daily maximum measured salinities at the mouth (SRWMD 02326140) were derived from the data and used as a time series in the offshore.
- Second, the errors in the measured versus simulated salinity at the mouth were evaluated.
- Finally, adjustments were made to the baseline offshore salinity (using the daily maximums) to minimize the salinity error at the mouth (SRWMD 02326140).

Using the daily maximums as the base, the comparisons at the station at the mouth were sufficiently representative so that no manipulation of the offshore conditions was needed to achieve boundary matching. Figure 2-5 presents the time series of the boundary forcing derived for the Econfina model.

At the offshore boundary in the model, the system was assumed to be well mixed, so that salinity at the surface and bottom are the same. The boundary matching at the mouth supported that this assumption produced reasonable salinity stratification conditions at the mouth. The offshore areas were included in the model to allow for mixing of the freshwater inflows with the offshore areas. Additionally, this provided an appropriate boundary for the output from the GCSM model as inputs to the EFDC model simulations for the MFL reduction and sea-level rise scenarios outlined in Section 4. For the model calibration, due to the use of the boundary matching approach, the key areas of valid model simulation extend from the mouth upstream to the extent of tidal intrusion.

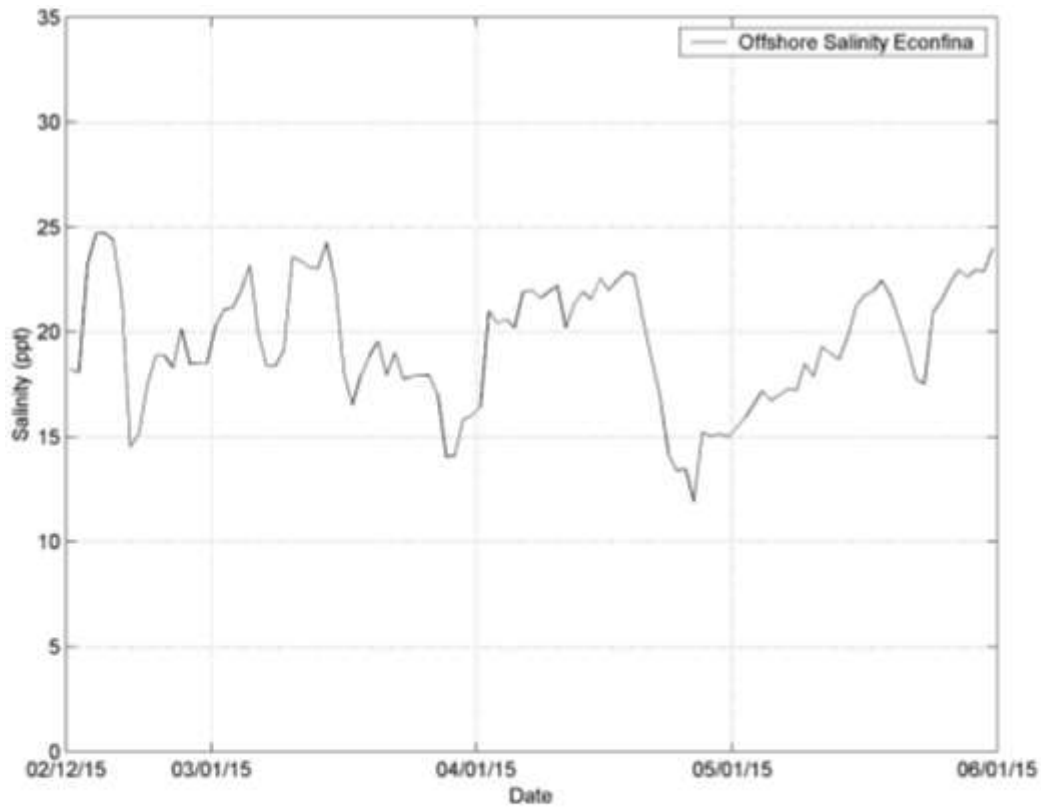

Figure 2-5. *Derived Offshore Salinity Boundary Condition.*

2.3.3 FRESHWATER INFLOW

The time series of freshwater inflow used in the hydrodynamic model was derived from the flow measured at SRWMD Station 02326100 (Figure 2-2). At this station, an accoustic Doppler current meter (ADCP) and a water level sensor were deployed for the period of the model calibration (February 2015 through May of 2015). At this site, the continuous measured velocities (6-minute interval across the river section) and continuous measured water levels (also at 6-minute interval) were used to derive a continuous time series of tidally driven flow. The details of the deployment and the analyses performed on these data are presented in detail in the hydrodynamic data collection report (ATM, 2015). The time series of tidal flow were then filtered using a low-band pass filter to remove the tidal components, leaving the net freshwater outflow. The filtered flow data were then averaged over a daily time step to provide the flow input to the model. The filtered and averaged flow represents the total freshwater inflow from the watershed above station SRWMD 02326100.

For the Econfina model, the total freshwater inflow was put into the model at the most upstream grid location. Figure 2-2 shows the location of the freshwater inflow point. Figure 2-6 presents the daily average total freshwater inflow input to the model.

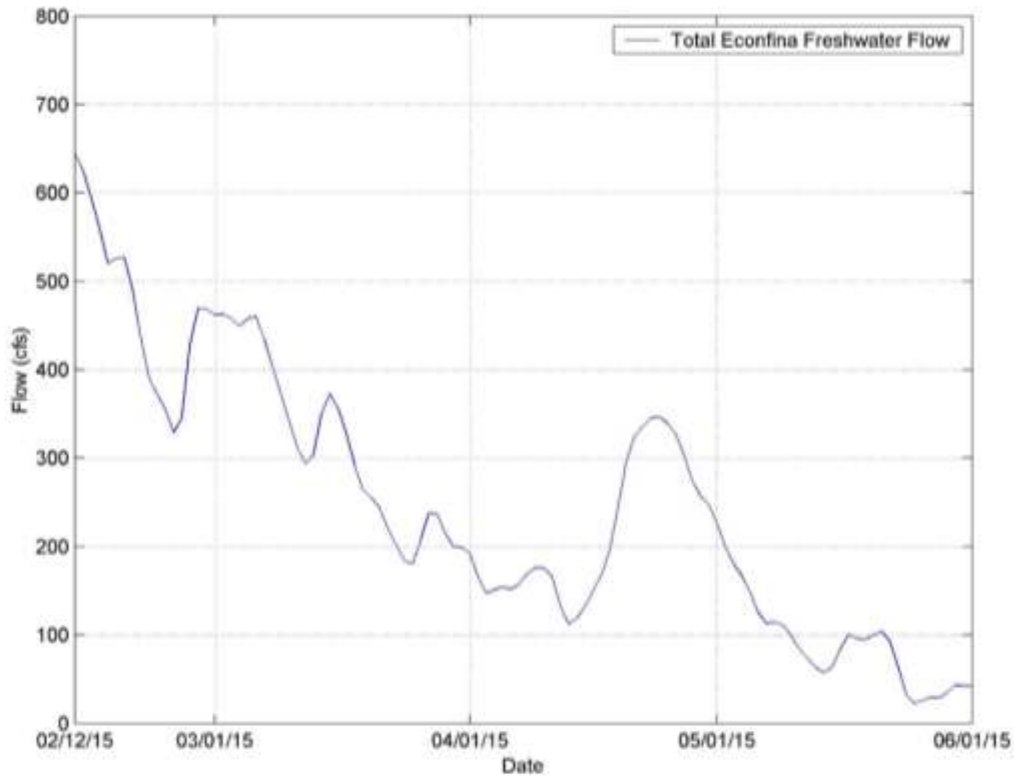

Figure 2-6. Total Freshwater Inflow.

2.3.4 WIND SPEED AND DIRECTION

The meteorological inputs to the model include the wind speed and direction acting on the water surface. The National Data Buoy Center (NDBC) Keaton Beach site was used for winds. Figure 2-7 presents the wind inputs, including the wind speed and direction.

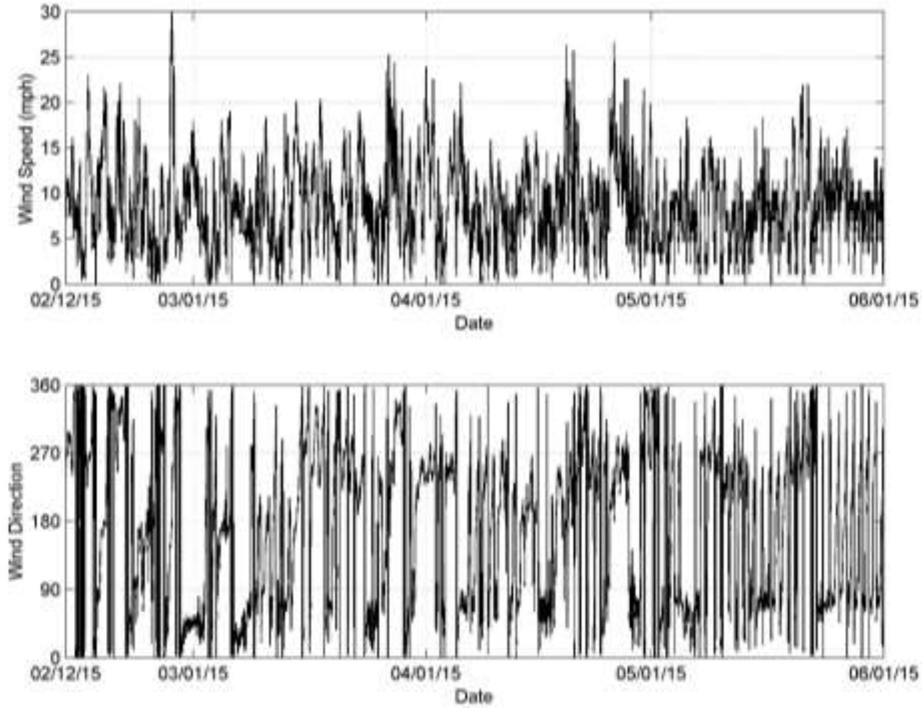

Figure 2-7. Wind Speed and Direction Model Inputs.

3.0 HYDRODYNAMIC MODEL CALIBRATION

This section provides a detailed description of the calibration of the hydrodynamic model, including the data used in the model calibration, a discussion of the calibration process used for this model, and presentation of the comparison of the model simulations to measured data for the water levels, flow, and salinity.

3.1 DATA USED IN MODEL CALIBRATION AND CALIBRATION STATISTICS

A companion hydrodynamic monitoring report (ATM, 2015) provides a detailed discussion of the data collected for this project. For the purposes of model calibration, the data used included the water levels at all three stations, the measured salinity at all three stations, and the time series of flow. Figure 3-1 presents the locations of the continuous monitoring stations along the main stem of the river. At the downstream station (SRWMD 02326140) and the upstream station (SRWMD 02326090), water level and bottom salinity data were collected. At the mid-station (SRWMD 02326100), water level, flow, and bottom and surface salinity were collected. Data from March 1, 2015 through May 31, 2015 were utilized for the calibration comparisons.

In addition to graphical comparisons of the simulated versus measured results, statistical comparisons were performed, where appropriate. The statistics include the root mean square error (RMS), the mean error (ME), and the coefficient of determination (R^2). The following presents how each of these error statistics are calculated.

- Root Mean Squared Error (RMS):

$$\sqrt{\frac{\sum_{i=1}^{n}(O_i - m_i)^2}{N}}$$

- Mean Error (ME):

$$\frac{\sum_{i=1}^{n}(O_i - m_i)}{N}$$

- Coefficient of determination (R^2):

$$\left(Corrcoef\ (O_i, m_i)\right)^2$$

where: O_i = observation

M_i = model output

N = number of observations

Note: Corrcoef is a MATLAB function for correlation coefficient

The data from the model were extracted to match times of available measured data for the analyses. The statistics were then calculated from the matched data sets for the period identified.

The RMS represents the deviation of each of the individual measured-versus-simulated matched data pairs and is the most direct measurement of model-to-simulation error or difference between the results. This measure does not have a sign (i.e., negative or positive), so it does not identify if this is an under-prediction or over-prediction, simply what the overall differences are. The ME represents whether or not there is a bias in the results. For example, if the ME is less than zero, it means that overall, the model is under-predicting in an absolute sense. For both the RMS and the ME, the results are presented as values in the units of measure [feet for water level and cubic feet per second (cfs) for flow] as well as percent error. The percent error is the value divided by the average range of the data signal being compared. The coefficient of determination (R^2) is a measure of how the model and data line up or correlate. If the model and data lined up perfectly, the R^2 value would be 1.

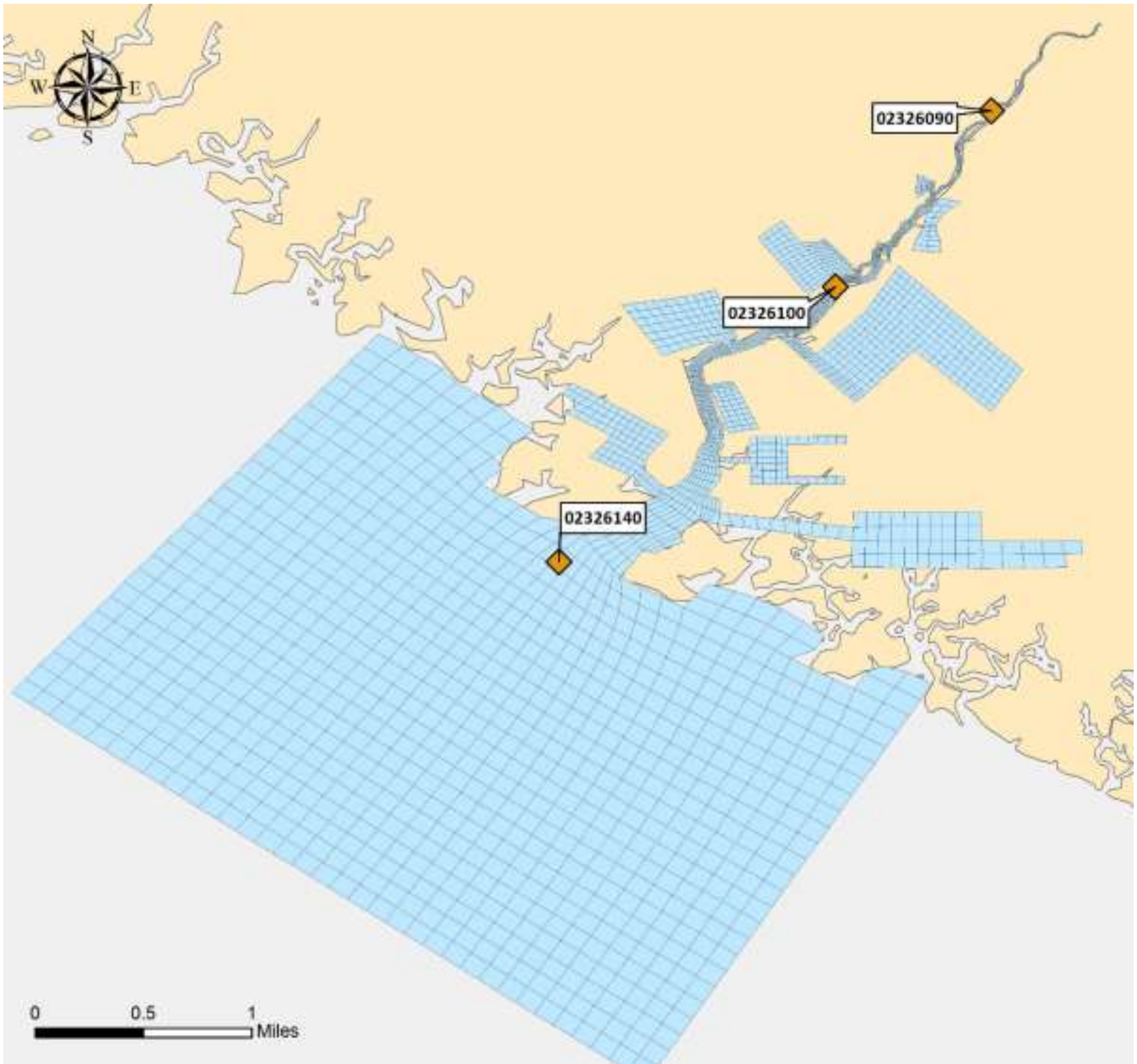

Figure 3-1. Locations of Continuous Monitoring Stations.

3.2 SIMULATED VERSUS MEASURED WATER LEVELS

Figures 3-2a through 3-2c present comparisons of the measured versus simulated water level at the three stations along the main stem of the Econfina. The comparisons are presented by month from March through May.

The comparisons presented within the figures show that the model is doing very well simulating the magnitudes of the water level fluctuations and, specifically, the distribution of the damping of the tidal wave as it moves upstream. Table 3-1 presents the model statistics for the water level measurements. The results show that the RMS errors are all less than 0.2 foot, which equates to less than a 5 percent error. The percent error is based on dividing the RMS value by the average range for the tides on a daily basis over the period of the error analyses. In addition to the RMS errors, the mean errors are low and the R^2 values are very good, all above 0.96, indicating very good correlation between the measured data and the simulated results. Recent peer-reviewed work under a SWFWMD project for Tampa Bay identified an allowable error for water level for a good calibration of 0.16 foot for RMS error, +/- 0.16 foot for mean error, and 0.90 for R^2 (Janicki, 2014). Based on these criteria, the water level simulations for the Econfina model represent a good calibration.

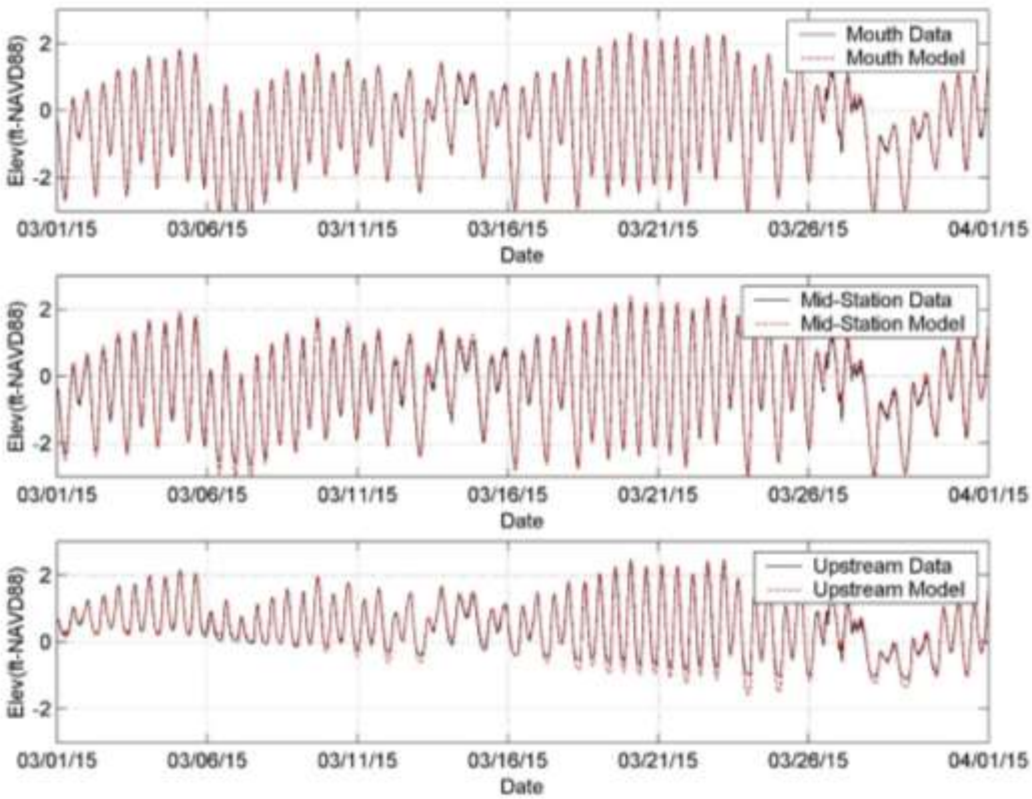

Figure 3-2a. Simulated versus Measured Water Levels at SRWMD Stations 02326140 (mouth - top panel), 02326100 (mid-river - middle panel), and 02326090 (upstream - bottom panel) in March 2015.

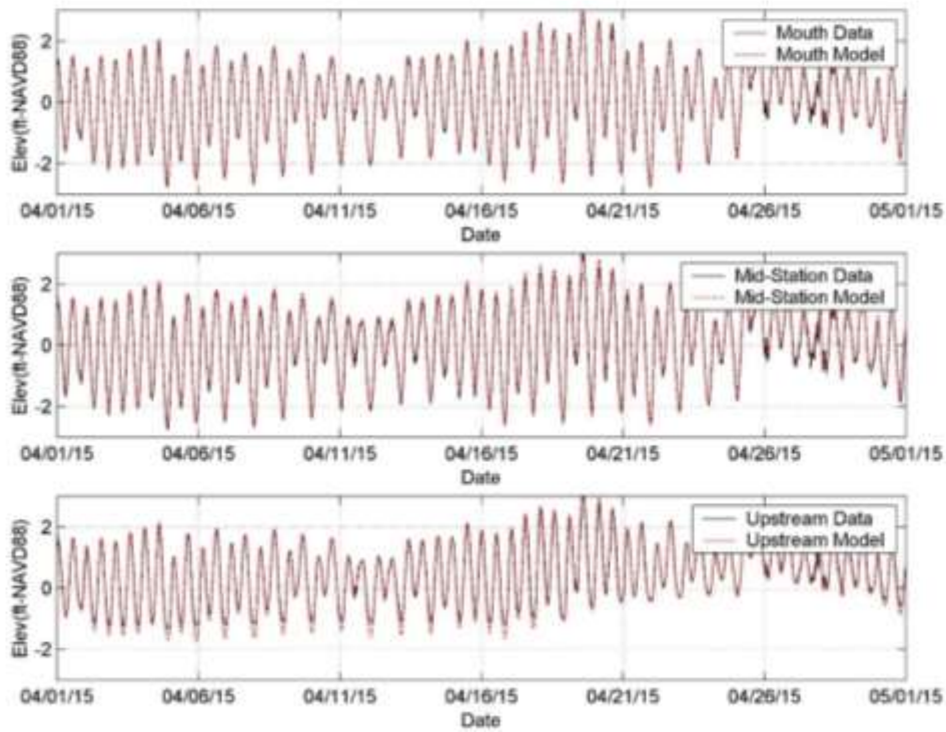

Figure 3-2b. *Simulated versus Measured Water Levels at SRWMD Stations 02326140 (mouth - top panel), 02326100 (mid-river - middle panel), and 02326090 (upstream - bottom panel) in April 2015.*

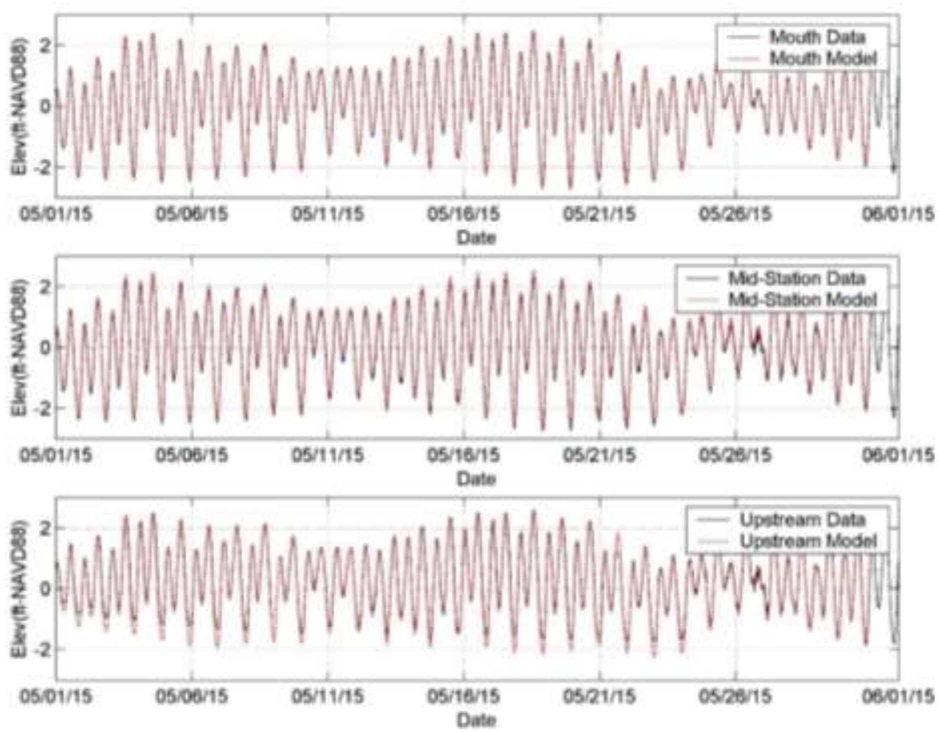

Figure 3-2c. *Simulated versus Measured Water Levels at SRWMD Stations 02326140 (mouth - top panel), 02326100 (mid-river - middle panel), and 02326090 (upstream - bottom panel) in May 2015.*

Table 3-1. Model Calibration Statistics.

Station Number	Station Name	Parameter	Units	RMS Error	RMS %	Mean Error	R^2
02326140	Econfina - Mouth	Water Level	ft	0.05	1%	0.01	1.00
02326100	Econfina - Middle	Water Level	ft	0.16	4%	0.09	0.99
02326909	Econfina - Upstream	Water Level	ft	0.18	4%	-0.07	0.98
02326100	Econfina - Middle	Flow	cfs	128.2	13%	2.0	0.78

3.3 SIMULATED VERSUS MEASURED FLOW

Figures 3-3a through 3-3f present comparisons of the measured versus simulated flow at Station SRWMD 02326100. The plots present month-long comparisons of the simulated versus the flows derived from the ADCP data along with the direct flow measurements used to develop the flow time series. Additionally, zoomed-in views in time are presented around the dates of the direct flow measurements. These comparisons show that the model is doing well simulating the magnitude, shape and timing of the flow signal. A key aspect of capturing the magnitude, shape and timing of the flow was the inclusion of the upstream storage areas that are fed from the tributaries. The storage areas flood and dry based upon the water level conditions, with the total area filled in the storage areas dependent upon the level reached under the high tide conditions. For higher tides (during spring tide conditions), more of the storage area fills and for a longer time frame.

Table 3-1 presents the model statistics for the flow comparisons. The results show that the RMS error is around 128 cfs, which is reflective of a 13 percent error. As with the water levels, the percent error was calculated using the average daily range of flow for the period of the error analysis. While the literature are sparse relative to tidal flow comparisons, recent peer-reviewed work for SWFWMD identified 20 percent as an acceptable percent RMS error for the simulation of tidal flow (Janicki, 2014). The mean error is very low, 2.0 cfs, and the R^2 value is 0.78, which is a reasonable correlation between the measured and modeled flow.

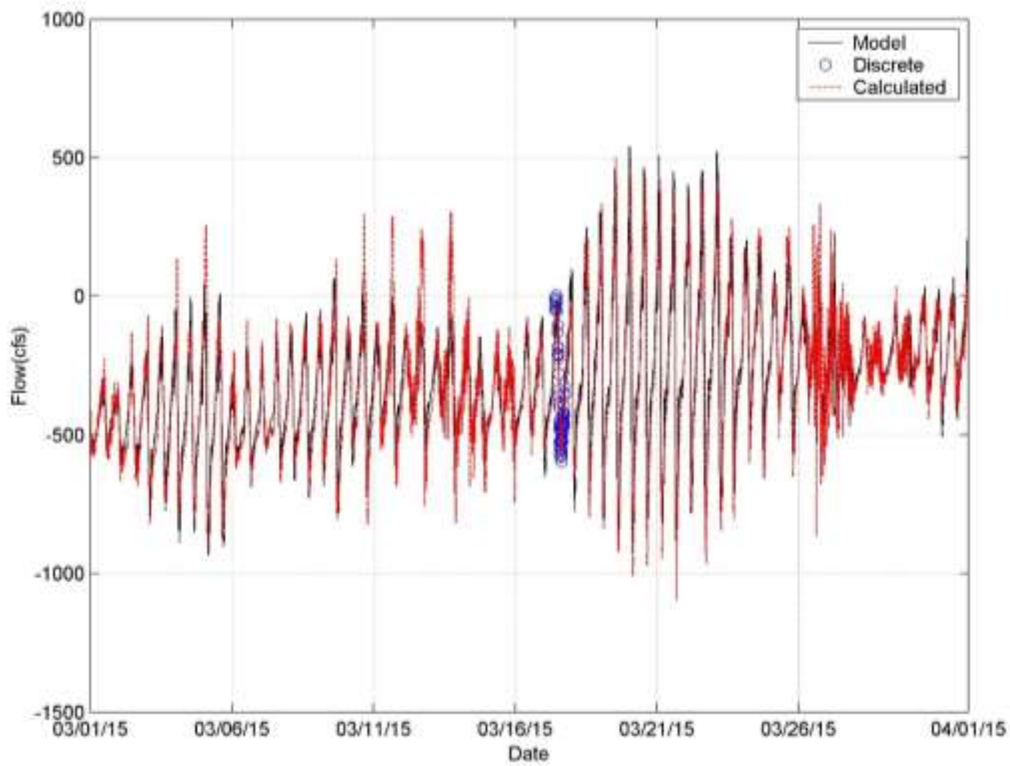

Figure 3-3a. Simulated versus Measured Flow at SRWMD 02326100 in March 2015.

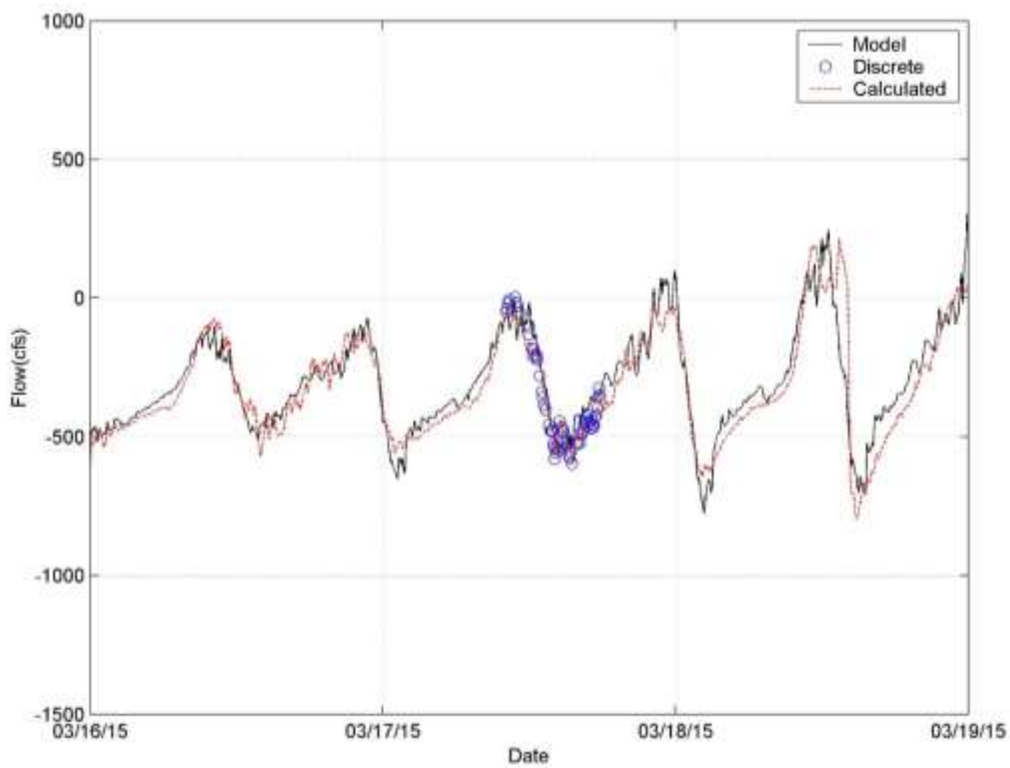

Figure 3-3b. Simulated versus Measured Flow at SRW,D 02326100 (March 16 to 19, 2015)

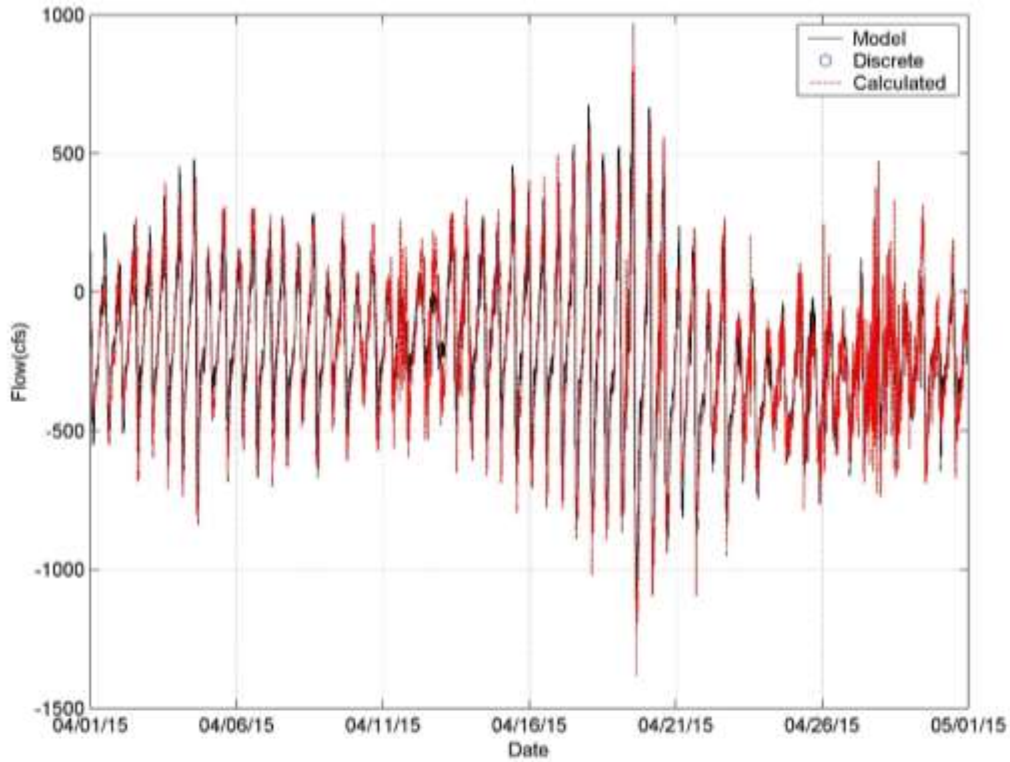

Figure 3-3c. Simulated versus Measured Flow at SRWMD 02326100 in April 2015.

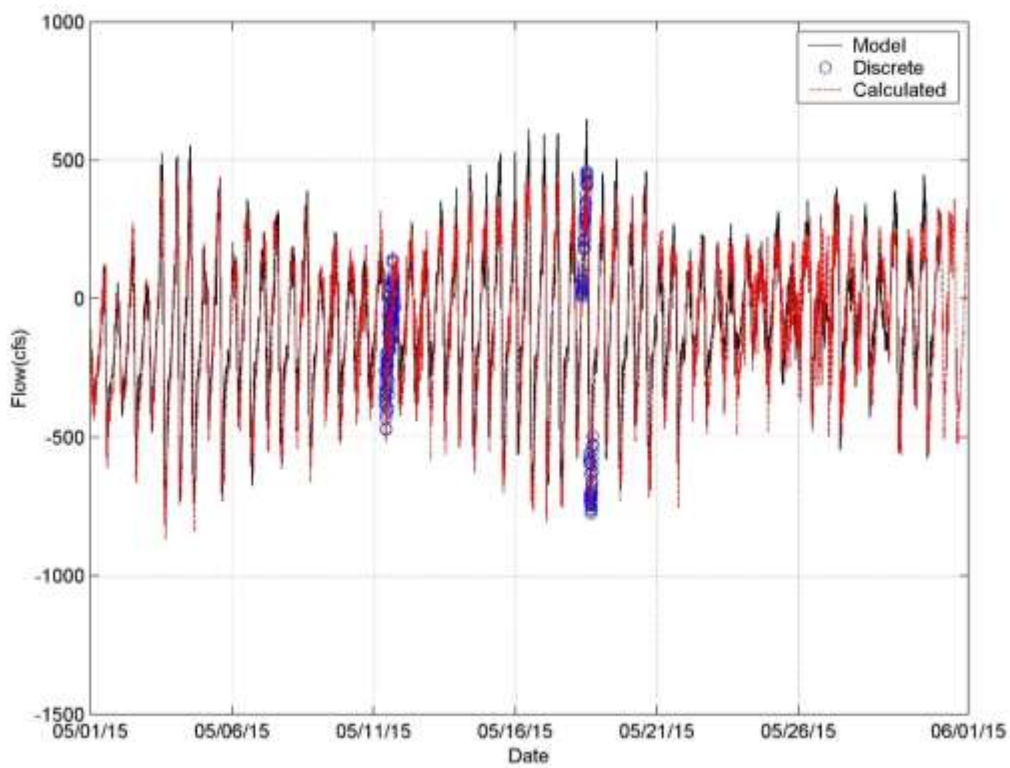

Figure 3-3d. Simulated versus Measured Flow at SRWMD 02326100 in May 2015.

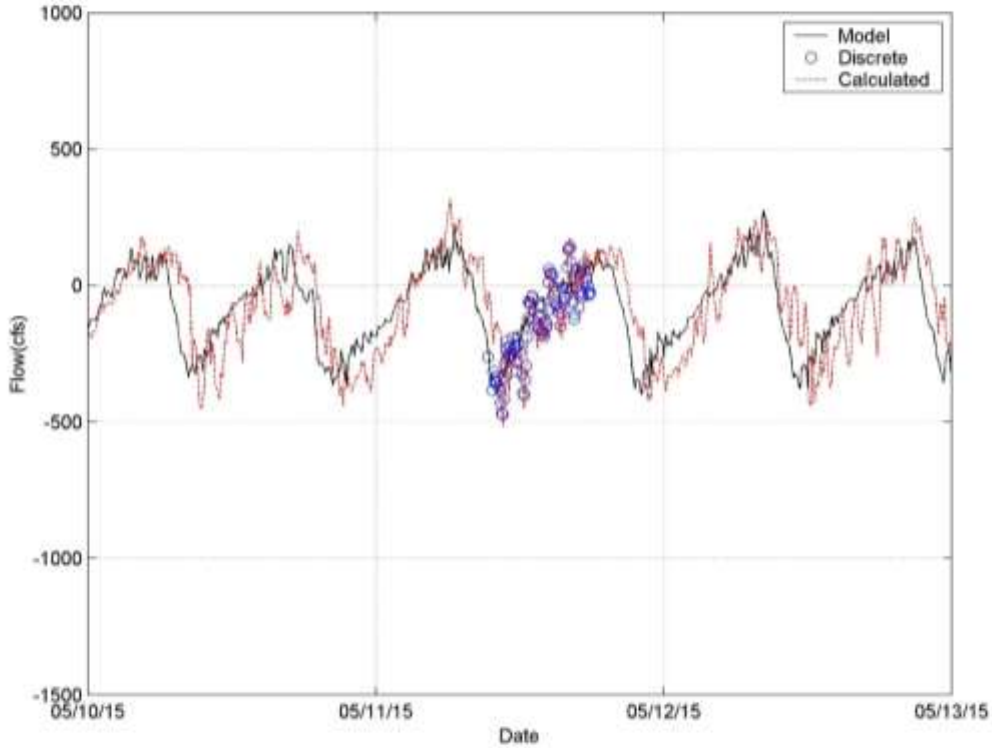

Figure 3-3e. Simulated versus Measured Flow at SRWMD 02326100 (May 10 to 13, 2015)

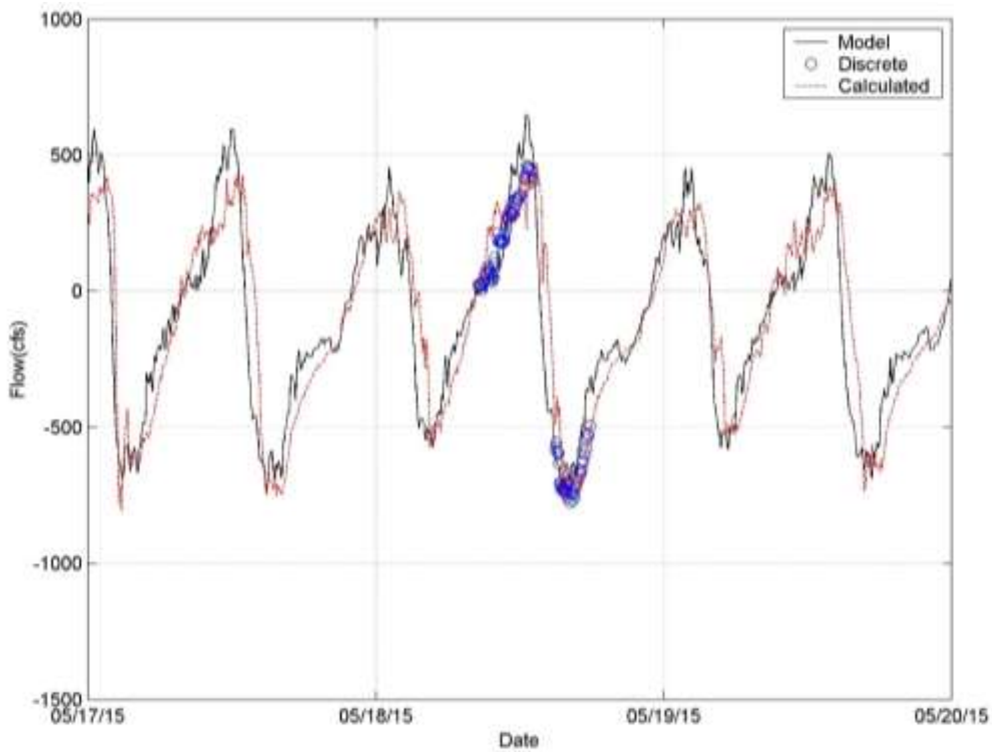

Figure 3-3f. Simulated versus Measured Flow at SRWMD 02326100 (May 17 to 20, 2015)

3.4 SIMULATED VERSUS MEASURED SALINITY

Figures 3-4a through 3-4c present comparisons of the measured versus simulated salinity at the downstream, mid-stream, and upstream stations. For the mid-stream station, comparisons are provided for both the surface and bottom results. Due to the nature of the salinity data and model simulations, with intermittent time frames where the salinity intrusion reaches the mid-stream station (the upstream station was beyond the reach of observed salinity intrusion during the calibration period), the error statistics presented for the water level and the flow do not apply. Additionally, the nature of the salinity intrusion is such that a very sharp salinity front moves up into the system, with the greatest level of intrusion occurring during neap tide conditions, when the energy is low and the level or sharpness of the stratification is highest. Due to the sharpness of the salinity front, a small error in the horizontal distance of the intrusion can result in a significant error in the salinity as the front moves up the system. For example, if the level of the salinity front intrusion in the model is 100 feet short of the location of the station where salinity measurements are taken, the data could show that salinities might reach on the order of 10 to 15 parts per thousand (ppt) on the bottom, but the model simulations could show zero salinity, even though the modeled intrusion level was only a short distance below the gage location. Additionally, models, by their nature, tend to smear sharp gradients based on the level of model vertical or horizontal resolution. For the Econfina model, the balance between having feasible run times for model scenarios and vertical resolution (needed to represent the sharp nature of the stratification in the system) lead to running the model with six vertical layers. While providing relatively good resolution in comparison with the depths, this level of vertical resolution still created some vertical smearing of the salinity profile. As a result of these issues, the graphical comparisons show that the model is doing well simulating the extent of the salinity intrusion and the overall magnitude response at the surface and bottom. A key aspect is that during the entire 3-month calibration period, during both high flow (early) and low flow (late), the model shows that the level and timing of intrusions measured at the mid-stream station were very good. This comparison at the upstream-most measured extent of salinity (the mid-stream site) further supports the model's capability to simulate the variations in salinity intrusion under varying freshwater inflow and tidal forcing conditions.

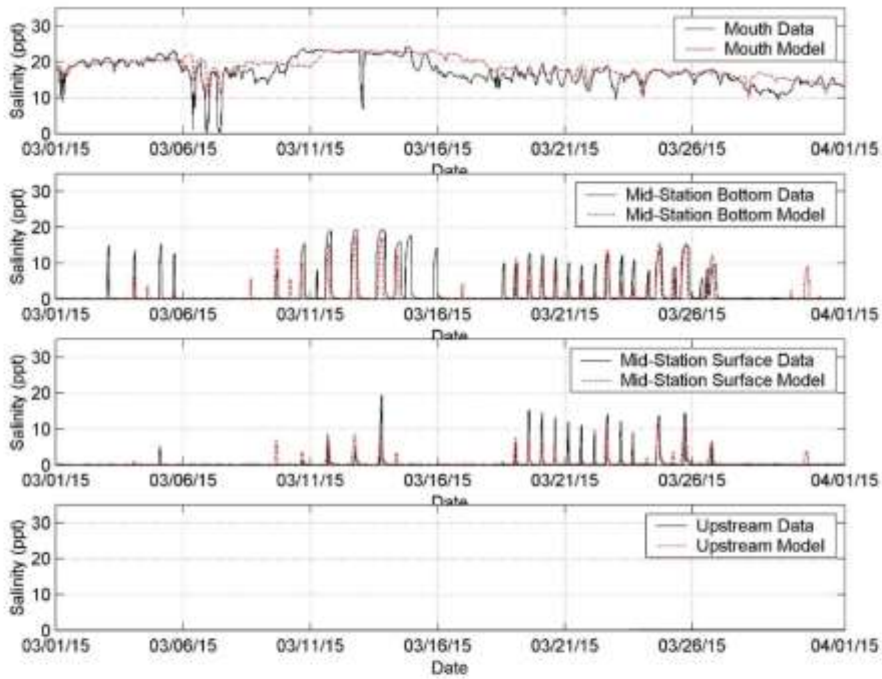

Figure 3-4a. *Simulated versus Measured Salinity at SRWMD Stations 02326140 (bottom), 02326100 (surface and bottom), and 02326090 (bottom) in March 2015. Note: where the salinity is zero, the flow was such that salinity was pushed downstream of the station.*

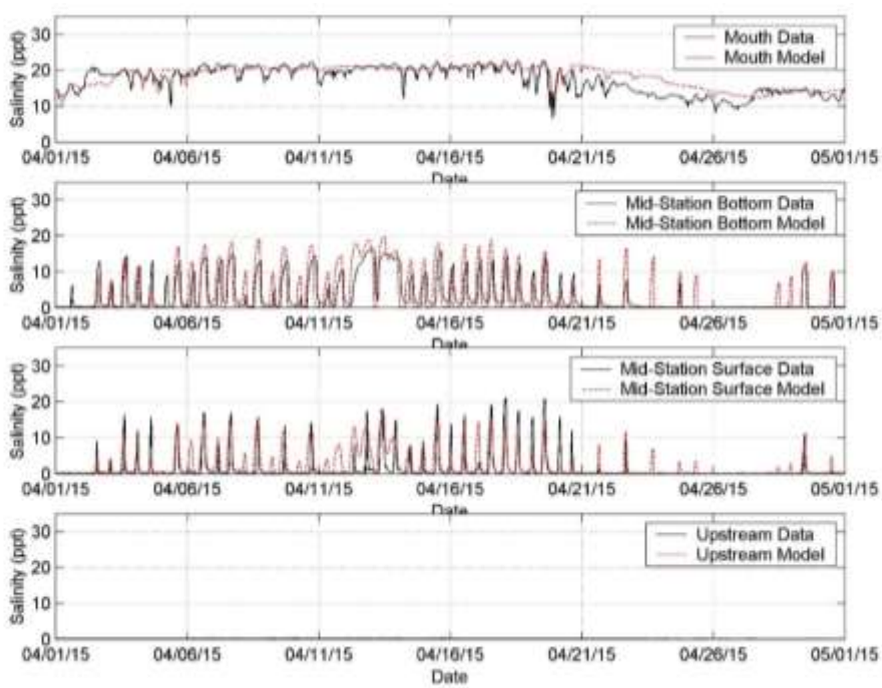

Figure 3-4b. *Simulated versus Measured Salinity at 02326140 (bottom), 02326100 (surface and bottom), and 02326090 (bottom) in April 2015. Note: where the salinity is zero, the flow was such that salinity was pushed downstream of the station.*

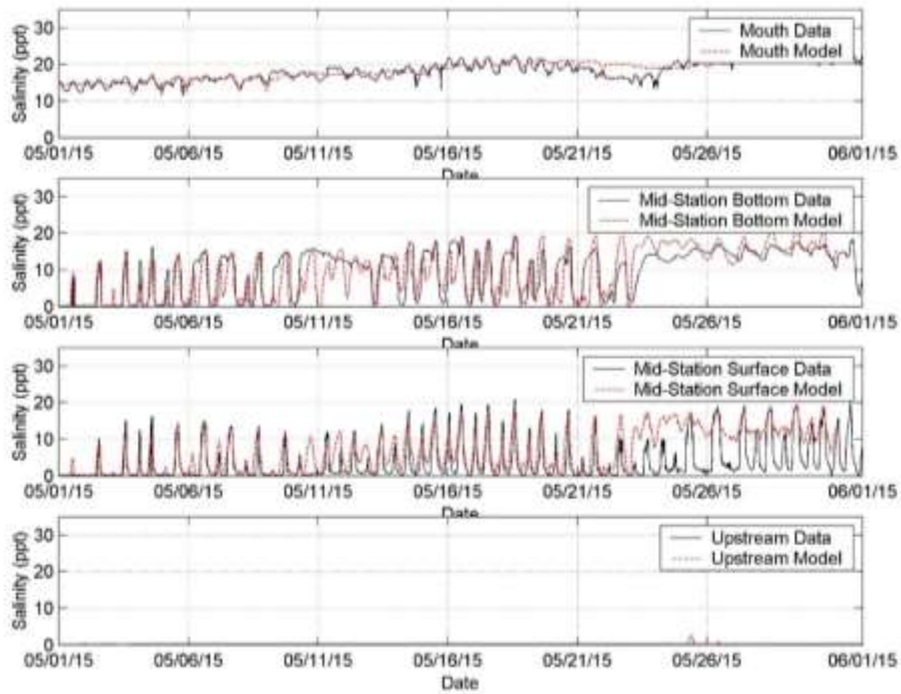

Figure 3-4c. *Simulated versus Measured Salinity at SRWMD Stations 02326140 (bottom), 02326100 (surface and bottom), and 02326090 (bottom) in May 2015. Note: where the salinity is zero, the flow was such that salinity was pushed downstream of the station.*

4.0 MFL SCENARIOS

Utilizing the calibrated hydrodynamic model, various scenarios were run to assess the impacts of flow reduction and sea level rise on the salinity conditions in the system. The salinity results from the scenario runs are presented in detail within the MFL document. This report presents the scenario conditions and model inputs. The specific model scenarios run include the following:

- Baseline condition
- 10 percent flow reduction
- 20 percent flow reduction
- 30 percent flow reduction
- Sea level rise (5.1 inches)

For all of the scenarios, a 2-year period was defined as representative of the full range of hydrologic (freshwater inflow) conditions seen for the river. The MFL document provides a detailed discussion of how this 2-year period was selected. For the Econfina River, the 2-year period was from October 1, 2001 through September 30, 2003.

For the Econfina model baseline time period of October 1, 2001 through September 30, 2003, the offshore boundary conditions for elevation and salinity were taken from the GCSM output. The GCSM output spanned the period 1995-2002. The GCSM output of September 15, 2001 to December 31, 2002 was used for the offshore boundary condition for the same period for the Econfina model, and the January 1, 2003 to September 30, 2003 offshore boundary conditions for the Econfina model were approximated by the GCSM output for January 1, 2002 to September 30, 2002.

The upstream inflow conditions were calculated based upon a relationship established between the upstream gage near Perry (USGS 02326000) (see Figure 1-1b) and the measured flow at the mid-station (02326100) for the period of the field data collection (February 2015 to May 2015). The details of the relationship are presented within the MFL document along with the flow conditions for the scenarios. For the flow reduction scenarios, the time series of flow used in the baseline run was reduced by the amounts listed above and the model simulations run using the identical water levels, offshore salinity, and wind conditions for the 2-year period.

For the Sea Level Rise scenario, the 5.1 inches was prescribed by SRWMD staff and this value was added as a constant value to the offshore forcing tides. This simulation then represented a future condition with a static 5.1 inch rise in sea level.

5.0 SUMMARY AND CONCLUSIONS

This report provided a summary of the development, calibration, and application of a hydrodynamic model developed for the tidal portion of the Econfina River. This included the following:

- Development of the model grid and bathymetry
- Development of the model input conditions
- Model calibration approach
- Graphical and statistical comparison of the simulations versus data
- Summary of the model inputs used for the MFL scenarios

The model extended offshore within the Gulf of Mexico and up the main stem of the Econfina River to a point approximately 3.5 miles upstream of the mouth, including adjacent tributaries and tidal flats (storage areas).

The EFDC model was used to simulate the hydrodynamics, including the water levels, currents, flow, and salinity. The model simulations for the calibration extended from mid-February 2015 to the end of May 2015.

The model had one open boundary condition approximately 2 miles offshore of the mouth of the Econfina River. For the model calibration, the offshore water level boundary conditions were developed from measured water levels at the mouth using boundary matching techniques. The offshore salinity boundary conditions were derived from the daily maxima of the continuous salinity measured at the mouth.

Graphical and/or statistical comparisons of the simulated versus measured water levels were presented at three locations along the system. This included data at the mouth, at a mid-river station, and at the upstream station. The results showed good agreement both graphically and statistically to the measured data.

Graphical and statistical comparisons of the simulated and measured time-dependent flow at the mid-river station were presented. The results showed good agreement between the measured and simulated flow magnitudes, phasing and characteristics.

Graphical comparisons of the simulated and measured salinity were presented. This included bottom data at the mouth, bottom and surface data at the mid-river station, and bottom data at the upstream station. The comparisons showed that the model captured the timing and magnitude of the responses to the freshwater inflow on salinity intrusion and the distribution of the salinity between the stations.

The calibrated hydrodynamic model was then utilized to perform MFL flow reduction simulations. The simulation period for the Econfina River was the 2-year period from October 1, 2001 through September 30, 2003. For this period, the offshore boundary conditions were taken from the GCSM model output for water level and salinity. The salinity and water level data, as well as the overall model geometry, were provided for use in the MFL analyses presented within the primary document.

6.0 REFERENCES

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APPENDIX B.

SEA LEVEL RISE SCENARIO HYDRODYNAMIC MODEL RESULTS

The Econfina River hydrodynamic model was applied to simulate the effects of sea level rise on the baseline condition. The process used to determine the amount of rise followed that used by the SWFWMD for the Chassahowitzka River (SWFWMD, 2012; USACE, 2011) with the rise projected to 2035 instead of 2030. The intermediate projection of 5.1 inches was used in the model to develop the results summarized here. The sea level rise scenario was achieved by increasing the boundary condition water surface elevation by this amount. All other model inputs were the same as used in the baseline scenario.

These observations from the inspection of the following were made:

- The seasonal patterns in the river volume, bottom area, and shoreline length for the 0 ppt, 0-2 ppt, and 0-5 ppt salinity conditions were similar for both the baseline and sea level rise scenarios (Figures 1-3).

- The cumulative distribution functions for the 0 ppt, 0-2 ppt, and 0-5 ppt salinity conditions were similar for both the baseline and sea level rise scenarios (Figure 4).

- The effect of the simulated sea level rise on the locations of both the surface and bottom water isohalines was small with the percent differences between the baseline and sea level rise scenarios ranging from 2.2% to 5.4% with the largest difference being found for the 5 ppt surface water isohaline (Tables 1-2).

- With respect to river volume, the differences between the baseline and sea level rise scenarios were also relatively small. The largest differences were 6.8% which was found for both the 0-2 ppt and 0-5 ppt salinity conditions (Table 3).

- With respect to the bottom area of the Econfina River, the differences between the baseline and sea level rise scenarios were relatively largest for all three salinities considered. These differences ranged from 13.1% to 16.8%, the largest difference was found for the 0-2 ppt salinity condition (Table 4).

- With respect to the shoreline length of the Econfina River, the differences between the baseline and sea level rise scenarios were also relatively large for all three salinities considered. These differences ranged from 8.3% to 16.5%, the largest difference was found for the 0 ppt salinity condition (Table 5).

- Examination of the longitudinal profile of the overall differences between the baseline and sea level rise scenarios shows that the greatest differences were generally found throughout the water column from RM 2.2 to RM 3.2 (Figure 5).

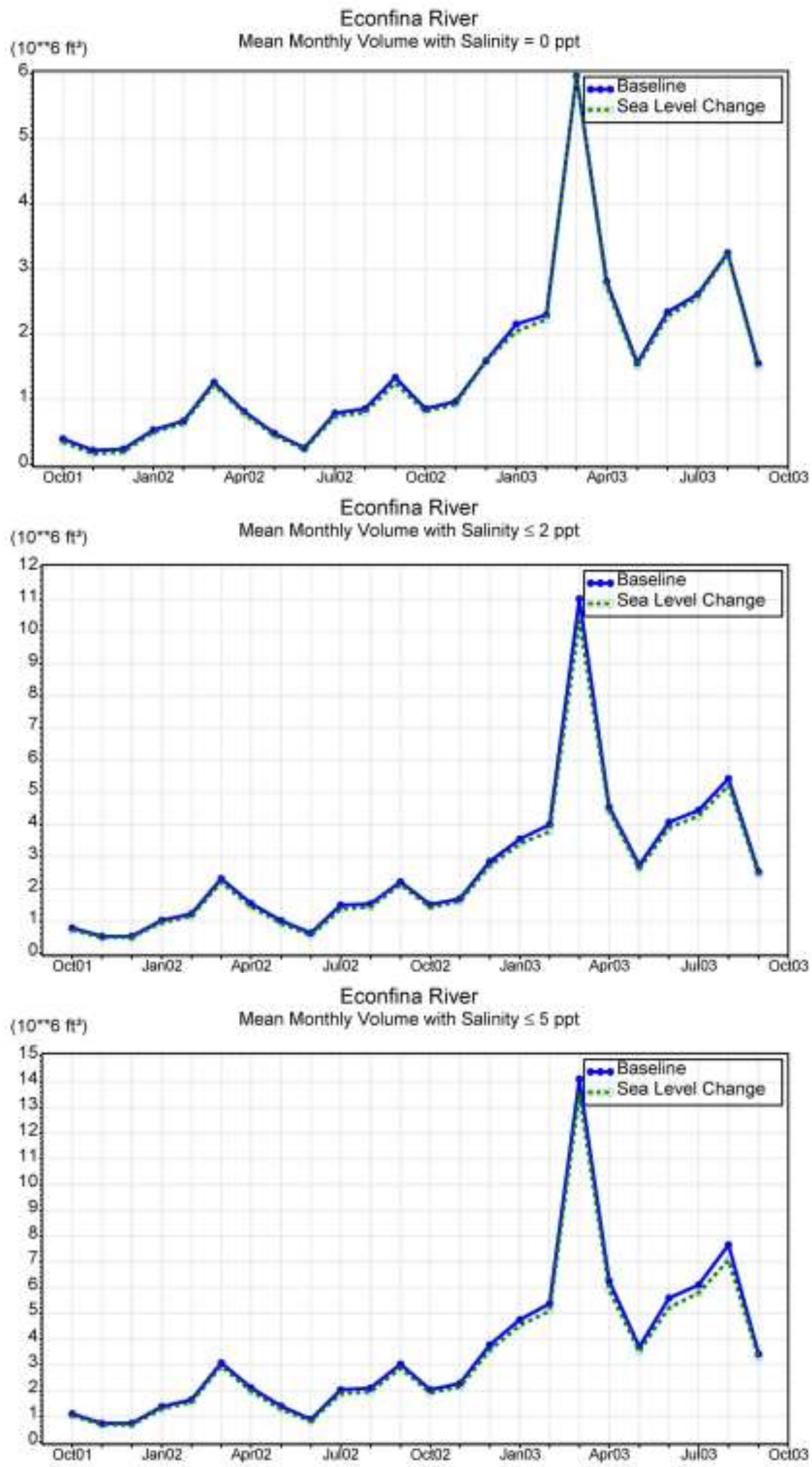

Figure 1. Comparison of the mean monthly river volume with 0, 0-2, and 0-5 ppt salinity for the baseline and sea level rise scenarios

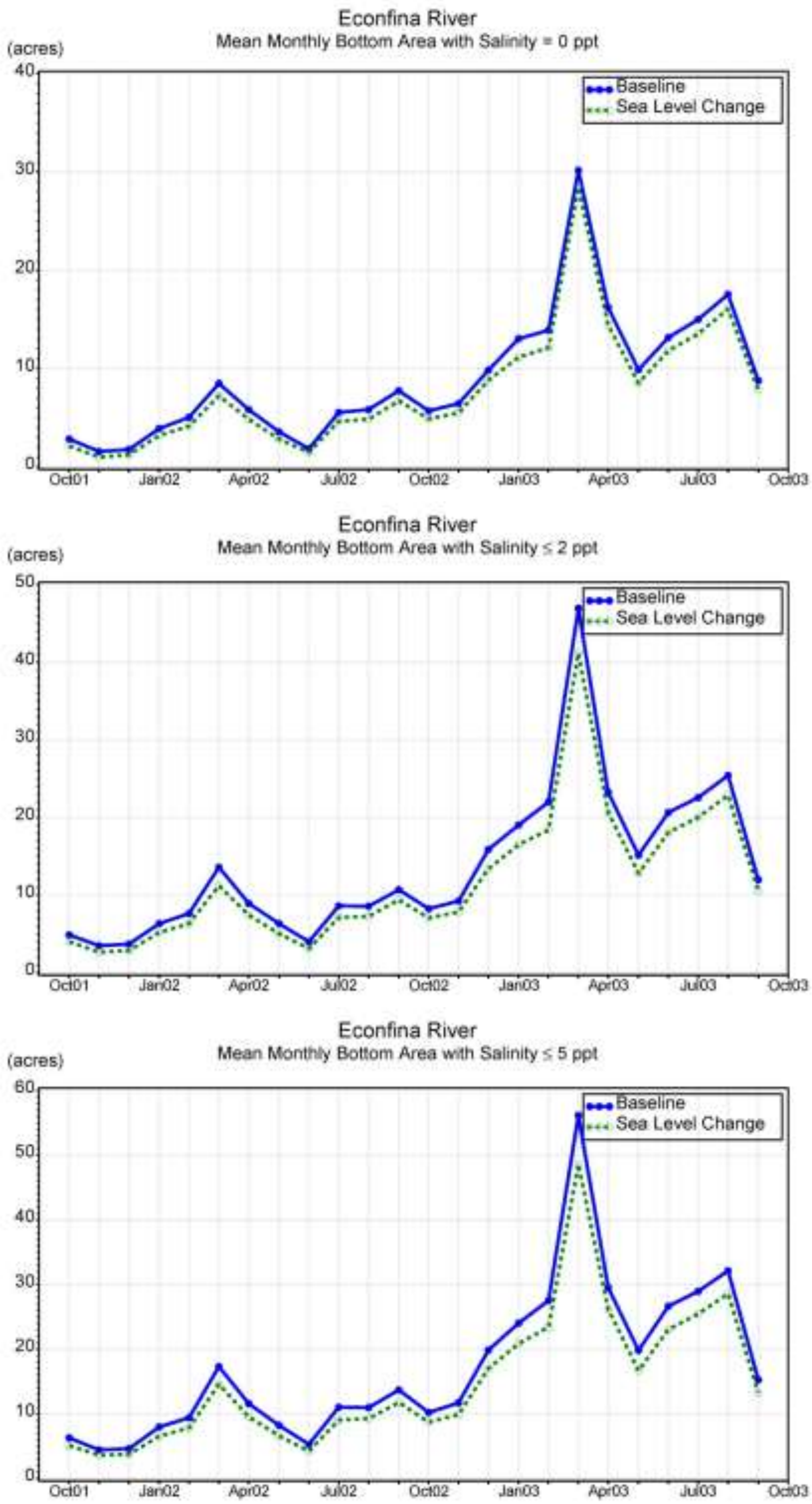

Figure 2. Comparison of the mean monthly bottom area with 0, 0-2, and 0-5 ppt salinity for the baseline and sea level rise scenarios

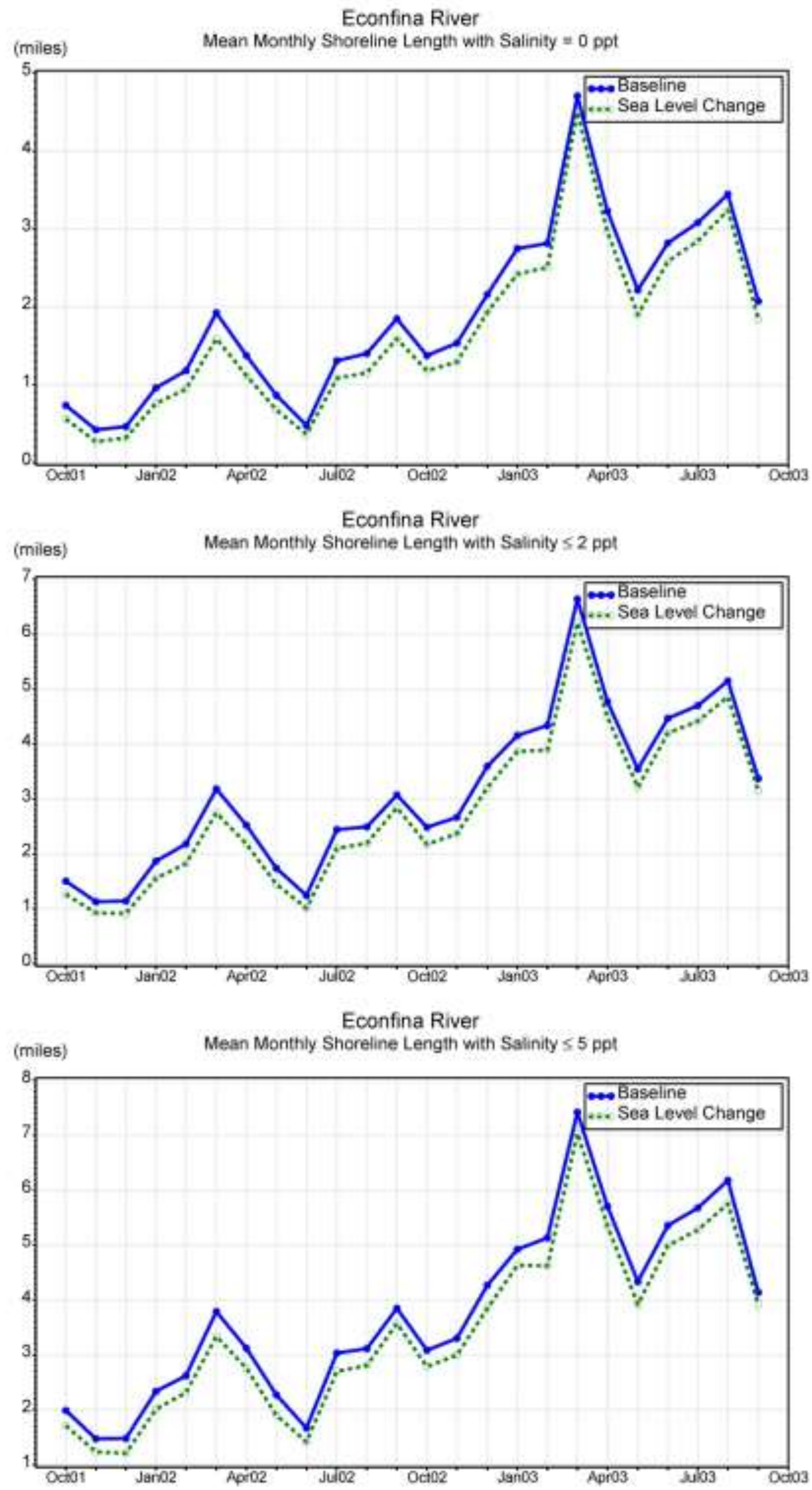

Figure 3. Comparison of the mean monthly shoreline length with 0 ppt salinity for the baseline and sea level rise scenarios.

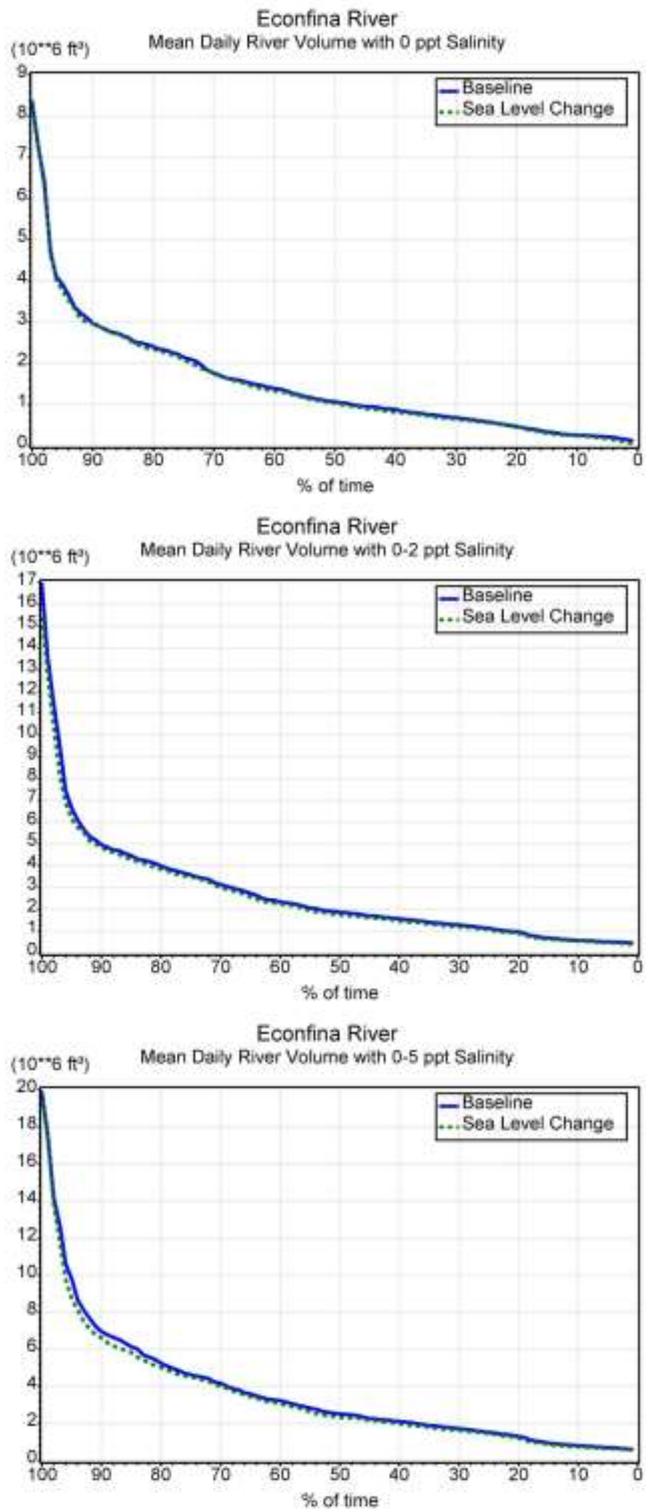

Figure 4. Comparison of the cumulative distribution functions of the mean monthly river volume with 0, 0-2, and 0-5 ppt salinity for baseline and sea level rise scenarios.

Table 1. Comparison of baseline surface isohaline locations to the isohalines to the sea level rise scenario.

Scenario	Parameter	0 ppt	2 ppt	5 ppt
Baseline	River Mile	2.73	2.20	1.92
Sea Level Rise	River Mile	2.79	2.29	2.02
	% Difference from Baseline	2.2%	4.1%	5.4%

Table 2. Comparison of baseline bottom isohaline locations to the isohalines to the sea level rise scenario.

Scenario	Parameter	0 ppt	2 ppt	5 ppt
Baseline	River Mile	2.73	2.46	2.29
Sea Level Rise	River Mile	2.79	2.55	2.38
	% Difference from Baseline	2.2%	3.6%	4.2%

Table 3. Comparison of baseline volume to the volumes for the sea level rise scenario.

Scenario	Parameter	0 ppt	0-2 ppt	0-5 ppt
Baseline	Volume ($ft^3 * 10^3$)	1,061	1,873	2,508
Sea Level Rise	Volume ($ft^3 * 10^3$)	1,029	1,746	2,337
	% Difference from Baseline	-3.0%	-6.8%	-6.8%

Table 4. Comparison of baseline bottom area to the bottom area for the sea level rise scenario.

Scenario	Parameter	0 ppt	0-2 ppt	0-5 ppt
Baseline	Bottom Area ($ft^2 * 10^3$)	7.0	10.2	12.8
Sea Level Rise	Bottom Area ($ft^2 * 10^3$)	6.1	8.5	10.8
	% Difference from Baseline	-13.1%	-16.8%	-16.0%

Table 5. Comparison of baseline shoreline length to the shoreline length for the sea level rise scenario.

Scenario	Parameter	0 ppt	0-2 ppt	0-5 ppt
Baseline	Shoreline Length (ft)	8,791	15,020	18,193
Sea Level Rise	Shoreline Length (ft)	7.344	13,208	16,681
	% Difference from Baseline	-16.5%	-12.1%	-8.3%

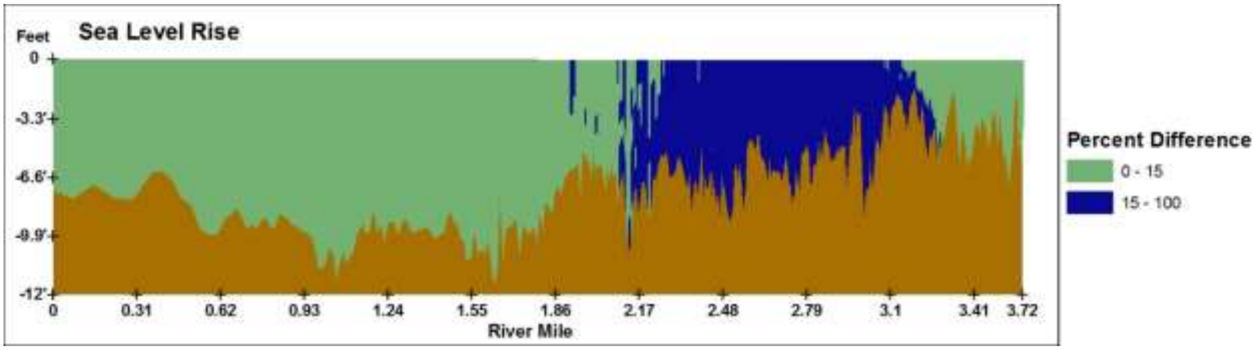

Figure 5. Comparison of the mean monthly river volume with 0 ppt salinity for the baseline and sea level rise scenarios. Values presented are differences in the averages for each lateral row of model cells.

Literature Cited

USACE, 2011. Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs. Circular No. 1165-2-212 http://140.194.76.129/publications/eng-circulars/EC_1165-2-212_2011Nov/EC_1165-2-212_2011Nov.pdf

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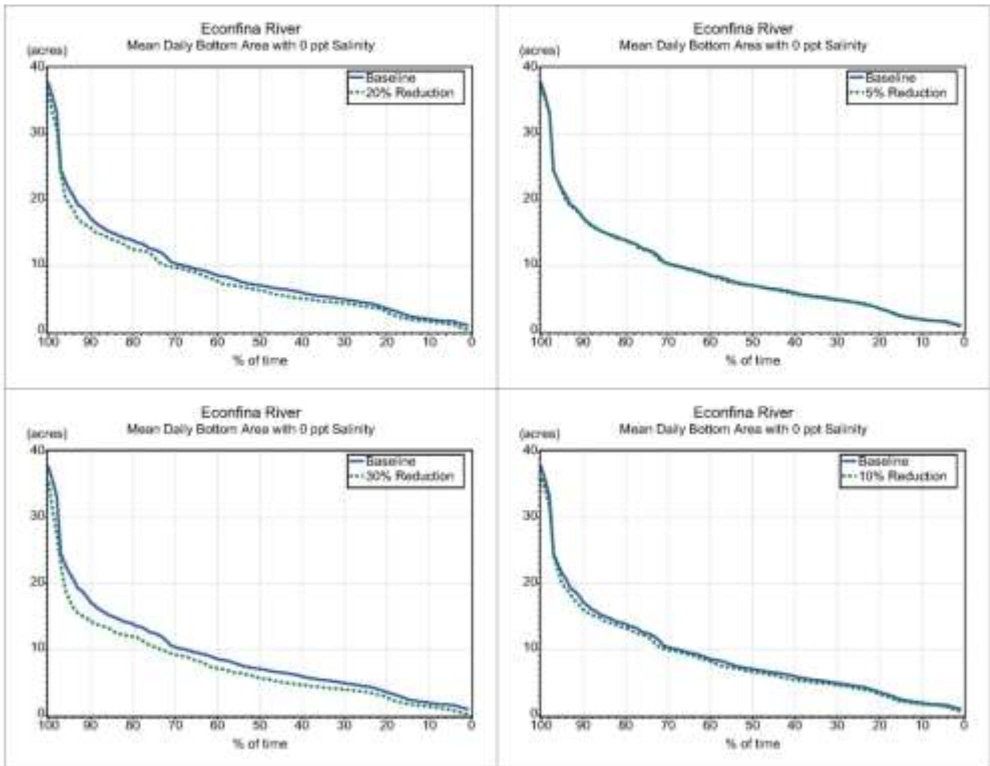
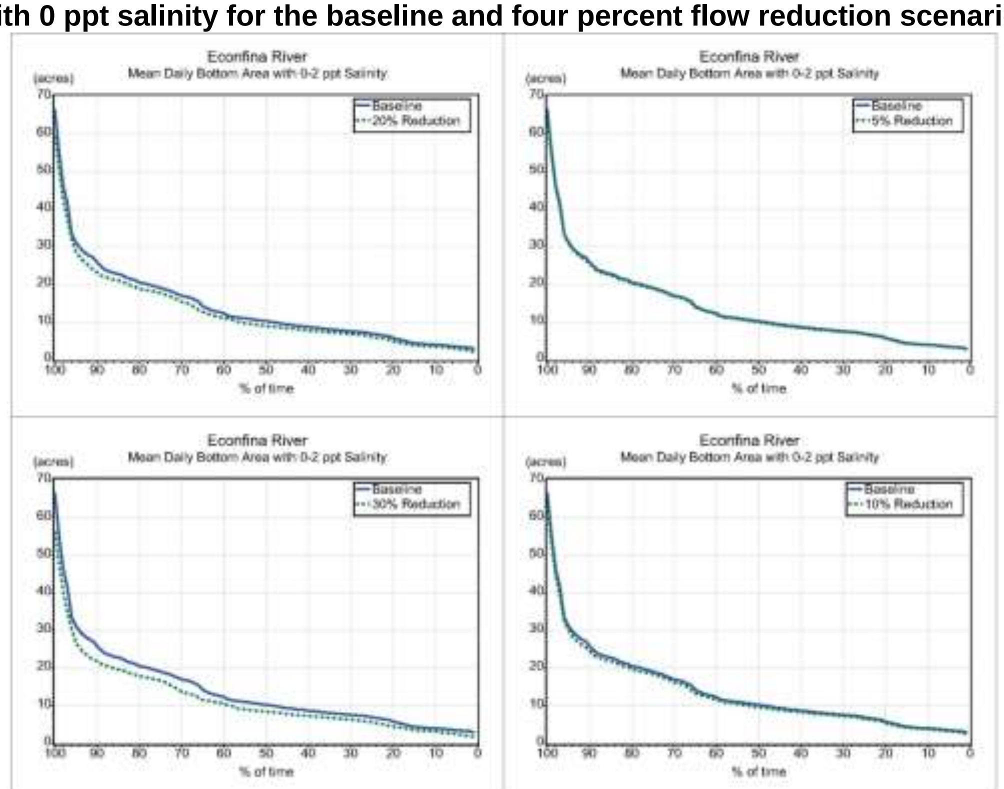
APPENDIX C.

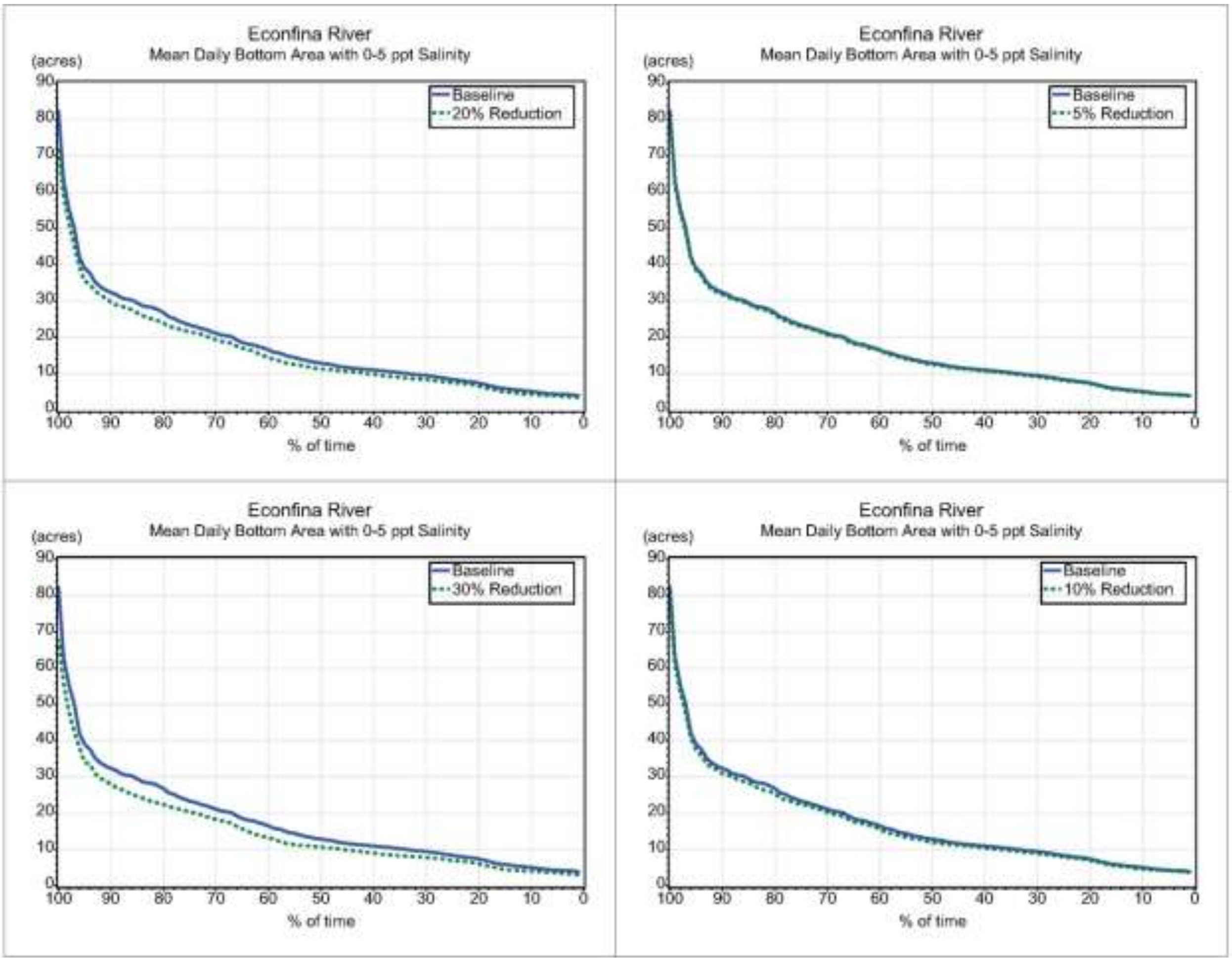
Comparison of the cumulative distribution functions of the mean monthly bottom area and shoreline length with 0 ppt, 0-2 ppt, and 0-5 ppt salinity for the baseline and four percent flow reduction scenarios and time series plots of the 0, 2, and 5 ppt isohalines



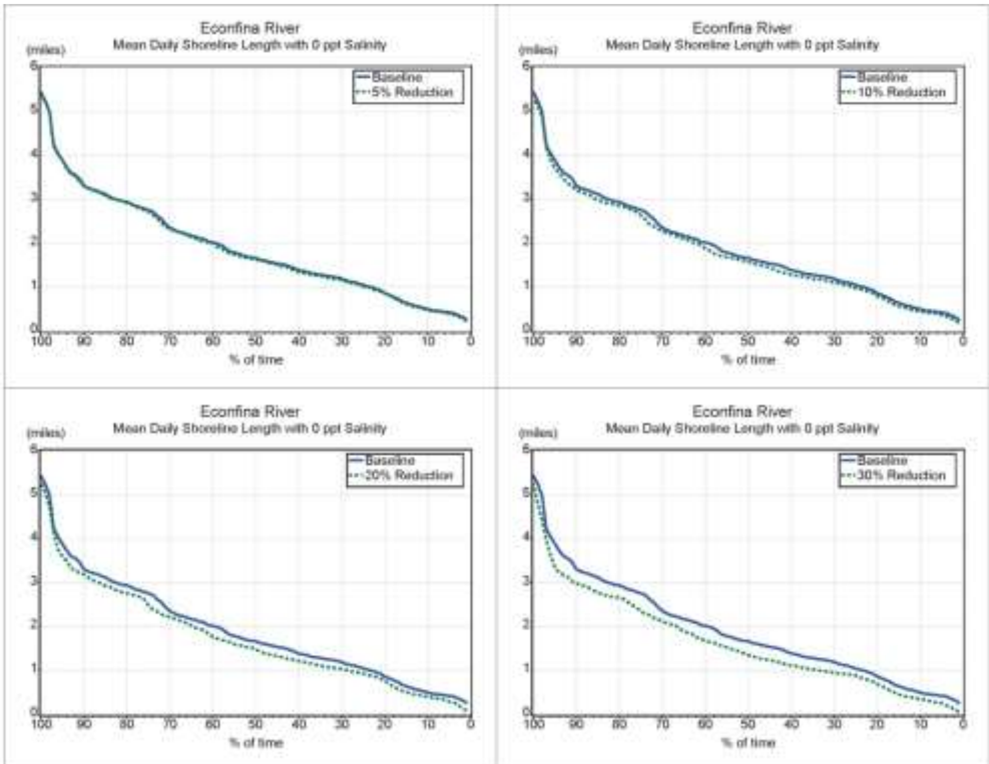
Comparison of the cumulative distribution functions of the mean monthly bottom area with 0 ppt salinity for the baseline and four percent flow reduction scenarios.



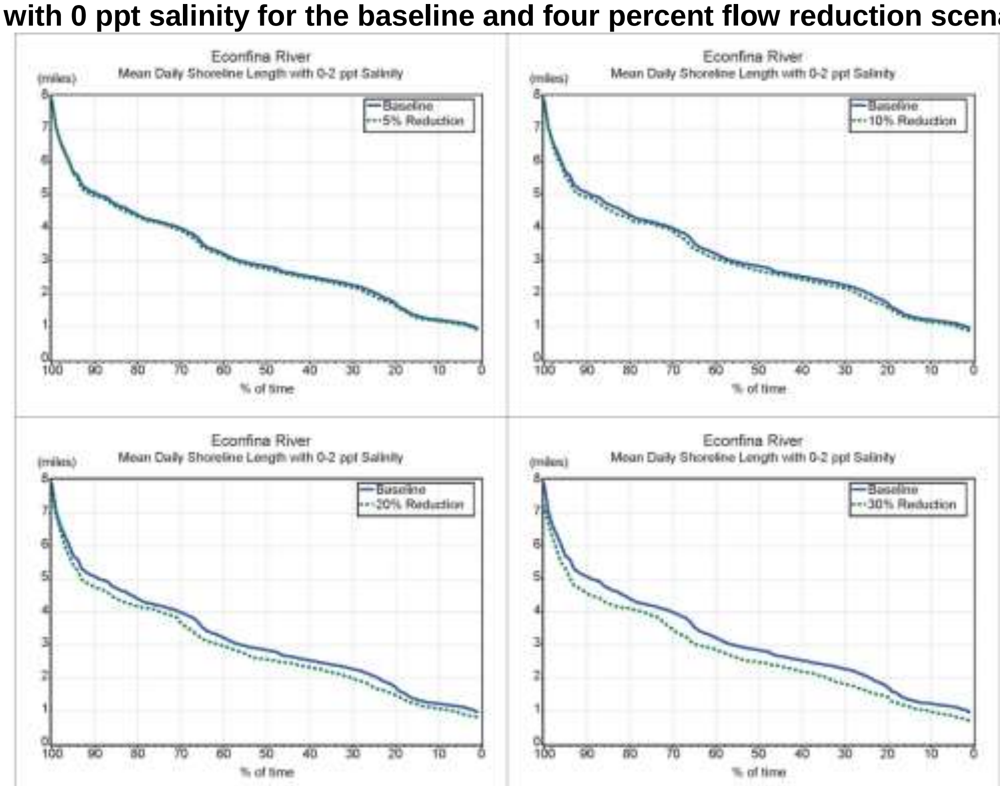
Comparison of the cumulative distribution functions of the mean monthly bottom area with 0-2 ppt salinity for the baseline and four percent flow reduction scenarios.



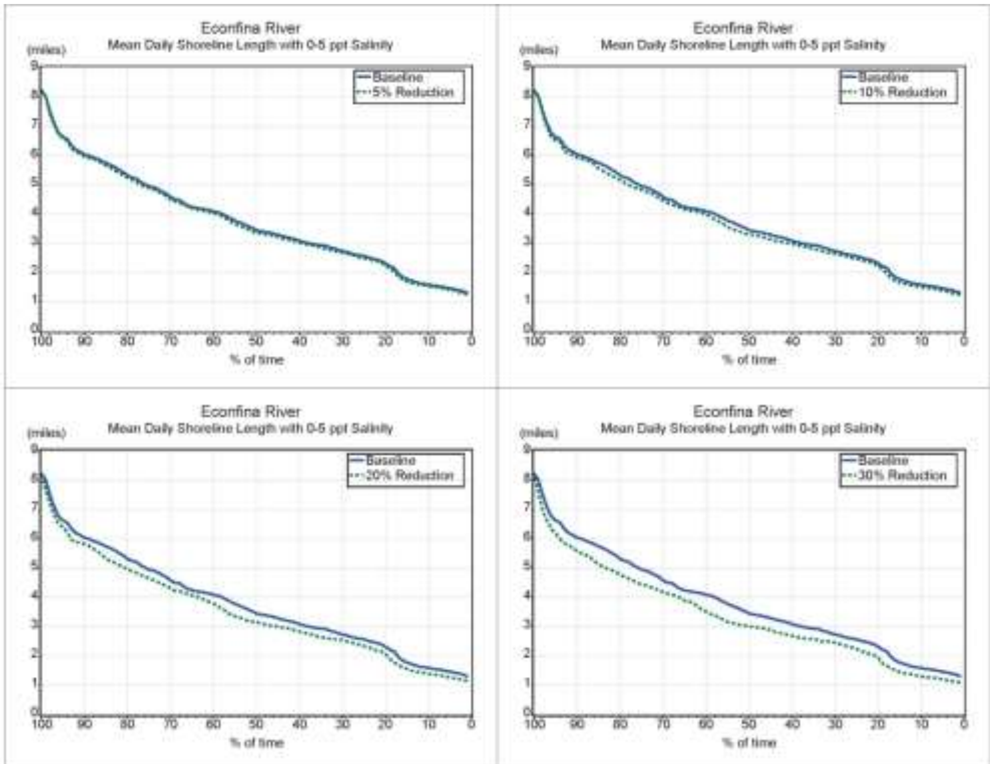
Comparison of the cumulative distribution functions of the mean monthly bottom area with 0-5 ppt salinity for the baseline and four percent flow reduction scenarios.



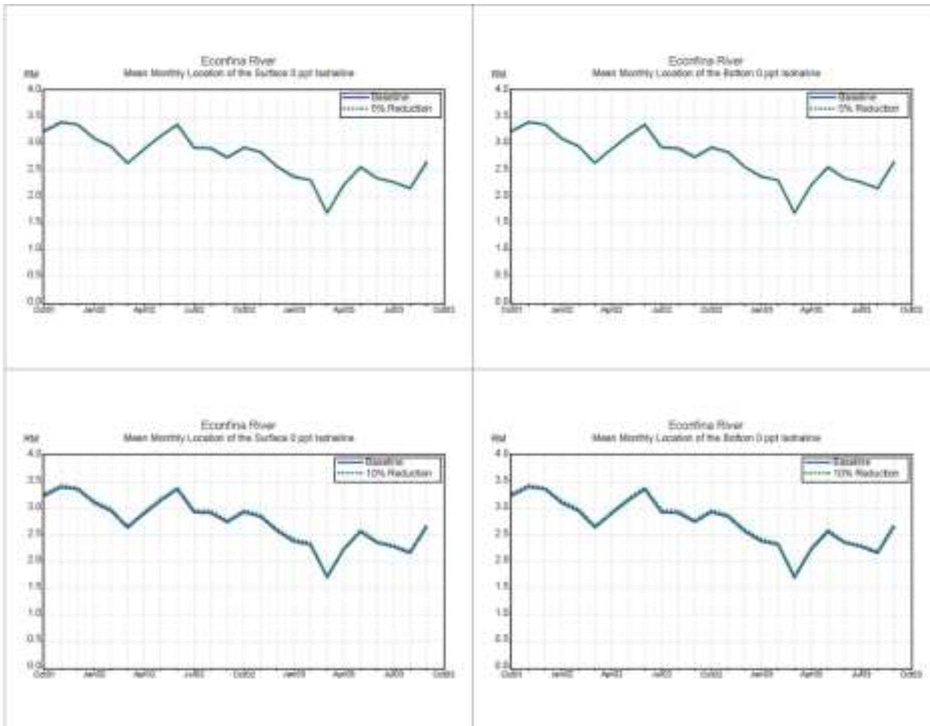
Comparison of the cumulative distribution functions of the mean monthly shoreline length with 0 ppt salinity for the baseline and four percent flow reduction scenarios.



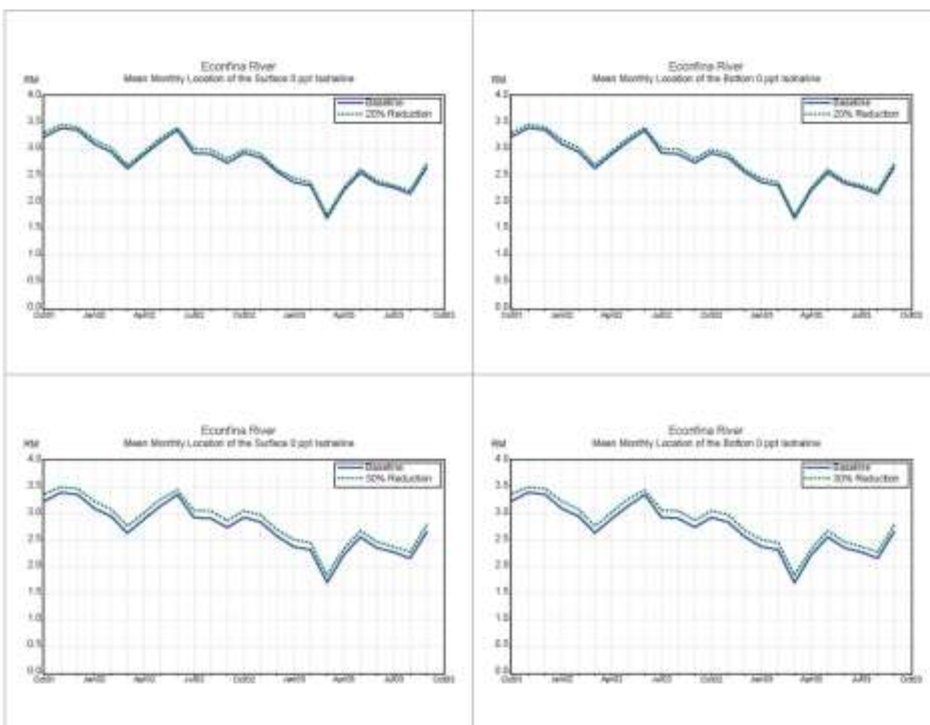
Comparison of the cumulative distribution functions of the mean monthly shoreline length with 0-2 ppt salinity for the baseline and four percent flow reduction scenarios.



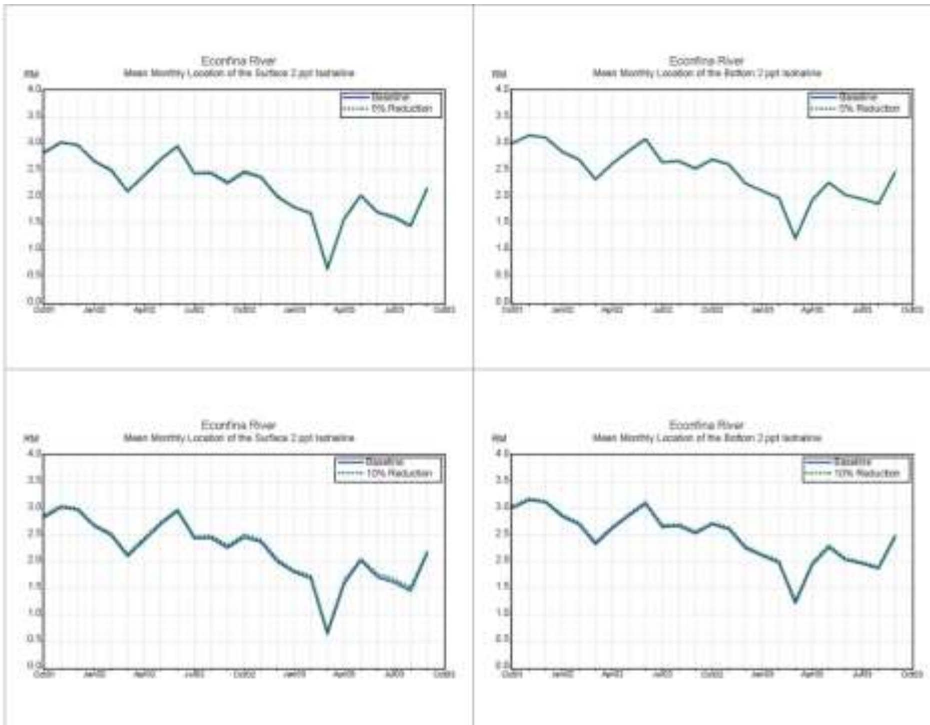
Comparison of the cumulative distribution functions of the mean monthly shoreline length with 0-5 ppt salinity for the baseline and four percent flow reduction scenarios.



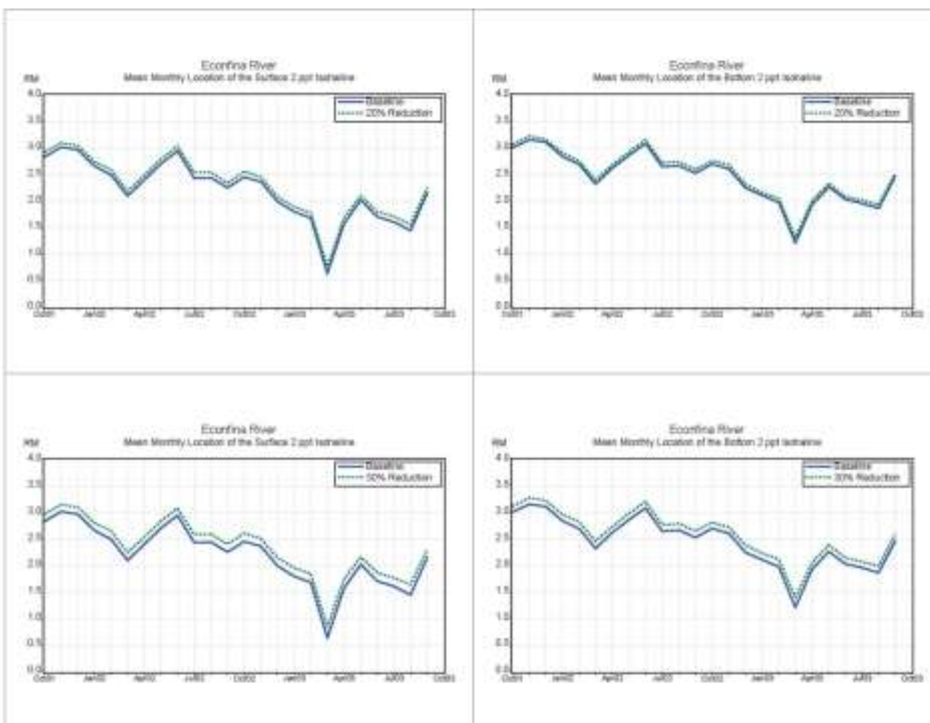
Comparison of the mean monthly surface and bottom 0 ppt isohalines for the baseline and the 5% and 10% flow reduction scenarios.



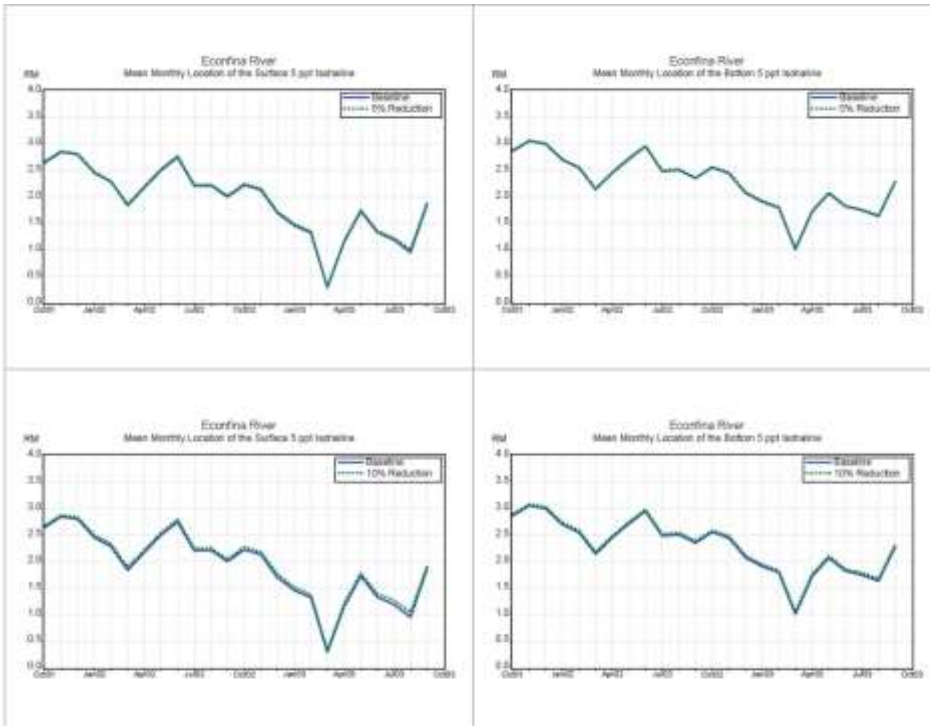
Comparison of the mean monthly surface and bottom 0 ppt isohalines for the baseline and the 20% and 30% flow reduction scenarios.



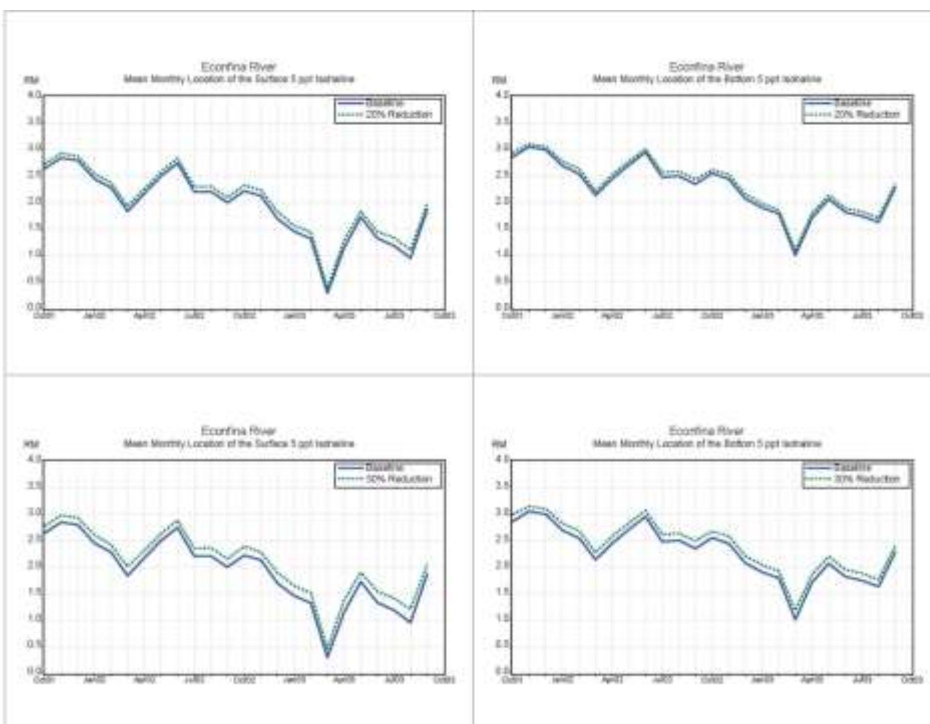
Comparison of the mean monthly surface and bottom 2 ppt isohalines for the baseline and the 5% and 10% flow reduction scenarios.



Comparison of the mean monthly surface and bottom 2 ppt isohalines for the baseline and the 20% and 30% flow reduction scenarios.



Comparison of the mean monthly surface and bottom 5 ppt isohalines for the baseline and the 5% and 10% flow reduction scenarios.

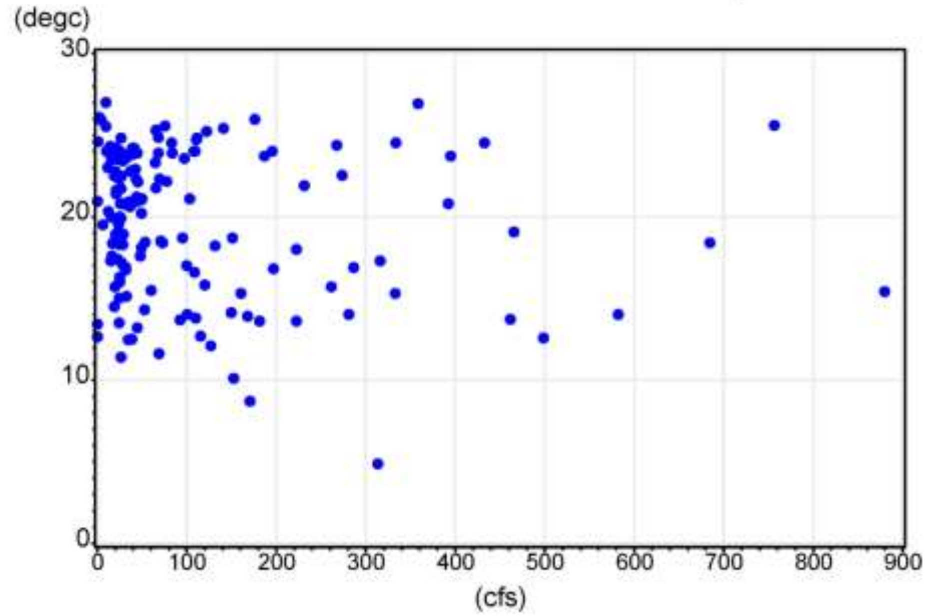


Comparison of the mean monthly surface and bottom 5 ppt isohalines for the baseline and the 20% and 30% flow reduction scenarios.

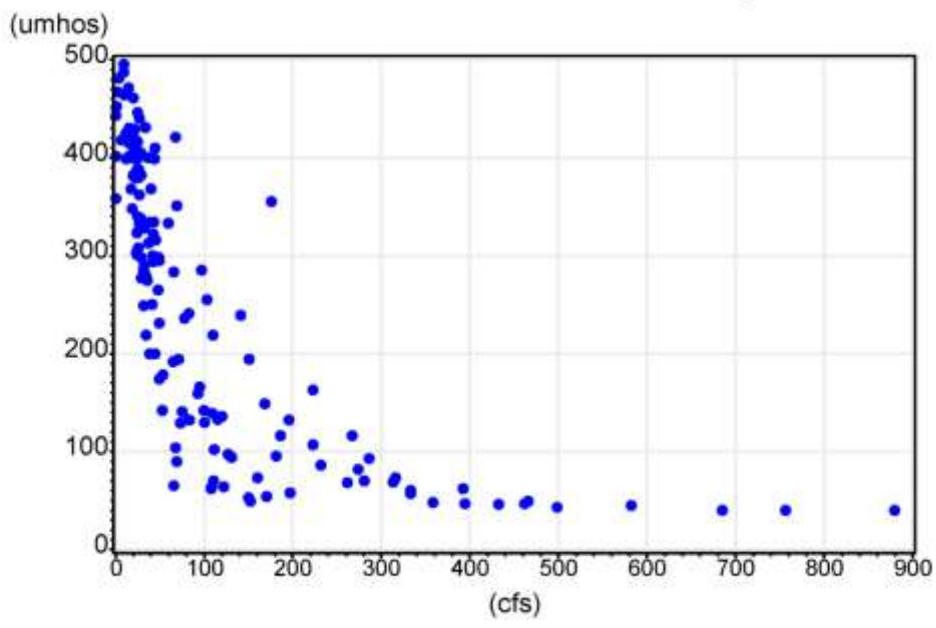
APPENDIX D.

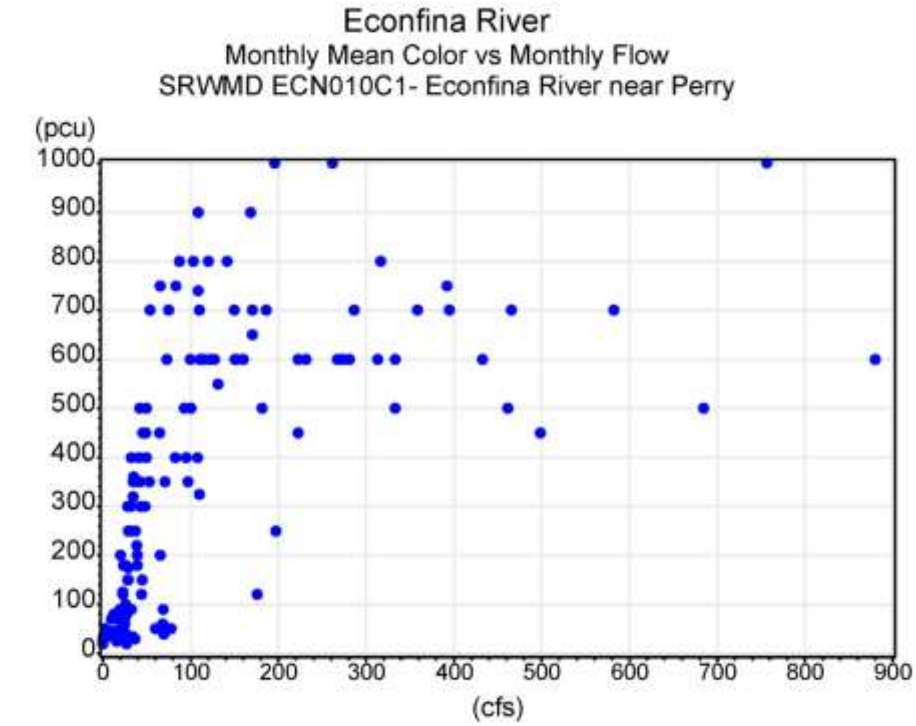
Relationships between water quality and River flow in the Econfina River.

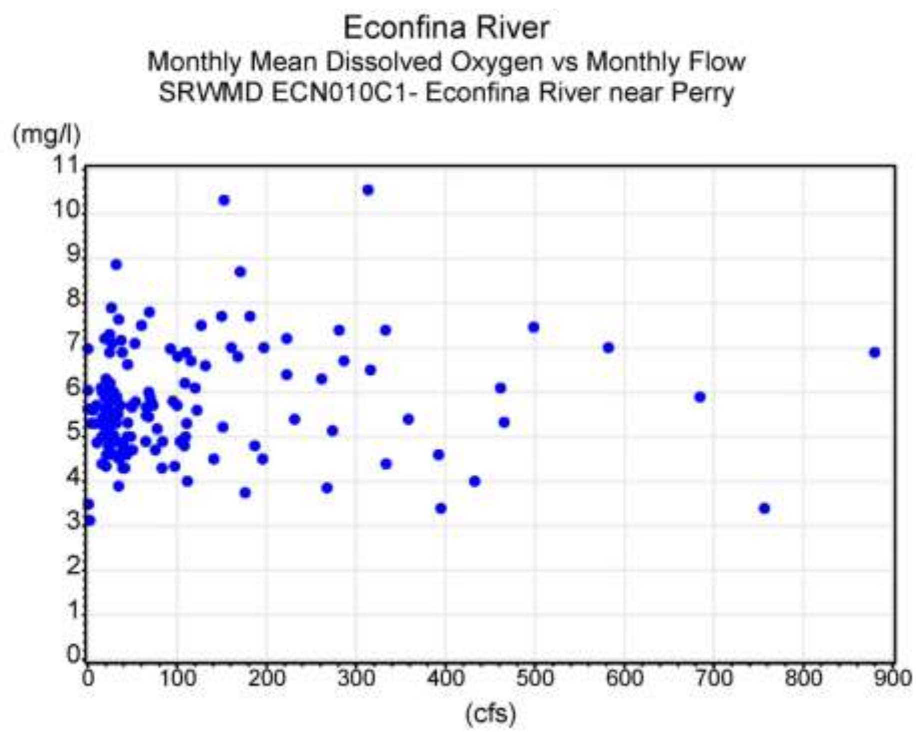
Econfina River
Monthly Mean Temperature vs Monthly Flow
SRWMD ECN010C1- Econfina River near Perry



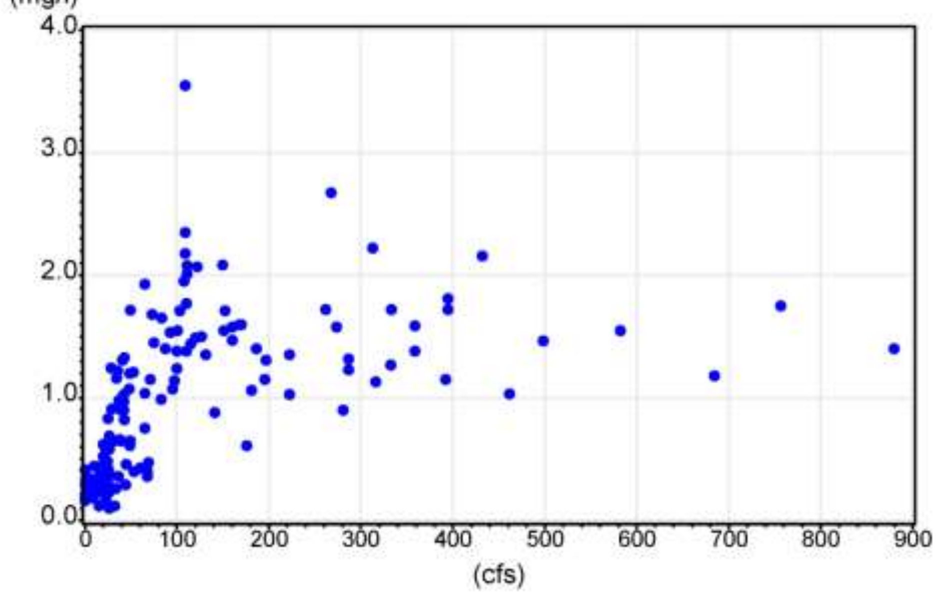
Econfina River
Monthly Mean Conductivity vs Monthly Flow
SRWMD ECN010C1- Econfina River near Perry




Econfina River
Monthly Mean Color vs Monthly Flow
SRWMD ECN010C1- Econfina River near Perry
(pcu)
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
(cfs)


Econfina River
Monthly Mean Dissolved Oxygen vs Monthly Flow
SRWMD ECN010C1- Econfina River near Perry
(mg/l)
11
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800
900
(cfs)

Econfina River
Monthly Mean Total Nitrogen vs Monthly Flow
SRWMD ECN010C1- Econfina River near Perry



Econfina River
Monthly Mean Total Phosphorus vs Monthly Flow
SRWMD ECN010C1- Econfina River near Perry