

MEMO

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Subject: Caloosahatchee River Basin Watershed Model Review and Calibration Refinement –
Final Task 1 Findings and Recommendations

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1.0 INTRODUCTION

Tetra Tech and AMEC were contracted by the Florida Department of Environmental Protection (department) to address department and stakeholder issues regarding the set up and calibration of the current versions of the Caloosahatchee River and Estuary Hydrologic Simulation Program – FORTRAN (HSPF) and Environmental Fluid Dynamics Code (EFDC) models. These models will be used to develop total maximum daily loads (TMDLs) for impaired freshwater bodies within the Caloosahatchee River Basin and to refine the Caloosahatchee tidal estuary TMDLs that the department adopted in 2009. The department provided Tetra Tech with the HSPF model files, as well as the associated report developed by Dynamic Solutions and CDM in 2009. The department provided the EFDC modeling report developed by Dynamic Solutions and CDM in 2009, but did not provide the associated EFDC modeling files. Since 2009, the department has made modifications to both the HSPF and EFDC models, including extending the model simulation time and adjusting the delineation boundaries. The revised HSPF and EFDC model files were provided for review in this project.

The first task in this project is to review the existing HSPF and EFDC models, including the conceptual structure, watershed delineations and reach segmentation, model input data, mathematical stability, model parameterization, and comments raised by stakeholders, and to suggest to the department possible model revision and recalibration needs for use in TMDL development. This memo summarizes the findings from the model reviews, and provides recommendations on the most effective ways of revising and recalibrating these model applications to meet the goal of TMDL development. Throughout this memo, the Dynamic Solutions/CDM model will be referred to as the “2009 Model” and the department’s updated version of the model will be referred to as the “2014 Model.” The new model will be referred to as the “2017 Model,” which is reflective of the project completion date in 2017.

In addition, Task 1 includes templates for the evaluation comparisons, memos, and reports that will be used during this project, as well as the model performance criteria that will be evaluated. This information is also included in this memo, but may change throughout the course of the project if new informational needs are identified.

2.0 HSPF MODEL REVIEW

2.1 CONCEPTUAL STRUCTURE

An HSPF watershed model was developed to simulate instream hydrology and water quality conditions for the Caloosahatchee River and its tributaries, which link Lake Okeechobee and San Carlos Bay. The 2009 Model was set up to simulate the time period of 1/1/1996–12/31/2005, which was later extended by the department in the 2014 Model to 12/31/2011. The 2009 Model was used to develop nutrient and dissolved oxygen (DO) TMDLs in the Caloosahatchee watershed.

The HSPF model consists of a set of modules arranged in a hierarchical structure, which permit the continuous simulation of a comprehensive range of hydrologic and water quality processes. The model

draws inputs from time series storage files to drive the modules for simulating watershed hydrology, erosion, water quality, and instream transport processes. The model is conceptually divided into land and receiving water modules as shown in **Table 1**. In general, as long as the user executes the model processes in the prescribed order, simulation instabilities are not a problem. An exception includes the simulation of water quality concentrations at very small flow rates/volumes, where mass balance calculations can cause anomalous results due to time step constraints. These conditions do not affect the Caloosahatchee model setup.

Table 1: HSPF Conceptual Structure

Category	Module	Module Description
Land modules (PERLND/IMPLND)	PWATER/IWATER	Simulates water budget for a pervious/impervious land segment
Land modules (PERLND/IMPLND)	SEDMNT/SOLIDS	Simulates production and removal of sediment for a pervious/impervious land segment
Land modules (PERLND/IMPLND)	PSTEMP	Simulates soil layer temperatures
Land modules (PERLND/IMPLND)	PWTGAS/IWTGAS	Estimates water temperature and dissolved gas concentrations in the outflows from pervious/impervious land segments
Land modules (PERLND/IMPLND)	PQUAL/IQUAL	Simulates water quality in the outflows from pervious/impervious land segments
Receiving water modules (RCHRES)	HYDR	Simulates instream hydraulic behavior
Receiving water modules (RCHRES)	ADCALC	Simulates instream advection of dissolved or entrained constituents
Receiving water modules (RCHRES)	HTRCH	Simulates instream heat exchange
Receiving water modules (RCHRES)	SEDTRN	Simulates instream behavior of inorganic sediment
Receiving water modules (RCHRES)	GQUAL	Simulates instream behavior of a generalized quality constituent
Receiving water modules (RCHRES)	RQUAL	Simulates instream behavior constituents involved in biochemical transformations

The Caloosahatchee River is fed by outflows from Lake Okeechobee, and flows southwest before emptying into the San Carlos Bay. There are three major control structures along the river (Moorehaven Lock [S-77], Ortona Lock [S-78], and Franklin Lock and Dam [S-79]) that are operated to maintain the water level in the Caloosahatchee River and for navigational purposes (**Figure 1**). The Moorehaven Lock (S-77) is located at the interface between Lake Okeechobee and the Caloosahatchee River and defines the upstream boundary of the HSPF model.

The HSPF model includes a representation of the major tributaries in the watershed, which generally flow perpendicularly to the Caloosahatchee River mainstem. The modeled drainages of the tributaries follow the existing waterbody identification (WBID) boundaries with some additional segmentation to account for stream confluences and areas of focus, including monitoring on impaired streams. The Caloosahatchee HSPF model is set up for each stream to have a single downstream target, although this is not an inherent

limitation of the HSPF model. For instance, a reach could be configured to have two outlets, where discharge to each could occur simultaneously or be switched on or off depending on the reach depth.

Currently, nine freshwater WBID segments in the Caloosahatchee watershed are listed as impaired for either DO, nutrients, or chlorophyll-*a*. Two WBID tidal segments of the Caloosahatchee River are also impaired for nutrients and chlorophyll-*a*. In order to represent the source loading, transport, and fate of pollutants related to the impairments, the watershed model is currently set up to simulate the water quality constituents listed below. Other constituents, such as pH, are independent of the HSPF model subroutines used to determine DO and nutrient concentrations.

- Water temperature
- Total suspended solids (TSS)
- 5-day biochemical oxygen demand (BOD5) from ultimate carbonaceous BOD (BOD)
- Nitrogen; including total nitrogen (TN), total Kjeldahl nitrogen (TKN), nitrite + nitrate (NO_x), organic nitrogen (OrgN), ammonia/ammonium (NH₃/NH₄) as total ammonia (TAM)
- Phosphorus; including total phosphorus (TP), organic phosphorus (OrgP), and orthophosphate (PO₄)
- Phytoplankton (as chlorophyll-*a*)
- DO

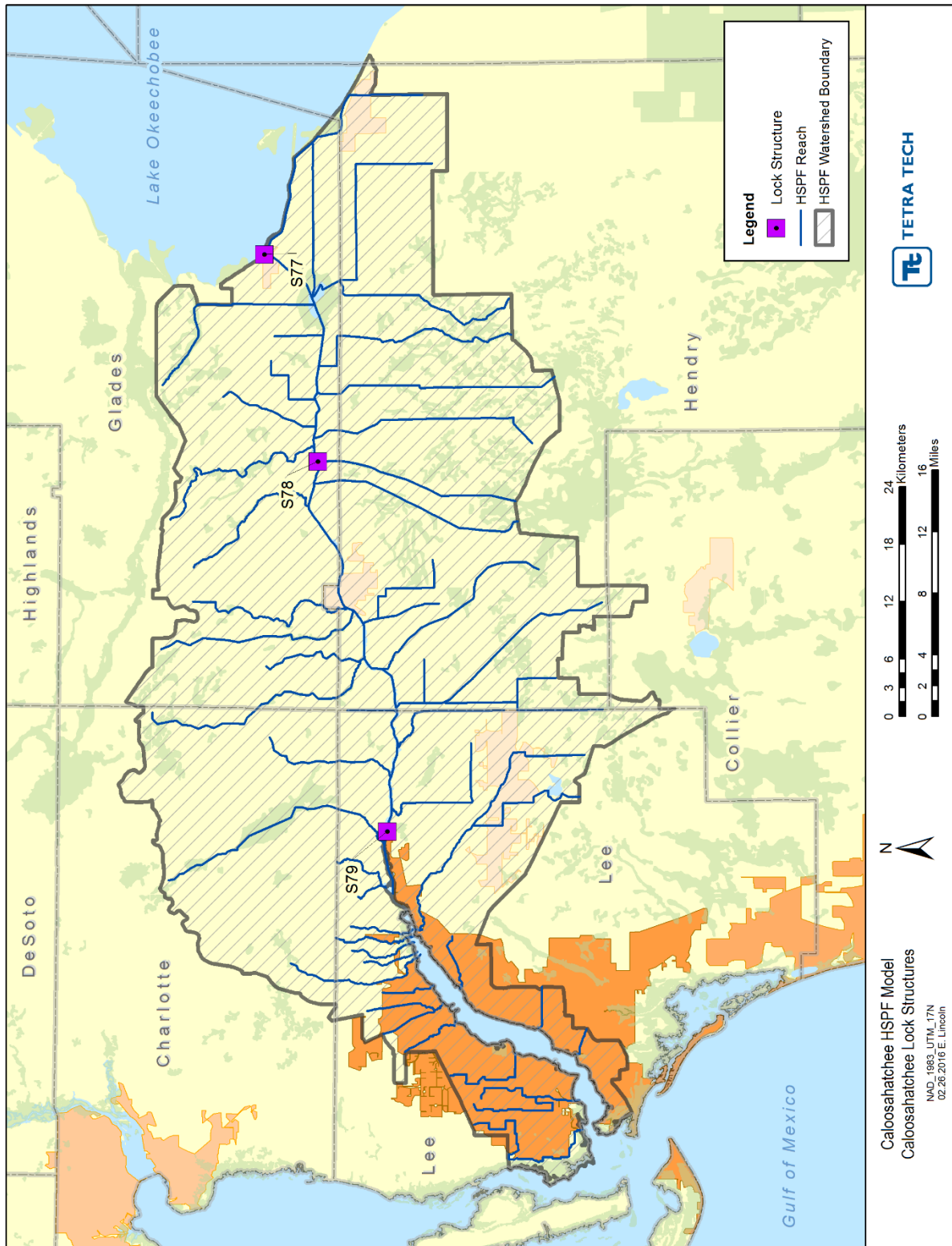


Figure 1: Location of major control structures on the Caloosahatchee River

Constituents simulated as originating from upland areas include TAM, NO_x, PO₄, refractory OrgN, and BOD. All land based loading are simulated using the HSPF PQUAL/IQUAL module using buildup and washoff parameters, as well as monthly concentrations specified for interflow and ground water outflows for pervious land segments. Wet deposition of nutrients, excluding BOD, is also represented on a monthly basis. As part of the HSPF model update, Tetra Tech will consider adding dry deposition of nutrients.

The upland loads represented in the HSPF PQUAL/IQUAL module are linked to instream water quality as shown in **Table 2**, where the PQUAL/IQUAL and RQUAL modules are generally described in **Table 1**. The multiplier listed in **Table 2** is used to split the upland PQUAL/IQUAL pollutant into the species required to drive the instream RQUAL water quality simulation. Instream constituents include those from upland simulations. However, NO_x is split into its requisite components and refractory OrgN is used to determine refractory OrgP and organic carbon species (based on available monitoring data at station CES01). The labile OrgN and OrgP are not explicitly represented as independent state variables in the HSPF model, but instead are represented implicitly as proportional to BOD based on the input specification of nitrogen to carbon and phosphorus to carbon ratios in input block CONV-VAL1. Both labile and refractory portions are tabulated together by the HSPF model as TORN (total organic nitrogen) and TORP (total organic phosphorus). The nutrient constituents are used to drive DO and phytoplankton simulations in the HSPF model.

Table 2: Upland instream constituent linkages

Upland PQUAL/IQUAL Pollutant	Multiplier	RQUAL Sub-Module	Instream RQUAL Pollutant
NO _x	0.5	NUTRX	NO ₃
NO _x	0.5	NUTRX	NO ₂
TAM	1	NUTRX	TAM
PO ₄	1	NUTRX	PO ₄
OrgN	1	PLANK	TORN
OrgN	0.02	PLANK	TORP
OrgN	5.7	PLANK	ORC
BOD	1	OXR	CBODU
Sediment	0.1	SED	Sand
Sediment	0.6	SED	Silt
Sediment	0.3	SED	Clay

In addition, total sediments are modeled as loads from upland areas using the HSPF SEDMNT module for pervious lands, SOLIDS module for impervious land, and instream simulation of TSS including representation of sand, silt, and clay fractions. There is no sediment association for the upland nutrient simulation; however, the HSPF model is set up to use RQUAL and represent PO₄ and TAM as sediment-associated with partition coefficients in the instream module. RQUAL simulates the complex kinetics that occur between the nitrogen and phosphorus species, DO, BOD, and chlorophyll-*a* (such as nitrification, adsorption, settling, and biomass ratios), while GQUAL simulates the kinetics using simplified first-order decay rates.

The initial model calibration and validation will be done in sequence with watershed hydrology calibrated first, followed by water quality. **Figure 2** presents a schematic of the HSPF model hydrology storages and pathways. In general, precipitation is routed as either surface runoff/interflow or infiltrated where it can enter various storages and ultimately percolate to ground water storage. Once in ground water storage,

water outflows as either active ground water (baseflow) or is lost to deep/inactive ground water. It should be noted that the HSPF model hydrology components and pathways are identical for land segments that do not have associated reaches (e.g. areas that directly drain to the estuary). The only difference is that modeled outflows (surface, interflow, and baseflow) are not combined into a reach, but remain separate at outflow.

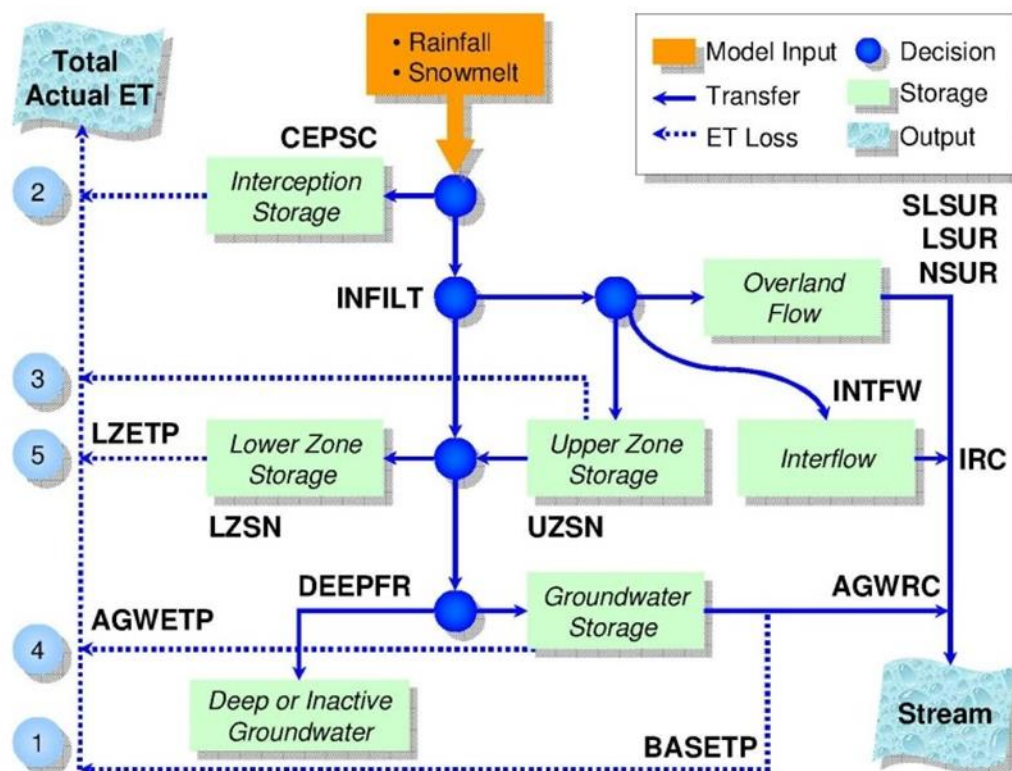


Figure 2: Schematic of HSPF hydrology components and pathways

The 2009 Model defined a hydrology calibration time period of 1/1/2001–12/31/2005 and a validation time period of 1/1/1997–12/31/1999. Water quality simulations were calibrated and validated for the time periods 1/1/2004–12/31/2005 and 1/1/2001–12/31/2003, respectively. The hydrology and water quality calibration period was later extended through 2011 in the 2014 Model.

The initial 2009 Model calibration/validation effort used four separate U.S. Geological Survey (USGS) monitoring locations. Two of the stations (USGS 02292480 and USGS 02292900), located on the Caloosahatchee River mainstem, were calibrated for both hydrology and water quality. The hydrology and water quality in the mainstem was predominately driven by the HSPF model Lake Okeechobee upstream boundary, and not by watershed tributary inputs. The department's 2014 Model extension assessed the modeled hydrology and water quality at additional calibration locations. The original and extended calibration locations are listed in **Table 3**.

Table 3: 2009 and 2014 HSPF Model calibration locations

N/A = Not applicable

Modeling Effort	Station Name	Hydrology Calibration	Water Quality Calibration	WBID
2009	Caloosahatchee Canal at the Ortona Lock (S-78), near La Belle	X	X	3237A
2009	Caloosahatchee River at the Franklin Lock and Dam (S-79), near Olga	X	X	3235A
2009	Whiskey Creek at Ft. Myers	N/A	X	3240H
2009	San Carlos Canal at Cape Coral	X	N/A	N/A
2014	Jacks Branch	X	X	3235D
2014	Crawford Canal (Fast Creek)	X	N/A	3235B
2014	Whiskey Creek	X	N/A	3240H
2014	Telegraph Creek	X	N/A	3236A
2014	Popash Creek	X	X	3240Q
2014	Billy's Creek	X	X	3240J
2014	Orange River	X	N/A	3240K
2014	Townsend Canal	N/A	X	3235L
2014	Cypress Branch	N/A	X	3235G
2014	Cape Coral	N/A	X	3240A2
2014	Lake Hicpochee	N/A	X	3237C
2014	Caloosahatchee River between S-79 and S-78	N/A	X	3235B
2014	S-4 Canal (C-21)	N/A	X	3246
2014	Long Hammock Creek	N/A	X	3237B
2014	Nine Mile Canal	N/A	X	3237D
2014	Deep Lagoon Canal	N/A	X	3240A4

Multiple model performance metrics were used to assess the quality of both the hydrology and water quality simulations of the Caloosahatchee River HSPF watershed model. Nash-Sutcliffe coefficients of model fit efficiency and average annual flow volume error were the primary measures used to assess model fit. The coefficient of determination (R^2) was also calculated for the 2009 Model. The department expanded the calibration metrics to include the Pearson Correlation Coefficient (R), and Root Mean Square Error (RMSE) for the 2014 Model. The department noted that, in general, although there is a relatively small error over the entire 11-year period of record at locations S-78 and S-79, there are multiple years with extremely large errors (2001, 2007, and 2008). The department identified the following improvements that should be made to the model to improve calibration:

- Set up the model to simulate the control structure operations.
- Model the flow reversals for the Caloosahatchee River reaches.
- Revise the representation of agricultural irrigation practices.

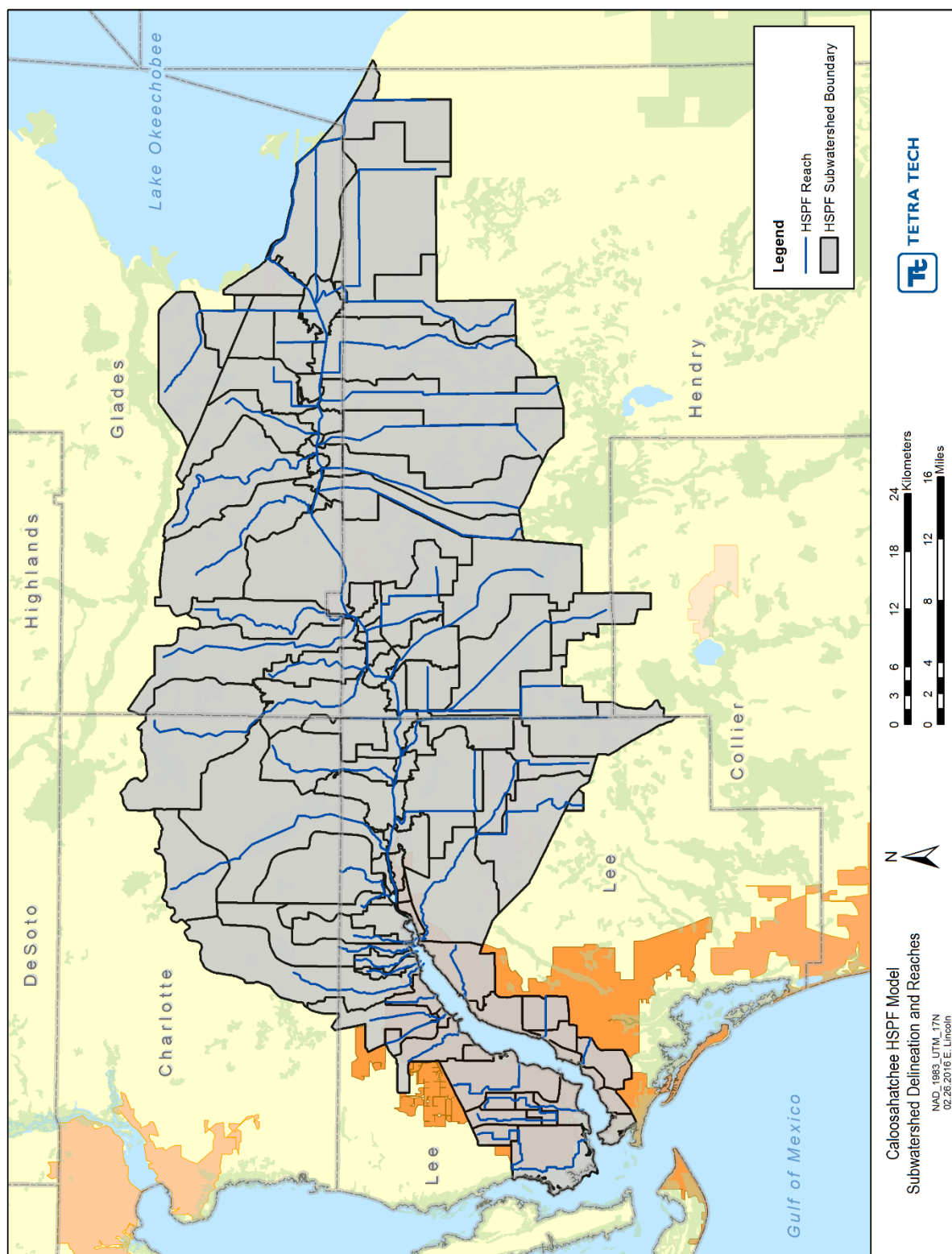
Water quality model performance metrics included the P-value for Wilcoxon Rank Sum Test and P-value for 2-Sided Kolmogorov-Smirnov Test, both of which were calculated for the entire simulation time period at the S-79 assessment location. Notes for the water quality calibration stated that “since watershed derived loads delivered at S-79 at the upstream boundary of the estuary accounted for 83% of total nitrogen (TN) and 77% of total phosphorus (TP) loads simulated with the HSPF model for the existing (2003-2005) calibration/validation case, the availability of observed nutrient data for comparison to HSPF model results at the S-79 location provides a good check on the credibility of the HSPF results as a tool for quantifying nutrient loading to the estuary.” Thus, it was determined that a reasonable calibration performance at this location was sufficient to drive the downstream EFDC estuary model simulations.

Assessment of the water quality calibration at S-79 using the 2-sided Kolmogorov-Smirnov Test showed that the distributions of measured and modeled water temperature, TSS, DO, PO₄, TKN, and NO_x were all considered similar. Application of the Wilcoxon Rank Sum Test showed water temperature, TKN, and PO₄ to have statistically different means between the measured and modeled data, while TSS, DO, and NO_x show statistically similar means.

2.2 WATERSHED DELINEATIONS AND REACH SEGMENTATION

The Caloosahatchee River HSPF model divides the watershed into 102 subbasins with an associated stream network of 97 reaches (**Figure 3**). Of the represented stream reaches, six are not associated with any land segment and represent nodes where two reaches come together. Thus, only 91 of the model subbasins include a reach segment, while the remaining 11 reflect land areas that drain directly to the Caloosahatchee River Estuary. Delineation of the model subbasins used existing WBID boundaries, topographic data (Composite Topography for Southwest Florida, 100-ft), and the High Resolution National Hydrography Dataset distributed by USGS.

One F-Table (a depth-discharge relationship or rating curve) was developed for each reach using an equivalent trapezoidal cross-section. A previous effort by the South Florida Water Management District (SFWMD) developed a MIKE-SHE model of the Caloosahatchee River watershed, compiled the stream cross-section data from various sources, and estimated reach characteristics using equivalent trapezoidal cross-sections. According to the Dynamic Solutions 2009 report, SFWMD provided the cross-sections for parts of the Caloosahatchee River, Jacks Branch, County Line Ditch, Canal 1, Canal 2, C-19, 42-foot canal, and Hilliard Canal. The cross-sections for other stream segments were likely estimated from the stream channel dimensions (average depth and width) captured in available topographic data and aerial imagery. This methodology is typically used when measured cross-sectional data are not available. As part of the model update, Tetra Tech will refine the stream cross-sections based on cross-sectional data provided by Lee County.

**Figure 3: HSPF model subbasin delineation and reaches**

The setup of the model segmentation and hydraulics seems reasonable in terms of the F-Table representation of reaches and lakes where simulated outflows, as reported by Dynamic Solutions (2009), are generally representative of observed conditions.

In addition, reaches 46 and 18 are associated with river locks S-78 and S-79, respectively, and have F-Tables that appear to generally capture the impoundment effects of these structures. Select areas in the watershed have been identified by the department as having complex hydraulics that are not fully represented by the current reach and F-Table setup. These locations include the City of Cape Coral canal networks and Deep Lagoon Canal, and representation may require additional delineation of the existing HSPF model subbasins to properly capture hydrologic conditions. Additional delineation may also be necessary to generate model output at the locations of select water quality monitoring locations.

2.3 REACHES WITH BIDIRECTIONAL FLOW

An analysis of available flow data, the site visit, a desktop analysis, and discussions with stakeholders indicate that there are a collection of streams throughout the watershed where bidirectional flow is occurring. Upstream of S-79, bidirectional flow is caused by agricultural irrigation pumping in the canal network. Downstream of S-79, bidirectional flow is caused by tidal propagation.

The reaches with bidirectional flow caused by agricultural pumping and flood protection pumping are located south of the Caloosahatchee River where the land use is predominately agriculture. The bidirectional flow occurs when large pumps transport water upstream over man-made levees and dikes located in the canals. Farmers use the water in the canals for agricultural irrigation, and remove the water from the main canals to a network of smaller ditches and canals that can transport water across their property and, in some areas, transport water across the HSPF model subbasin delineation boundaries. Water not used by the farmers for irrigation is returned towards the Caloosahatchee River via gravity flow. The following reaches have been preliminarily identified as having bidirectional flow caused by agricultural pumping and irrigation (**Figure 4**):

- Caloosahatchee River (between S-77 and S-78)
- Townsend Canal
- C-3
- Hilliard Canal
- Flaghole Canal
- Disston Canal
- Industrial Canal

Water pumped upstream through the C-3 is transported west by farmers and returns to the Caloosahatchee River via gravity flow through the C-2 and C-1. Water pumped upstream through the Townsend Canal is transported east and returns to the Caloosahatchee River via gravity flow in the Roberts Canal and Fast Creek (George Creek).

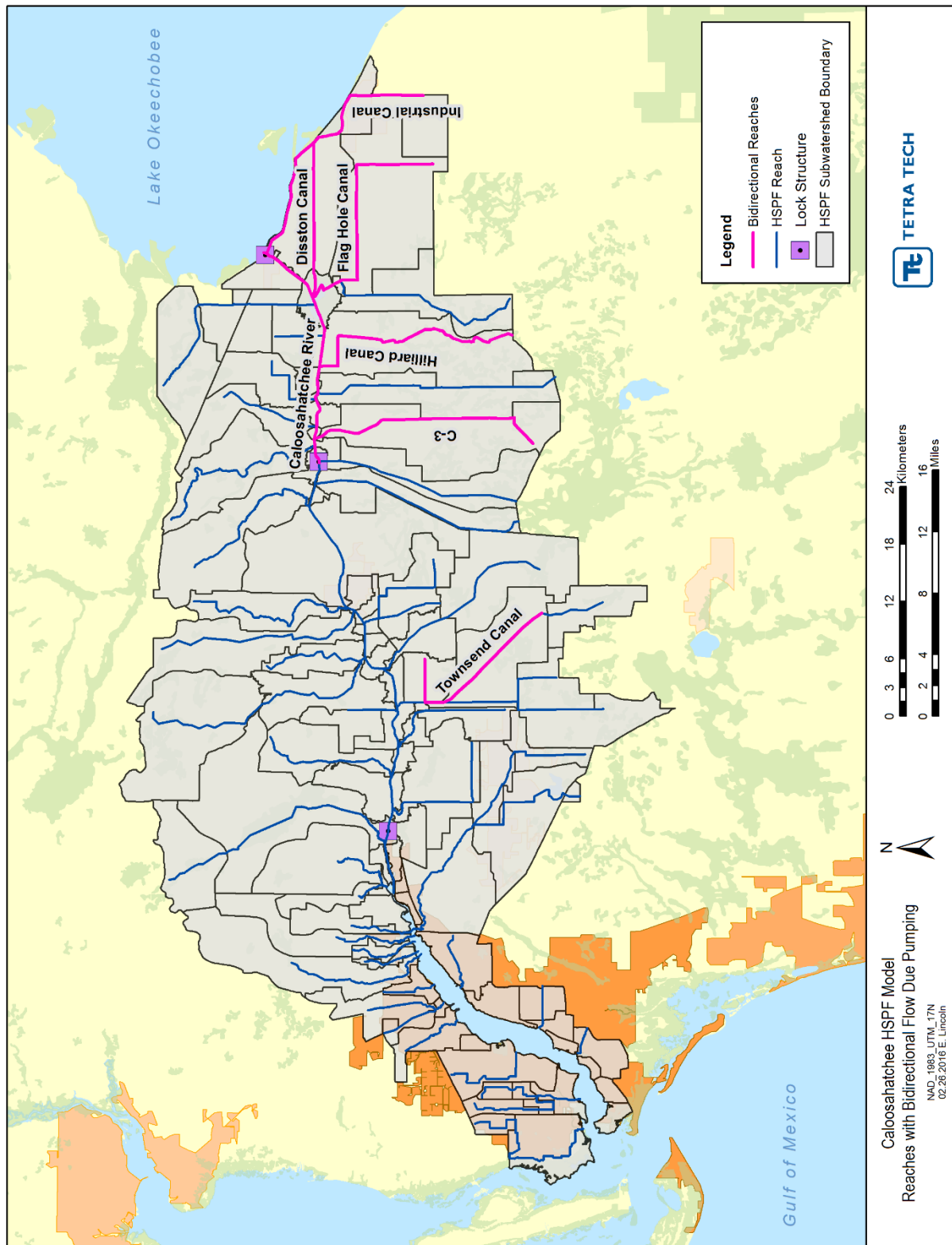


Figure 4: Reaches with bidirectional flow due to agricultural and flood protection pumping

Measured flow at Jacks Branch, Pollywog Creek, and Fast Creek indicate that there may be bidirectional flow in these reaches. However, the negative flows recorded at Jacks Branch and Fast Creek occurred during extremely low flow periods when the flow measurement instrumentation could not properly measure velocity and flow in the creeks. The flow instrumentation is not able to measure flow velocities below 0.03 feet/second; therefore, any flows below this value will be removed from the dataset and will not be used during the 2017 Model calibration. The rest of the flow data from these locations will be used in model calibration. The station on Pollywog Creek was located near the confluences of Pollywog Creek and the Caloosahatchee River, and the reversing flows measured at the station were caused by reversing flow in the river. Therefore, Pollywog Creek does not have reversing flows.

Some reaches located downstream of S-79 have bidirectional flow caused by tidal propagation. Reaches downstream of S-79 that are not tidally influenced, such as Whiskey Creek, have channel features or structures located near their confluence with the Caloosahatchee River that prevent the tide from moving upstream into the HSPF model reach and subbasin. The following reaches were identified as having bidirectional flow caused by tidal propagation:

- Cape Coral Canals
- Deep Lagoon Canal
- Yellow Fever Creek
- Billy's Creek
- Orange River
- Popash Creek
- Telegraph Creek

The HSPF model cannot represent bidirectional flow, and the 2009 and 2014 HSPF Models did not explicitly represent the bidirectional flow in the watershed reaches. In the models, the reaches were assumed to be one-directional towards the Caloosahatchee River. The F-Tables represented the net positive flows to the Caloosahatchee River. In addition, there are no pumping records available that provide information as to the timing and volume of water moved through the canal systems. Tetra Tech will assume that pumping is occurring when farmers need water for irrigation, and that the volume of water pumped upstream in each canal is directly related to crop irrigation. Tetra Tech has provided several recommendations for representing the bidirectional flows in both the agricultural and tidal reaches in **Section 2.6**.

2.4 MODEL INPUT DATA

The model input datasets used to develop the Caloosahatchee HSPF watershed model can generally be grouped into the following categories:

- Meteorological time series
- Land use classifications
- Boundary condition time series
- Point source time series
- Irrigation/withdrawal time series
- Best management practices (BMPs)

National Oceanic and Atmospheric Administration's (NOAA) Doppler satellite Next Generation Weather Radar (NEXRAD) network was the source for the hourly precipitation data developed for the Caloosahatchee River watershed model. The gridded data were aggregated into 15 area-weighted precipitation time series representing different parts of the watershed. A seasonal summary of the precipitation total for the 15 zones is presented in **Figure 5** and these areas are shown in **Figure 6**. Model evapotranspiration data were calculated from daily observed temperature data that were available from SFWMD at meteorological station S78W. The daily potential evaporation (PET) data were computed using the Hamon method (Hamon 1961) and the total annual PET was then compared with available evapotranspiration data at S78W and adjusted to ensure that the computed PET time series was representative of the Caloosahatchee River watershed. It is not anticipated that any changes will be made to the precipitation zone boundaries as a result of watershed segmentation updates.

The meteorological data appear reasonable based on a preliminary review. The model precipitation and PET data are consistent with protocols generally used to develop weather forcing data for HSPF model applications. Tetra Tech evaluated the HSPF model representation of annual rainfall and PET and found them to be consistent with independent local estimates of these variables available from National Climatic Data Center datasets available at the Fort Myers Airport (WBAN 12835).

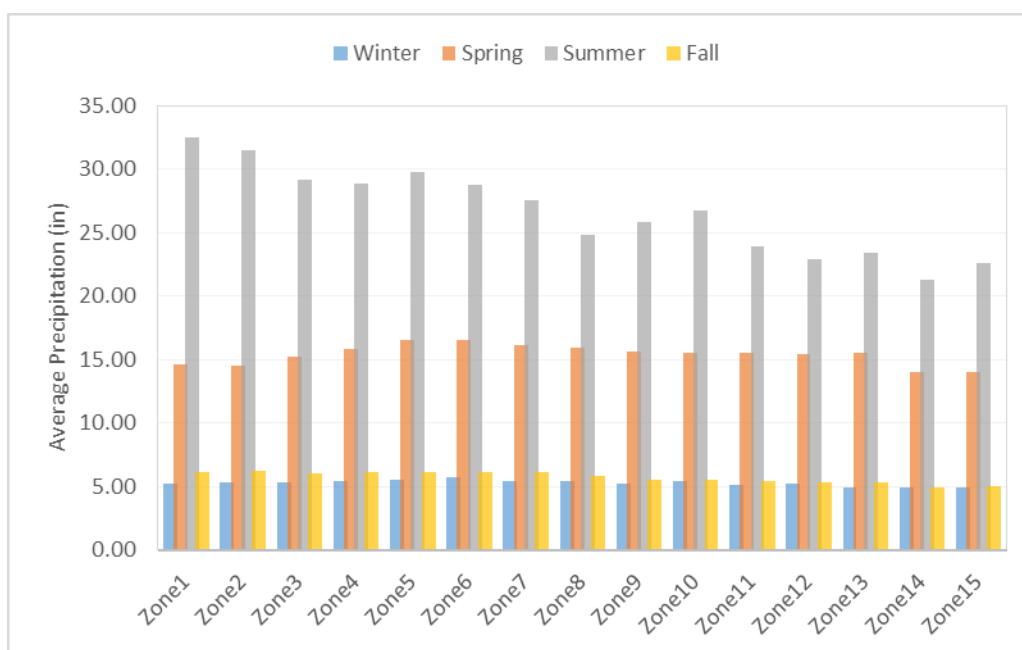


Figure 5: Average annual seasonal rainfall totals for the HSPF model

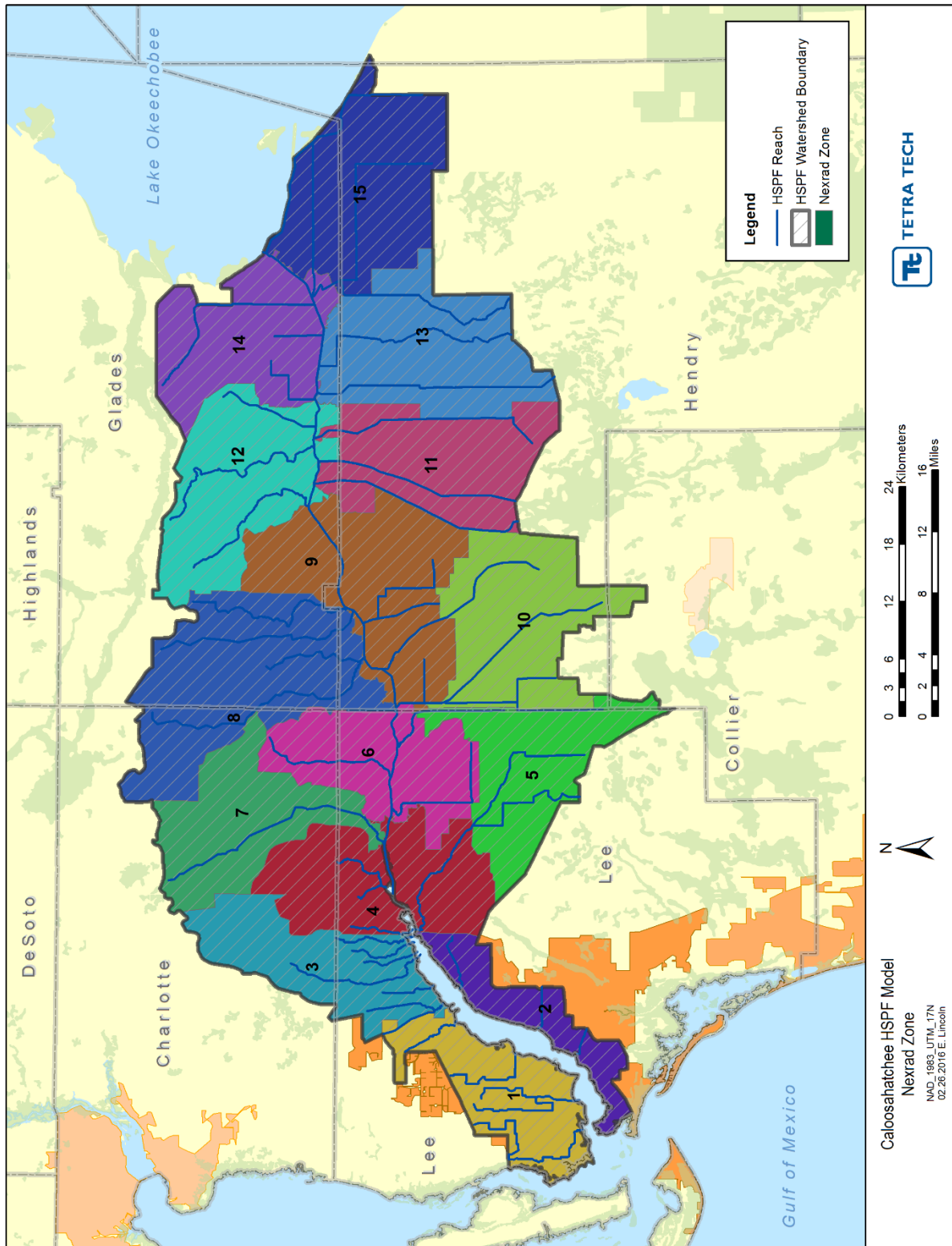


Figure 6: HSPF model NEXRAD zones

The final Caloosahatchee River HSPF modeling report (Dynamic Solutions 2009), states that a “seamless GIS coverage of a 2004 land use data provided by the SFWMD was considered appropriate for the development of the existing condition model.” The seamless data were grouped into 10 land cover classifications for the model definition of PERLND and IMPLND land segments as shown in **Table 4** and **Figure 7**.

Table 4: Caloosahatchee model land use areas

Land Cover Class	PERLND Area (acres)	IMPLND Area (acres)
Citrus	97,635	986
Commercial/industrial	6,232	12,097
Cropland/improved pasture	272,889	2,756
High density residential	4,735	4,550
Low density residential	53,025	5,892
Medium density residential	25,014	8,789
Rangeland/open land	95,618	966
Unimproved pasture	51,028	515
Upland forests	72,473	732
Wetlands/water	164,077	--
Total	842,727	37,283

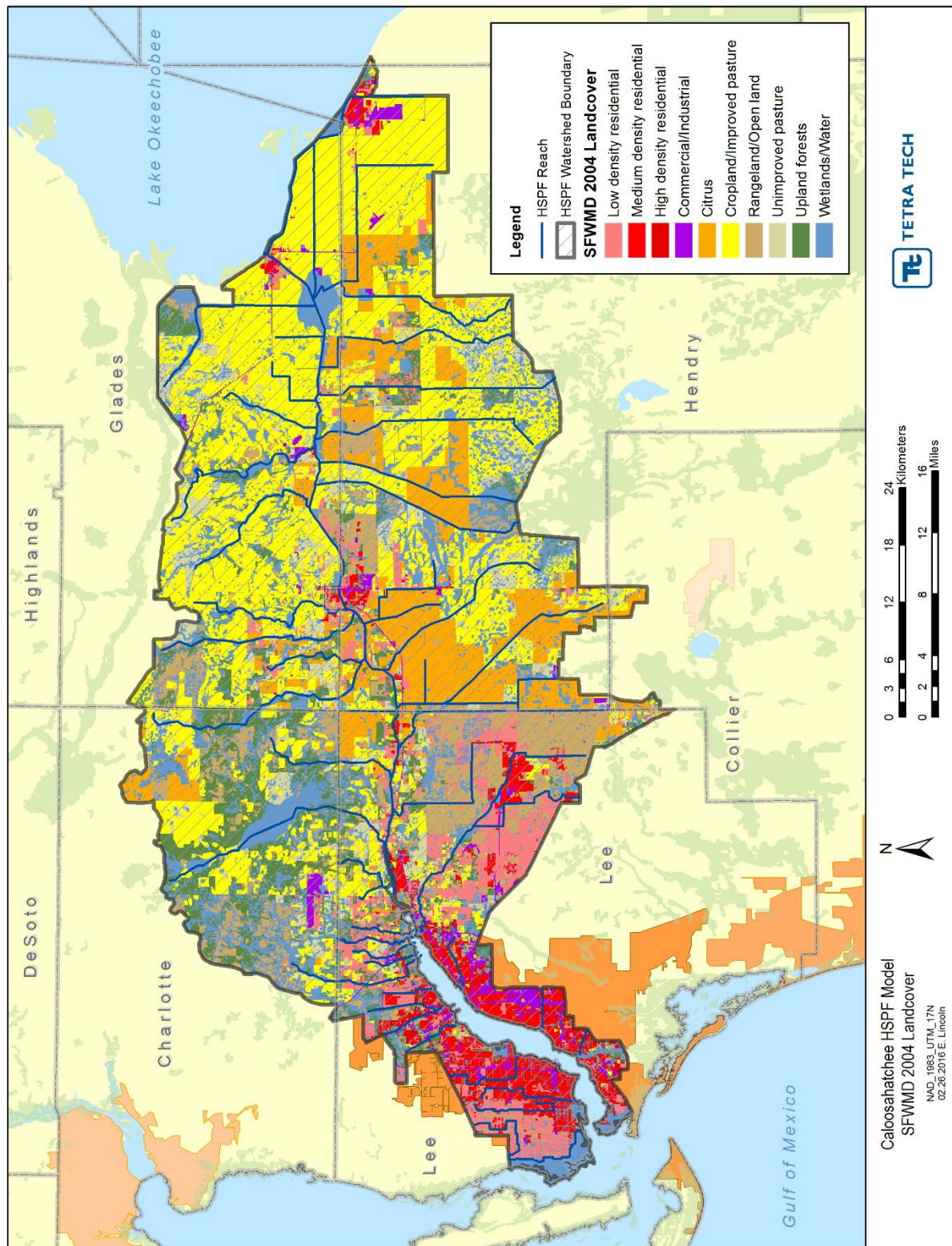


Figure 7: 2004 SFWMD land use coverage

Land use data sources and aggregation into model land use appears reasonable and is similar to the more recent 2008 SFWMD coverage. As part of Task 2, Tetra Tech will compare the 2008 land use coverage to the 2012 coverage to determine if there were major changes in land uses. Based on this evaluation, a determination of which land use coverage to use in the model will be made. For impervious land, assumptions of traditionally pervious land cover types (e.g. cropland, pasture, and forest) as having directly connected impervious area (DCIA) may not be appropriate. Although small, these areas could be causing the over-estimation of peak storm flows in some areas. Further evaluation of hydrologic conditions on impacted tributaries should be made to determine if this is the case. In the event that this indicates a need to refine the impervious area assignments, these assignments will need to be corrected to DCIA. If detailed local studies of the connected fraction are available, these will be preferable; otherwise, total impervious area can be converted to disconnected impervious areas using the methods described in Sutherland (1995), which specifies a percent of DCIA by general land use type.

Flow and ambient water quality measurements at S-77 were used to develop time series input data for the boundary condition. Discharge through Franklin Lock and Dam (S-79) and Ortona Lock (S-78) were computed using specific F-Tables and modeled flows in the upstream reaches. Daily mean flow data are available from two SFWMD gages, S77-S at Moorehaven Lock and S78-T at Ortona Lock.

The 2009 and 2014 models include nine connected point sources as shown in **Table 5**. There are a total of 44 point sources in the WDM file; however, these are not discharging to reaches in the current model set up. Model point sources include contributions of organic and inorganic nutrients, as well as BOD and sediments (sand, silt, and clay). Discussions with the department have indicated that the facilities assigned general permits (ID: FLA) should not be included as direct point sources in the model setup. Facilities with permits beginning with FLA are reuse facilities, which typically apply the processed water to land or manmade waterbodies nearby. Therefore, the currently connected general permits will be removed and replaced with the facilities assigned National Pollutant Discharge Elimination System (NPDES) permits that discharge directly to the HSPF model reaches as identified in **Section 2.6**.

Table 5: Point sources included in the 2009 and 2014 Models

Facility ID	Facility Name	Design Flow (MGD)	UCI Reach
FL0040665	Clewiston, City of - WWTF	1.5	58
FLA014283	Labelle, City of	-	40
FLA014290	Port Labelle	0.25	41
FLA014548	North Fort Myers Utility	3.5	91
FLA014565	Lehigh Acres WWTP	2.48	10
FLA014676	River Trails Mobile Home Park	0.097	87
FL0039829	Lee County Utilities - Fiesta Village	-	4
FLA014563	Del Tura Country Club	-	91
FLA014658	Jamaica Bay West, Large	-	4

There are 40 known reuse facilities in the Caloosahatchee River Basin, 11 of which have permitted capacities greater than 0.09 million gallons per day (MGD). These 11 facilities represent 98.9% of the reuse water in the basin. (**Table 6**). While six of the facilities were represented as direct point sources in the 2009 and 2014 Models (**Table 5**), none of the reuse facilities were represented as land- or wetland-applied facilities. Many of the smaller facilities, with permitted capacities less than 0.09 MGD, supply their treated effluent to fast-infiltration percolation ponds. Discharge from the larger facilities is typically applied to land application sites (LAS), used for residential, commercial, and agricultural irrigation, or

used in industrial cooling and wash processes. The facilities with discharges greater than 0.09 MGD should be included in the HSPF model in order to account for the land use loadings.

Table 6: Permitted wastewater reuse discharge facilities

Facility ID	Facility Name	Facility Type	Usage(s)	Permitted Capacity (MGD)
FL0021261	Fort Myers Central AWWTF	DW	Irrigation and industrial uses	6.0
FL0030007	Cape Coral, City of - Everest WRF	DW	Irrigation	29.4
FL0039829	Fiesta Village Advance Wastewater Treatment Plant	DW	Stormwater lake storage	2.976
FL0040665	Clewiston, City of - WWTF	DW	LAS and irrigation	2.02
FLA013741	Crooked Hook Campground	DW	no data	no data
FLA014248	Whisper Creek RV Resort	DW	Percolation pond	0.044
FLA014250	M RV Resort LLC	DW	Percolation pond	0.030
FLA014260	Sportsmans Village RV Condo WWTP	DW	Percolation pond	0.030
FLA014263	Benbow WWTP	DW	Percolation pond	0.040
FLA014267	Meadowlark Campground	DW	Percolation pond	0.015
FLA014272	Glades RV Resort	DW	Percolation pond	0.025
FLA014278	River Oaks Utilities	DW	Percolation pond	0.015
FLA014283	Labelle, City of	DW	LAS	0.750
FLA014287	Grandma's Grove RV Park	DW	Irrigation	0.025
FLA014288	Riverbend Estates	DW	Percolation pond	0.020
FLA014290	Port Labelle	DW	Percolation pond	0.499
FLA014294	Riverside Retreat	DW	Percolation pond	0.012
FLA014300	Clewiston/Lake Okeechobee RV Resort	DW	Percolation pond	0.015
FLA014304	Labelle Labor Village	DW	Percolation pond	0.055
FLA014308	Greentree South	DW	Percolation pond	0.020
FLA014417	Alva Schools - Elementary and Middle	DW	Percolation pond	0.020
FLA014419	Charleston Park STP	DW	Absorption field	0.015
FLA014446	Oak Park Mobile Home Village	DW	Percolation pond	0.020
FLA014450	Whispering Pines Condo Association	DW	Absorption field	0.010
FLA014451	Julia Park	DW	Percolation pond	0.015
FLA014491	High Point WWTP	DW	Percolation pond	0.025
FLA014548	Del Prado WWTF (formerly North Fort Myers Utility)	DW	Irrigation	5.251
FLA014565	Lehigh Acres WWTP	DW	Percolation ponds and irrigation	4.040
FLA014566	Seminole Campground	DW	Percolation pond	0.010
FLA014596	Swan Lake Mobile Home Park	DW	Percolation pond	0.025
FLA014664	Labontes Garden RV Park WWTP	DW	Percolation pond	0.005
FLA014676	River Trails Mobile Home Park	DW	Percolation pond	0.097
FLA016891	Glades County Correctional	DW	LAS and wetland application site	0.315
FLA144215	Fort Myers Beach STP	DW	Irrigation, industrial uses, and ponds	5.540
FLA184756	Airglades Industrial Park	DW	Storage ponds and LAS	0.030
FLA185281	Maple Corner WWTP	DW	Percolation pond	0.013
FLA269913	River Bend Motorcoach Resort	DW	Absorption field	0.051
FLA324418	West Glades Elementary	DW	Percolation pond	0.015
FLA430901	Azteca WWTP	DW	Percolation pond	0.030
FLA455458	Cape Coral, City of - Southwest WRF	DW	Provided to FL0030007	no data

The Caloosahatchee HSPF model is currently configured to represent the application of irrigation water as a point source. The represented volumes are assumed to be completely sourced from ground water, although withdrawals from the modeled ground water storage are not simulated explicitly. Historic records of flow data were used to develop monthly average pumped volumes for the affected areas, which include 47 of the modeled reaches. The associated nutrient concentration of the irrigation water were assigned based on analysis of observed ground water concentrations from local monitoring wells. The simulated flows and pollutant loads from irrigation water are then input to the model as direct discharges to the nearest tributary. The simplifications used to represent irrigation in the current HSPF model set up will be improved to better capture the processes generally associated with cropland irrigation as described in **Section 2.6**.

The Caloosahatchee HSPF model also incorporates a representation of existing flow and pollutant load reductions provided by existing BMPs. These are applied to urban and agricultural areas and are represented as removal efficiencies that were determined through a data collection and analysis effort for the urban areas and as provided by the Florida Department of Agricultural and Consumer Services (FDACS) for the agricultural areas.

2.5 MODEL PARAMETERIZATION

The final set of HSPF model hydrologic parameters were checked against recommended ranges from the U.S. Environmental Protection Agency's (EPA) BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters for HSPF, and most were found to be reasonable (USEPA 2000). The following parameters were found to be outside the recommended range:

- The recommended range for BASETP is 0 to 0.05 with a maximum possible value of 0.2. The Caloosahatchee River model uses a value of 0.99 for all land uses. BASETP represents the fraction of PET taken directly from baseflow and is, generally, attributable to riparian vegetation. It may be reasonable to have values toward the higher end of the possible range for natural vegetated land cover in areas with a dense stream network (e.g. canals). However, the current configuration appears to be well beyond that range and is applied to all land uses.
- The recommended range for AGWETP is 0 to 0.05 with a maximum possible value of 0.2. The Caloosahatchee River model uses a value of 0.5 for all land uses. AGWETP represents the fraction of PET directly taken from shallow ground water and is typically considered as a function of wetlands extent. Thus, it may be reasonable to have values toward the higher end of the possible range for wetland land cover. However, the current configuration appears to be well beyond that range and is applied to all land uses.
- The recommended range for CEPSC is 0.03 to 0.2 with a minimum possible value of 0.01. The Caloosahatchee River model uses a single set of monthly values that is applicable to all pervious land uses and is assigned 0 for the months of January and December. It is conceivable that an interception would be at a minimum during the winter months, but the assignment of 0 is probably not appropriate. In addition, there should be some variability across land uses (e.g. interception for forested areas should be greater than for urban lawns).
- The recommended range for LZETP is 0.2 to 0.7 with a maximum possible value of 0.9. The Caloosahatchee River model uses a range of 0.25 to 1.49, with the highest values assigned to land

uses occurring in precipitation zones 1–5. LZETP represents the fraction of PET taken from the lower zone soil layer and is usually considered in terms of vegetation type and density.

The HSPF model sediment parameters were also checked against recommended ranges from EPA's BASINS Technical Note 8: Sediment Parameter and Calibration Guidance for HSPF, and most were found to be reasonable (USEPA 2006). The following parameters were found to be outside the recommended range:

- The recommended range for K_{RER} is 0.15 to 0.45 with a minimum possible value of 0.05. The Caloosahatchee River model uses a range of 0.001 to 0.25, with the lowest values assigned to the wetlands/water land use. K_{RER} is the coefficient in the soil detachment equation and is analogous to the soil erodibility factor (K) in the Universal Soil Loss Equation (USLE).
- The recommended range for COVER is 0 to 0.9 with a maximum possible value of 0.98. The Caloosahatchee River model uses a range of 0.3 to 1, with the values of 1 assigned to the wetlands/water land use. COVER is the fraction of land surface protected from rainfall and a value of 1 equates to effectively no sediment erosion occurring.
- The recommended range for K_{SER} is 0.5 to 5 with a minimum possible value of 0.1. The Caloosahatchee River model uses a range of 0.001 to 0.34, with the values of 0.001 assigned to the wetlands/water land use. K_{SER} is the coefficient in the sediment wash off equation for pervious lands, where a lower value represents a lower potential for detached sediment to wash off the land.
- The recommended range for K_{EIM} is 0.5 to 5 with a minimum possible value of 0.1. The Caloosahatchee River model uses a universal value of 0.075 for all land uses. K_{EIM} is the coefficient in the sediment wash off equation for impervious lands, where a lower value represents a lower potential for detached sediment to wash off the land.

A consistent set of instream sediment parameter values was applied to all model reaches, except for BEDWID. BEDWID, which represents the streambed width, was appropriately varied across the model reaches. Instream sediment parameters also appropriately represent the differences in behavior of the three sediment classes (sand, silt, and clay) and all values are within recommended ranges.

For the upland simulation of NO_x, TAM, OrgN, PO₄, and BOD, the pollutant accumulation rates and limits seemed to have been developed using a manual calibration for both pervious and impervious lands. The values vary across the modeled pervious land uses, but are consistent for the same land use category in different precipitation zones. This is also the case for the monthly interflow and ground water concentrations assigned to pervious land uses. A single pollutant accumulation rate and limit was applied to all impervious land uses for each upland pollutant.

WSQOP, defined as the rate of surface runoff that removes 90% of the accumulated pollutant, was set at 0.5 inches for all pollutants for impervious land uses. The values assigned to pervious areas varies across land uses, but like the accumulation rates and limits, is consistent across precipitation zones. Atmospheric deposition of NO_x, TAM, OrgN, and PO₄ to surface waters is represented on a monthly basis. For the instream nutrient simulation using HSPF RQUAL, all parameters were fixed (generally to HSPF model defaults) except PHYSET, which is the phytoplankton settling rate. This parameter was generally assigned a value of 0.015 ft/hr, though smaller values were assigned to some reaches.

When loads are transferred from the upland simulation to the reach simulation, assumptions are made for disaggregating upland parameters to instream constituents as shown in **Table 2**. The only disaggregation

that is referenced, however, is the relation of ORP to ORN, which is described as being “based on [station] CES01 data” in the model UCI file notes. For the remainder of the modeled pollutants (sediment, organic carbon, and NO_x species) there is no documentation on how the splits were determined. Additional effort may be required to better characterize the disaggregation. It should be noted that BOD entering reaches also implicitly contains labile forms of OrgN, OrgP, and organic carbon determined by ratios set within the RQUAL module. These labile forms are converted to inorganic nitrogen, phosphorus, and carbon when BOD decays. A summary of the unit area pollutant loads for pervious areas from the 2014 Model by model land use are provided in **Figure 8** through **Figure 11**. These unit area loads are calculated from the HSPF model output, and the model was not forced to match any literature values.

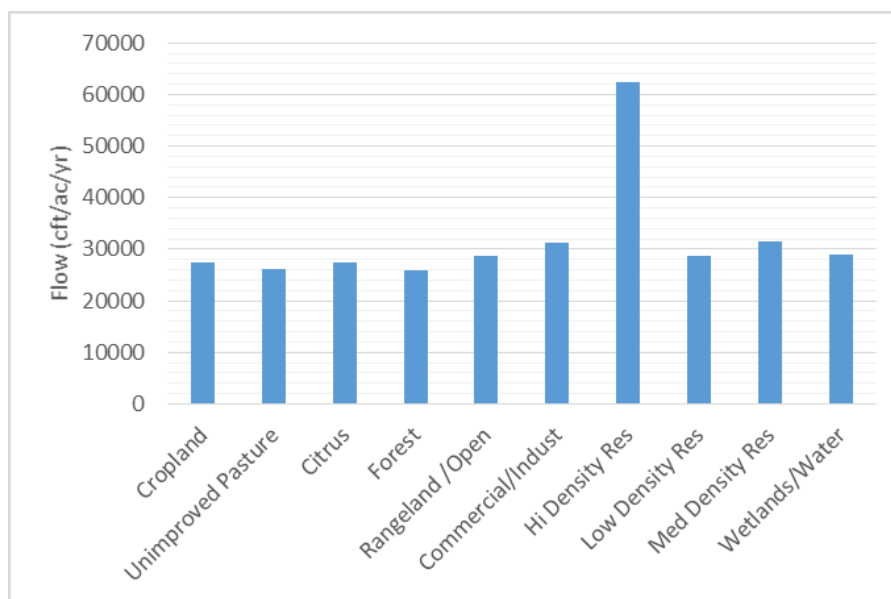


Figure 8: Unit area flows by land use for pervious areas

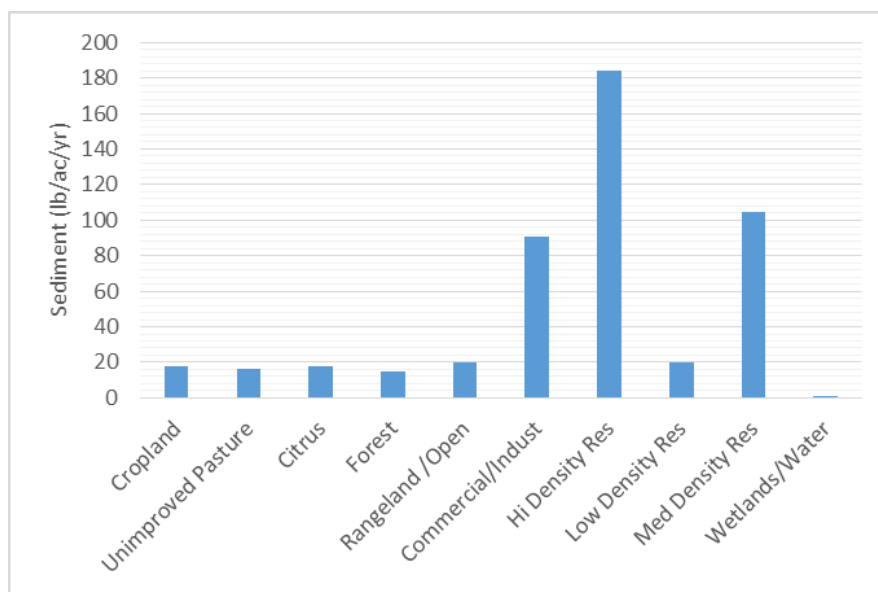


Figure 9: Unit area sediment loading by land use for pervious areas

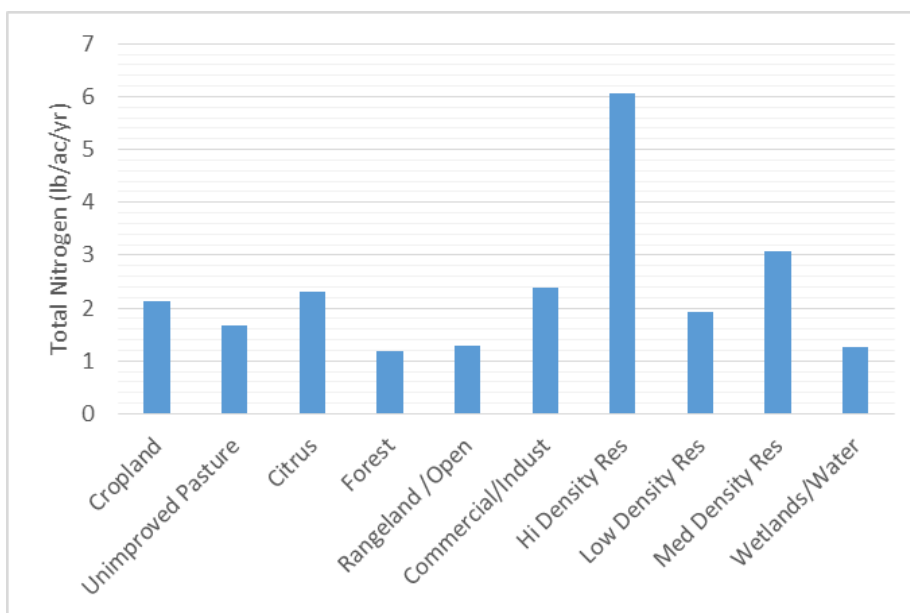


Figure 10: Unit area TN loading by land use for pervious areas

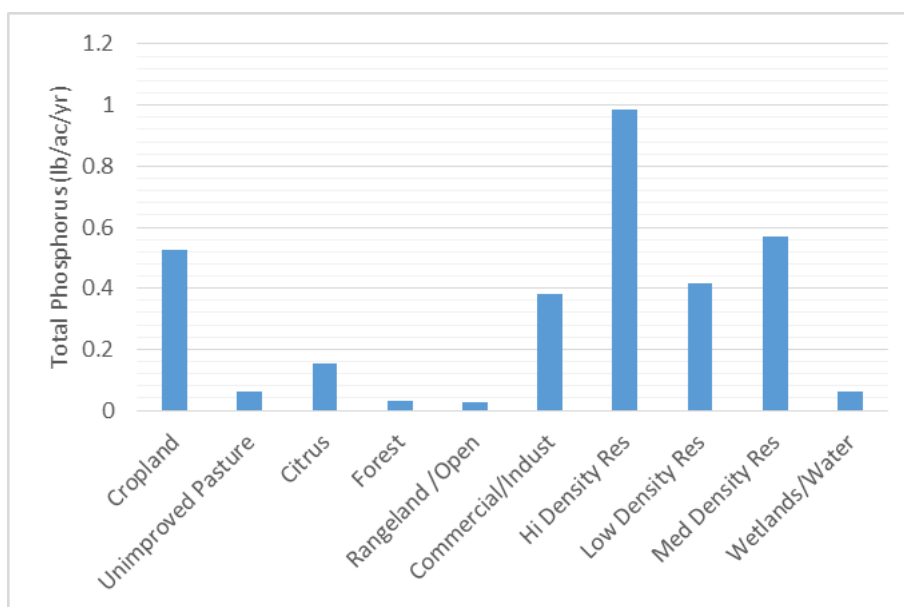


Figure 11: Unit area TP loading by land use for pervious areas

2.6 RECOMMENDATIONS

Based on our review and assessment, Tetra Tech has identified the following issues and recommendations for the HSPF model.

Issue #1: The current model simulation period ends in 2011.

Recommendation: After discussions with the department, Tetra Tech will extend the current HSPF model time period from 2012 to the end of 2014. The department will provide the weather files for the model simulation time period and Tetra Tech will process the data for inclusion in the model.

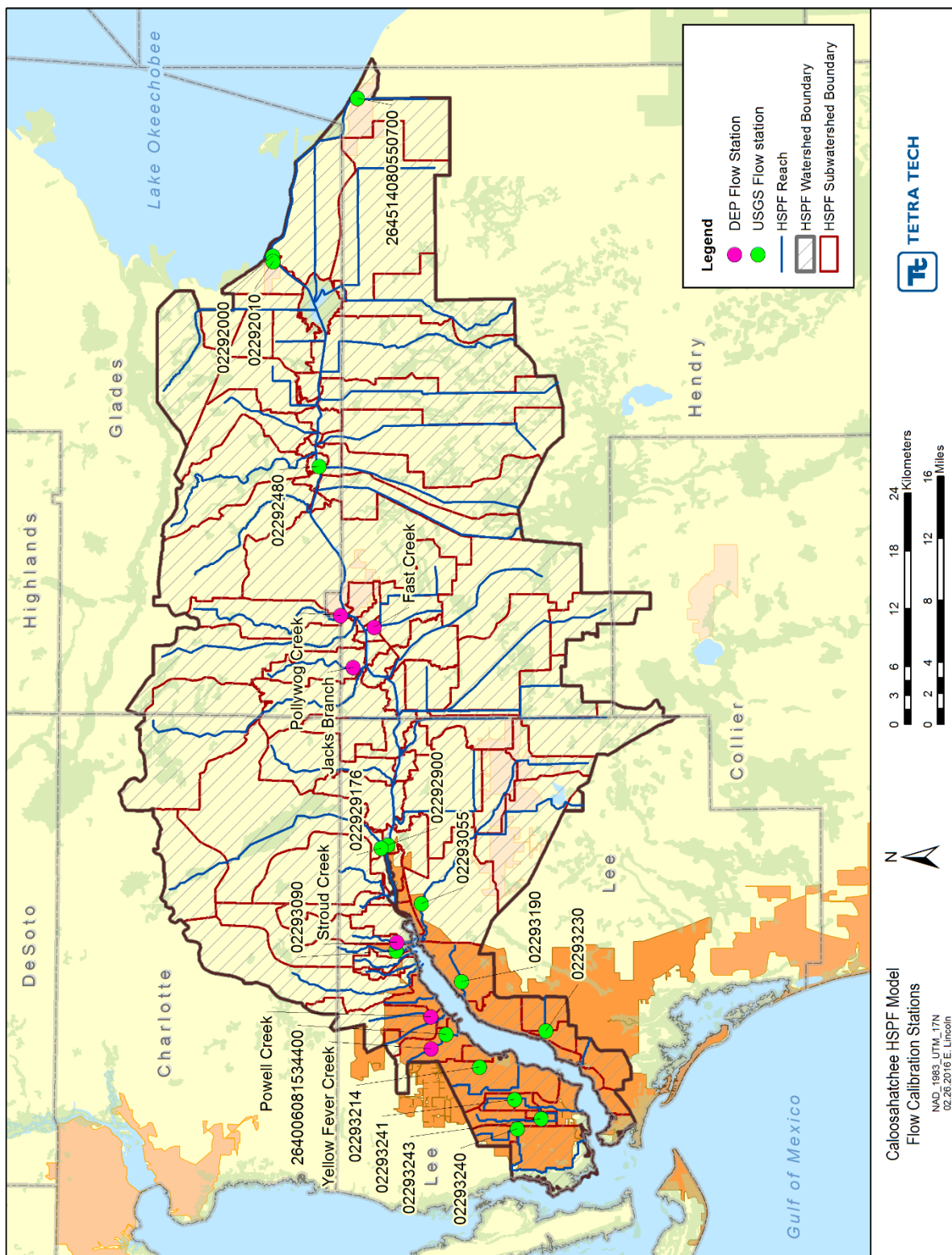
Issue #2: (*Stakeholder comment*) Model watershed delineations and reach segmentation may not correctly represent some watersheds, and are not delineated to some flow stations that will be used in the 2017 Model.

Recommendation: Overall, the current model watershed delineations and reach segmentation were determined to be appropriate. Lee County provided the department with information on minor modifications to the southern boundary of the Deep Lagoon Canal watershed, and these changes will be incorporated in the model. The department has requested that the Ninemile Canal watershed be delineated, and Tetra Tech will include this delineation in the update. Additional delineations may be completed as needed to represent the complex hydrodynamics of the watershed around the Townsend Canal, C-3, Hilliard Canal, Flaghole Canal, and Disston Canal.

Six of the 21 flow stations in the Caloosahatchee watershed were identified that are not located in close proximity to a subbasin outlet (**Table 7** and **Figure 12**). Two of the stations, 02292000 and 02292010, are located at the upstream boundary condition of the HSPF model at the beginning of the Caloosahatchee River. These stations will be used to verify the S-77 Lake Okeechobee boundary condition, but will not be used for HSPF model calibration. Station 02293214 is located on a small canal in Cape Coral, and redelineation is not recommended for this location. Tetra Tech recommends updating the HSPF model delineation so stations 264514080550700, 02293055, and Yellow Fever Creek are located at subbasin outlets to allow for calibration or validation at these stations. Both 02293055 and Yellow Fever Creek are tidally influenced, so HSPF calibration at these locations will be visual only.

Table 7: Flow stations not located near an HSPF subbasin outlet

Station ID	Station Name	Agency	Recommend Redelineation
02292000	Caloosahatchee Canal at Moore Haven	USGS	No
02292010	Caloosahatchee Canal Downstream S-77	USGS	No
264514080550700	Industrial Canal at Clewiston	USGS	Yes
02293055	Orange River near Buckingham	USGS	Yes
Yellow Fever Creek	Yellow Fever Creek	DEP	Yes
02293214	Mead Canal at Cape Coral	USGS	No

**Figure 12: Flow stations in the Caloosahatchee watershed**

Issue #3: (*Stakeholder comment*) There are priority reaches within the Caloosahatchee Basin with bidirectional flow. The bidirectional flow was not adequately modeled in the 2009 and 2014 models.

Recommendation: Seven canals have been preliminarily identified as having bidirectional flow caused by agricultural irrigation, and Tetra Tech and the department will evaluate the best method to represent bidirectional flow in the watershed model. Tetra Tech has identified two potential methodologies to represent the agricultural canal bidirectional flows, as described below. The methodologies can be used in combination, or a different methodology can be used, as appropriate.

Method 1: Tetra Tech will overlay an EFDC model on impaired reaches with bidirectional flow (Townsend Canal and Caloosahatchee River). The HSPF model will provide watershed flows (surface, interflow, and ground water) and water quality loadings (PQUAL/IQUAL concentrations) to the EFDC model. The PQUAL/IQUAL constituent fractionation shown in **Table 2** will be used to deliver the nutrient concentrations to the EFDC model. The EFDC model will be used to simulate the hydrodynamics and in-stream water quality of the impaired reaches.

Method 2: Tetra Tech will use a targeted withdrawal setup to simulate the bidirectional flow in HSPF reaches with bidirectional flow caused by agricultural irrigation. Tetra Tech will determine the timing and quantity of surface water needed in each subbasin to satisfy agricultural irrigation demands (see Issue #7). Using this information, Tetra Tech will develop a pumping record for the canals that is directly related to the agricultural irrigation demand. Tetra Tech will withdraw water from the downstream reach of the canal and transfer the water, including the associated water quality concentrations, to the upstream areas of the canal or neighboring subbasins. The targeted withdrawals will mimic the reverse flows that occur in the canals, and approximate the mixing effects associated with the flow reversals and transfers.

For both of these methods, there are no data documenting the timing and quantity of the reversing flows in most canals. The methodologies described above, specifically the methodology to determine when pumping and reversing flows occur in the canals, may be adjusted during calibration, as needed, to improve the model simulation at nearby and downstream locations where flow and water quality data are available.

The bidirectional flow in tidal reaches will not be represented by the HSPF model. The Caloosahatchee EFDC model will be extended into the tidally influenced reaches downstream of S-79, including the Cape Coral canals, Deep Lagoon Canal, Billy's Creek, Orange River, Yellow Fever Creek, Popash Creek, and Telegraph Creek. The HSPF model will provide the watershed flows and water quality loadings to the EFDC model. The EFDC model will simulate hydrodynamics and in-stream water quality of the tidal reaches, including the influence of the Caloosahatchee River on the reach water quality.

Issue #4: The HSPF model needs to be calibrated to additional flow and water quality stations.

Recommendation: Tetra Tech will calibrate and validate the HSPF model to flow stations located on reaches throughout the HSPF model watershed. Tetra Tech expects to calibrate the model at flow stations on reaches where flow is one-directional, and visually validate the model at stations

on reaches where flow is bidirectional due to agricultural pumping or tidal propagation. Tetra Tech will work with the department to identify approximately 20 water quality calibration and 20 water quality validation stations that will be used in the HSPF model.

Issue #5: There is no representation of onsite sewage treatment and disposal systems (septic systems).

Recommendation: The current version of the model does not include septic systems. Tetra Tech recommends adding septic systems to the model using Florida Department of Health and/or local county data on the locations of septic systems in the watershed. Both functioning and failing septic systems will be represented in the model.

Tetra Tech will determine the number of septic systems in each subbasin using county-provided GIS septic coverage shapefiles or a Florida Department of Health GIS septic coverage shapefile. For properly functioning systems, Tetra Tech will assume that each septic tank serves a household of 2.73 people, each person accounts for 70 gallons/day of water use, and 15% of the water used in the house is consumptive and does not reach the septic tank. Tetra Tech will use information from the department on average travel times for septic flows to reach a body of water (**Table 8**), and a first order decay rate will be applied to each constituent to determine the concentration. The concentration of septic tank effluent, decay rates for each constituent, and the concentration after decay will be determined during model calibration based on any available local information. For phosphorus, it will also be assumed that 90% is sorbed to sediment; therefore only 10% of the effluent concentration will be used to calculate decay. Non-failing septic systems loads will be developed into a direct input time-series, for each subbasin, and will be handled as a point source in the computational domain. The percentage of failing septic systems for each county will be estimated using available data, and if no data are available, Tetra Tech will assume a 15% fail rate. Because it is assumed that no decay occurs and raw effluent is directly applied to the land for these systems, Tetra Tech will adjust buildup and storage mass rates on residential land uses to account for these failing systems. Subbasins with greater numbers of failing systems will receive proportionally increased build-up and storage rates. Final rates will be adjusted during the calibration process.

Table 8: Travel Time for Septic Tank Plumes

Buffer zone	Travel Distance (m)	Average Velocity (m/day)	Average Travel Time (days)
1	<50	0.182	137.6
2	51-200	0.126	1,385.7
3	>200	0.060	9,641.0

Issue #6: The incorrect NPDES permitted point sources are represented and reuse facilities are represented incorrectly.

Recommendation: There are nine wastewater treatment facilities in the watershed with permitted surface water discharges, although five are listed on the Environmental Protection Agency Permit Compliance System as directly discharging to the estuarine portion of the Caloosahatchee River (FL0021261, FL0021270, FL003007, FL0030325, and FL0039829) (**Figure 13**). These five facilities, along with FL0001490, will be included in the EFDC model. A tenth facility, FL0591190 (S-4) was not active during the model time period and will not be included.

Table 9 lists the three domestic wastewater (DW) and industrial wastewater (IW) treatment facilities that will be evaluated for inclusion in the HSPF model. The discharge monitoring report (DMR) data received by the department will be reviewed to determine how to best represent these facilities in the model. Tetra Tech will develop point source time series to include in the model.

Table 9: NPDES facilities to include in the 2017 HSPF Model

NPDES ID	Facility Name	Type	Design Capability (MGD)
FL0037541	E R Jahna Ind - Ortona Mine	IW	4
FL0040088	Cape Coral, City of - RO WTP	IW	1.2
FL0040665	Clewiston, City of - WWTF	DW	1.5

Tetra Tech will include discharge from reuse facilities in the model with permitted discharge greater than 0.09 MGD (**Table 10**). The effluent discharge will be directly applied to the land in the model.

Table 10: Reuse facilities to include in the 2017 HSPF Model

Facility ID	Facility Name	Facility Type	Usage(s)	Permitted Capacity (MGD)
FL0021261	Fort Myers Central AWWTF	DW	Irrigation and commercial uses	6.0
FL0030007	Cape Coral, City of - Everest WRF	DW	Irrigation	29.4
FL0039829	Fiesta Village Advance Wastewater Treatment Plant	DW	Stormwater lake storage	2.976
FL0040665	Clewiston, City of - WWTF	DW	LAS and irrigation	2.02
FLA014283	Labelle, City of	DW	LAS	0.750
FLA014290	Port Labelle	DW	Percolation pond	0.499
FLA014548	Del Prado WWTF (formerly North Fort Myers Utility)	DW	Irrigation	5.251
FLA014565	Lehigh Acres WWTP	DW	Percolation ponds and irrigation	4.040
FLA014676	River Trails Mobile Home Park	DW	Percolation pond	0.097
FLA016891	Glades County Correctional	DW	LAS and wetland application site	0.315
FLA144215	Fort Myers Beach STP	DW	Irrigation, commercial uses, and ponds	5.540

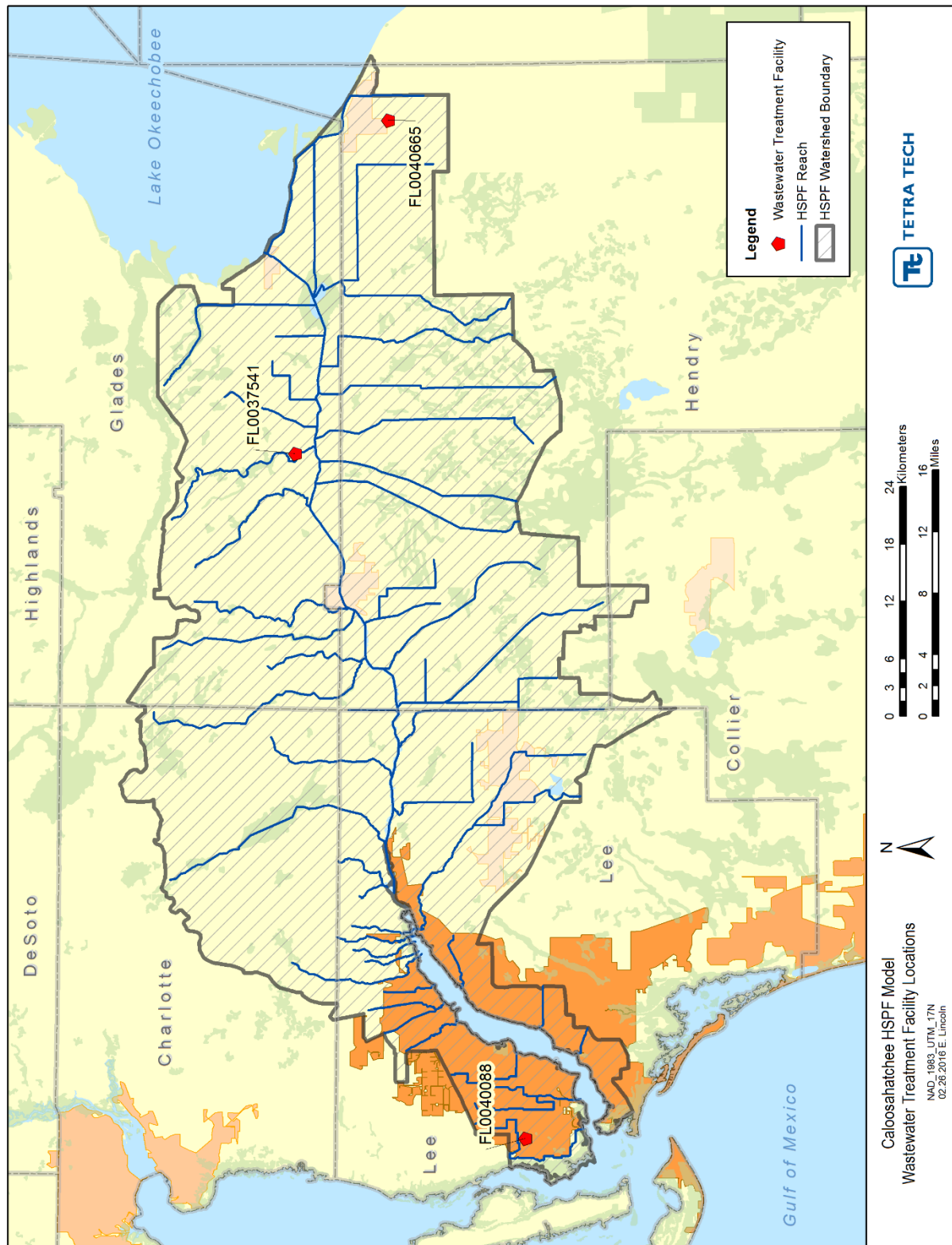


Figure 13: NPDES wastewater treatment facilities that will be included in the 2017 HSPF model

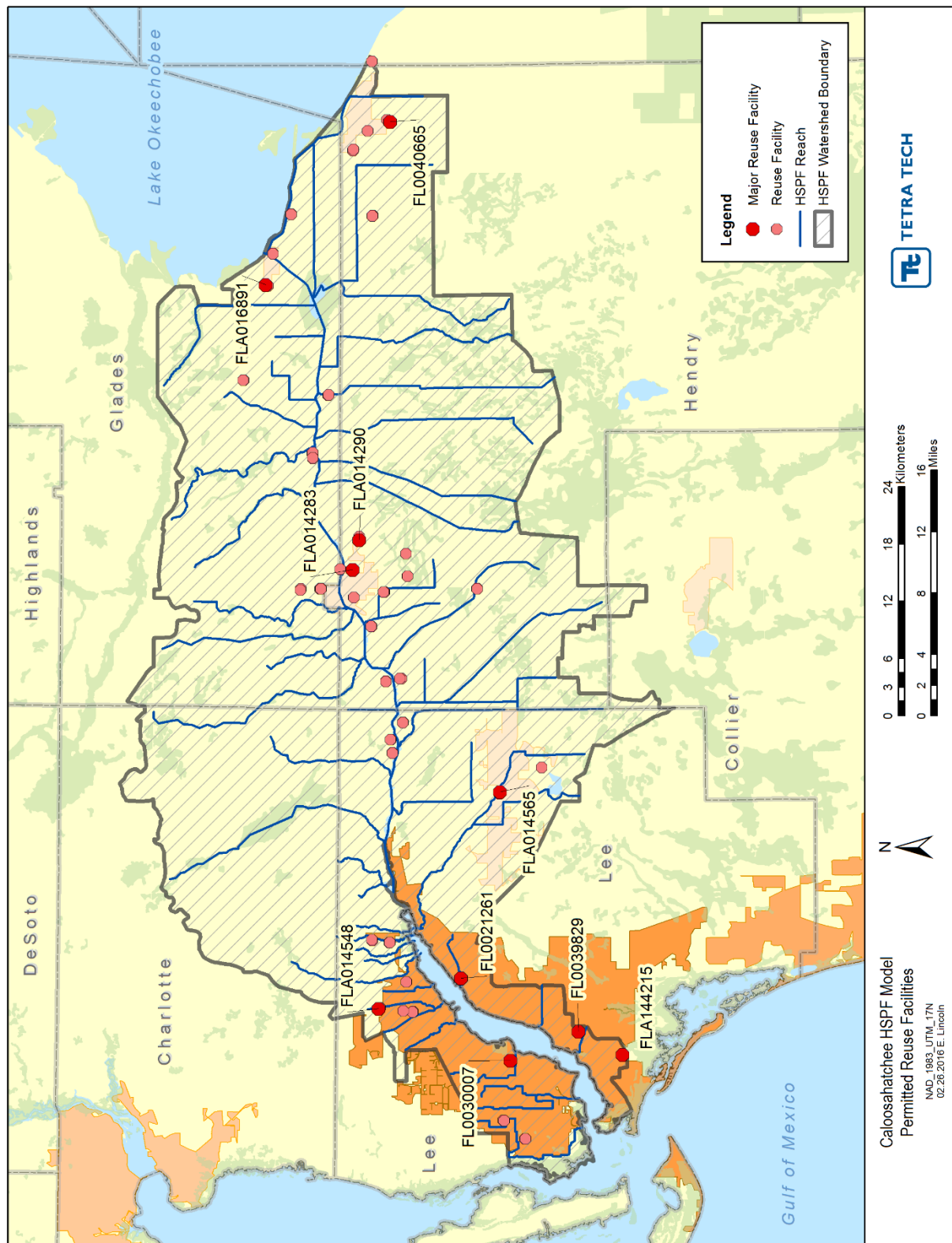


Figure 14: Wastewater treatment reuse facilities located in the watershed (major reuse facilities have permitted discharge greater than 0.1 MGD)

Issue #7: Representation of agricultural irrigation volumes and withdrawals may not properly represent withdrawal and demand.

Recommendation: The model currently represents agricultural irrigation as a point source that discharges directly to the HSPF model reaches, but the source of the water is not specified. Tetra Tech recommends that irrigation continue to be represented, but as a point source applied to the land. Information from the SFWMD on the dominant source of irrigation water (Caloosahatchee River, Lake Okeechobee, or ground water) will be used to assist in determining the source(s) of water for each subbasin (**Figure 15**). The irrigation will be represented in the model as a demand. This representation of irrigation water application is calculated outside of the model and does not use the built in HSPF irrigation module.

Tetra Tech will review the FDACS Florida Statewide Agricultural Irrigation Demand (FSAID) geodatabase, which is a central data repository for agricultural water use projects that contains the standardized statewide parcel-level geographic information system coverage for all agricultural and irrigated lands. Tetra Tech will consider the information in this database when determining where agricultural irrigation is occurring in the basin, specifically the acreage of irrigated land by crop type in each subbasin.

Tetra Tech recommends using the landscape coefficient method described in the WUCOLS III (Water Use Classifications of Landscape Species) manual in order to calculate the evapotranspiration (ET) demands within the Caloosahatchee River Basin. The equation to calculate ET Demand is:

$$\text{ET Demand} = \text{ETo} * \text{Kc}$$

Where ET Demand = Crop evapotranspiration demand (in.), ETo = Reference crop evapotranspiration (in.), and Kc = crop coefficient (dimensionless).

Irrigation application depths are the difference between ET Demand and rainfall, and the application depths will be used to develop the irrigation demand time series for the HSPF model. Tetra Tech will research the best values to use for ETo and Kc. Tetra Tech will use available information from the Agricultural Field-Scale Irrigation Requirements Simulation (AFSIRS) model, FSAID report, Blaney-Criddle Model, and FDEP Lake Okeechobee Watershed Assessment Model. ETo and Kc values will be estimated for crops that are irrigated in the Caloosahatchee watershed, such as citrus, row, and sugar cane crops.

Issue #8: The land coverage used in the 2009 and 2014 Models should be updated. The cropland/improved pasture reduced land cover description from the 2009 and 2014 Models should be broken out into at least four separate land covers, and the Florida Department of Transportation (FDOT) right-of-ways should also be a separate land cover. For impervious land, assumptions of traditionally pervious land cover types (e.g. cropland, pasture, and forest) as having DCIA may not be appropriate and representation should be evaluated.

Recommendation: As part of Task 2, Tetra Tech will compare the 2008 land use coverage to the 2012 coverage to determine if there were major changes in land uses. Based on this evaluation, a determination of which land use coverage to use in the model will be made. The land cover will

be reclassified using the same initial classifications as the 2009 and 2014 Models. Sugar cane, nurseries/ornamentals/vineyards, improved pasture, and row/field crops will be represented as four separate land covers, wetlands and water will be represented as two separate land covers, and the FDOT right-of-ways will be represented as a separate land cover. Tetra Tech expects to use 16 land cover classes in the 2017 Model.

Table 11: Proposed 2017 Model land cover classes using the 2008-2009 SFWMD land cover

Land Cover Class	Land Cover Class Description
1	Low Density Residential
2	Medium Density Residential
3	High Density Residential
4	Commercial / Institutional / Transportation
5	FDOT Right-of-Way
6	Industrial / Extractive
7	Developed Open Space / Disturbed
8	Sugar Cane
9	Row and Field Crops
10	Nurseries, Ornamentals, and Vineyards
11	Citrus Groves / Other Groves
12	Improved Pasture
13	Rangeland / Unimproved Pasture / Woodland Pasture / Shrub
14	Upland Forests
15	Wetlands
16	Water

Tetra Tech will update the representation of the DCIA using the Sutherland method and the National Land Cover Database (NLCD) spatial impervious coverage. Tetra Tech will use the NLCD impervious coverage to determine the total mapped impervious area (MIA) of each land cover class that is impervious, and then apply the Sutherland method formulas to the DCIA that will be used in the model.

The Sutherland method assumes that impervious areas associated with High Intensity Development are fully connected to the subbasins. In these areas, Sutherland assumes that 100% of the urban area within the basin is storm sewered. For impervious areas associated with Medium and Low Density Development, the basin may not be entirely sewered, and there are residential areas where rooftops are not directly connected to the storm sewer, and roads may be served by grassy swales or ditches. In extremely disconnected basins, such as impervious areas located in agricultural or forested areas, 70% or more of the basin is likely not directly connected to the stream. Sutherland provides the following four formulas for High Intensity Development (fully connected), Medium Intensity Development (average connection), Low Intensity Development (somewhat disconnected), and agricultural and forested lands (extremely disconnected) (Sutherland 1995):

Fully Connected: $DCIA = MIA$

Average Connection: DCIA = 0.1 (MIA)^{1.5}

Somewhat Disconnected: DCIA = 0.04 (MIA)^{1.7}

Extremely Disconnected: DCIA = 0.01 (MIA)^{2.0}

Issue #9: Some HSPF model parameterization, for hydrology, sediment, and water quality loading rates, are outside of the expected ranges.

Recommendation: Tetra Tech will evaluate the current model parameterization during the model updates. Based on the initial evaluation of parameterization in described in **Section 2.5**, Tetra Tech recommends the following actions:

- Check and re-evaluate the identified PET parameters (BASETP, AGWETP, LZETP) values.
- Develop land use variable CEPSC parameter values and adjust the values assigned to January and December to be within range.
- The parameter values identified as being out of range for KRER, COVER, and KSER are all applicable to the wetlands/water land use. These sediment parameters are geared towards eliminating sediment contributions, and the values will be reviewed during model calibration and adjusted as needed while ensuring that sediment loading rates are reasonable for the wetlands/water land uses.
- Check KSER and KEIM values to ensure that the relative magnitude of sediment delivery rates among different land uses are consistent with literature.
- Evaluate the pollutant accumulation rates, interflow concentrations, and ground water concentrations for land uses and compare to available measured data and reports.

Issue #10: (*Stakeholder comment*) Representation of wetlands in the model should be evaluated.

Recommendation: Tetra Tech will update the model parameterization of wetlands to represent them as a nutrient sink under low flow conditions when they are contributing to interflow and ground water flow, and as a nutrient source during high flow conditions when water is leaving the wetlands system.

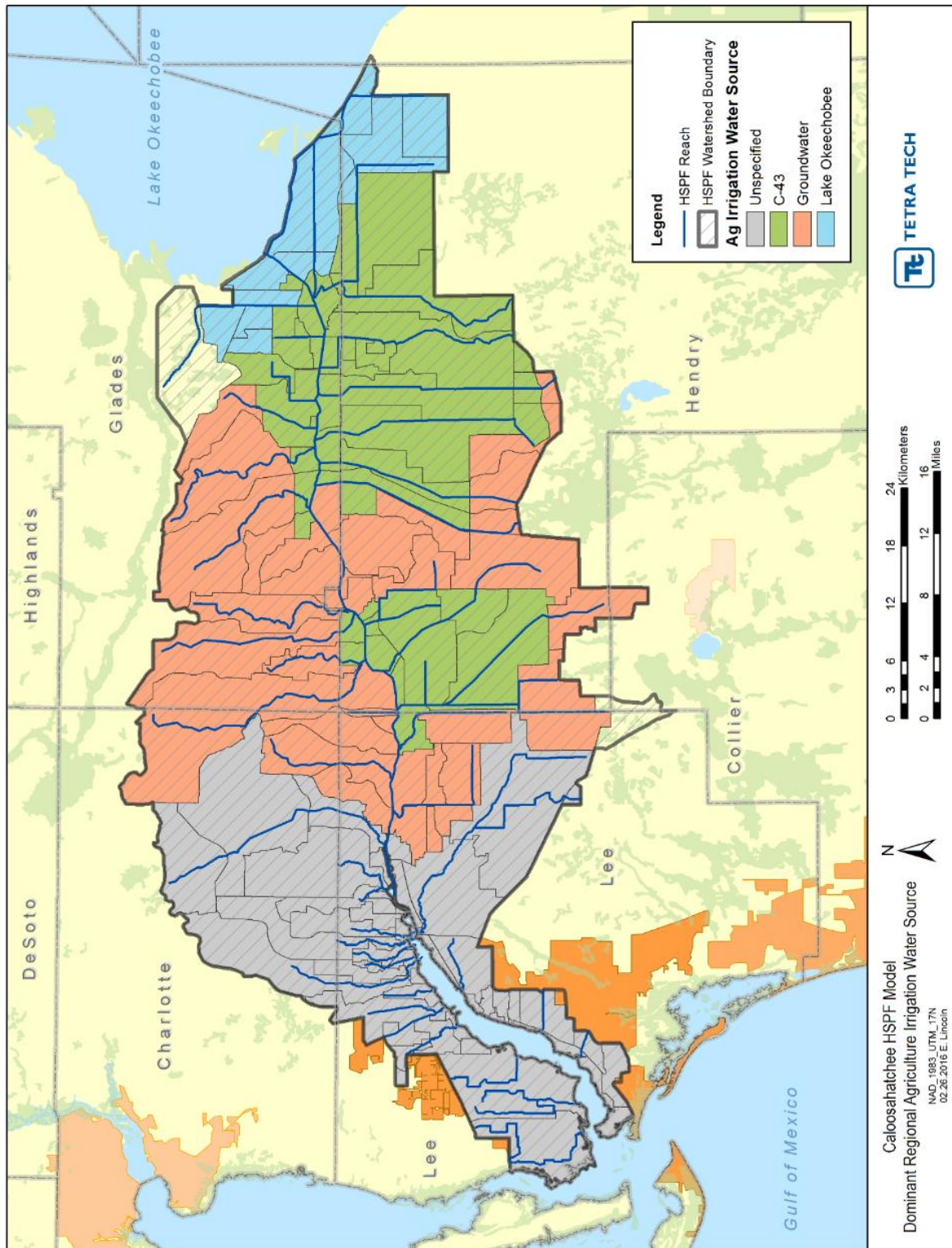


Figure 15: Dominant agricultural irrigation water withdrawal source

3.0 EFDC MODEL REVIEW

3.1 CONCEPTUAL STRUCTURE

The 2009 Model is documented in the Dynamic Solutions 2009 report. The department and stakeholders identified additional model needs for the TMDLs. Therefore, the department expanded to the present 2014 Model grid. There is limited documentation for the 2014 Model set up and the following comments and recommendation are based on a detailed review of the 2014 Model input files.

The overall 2014 Caloosahatchee EFDC grid set up has a good spatial representation of the harbor and estuary areas. However, there are some issues with the implementation of this grid set up.

The 2009 and 2014 Model grids included boundary tidal cells for both the main waterbody and shallow marsh areas that vary between wet and dry conditions. This is the case for both the Matlacha Pass and Pine Island Sound model areas (**Figure 16** and **Figure 17**). Applying tidal boundaries to cells that represent both wet and dry conditions can cause some instability in the model. Therefore, both of these tidal boundaries should be modified so that only the cells in the open water area are included.



Figure 16: Matlacha Pass model tidal boundary



Figure 17: Pine Island Sound model tidal boundary

The current model grid also does not represent the deep channels well. Some of the deep water model cells are not well connected to the channels due to large depth differences between adjacent cells, which could be causing issues with representing how the salinity wedge moves in these channels. The channel depths will be reviewed to ensure a well-connected channel is represented to move the salt wedge up and down the estuary.

A sigma grid of four layers is currently being used in the EFDC model, which results in cell depths ranging from 0.1 meters to 5 meters. The Caloosahatchee system may be better represented using the generalized vertical coordinate (GVC) multi-layer grid with variable cell layers and increasing the number of maximum layers to six, with an average cell depth of about 1 meter. This will increase the model's vertical resolution in the deeper areas and convert shallower, seagrass cells to one layer. In addition, this change should decrease the overall number of vertical cells and yield faster model run times without losing accuracy. In addition, thin bottom cells can have problems properly representing sediment oxygen demand (SOD) and DO. The SOD impacts are overstated due to the small cell volume and the resultant DO is much lower than expected. With less layers and larger cell volume, the SOD impacts are more realistically calculated.

The marsh areas, as represented in the current grid, are much deeper than the depths indicated on the NOAA nautical charts. Most likely, the routine used to set the various grid depths used the marsh channels' contour lines to assign depths for the entire marsh area, which resulted in marsh area depths of 1 to 2.5 meters. Tetra Tech recommends that the depths for the areas that are salt marshes be capped at a maximum depth of 0.5 meters, with the appropriate vegetation settings.

The original bathymetry appears to be from online NOAA depth data and should be adequate for this project. However, these data need to be checked against NOAA nautical charts to ensure the data are translated to the model grid correctly (**Figure 18**).

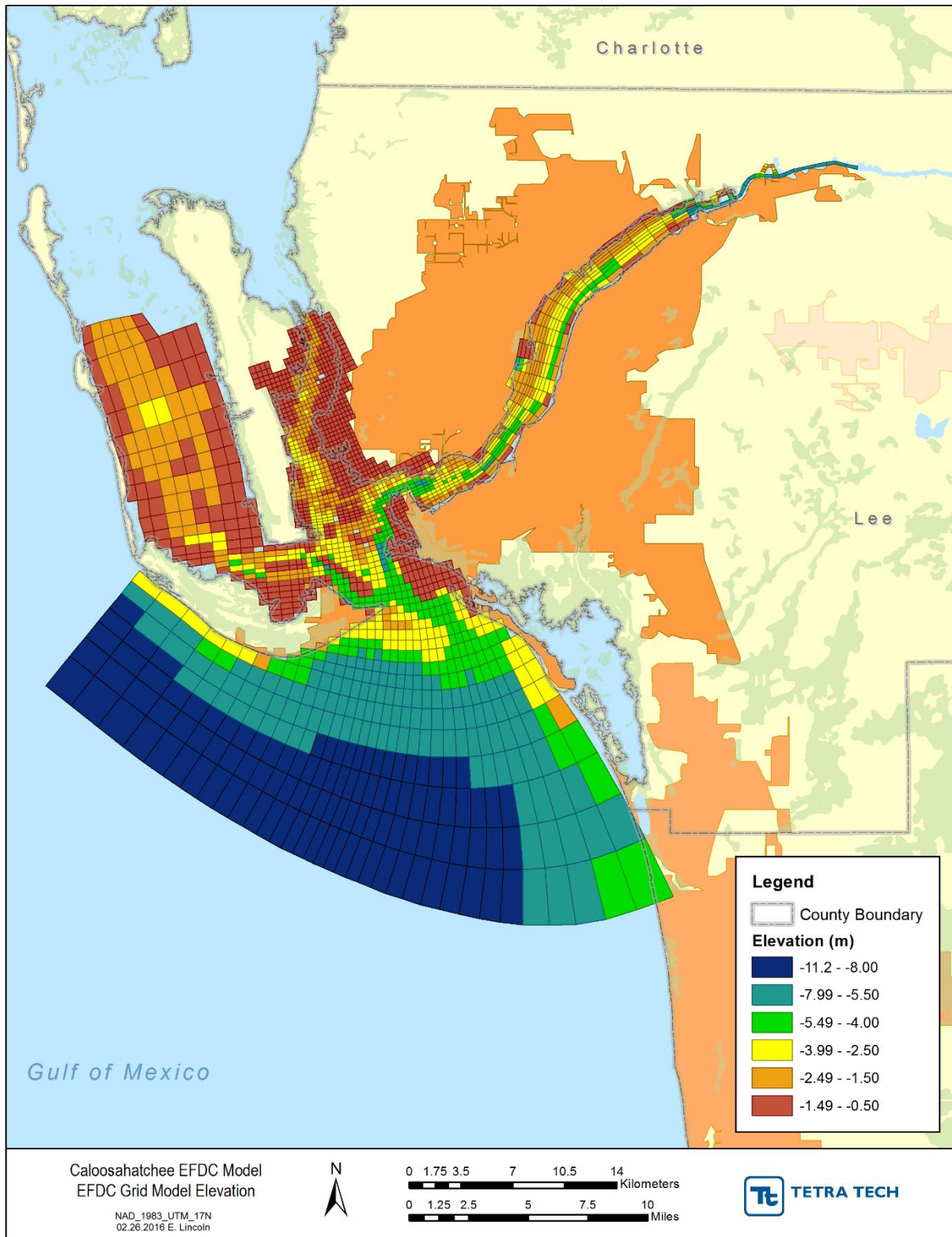
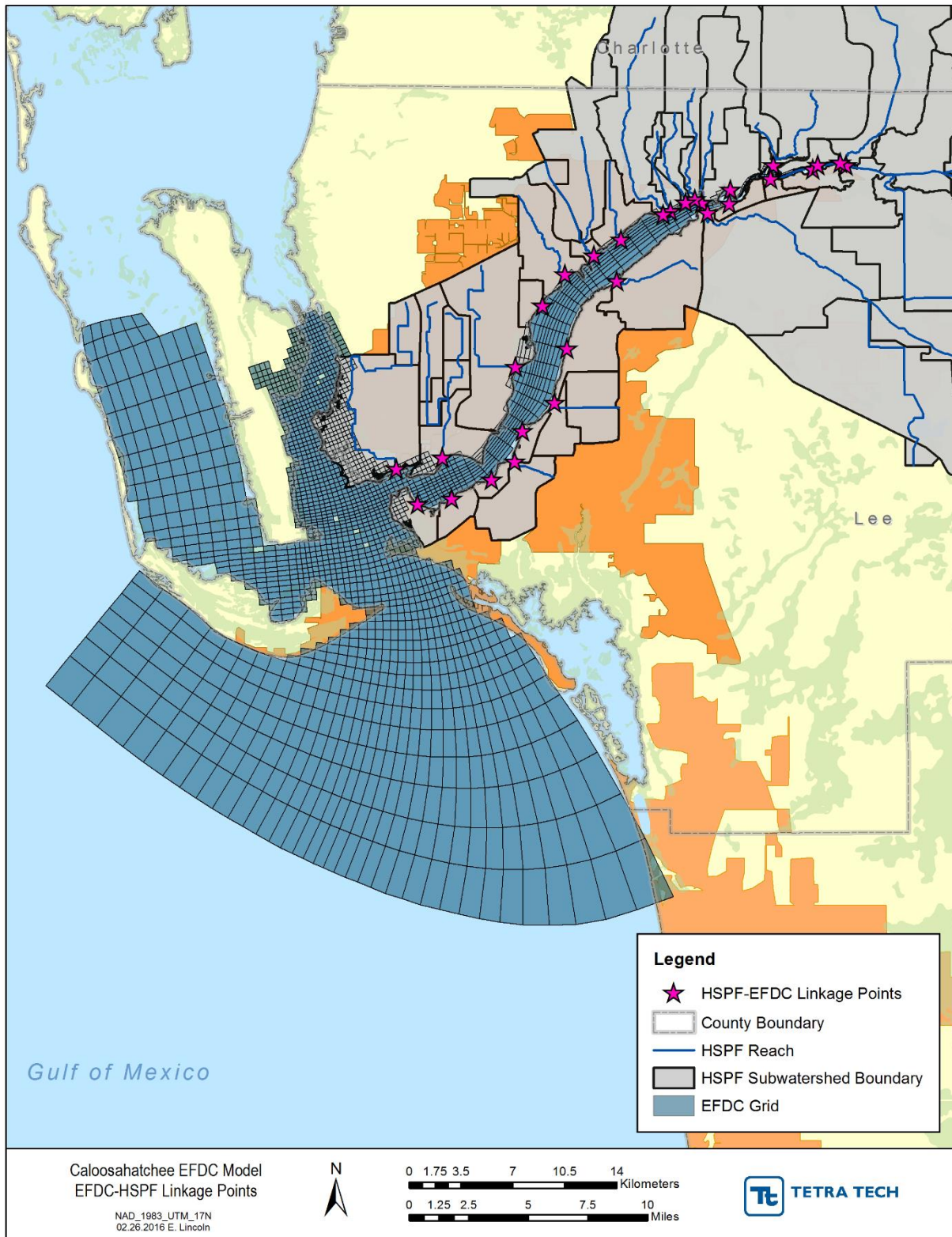


Figure 18: Caloosahatchee EFDC bottom elevations

The 2009 and 2014 EFDC Models are linked to the HSPF model and all the linkages seem to be correct. **Table 12** and **Figure 19** show the HSPF model outputs and EFDC model cells where they are linked.

Table 12: HSPF Model outputs and linkages to EFDC Model cells

HSPF Model Segment	EFDC Model Cell I	EFDC Model Cell J
S-79 Structure	98	30
HSPF 02	97	30
HSPF 03	95	30
HSPF 04	94	30
HSPF 05	90	34
HSPF 06	89	30
HSPF 07	81	35
HSPF 08	81	30
HSPF 09	78	33
HSPF 10	79	30
HSPF 11	77	36
HSPF 12	76	36
HSPF 13	75	36
HSPF 14	74	37
HSPF 15	72	37
HSPF 16	71	29
HSPF 17	71	37
HSPF 18	68	37
HSPF 19	65	38
HSPF 20	62	29
HSPF 21	61	40
HSPF 22	59	29
HSPF 23	56	30
HSPF 24	54	29
HSPF 25	53	29
HSPF 26	49	39
HSPF 27	47	30
HSPF 28	42	30
HSPF 29	39	42

**Figure 19: EFDC Model cell linkages to HSPF Model outputs**

There were five point sources discharging directly to the 2007 and 2014 EFDC Models. **Table 13** lists these point sources and their EFDC cell location and the locations are shown in **Figure 13** (Section 2.4).

Table 13: Point sources in the EFDC Model

NPDES ID	Facility Name	Type	Design Capacity (MGD)	EFDC Model Cell I	EFDC Model Cell J
FL0021261	Fort Myers Central AWWTF	DW	11	72	29
FL0021270	South AWWT Facility	DW	12	61	29
FL0030007	Cape Coral, City of - Everest WRF	DW	15.1	62	40
FL0030325	Waterway Estates	DW	5	64	38
FL0039829	Fiesta Village Advanced WWTF	DW	1.5	55	30

There is limited detail on how the 2009 or 2014 Model open boundary conditions were developed. These inputs will be reviewed and updated based on the available NOAA tide data and the measured salinity data. The meteorological data are from the Fort Myers Page Field records, which were supplemented with the Fort Myers Southwest Regional records. These data will be expanded to extend through 2014.

The water quality parameters are within expected normal ranges for southeastern estuaries. Only one algal group was used to represent the estuary's algal community; however, most southeast estuaries are represented using three algal groups.

3.2 MODEL INPUT FILES

Tetra Tech ran the EFDC model and examined the auxiliary input files. From this evaluation, the following was found:

- DXDY.inp: The depths and bottom elevation values do not match up, which is causing instability at the start of the model runs. The bottom roughness coefficient of 0.02 is in the appropriate range; however, Tetra Tech will examine the results using a higher roughness coefficient for the shallow marsh areas.
- VEGE.inp: This file factors aquatic vegetation impact in the model and provides more friction to the water movement. This can be accomplished by either: (1) increasing the bottom roughness coefficient, which only impacts the bottom layer; or (2) including an aquatic bottom fixed vegetation estimate for each cell. This file was used but may have been modified from the original EFDC model coding; however, there is no documentation for what changes were made, if any. If the 2009 Model used the original VEGE.inp file set up, a factor was included that zeroed out any vegetative resistance to water movement.
- SSER.inp: A freshwater salinity concentration of 0.5 ppt was used in the 2009 Model. Unless there is some evidence of minor saltwater intrusion, this value should be set to 0. An offshore constant salinity boundary of 35 ppt was used for south boundary. Stations along the Pine Island Sound, Matlacha, and Estero Bay areas will be evaluated for determining the north boundary salinity forcing time series.

- TSER.inp: The temperature data in the input file appear reasonable; however, the 2009 Model is over predicting the summer temperature in 2003. The 2017 Model will need to be recalibrated to all available data.
- PSER.inp: The boundary elevations in this file seem reasonable. The 2009 Model report only includes one graph showing year 2003 at the NOAA tide station 8725520, with minimal statistics. Therefore, it is difficult to determine if the 2009 Model is predicting low and high tides correctly. During model recalibration, the water surface elevation will be recalibrated to all available data, including the USGS station located at S-79 and the USGS station at Whiskey Creek.
- ASER.inp: The meteorological data and coefficients in the input file appear reasonable; however, adjustments may need to be made to better calibrate temperature.
- WSER.inp: The data in the input file appears reasonable.
- QSER.inp: Flows in the QSER.inp file are two to three times the measured flow at the USGS gage and the HSPF model flows. For the S-79, the HSPF model flow is 1,200 cubic feet per second (cfs) and the USGS gage flow is 1,480 cfs. However, the EFDC QSER.inp flow is 3,561 cfs. In addition, at Whiskey Creek, the HSPF model flow is 13 cfs and the USGS gage flow is 10.3 cfs. However, the EFDC QSER.inp flow is 31 cfs. It appears that the conversion program used for inputting the HSPF model flows to the EFDC QSER.inp file calculated the flows incorrectly, and this will need to be corrected in the updated model.
- ALGALGRO.inp: This file provides the algal growth kinetics by zone. The 2009 and 2014 Models did not use this file; however, there is an undocumented WQALGG.inp file, which is hardwired into the 2009 and 2014 Models code. Tetra Tech recommends using the ALGALGRO.inp file and its documented parameters.

3.3 MODEL PARAMETERIZATION

Tetra Tech determined that the water quality and TSS kinetics and parameters for the water column are within normal ranges for southeastern estuaries. However, the water quality variables will be reevaluated in light of the more recent data that will be used in the 2017 Model. The main input file for the 2009 and 2014 models has various additions from the public domain version, suggesting changes have been made to the original code. These changes have not been documented and may cause an issue when comparing the outputs of the 2017 Model to the 2009 Model. Specific changes that will be made for the 2017 Model are noted in **Section 3.5**.

Tetra Tech could not determine how the sediment nitrogen and phosphorus water column fluxes were developed. The input files noted that a special modeling routine was used that is undocumented. Also, the SOD values were input as non-temperature varying, with no documentation on how or why this was done. Tetra Tech will review the latest SOD and nutrient flux measurements and determine the appropriate method to incorporate the available data into the EFDC model. During model calibration, Tetra Tech will evaluate the dynamics of the system and determine if sediment diagenesis is needed to capture the nutrient sources in the estuary, or if they can be represented using parameterization by water quality zone.

3.4 MODEL STABILITY

Tetra Tech could not determine if the proprietary EFDC model was stable. Tetra Tech set up an initial public domain hydrodynamic EFDC model, which incorporated the changes recommended in this memo and checked stability. For the time period of May 2010 to October 2010, at a time step of 30 seconds, the model ran without instabilities.

3.5 RECOMMENDATIONS

Based on our review and assessment, Tetra Tech has identified the following issues and recommendations for the EFDC model.

Issue #1: The 2009 and 2014 Models use the Dynamic Solutions proprietary EFDC model.

Recommendation: Tetra Tech will convert the current proprietary version of the EFDC model to the public domain application of the model. The model code will be supplied to the department.

Issue #2: (*Stakeholder comment*) Change light extinction in the public domain code.

Recommendation: In the 2009 Model, light extinction is hardwired into the code of the main water quality input file, and Tetra Tech is unsure if the typical model equations are still available. Tetra Tech recommends including the light extinction equations in the public domain version of the model. This is part of Task 4 of this project.

Issue #3: (*Stakeholder comment*) Color can contribute up to 80% of the light attenuation in the Caloosahatchee River. It is critical to account for the temporal and spatial variation of color.

Recommendation: Based on this comment, the 2014 Model was updated to include a new set of light extinction equations. These equations will be included in the public domain 2017 EFDC Model. The general equation to be incorporated in to the 2017 EFDC Model is:

$$K_e = K_{eback} + K_{eshd} + K_{esolid} + K_{eDOC}$$

Tetra Tech will describe the approach to implement these equations in the 2017 EFDC Model, provide the department with FORTRAN coding and coordinate with the department to ensure the approach represents what the department and stakeholders intended. To account for the variations in color throughout the estuary and the relationship between color and salinity, the extinction coefficients will be varied by zone and will be determined during model calibration by reviewing available water quality data.

Issue #4: (*Stakeholder comment*) The current model timeline ends in 2010 and does not allow model calibration to new datasets.

Recommendation: After discussions with the department, Tetra Tech will extend the current EFDC model time period from 2011 to the end of 2014. The department will provide the weather

files for the model simulation time period and Tetra Tech will process the data for inclusion in the model.

Issue #5: The original model grid included boundary tidal cells for the main waterbody and shallow marsh areas that vary between wet and dry conditions.

Recommendations: Tetra Tech recommends that the Matlacha Pass and Pine Island Sound tidal boundaries only be applied to cells in the open water area to prevent model instability.

Issue #6: A sigma grid of four layers is currently being used in the model.

Recommendations: Tetra Tech recommends changing the grid to a GVC multi-layer grid with variable cell layers. This will convert shallower cells to one layer, and decrease the overall number of vertical cells while yielding faster model run times without losing accuracy. Tetra Tech also recommends determining if changing the channel from four to six layers would improve the model calibration and performance, and this testing will be done during calibration. However, adding layers will decrease run time, so if the addition of the layers does not appear to increase model calibration performance, the additional layers will not be added.

Issue #7: The deep channels are not well represented in the current model, which could be causing issues with representing how the salinity wedge moves in these channels.

Recommendations: The channel depths will be reevaluated to ensure that the channels are appropriately represented and that there are no unintended blockages to the saltwater moving upstream.

Issue #8: The DXDY.inp file includes initial depths that did not match up with the bottom elevations, which is causing instability in the startup of the EFDC model runs.

Recommendation: The initial depths should be revised to follow the bottom elevation. In addition depths at the boundary conditions vary, which may be causing additional instability issues. Tetra Tech will evaluate setting all boundary cells at the same depth to determine if instability issues could be further reduced.

Issue #9: The boundary condition files should be evaluated and updated as necessary.

Recommendation: Tetra Tech will use measured data at the northern boundary condition at stations along the Pine Island Sound and Matlacha Pass. Tetra Tech will evaluate the current boundary conditions for the south boundary and determine if additional data are available to update the boundary conditions. During calibration, Tetra Tech will compare measured water quality data to modeled water quality data at the Estero Bay outlet and determine if an additional boundary should be added to represent loads entering the model domain at the Estero Bay outlet

Issue #10: The QSER.inp flow file has flows that are two to three times the measured flow at the USGS gage and the HSPF model flows.

Recommendation: It appears that the conversion program used for inputting the HSPF model flows to the EFDC QSER.inp file was calculating the flows incorrectly, and this will be corrected

in the updated model. The water quality input loads may also be an issue and will be corrected if needed.

Issue #11: The VEGE.INP file may not be set up correctly and is underestimating the vegetative resistance to water flow in the non-channel areas.

Recommendation: Tetra Tech recommends setting up a VEGE.inp file with approximately five zones (the 2009 Model has two zones) that correspond to the various depths and aquatic plants in each area. The extent of each zone will be determined after reviewing the available data and during calibration.

Issue #12: (*Stakeholder comment*) Algal representation may not be adequate.

Recommendation: In the 2009 Model, the main water quality input file was changed to include an algae sub-model routine. However, there is no definition of what this sub-model does. In addition, only one algal class was activated. Tetra Tech recommends using three algal classes, cyanobacteria, diatoms, green algae groups, which will represent the spring, summer, and fall algal blooms, that are typical for southern waterbodies. In addition, Tetra Tech recommends using the ALGALGRO.inp file, which provides the algal growth and death rates by zone, along with appropriate algal rates for each algal group. These rates will be adjusted during calibration based on the available algal data.

Issue #13: The SOD assumptions may be incorrect.

Recommendation: The 2009 Model included an extra variable in the code to ignore SOD temperature effects, and this is not a standard modeling assumption. Tetra Tech recommends that this be evaluated during model recalibration.

Issue #14: The representation of point sources inputs can be improved.

Recommendation: In the 2009 and 2014 models, point sources are input as loadings. Therefore, if the point source flows are wrong, the loadings are also incorrect. Tetra Tech recommends inputting tributary and point source parameters as concentrations, not loads, with the correct HSPF model calibrated flows. The benefit of this approach is that it is simple to assess the time series and verify that the concentrations are within expected ranges or if there are issues with the time series. The DMR data received by the department will be reviewed to determine how to best represent these facilities in the model. Tetra Tech will develop point source time series to include in the model.

FL0030325 did not discharge for the entire 2017 Model simulation period, and the point source time series will be reflective of their active discharge dates. FL0030325 was officially closed on December 18, 2012. Waste received at this facility was diverted to the reuse facility FL014548 in October 2012.

Tetra Tech will add the Florida Power & Light (FPL) Fort Myers power plant (FL0001490) to the EFDC model, as requested by FPL. This facility withdraws water from the Caloosahatchee River and discharges into Orange River. The department will coordinate with FPL to gather data about

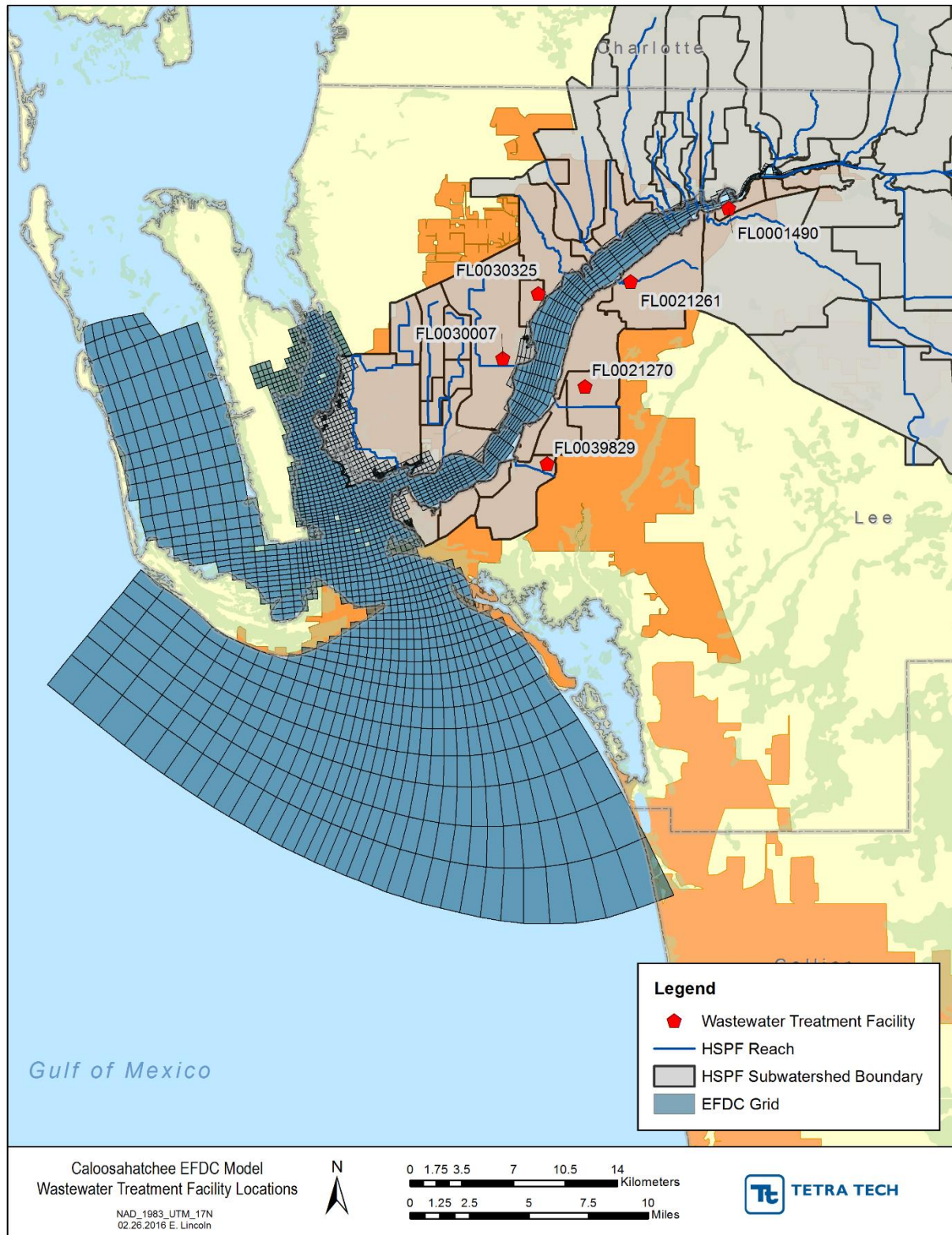
the facility's processes, and Tetra Tech will use this information to determine how best to represent the facility in the model.

Table 14 lists all point sources that will be included in the EFDC model, and the locations are shown in **Figure 20**.

Table 14: Point sources in the EFDC Model

NPDES ID	Facility Name	Type	Design Capacity (MGD)	EFDC Model Cell I	EFDC Model Cell J
FL0021261	Fort Myers Central AWWTF	DW	11	72	29
FL0021270	South AWWT Facility	DW	12	61	29
FL0030007	Cape Coral, City of - Everest WRF	DW	15.1	62	40
FL0030325	Waterway Estates	DW	5	64	38
FL0039829	Fiesta Village Advanced WWTF	DW	1.5	55	30
FL0001490	Florida Power and Light Fort Myers	IW	590.6	TBD [†]	TBD

[†] To be determined (TBD) - Location of FL0001490 discharge will be identified during modeling

**Figure 20: Wastewater treatment facility locations**

Issue #15: Atmospheric deposition was not included in the model.

Recommendation: No wet or dry atmospheric deposition is currently included in the model. Tetra Tech recommends including atmospheric deposition from the nearest monitoring station.

Issue #16: Tidal tributaries are represented only in the HSPF model.

Recommendation: Tetra Tech will improve the model simulation of the tidal prism in the tributaries and canals that are tidally influenced. This includes, but is not limited to, Cape Coral Canals, Billy's Creek, Orange River, and Yellow Fever Creek. The number of drainages that will be included in the EFDC estuary model grid will be determined as model development progresses.

Issue #17: The EFDC model needs to be calibrated to water surface elevation and flow station data, where available.

Recommendation: Tetra Tech will compare the hydrodynamics of the model to stations with hydrodynamic data, specifically USGS 02293210 (Shell Point) and USGS 02293205 (Channel Marker 52).

Issue #18: (*Stakeholder comment*) An insufficient number of water quality stations were used for model calibration.

Recommendation: Tetra Tech will work with the department to identify approximately 10 calibration and 10 validation stations that will be used in the EFDC model.

4.0 PROJECT TEMPLATES

Tetra Tech has prepared this memorandum in the style and format that will be used for all future memorandums. The department should review the template and let Tetra Tech know if there are any changes needed to structure, format, and general content.

Tetra Tech has also prepared an outline of the HSPF and EFDC modeling report, and the outline is attached at the end of this memorandum. The report outline documents the expected sections and information that will be contained in the final report. The outline may be updated during the process of report writing as necessary to reflect additional information that may need to be provided.

Both the memorandum and modeling report contain a sample of map figures, calibration plots (temporal and depth profiles), general informational tables, and calibration statistical tables. These figures and tables display the general coloring schematic and formats that will be used throughout the memorandums and in the final report. The department should review the figures and tables and inform Tetra Tech if any formatting changes should be made.

5.0 MODEL PERFORMANCE CRITERIA

For this project, the department requested that Tetra Tech evaluate the goodness-of-fit of the model simulations by comparing the central tendency, time series, and data distribution for the model results to the measured data. These comparisons will be made through graphs, such as box and whisker plots, time series plots, and frequency distribution curves. In addition, summary statistics, such as relative error, root mean square error, Nash-Sutcliffe model efficiency, and Kolmogorov-Smirnov test will be used to evaluate the results.

To evaluate the statistical results, Tetra Tech recommends using the performance criteria in the tables below, which come from Donigian (2002) and McCutcheon et al. (1990). These performance criteria will be applied to the percent difference between the median of the model results and the median of the observed values.

Table 15: Donigian 2002 calibration/validation targets or tolerances for percent difference between modeled observed results for hydrologic parameters

Category	Range
Very Good	<10%
Good	10% - 15%
Fair	15% - 25%
Poor	>25%

Table 16: Donigian 2002 and McCutcheon et al. 1990 calibration/validation targets or tolerances for percent difference between modeled observed results for water quality parameters

Category	Salinity	Water Temperature	Water Quality/DO	Nutrients/Chlorophyll-a
Very Good	<15%	<7%	<15%	<30%
Good	15%-25%	7%-12%	15%-25%	30%-45%
Fair	25%-40%	12%-18%	25%-35%	45%-60%
Poor	>40%	>18%	>35%	>60%

Table 17: Donigian 2002 R, R², Nash-Sutcliffe, and Index of Agreement ranges for model performance

Category	Range
Very Good	>0.8
Good	0.7 - 0.8
Fair	0.6 - 0.7
Poor	<0.6

These performance criteria will be only one line of evidence for evaluating the model results. While the goal will be to achieve results that fall into the “very good” and “good” categories, there may be locations in the river or watershed or certain parameters with results in the “fair” or “poor” categories. The other lines of evidence, such as a visual comparison of the model results to the observed values, will then be evaluated to determine if overall model performance still meets the project objectives of providing the department with models that can be used to develop the TMDLs for the impaired freshwater bodies and to refine the Caloosahatchee tidal estuary TMDLs.

6.0 REFERENCES

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APPENDIX A: DRAFT HSPF AND EFDC MODELING REPORT TEMPLATE

Hydrology and Water Quality Modeling Report

for the

Caloosahatchee River, Florida

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April 11, 2016

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Contract: 100-ATL-T35417
Task: 01



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LIST OF ACRONYMS AND ABBREVIATIONS

BMAP	Basin Management Action Plan
Department	Florida Department of Environmental Protection
EFDC	Environmental Fluid Dynamics Code (model)
HSPF	Hydrologic Simulation Program – FORTRAN (model)
SFWMD	South Florida Water Management District
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus

EXECUTIVE SUMMARY

The Executive Summary is a highly condensed version of the full document and should contain enough information for readers to become acquainted with the full document without becoming overwhelmed with details. The Executive Summary should be able to stand as an independent element.

1.0 INTRODUCTION

Project background, goal of the project, and description of the watershed

FIGURE 1: PLACEHOLDER

TABLE 1: PLACEHOLDER

Title	Title	Title	Title

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2.3 HSPF-EFDC Model Linkage

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4.2.8 Point Sources

4.2.9 Nonpoint Sources

4.2.10 Best Management Practices

4.3 HSPF Hydrodynamic Calibration

Model calibration and validation overview – additional details in Appendix A

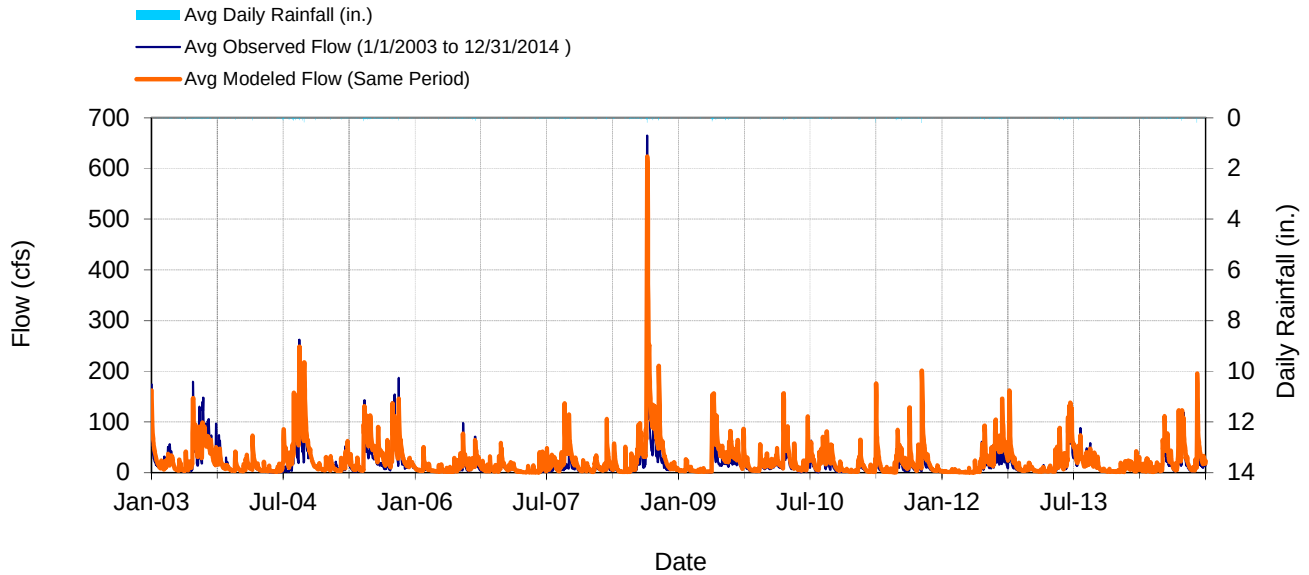


FIGURE 2: TIME SERIES COMPARISON OF MODEL RESULTS TO USGS GAGE XXXXX

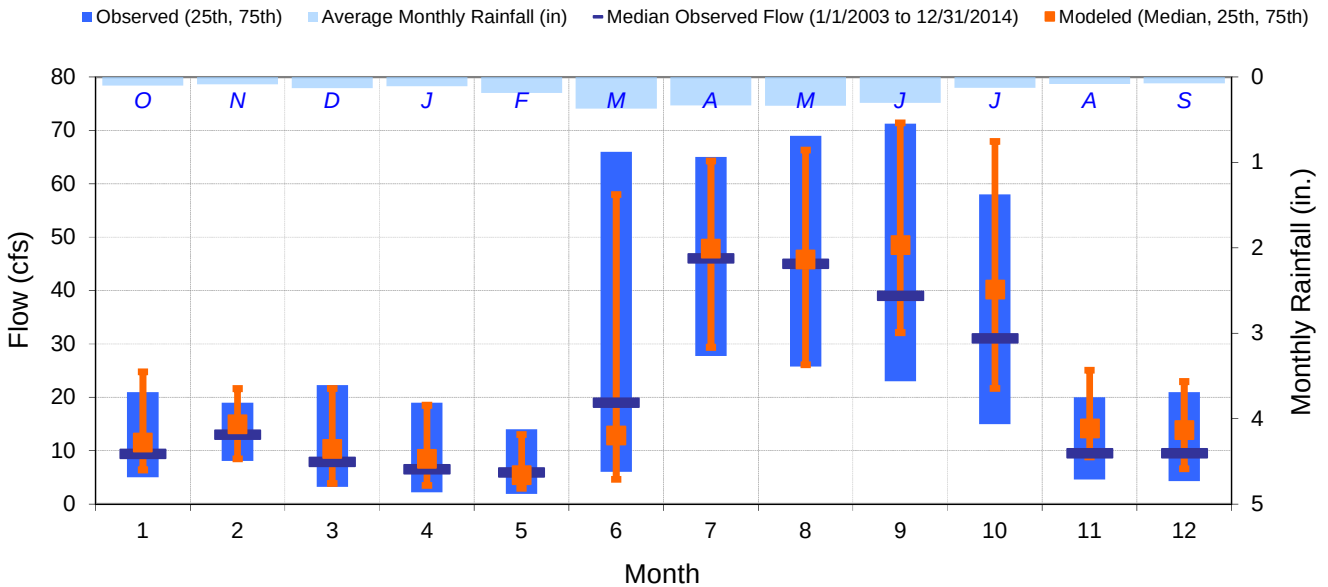


FIGURE 3: BOX AND WHISKER PLOTS (OBSERVED AND SIMULATED MONTHLY FLOWS) FOR USGS GAGE XXXXX

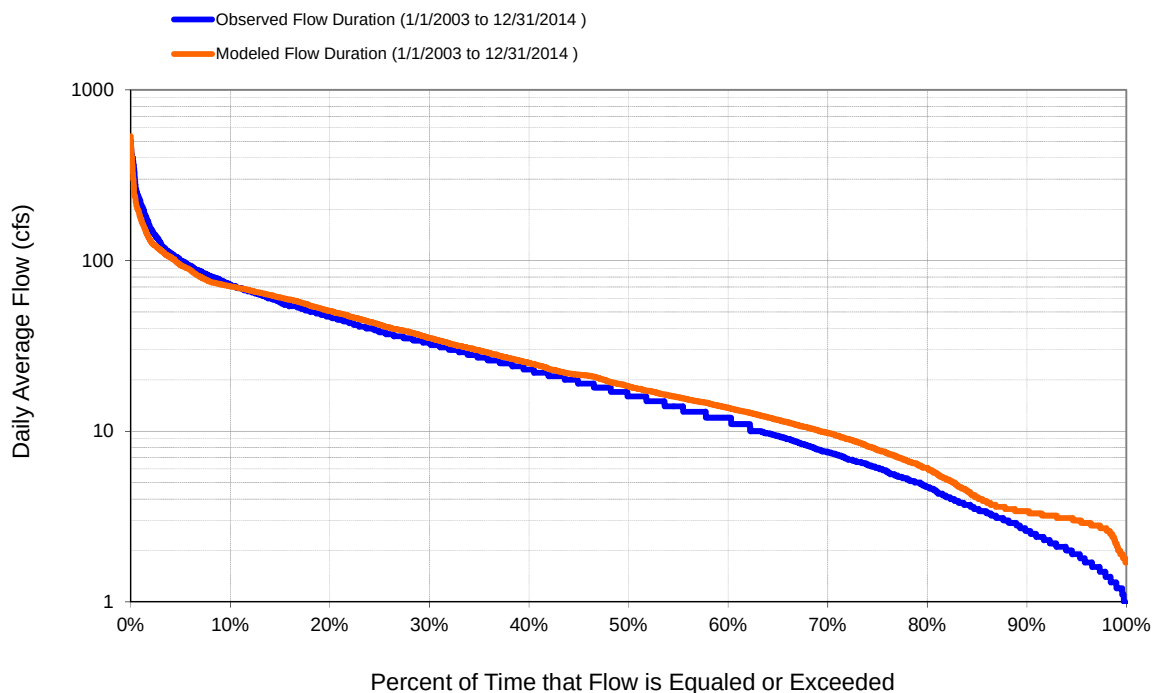


FIGURE 4: FREQUENCY DISTRIBUTION CURVE (OBSERVED AND SIMULATED DAILY FLOWS) FOR USGS GAGE XXXXX

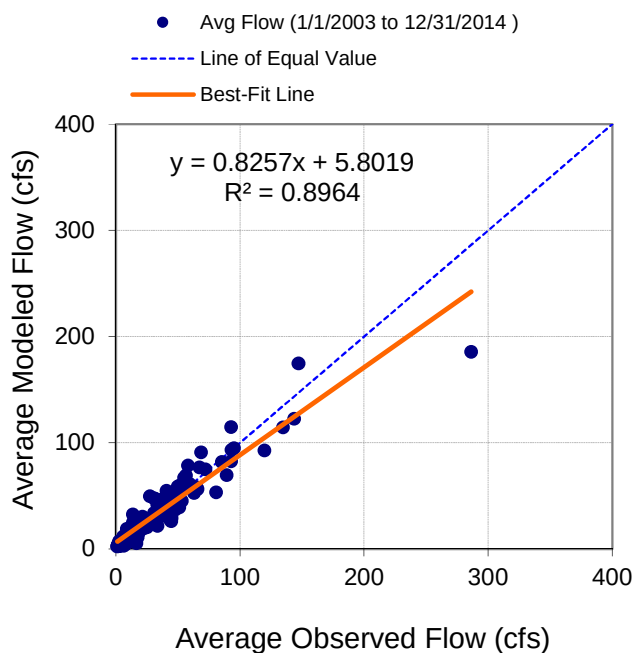


FIGURE 5: SCATTER PLOT (OBSERVED AND SIMULATED MONTHLY FLOWS) FOR USGS GAGE XXXX

TABLE 2: ERROR STATISTICS FOR USGS GAGE XXXXX FOR THE PERIOD OF 1/1/2003 – 12/31/2014

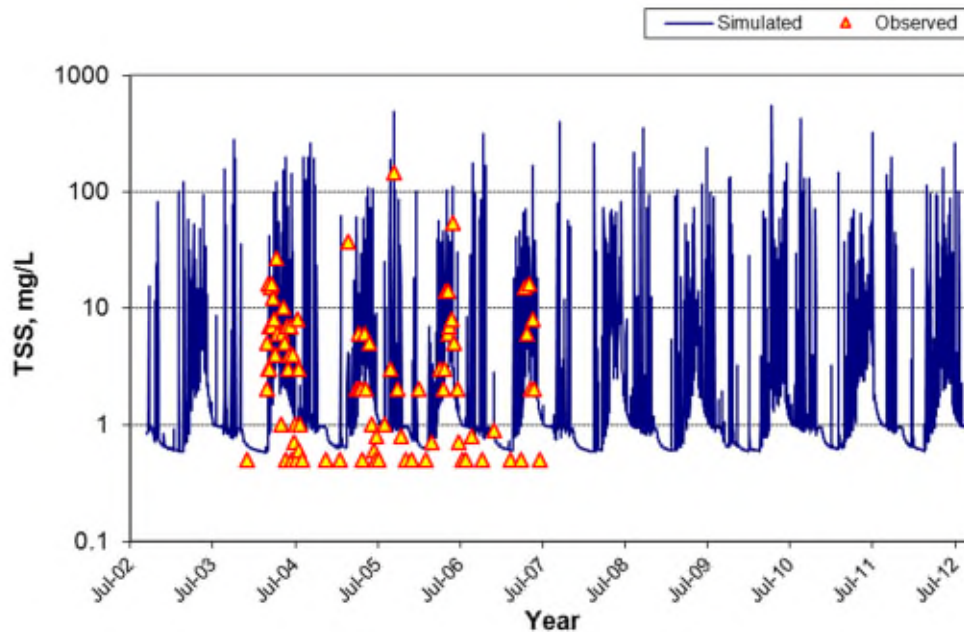
Note: Nash-Sutcliffe Coefficient of Efficiency = 0.839

Flow Category	HSPF Simulated Flow from Subbasin XX (inches/year)	Observed Flow from Gage XXXX (inches/year)	Error (Simulated – Observed)
Total in-stream flow	9.66	9.91	-2.51
Total of highest 10% flows	3.93	4.14	1.30
Total of lowest 50% flows	1.14	1.12	-4.94
Summer flow volume (months 7-9)	4.50	4.78	-5.96
Fall flow volume (months 10-12)	2.37	2.10	13.06
Winter flow volume (months 1-3)	1.37	1.28	7.79
Spring flow volume (months 4-6)	1.41	1.75	-19.31
Total storm volume	1.67	1.49	11.90
Summer storm volume (months 7-9)	0.81	0.72	11.60

4.4 HSPF Water Quality Calibration

4.4.1 Calibration Methodology

4.4.2 Sediment

**FIGURE 6: COMPARISON OF MODELED TSS AND OBSERVED TSS CONCENTRATIONS AT STATION XXXX**

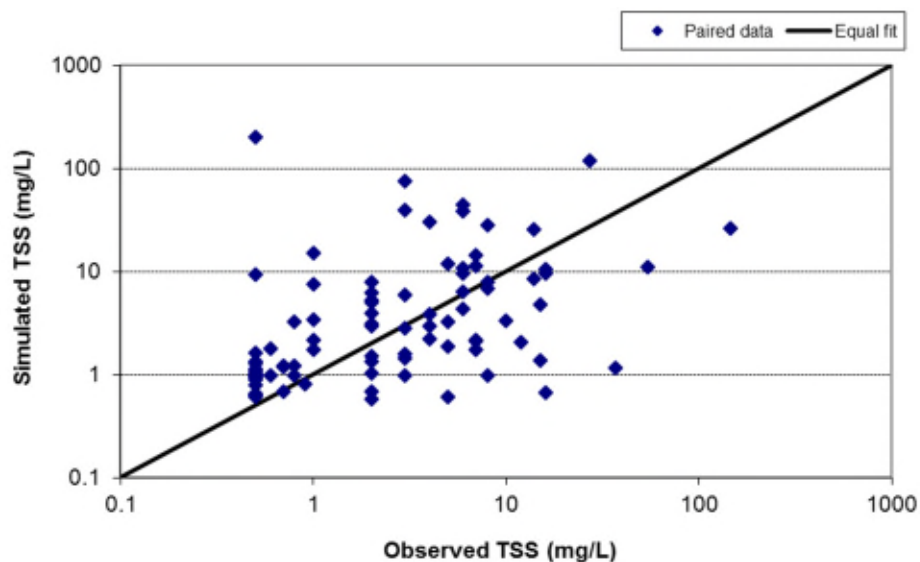


FIGURE 7: LINEAR REGRESSION OF MODELED TSS AND OBSERVED TSS CONCENTRATIONS AT STATION XXXX

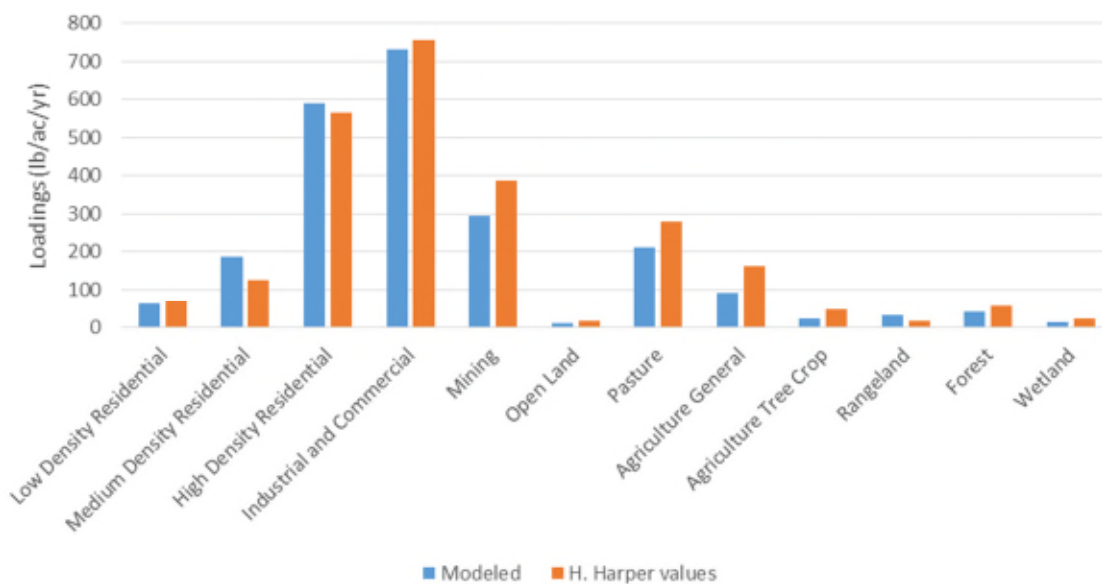


FIGURE 8: COMPARISON OF MODELED AND LITERATURE VALUES FOR ANNUAL SEDIMENT LOADING PER ACRE BY LAND USE TYPE

4.4.3 BOD

4.4.4 Nitrogen

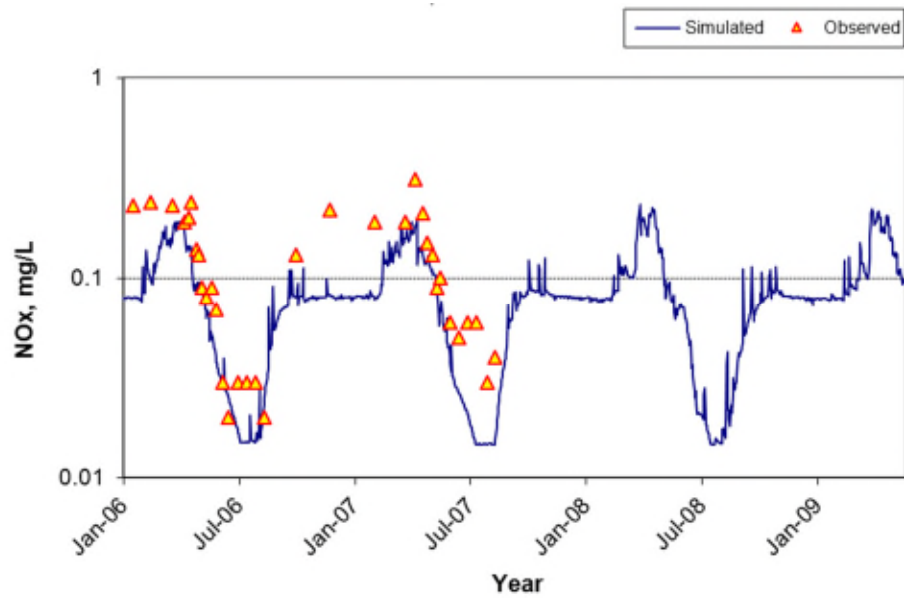


FIGURE 9: COMPARISON OF MODELED NO_x AND OBSERVED NO_x CONCENTRATIONS AT STATION XXXX

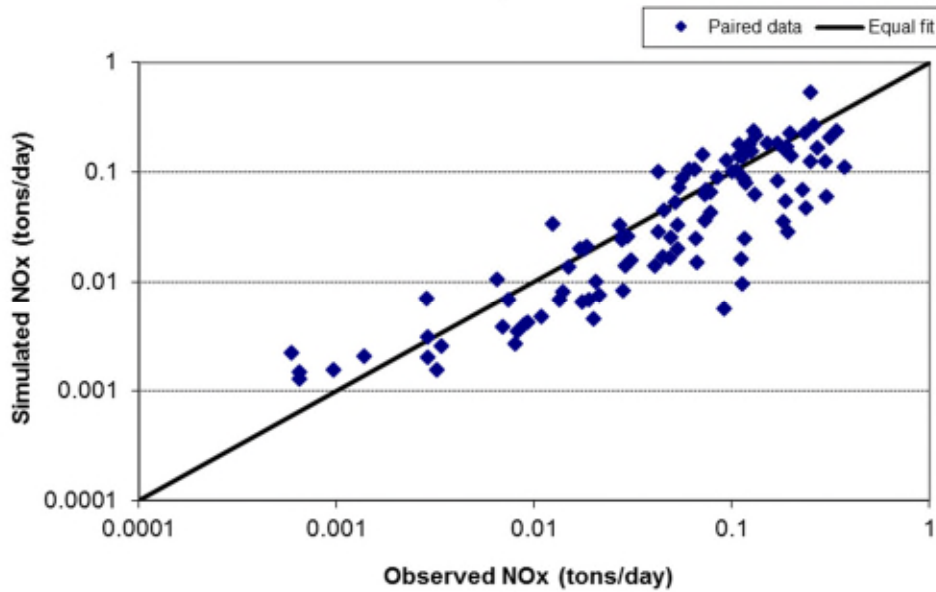


FIGURE 10: LINEAR REGRESSION OF MODELED NO_x AND OBSERVED NO_x LOADS AT STATION XXXX

4.4.5 Phosphorus

4.4.6 Chlorophyll-*a*

5.0 EFDC ESTUARY MODEL

5.1 Issues and Recommendations

5.2 EFDC Code Updates

5.3 Model Revisions and Setup

5.3.1 Computational Grid

5.3.2 Model Segmentation

5.3.3 Model Bathymetry

5.3.4 Layers

5.3.5 Simulation Period

5.3.6 Hydrodynamic Boundary Conditions

5.3.7 Meteorological Conditions

5.3.8 HSPF Model Linkage

5.3.9 Open Boundary Conditions

5.4 EFDC Hydrodynamic Calibration

Model calibration and validation overview – additional details in Appendix B

5.4.1 Calibration Methodology

5.4.2 Water Surface Elevation

TABLE 3: MODEL WATER SURFACE ELEVATION CALIBRATION STATISTICS FOR THE PERIOD OF 1/12/2013 – 4/30/2014

Station ID	Mean Measured (m MLLW)	Median Measured (m MLLW)	5 th Percentile Measured (m MLLW)	95 th Percentile Measured (m MLLW)	Mean Simulated (m MLLW)	Median Simulated (m MLLW)	5 th Percentile Simulated (m MLLW)	95 th Percentile Simulated (m MLLW)	R ²	MAE (m MLLW)	RMSE (m MLLW)	Normal RMSE	Index of Agreement
XXXXXXX	1.89	2.17	0.60	2.86	1.80	1.94	0.56	3.04	0.92	0.20	0.25	0.13	0.97
XXXXXXX	1.45	1.74	-0.01	2.69	1.39	1.57	-0.05	2.85	0.97	0.15	0.19	0.11	0.99
XXXXXXX	1.60	1.88	0.14	2.84	1.40	1.57	0.03	2.84	0.97	0.21	0.25	0.14	0.98
XXXXXXX	1.21	1.40	0.00	2.36	1.26	1.44	0.00	2.47	0.99	0.07	0.09	0.06	1.00
XXXXXXX	1.40	1.66	-0.02	2.66	1.32	1.52	-0.09	2.72	0.98	0.12	0.15	0.09	0.99
XXXXXXX	1.57	1.84	0.17	2.73	1.38	1.51	0.08	2.79	0.95	0.22	0.27	0.16	0.98

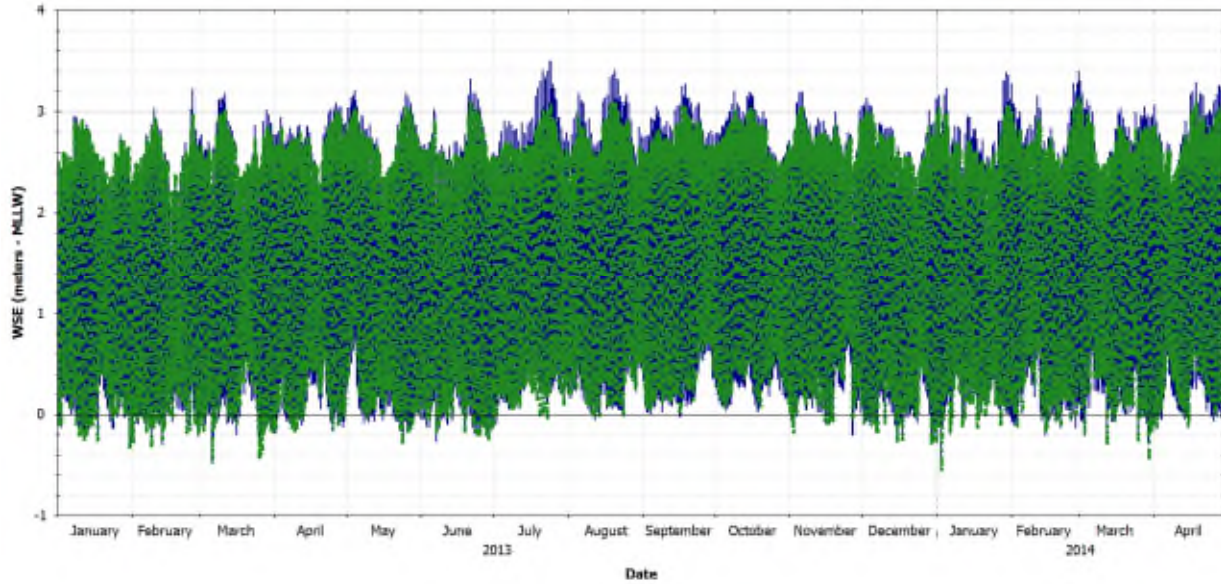


FIGURE 11: WATER SURFACE ELEVATION COMPARISON AT USGS STATION XXXXXXXX FOR THE PERIOD 01/01/2013 – 04/30/2014

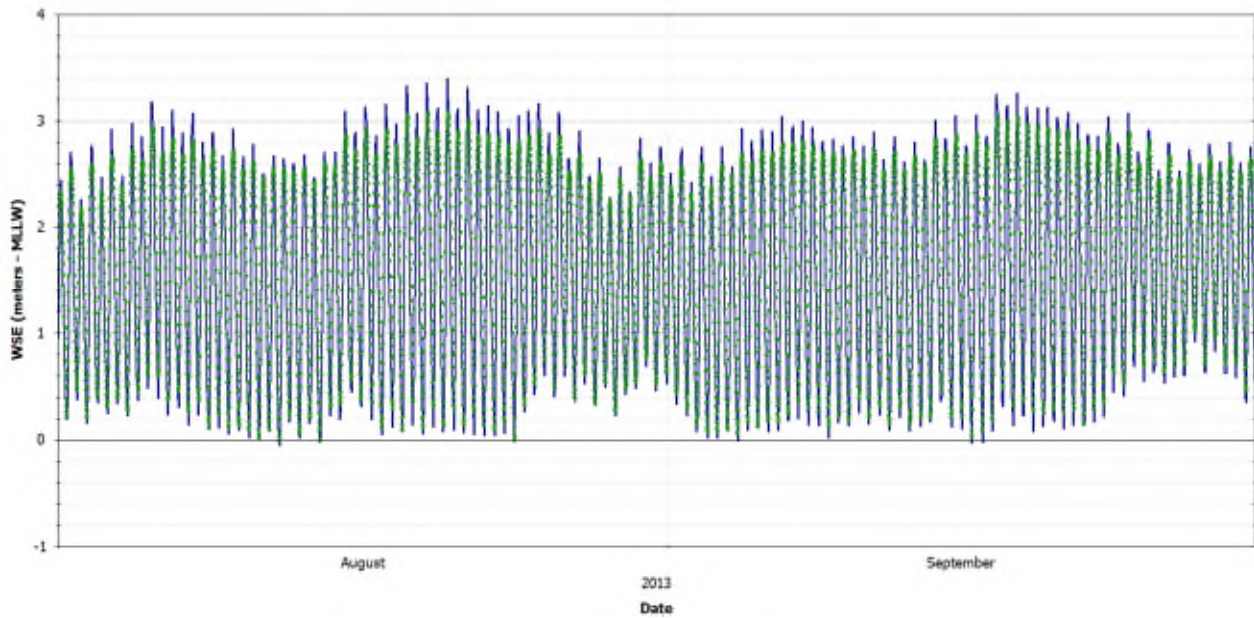


FIGURE 12: WATER SURFACE ELEVATION COMPARISON AT USGS STATION XXXXXXXX FOR THE PERIOD 08/01/2013 – 09/30/2013

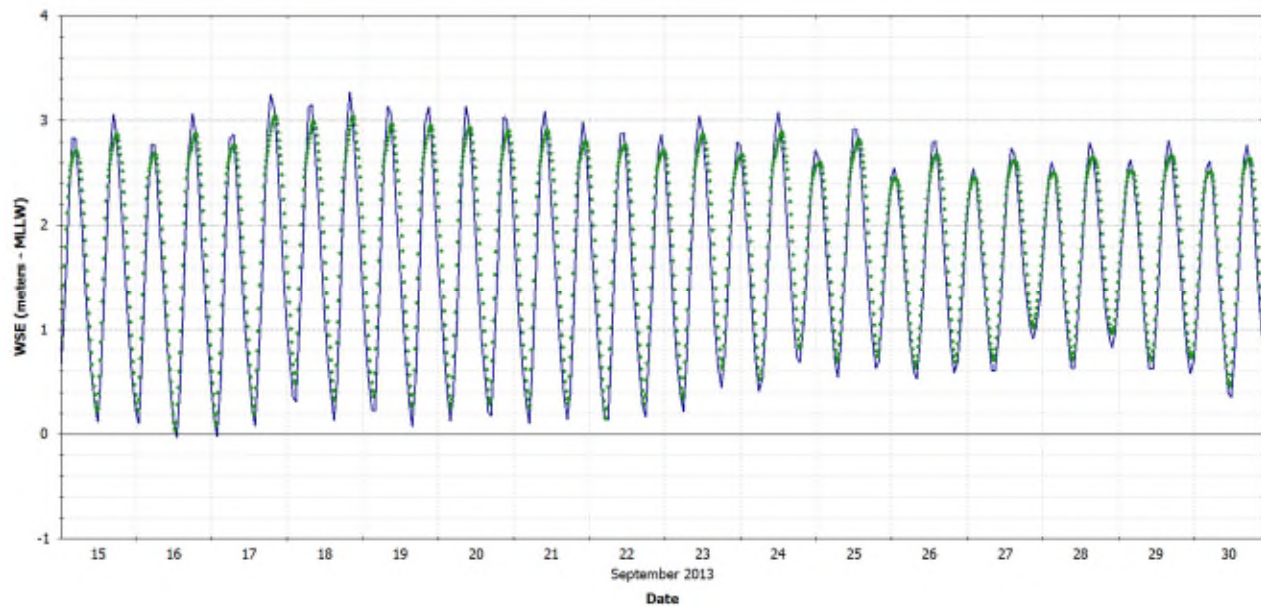


FIGURE 13: WATER SURFACE ELEVATION COMPARISON AT USGS STATION XXXXXXXX FOR THE PERIOD 09/15/2013 – 09/30/2013

5.4.3 Flows

TABLE 4: MODEL FLOW CALIBRATION STATISTICS FOR THE PERIOD OF 1/1/2013 – 4/30/2014

Station ID	Mean Measured (cms)	Median Measured (cms)	5 th Percentile Measured (cms)	95 th Percentile Measured (cms)	Mean Simulated (cms)	Median Simulated (cms)	5 th Percentile Simulated (cms)	95 th Percentile Simulated (cms)	R ²	MAE (cms)	RMSE (cms)	Normal RMSE	Index of Agreement
XXXXXXX	-313.8	-195.3	-1,437.1	869.4	-299.8	-350.6	-1,265.5	1,052.4	0.88	225.1	283.7	0.34	0.97
XXXXXXX	-38.3	12.1	-402.1	317.9	-36.2	-60.4	-316.1	345.1	0.87	70.7	86.6	0.38	0.96
XXXXXXX	-721.4	148.0	-6,964.3	5,809.7	-294.6	321.3	-5,574.5	5,676.9	0.95	821.4	1048.5	0.25	0.98
XXXXXXX	-483.6	-199.1	-2,702.1	1,953.4	-341.1	-227.7	-2,429.5	2,256.7	0.93	373.2	462.7	0.28	0.98
XXXXXXX	-45.7	-22.8	-253.8	161.2	-49.8	-73.9	-203.8	152.0	0.67	62.3	82.0	0.65	0.89

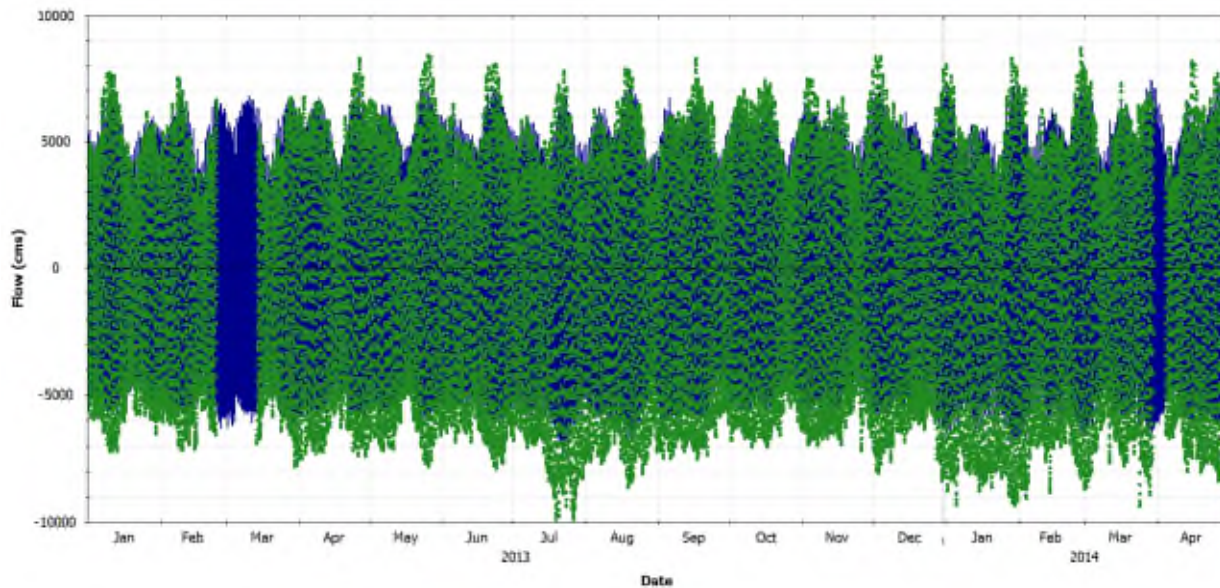


FIGURE 14: FLOW COMPARISON AT USGS STATION XXXXXXXX FOR THE PERIOD 01/01/2013 – 04/30/2014

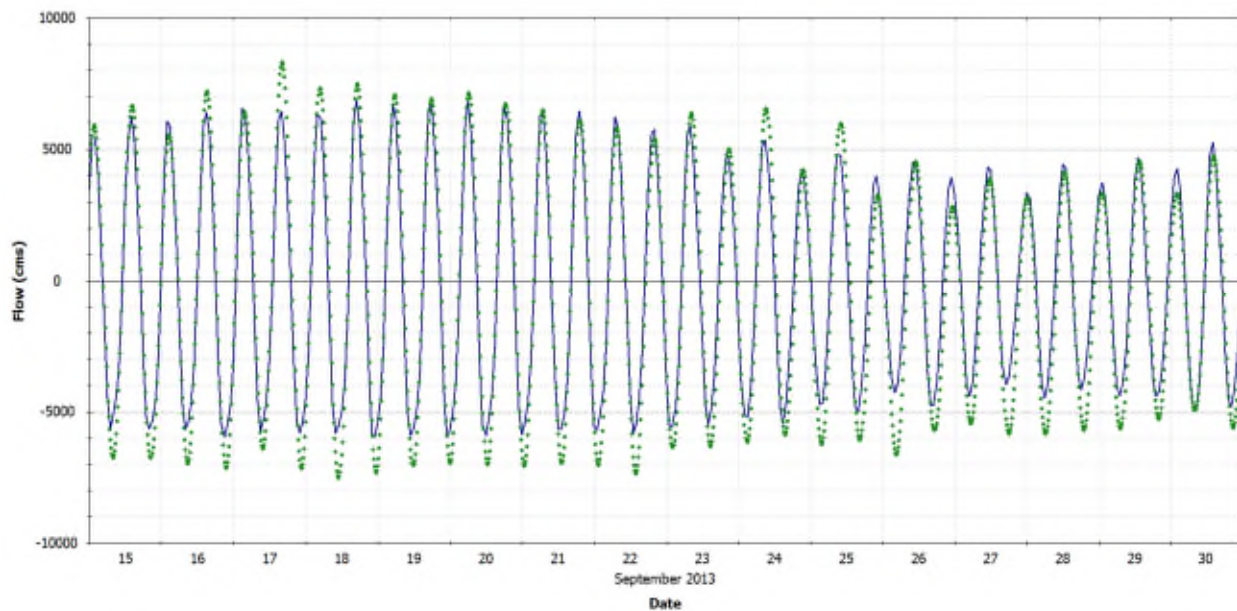


FIGURE 15: FLOW COMPARISON AT USGS STATION XXXXXXXX FOR THE PERIOD 08/01/2013 – 09/30/2013

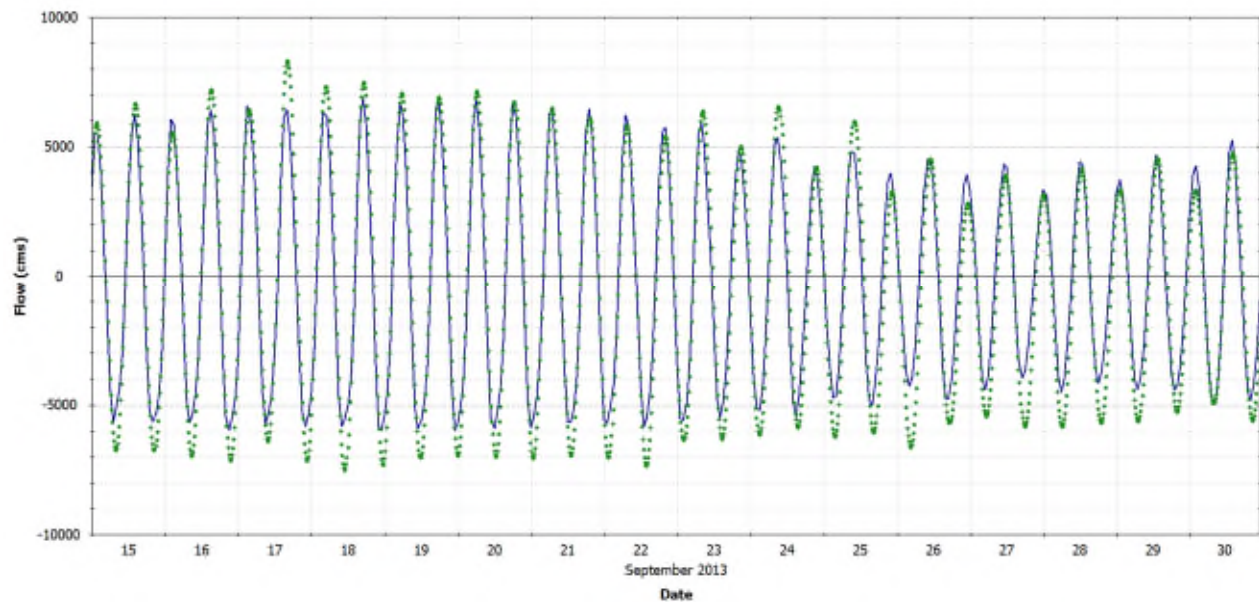


FIGURE 16: FLOW COMPARISON AT USGS STATION XXXXXX FOR THE PERIOD 09/15/2013 – 09/30/2013

5.4.4 Water Temperature

TABLE 5: MODEL WATER TEMPERATURE CALIBRATION STATISTICS FOR THE PERIOD OF 1/11/2013 - 4/30/2014 FOR THE USGS STATIONS AND 8/15/2013 - 10/1/2013 FOR THE PROJECT STATIONS

Station ID	Mean Measured (°C)	Median Measured (°C)	5 th Percentile Measured (°C)	95 th Percentile Measured (°C)	Mean Simulated (°C)	Median Simulated (°C)	5 th Percentile Simulated (°C)	95 th Percentile Simulated (°C)	R ²	MAE (°C)	RMSE (°C)	Normal RMSE	Index of Agreement
XXXXXXX	17.41	18.20	8.70	25.70	17.77	18.56	8.71	26.33	1.00	0.44	0.55	0.03	1.00
XXXXXXX	17.78	18.40	8.80	26.10	18.03	18.75	8.72	26.67	0.99	0.45	0.56	0.03	1.00
XXXXXXX	16.46	16.50	7.60	25.80	17.08	17.04	7.82	26.89	0.99	0.81	0.99	0.06	0.99
XXXXXXX	17.46	17.30	8.90	28.10	17.33	17.87	7.89	27.69	0.98	0.82	0.98	0.05	0.99
XXXXXXX	18.08	18.60	9.10	26.80	18.18	18.53	8.85	27.13	0.98	0.65	0.83	0.04	1.00
XXXXXXX	16.46	16.30	7.60	26.10	17.16	16.85	7.80	27.18	0.98	0.97	1.19	0.07	0.99
XXXXXXX	24.92	24.97	23.30	26.59	25.49	25.76	23.91	27.14	0.76	0.60	0.78	0.03	0.87
XXXXXXX	24.87	24.95	23.03	26.59	25.37	25.46	23.78	27.09	0.87	0.52	0.64	0.03	0.92
XXXXXXX	26.54	26.92	24.42	27.92	26.55	26.69	24.62	27.62	0.36	0.73	0.87	0.03	0.76
XXXXXXX	25.24	25.37	23.56	27.09	25.85	25.96	24.44	27.36	0.86	0.63	0.73	0.03	0.88
XXXXXXX	27.35	28.20	24.13	28.67	27.08	27.22	25.74	27.86	0.52	1.04	1.11	0.04	0.70
XXXXXXX	26.90	27.38	24.16	28.65	27.11	27.46	25.54	28.30	0.66	0.72	0.88	0.03	0.84
XXXXXXX	24.54	24.60	22.68	26.16	25.00	25.00	23.24	26.69	0.94	0.46	0.53	0.02	0.94

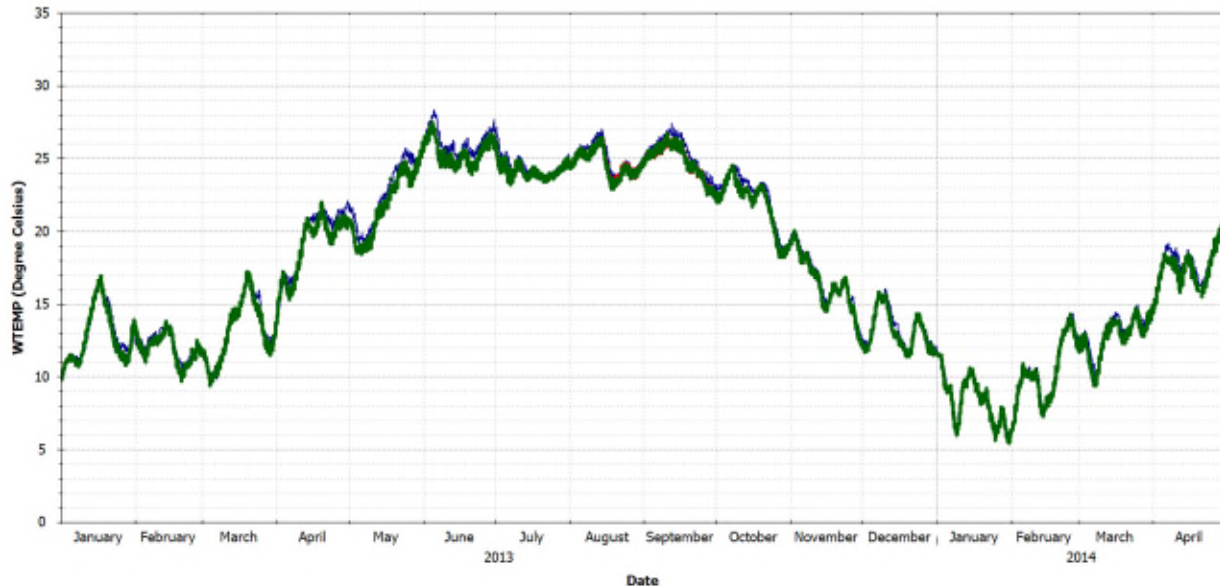


FIGURE 17: WATER TEMPERATURE TIME SERIES COMPARISON AT PROJECT STATION XXX AND USGS STATION XXXXXXXX FOR THE PERIOD 01/01/2013 – 04/30/2014

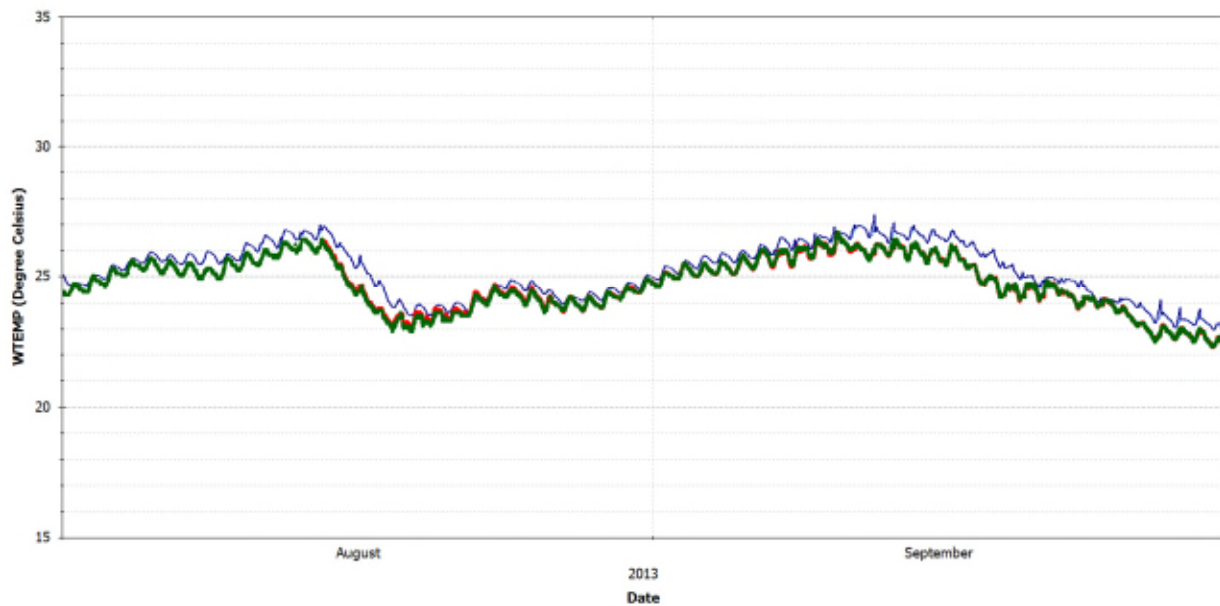


FIGURE 18: WATER TEMPERATURE TIME SERIES COMPARISON AT PROJECT STATION XXX AND USGS STATION XXXXXXXX FOR THE PERIOD 08/01/2013 – 09/30/2013

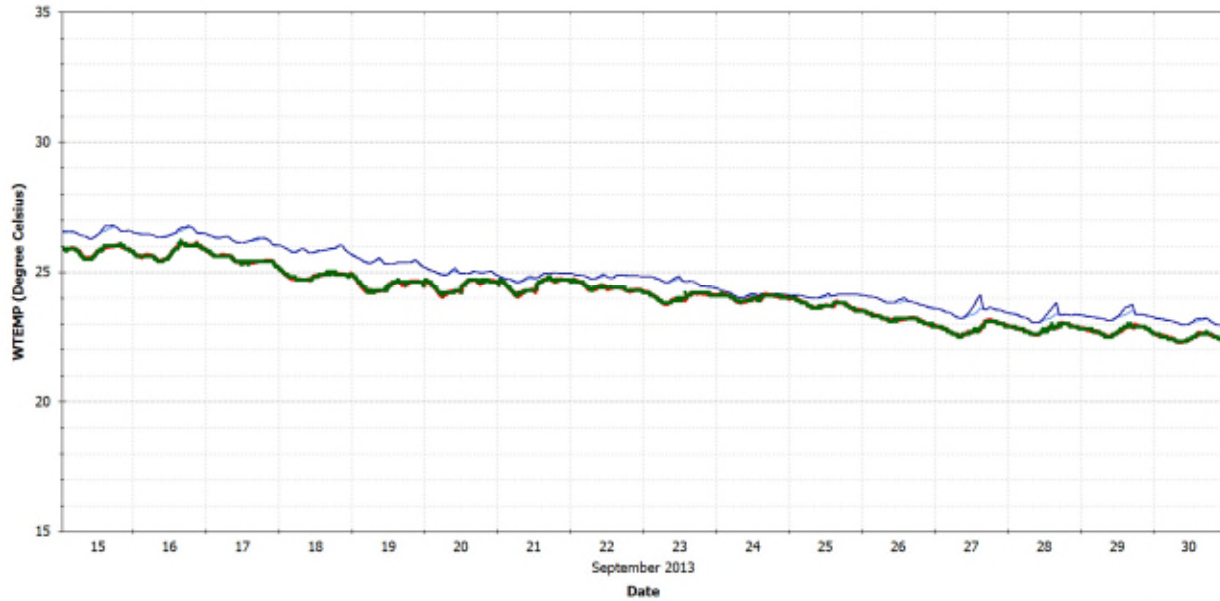


FIGURE 19: WATER TEMPERATURE TIME SERIES COMPARISON AT PROJECT STATION XXX AND USGS STATION XXXXXX FOR THE PERIOD 09/15/2013 – 09/30/2013

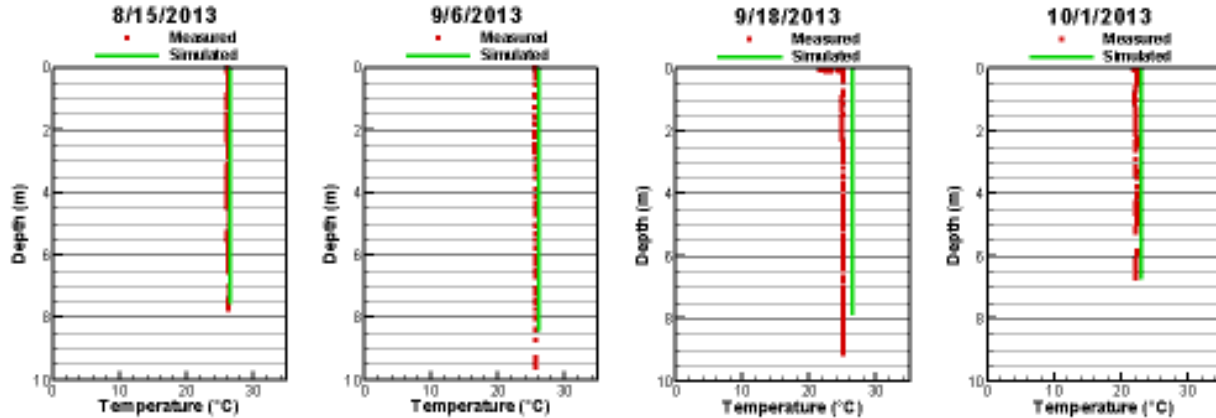


FIGURE 20: WATER TEMPERATURE VERTICAL PROFILES COMPARISON AT PROJECT STATION XXX

5.4.5 Salinity

TABLE 6: MODEL SALINITY CALIBRATION STATISTICS FOR THE PERIOD OF 1/1/2013 - 4/30/2014 FOR THE USGS STATIONS AND 8/15/2013 – 10/1/2013 FOR THE PROJECT STATIONS

Station ID	Mean Measured (PSU)	Median Measured (PSU)	5 th Percentile Measured (PSU)	95 th Percentile Measured (PSU)	Mean Simulated (PSU)	Median Simulated (PSU)	5 th Percentile Simulated (PSU)	95 th Percentile Simulated (PSU)	R ²	MAE (PSU)	RMSE (PSU)	Normal RMSE	Index of Agreement
XXXXXXX	0.05	0.05	0.04	0.06	0.01	0.00	0.00	0.05	0.54	0.04	0.05	1.80	0.48
XXXXXXX	2.69	1.32	0.04	10.30	2.36	2.01	0.07	6.69	0.83	1.12	1.78	0.48	0.90
XXXXXXX	6.27	6.41	0.67	13.50	9.88	10.91	0.82	17.16	0.71	3.70	4.46	0.50	0.79
XXXXXXX	1.12	0.06	0.03	8.23	1.77	0.19	0.00	10.53	0.57	1.13	2.29	0.76	0.86
XXXXXXX	0.39	0.05	0.03	2.34	0.76	0.16	0.00	3.63	0.37	0.57	1.13	1.12	0.72
XXXXXXX	11.48	11.29	1.14	23.10	14.25	15.79	0.18	22.82	0.41	4.93	5.78	0.42	0.76
XXXXXXX	4.34	4.52	0.61	8.10	4.74	5.11	0.98	8.69	0.69	1.13	1.44	0.29	0.90
XXXXXXX	27.31	28.63	20.19	32.38	29.65	30.66	22.86	32.25	0.44	2.82	3.65	0.13	0.70
XXXXXXX	16.26	16.28	8.76	25.02	17.08	18.45	7.13	24.82	0.76	2.22	2.89	0.17	0.93
XXXXXXX	0.04	0.04	0.03	0.04	0.00	0.00	0.00	0.00	0.01	0.04	0.04	107.86	0.00

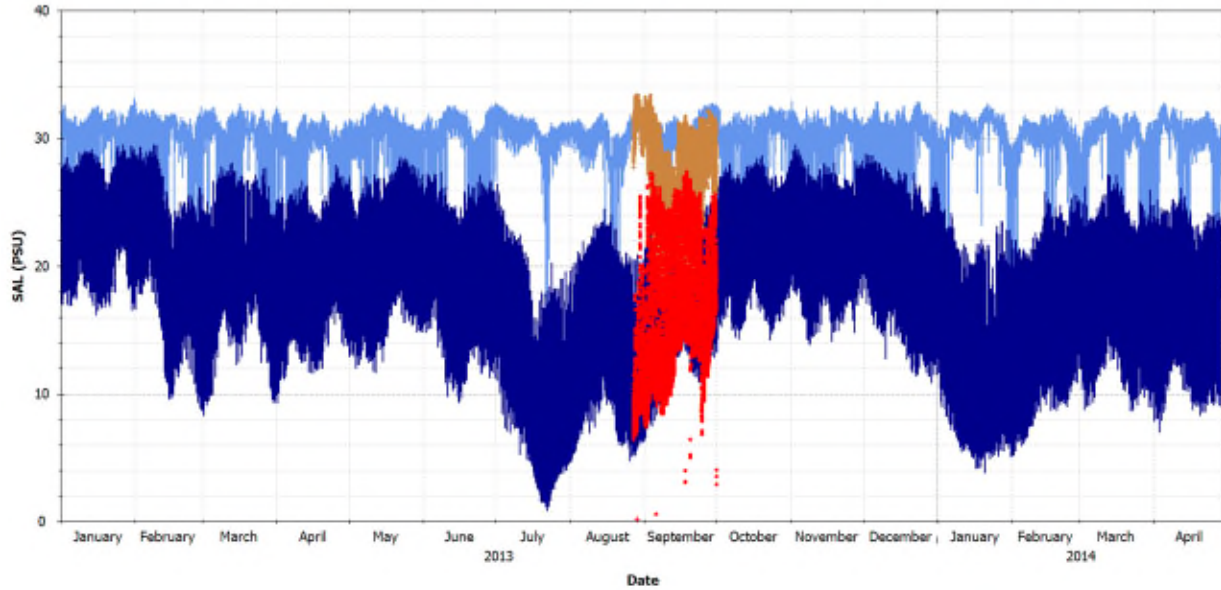


FIGURE 21: SALINITY TIME SERIES COMPARISON AT PROJECT STATION XXX FOR THE PERIOD 01/01/2013 – 04/30/2014

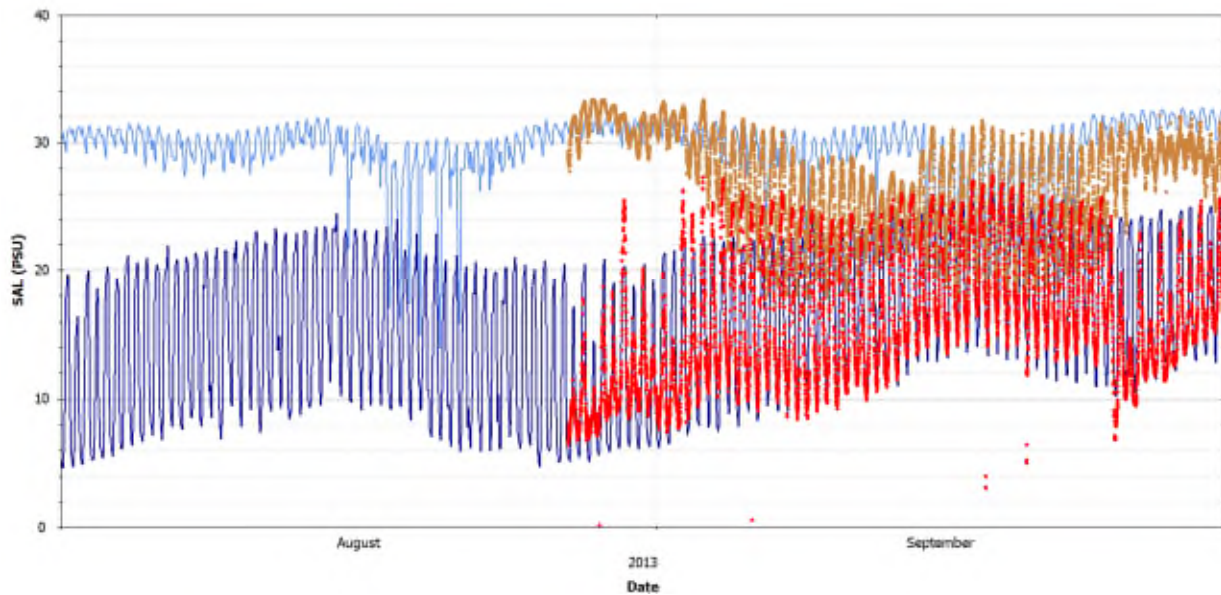


FIGURE 22: SALINITY TIME SERIES COMPARISON AT PROJECT STATION XXX FOR THE PERIOD 08/01/2013 – 09/30/2013

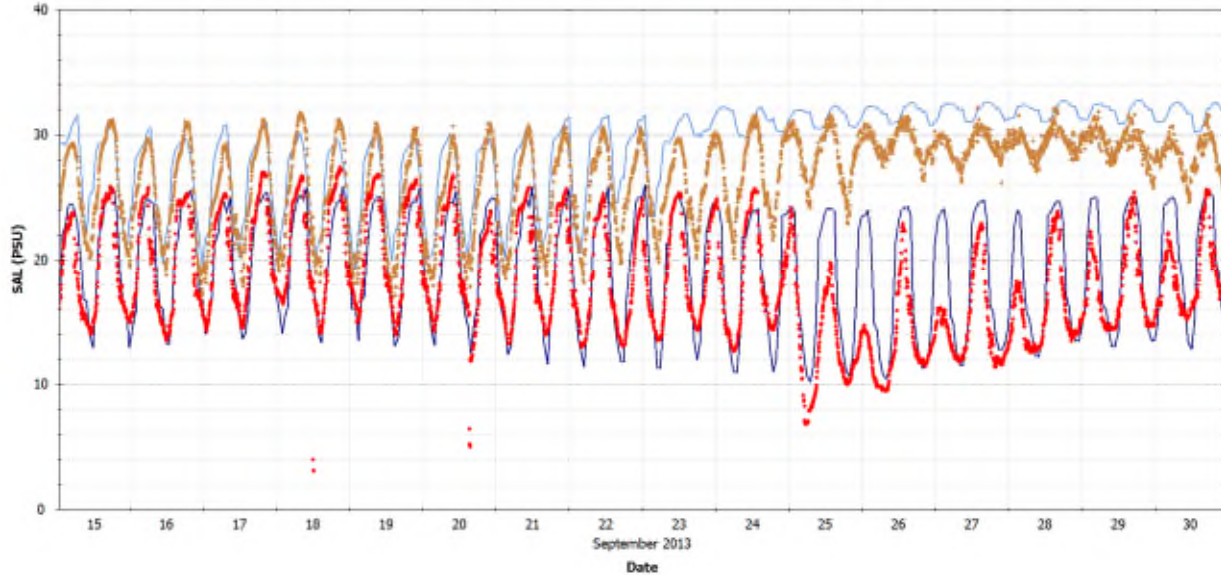


FIGURE 23: SALINITY TIME SERIES COMPARISON AT PROJECT STATION XXX FOR THE PERIOD 09/15/2013 – 09/30/2013

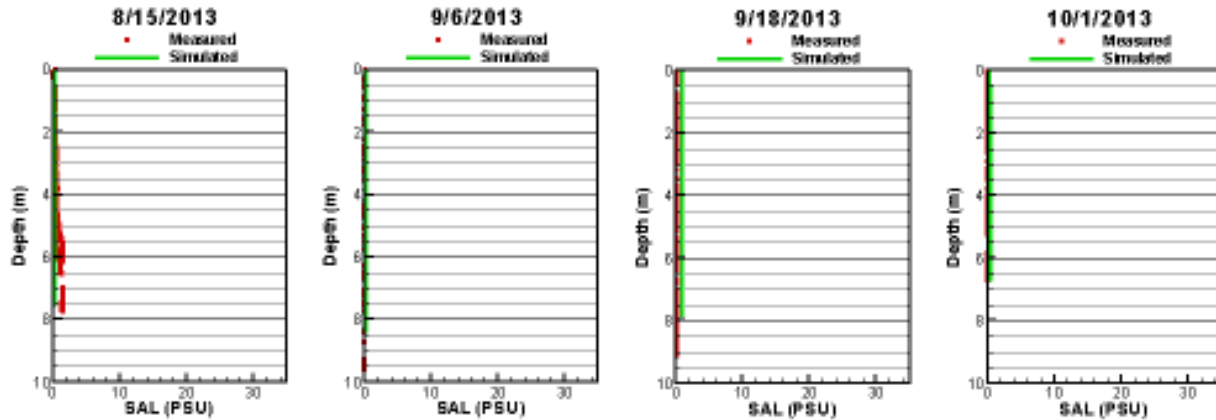


FIGURE 24: SALINITY VERTICAL PROFILES COMPARISON AT PROJECT STATION XXX

5.5 EFDC Water Quality Calibration

5.5.1 Calibration Methodology

5.5.2 BOD

5.5.3 Nitrogen

5.5.4 Phosphorus

5.5.5 Chlorophyll-a

6.0 SUMMARY AND CONCLUSIONS

7.0 REFERENCES

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APPENDIX A: HSPF MODEL CALIBRATION RESULTS

APPENDIX B: EFDC MODEL CALIBRATION RESULTS