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Florida Department of Environmental Protection

STEVENSON CREEK WATERSHED TMDL MODEL DEVELOPMENT

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Prepared for the

Division of Water Resource Management
Watershed Assessment Section
Tallahassee, Florida

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Introduction

1.1 Background

The Florida Department of Environmental Protection (FDEP) has contracted with Camp Dresser & McKee Inc. (CDM) to develop a Stevenson Creek watershed pollutant loading model and receiving water hydrodynamic and water quality model. The tidal segment of Stevenson Creek (WBID 1567) is 303(d) listed, and therefore impaired. The water quality parameters assessed using the Impaired Waters Rule (IWR) are dissolved oxygen, and nutrients (chlorophyll-a). WBID 1567's designated use is "recreation, propagation, and maintenance of a healthy, well balanced population of fish and wildlife in marine waters". The freshwater portions of Stevenson Creek (WBID 1567 C) and its tributaries (i.e., Spring Branch – WBID 1567B) are not 303(d) listed and, therefore, are not impaired. Stevenson Creek is part of the Springs Coast Group 5 Basin, Anclote River/Coastal Pinellas County Planning Unit.

The linked models will be used by the FDEP to develop Total Maximum Daily Loads (TMDLs) for dissolved oxygen, and nutrients. Under Section 303(d) of the federal Clean Water Act and the Florida Watershed Restoration Act, TMDLs must be developed for waters that do not meet their designated uses. A TMDL represents the maximum pollutant loading that a water body can assimilate and continue meeting its designated use by remaining compliant with respect to state water quality standards. A water body is deemed to be impaired if it does not meet the applicable criteria for a particular pollutant; consequently, TMDLs are required to be established for these waters to reduce the concentrations of the violating criterion in order to comply with state water quality standards.

1.2 Objectives

The objectives of the Stevenson Creek watershed TMDL model development task assignment, which was comprised of three tasks, are discussed below.

- The objective of Task 1 was to identify, collect, and evaluate all existing, readily-available data that are applicable to the Stevenson Creek watershed, and will support the set-up, calibration, and validation of a defensible watershed pollutant loading computer model, and receiving-water hydrodynamic and water quality model(s). The work effort expended and completed under Task 1 is documented in Section 2.

- The objective of Task 2 was to identify and evaluate watershed pollutant loading and receiving water hydrodynamic & water quality models that are appropriate for application in the development of dissolved oxygen and nutrient TMDLs for impaired water bodies, and to recommend the most suitable models based upon specific criteria established by the Florida Department of Environmental Protection (FDEP) for the impaired segment of Stevenson Creek. The work effort expended and completed under Task 2 is documented in Section 3.

- The objective of Task 3 was to set-up, refine, calibrate, and validate the selected watershed pollutant loading model and receiving water hydrodynamic and water quality model for application in the development of dissolved oxygen and nutrient TMDLs for the tidally influenced and impaired segment of Stevenson Creek (WBID 1567). The work effort expended and completed under Task 3 is documented in Section 4.

1.3 Project Area Description

The Stevenson Creek Watershed encompasses 6,286 acres in west central Pinellas County. The watershed area spans across several jurisdictions including the City of Clearwater (4,057 acres or 65 percent), City of Dunedin (1,287 acres or 20 percent), unincorporated parts of Pinellas County (859 acres or 14 percent) and the City of Largo (83 acres or 1 percent). Land uses within the basin are predominantly medium and high density residential, commercial, and open space. Approximately 90 percent of the watershed is urbanized with a significant portion of the development occurring prior to the implementation of regulatory requirements for floodplain preservation, environmental protection, stormwater treatment, and peak runoff attenuation. Several developments were constructed within the creek's floodplain and have experienced severe flooding. In addition, the creek and its tributaries experience moderate to severe erosion problems due to steep embankments, improper maintenance, highly erodible soils, and inadequate right-of-way.

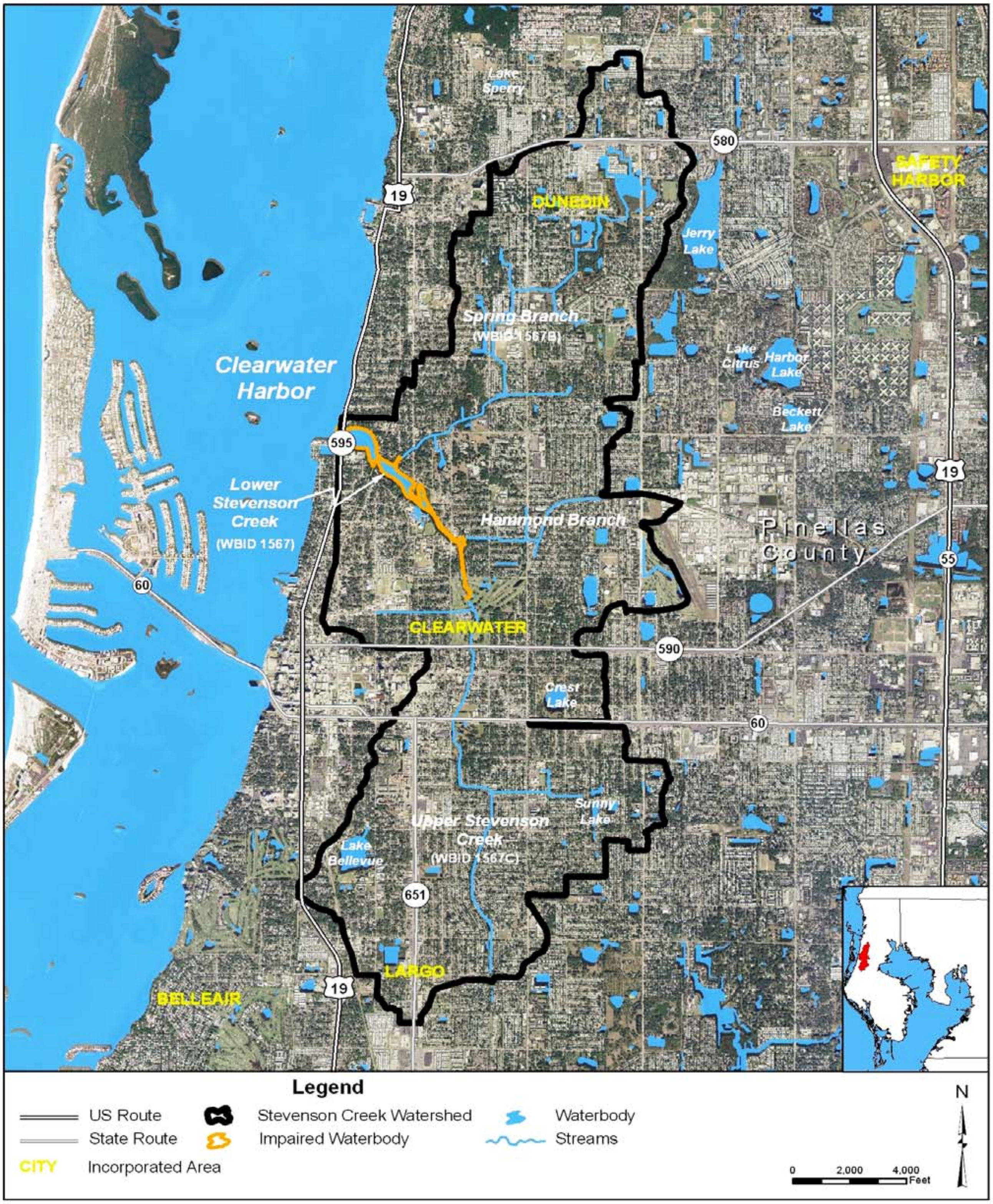
The areal extent of the Stevenson Creek watershed and its hydrography are displayed in **Figure 1-1**. The figure clearly displays the extent of the tidal and impaired segment of Stevenson Creek (WBID 1567 - which flows to Clearwater Harbor), and the extent of the non-tidal segment (WBID 1567C). Two freshwater tributaries to Stevenson Creek (i.e., Spring Branch (WBID 1567B), and Hammond Branch) are also clearly displayed in the figure.

1.4 Report Contents

This report and associated deliverables have been developed in sections as follows:

- Section 2- Data Acquisition, Compilation of Previous Studies, and Evaluation
- Section 3 - Watershed Pollutant Loading and Receiving Water Hydrodynamic & Water Quality Model Evaluations and Recommendations
- Section 4 - HSPF and EFDC Models Set-Up, Refinement, Calibration, Validation, and recommendations
- Section 5 – References
- Section 6 – Appendices

Figure 1-1 Stevenson Creek Watershed



Section 2
Data Acquisition, Compilation of Previous Studies, and Evaluation

2.1 Data Requirements

The set-up, refinement, calibration, and validation of a watershed pollutant loading model coupled with a receiving water hydrodynamic and water quality model require a variety of data types. Data is used to characterize the many attributes of the watershed, to provide the models inputs, and for calibration and validation processes that compare model simulation results to observed data. When a tidally influenced stream is contained within a watershed, the open marine water domain must also be modeled such that the effects of the diurnal tides are also accounted for.

For the watershed pollutant loading model, data requirements fall within the following data categories:

- Meteorology – Rainfall depth, incident solar radiation, cloud cover, atmospheric pressure, air temperature, dew-point temperature, relative humidity, wind speed and direction, and evapotranspiration
- Topography – Ground elevation, watershed boundaries.
- Hydrography – Stream reach cross section, volume, and length.
- Impaired stream segment identification
- Stream flows and stages
- Baseflow, water supply withdrawals, diversions, irrigation, and wastewater plant effluent discharges
- Land use classifications
- Soil hydrology – Hydrologic soil group
- Pollutant loading coefficients
- Baseflow constituent concentrations
- Water Budget
- Water quality constituent concentrations
- Atmospheric deposition

For the receiving water hydrodynamic and water quality model, data requirements fall within the following data categories:

- Topography
- Ambient water surface elevation and hydrography
- Freshwater discharges to upstream modeled domain boundary
- Ambient water surface elevation and hydrography
- Atmospheric forcing
- Shoreline planar coordinates, bathymetric coordinates and associated bottom elevation (depth of water)

- Open water surface elevation, salinity, and temperature
- Flow rate, salinity and temperature of freshwater at upstream boundary of model domain
- Atmospheric pressure, air temperature, relative humidity, wind speed and direction, incident solar radiation, cloud cover, rainfall, and evaporation
- Wastewater pollutant loads at the upstream tidal boundary
- Ambient water quality
- Sediment/water fluxes
- Atmospheric deposition
- Open-water tidal boundary
- Constituent concentration at the open water tidal boundary
- Ambient water quality constituent concentrations
- Sediment/water fluxes of oxygen (SOD), nutrients, bottom water oxygen, sediment bed organic matter as dry weight, organic carbon, organic nitrogen, and organic phosphorous

2.1.1 Data Sources

A variety of existing data sources for the watershed pollutant loading model, and the receiving water hydrodynamic and water quality model were identified at the project outset. These sources included the:

- Florida Department of Environmental Protection (FDEP)
- Southwest Florida Water Management District (SWFWMD)
- Pinellas County Department of Environmental Management
- City of Clearwater Engineering Department
- US Army Corps of Engineers, Jacksonville District (USACE)
- National Climatic Data Center (NCDC)
- US Environmental Protection Agency (EPA)
- US Geological Survey (USGS)

2.2 Watershed Pollutant Loading Model

2.2.1 Tributary Area

The Stevenson Creek watershed can be conveniently divided into four sub-watersheds that include Spring Branch, Hammond Branch, Upper Stevenson Creek (i.e., the non-tidal segment of Stevenson Creek), and Lower Stevenson Creek (i.e., the tidally influenced segment of Stevenson Creek). These water bodies are illustrated in Figure 1-1. Spring Branch captures stormwater runoff from the northern portion of the watershed, Hammond Branch collects water from a smaller area east of Stevenson Creek, and Upper Stevenson Creek drains the southern part of the watershed. Stormwater runoff is generated within these sub-watersheds and is ultimately delivered to the tidally influenced and impaired segment of Stevenson Creek (i.e., Lower Stevenson Creek). Stevenson Creek discharges to the open ocean at Clearwater Harbor.

2.2.2 Topography

Topographic data, which is used to delineate watershed and sub-watershed boundaries, was obtained in 5-ft contour elevations from the Florida Geographic Database Library (FGDL) for the Pinellas County area. A digital elevation map was generated from the 5-ft contour elevation data, and is presented as **Figure 2-1**. The lower elevations that may be subject to tidal influences (5 – 20 ft) expand over a large area surrounding the Stevenson Creek estuary into the lower parts of the three main tributaries, extending furthest upstream in the Spring Branch subwatershed. The highest elevations (70 -75 ft) are in the southeastern part of the watershed, located in the Upper Stevenson Creek subwatershed. The tributary areas to Upper Stevenson Creek are relatively steeper than those areas draining to either the Hammond Branch or Spring Branch sub-watersheds.

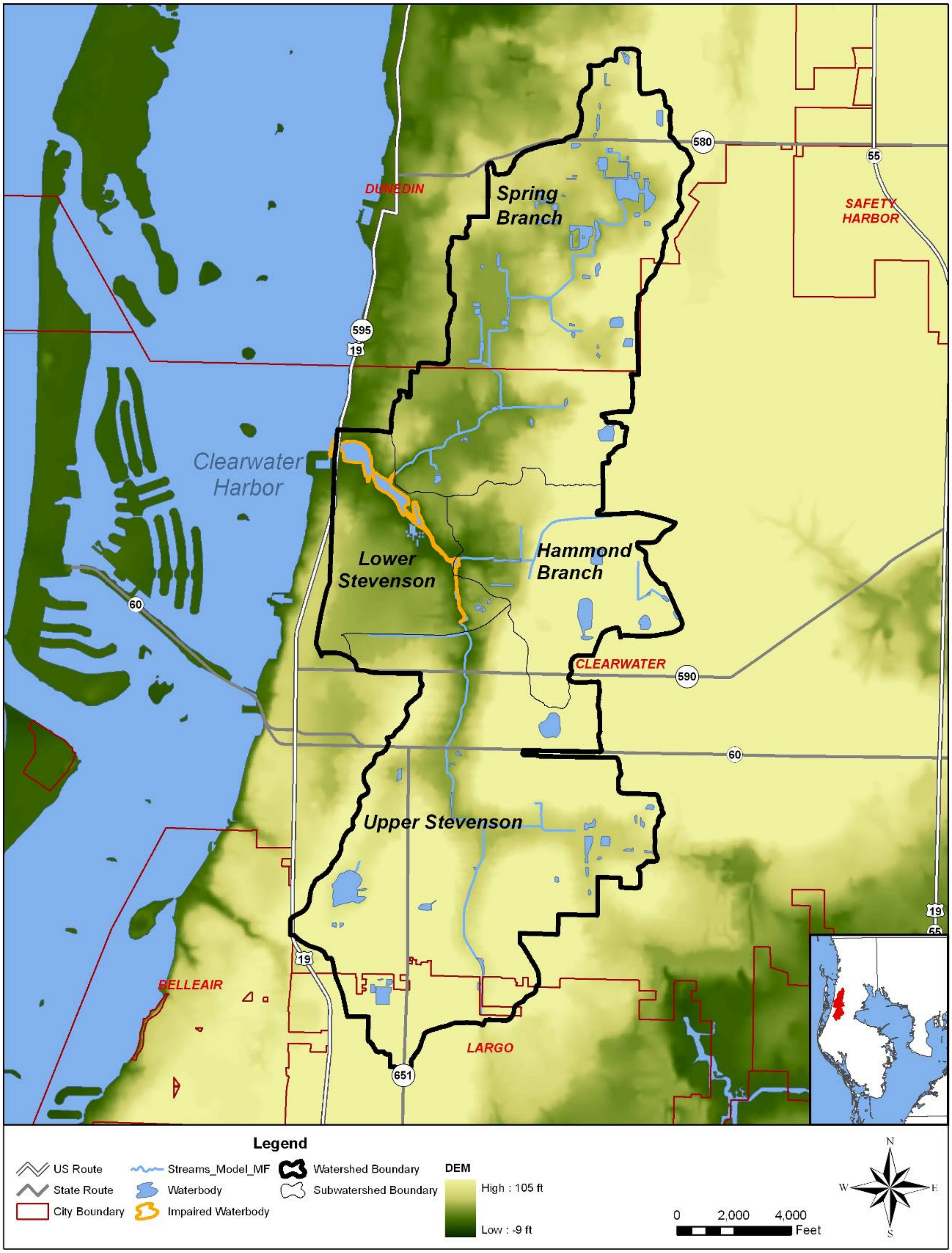
2.2.3 Hydrography

A Geographic Information System (GIS) shapefile that identifies the Stevenson Creek stream network was made available by FDEP. Stream channel geometric data was extracted from an AdICPR model that was developed as part of the Stevenson Creek Watershed Management Plan, a study commissioned by the City of Clearwater (Parsons, 2001). AdICPR input/output files were used to characterize stage, discharge, and cross-sectional area relationships for select cross-sections of stream reaches in the model. Channel section geometry data was imported into a HEC-RAS model to simulate water depth and cross sectional area at different downstream flow rates. Using the simulated water surface profile, storage volume and surface area were estimated by interpolating between two channel cross sections; the furthest downstream and upstream sections for each of the stream reaches in the model. Additional data extracted from the GIS drainage layer to parameterize the model including channel lengths and estimated roughness coefficients.

Additional storage volume in Upper Stevenson Creek is provided by two in-line stormwater management facilities, including the Glen Oaks Stormwater Detention Facility and the Upper Stevenson Creek In-Stream Storage through Channel Widening, located on the City of Clearwater golf course. In order to estimate the additional storage volume and surface area that these projects would provide during different hydrologic conditions, the water surface elevation in the facility was estimated at different flow rates downstream. For the Upper Stevenson Creek In-Stream Storage through Channel Widening facility, it was assumed that the depth of water at the downstream cross section was equal to the depth of water within the facility. This project involves a flow through type BMP, where the outflow structure (a long gabions berm) does not significantly restrict flow. Therefore, it is approximated that this project adds 1.3 ac-ft of storage volume for every foot of channel depth.

The Glen Oaks Stormwater Detention Facility includes an outflow structure that is designed to detain water at a higher water surface elevation than Stevenson Creek. The water level in the detention area was estimated by solving for the head above the invert of the outflow structure that would result in the discharge at each point on the downstream depth-discharge rating curve. The design plan shown in Figure 3-18.1 of the Glen Oaks Stormwater Detention Facility (Parsons, 2001) shows the outflow structure to include four 4” diameter orifices at an 8’ invert elevation, and a 150’ long broad crested high flow weir at a 15.3’ invert elevation. These dimensions were used to parameterize the orifice and weir equations to solve for head and associated storage volume at a given discharge. The Glen Oaks Stormwater Detention Facility adds approximately 10-20% of the within channel storage volume (5 – 60 ac-ft depending upon the stream flow rate).

Figure 2-1 Topography in the Stevenson Creek Watershed



2.2.4 Stream Flow

There is no long-term, historical stream flow gage within the Stevenson Creek watershed; however some flow gages have operated over limited periods. Pinellas County began monitoring streamflow and gage height in a non-tidally influenced segment of Stevenson Creek at the end of August of 2006. A continuous, measured streamflow record exists for this gage from August 28, 2006 through January 2007. The gage is located on Stevenson Creek behind the Clearwater Country Club building a short distance away from the Upper Stevenson Creek/Lower Stevenson Creek boundary. Additionally, twelve observations of instantaneous flow measurements collected over the year 2004 through 2005 period by Pinellas County during routine monitoring at each of two ambient water quality monitoring locations (one located on Upper Stevenson Creek, and the other located on Spring Branch) also exist. Hourly surface water depth measurements were recorded for Spring Branch at King's Highway and Stevenson Creek at Drew Street from May 21, 2000 through November 23, 2000 as part of the Stevenson Creek Watershed Management Plan (Parsons, 2001). No depth-discharge rating curve was developed for Stevenson Creek at this location; therefore use of these data was of limited value.

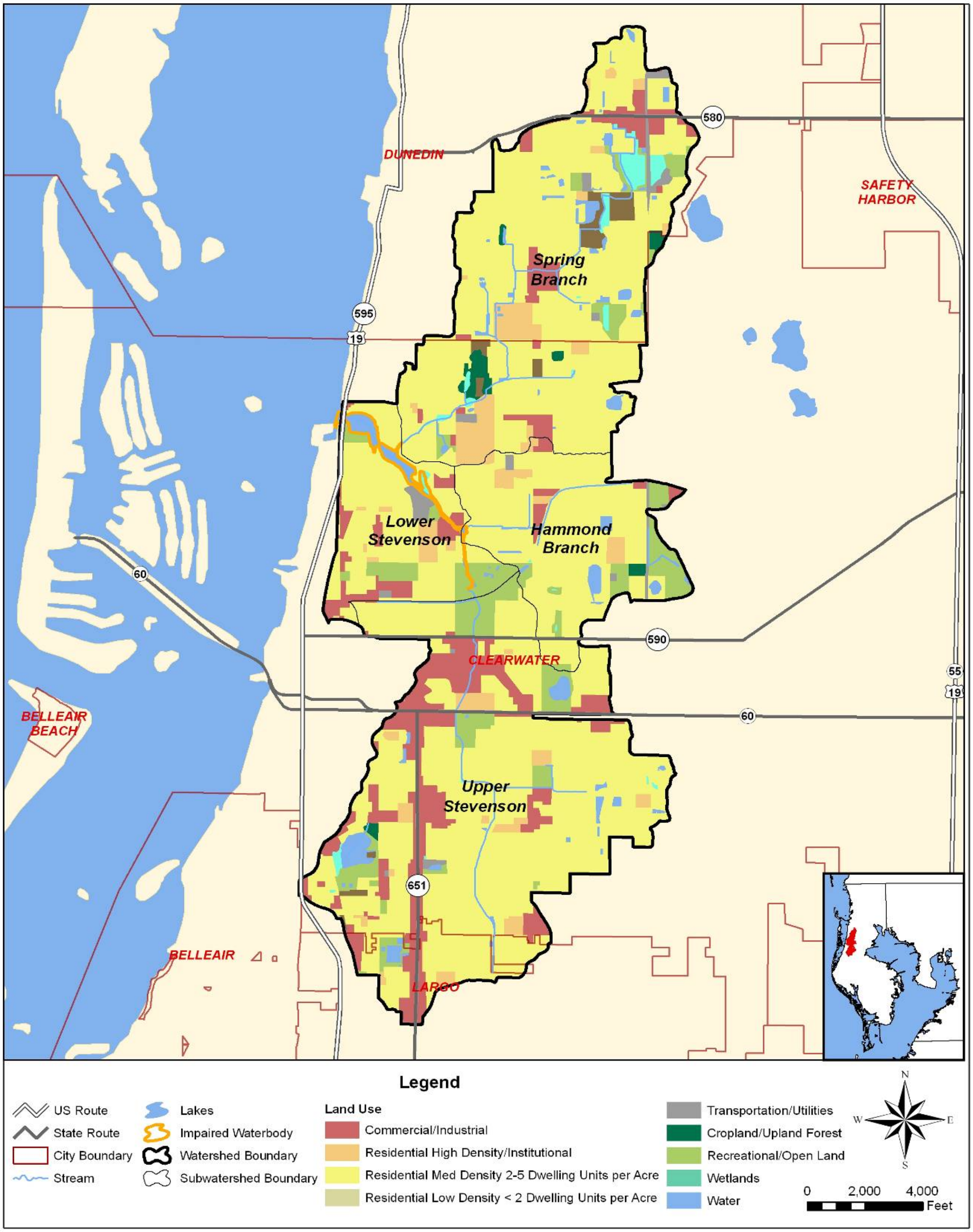
2.2.5 Land Use

Land use data for the Stevenson Creek watershed was obtained from the SWFWMD as a GIS coverage and is representative of conditions in 2004. The Stevenson Creek has been predominantly "built out" for over two decades. According to the Florida Land Use and Cover Classification System (FLUCCS), there are 26 land use categories (Level 4) within the Stevenson Creek watershed. For the purpose of this study, and considering the most predominant land use categories in the Stevenson Creek watershed, the FLUCCS land use categories were aggregated into nine groups and are presented in **Table 2-1** with their respective distribution within each of the model subwatersheds. **Figure 2-2** displays the distribution of the aggregated land use categories within the watershed.

Table 2-1 Land Use Distribution in the Stevenson Creek Watershed (2004 FLUCCS Data)

Land Use	Acreage					% of Watershed
	Hammond Branch	Lower Stevenson	Spring Branch	Upper Stevenson	Total	
Commercial / Industrial	40.2	70.8	129.8	415.9	656.6	10.4
Cropland / Upland Forest	5.7		38.2	4.8	48.7	0.8
Recreational / Open Land	123.3	91.7	59.7	174.4	449.0	7.1
Residential High Density / Institutional	38.4	30.5	143.5	83.2	295.6	4.7
Residential Low Density: < 2 DU/ac			58.5	8.8	67.3	1.1
Residential Med Density: 2 to 5 DU/ac	647.1	393.3	1,551.9	1,786.4	4,378.6	69.6
Transportation / Utilities	23.8	19.2	54.4	37.6	134.9	2.1
Water	26.5	35.2	60.1	64.9	186.6	3.0
Wetlands	0.8	6.3	55.5	8.4	70.9	1.1
Total	905.7	646.9	2,151.5	2,584.3	6,288.4	100.0

Figure 2-2 Land Use Distribution within the Stevenson Creek Watershed



2.2.6 Soils

Data for Pinellas County soils was obtained from FDEP as a GIS coverage with attributes for individual soil series extracted from the NRCS SSURGO database. The soils GIS coverage was processed to associate each soil category within the watershed to the appropriate hydrologic soil group. The hydrologic soil group is a parameter that is estimated for individual soil series types and provides a measure of a soil's capacity to infiltrate water. As shown in **Table 2-2**, the majority of the Stevenson Creek watershed is comprised of group A and group B/D soils. The hydrologic soil groups were used to develop distinct parameter sets for simulating subsurface hydrology in the watershed model. **Figure 2-3** displays the distribution of hydrologic soil group within the model subwatersheds.

Table 2-2 Hydrologic Soil Group Distribution in the Stevenson Creek Watershed

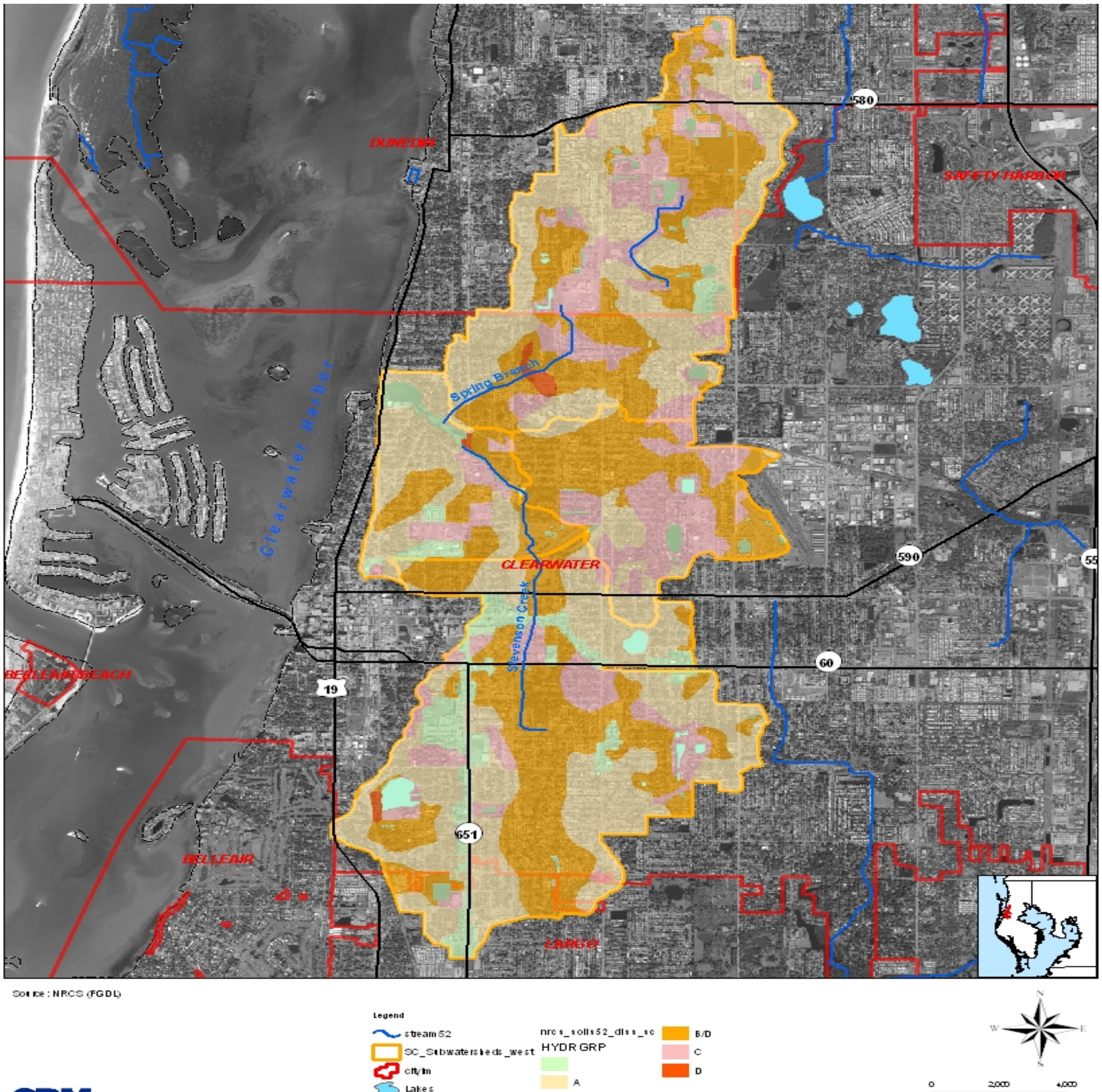
Hydrologic Soil Group	Total Acreage	Percentage of Watershed
A	2,424	38.5
B	23	0.4
B/D	2,158	34.3
C	1,114	17.7
D	370	5.9
W	199	3.2
Total	**6,288**	**100.0**

2.2.7 Meteorological Data

High-resolution hourly rainfall data (FDEP NEXRAD database) applicable to the Stevenson Creek watershed were extracted from the FDEP statewide datasets. A close analysis of these data indicates that missing values exist for the following periods: the entire year of 2006; the entire month of December 1999; the entire month of April 2001; the entire month of December 2001; and the last five days of May 2000.

A complete set of hourly meteorological data (incident solar radiation, wind speed and direction, cloud cover, barometric pressure, air temperature, relative humidity, dew point temperature, and precipitation) covering the period from January 1, 1999 through December 31, 2006 was acquired from the NOAA National Climatic Data Center for the weather station located at the St. Petersburg/ Clearwater International Airport. A comparison of annual precipitation amounts recorded at this weather station versus NEXRAD database values for the years 1999 through 2006 is presented in **Table 2-3**. For the referenced period of record, the average annual precipitation was 52.7 inches, and annual precipitation totals ranged from a low of 32.9 inches (in year 2000) to a high of 71.3 inches (in year 2004).

Figure 2-3 Hydrologic Soil Groups within the Stevenson Creek Watershed



CDM

Table 2-3 Observed Annual Precipitation Comparison

Year	St. Petersburg/ Clearwater International Airport (inches)	NEXRAD Database (inches)
1999	42.2	44.3 (note: all of 12/1999 missing)
2000	32.9	31.8
2001	49.6	35.3 (note: all of 12/2001 missing)
2002	61.8	61.6
2003	65.4	57.5
2004	71.3	57.6
2005	47.1	44.6
2006	51.2	(note: entire year missing)

2.2.8 Ambient Water Quality

Ambient water quality monitoring is conducted in Stevenson Creek and Spring Branch, as part of the Impaired Waters Rule (IWR), which provides criteria for selecting waterbodies to monitor and for listing/delisting of specific impairments. The tidally influenced reach of Stevenson Creek (WBID 1567) is being monitored by the FDEP to address existing 303(d) listed impairments and upstream tributary reaches (i.e., WBID 1567C) are also monitored to assess any additional listings that may be warranted. **Figure 2-4** displays the locations of known ambient water quality monitoring stations within Stevenson Creek watershed. Water quality data associated with these sites were obtained from FDEP.

2.2.9 Groundwater

Groundwater levels are monitored daily at several USGS wells surrounding the Stevenson Creek watershed. These data were downloaded from the USGS National Water Information System web interface for several stations. **Figure 2-5** shows the groundwater level in the Floridan aquifer at the Garden Street Triangle Well (USGS Station# 275843082474201) for the proposed simulation period. Additionally, the SWFWMD uses a series of groundwater monitoring wells in its region to create potentiometric surface maps at 10 ft contour intervals intended to be representative of May and September of each year. The potentiometric surface within the Stevenson Creek watershed does not usually reach more than 10 ft above NGVD. Based on a review of data from the SWFWMD, there are no documented groundwater springs within the Stevenson Creek watershed.

Groundwater quality data was obtained from wells in the upper parts of the Stevenson Creek Watershed or from wells located just outside of the watershed boundary (refer to **Figure 2-6**). Samples from these wells were analyzed for a large set of constituents, including nutrients that are 303(d) listed in surface waterbodies. Most of the available data from Pinellas County for these wells were collected between the years 1990 through 1999, with one sample in 2003.

Figure 2-4 Ambient Water Quality Monitoring Station Locations within the Stevenson Creek Watershed

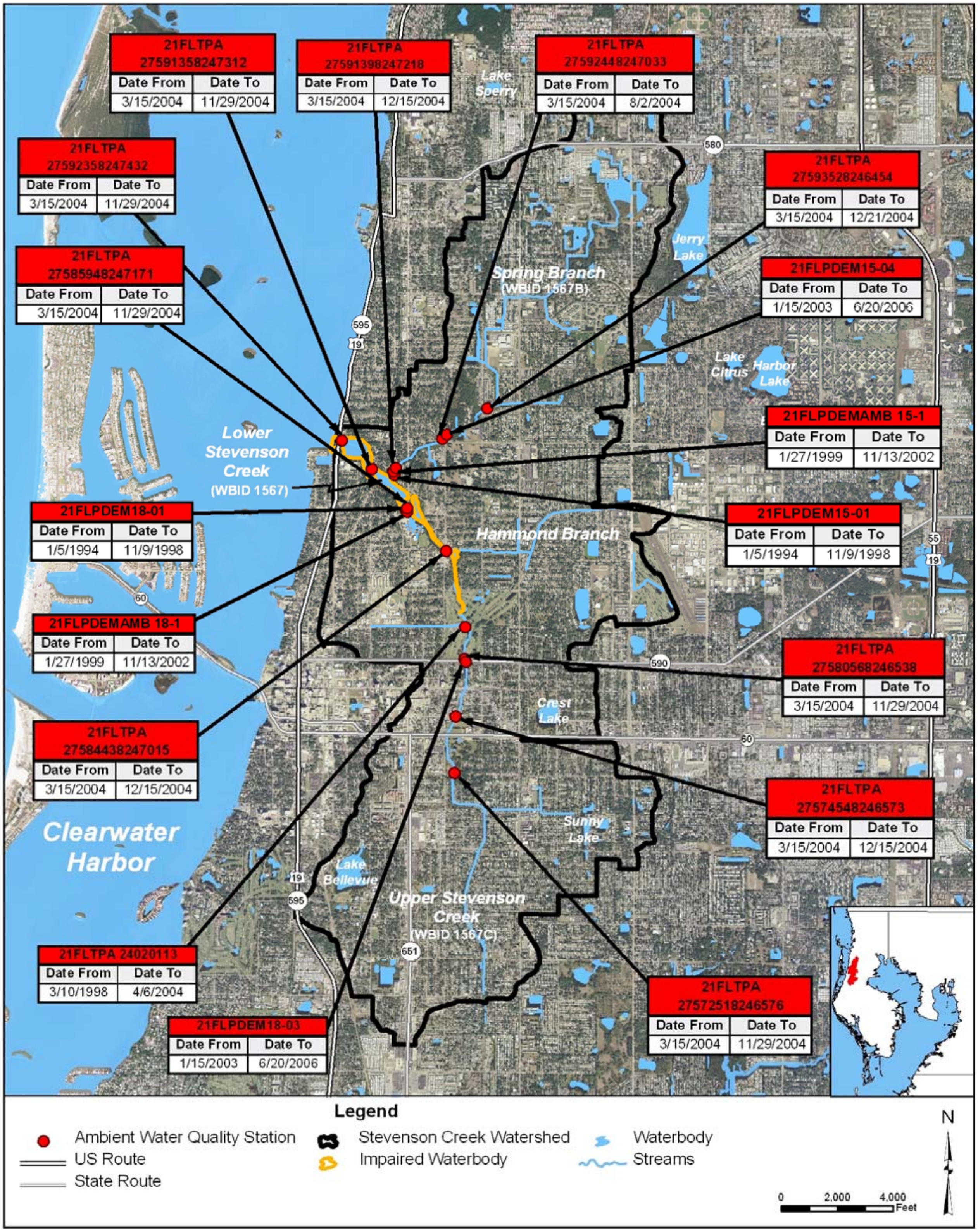


Figure 2-5 Groundwater Level in Floridan Aquifer within the Stevenson Creek Watershed

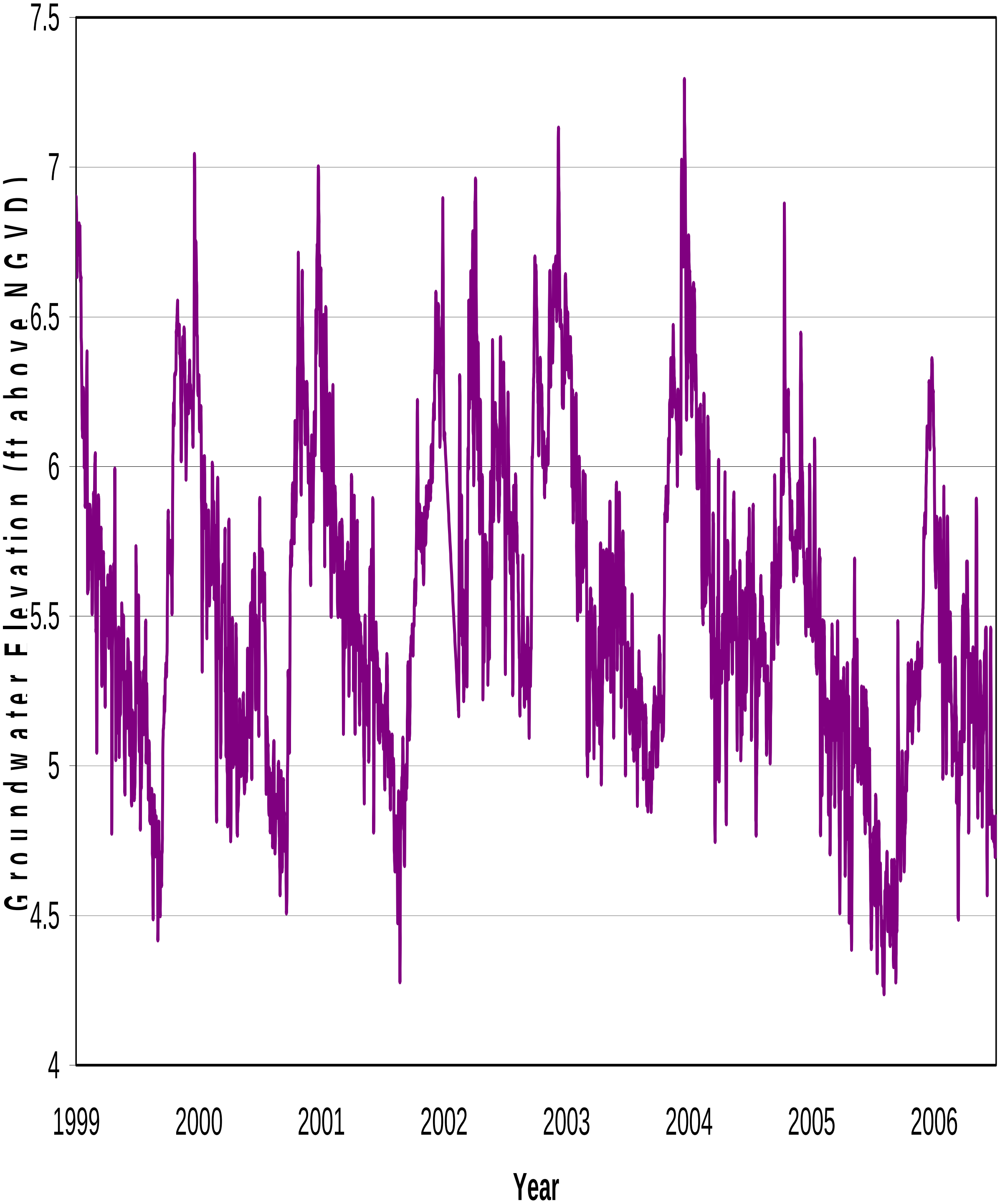
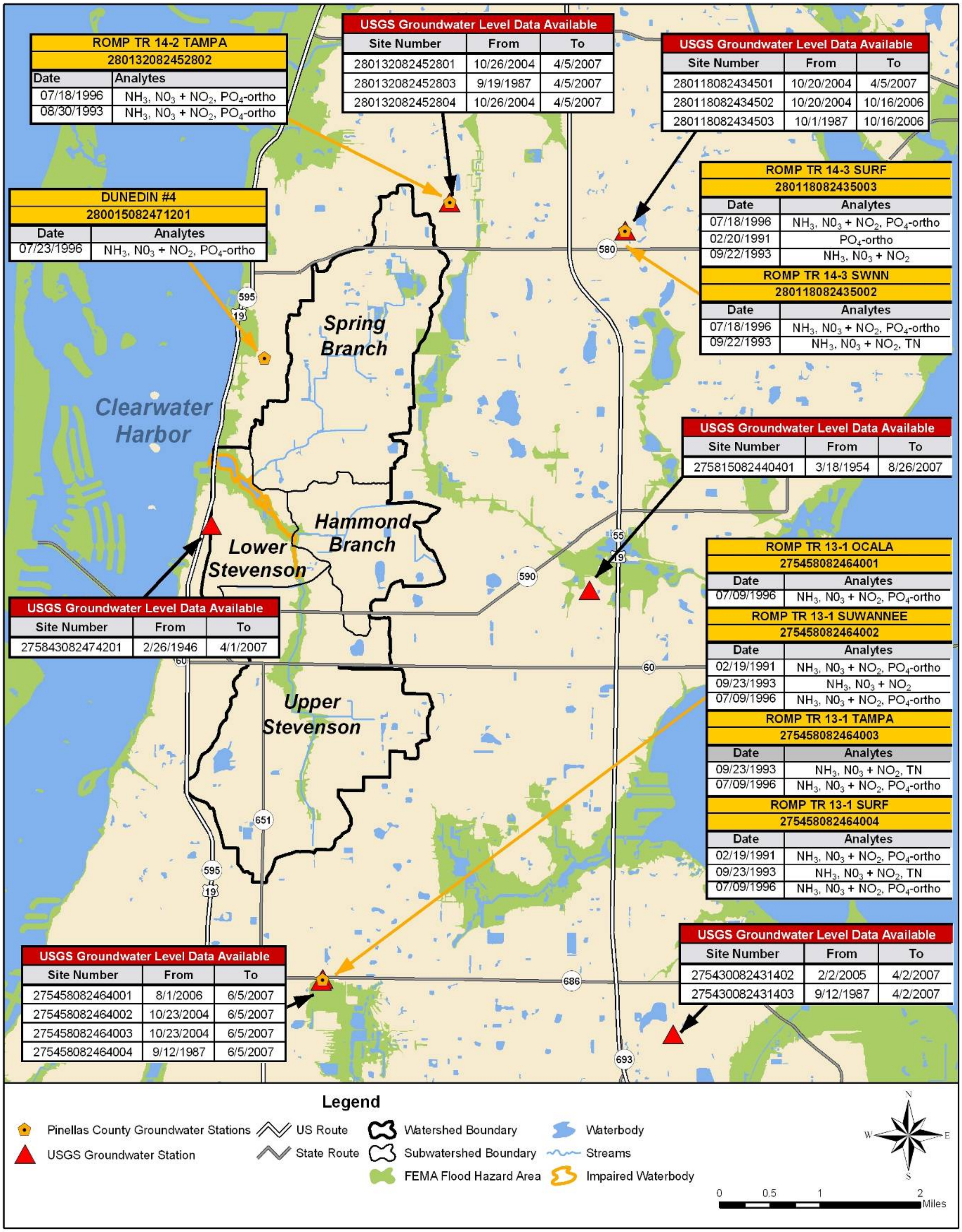


Figure 2-6 Groundwater Monitoring Wells in the Vicinity of the Stevenson Creek Watershed



2.2.10 Point Sources

Generally speaking, point sources include municipal wastewater treatment facility discharges, industrial wastewater treatment facility discharges, municipal separate storm sewer system (MS4) discharges, industrial activity stormwater discharges, and construction activity stormwater discharges. All of these point sources are permitted through the National Pollutant Discharge Elimination System (NPDES) program. Only one NPDES permitted municipal wastewater treatment facility (i.e., the Marshall Street AWWTP – Permit No. FL0021857) exists within the Stevenson Creek watershed. A portion of the treated effluent is routed through Reuse System R001 and used for irrigation on public-access areas under the City of Clearwater Master Reuse System (FL186261). The remaining effluent is discharged via Outfall D-001, which is located near the mouth of Stevenson Creek.

Pinellas County and the cities of Clearwater, Dunedin, and Largo are currently covered by a NPDES MS4 Stormwater Discharge Permit (DEP Permit FLS000005 as Revised in January 2006). CDM has reviewed and evaluated the specific requirements of this permit.

2.2.11 Septic Tanks

The locations of septic tanks within the Stevenson Creek watershed, as shown in GIS data published by the Florida Department of Health, are displayed in **Figure 2-7**. Failure rates and loading factors could be found in the 2001 WMM or can be extracted from a study of septic system impacts in the Peace and Myakka river basins, located north of Fort Meyers, FL (Assessing the Densities and Potential Water Quality Impacts Of Septic Tank Systems in the Peace and Myakka River Basins, Charlotte Harbor Environmental Center, Inc, September 2003). Pinellas County and the cities of Clearwater, Dunedin, and Largo are currently covered by a NPDES MS4 Stormwater Discharge Permit (DEP Permit FLS000005 as Revised in January 2006).

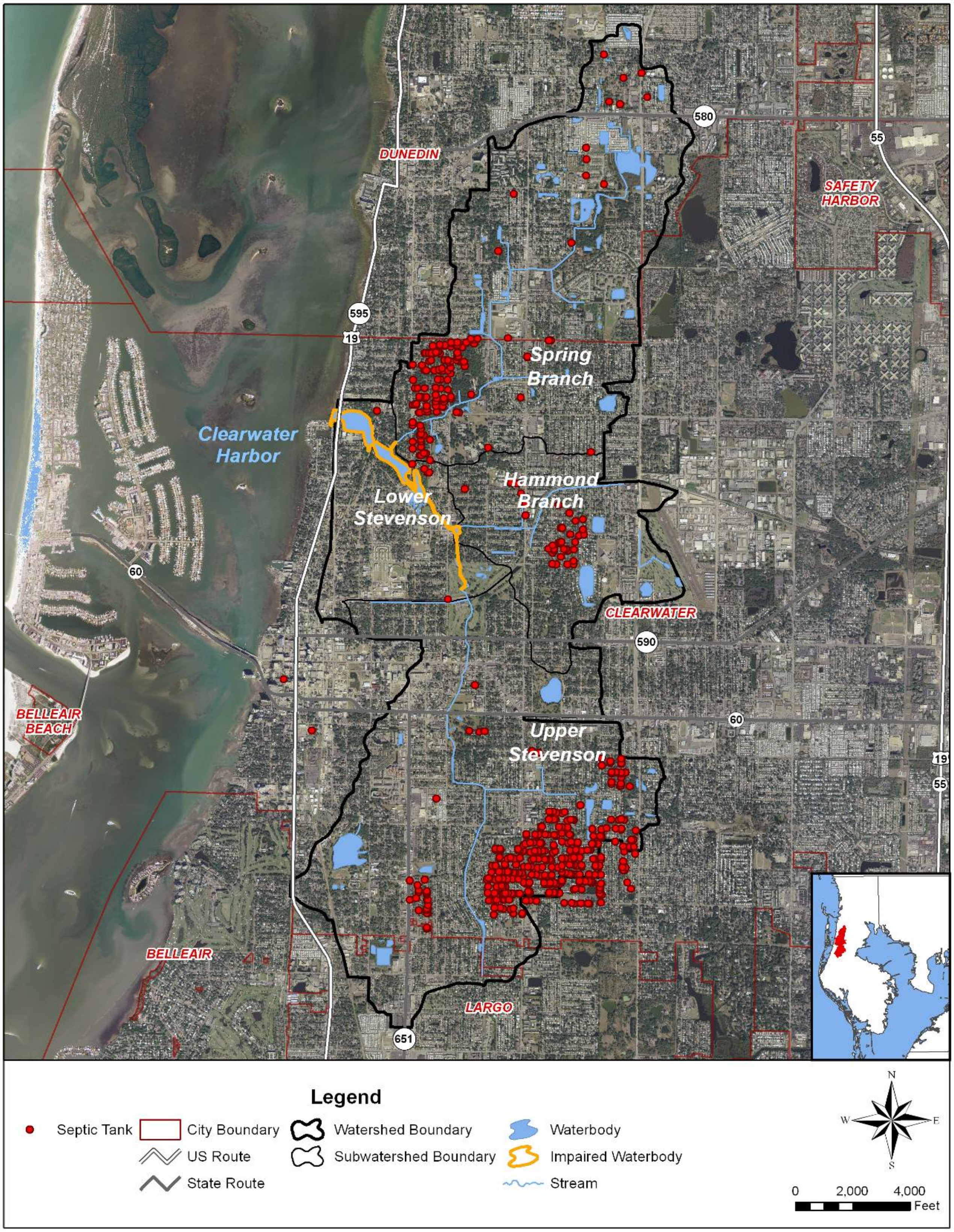
2.2.12 Structural Best Management Practices

A field survey of the Stevenson Creek watershed conducted by CDM staff identified three stormwater structural best management practice (BMP) facilities. One is located on Spring Branch and has been identified as the Pinellas County Mitigation area. This facility consists of a widening of the stream channel with thick sections of special vegetation within this widened channel section designed to retard flow and uptake nutrients. Two structural BMP facilities were identified on the non-tidal segment of Stevenson Creek (i.e., Upper Stevenson Creek) - one of these was identified as the Glen Oaks Stormwater Detention Facility and is located where the Glen Oaks Golf Course was once located. The other is a detention facility created via a widening of the stream channel to the east and separated by a rock-wall that was built along the original eastern bank of the stream. This facility is located on the City of Clearwater golf course and was designed to alleviate structural flooding of golf course dwellings (i.e., the maintenance shop) during significant storm events.

2.3 Receiving Water Quality Model

Major freshwater inflows to the tidally influenced and impaired portion of Stevenson Creek (i.e., WBID 1567) consist of the non-tidally influenced portion of Stevenson Creek, Spring Branch, and Hammond Branch. Freshwater pollutant loads from these stream reaches will be read from the watershed pollutant loading model output files. These loads will constitute the receiving water quality model upstream boundary pollutant Loads.

Figure 2-7 Septic Tank Locations within the Stevenson Creek Watershed



2.3.1 OPEN WATER TIDAL BOUNDARIES

The open ocean boundary condition for the Stevenson Creek receiving water quality model will be located in Clearwater Harbor. Boundaries for the Stevenson Creek hydrodynamic model will be assigned using stage, salinity and temperature extracted from a small scale coastal model of Clearwater Harbor and St. Joseph's Sound (CHJS) that is under development. The CHJS model provides a logical and systematic methodology for estimating the open boundary conditions for the Stevenson Creek model in Clearwater Harbor. The CHJS model is being constructed using NOAA bathymetric data, the NOAA Clearwater Beach tides, estimates of the freshwater inflow from the major drainages, and winds/atmospheric data from the NOAA station located at the St. Petersburg/Clearwater International Airport (refer to **Figure 2-8**). Summary information about the Clearwater Beach tide station is presented in **Table 2-4**.

Table 2-4 Clearwater Beach Tide Station Location

STATION	NAME/LOCATION	BEGIN	END	LAT	LON
8726724	Clearwater Beach, FL	1/13/1999	10/09/2002	27° 58.7' N	82° 49.9' W

2.3.2 Point Source Discharges

The framework for the Stevenson Creek TMDL model is envisioned to consist of a watershed pollutant loading model linked to a receiving water hydrodynamic and water quality model. The Marshall Street AWWTP effluent discharge rates and associated water quality parameter concentrations data will be extracted from the facility's discharge monitoring reports (DMRs) and will be used as model input data. Point source discharges located within the receiving water quality model domain will be represented in as direct flow and pollutant concentration inputs to a grid cell that is nearest to the wastewater treatment facility outfall location.

2.3.3 Ambient Water Quality

Water quality data is available from EPA's STORET databases (http://www.epa.gov/storet) for the Stevenson Creek watershed. Water quality station data sets have also been obtained from FDEP and the USGS NWIS. Inventories of the estuary and stream water quality observation records available from EPA's STORET database for 1999-2006 are summarized in the **Table 2-5**. Water quality data covering the period from 1999 to 2006 are needed to support development of the watershed pollutant loading model and the receiving water hydrodynamic and water quality model.

Following the approach that will be used for calibration of salinity and temperature, stations will be selected from EPA STORET database to show observed water quality data vs. model results as time series for the selected locations in Stevenson Creek. Stations will also be selected to show observed summary statistics of water quality data vs. model results as time averaged spatial transect plots along Stevenson Creek.

Figure 2-8 Clearwater Harbor and the Clearwater Beach NOAA Gage

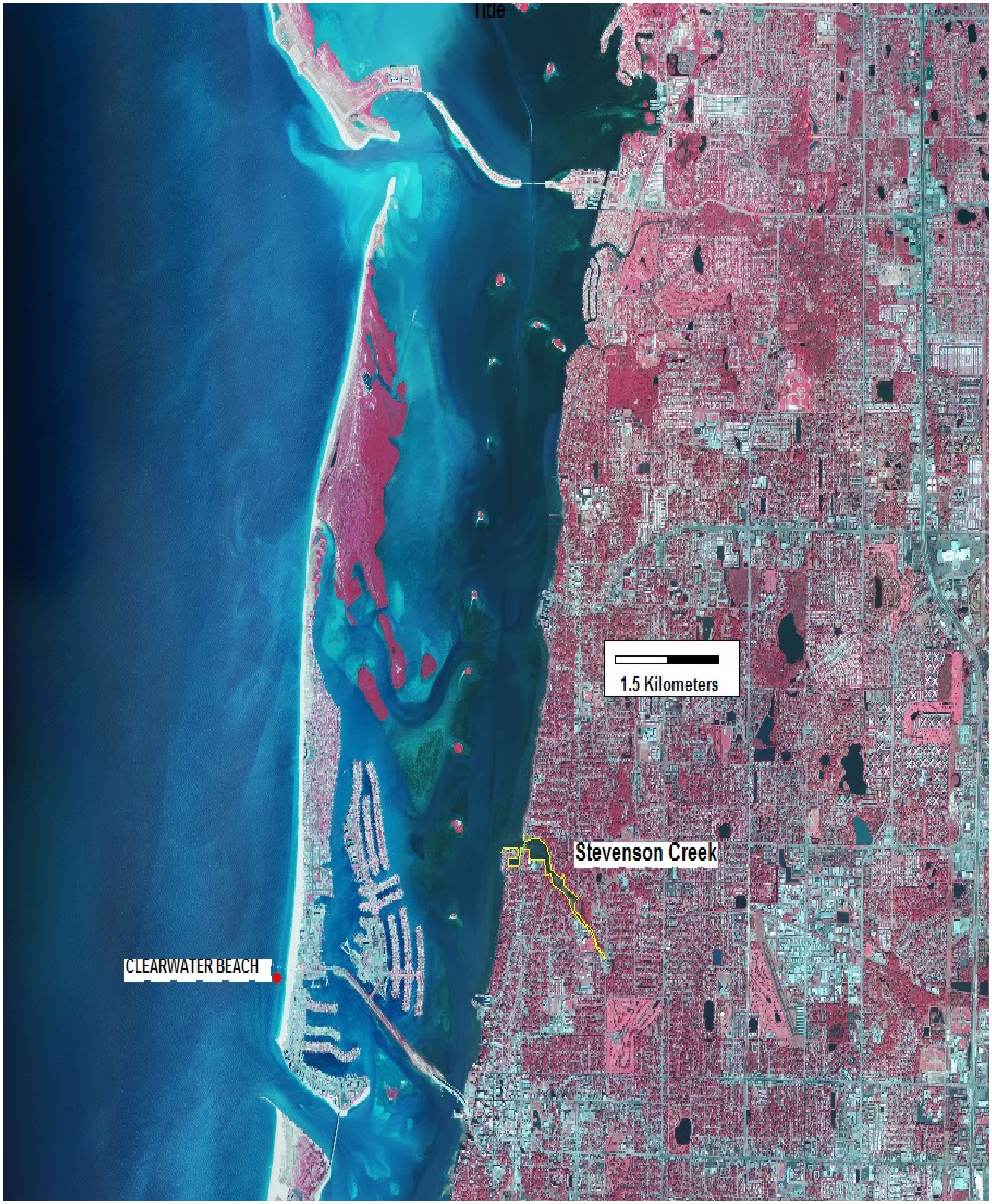


Table 2-5 Summary Inventory of EPA Modern STORET for Stevenson Creek

ESTUARY	TOTAL	1999	2000	2001	2002	2003	2004	2005	2006
BOD5_mgl	89	23	20	22	24				
BODultcarbonaceous_ugl	25						25		
Ca_mgl	25						25		
CarbAlk_mgl	25						25		
Chla_ugl	95	23	24	24	24				
Chlb_ugl	93	23	24	22	24				
Chlc_ugl	120	23	24	24	24		25		
Cl_mgl	25						25		
Color_apparent_pcu	25						25		
Cond_umhocm	123	24	24	24	24		27		
DO_mgl	121	22	24	24	24		27		
Depth_ft	26						26		
F_mgl	25						25		
Fcoli_100ml	25						25		
Fe_ugl	5						5		
K_mgl	25						25		
Mg_mgl	25						25		
Na_mgl	25						25		
NH3_N_ugl	25						25		
NOx_ugl	120	23	24	24	24		25		
OP_mgl	120	23	24	24	24		25		
pH	123	24	24	24	24		27		
Pheo_ugl	120	23	24	24	24		25		
Salinity_ppt	123	24	24	24	24		27		
SECCHI_FT	27						27		
SO4_mgl	25						25		
Tcoli_100ml	27						27		
TDS_mgl	25						25		
TempW_F	96	24	24	24	24				
TKN_UGL	122	23	24	24	24		27		
TN_ugl	120	23	24	24	24		25		
TP_ugl	120	23	24	24	24		25		
TOC_mgl	0								
TSI	120	23	24	24	24		25		
TSS_mgl	120	23	24	24	24		25		
Turb_ntu	83	23	12	24	24				

2.3.4 Sediment Bed Characteristics

The biogeochemical processes and reactions related to eutrophication, nutrient enrichment and dissolved oxygen depletion in Stevenson Creek are governed by the following processes:

- External loading of nutrients and organic matter from the watershed
- Exchange of oxygen across the air-water interface
- Net photosynthetic production of oxygen
- Consumption of oxygen by nitrification and decomposition of organic matter
- Exchange of nutrients and dissolved oxygen within a stratified water column
- Exchange of nutrients across the sediment bed-water column interface
- Consumption of bottom water oxygen by organic matter decay in the sediment bed.

Bed processes related to the flux, or mass transport, of nutrients and dissolved oxygen across the sediment-water interface are thus important features that are tightly coupled with eutrophication, nutrient cycling and oxygen depletion processes in the water column of Stevenson Creek. No information was found to be available concerning sediment bed qualitative. The Jacksonville District of the USACE conducted of series of sediment borings in 2003. These borings were analyzed for grain size only.

2.3.5 Hydrodynamic Model Shoreline and Bathymetry

Shoreline data was obtained as shapefiles from the Florida Geographic Information System Data Library. Bathymetric information, channel cross-sections, and sediment borings for the tidally influenced portion of Stevenson Creek are available in the form of paper reports from a USACE report entitled *Ecosystem Restoration Report and Environmental Assessment, Stevenson Creek Estuary, City of Clearwater, Pinellas County*, Florida that was issued in final form in September 2003.

2.3.6 Hydrodynamic Model Open Water Tidal Boundaries for Gulf of Mexico

The open ocean boundary condition for the Stevenson Creek model will be located in the Clearwater Harbor. There are not any monitoring stations with a continuous record of tide, salinity, temperature or water quality in Clearwater Harbor for the period of interest. Therefore, the boundary forcings for the Stevenson Creek hydrodynamic model will be assigned using stage, salinity and temperature extracted from a small scale coastal model of Clearwater Harbor and St. Joseph's Sound (CHJS) that is under development. The CHJS model will provide a logical and systematic methodology for estimating the open boundary conditions for the Stevenson Creek model in the Clearwater Harbor. The CHJS model is being constructed using NOAA bathymetric data, the NOAA Clearwater Beach tides, estimates of the freshwater inflow from the major drainages, and winds/atmospheric data from the NOAA station located at the St. Petersburg/Clearwater International Airport. Figure 2-8 displays the location of the Clearwater each NOAA tide gage and the Clearwater Harbor/St. Josephs Sound area. Summary information about the Clearwater Beach tide station is presented in **Table 2-6**.

Table 2-6 Clearwater Beach Tide Station Location

STATION	NAME/LOCATION	BEGIN	END	LAT	LON
8726724	Clearwater Beach, FL	1/13/1999	10/09/2002	27° 58.7' N	82° 49.9' W

2.3.7 Hydrodynamic Model Ambient Water Surface Elevation

Hourly measurements of water surface elevation are not known to be available for use in the calibration of the hydrodynamic model. Tide gage time series records of water surface elevation are available as electronic files from NOAA NOS for the station locations and date ranges as presented in **Table 2-7.**

Table 2-7 Tide Gage Station at Clearwater Beach, Florida

STATION	NAME/LOCATION	BEGIN	END	LAT	LON
8726724	Clearwater Beach, FL	1/1/1999	12/31/2006	27° 58.7' N	82° 49.9' W

2.3.8 Hydrodynamic Model Ambient Water Temperature and Salinity

Seventy ambient water temperature and salinity observations are available on a semi-continuous basis during 1999 to 2002 for a water quality monitoring station located approximately 200 meters west of the mouth of Stevenson Creek (AMB 54-3). A number of other stations are located in Clearwater Harbor, in the vicinity of Stevenson Creek. These are summarized in the **Table 2-8**.

Table 2-8 – Salinity and Temperature Monitoring Stations Located in Clearwater Harbor

Station #	Station Name	Type	Begin	End	Easting	Northing
AMB 54-3	Clearwater Harbor	Estuary	1/13/1999	10/9/2002	517781	443224
W2-B-03-05	Clearwater Harbor	Estuary	6/24/2003	6/24/2003	517849	444037
W2-B-06-04	Clearwater Harbor	Estuary	5/9/2006	5/9/2006	517834	444053
W2-B-06-08	Clearwater Harbor	Estuary	10/17/2006	10/17/2006	517294	443123
W2-C-04-08	Clearwater Harbor	Estuary	10/25/2004	10/25/2004	518189	443970
W2-C-05-05	Clearwater Harbor	Estuary	6/29/2005	6/29/2005	517745	442708
W2-D-03-03	Clearwater Harbor	Estuary	4/1/2003	4/1/2003	517275	443115
W2-D-03-04	Clearwater Harbor, North	Estuary	5/19/2003	5/19/2003	517613	443112
W2-D-04-02	Clearwater Harbor	Estuary	2/11/2004	2/11/2004	517272	443133

2.3.9 Meteorological Data

Meteorological data is used to model water temperature and hydrodynamic processes. Parameters needed for the hydrodynamic model include barometric pressure, air temperature, relative humidity, wind speed and direction, precipitation, evaporation, incident solar radiation and cloud cover. Data sources and the availability of meteorological data for input to the hydrodynamic model were summarized earlier in the discussion of data sources and availability for the watershed pollutant loading model.

Section 3
Watershed Pollutant Loading Model and Receiving Water Hydrodynamic & Water Quality Model Evaluations and Recommendations

3.1 Model Evaluations

The transport pathways and fate of naturally occurring constituents and synthetic organic chemicals in a watershed are driven by complex interactions of several factors including precipitation, land uses, urban/rural watershed runoff, groundwater and surface water transport, wastewater inputs, and chemical transformations and biological processes in both the water column and sediment bed.

Watershed pollutant loading models, which are based on topography, land uses, and hydrologic processes, are used to predict streamflow and pollutant loadings delivered from the land surface of a watershed to the surface waters of a receiving stream, river, lake or estuary.

Receiving water models are used to determine the fate and transport of pollutants in surface waters, as well as to predict the interactions between other water quality constituents of interest. These models may be used to facilitate the development of water pollution control/water quality management plans, including TMDLs, based on quantitative comparisons of the effectiveness of alternative point and nonpoint source control policies.

3.1.1 Available Models

Surface water models can be differentiated according to how the boundaries of the physical domain are defined and by the corresponding specification of terms in the model equations. Pollutant loads, physical transport processes, and kinetic interactions can be defined as (a) externally provided input data to a model or as (b) internally calculated by the model. As water quality management issues have become increasingly complex, the domain boundaries of water quality models have expanded. For example, the transport pathways and mass loading of pollutants, such as nitrogen in the Chesapeake Bay Program model (http://www.chesapeakebay.net/model.htm), are computed and coupled internally through watershed pollutant loading models, regional air quality models, groundwater models, hydrodynamic models, eutrophication and aquatic ecosystem models, sediment diagenesis models, and sediment transport models.

Watershed pollutant loading and receiving water models can be further differentiated according to the level of complexity, spatial and temporal scales, the state variables (i.e., a set of variables that are used to represent the state of a physical entity, such as its temperature, etc.), and the kinetic interactions and processes considered in a modeling process framework. To account for these distinguishing features between models, three levels of models were used to assist in the review and selection of appropriate models for the Stevenson Creek TMDL Model Development project. A description of each level follows:

<u>Level 1 - Simple Screening Models</u>

Screening-level water quality models represent only a few selected pollutants as state variables with limited interactions and processes considered, and minimal, if any, calibration to observed data. Screening models provide preliminary coarse level estimates of water quality conditions. Simplified screening models can be set up and applied to critical watersheds, geographic areas, or river reaches that may have major pollution sources and related water quality problems. The results of screening-level analyses can then be used to identify where monitoring efforts are needed or where more detailed modeling investigations may be required.

Level 2 - Mid-Range Intermediate Models

Mid-range or intermediate planning-level models generally include a more detailed characterization of transport processes and pollutant loads, and estimate the fate and transport of multiple pollutants. Consideration is typically given to multiple processes and kinetic interactions. Mid-range models, are often developed with geographic information system (GIS) or graphical user interfaces (GUI), and require calibration and validation to observed data sets.

Level 3 - Complex or Advanced Models

Complex watershed and receiving water quality models represent state-of-the-art mathematical representations of a wide range of watershed and aquatic ecosystem processes, and kinetic interactions between numerous chemical and biological constituents. These constituent interactions occur within the water column, and between the water column and sediment bed. Level 3 models provide detailed assessments of the interrelationships between physical transport, and biological and chemical processes. These processes determine the quality of receiving waters in response to pollutant loading from both natural and human related activities such as land use changes and point source discharges. Level 3 models typically require assignment of numerous model coefficients and parameters, and are often developed initially for applied research purposes. After peer review, they may be adopted for practical water quality management evaluations such as TMDLs. Complex watershed pollutant loading models are typically linked to complex receiving water hydrodynamic and water quality models to address issues related to oxygen depletion, nutrients, eutrophication, sediment transport, toxic chemical fate and bioaccumulation of toxics.

Table 3-1 presents a list of common watershed pollutant loading models and receiving water hydrodynamic and water quality models that fall into the categories described above. A description of each model listed in Table 3-1 and its capabilities is provided below.

Watershed Pollutant Loading Models

The Hydrologic Simulation Program - FORTRAN (HSPF) is a public domain model and is supported by the EPA and the US Geological Survey (USGS). It is a lumped-parameter watershed model that simulates watershed hydrology and non-point source pollutant loadings for organic matter, nutrients, sediments, bacteria and toxic chemicals within a watershed network of delineated sub-basins. The receiving water model routes flow and water quality constituents through a network of stream or lake associated with the sub-basin of the watershed. The HSPF hydrologic sub-model for the sub-basins and reaches provides for simulation of water balances based on precipitation, evaporation, water withdrawals, irrigation, diversions, wastewater discharges. Empirical model parameters are assigned for each sub-basin land use through model calibration to simulate the water balance and pollutant loading from a sub-basin. HSPF is designed as a time variable model with results generated on an hourly or daily basis. Hundreds of applications of HSPF over the past two decades have included short-term storm events and/or continuous simulations over annual and decadal cycles. BMP alternatives designed to reduce pollutant loads to receiving waters can be represented in HSPF by adjustments of land use-based yield coefficients for a pollutant. Windows-based user-friendly GUI software tools such as WinHSPF (Duda et al., 2001), GenScn (Kittle et al., 1998) and HSPFParm (Donigian et al., 1999) have been developed to facilitate pre- and post-processing tasks for HSPF. Time series results for streamflow and pollutant loads generated by HSPF have been linked for input to hydrodynamic (e.g., EFDC) and water quality models (e.g., EFDC, WASP7) in numerous applications over the past decade. HSPF is considered a Level 3 complex or advanced model. More detailed HSPF information is available from the EPA at: http://www.epa.gov/ceampubl/swater/hspf/index.htm.

Table 3-1 Watershed Pollutant Loading and Receiving Water Hydrodynamic & Water Quality Models

Watershed Pollutant Loading Models					
Model	**Name**	**Sponsor & Developer**	**Complexity Level [(a)]**	**Spatial Resolution**	**Transport**
HSPF	Hydrological Simulation Program Fortran	USGS Aqua Terra	3	sub-basin	Hourly Daily
BASINS-HSPF	Better Assessment Science Integrating Point & Nonpoint Sources-HSPF	EPA Aqua Terra TetraTech	3	sub-basin	Hourly Daily
WMM	Watershed Management Model	Florida DEP CDM	1	sub-basin	Annual Seasonal
WAMView	Watershed Assessment Model	Florida DEP EPA SWET	2	grid-based	Hourly Daily
SWAT	Soil and Water Assessment Tool	USDA ARS Texas A & M	3	sub-basin	Daily
SWMM	Storm Water Management Model	EPA CDM	3	sub-basin	Hourly
Receiving Water Hydrodynamic & Water Quality Models					
Model	**Name**	**Sponsor & Developer**	**Complexity Level [(a)]**	**Spatial Variation [(b)]**	**Transport**
QUAL2K QUAL2E		Tufts U (Chapra) EPA Athens ERL	2.	1D(x)	internal hydraulics
WASP7	Water Quality Analysis Simulation Program	EPA Athens ERL Wool et al.	3	3D	external linked
CE-QUAL-W2		USACE WES Portland State U. Cole & Wells, (2000)	3	2D(xz)	internal hydrodynamic
EFDC	Environmental Fluid Dynamics Code	EPA Tetra Tech	3	3D	internal hydrodynamic

Notes: (a) 1 = simple; 2 = mid-range/intermediate; 3 = advanced/complex.
(b) 1D(x) = varies along longitudinal axis; 2D(xz) = varies along longitudinal axis and vertical axis; 3D = varies in all three dimensions.

The Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) surface water modeling system was developed by EPA as a public domain modeling framework to facilitate the (a) extraction of environmental data from national databases (e.g., STORET, PCS, digital elevation, USGS streamflow, RF1, NHD, land use, soils); (b) setup and configuration of watershed runoff and surface water quality models; and (c) integrated framework for model execution including comparison and evaluation of management alternatives, and the development of TMDLs for improving surface water quality conditions (Lahlou et al., 1998). The ArcView GIS interface provides an integrated framework for organizing, displaying and analyzing data and model results. Watershed models integrated in BASINS model include HSPF and the Soil and Water Assessment Tool (SWAT) (described below). BASINS-HSPF is considered a Level 3 complex or advanced model. More detailed HSPF information is available from the EPA at: http://www.epa.gov/athens/wwqtsc/html/basins.html.

The Watershed Management Model (WMM) for Windows is a public domain model, and is the latest version of the WMM originally developed by CDM using Lotus 123. The WMM for Windows framework provides a more robust and user-friendly interface than the previous versions of WMM, and functions as a stand-alone application requiring no additional software. The WMM was developed specifically to estimate average annual or seasonally averaged sub-basin flow and pollutant loads derived from various watershed sources including surface runoff, baseflow, and wastewater discharges, and to assess the load reduction benefits of best management practices (BMPs). WMM estimates loads based on local hydrology and non-point loading factors (Event Mean Concentrations, EMCs), which relate land use patterns and percent imperviousness in a watershed to drainage area normalized pollutant loadings (mass/time-area). The loading impacts of failing septic tanks are addressed by increasing the surface runoff loading calculated by WMM, based on user-defined failing septic tank loading rates, septic tank coverage, and percent incidence of failing septic tanks. Receiving water quality evaluation is limited to a user-defined "delivery ratio", which indicates the fraction of suspended pollutant from each sub-basin that will reach the study area outlet. Since watershed loads can only be estimated as annual or seasonal averages, WMM is considered a Level 1 simplified screening model. More detailed WMM information is available at: http://www.rougeriver.com/proddata/wmm.html

The Watershed Assessment Model (WAMView) is supported by EPA's Watershed and Water Quality Modeling Center as a public domain model, and is a continuous simulation, grid-based watershed scale modeling tool that has been shown to be useful in the assessment of watershed-related properties on water quality (Bottcher et al., 1998; 2005). WAMView was developed to allow engineers and planners to assess the water quality of both surface water and groundwater based on topography, land use, soils, climate, and agricultural practices. Using a physically-based spatial grid, the model simulates the key physical processes important for watershed hydrology and pollutant transport. The WAM GIS-based data sets include land use, soils, topography, hydrography, basin and sub-basin boundaries, point source wastewater facilities and service area coverages and climate data. WAMView simulates surface water and ground water flow allowing for the assessment of flow and pollutant loading for a tributary reach at both daily and hourly time increments as necessary. Water quality constituents represented in WAM include particulate and soluble phosphorus, particulate and soluble nitrogen (NO_3, NH_4, and organic N), total suspended solids, and biological oxygen demand. The results of WAMView are generated as time series outputs located at the source cells, sub-basins, and individual tributary reaches. Results can be displayed as source load maps (surface water and groundwater), attenuated sub-basin and basin loads, ranking of land uses by load source, daily time series of flows and pollutants, and comparative displays showing the effects of different BMP/Management Scenarios. Windows-based user-friendly GUI software tools have been developed to facilitate pre- and post-processing tasks for this model. WAMView is considered a Level 2 mid-range or Intermediate level model due to its limited receiving water capabilities. More detailed WAMView information is available at: http://www.epa.gov/athens/wwqtsc/html/wamview.html.

The Soil and Water Assessment Tool (SWAT) was developed in the early 1990's at Texas A&M University by the USDA Agricultural Research Service (ARS) as a public domain model, and has many of the same functions as HSPF. Unlike HSPF, however, SWAT incorporates a coupled ground water sub-model as a component of the hydrologic water balance, and is limited to a daily time step; hence, SWAT lacks the capability of analyzing hourly storm event distributions. SWAT was developed as a tool to predict water, soil, and chemical runoff yield due to land management practices including agriculture. SWAT is a continuous model and was designed to model large-scale complex watersheds or river basins. These can be subdivided into smaller homogeneous sub-basin parts that can be analyzed separately or holistically. SWAT interfaces with ArcView, Visual Basic, and GRASS to provide user-friendly pre- and post-processing tools to facilitate development and application of the model. With many of the same features as HSPF, SWAT is also considered a Level 2 complex or advanced model. More detailed SWAT information is available at: http://www.brc.tamus.edu/swat/index.html.

The EPA's Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model that is used for single event or continuous simulation of runoff quantity and quality. It is primarily applied to urban areas. This public domain model was first developed in 1971, and has undergone several major upgrades since then. SWMM Version 5 is the current edition of the model and was completely re-written for the Windows environment as a joint development project between the EPA and CDM. SWMM 5 provides a graphically integrated environment for editing study area input data, running hydrologic, hydraulic, and water quality simulations, and viewing the results in a variety of formats. These GUIs include color-coded drainage area and conveyance system maps, time series graphs and tables, profile plots, and statistical frequency analyses. SWMM accounts for various hydrologic processes that produce runoff (e.g., time-varying rainfall, evaporation of standing water, infiltration of rainfall into unsaturated soil layers, interflow between groundwater and the drainage system, etc.), contains a flexible set of hydraulic modeling capabilities (e.g., kinematic or full dynamic wave flow routing, control structures, flow regimes, etc.), and estimates the production of watershed pollutant loads associated with runoff based upon specific land uses. Processes that can be modeled for any number of general, user-defined water quality constituents include dry-weather pollutant accumulation on land, pollutant washoff, transport, and treatment. Aside from surface runoff, SWMM allows pollutants to be introduced into the drainage system through user-defined time series of direct inflows, dry-weather inflows, groundwater interflow, and rainfall dependent inflow/infiltration. SWMM is considered a level 3 complex or advanced model. More detailed SWMM information is available at: http://www.epa.gov/ednnrmrl/models/swmm/index.htm

Receiving Water Hydrodynamic and Water Quality Models

QUAL2K is a river and stream water quality model (Pelletier and Chapra, 2005) designed to upgrade and replace QUAL2E (Brown and Barnwell 1987), which is a well-known model with numerous applications to streams and rivers. Like QUAL2E, QUAL2K represents a stream or river as a one-dimensional (1D) channel that is considered well-mixed over depth and the cross-section of the river. QUAL2K and QUAL2E represent transport with non-uniform, steady-state hydraulics based on Manning's equation. QUAL2K and QUAL2E both represent time variability with a diurnal heat budget for water temperature and dissolved oxygen. State variables of QUAL2K include water temperature, organic carbon (BOD), dissolved oxygen, nutrients, algae and benthic algae, pH and alkalinity. As an upgrade of QUAL2E, deposition of particulate organic matter and the resulting sediment water exchange of nutrients and oxygen is incorporated in QUAL2K with an internally coupled steady state sediment flux model (Di Toro, 2001). In contrast to QUAL2E, which is executed from the MS-DOS screen, QUAL2K is implemented within the Microsoft Windows environment. The model is programmed in Visual Basic for Applications (VBA) and Excel is used as a user-friendly graphical user interface to facilitate pre-processing data input and post-processing graphical and tabular display of model results (Pelletier and Chapra, 2005). Although the water quality kinetics of QUAL2K represent an advanced model framework, the QUAL2K model, since it is limited to steady state applications in

one-dimensional rivers and streams, is considered to be a Level 2 mid-range intermediate model. More detailed QUAL2K information is available at:
(http://www.epa.gov/athens/wwqtsc/html/qual2k.html)

The current version of the Water Quality Analysis Simulation Program (WASP7) is supported by the EPA as a public domain model and represents a Windows-based upgrade and kinetic enhancement of earlier versions of the original WASP code (WASP3: Di Toro et al., 1983; WASP4: Ambrose et al., 1988; WASP5: Ambrose et al. 1993). WASP is a time variable model that allows for the flexible spatial representation of a water body as 1D, 2D or 3D domains. The water column and the sediment bed are coupled via particulate deposition and exchange of materials across the sediment water interface. In comparison to WASP5, WASP7 includes a more complex representation of water quality kinetics and an internally coupled sediment flux model of Di Toro (2001). The WASP7 model helps water quality modelers interpret and predict water quality responses to natural phenomena and manmade pollution for evaluations of alternative management scenarios for point source (wastewater) and nonpoint source (BMP) controls. State variables of WASP include BOD/organic carbon, dissolved oxygen, nutrients, algae and benthic algae, suspended solids and toxic chemicals. Transport data must be externally input to WASP either as (a) user-supplied data or (b) provided by linkage with hydrodynamic models (e.g., EFDC-Hydro) that can provide flow, depth, velocity and water temperature. Similarly, sediment transport deposition and re-suspension velocities for different size classes must be externally input either as (a) user-supplied input data or (b) provided by linkage with a sediment transport model. As a Windows-based model, WASP7 provides table based pre-processing capabilities and graphical post-processing to display time series results. Computational grid generation, grid display and animation of results is not included in WASP7. With advanced water quality kinetics and the internal sediment flux model, WASP7 represents a Level 3- complex or advanced water quality model framework. More detailed WASP7 information is available at:
http://www.epa.gov/athens/wwqtsc/html/wasp.html

CE-QUAL-W2 was originally developed by the US Army Corps of Engineers Waterways Experiment Station for applications to narrow lakes, reservoirs and estuaries. CE-QUAL-W2 is a longitudinal/ vertical time variable hydrodynamic and water quality model that has had extensive use throughout the US and the world as a management and research tool with more than 300 applications worldwide. Version 3.0 is a significant update to Version 2 (Cole and Buchak, 1995) that now includes the ability to model multiple water bodies and the river reaches in between them (Cole and Wells, 2000; Wells and Cole, 2000). The model can now be applied to entire drainage basins including rivers, reservoirs, and estuaries. State variables of CE-QUAL-W2 include water temperature, total dissolved solids or salinity, biochemical oxygen demand/organic carbon, dissolved oxygen, nutrients, algae, iron, fecal coliform bacteria, suspended solids, inorganic carbon, pH and alkalinity. Sediment-water exchange of nutrients and dissolved oxygen is included as user-defined forcing function fluxes. With internal linkage to a hydrodynamics model and advanced water quality kinetics, CE-QUAL-W2 is considered to be a Level 3- complex or advanced model. More detailed CE-QUAL-W2 information is available at: http://www.ce.pdx.edu/w2.

The Environmental Fluid Dynamics Code (EFDC) is a general-purpose modeling package designed to simulate 1-dimensional, 2-dimensional, and 3-dimensional flow, transport, and bio-geochemical processes in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and near shore to shelf scale coastal regions. The public domain EFDC model, originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications, is supported by the EPA. The hydrodynamic sub-model is comparable to the Princeton Ocean Model (Blumberg and Mellor, 1987) while the water quality and eutrophication sub-model is functionally equivalent to the Chesapeake Bay Model (CE-QUAL-ICM) developed by the US Army Corps of Engineers, Waterways Experiment Station (Cerco and Cole, 1993; 1995). In addition to hydrodynamic processes, salinity and water temperature, EFDC also simulates sediment transport, eutrophication, toxic contaminants and sediment diagenesis. EFDC is unique among advanced surface water models in that it is designed to interface hydrodynamics (Hamrick, 1992) with sediment transport (Tetra Tech, 2000), toxic chemicals (Tetra Tech, 1999b), eutrophication (Park et al., 1995) and sediment diagenesis (Di Toro, 2001) within a single source code (Hamrick, 1996). EFDC has provided an advanced modeling framework for hundreds of applications worldwide, including Mobile Bay (Wool et al., 2003), to support the simulation of hydrodynamic transport and the interpretation and prediction of water quality responses to natural phenomena and manmade pollution for TMDLs and other evaluations of alternative management scenarios for point source (wastewater) and nonpoint source (BMP) controls. As a public domain model with source code readily available, EFDC has been modified and improved over the years to support various modeling projects. More detailed EFDC information is available at: http://www.epa.gov/athens/research/modeling/efdc.html. The availability and capabilities of pre- and post-processing software tools is critical for efficient applications of EFDC. To efficiently test, setup and calibrate EFDC models, Dynamic Solutions LLC developed the EPA-licensed EFDC_Explorer pre- and post processor. EFDC_Explorer, developed to support the EFDC sub-models for hydrodynamics, sediment transport, toxic chemicals, water quality and sediment diagenesis, is a public domain, Windows-based GUI available from Dynamic Solutions. EFDC_Explorer is designed to support EFDC model set-up and configuration, grid generation (cartesian or curvilinear), model testing, calibration and validation. EFDC_Explorer provides the capability for data visualization, including display of the computational grid, map overlays, spatial results, time series and vertical profile plots. Animation of results can easily be generated and saved to an AVI file (Craig, 2004). More detailed information on EFDC_Explorer is available at: http://www.ds-intl.biz/fs_ee.html and at: http://www.dsintl.biz/Programs/EFDC_Explorer%20Overview.pdf

3.1.2 Model Selection Criteria

Per FDEP requirements, the following criteria were considered in selecting Stevenson Creek TMDL models:

- The models selected must be in the public domain and have associated pre- and post-processing tools, preferably in a graphical user interface.
- The models must be capable of simulating the dynamic conditions over both short time periods (daily) and long time periods (annual time frames). Time steps between hydrodynamic and water quality simulations must be compatible.
- The models must be capable of simulating, at a minimum, the spatial changes in hydrodynamics and water quality occurring both longitudinally and vertically in the water bodies.
- The models must be capable of simulating both time variable point source and nonpoint source inputs. The nonpoint source inputs may include atmospheric deposition, groundwater inputs, and sediment fluxes in addition to surface runoff.
- The models must be capable of simulating the surface water quality dynamics necessary to develop TMDLs for the dissolved oxygen and nutrient impairment.

Additional criteria considered in the model selection process included:

- Relative level of peer review and verification of model code;
- Anticipated model run times;
- Availability of up-to-date, comprehensive model documentation; and
- Access to source code to perform modification ease (if required).

3.1.3 Model Evaluation Results

The FDEP model selection criteria were applied to each available model listed in Table 1 to identify those models that merited further consideration. The watershed pollutant loading models that do not meet all of the listed FDEP criteria are WMM, SWAT, and WAMView. The WMM was designed as a Level 1 screening model to compute average annual or seasonal pollutant loads, and clearly does not meet the dynamic, and small time step simulation capability requirements. SWAT does not support the simulation of storm events as the time step can not be set to less than one day, and is best suited for agricultural applications. Although WAMView meets the FDEP established criteria, it was considered an inappropriate choice due to lack of comprehensive model documentation, lack of peer review and model code verification, and anticipated lengthy run times. WAMView is also best suited to agricultural applications rather than urban ones. The inability of SWMM to simulate non-event mean concentration based water quality constituents (e.g., stream temperature, and dissolved oxygen) makes it an unsuitable choice for the Stevenson Creek TMDL model project.

The watershed loading model deemed most appropriate for application as a Stevenson Creek TMDL model was HSPF. This model (specifically, the WinHSPF version) clearly meets both the FDEP established criteria and the additional criteria listed above. In addition, the model is capable of estimating water temperature and the dissolved oxygen levels in runoff and baseflow, and land-based loading factors can be varied by season when such analysis is required.

Several receiving water models listed in Table 1 did not meet the full set of criteria for receiving water hydrodynamic and water quality model selection. QUAL2E and QUAL2K did not meet the criteria as both models are limited to steady-state and one-dimensional receiving water applications. CE-QUAL-W2 did not meet the criteria for this project since it was designed for two-dimensional, laterally averaged representations of hydrodynamics and water quality of a waterbody. As 3-dimensional dynamic analysis may be required, CE-QUAL-W2 was not considered further.

WASP7 did not meet the criteria for this study due to a number of practical reasons. These include the limited capabilities of its pre- and post-processors (for example, WASP7 does not internally support graphic displays of the computational grid or a map of the spatial results generated by the model), and its required external linkage to a hydrodynamic model (such as EFDC) for transport. If EFDC were to be used to simulate hydrodynamic processes and then linked to WASP7 for receiving water quality simulations, the use of WASP7 would constitute an inefficient use of resources since the water quality simulation modules of WASP7 and EFDC are more or less comparable in their kinetic processes details.

The receiving water hydrodynamic & water quality model deemed most appropriate for application as a Stevenson Creek TMDL model was EFDC as it meets all of the model selection criteria.

3.2 Model Recommendations

Based upon the results of the model evaluation activities documented above, the CDM Team recommends that WinHSPF coupled with EFDC be selected for implementation on the Stevenson Creek TMDL Model Development project.

HSPF has been applied in many watershed studies in the southeastern states, and has been accepted as the technical basis for numerous TMDL evaluations. In addition to its technical capabilities, its user interface, and its linkage with EFDC, the CDM team has extensive experience with the set-up, calibration, and validation of HSPF, and its linkage with EFDC.

The EFDC model has been used worldwide for hundreds of applications for rivers, lakes, reservoirs, wetlands, estuaries and coastal waters. As one of EPA's most advanced surface water modeling system for hydrodynamics and water quality studies, EFDC has been accepted as the technical basis for numerous TMDL evaluations. In addition to the outstanding technical features and capabilities of EFDC, the CDM team has extensive experience with the set-up, calibration, and validation of the EFDC model, modification and enhancement of the EFDC code, and development and modification of EFDC_Explorer (the innovative pre- and post-processor developed by Dynamic Solutions to support EFDC applications).

Well established links between these two public domain and US Environmental Protection Agency (EPA) supported models provide a seamless framework within which pollutant fate and transport phenomena are closely simulated and validated. Both of these peer reviewed models have been applied in hundreds of applications worldwide. Numerous TMDL studies in rivers and estuaries of the US have been developed with these recommended models including the Mobile Bay TMDL study (Wool et al., 2003), and they meet all of the model capability criteria established by FDEP for the Stevenson Creek Model Development project.

Based on a review of existing and readily-available data, the CDM team proposes the following modeling activities:

(a) Number of hydrologic units and routing reaches – At this time, based on available data, it is expected that the HSPF watershed pollutant loading model will be set up to use 4 hydrologic units and associated routing reaches (i.e., Lower Stevenson Creek, Spring Branch, Hammond Branch, and Upper Stevenson Creek). The CDM has evaluated the AdICPR model developed by Parsons ES for the Stevenson Creek watershed to determine the final model details.

(b) Number of grid cells for the hydrodynamic model and water quality model – This number is still in the process of being determined based on the assessment of available bathymetric and other data. A coarse EFDC hydrodynamic model of up to 300 grid cells for the Clearwater Harbor and St. Joseph Sound will be developed in order to set the downstream boundary condition for the more detailed Stevenson Creek EFDC receiving water hydrodynamic and water quality model. This more detailed model domain will have up to 400 cells in the horizontal plane with 3 to 5 vertical layers.

(c) Model state variables and boundary condition data that will be used for model calibration and validation –

(c.1) HSPF Watershed Pollutant Loading Model

- Rainfall
- Impervious area (from land use)
- Soils parameters (upper and lower zone storage and infiltration rates)
- Reported wastewater point source flows and loads (for parameters listed below)
- Loading factors for:
  - Ultimate carbonaceous biochemical oxygen demand ($CBOD_u$),
  - Ammonia nitrogen (NH_3-N)
  - Nitrate plus nitrite ($NO_2^- + NO_3^-$)
  - Ortho-phosphate (PO_4^-)
  - Total nitrogen (TN)
  - Total phosphorous (TP)
- In-watershed routing and evaluation of temperature, total suspended solids (TSS), dissolved oxygen (DO), chlorophyll-a (Chl-a), refractory organic N, and the listed water quality parameters

- FTable routing reach data based on ICPR model and other variable information that is still being evaluated
- Flows based on Pinellas County streamflow gaging station located on Stevenson Creek behind the City of Clearwater Country Club building

(c.2) EFDC hydrodynamic and water quality model

- Water surface elevation
- Salinity
- Water temperature
- Tides

(c.3) EFDC (receiving water) Water Quality Model

- TSS
- DO
- Chl-a
- $NO_2^- + NO_3^-$
- (NH_3-N)
- Total organic nitrogen
- Refractory organic nitrogen
- PO_4^-
- Total organic phosphorous
- Total organic carbon derived from $CBOD_u$
- Phytoplankton

(d) Model simulation, calibration, and validation periods – The simulation period for both HSPF and EFDC will run from January 1, 1999 through December 31, 2006. However, due to data availability limitations, model calibration and validation for HSPF and EFDC will be conducted over subsets of the full simulation period. Data availability suggests that specific periods within the years1999 through 2006 are the most suitable for water quality calibration and validation of HSPF and EFDC. The proposed water quality calibration period for HSPF runs from the beginning of year 2003 through the end of year 2005, whereas the proposed HSPF water quality validation period runs from the beginning of year 2006 through the end of year 2006. The proposed EFDC calibration and validation periods are proposed to consist of time durations of approximately 3 to 6 continuous months within the period that runs from the beginning of year 1999 through the end of year 2002.

No USGS owned/operated streamflow gaging stations exist within the entire Stevenson Creek watershed. However, Pinellas County installed a streamflow gaging station on Stevenson Creek behind the City of Clearwater Country Club building in August 2006. Mean daily streamflows measured at this gaging station are available from August 22, 2006 through December 31, 2006, and will be used to calibrate HSPF simulated streamflows.

(e) Ambient water quality monitoring stations – A number of ambient water quality monitoring stations maintained by different organizations exist within the Stevenson Creek watershed. The station ID and location of each of these monitoring stations were presented in Figure 2-4. Data associated with these stations suggest that two stations will be useful as HSPF model calibration/validation points, and two other stations will be useful in calibrating/validating the EFDC receiving water quality model.

Another station, AMB 54-3, whose location is not shown in Figure 3-1, is located approximately 200 meters west of the mouth of Stevenson Creek and might be of some use in the EFDC hydrodynamics model as well.

Stations 21FLPDEM AMB 15-1, and Station 21FLPDEM AMB 18-1 are both located in the tidally influenced (and impaired) segment of Stevenson Creek and both have data associated with them that runs from year 1999 through year 2002. These two stations are located within the EFDC model domain and will be used to calibrate and validate the EFDC model.

Data associated with Stations 21FLPDEM 15-04, and 21FLPDEM 18-03 clearly indicate the lack of any tidal influence, and the sampling period for both runs from year 2003 through year 2006. Both of these stations will be used to calibrate/validate the HSPF model.

Section 4
HSPF and EFDC Models Set-Up, Refinement, Calibration, Validation and Recommendations

4.1 Introduction

Pursuant to the results of the evaluation of an appropriate TMDL modeling framework for the Stevenson Creek watershed as documented in Section 3 – Model Evaluations and Recommendations, the HSPF model (i.e., the watershed pollutant loading model) was set-up, refined, calibrated, and validated to available observed data. Following this effort, the EFDC model (i.e., the receiving water hydrodynamic and water quality model) was set-up, refined, and linked to the calibrated and validated HSPF model, such that watershed pollutant loads calculated by the HSPF model were imported into the EFDC model as boundary conditions. The EFDC model was then calibrated and validated to observed data.

Sub-sections 4.2 through 4.5 document the set-up, refinement, calibration and validation of the HSPF model, and sub-sections 4.6 through 4.9 document the set-up, refinement, calibration and validation of the EFDC model. Sub-section 4.10 provides conclusions and recommendations for future HSPF and EFDC linked model refinements based on the need for more robust and complete datasets.

4.2 HSPF Model Development

Based on the availability of Stevenson Creek watershed data as documented in Section 2, the HSPF model was developed to simulate Stevenson Creek watershed streamflows and water quality constituent loads for the period beginning on January 1, 1999 and ending on December 31, 2006.

The bulk of the ambient water quality monitoring data for the Stevenson Creek watershed was collected between the late 1990s and 2006. Time-series plots of measured and modeled water quality constituent concentrations for these periods were evaluated to assess the HSPF model's predictive watershed pollutant load capabilities.

4.2.1 HSPF Model Parameters

The developed Stevenson Creek watershed HSPF model was set up to simulate the following parameters:

- Streamflow rate
- Water temperature
- Ultimate carbonaceous biochemical oxygen demand ($CBOD_u$)
- Dissolved oxygen (DO)
- Total suspended solids (TSS)
- Nitrogen species (refractory organic nitrogen (ORN), ammonia (NH_4-N), total Kjehldahl nitrogen (TKN), nitrite-plus-nitrate, total N)
- Phosphorus species (orthophosphorus and total P)
- Chlorophyll-a

All of these constituents were modeled for the watershed area, and were loaded to the HSPF reaches for the watershed. The HSPF reaches then account for the flow and load routing (transport) and the processes that occur in the reaches (transformation). Time-series of flow, temperature and water quality constituent concentrations serve as input to the EFDC model of the impaired segment of Stevenson Creek (i.e., Lower Stevenson Creek).

4.2.2 HSPF Input Data

Section 2 documents the identification, collection, and evaluation of all existing and readily-available data that are applicable to the Stevenson Creek watershed. These data were used to support the set-up, calibration, and validation of the Stevenson Creek watershed HSPF and EFDC models.

4.2.2.1 Topography

Stevenson Creek watershed topography in 5-ft contour intervals was obtained from the Florida Geographic Database Library (FGDL). Figure 2-1, as presented in Section 2, displays the areal extent of the Stevenson Creek watershed, and its associated topography superimposed on an aerial photograph, which was obtained from Pinellas County. All topographic data required by the HSPF model was based upon this acquired data.

4.2.2.2 Hydrography

In order to simulate pollutant loads conveyed to a receiving water body, a watershed's stream network is divided into discrete reaches that represent the characteristics of each stream in the network, and key locations (e.g., impaired stream segments, flow gages, water quality monitoring stations, point source discharges, etc.) are identified. Non-point source and point-source flow quantities and associated pollutant loads are then routed through the stream network until they reach the receiving water body. Any significant water quality processes that might occur within the stream network are accounted for. A Geographic Information System (GIS) shapefile that identifies the Stevenson Creek stream network was made available by the FDEP. Information regarding currently impaired waterbodies within the Stevenson Creek was received from the FDEP.

The HSPF model domain consisted of four subwatersheds that collectively constitute the entire Stevenson Creek watershed (refer to **Figure 4-1**); these are: (i) Upper Stevenson Creek (WBID 1567C); (ii) Hammond Branch; (iii) Spring Branch (WBID 1567B); and (iv) Lower Stevenson Creek (WBID 1567). Lower Stevenson Creek is the only tidally influenced stream segment within the watershed and is impaired with respect to nutrients, and dissolved oxygen. The other three stream segments contribute freshwater to Lower Stevenson Creek and are not impaired for nutrients and dissolved oxygen. Within the context of the HSPF model, stream segments are called reaches (RCHRES).

4.2.2.3 Reach Channel Geometry and Stage

HSPF reach channel geometric data was extracted from the existing Stevenson Creek AdICPR model that was developed and applied for the Stevenson Creek Watershed Management Plan project. This study was commissioned by the City of Clearwater, Florida. AdICPR input/output files were used to characterize stage, discharge, and surface area relationships for each of the HSPF reaches to develop the appropriate HSPF FTABLES data.

4.2.2.4 Streamflow

No long-term, historical streamflow data exist anywhere within the Stevenson Creek watershed. Pinellas County began monitoring streamflow and gage height in a non-tidally influenced segment of Stevenson Creek at the end of August of 2006. A continuous, measured streamflow record exists for this gage from August 28, 2006 through January 2007. The gage is located on Stevenson Creek behind the Clearwater Country Club building a short distance away from the Upper Stevenson Creek/Lower Stevenson Creek boundary (refer to Figure 4-1 for the subwatershed boundaries).

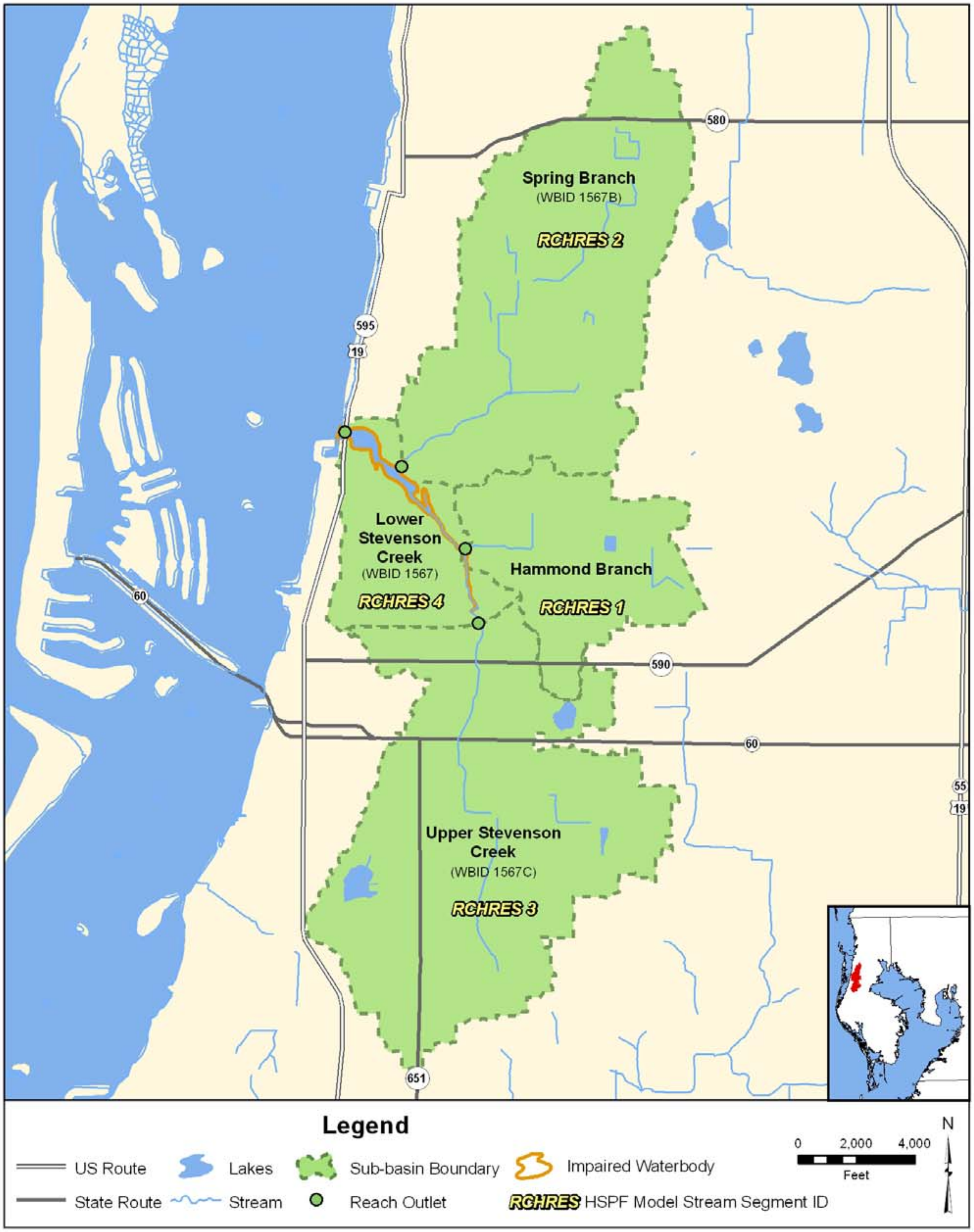


Figure 4-1 Stevenson Creek Watershed with HSPF Reach Delineation

Additionally, 12 observations of instantaneous flow measurements collected over the year 2004 through 2005 period by Pinellas County during routine monitoring at each of 2 ambient water quality monitoring locations (i.e., Station 21FLPDEM18-03 on Upper Stevenson Creek, and Station 21FLPDEM 15-04 on Spring Branch) also exist, and these observations were used as HSPF model flow validation data.

Because it was at first postulated that a 4-month measured streamflow dataset would be insufficient to calibrate the HSPF model appropriately, and that the data would consequently need to be supplemented by estimated flows, a search was conducted for a continuous, long-term USGS owned and operated streamflow gage station in a nearby watershed. USGS gage 02307668 is located on Alligator Creek below Belcher Road within the City of Clearwater, Florida and has an associated period-of-record that runs from October 1, 1995 through present. As the tributary area to this USGS gage station (3.67 square miles) is nearly identical to the tributary area to the Pinellas County Stevenson Creek gage station (3.60 square miles) it was assumed that the USGS gage station could be used to generate an extended streamflow time-series for the Pinellas County gage station. **Figure 4-2** displays a scatter plot of streamflows measured at the Pinellas County gage station versus those measured at USGS gage 02307668 over the period from late August 28, 2006 through January 2007.

Based on the relatively high correlation between the two gage stations (i.e., $R^2 = 0.81$), an estimated streamflow time-series that extended over the entire established model simulation period (i.e. 1999 through 2006) was generated for the referenced Stevenson Creek gage station to supplement the existing, measured 4-month continuous streamflow time-series. During the model calibration process, however, it became clear that the correlation between the model-simulated streamflows at the Stevenson Creek gage and this extended streamflow time-series yielded results that were significantly inferior ($R^2 = 0.43$) to simply using the 4-month measured streamflow dataset ($R^2 = 0.75$). This result is very clearly evident in the statistical graphs presented in **Figure 4-3** and **Figure 4-4**. Upon further analysis of these results, it became evident that the Alligator Creek streamflow dataset yielded good results only as long as Stevenson Creek streamflows did not exceed 20 cubic feet per second (cfs), and consequently, use of the USGS Alligator Creek gage station data to generate Stevenson Creek estimated flows was not pursued further.

4.2.2.5 Groundwater Levels

Groundwater level data was not used in the HSPF model as HSPF does not provide the ability to simulate groundwater levels or quality. In HSPF, deep groundwater storage is considered lost from the system. Determining groundwater levels and quality requires coupling HSPF with a groundwater model such as MODFLOW (Swain and Wexler, 1996).

4.2.2.6 Land Use

Year 2004 Stevenson Creek watershed land use data were used in the HSPF model. These data were received in GIS format from FDEP. The source of the 2004 land use data was the SWFWMD. Within the GIS files, land use within the Stevenson Creek watershed was organized into twenty-six discrete land use categories as per the Florida Land Use and Cover Classification System. Based upon an evaluation of the predominant land uses within the Stevenson Creek watershed, the twenty-six land uses were aggregated into nine categories for use in the HSPF model. Table 2-1presented the areal extents and associated percentage of total watershed area of each the nine land use categories used in HSPF, and Figure 2-3 displays these data graphically.

Figure 4-2 Stevenson Creek Flows versus Alligator Creek Flows

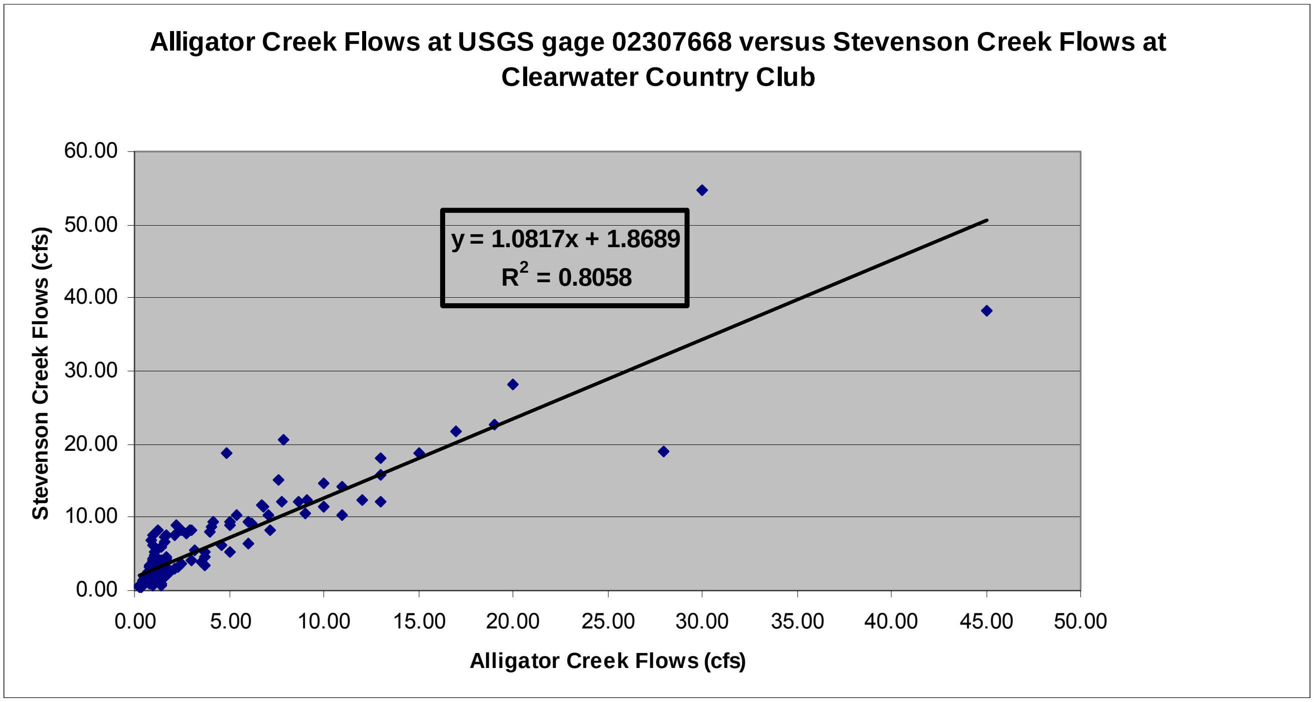


Figure 4-3 HSPF Simulated versus Supplemented Measured Stevenson Creek Flows

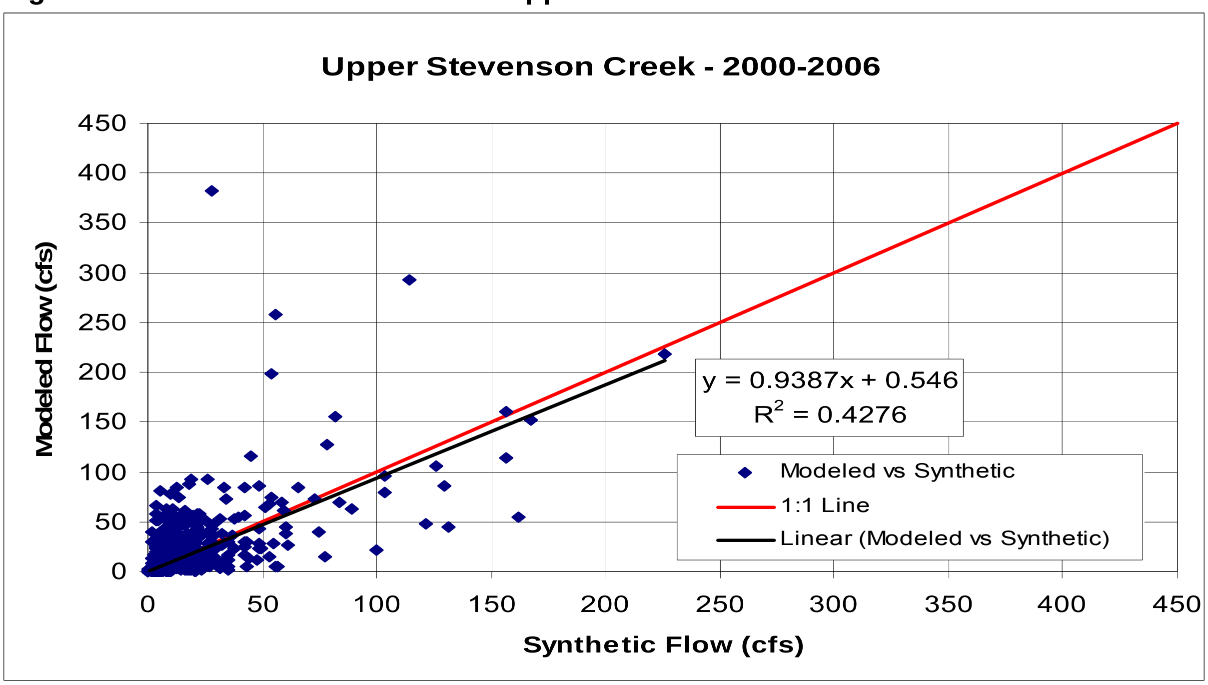
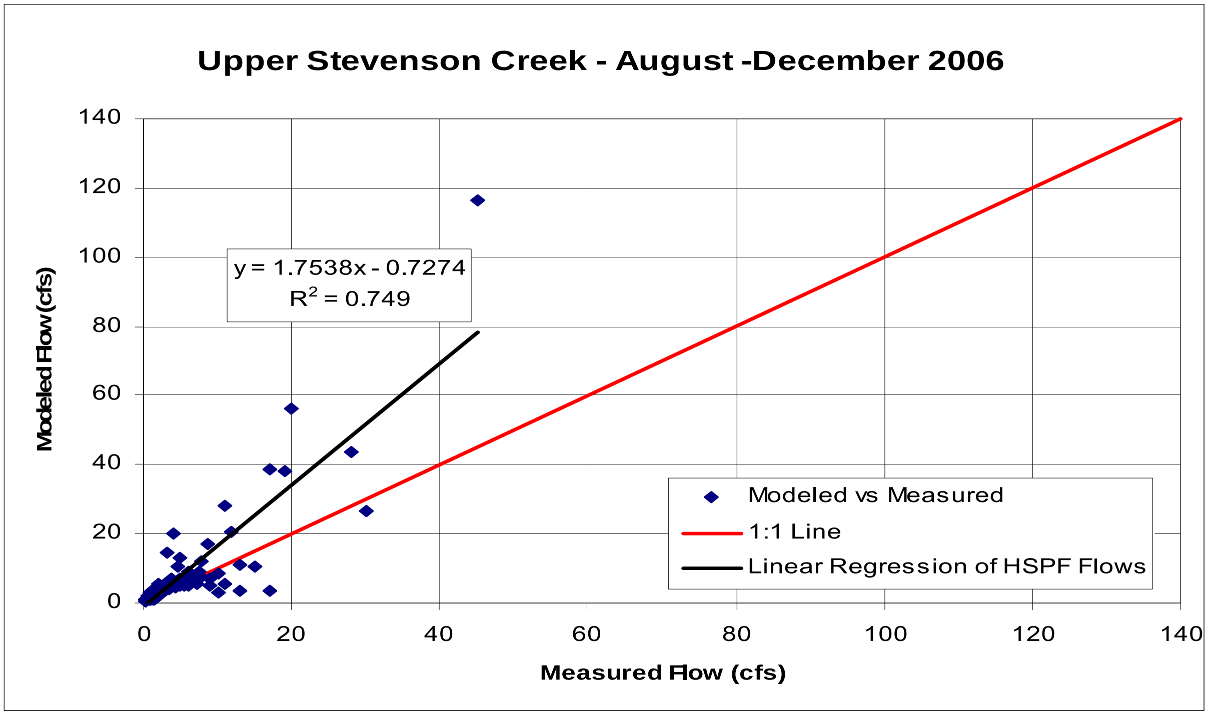


Figure 4-4 HSPF Simulated versus Measured Stevenson Creek Flows



4.2.2.7 Hydrologic Soil Groups

Available hydrologic soil group data for the Stevenson Creek watershed, and a discussion of these data were presented in Section 2. Table 2-2 presented the areal extents and associated percentage of the total watershed area of each of the six hydrologic soil groups that exist in the Stevenson Creek watershed, and Figure 2-4 presented these data graphically. The six hydrologic soil groups consist of A, B, B/D, C, D, and W (i.e., water). In order to utilize the hydrologic soil group data reported in Table 2-2 for the HSPF model, it was necessary to estimate the areal extent of each hydrologic soil group within each of the four sub-watersheds. **Table 4-1** presents these results.

4.2.2.8 Point Sources

Generally speaking, point sources include municipal wastewater treatment facility discharges, industrial wastewater treatment facility discharges, municipal separate storm sewer system (MS4) discharges, industrial activity stormwater discharges, and construction activity stormwater discharges. All of these point sources are permitted through the National Pollutant Discharge Elimination System (NPDES) program. Only one NPDES permitted municipal wastewater treatment facility (i.e., the Marshall Street AWWTP – Permit No. FL0021857) exists within the Stevenson Creek watershed and it discharges its effluent near the mouth of Stevenson Creek. Because this facility’s treated effluent outfall is located outside of the HSPF model domain and inside the EFDC model domain, it was not included as a point source in the HSPF model. Pinellas County and the cities of Clearwater, Dunedin, and Largo are all covered under one NPDES Phase I MS4 permit (Permit No. FLS000005), and although some water quality monitoring at the stormwater outfalls is required by the permit, the available data was sparse and not particularly well suited for inclusion in the HSPF model.

Alternatively, the impact of permitted MS4 discharges on ambient water quality was included as a non-point source, pollutant accumulation/wash-off simulation in HSPF.

Table 4-1 Hydrologic Soil Group Distributions within Stevenson Creek Sub-watersheds

Hydrologic Soil Group	Total Acreage	Percentage of Sub-watershed
	Upper Stevenson Creek	
A	1,051.76	40.44
B/D	912.62	35.09
C	273.86	10.53
D	304.03	11.69
W	58.53	2.25
Total	2,600.80	100.0
	Hammond Branch	
A	138.16	16.01
B/D	391.45	45.36
C	306.53	35.52
W	26.80	3.11
Total	862.94	100.0
	Spring Branch	
A	947.54	44.15
B/D	652.66	30.41
C	444.91	20.73
D	30.05	1.40
W	71.03	3.31
Total	2146.19	100.0
	Lower Stevenson Creek	
A	289.04	42.63
B/D	216.90	31.99
C	82.24	12.13
D	42.31	6.24
W	47.53	7.01
Total	678.02	100.0

4.2.2.9 Reclaimed Water for Irrigation

The City of Clearwater Marshall Street AWWTP discharges its treated effluent to Clearwater Harbor and also partially transfers reclaimed water to the City of Clearwater Master Reuse System. This reuse system is a Part II slow rate public access land application system, which is permitted by FDEP via permit number FLA 186261-01. For the established HSPF simulation period, reclaimed water was supplied to the Clearwater Country Club Golf Course. The reclaimed water is applied throughout the golf course at a slow rate via a spray irrigation system, and due to its proper administration, it is not anticipated to contribute to ambient water quality degradation. Consequently, use of reclaimed water use data in HSPF was deemed unnecessary as it would not contribute to the accuracy of the model.

4.2.2.10 Septic Tanks

The distribution of septic tank systems as shown in Figure 2-7 was used in the HSPF model. The incidence of septic tank coverage within the Stevenson Creek watershed is relatively low due to the high level of development within the watershed (i.e., over 90% built-out). The cities of Clearwater, Dunedin, and Largo lie entirely within the watershed. To account for septic system loadings, the HSPF model was adjusted to match the estimated annual loadings through the use of accumulation/wash off, interflow and base flow parameters. Initial values of the accumulation/wash off, interflow and base flow parameters for each land use were obtained from the Perdito Bay HSPF model. These values were adjusted in individually to match the estimated range of loadings on a land-use specific basis.

4.2.2.11 Structural BMPs

The evaluation of existing stormwater BMPs conducted during the data acquisition and compilation of previous studies (as documented in Section 2), identified three major stormwater management improvement BMPs as discussed in Section 2.2.3 and Section 2.2.12. All of these facilities have the capability of attenuating flow peaks. However, only the Pinellas County Mitigation Area and the Glen Oaks Stormwater Detention facility are deemed capable of attenuating pollutant loads. Specifics on how data associated with these facilities were used in the HSPF calibration process are documented in Section 4.6.1, and Section 4.6.3.

4.2.2.12 Water Use Permits

Grounwater water withdrawal data was not used in the HSPF model because the effect of grounwater withdrawals on surface water cannot be simulated in HSPF although researchers have coupled HSPF with an analytical model for this purpose (Zarriello, Barlow and Duda 2001).

4.2.2.13 Meteorological Data

For the simulation of hydrology in HSPF, the key meteorological model inputs are rainfall and potential evapotranspiration (PET). HSPF reads the rainfall time-series and applies that rainfall to the land surface and surface storage, and calculates the amount of the rainfall that is converted to surface runoff or interflow, or infiltrates into the soil profile. The PET time-series establishes the maximum amount of evapotranspiration that may occur under an unlimited supply of water. The actual evapotranspiration (ET) depends upon the PET and the actual availability of water on the surface and in the soil profile.

The weather station that is closest to the centroid of the Stevenson Creek watershed is located at the St. Petersburg/ Clearwater International Airport (NOAA station ID12873). A complete set of hourly meteorological data (incident solar radiation, wind speed and direction, cloud cover, barometric pressure, air temperature, relative humidity, dew-point temperature, and precipitation) covering the period from January 1, 1999 through December 31, 2006 was acquired from the NOAA National Climatic Data Center for this weather station. For the referenced period of record, the average annual precipitation was 52.7 inches, and annual precipitation totals ranged from a low of 32.9 inches (in year 2000) to a high of 71.3 inches (in year 2004).

The PET time-series was established by using the Hamon PET computing method. In the Hamon method, hourly PET is computed on the basis of air temperature (which was available at the referenced NOAA weather station), and monthly coefficients. The monthly coefficients were set so that the average annual PET was about 61 inches per year, which is consistent with values used in previous Florida studies **(**Swancar et al, 2000**).** The annual PET values ranged from 59 inches (in year 2001) to 63 inches (in year 2005).

Modeling of water temperature requires additional meteorological data, which includes solar radiation, cloud cover, air temperature, dew-point temperature, and wind speed. As indicated earlier, these data were available for the NOAA weather station located at the St. Petersburg/Clearwater International Airport, and were acquired from NOAA for the established HSPF model simulation period.

4.2.2.14 Water Quality Data

Data from the following Stevenson Creek watershed ambient water quality stations were used for comparison with the HSPF model water quality results:

- Upper Stevenson Creek: Station 21FLPDEM18-03 (approximately 200 feet upstream of Drew Street); and
- Spring Branch: Station 21FLPDEM 15-04 (approximately 150 feet west of the Sunset Point Road/ Betty Lane intersection).

Both stations had available water quality data for the established calibration and validation periods (respectively, 2003-2004, and 2005-2006).

Tables 4-2 and 4-3 summarize the water quality data for the calibration/validation monitoring station locations. Each table (one table per location) presents the start date, end date, number of samples, and average and median values for each water quality constituent. As evident in the tables, the constituent concentrations in the two stream segments are highly comparable. Considering the high level of development in the entire Stevenson Creek watershed (i.e., over 90 percent built-out), and the fact that medium density residential is the predominant land use, this is not an unexpected result.

In addition to matching in-stream water quality, expected ranges of mass export were developed to be used as an additional calibration target. A literature review of land use specific water quality monitoring indicated that most published data is provided in the form of land use specific event mean concentrations (EMCs) as opposed to mass loading rates. To estimate a reasonable range of loads, Florida-specific EMCs were applied to an estimated annual runoff volume for each of the land use types included in the Stevenson Creek watershed HSPF model.

The Simple Method to compute annual runoff volume was employed, where annual runoff volume is equal to annual rainfall (in/yr) multiplied by 0.9 and by the runoff coefficient (R_c). Using this approach, differences in EMC and R_c values impacted the estimated ranges of potential loading from the model land segments. Typical Florida EMC values at the 90th percentile confidence interval (i.e., the probability that the range includes the true value is 90%) used to develop these calibration targets are presented in **Table 4-4**.

Calculated constituent loading rates were adjusted for each subwatershed to account for additional load inputs from septic tank systems, and load reductions that would be expected from implementation of structural BMPs (e.g., wet detention ponds, wetlands, etc.). Values used to calculate septic loadings are presented in **Table 4-5**, while BMP removal efficiencies are presented in **Table 4-6.**

4.3 HSPF Calibration and Validation

Due to the limited availability of measured streamflows within the watershed, the period from August 2006 through December 2006 was chosen as the HSPF streamflow calibration period, and the period from February 2004 through March 2005 was chosen as the HSPF streamflow validation period. It should be noted that streamflow calibration was performed at one Stevenson Creek location, while streamflow validation was performed at a different Stevenson Creek location, and at a Spring Branch (a tributary of Stevenson Creek) location. The streamflow validation data consist of twelve observations at each of these two locations.

Based on available ambient water quality data, the period from January 1, 2003 through December 31, 2004 was chosen as the HSPF model calibration period, and the period from January 1, 2005 through December 31, 2006 was chosen as the HSPF model validation period.

Table 4-2 Measured Data for the Upper Stevenson Creek Subwatershed

Calibration (2003-2004)					
Constituent	**Start Date**	**End Date**	**No. of Samples**	**Average**	**Median**
5-day BOD (mg/l)	3/15/2004	11/29/2004	5	1.98	0.77
DO (mg/l)	1/15/2003	11/29/2004	26	6.1	6.4
Total Phosphorus (mg/L)	1/15/2003	11/29/2004	23	0.2	0.14
Ammonia NH_4 (mg/l)	1/15/2003	11/29/2004	23	0.05	0.04
Chlorophyll-a (µg/L)	1/12/2004	11/29/2004	12	5.8	4.5
Nitrite-plus-Nitrate N (mg/l)	1/15/2003	11/29/2004	23	0.2	0.21
Orthophosphorus (mg/L)	1/12/2004	11/29/2004	14	0.105	0.090
Total Nitrogen (mg/L)	1/15/2003	11/29/2004	23	1.06	1.055
Water Temperature (deg. C)	1/15/2003	11/29/2004	26	23.1	24.17
TKN (mg/l)	1/15/2003	11/29/2004	23	0.85	0.81
Validation (2005-2006)					
Constituent	**Start Date**	**End Date**	**No. of Samples**	**Average**	**Median**
5-day BOD (mg/l)	2/23/2005	3/6/2006	5	3	4
DO (mg/l)	1/6/2005	6/20/2006	12	5.1	4.9
Total Phosphorus (mg/L)	1/6/2005	6/20/2006	12	0.21	0.18
Ammonia NH_4 (mg/l)	1/6/2005	6/20/2006	12	0.035	0.040
Chlorophyll-a (µg/L)	1/6/2005	6/20/2006	12	8.1	5.2
Nitrite-plus-Nitrate N (mg/l)	1/6/2005	6/20/2006	12	0.10	0.06
Orthophosphorus (mg/L)	1/6/2005	6/20/2006	12	0.114	0.110
Total Nitrogen (mg/L)	1/6/2005	6/20/2006	12	0.85	0.90
Water Temperature (deg. C)	1/6/2005	6/20/2006	12	24.0	23.0
TKN (mg/l)	1/6/2005	6/20/2006	12	0.75	0.74

Table 4-3 Measured Data for Spring Branch Subwatershed

Constituent	Start Date	End Date	No. of Samples	Average	Median
Calibration (2003-2004)					
5-day BOD (mg/l)	N/O*	N/O*	N/O *	N/A **	N/A **
DO (mg/l)	1/15/2003	11/29/2004	20	5.0	4.9
Total Phosphorus (mg/L)	1/15/2003	11/29/2004	17	0.18	0.18
Ammonia NH_4 (mg/l)	1/15/2003	11/29/2004	17	0.1	0.1
Chlorophyll-a (µg/L)	1/12/2004	11/29/2004	8	2.1	1.4
Nitrite-plus-Nitrate N (mg/l)	1/15/2003	11/29/2004	17	0.15	0.15
Orthophosphorus (mg/L)	1/12/2004	11/29/2004	8	0.11	0.10
Total Nitrogen (mg/L)	1/15/2003	11/29/2004	16	1.13	1.17
Water Temperature (deg. C)	1/15/2003	11/29/2004	20	22.11	22.03
TKN (mg/l)	1/15/2003	11/29/2004	16	0.98	0.97
Validation (2005-2006)					
Constituent	**Start Date**	**End Date**	**No. of Samples**	**Average**	**Median**
5-day BOD (mg/l)	2/23/2005	5/4/2006	6	4.5	4.0
DO (mg/l)	1/6/2005	6/20/2006	15	2.7	3.1
Total Phosphorus (mg/L)	1/6/2005	6/20/2006	14	0.35	0.36
Ammonia NH_4 (mg/l)	1/6/2005	6/20/2006	14	0.3	0.3
Chlorophyll-a (µg/L)	1/6/2005	6/20/2006	14	3.3	2.0
Nitrite-plus-Nitrate N (mg/l)	1/6/2005	6/20/2006	14	0.12	0.12
Orthophosphorus (mg/L)	1/6/2005	6/20/2006	14	0.21	0.20
Total Nitrogen (mg/L)	1/6/2005	6/20/2006	14	1.50	1.37
Water Temperature (deg. C)	1/6/2005	6/20/2006	15	21.9	20.8
TKN (mg/l)	1/6/2005	6/20/2006	14	1.39	1.30

Notes: * N/O = No observations
** N/A = Not applicable

Table 4-4 90th Percentile Confidence Interval for Average Florida EMC Values

	Commercial / Industrial			High Density Residential			Low/Medium Density Residential			Transportation / Utilities*		
5-day BOD (mg/L)	6.12	-	9.05	9.32	-	18.10	8.16	-	12.05	6.12	-	9.05
PO4P (mg/L)	0.09	-	0.16	0.11	-	0.26	0.18	-	0.32	0.09	-	0.16
NOXN (mg/L)	0.73	-	1.75	0.52	-	0.39	0.64	-	1.22	0.73	-	1.75
TKN (mg/L)	0.80	-	1.28	1.05	-	1.78	1.15	-	1.78	0.80	-	1.28

Notes: * Values for transportation were assumed to equivalent to commercial land use

Table 4-5 Values used in Septic Tank System Load calculations

System Attribute	Value	Units	Reference
Total N concentration in effluent	15	mg/L	(CDM,1998)
PO4-P concentration in effluent	2	mg/L	(CDM,1998)
5-day BOD concentration in effluent	130	mg/L	(GBRA, 2003)
Daily wastewater discharge	70	gal/person/day	(Tchobanoglous et al, 2003)
Individuals per septic system household	2.17	per system	(U.S. Census, 2000)
Septic System Failure Rate	10%	percent	(FDEP, 2005)

Table 4-6 BMPs Constituent Load Removal Efficiencies

Constituent	Percent of Upper Stevenson Creek sub-watershed area tributary to the Glen Oaks Stormwater Wet-Detention Facility*	Percent of Spring Branch subwatershed area tributary to Pinellas County Wetland Mitigation Area *	Average BMP Removal Efficiencies	Reference for BMP Removal Efficiency
Ortho-P	52%	90%	50%	(FDEP, 2005)
NH3-N	52%	90%	65%	(US EPA, 1999)
NOx-N	52%	90%	35%	(FDEP, 2005)
$CBOD_U$	52%	90%	30%	(FDEP, 2005)
ORN	52%	90%	65%	(US EPA, 1999)

Note: * These are significant in-line water-quantity/water-quality BMP facilities

It is important to note that observed water quality constituent data reflect grab-sample analysis results, and the number of observations is relatively low.

4.3.1 Streamflow

A comparison of modeled HSPF flows in the Upper Stevenson Creek subwatershed versus the measured flows average over the 4-month period-or-record associated with the Pinellas County streamflow gage station indicates a difference of approximately 2 cfs (respectively, 4 cfs versus 6 cfs). The error in average flows reflects the influence of extreme events, such as those observed as a result of significant storms. Although the HSPF simulated hydrograph trends correctly for the entire simulation period (i.e., flow peaks occur as a result of rainfall events), a significant discrepancy exists between event based peak model simulated flows and peak measured flows as illustrated in **Figure 4-5**.

In order to reduce this discrepancy, several refinements were made to the model. First, refinements of channel geometry data included in the F-Tables block of the HSPF model were performed in order to account for significant volume detention provided by two in-line stormwater improvement projects. These projects were designed to alleviate flooding and include the Glen Oaks Stormwater Detention Facility, and the Clearwater Golf Course Detention facility and are discussed in detail in Section 2.2.3. Additional efforts involved adjusting a significant number of model parameters that included soil infiltration, impervious retention storage, pervious interception storage, percent impervious cover for each land use category, interflow recession coefficient, deep groundwater storage. Soil infiltration was calculated using expected soil infiltration for each hydrologic soil group and adjusting by the percentage of that soil group that exists in the subwatershed.

Refinement of these parameters resulted in pushing many of these parameters to the maximum extent permitted by the Florida DEP TMDL protocol (FDEP, 2005) and US EPA (2000) technical guidance. From this refinement process, it was determined that the model continued to accurately reflect the precipitation patterns in the watershed along with accurate timing, but the peak flow hydrograph for short-term duration/high intensity storm events could not be reduced significantly. This overestimation of peak flows was attributed to the well-documented tendency of HSPF to over-predict peak flows in urban watersheds.

The paired daily flows (observed and modeled) along with a linear regression line for the paired data, and a line representing equal values of measured and modeled flow were presented earlier in Figure 4-4. As illustrated in the figure, there is scatter around the equal value line, but generally the model does not appear biased (i.e., number of values above and below the equality line seem to be similar). The correlation coefficient (R^2) value is 0.75 for the measured flow comparison. Finally, the stream gage used for the measured data was installed on August 28, 2006 and thus provided data only for the latter portion of 2006. The short-term, available measured-flow dataset should be expected to affect the quality of the flow calibration.

Although the flow calibration would be highly improved if a continuous, long-term streamflow time-series were available, an independent assessment of the flow calibration using instantaneous flow measurements collected by Pinellas County during routine monitoring at stations 21FLPDEM18-03, and 21FLPDEM14-04 indicates that the flow calibration is quite good for both Upper Stevenson Creek and Spring Branch. **Figures 4-6** and **4-7** present a comparison of these instantaneous flow measurements versus the HSPF modeled flows. These figures indicate a very good fit between observed and modeled flow data, and serve as model-simulated flow validation checks.

4.3.2 Average Annual Water Balance

The HSPF simulated average annual water balance four Stevenson Creek watershed reaches are presented in **Table 4-7** through **Table 4-10.**

Figure 4-5 Measured and Modeled Streamflow in Upper Stevenson Creek

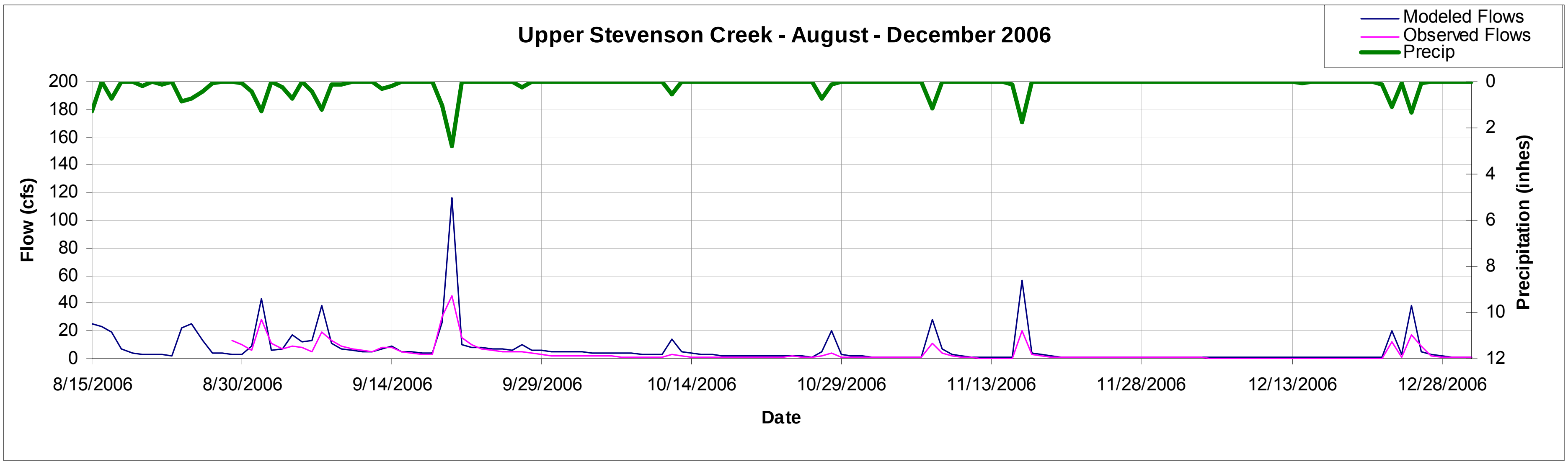


Figure 4-6 Modeled Streamflow versus Observed Streamflow at Station 21FLPDEM18-03

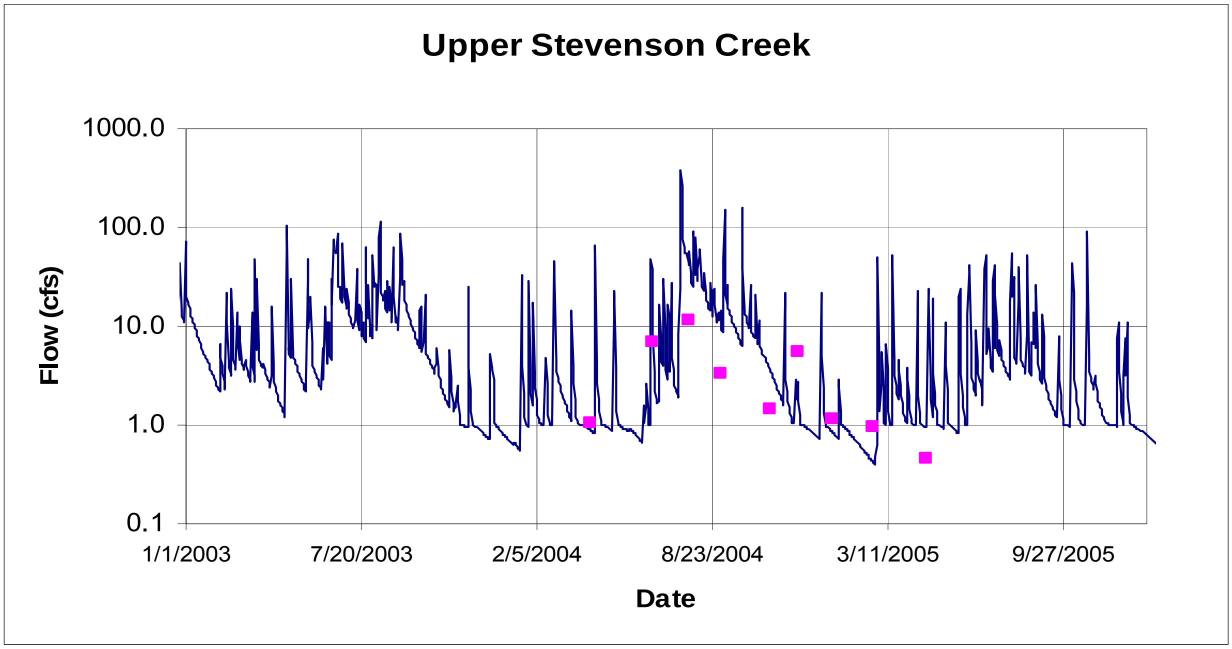


Figure 4-7 Modeled Streamflow versus Observed Streamflow at Station 21FLPDEM14-04

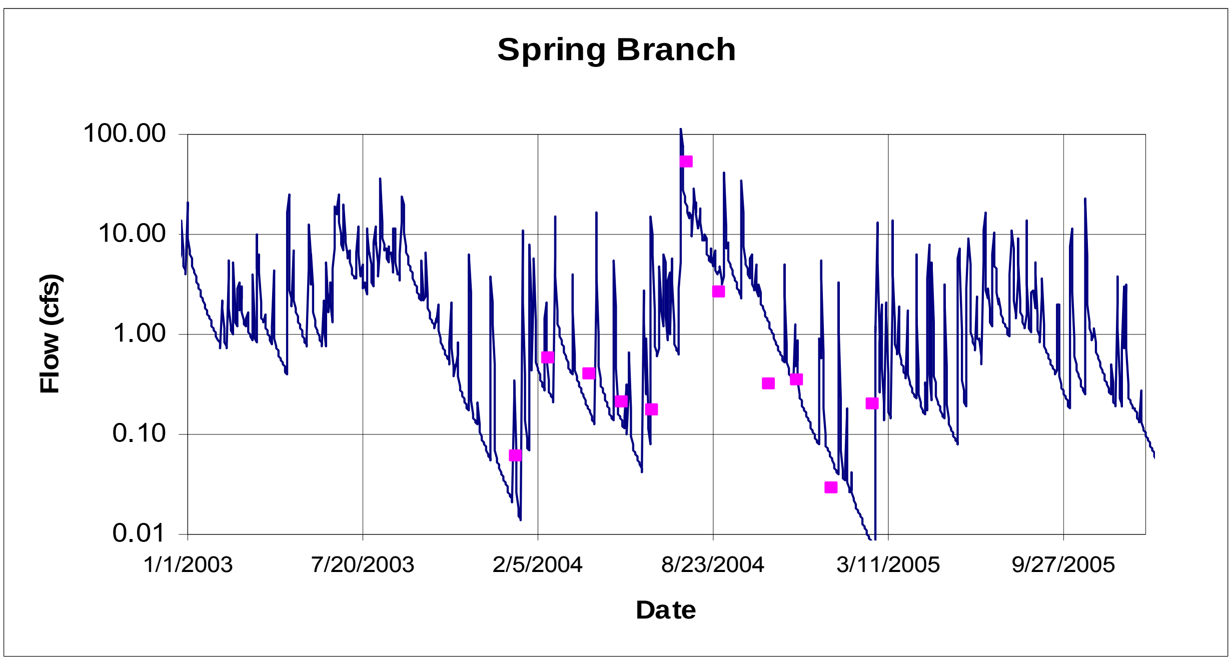


Table 4-7 HSPF Simulated Water Balance for Upper Stevenson Creek (Reach 3)

Calendar Year	Annual Water Balance (acre-ft per year)						
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Evaporation	Reach Outflow	Change in volume
1999	2258	105	1208	0	0	-3491	80
2000	1768	52	602	0	0	-2422	-1
2001	2898	210	1399	0	0	-4516	-8
2002	3653	323	1466	0	0	-5332	110
2003	3743	524	3278	0	0	-7662	-117
2004	4444	1079	2695	0	0	-8204	14
2005	2599	57	832	0	0	-3500	-12
2006	3047	260	1197	0	0	-4488	16
Average	3051	326	1585	0	0	-4952	10

Table 4-8 HSPF Simulated Water Balance for Hammond Branch (Reach 1)

Calendar Year	Annual Water Balance (acre-ft per year)						
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Evaporation	Reach Outflow	Change in volume
1999	621	64	438	0	0	-1123	0
2000	480	35	218	0	0	-732	0
2001	806	109	506	0	0	-1421	0
2002	1015	165	530	0	0	-1674	36
2003	1044	256	1184	0	0	-2519	-35
2004	1281	456	966	0	0	-2703	0
2005	706	38	303	0	0	-1047	0
2006	854	125	431	0	0	-1410	0
Average	851	156	572	0	0	-1579	0

Table 4-9 HSPF Simulated Water Balance for Spring Branch (Reach 2)

Calendar Year	Annual Water Balance (acre-ft per year)						
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Evaporation	Reach Outflow	Change in volume
1999	1587	65	1099	0	0	-2750	1
2000	1247	24	546	0	0	-1817	0
2001	2034	164	1272	0	0	-3471	-1
2002	2571	250	1332	0	0	-3994	158
2003	2631	434	2984	0	0	-6208	-158
2004	3122	961	2442	0	0	-6523	1
2005	1834	25	754	0	0	-2613	0
2006	2135	219	1083	0	0	-3435	1
Average	2145	268	1439	0	0	-3851	0

Table 4-10 HSPF Simulated Water Balance for Lower Stevenson Creek (Reach 4)

Calendar Year	Annual Water Balance (acre-ft per year)						
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Evaporation	Reach Outflow	Change in volume
1999	496	58	262	0	0	-816	0
2000	384	28	129	0	0	-540	0
2001	644	103	298	0	0	-1044	1
2002	813	146	316	0	0	-1268	6
2003	836	235	710	0	0	-1785	-4
2004	1033	385	547	0	0	-1965	1
2005	564	31	183	0	0	-777	0
2006	684	126	241	0	0	-1050	1
Average	682	139	336	0	0	-1156	1

4.3.3 Water Quality - Upper Stevenson Creek

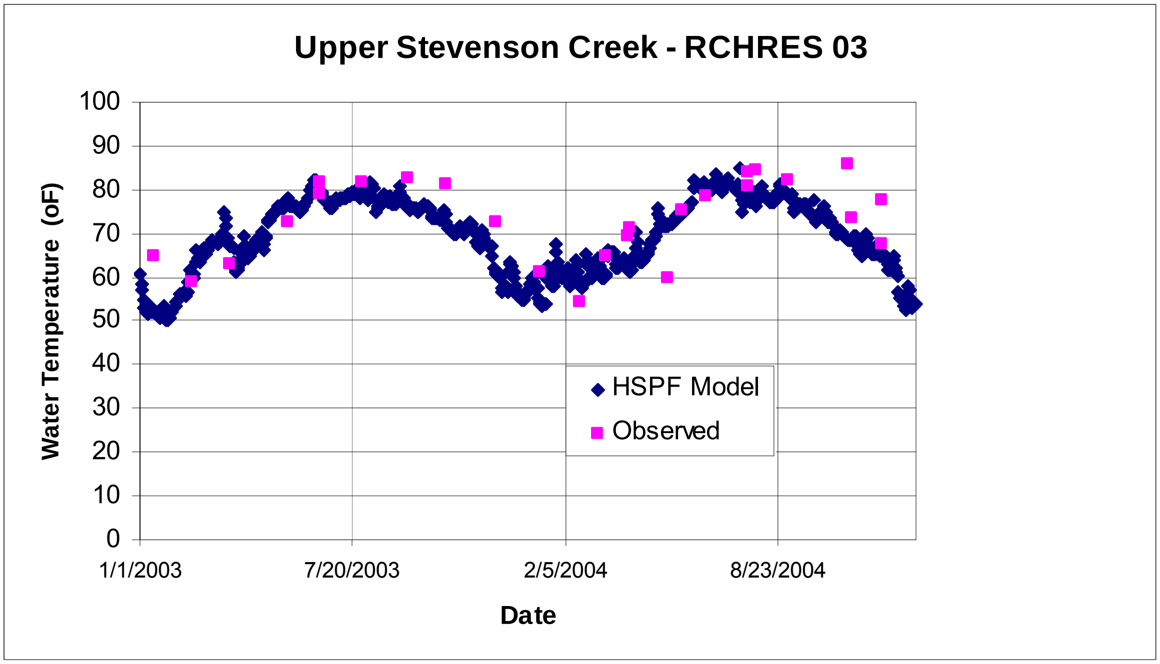
Figures 4-8 through **4-17** compare various measured and modeled water quality constituent concentrations in Upper Stevenson Creek for the selected calibration and validation periods. Although there was a very limited water quality data set available for calibration, the time-series data generally show that the modeled concentrations are representative of the range of measured values during the calibration and validation periods. In addition, accumulation/washoff coefficients in the model were adjusted so that model-simulated annual loading rates were consistent with estimated watershed loading rates. These estimated watershed loading rates were calculated using EMCs and related assertions documented in Section 4.2.2.14.

Estimated annual loading rates are presented in **Table 4-11**. The calibrated watershed loading rates for Upper Stevenson Creek are presented in **Table 4-12**. The majority of the modeled annual average loadings rates are within the range of the estimated loading rates in Table 4-11, with the only exceptions being underestimation of TKN for low density residential, upland forest/cropland, and open land/recreational land uses. However, it should be noted that the Stevenson Creek watershed is more than 90% built-out, and that these three land use categories collectively constitute only 9.0 percent of the total Stevenson Creek watershed area (refer to Table 2-1 for land use distributions in the watershed as derived from the 2004 FLUCCS data). Lastly, in order to correctly compare observed BOD_5 concentrations to HSPF simulated $CBOD_u$ concentrations, BOD_5 was converted to $CBOD_u$ using a conversion factor of 2.47 $CBOD_u$ / BOD_5 . Specific comments on the water quality calibration results are presented below:

- **Chlorophyll a.** In addition to ensuring representative modeled concentrations, the chlorophyll a calibration also focused on matching average concentrations. The graphs show that the model generally matches the observed average chlorophyll a concentrations; however the range of values is not as well simulated. The model simulates large increases in chlorophyll a concentrations between May and August each year, while in-between periods tend to be lower than observed levels. As obtaining an adequate fit between average observed and modeled concentrations was part of the calibration criteria, this over/under estimation could not be significantly improved. However, further HSPF model parameter manipulation should be explored in the future to ascertain that all possible model mechanisms that affect chlorophyll-a levels have been investigated.
- **Dissolved Oxygen.** The calibration focused on adjusting re-aeration and sediment oxygen demand (SOD) to match observed DO values. Modeled concentrations in Upper Stevenson Creek exhibit infrequent anoxic conditions and underestimates observed concentrations to some degree and do not fully simulate observed conditions. The results indicate that DO concentrations in the winter are generally low while summer concentrations are high. This unexpected result should be further explored by examining other model parameters that may be controlling dissolved oxygen levels.
- **Nitrite-plus-Nitrate.** Analysis of the modeling results suggests that the modeled Nitrite-plus-Nitrate values tend to be higher than the measured values. These errors may be a result of the very limited data available to calibrate the model. In addition, the estimated watershed loading used to adjust build-up/wash-off coefficients may not account for a specific watershed process.

For the other constituents, the time series of modeled data appears to match well with the measured data, and no additional refinement is recommended at this time.

The HSPF simulated Total P, Total N, and $CBOD_u$ load budgets for the Upper Stevenson Creek reach are presented in **Table 4-13**, **Table 4-14**, and **Table 4-15**, respectively.



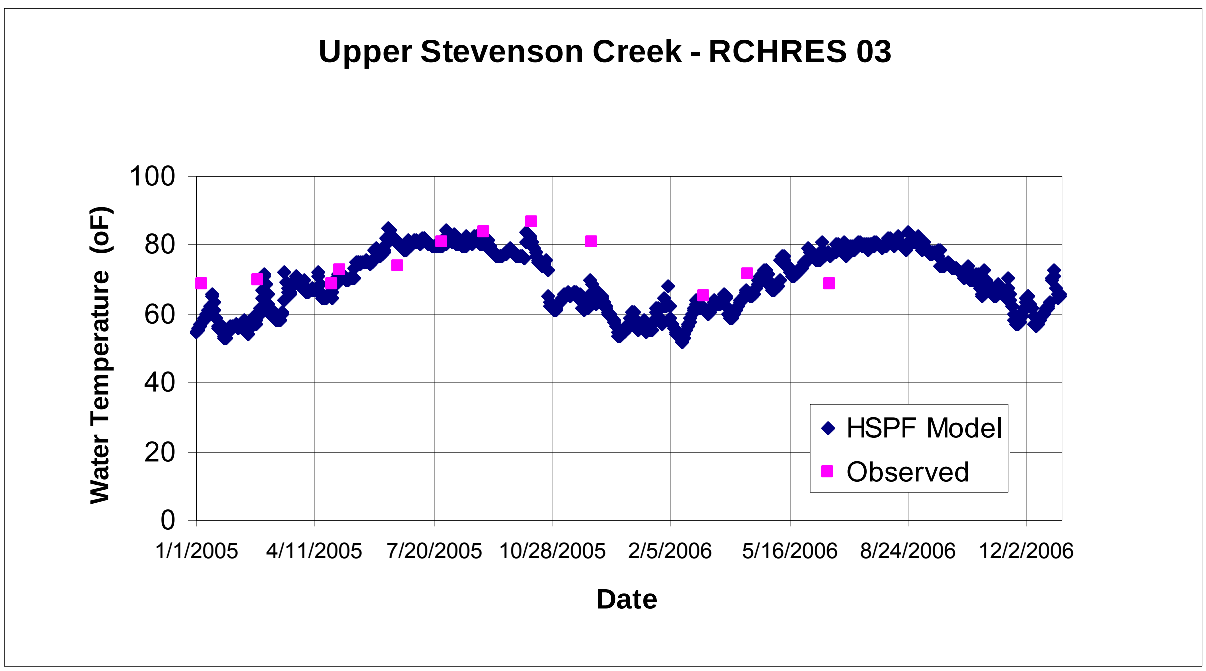
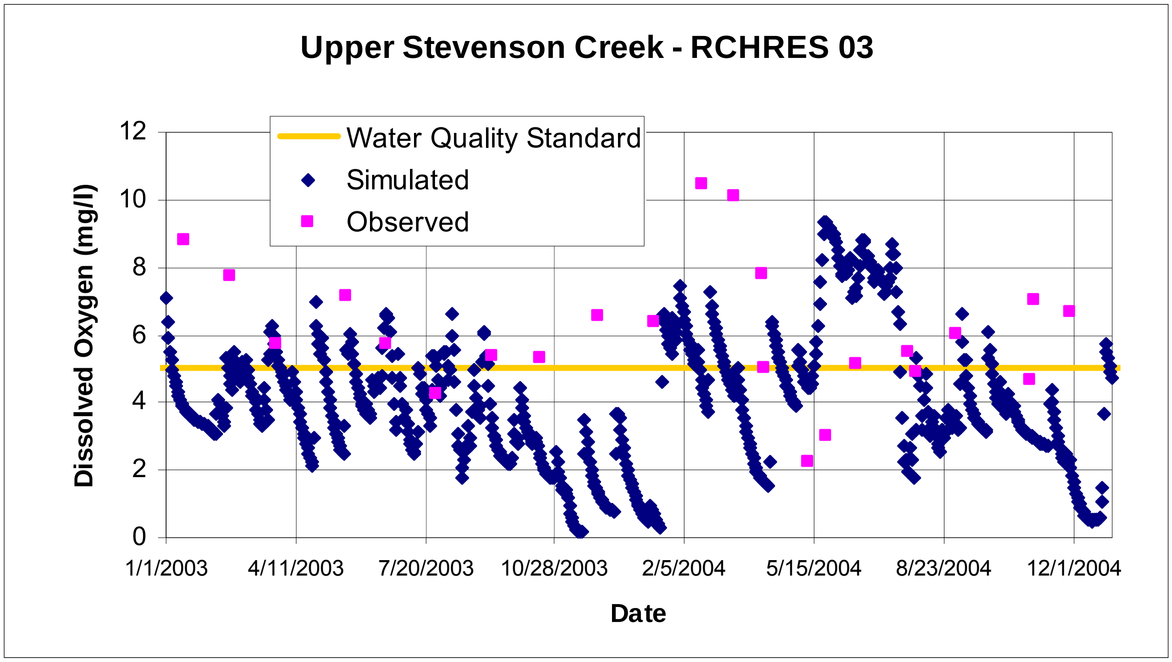


Figure 4-8 Measured and HSPF Modeled Water Temperature in Upper Stevenson Creek



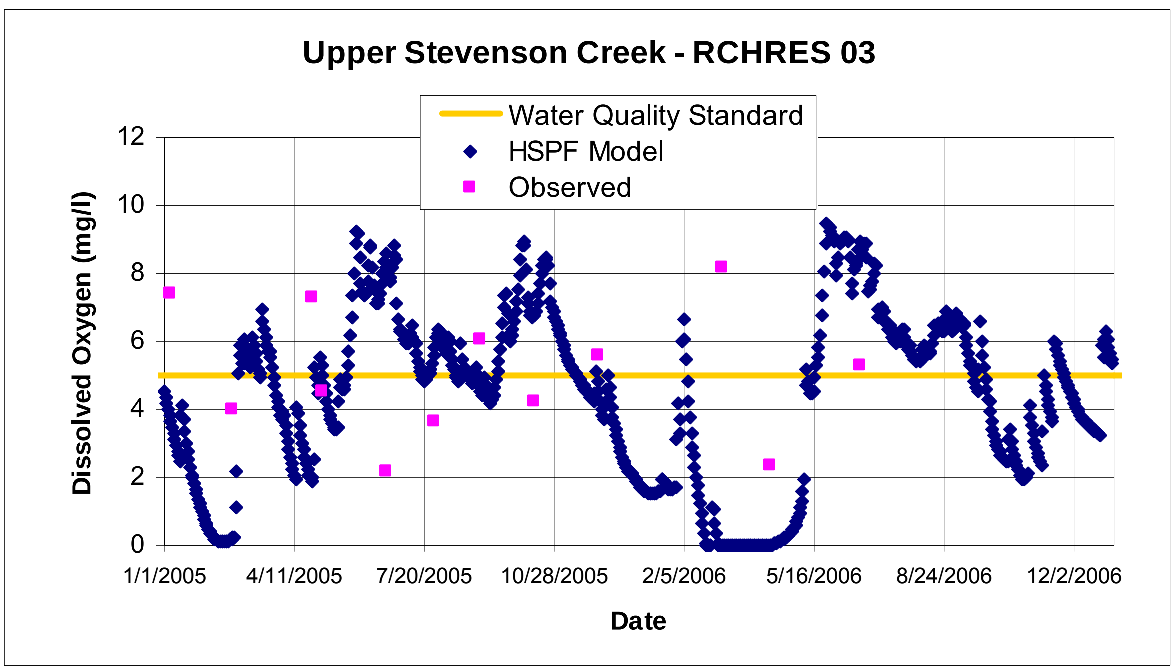
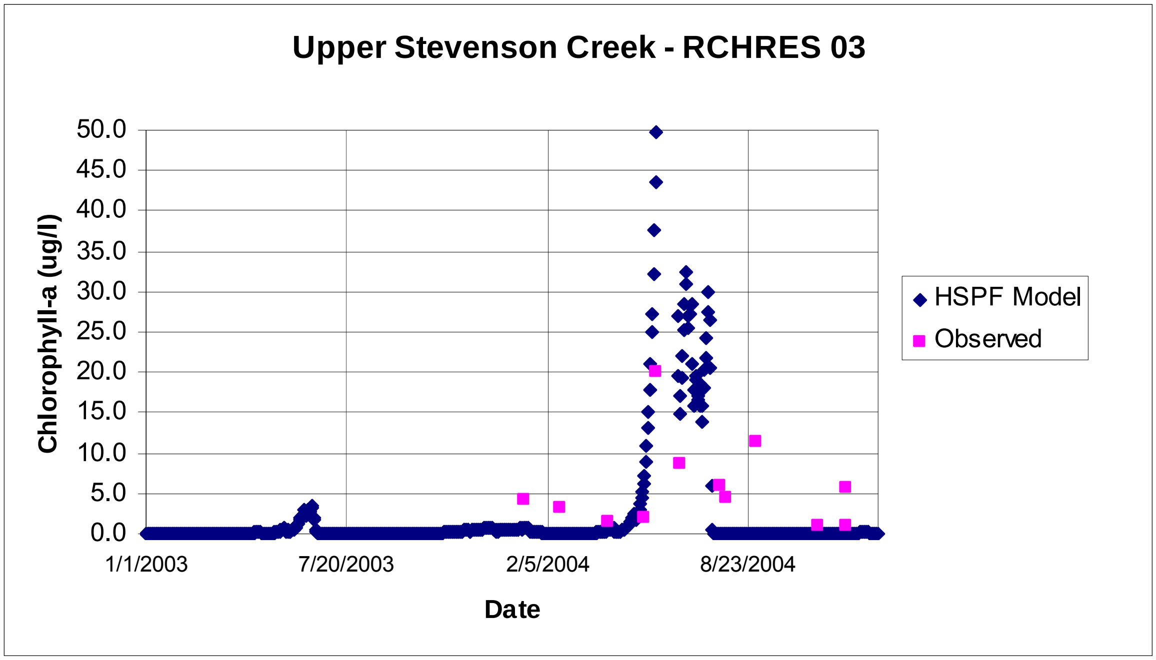


Figure 4-9 Measured and HSPF Modeled Dissolved Oxygen in Upper Stevenson Creek



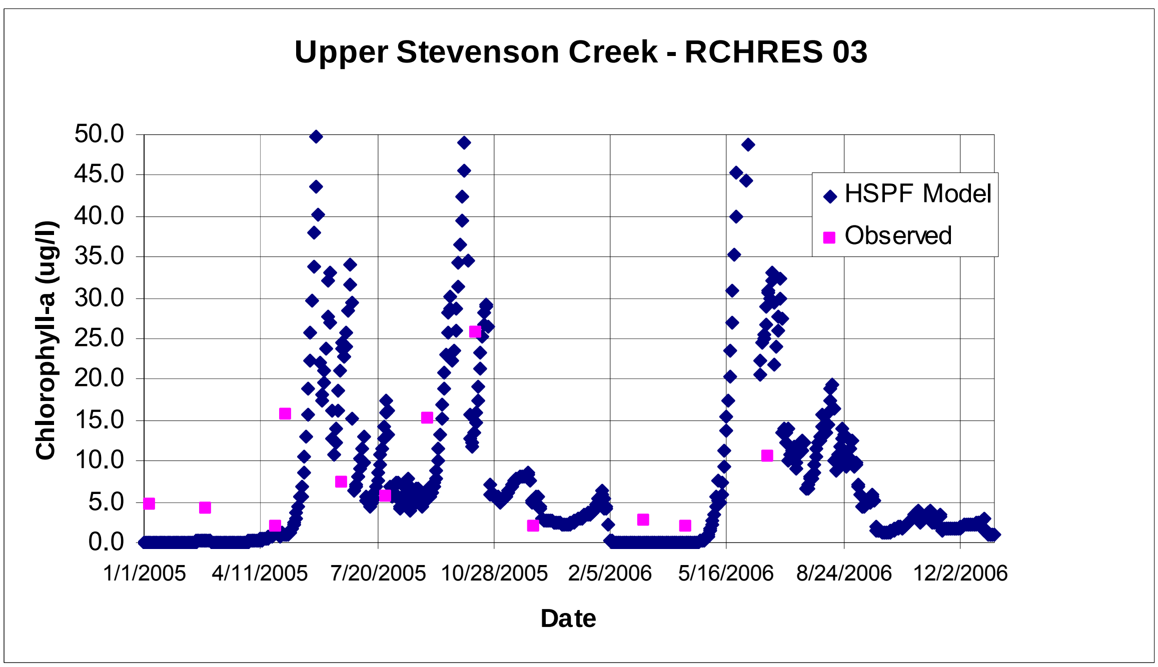
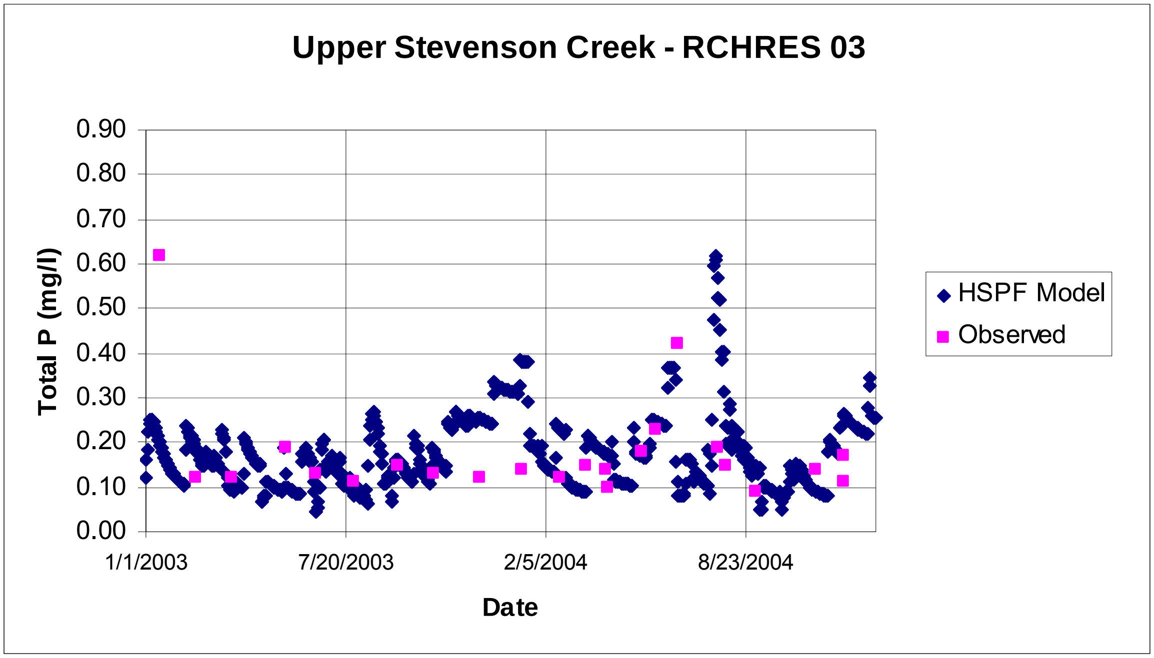


Figure 4-10 Measured and HSPF Modeled Chlorophyll-a in Upper Stevenson Creek



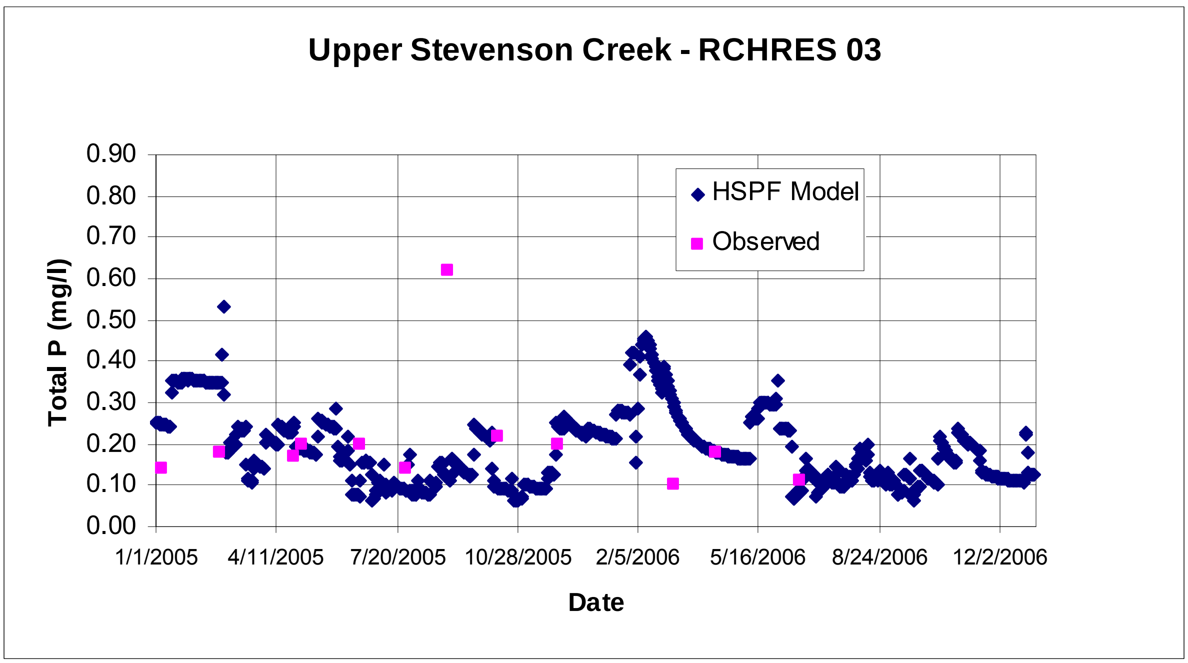
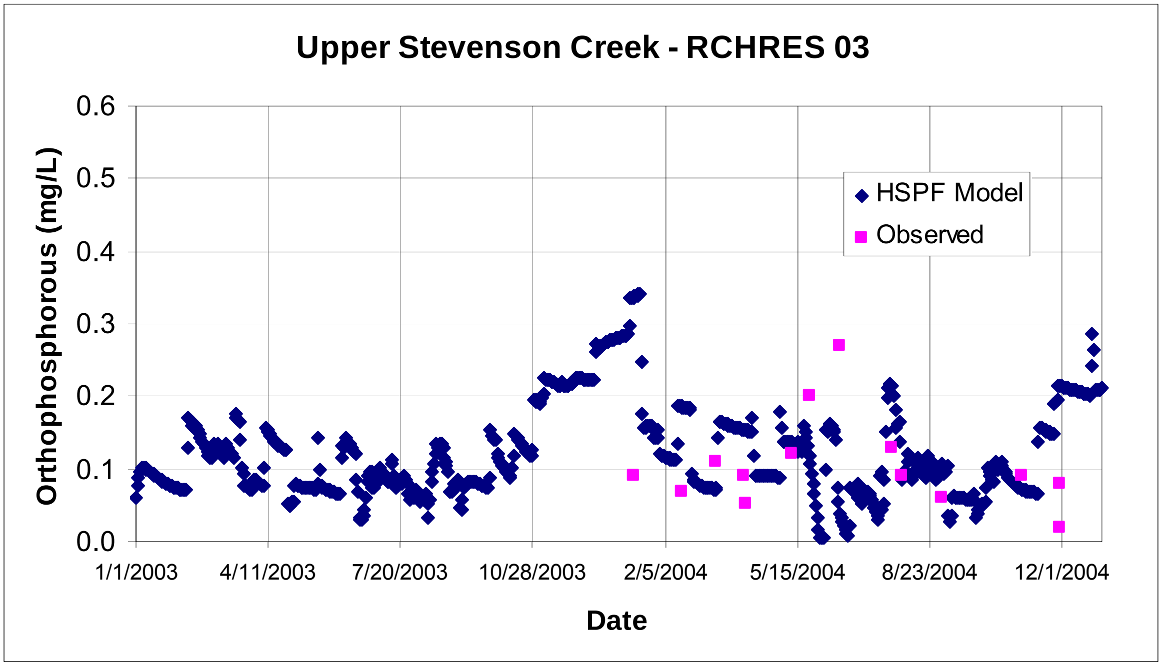


Figure 4-11 Measured and HSPF Modeled Total P in Upper Stevenson Creek



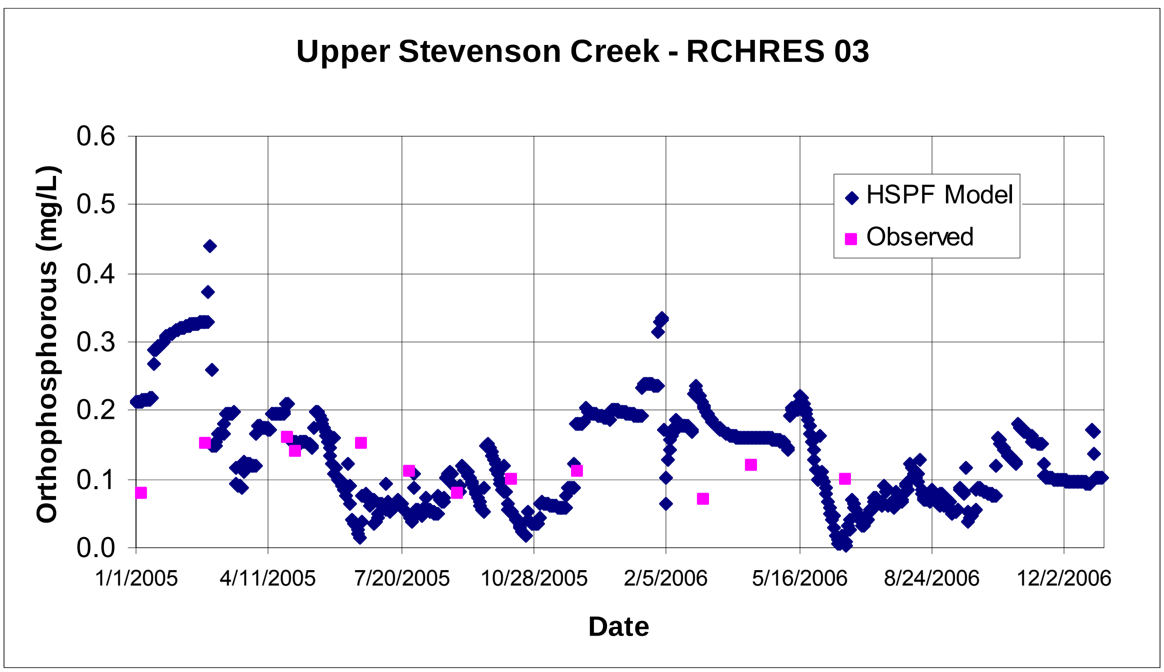
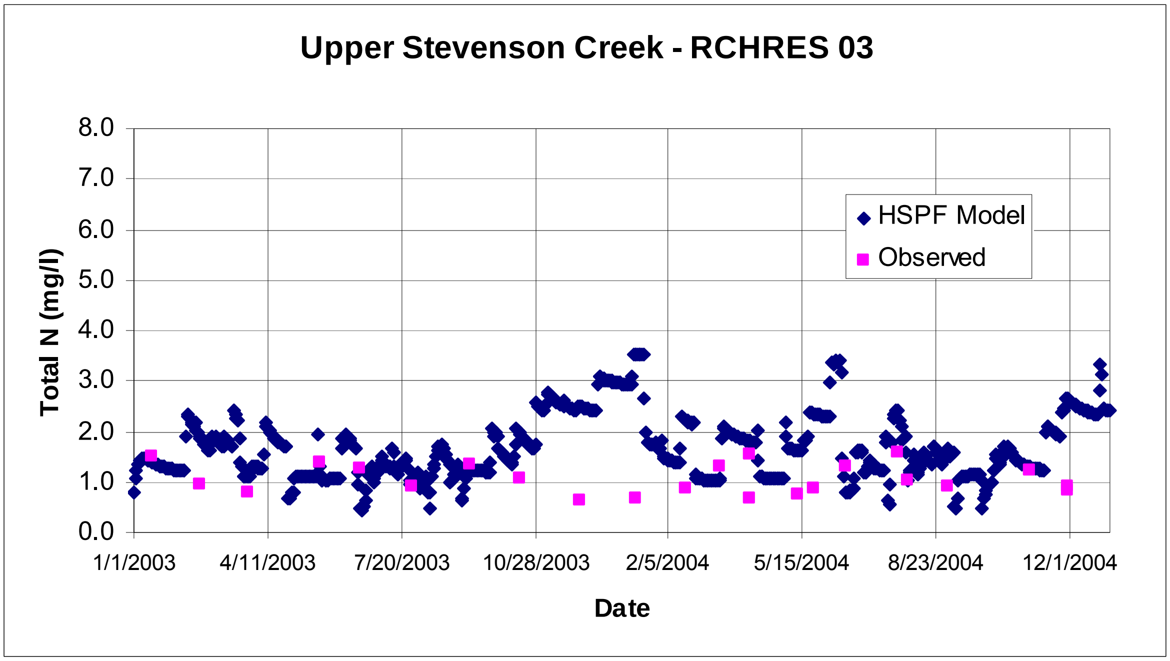


Figure 4-12 Measured and HSPF Modeled Orthophosphorus in Upper Stevenson Creek



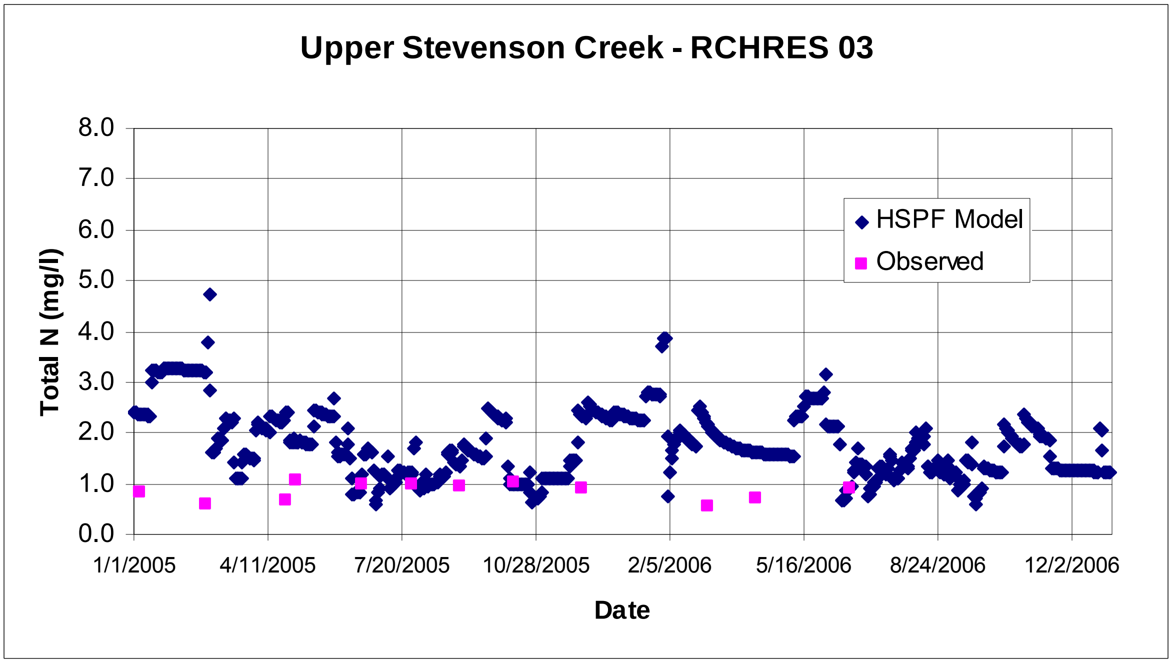
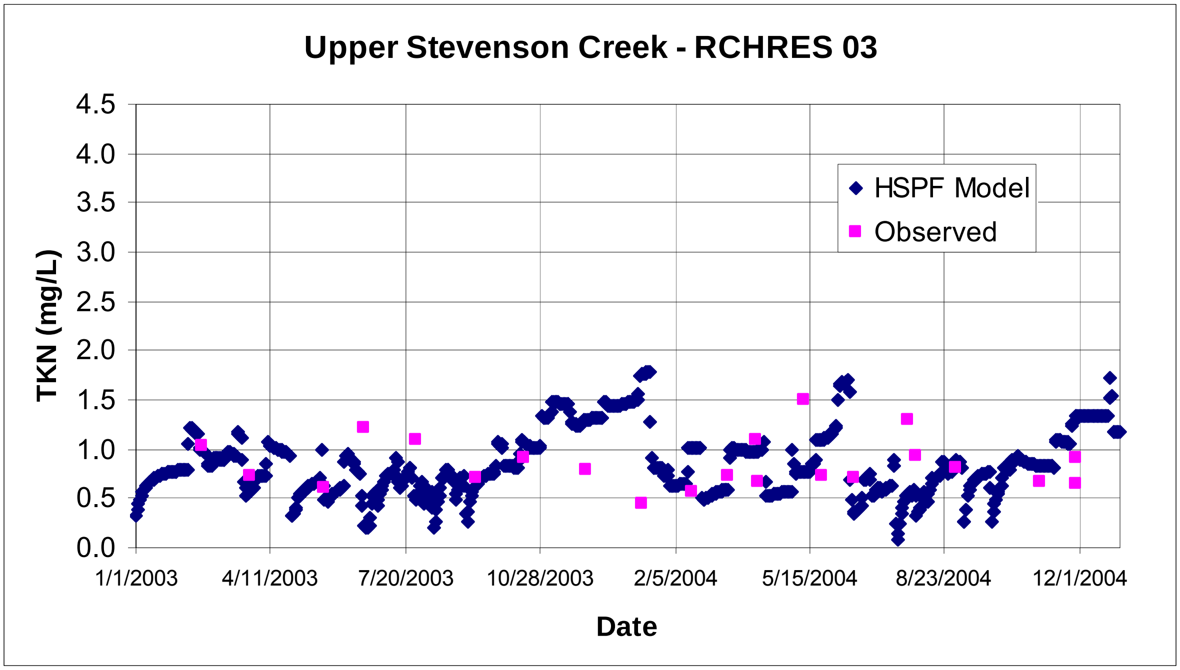


Figure 4-13 Measured and HSPF Modeled Total N in Upper Stevenson Creek



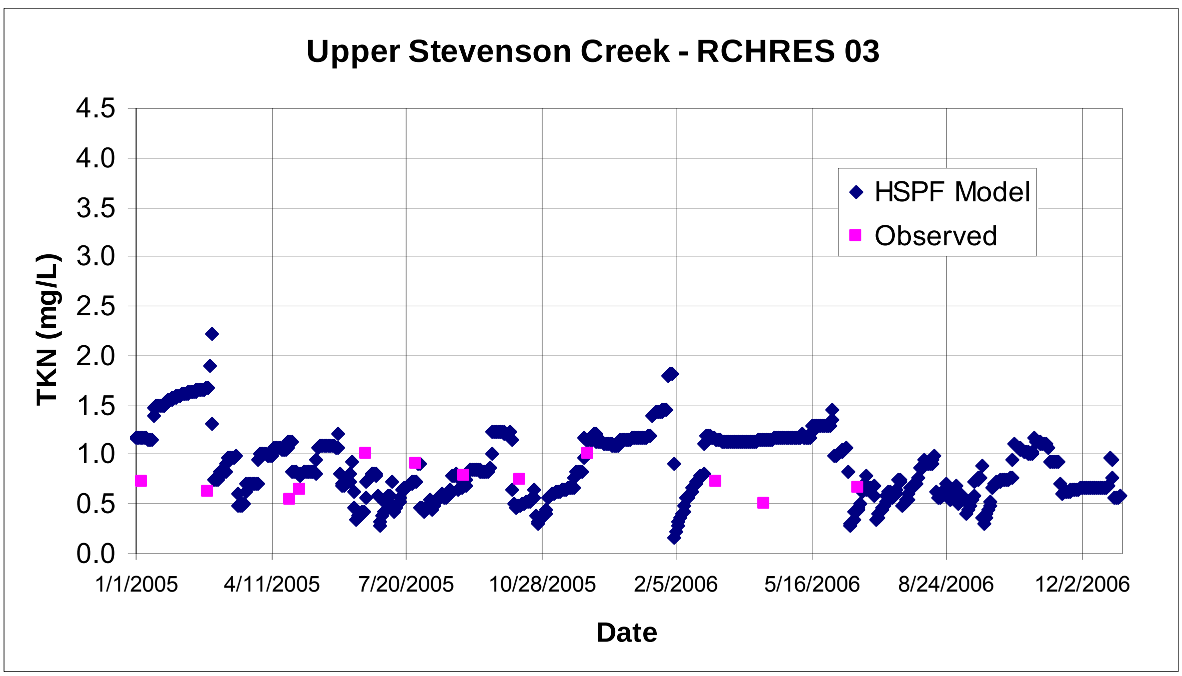
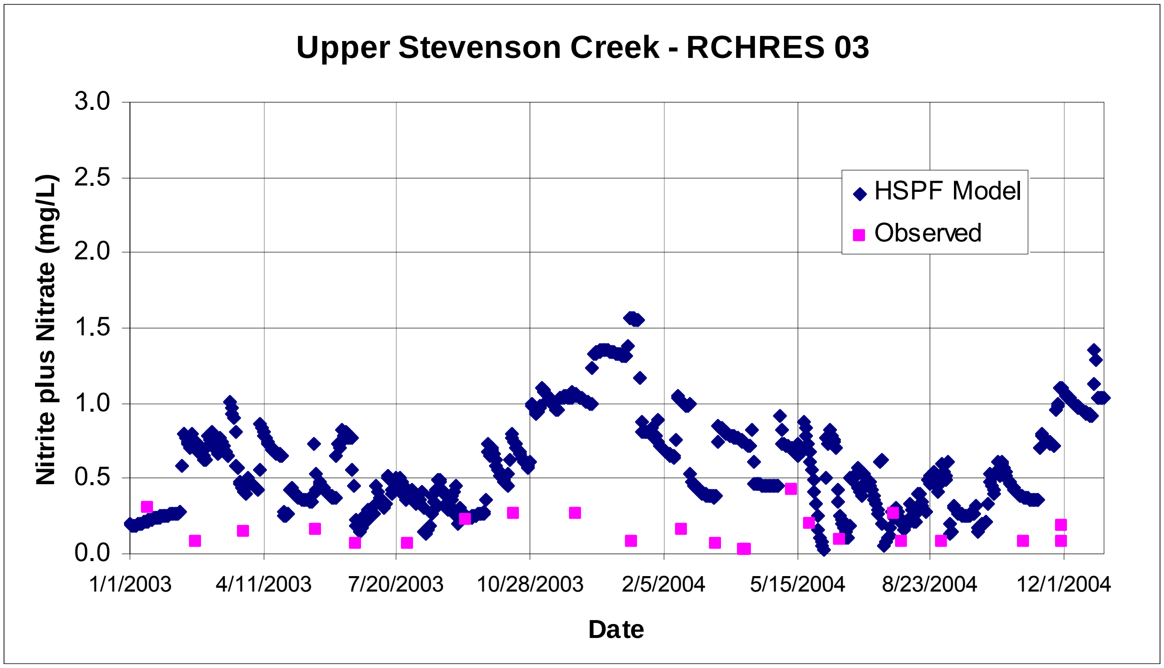


Figure 4-14 Measured and HSPF Modeled TKN in Upper Stevenson Creek



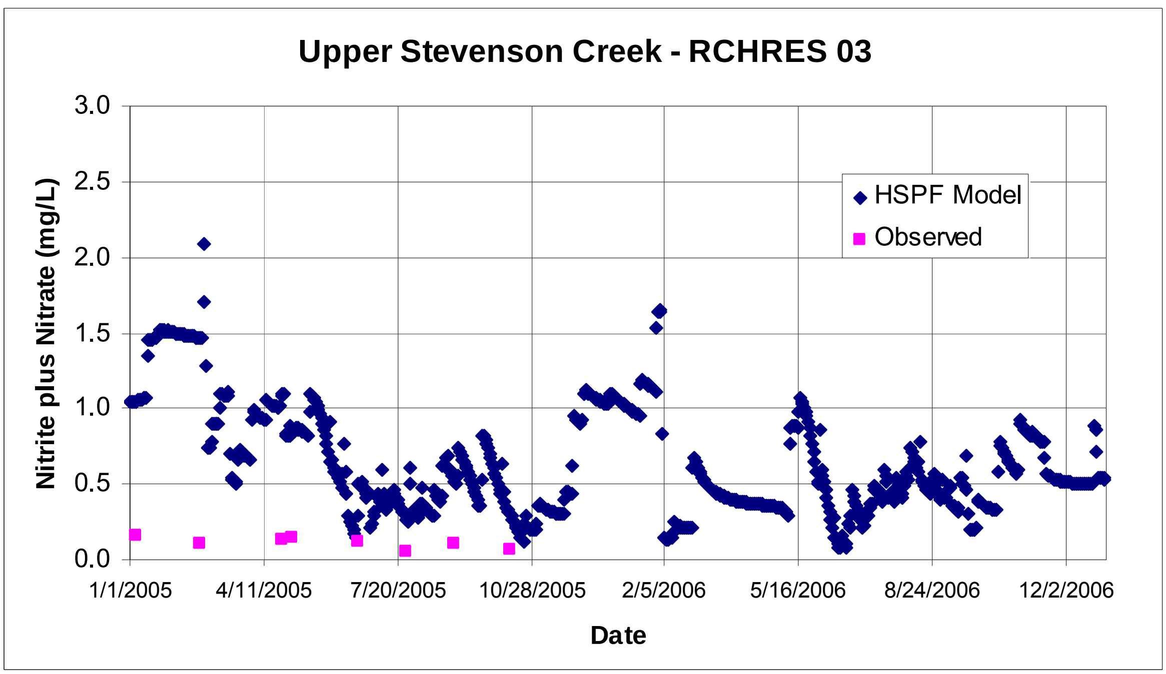
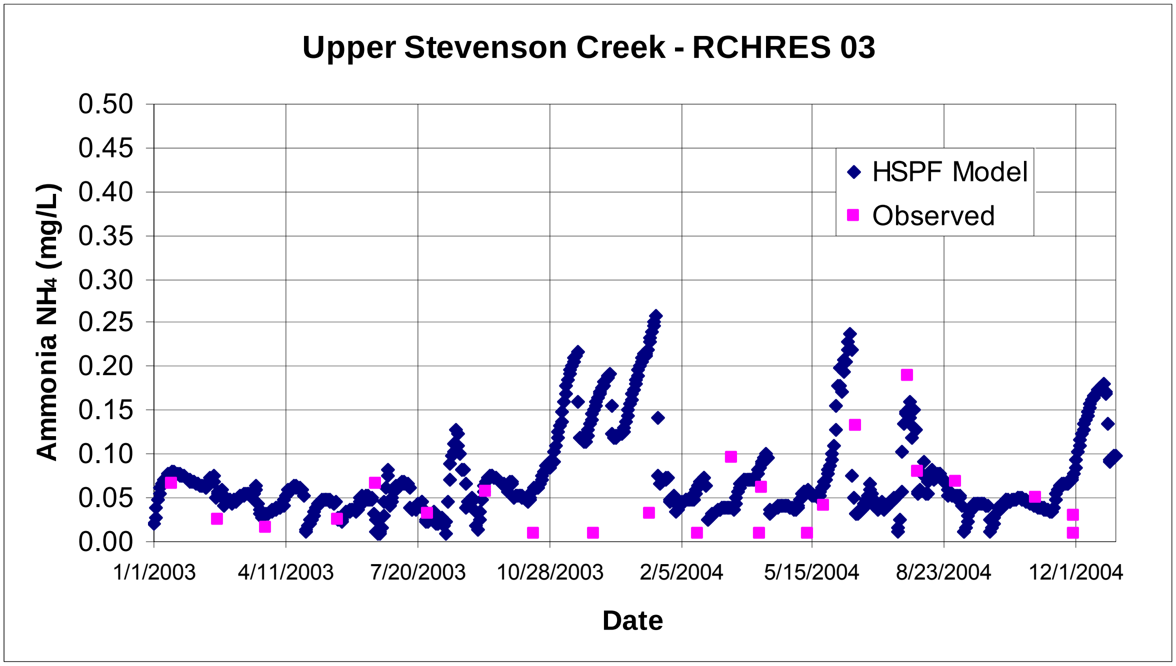


Figure 4-15 Measured and HSPF Modeled Nitrite-plus-Nitrate in Upper Stevenson Creek



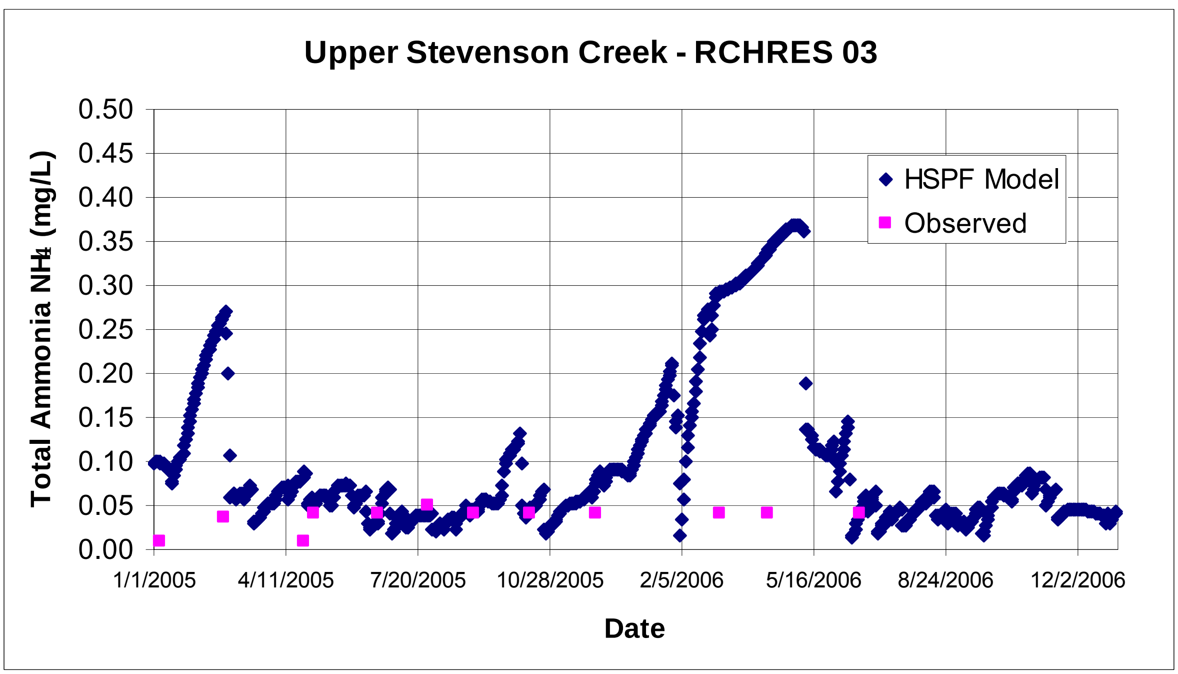
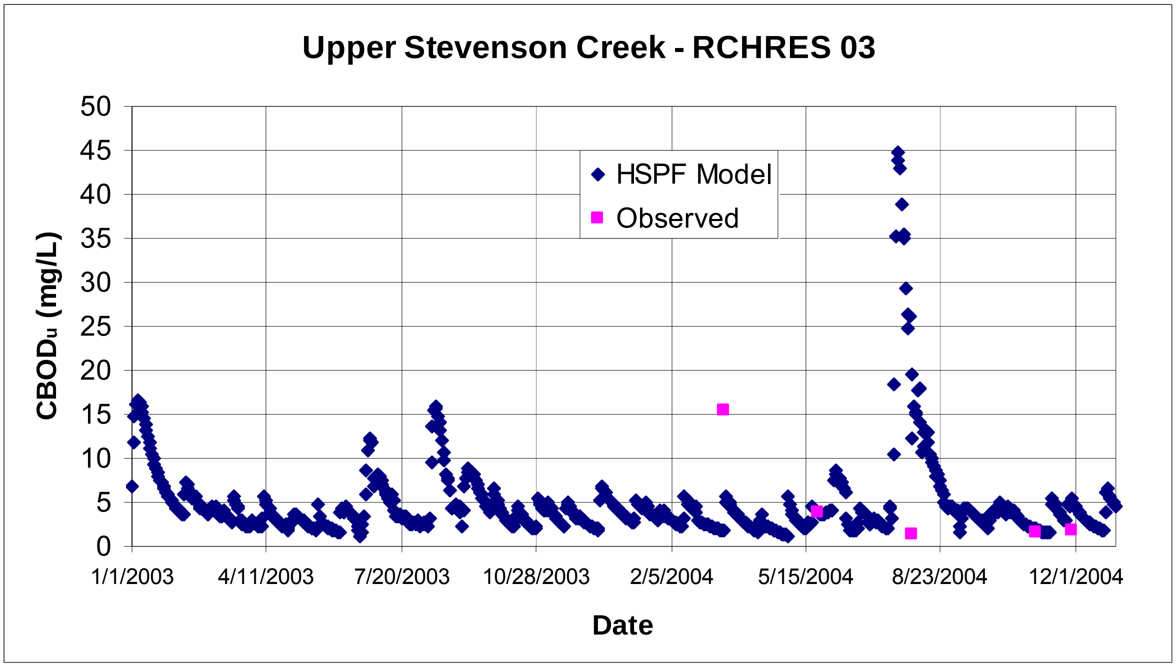


Figure 4-16 Measured and HSPF Modeled Ammonia (NH_4) in Upper Stevenson Creek



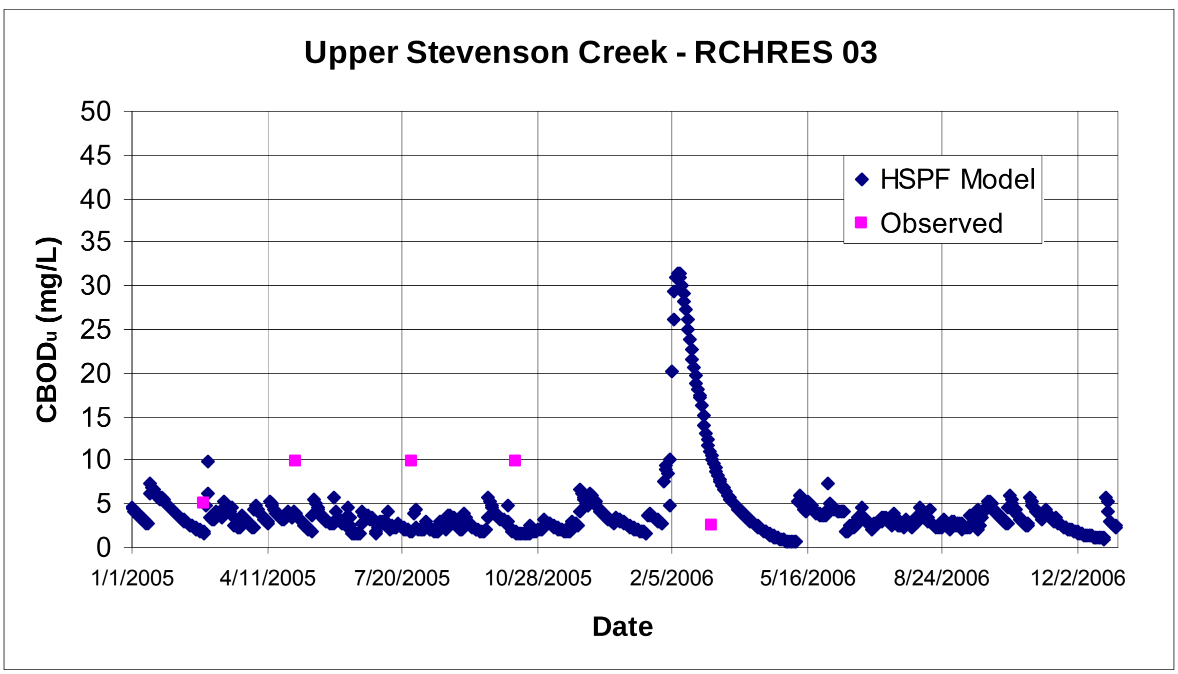


Figure 4-17 Measured and HSPF Modeled $CBOD_u$ in Upper Stevenson Creek

Table 4-11 Range of Estimated Watershed Loading Rates for Upper Stevenson Creek

Year	Commercial / Industrial	High Density Residential / Institutional	Medium Density Residential	Low Density Residential	Transportation / Utilities	Upland Forest / Cropland	Open Land/ Recreational	Wetlands
Phosphorus (lbs/ac/year)								
2000	0.34 to 0.62	0.23 to 0.53	0.25 to 0.44	0.09 to 0.15	0.34 to 0.62	0.03 to 0.05	0.03 to 0.05	0.03 to 0.05
2001	0.51 to 0.93	0.35 to 0.80	0.37 to 0.66	0.13 to 0.23	0.51 to 0.93	0.05 to 0.07	0.05 to 0.07	0.05 to 0.07
2002	0.63 to 1.17	0.43 to 0.99	0.47 to 0.82	0.16 to 0.29	0.63 to 1.17	0.06 to 0.09	0.06 to 0.09	0.06 to 0.09
2003	0.35 to 0.65	0.24 to 0.55	0.26 to 0.46	0.09 to 0.16	0.35 to 0.65	0.04 to 0.05	0.04 to 0.05	0.04 to 0.05
2004	0.73 to 1.34	0.50 to 1.14	0.54 to 0.95	0.19 to 0.33	0.73 to 1.34	0.07 to 0.10	0.07 to 0.10	0.07 to 0.10
2005	0.50 to 0.91	0.34 to 0.78	0.37 to 0.64	0.13 to 0.22	0.50 to 0.91	0.05 to 0.07	0.05 to 0.07	0.05 to 0.07
2006	0.52 to 0.97	0.36 to 0.82	0.39 to 0.68	0.14 to 0.24	0.52 to 0.97	0.05 to 0.07	0.05 to 0.07	0.05 to 0.07
Average	**0.51 to 0.94**	**0.35 to 0.80**	**0.38 to 0.66**	**0.13 to 0.23**	**0.51 to 0.94**	**0.05 to 0.07**	**0.05 to 0.07**	**0.05 to 0.07**
NO2+NO3 (lbs/ac/year)								
2000	3.07 to 7.39	0.42 to 0.88	0.97 to 1.84	0.34 to 0.64	3.07 to 7.39	0.01 to 0.06	0.01 to 0.06	0.01 to 0.06
2001	4.61 to 11.12	0.63 to 1.32	1.45 to 2.76	0.51 to 0.96	4.61 to 11.12	0.01 to 0.09	0.01 to 0.09	0.01 to 0.09
2002	5.76 to 13.90	0.78 to 1.65	1.82 to 3.45	0.63 to 1.19	5.76 to 13.90	0.01 to 0.11	0.01 to 0.11	0.01 to 0.11
2003	3.19 to 7.69	0.43 to 0.92	1.01 to 1.91	0.35 to 0.66	3.19 to 7.69	0.01 to 0.07	0.01 to 0.07	0.01 to 0.07
2004	6.63 to 16.00	0.90 to 1.90	2.09 to 3.97	0.73 to 1.37	6.63 to 16.00	0.01 to 0.13	0.01 to 0.13	0.01 to 0.13
2005	4.50 to 10.85	0.61 to 1.29	1.42 to 2.69	0.49 to 0.93	4.50 to 10.85	0.01 to 0.09	0.01 to 0.09	0.01 to 0.09
2006	4.76 to 11.49	0.65 to 1.37	1.50 to 2.85	0.52 to 0.99	4.76 to 11.49	0.01 to 0.10	0.01 to 0.10	0.01 to 0.10
$CBOD_u$ (lbs/ac/year)								
2000	38.94 to 57.54	31.60 to 61.29	18.58 to 27.41	6.45 to 9.50	38.94 to 57.54	4.53 to 21.12	4.53 to 21.12	4.53 to 21.12
2001	58.56 to 86.54	47.51 to 92.19	27.92 to 41.21	9.68 to 14.27	58.56 to 86.54	6.79 to 31.75	6.79 to 31.75	6.79 to 31.75
2002	73.15 to 108.11	59.35 to 115.17	34.88 to 51.47	12.08 to 17.81	73.15 to 108.11	8.46 to 39.65	8.46 to 39.65	8.46 to 39.65
2003	40.49 to 59.82	32.85 to 63.73	19.31 to 28.49	6.71 to 9.88	40.49 to 59.82	4.71 to 21.96	4.71 to 21.96	4.71 to 21.96
2004	84.23 to 124.48	68.33 to 132.61	40.15 to 59.26	13.90 to 20.51	84.23 to 124.48	9.74 to 45.65	9.74 to 45.65	9.74 to 45.65
2005	57.11 to 84.40	46.33 to 89.90	27.23 to 40.19	9.44 to 13.92	57.11 to 84.40	6.62 to 30.96	6.62 to 30.96	6.62 to 30.96
2006	60.51 to 89.42	49.09 to 95.26	28.85 to 42.58	10.00 to 14.74	60.51 to 89.42	7.01 to 32.80	7.01 to 32.80	7.01 to 32.80
Average	**59.00 to 87.19**	**47.87 to 92.88**	**28.13 to 41.51**	**9.75 to 14.38**	**59.00 to 87.19**	**6.84 to 31.98**	**6.84 to 31.98**	**6.84 to 31.98**
TKN (lbs/ac/year)								
2000	2.72 to 4.38	1.91 to 3.24	1.41 to 2.17	0.49 to 0.75	2.72 to 4.38	0.12 to 0.23	0.12 to 0.23	0.12 to 0.23
2001	4.10 to 6.58	2.87 to 4.88	2.12 to 3.27	0.73 to 1.13	4.10 to 6.58	0.17 to 0.35	0.17 to 0.35	0.17 to 0.35
2002	5.12 to 8.22	3.58 to 6.09	2.64 to 4.08	0.92 to 1.41	5.12 to 8.22	0.21 to 0.43	0.21 to 0.43	0.21 to 0.43
2003	2.83 to 4.55	1.98 to 3.37	1.46 to 2.26	0.51 to 0.78	2.83 to 4.55	0.12 to 0.24	0.12 to 0.24	0.12 to 0.24
2004	5.89 to 9.47	4.13 to 7.01	3.04 to 4.70	1.05 to 1.63	5.89 to 9.47	0.25 to 0.50	0.25 to 0.50	0.25 to 0.50
2005	3.99 to 6.42	2.80 to 4.76	2.06 to 3.19	0.72 to 1.10	3.99 to 6.42	0.17 to 0.34	0.17 to 0.34	0.17 to 0.34
2006	4.23 to 6.80	2.96 to 5.04	2.19 to 3.38	0.76 to 1.17	4.23 to 6.80	0.18 to 0.36	0.18 to 0.36	0.18 to 0.36
Average	**4.13 to 6.63**	**2.89 to 4.91**	**2.13 to 3.29**	**0.74 to 1.14**	**4.13 to 6.63**	**0.17 to 0.35**	**0.17 to 0.35**	**0.17 to 0.35**

Table 4-12 Simulated Watershed Annual Loading Rates for Upper Stevenson Creek

Year	Commercial/Industrial	High Density Residential	Medium Density Residential	Low Density Residential	Transportation/ Utilities	Upland Forest/Cropland	Open Land/ Recreational	Wetlands	Total
Orthophosphorus (lb/acre/year)									
2000	0.59	0.44	0.36	0.16	0.52	0.05	0.04	0.04	2.2
2001	0.48	0.34	0.28	0.1	0.42	0.02	0.02	0.01	1.67
2002	0.6	0.52	0.39	0.18	0.51	0.05	0.05	0.05	2.35
2003	0.77	0.69	0.5	0.21	0.64	0.06	0.06	0.07	3
2004	0.8	0.87	0.61	0.34	0.65	0.11	0.09	0.15	3.62
2005	0.95	1.41	0.78	0.35	0.66	0.1	0.08	0.13	4.46
2006	0.64	0.45	0.37	0.14	0.57	0.03	0.03	0.02	2.25
Average	**0.63**	**0.59**	**0.41**	**0.17**	**0.53**	**0.05**	**0.04**	**0.04**	**2.46**
Nitrite-plus-Nitrate (lb/acre/year)									
2000	5.78	0.63	1.69	0.71	10.1	0.05	0.01	0.01	18.98
2001	4.36	0.46	1.27	0.43	8.27	0.02	0.01	0	14.82
2002	5.51	0.68	1.72	0.79	9.83	0.05	0.01	0.02	18.61
2003	7.11	0.73	2.08	0.87	12.4	0.05	0.01	0.02	23.27
2004	7.46	1.18	2.6	1.61	12.1	0.11	0.03	0.05	25.14
2005	6.95	1.06	2.41	1.38	11.9	0.09	0.02	0.04	23.85
2006	6.13	0.54	1.71	0.58	11.1	0.03	0.01	0.01	20.11
Average	**5.67**	**0.65**	**1.69**	**0.72**	**10.1**	**0.04**	**0.01**	**0.02**	**18.9**
$CBOD_u$ (lb/acre/year)									
2000	68.1	32.9	8.63	6.43	68.3	8.27	10.6	6.66	209.89
2001	55.4	24.7	3.97	3.1	55.5	3.65	6.3	2.04	154.66
2002	68.9	39.9	18.3	8.92	69.7	14	13.1	10.8	243.62
2003	88.2	53.1	26.4	10.5	89.1	16.9	18.4	13.8	316.4
2004	90.1	68.6	47.8	21.9	91.4	30.6	26.7	29.5	406.6
2005	105	117	110	30	107	50.2	26.2	29.6	575
2006	74.5	33.1	5.25	4.22	74.6	4.9	7.54	2.25	206.36
Average	**72.3**	**45.8**	**25**	**9.19**	**74.7**	**18.1**	**11.7**	**7.65**	**264.44**
TKN (lb/acre/year)									
2000	4.87	3.04	2.36	0.63	4.51	0.14	0.03	0.13	15.71
2001	3.87	2.18	1.53	0.51	3.7	0.07	0.02	0.05	11.93
2002	4.76	3.15	2.53	0.62	4.36	0.16	0.04	0.15	15.77
2003	5.94	3.73	2.9	0.78	5.53	0.16	0.04	0.16	19.24
2004	6.22	5.16	4.75	0.78	5.3	0.34	0.08	0.43	23.06
2005	5.99	4.65	4.13	0.77	5.22	0.28	0.05	0.3	21.39
2006	5.2	2.94	2.08	0.69	4.98	0.1	0.03	0.07	16.09
Average	**4.82**	**3.04**	**2.36**	**0.63**	**4.48**	**0.13**	**0.03**	**0.12**	**15.61**

Table 4-13 HSPF Simulated Total P Budget for Upper Stevenson Creek

Calendar Year	Annual TP Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	1132	79	220	0	-1343	88
2000	932	18	109	0	-1065	-4
2001	1106	309	255	0	-1695	-25
2002	1409	505	267	0	-2206	-26
2003	1350	888	597	0	-2840	-6
2004	1363	2467	490	0	-4348	-27
2005	1254	18	151	0	-1438	-15
2006	1142	486	218	0	-1866	-20
Average	1211	596	288	0	-2100	-4

Table 4-14 HSPF Simulated Total N Budget for Upper Stevenson Creek

Calendar Year	Annual TN Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	10653	252	3730	0	-13816	820
2000	8629	63	1863	0	-10638	-82
2001	10296	1000	4333	0	-15833	-205
2002	13118	1642	4538	0	-19636	-338
2003	12738	2863	10158	0	-25705	54
2004	12349	8059	8391	0	-28976	-177
2005	11710	63	2562	0	-14460	-125
2006	10586	1594	3718	0	-16106	-208
Average	11260	1942	4912	0	-18146	-33

Table 4-15 HSPF Simulated $CBOD_u$ Budget for Upper Stevenson Creek

Calendar Year	Annual $CBOD_u$ Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	35233	6159	9849	0	-32390	18851
2000	29090	1548	4905	0	-22984	12559
2001	34307	24366	11411	0	-51496	18587
2002	43523	40028	11956	0	-74449	21058
2003	41620	69765	26735	0	-109740	28380
2004	40904	196398	21979	0	-225220	34061
2005	39122	1536	6782	0	-32438	15003
2006	35237	38846	9761	0	-63432	20413
Average	37379	47331	12922	0	-76518	21114

4.3.4 Water Quality - Spring Branch

Figures 4-18 through **4-27** present the time-series data for the measured and modeled water quality constituents in Spring Branch for the established calibration and validation periods. The time-series data generally show that the modeled concentrations are representative of the range of measured values during the calibration and validation periods.

Accumulation/washoff coefficients in the model were adjusted so that constituent annual loadings were consistent with estimated watershed loadings. These estimated watershed loadings were calculated using appropriate EMCs and the related assertions documented in Section 4.2.2.14.

Model adjustments also included constituent load reduction due to the Pinellas County wetland mitigation area located on Spring Branch a short distance upstream of the Sunset Point Road/Betty Lane intersection. Estimated watershed loadings are shown in **Table 4-16.** The calibrated watershed loadings for Spring Branch are presented in **Table 4-17**. The majority of the HPSF model's simulated average annual loadings are within the range of the majority of the estimated constituent loads shown in Table 4-17. However, the model appears to overestimate orthophosphorus loads from the upland forest /cropland land use category, and underestimate orthophosphorus loads from the open land /recreational land use category, and also appears to overestimate $CBOD_u$ from the upland forest / cropland land use category. However, it should be noted that the Stevenson Creek watershed is more than 90% built-out, and that the upland forest/cropland and open land /recreational land use categories collectively constitute only .7.9% of the total Stevenson Creek watershed area (refer to Table 2-1 for land use distributions in the watershed as derived from the 2005 FLUCCS data) . In order to correctly compare observed BOD_5 concentrations to HSPF simulated $CBOD_u$ concentrations, BOD_5 was converted to $CBOD_u$ using a conversion factor of 2.47 $CBOD_u$ / BOD_5 . Specific comments on the water quality calibration results are presented below.

- **Chlorophyll a.** In addition to ensuring representative modeled concentrations, the chlorophyll a calibration also focused on matching average concentrations. The graphs show that the model generally matches the observed average chlorophyll a concentrations; however the range of values is not as well simulated. The model simulates large increases in chlorophyll a concentrations between May and August each year, while in-between periods tend to be lower than observed levels. As obtaining an adequate fit between average observed and modeled concentrations was part of the calibration criteria, this over/under estimation could not be further improved.
- **Total phosphorus, Total Nitrogen, Orthophosphorus, Ammonia, TKN, and Nitrite-plus-Nitrate.** Analysis of the modeling results suggests that the modeled values tend to have spikes in their data higher than measured values. In addition, concentrations for phosphorus, particularly orthophosphorus, and nitrogen appear to be low. These errors may be a result of the very limited data available to calibrate the model or related to the fact that the estimated watershed pollutant loading rate used to adjust build-up/wash-off coefficients may not account for a specific watershed process. In addition, further examination of the measured data is also indicated to determine which concentrations are representative of dry weather periods, which could be used to adjust baseflow concentrations of some of these parameters.

For the other constituents, the time series of modeled data appears to match well with the measured data, and no additional refinement is recommended at this time.

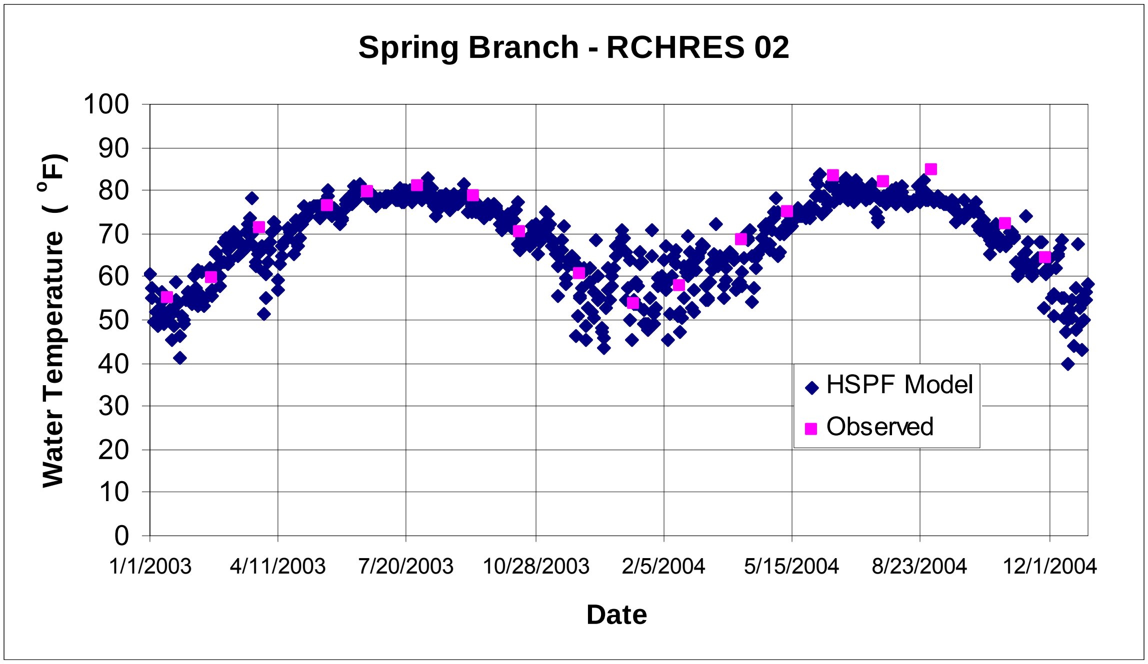
The HSPF simulated Total P, Total N, and $CBOD_u$ load budgets for the Spring Branch reach are presented in **Table 4-18**, **Table 4-19**, and Table **4-20**, respectively.

4.3.5 Water Quality – Hammond Branch

Figures 4-28 through **4-37** present the time series data for modeled constituents in Hammond Branch for the calibration and validation periods. No observed data were available for calibration, thus only the simulated water quality constituent concentrations are presented. Calibration focused on adjusting constituent loads at each subwatershed outlet to match loads estimated using representative Florida EMCs. These loads were adjusted to reflect expected increased loads from septic systems in the watershed.

In addition, accumulation/washoff coefficients in the model were adjusted so that model annual loading was consistent with estimated watershed loads. These estimated watershed loadings were calculated using EMCs and related assertions documented in Section 4.2.2.14. Estimated watershed loadings are shown in **Table 4-21**. The calibrated watershed loadings for Hammond Branch are presented in **Table 4-22**. Nearly all of the annual average loads are within the range of estimated loads, except for the orthophosphorous loads associated with the upland forest/cropland land (which are slightly overestimated), and the $CBOD_u$ loads associated with wetlands, which are slightly underestimated. It should be noted, however, that the Stevenson Creek watershed is over 90% built-out, and that the upland forest/cropland and wetlands land use categories constitute 0.8%, and 1.1% of the total Stevenson Creek watershed area, respectively ((refer to Table 2-1 for land use distributions in the watershed as derived from the 2004 FLUCCS data).

The HSPF simulated Total P, Total N, and $CBOD_u$ load budgets for the Hammond Branch reach are presented in **Table 4-23, Table 4-24, and Table 4-25,** respectively.



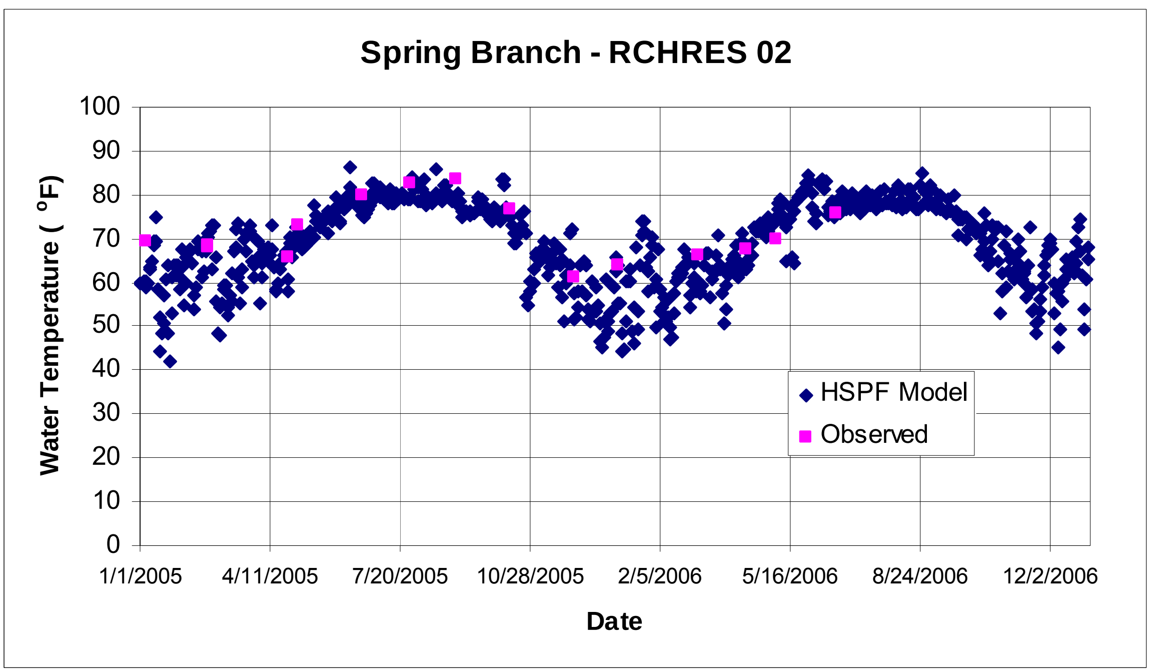
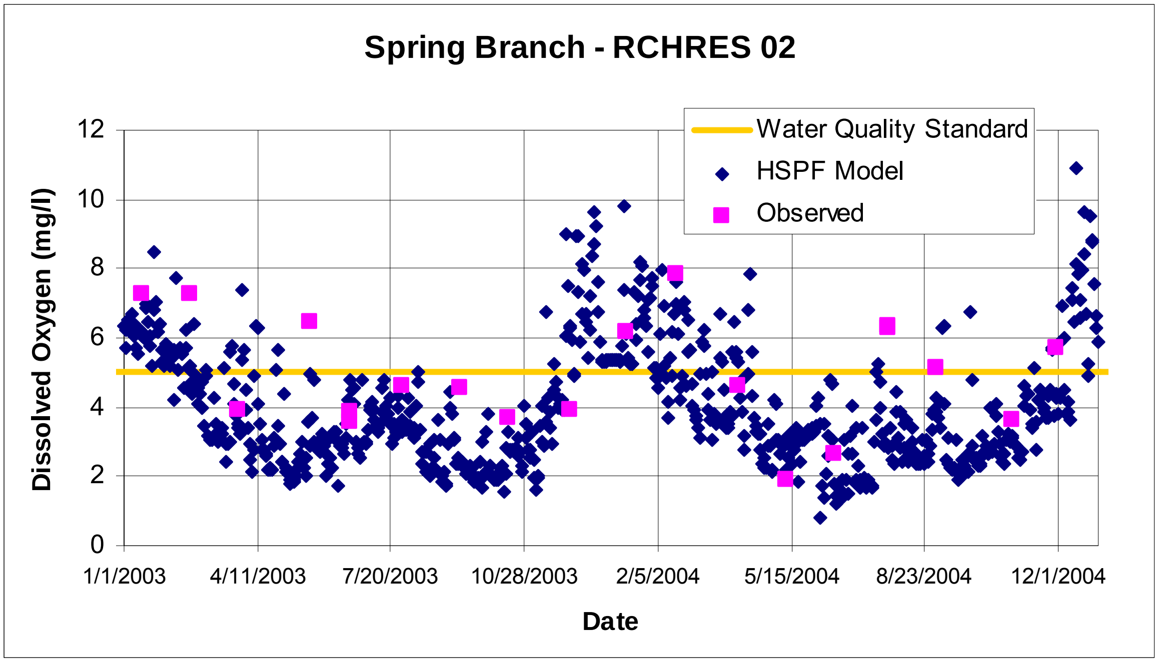


Figure 4-18 Measured and HSPF Modeled Water Temperature in Spring Branch



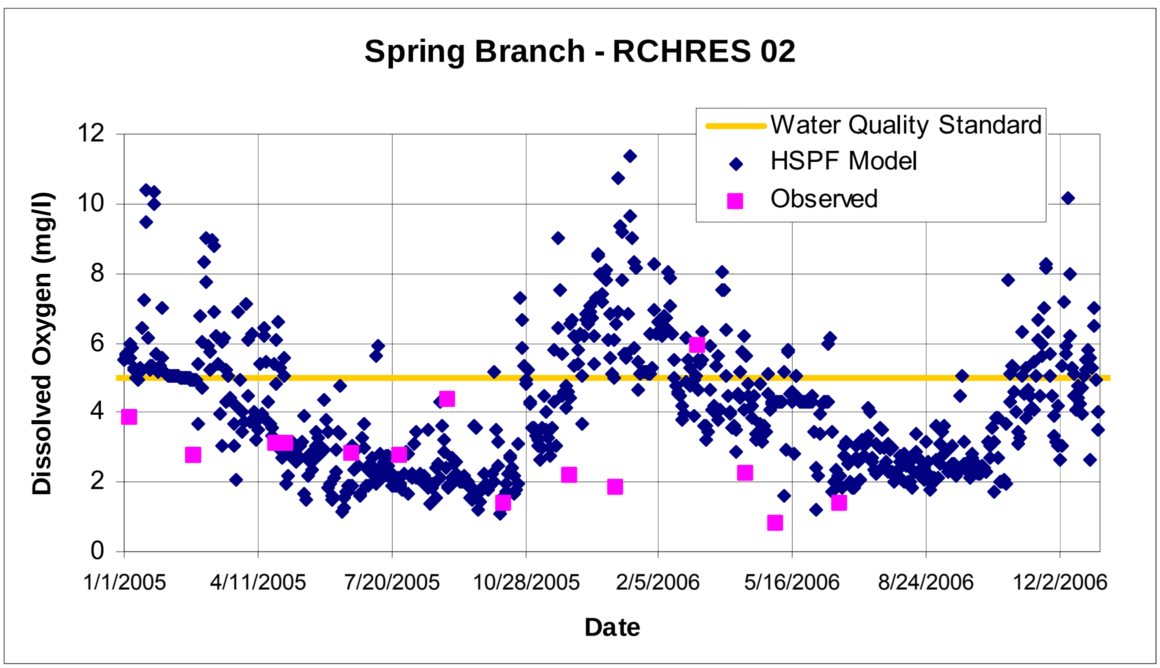
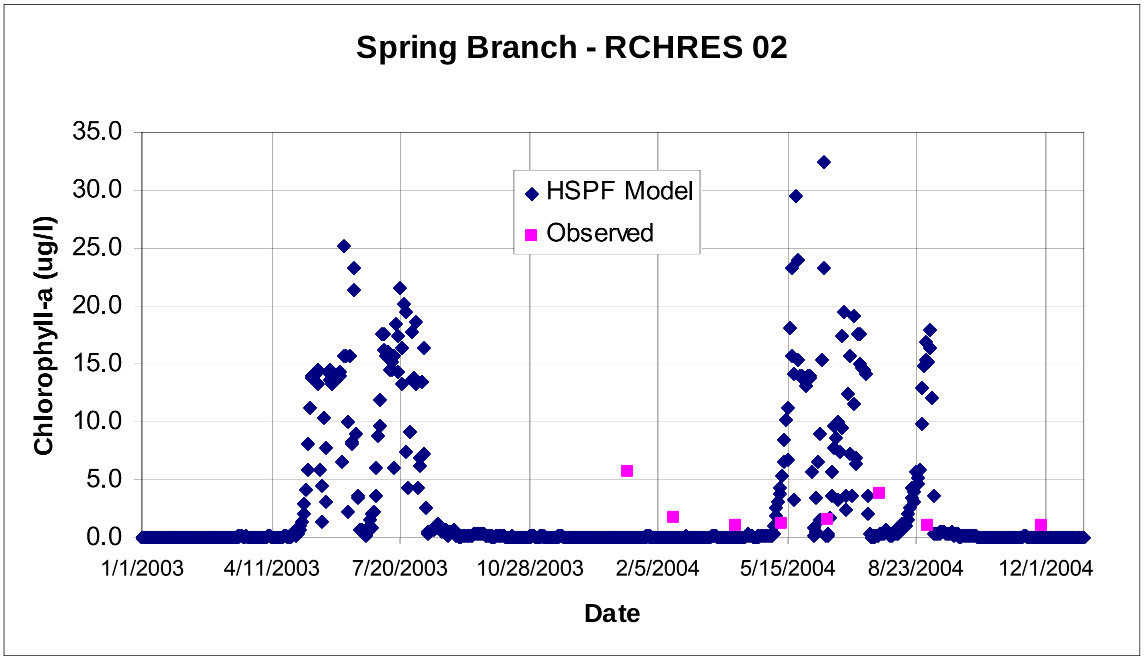


Figure 4-19 Measured and HSPF Modeled Dissolved Oxygen in Spring Branch



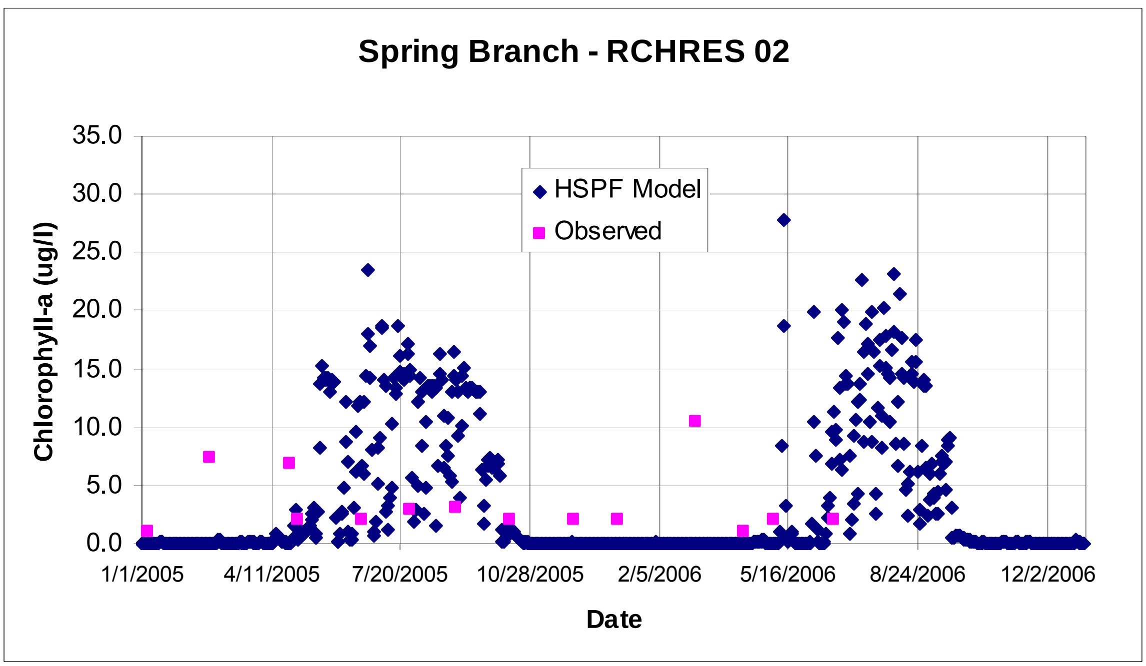
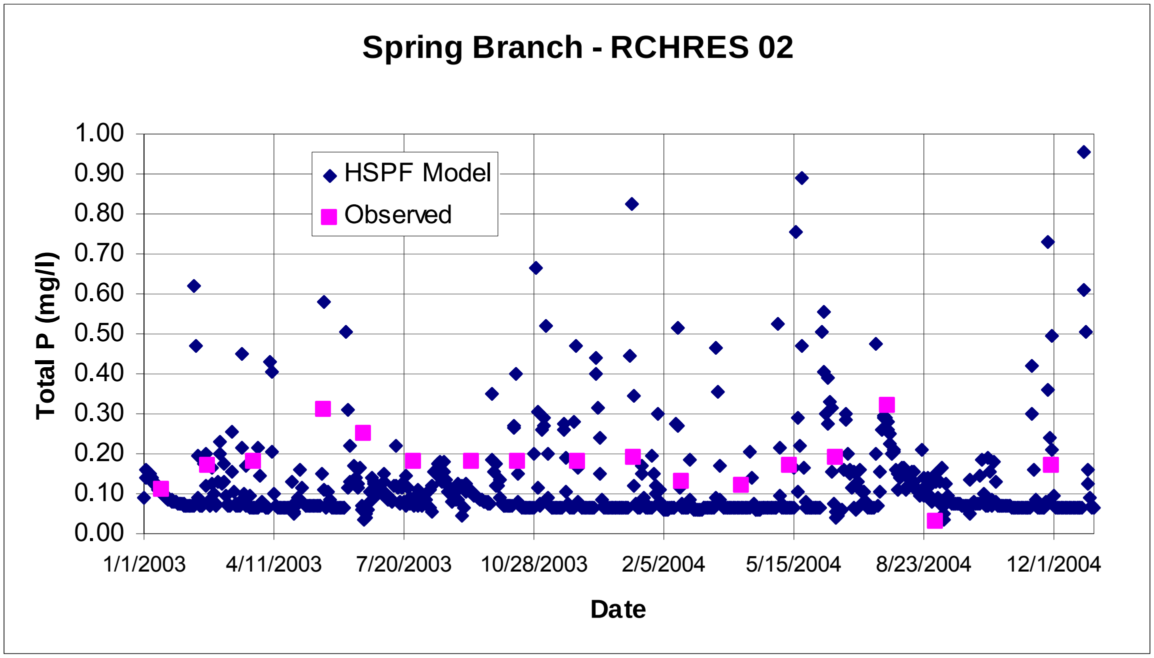


Figure 4-20 Measured and HSPF Modeled Chlorophyll-a in Spring Branch



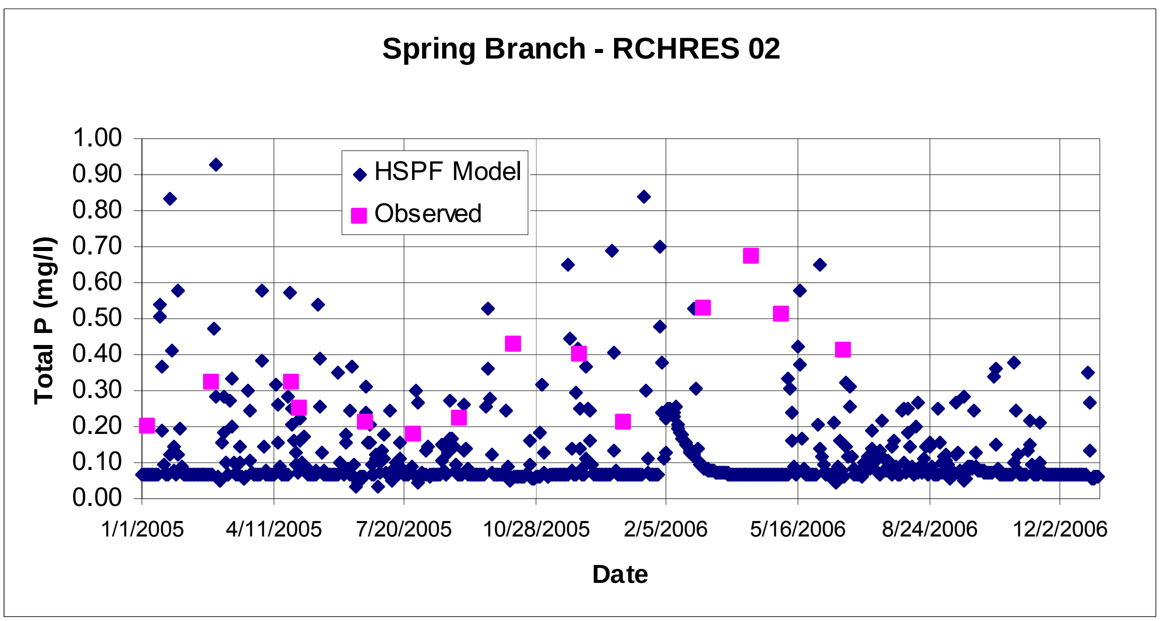
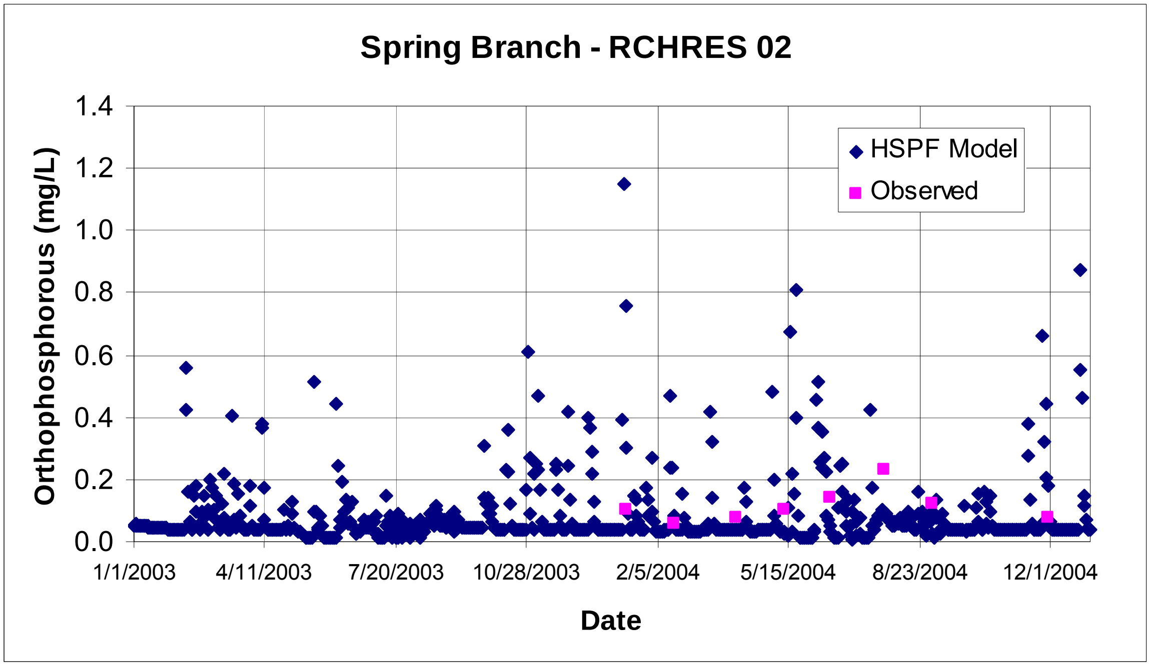


Figure 4-21 Measured and HSPF Modeled Total P in Spring Branch



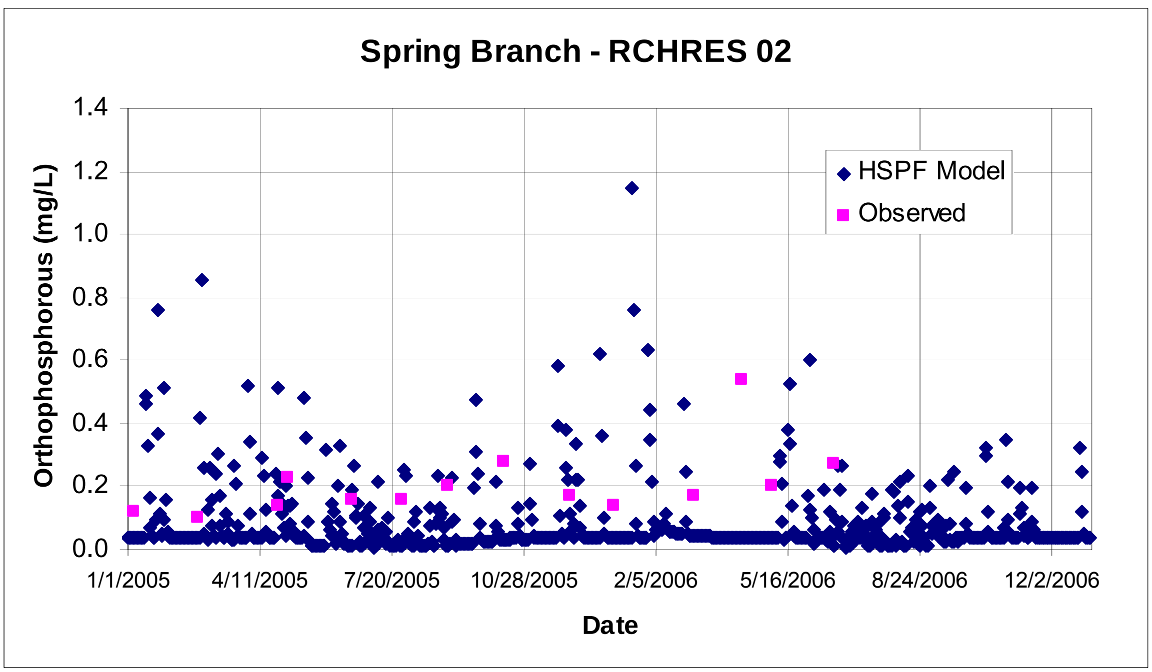
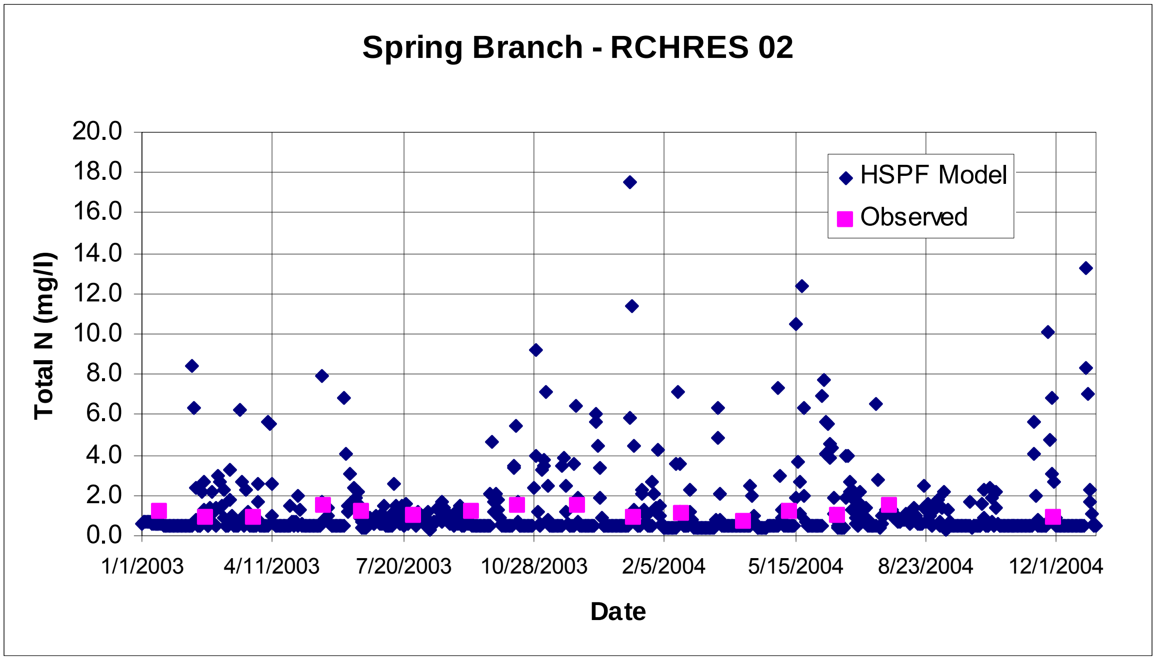


Figure 4-22 Measured and HSPF Modeled Orthophosphorus in Spring Branch



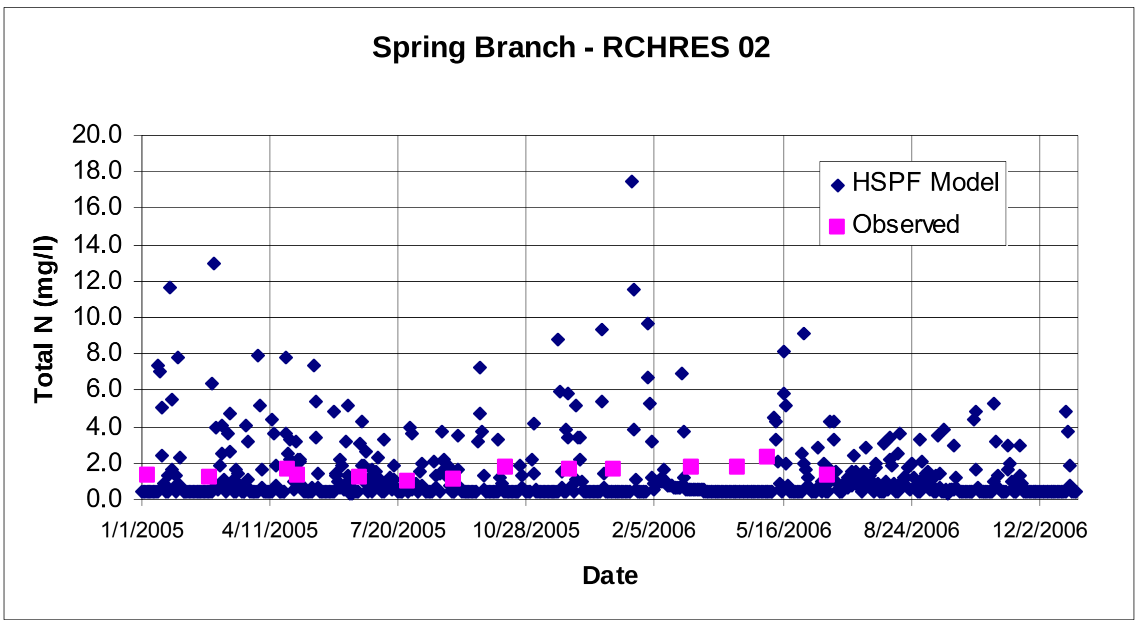
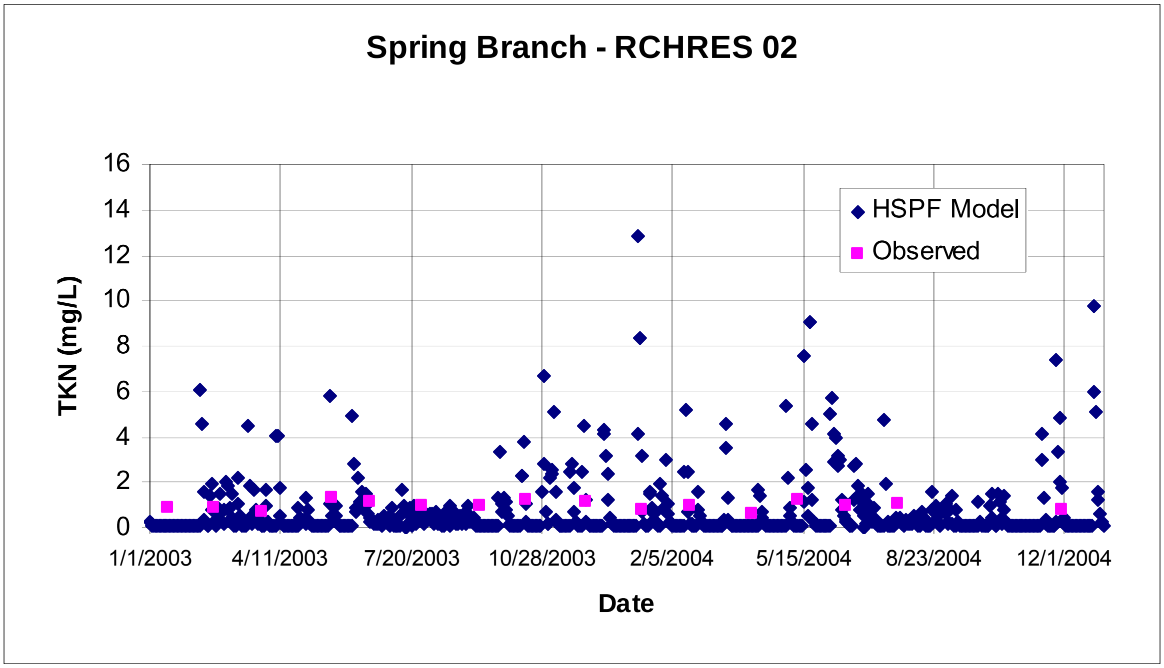


Figure 4-23 Measured and HSPF Modeled Total N in Spring Branch



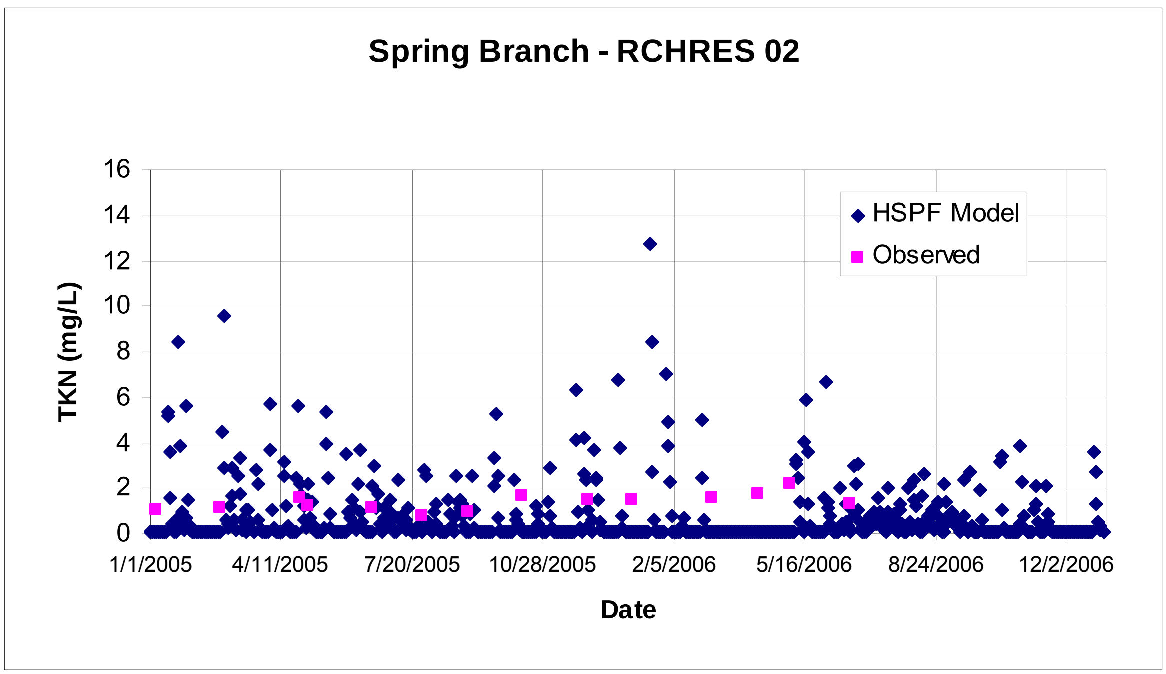
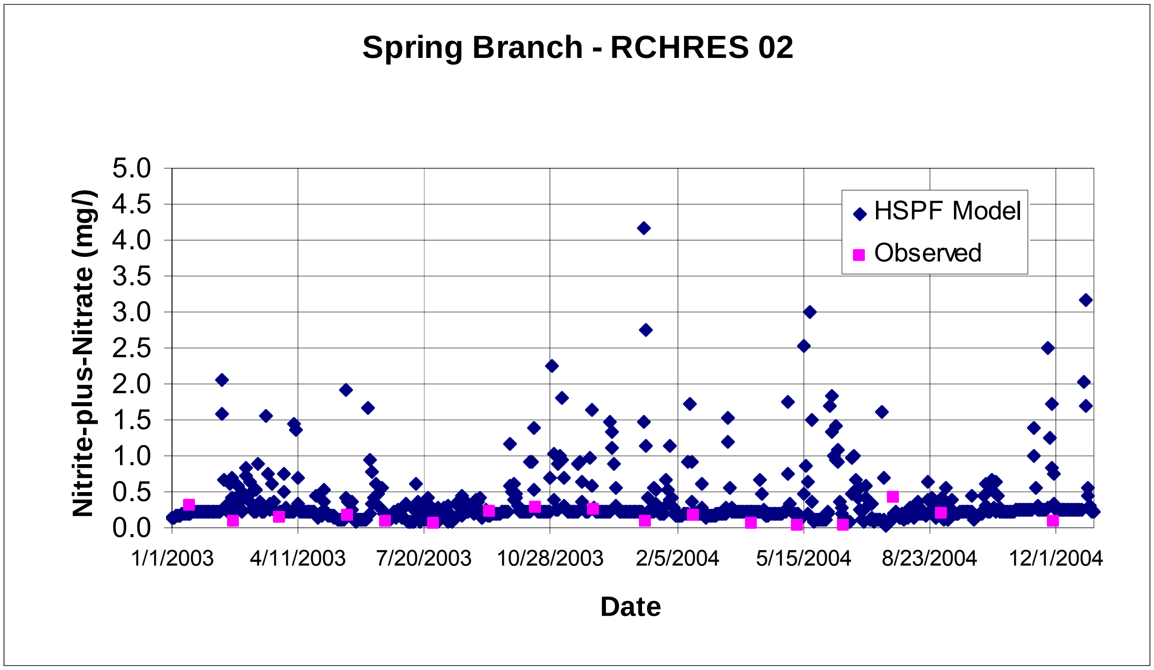


Figure 4-24 Measured and HSPF Modeled TKN in Spring Branch



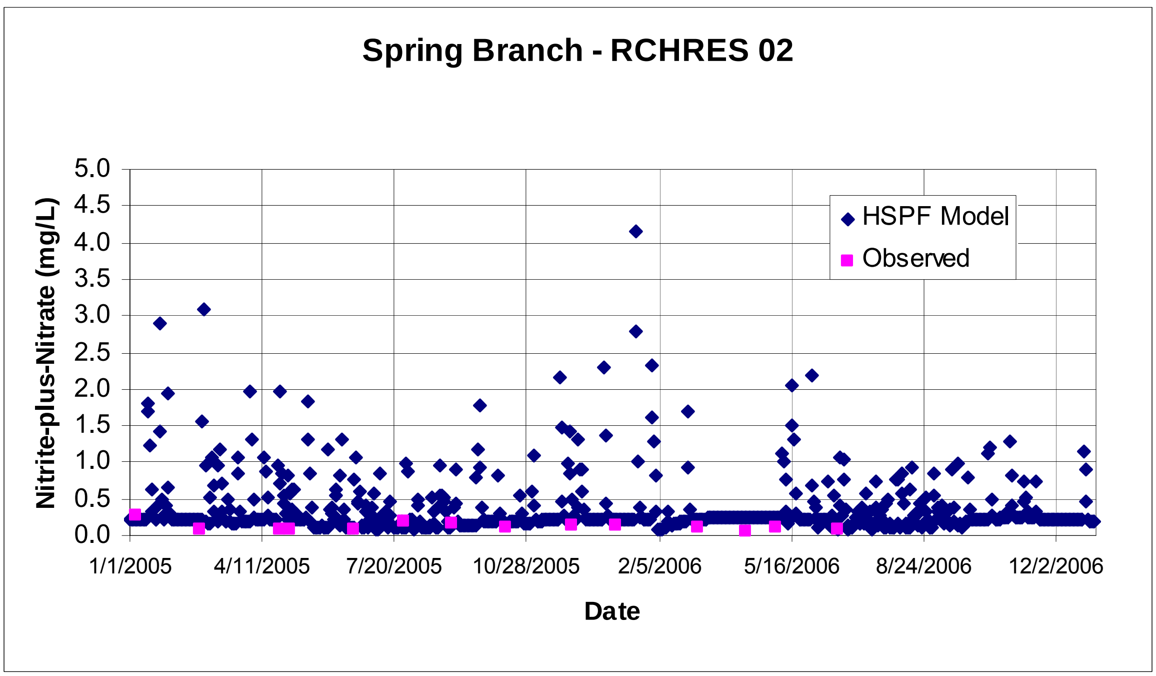
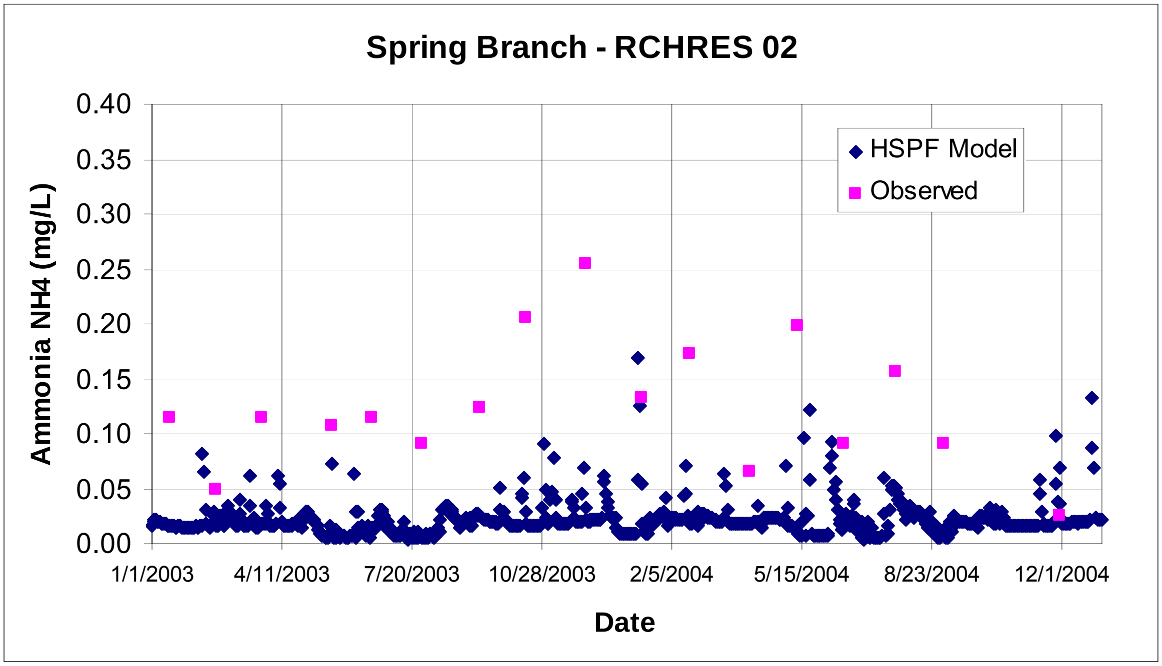


Figure 4-25 Measured and HSPF Modeled Nitrite-plus-Nitrate in Spring Branch



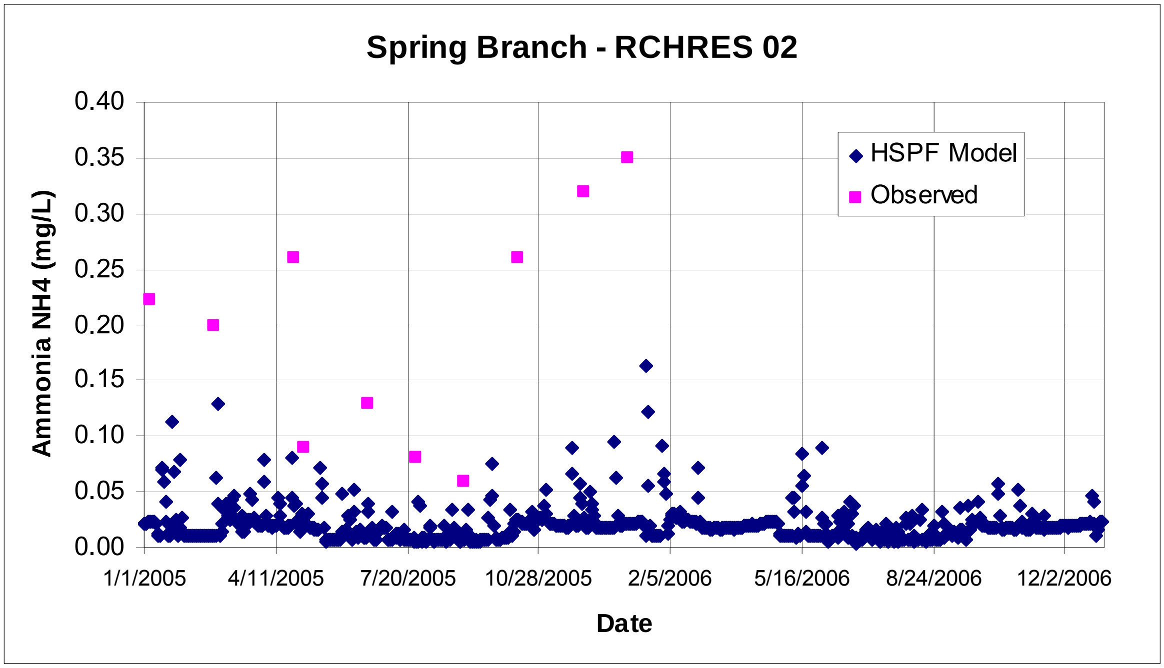
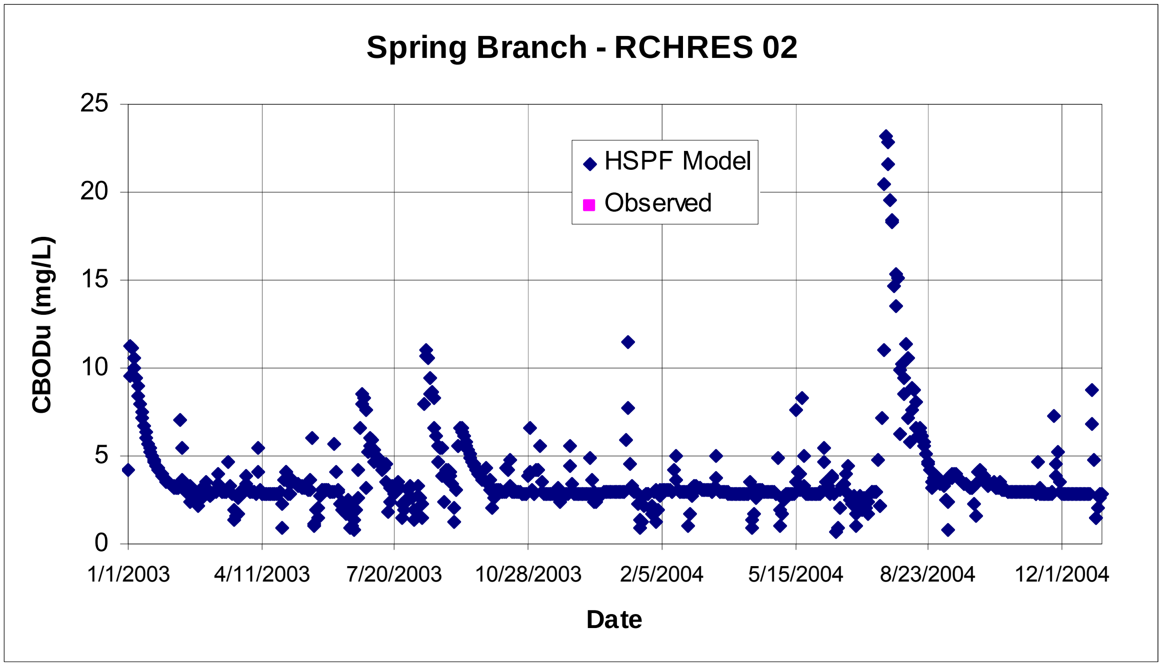


Figure 4-26 Measured and HSPF Modeled Ammonia (NH_4) in Spring Branch



Note: there were no BOD_5 observations over the period 1/1/2003 through 12/1/22004

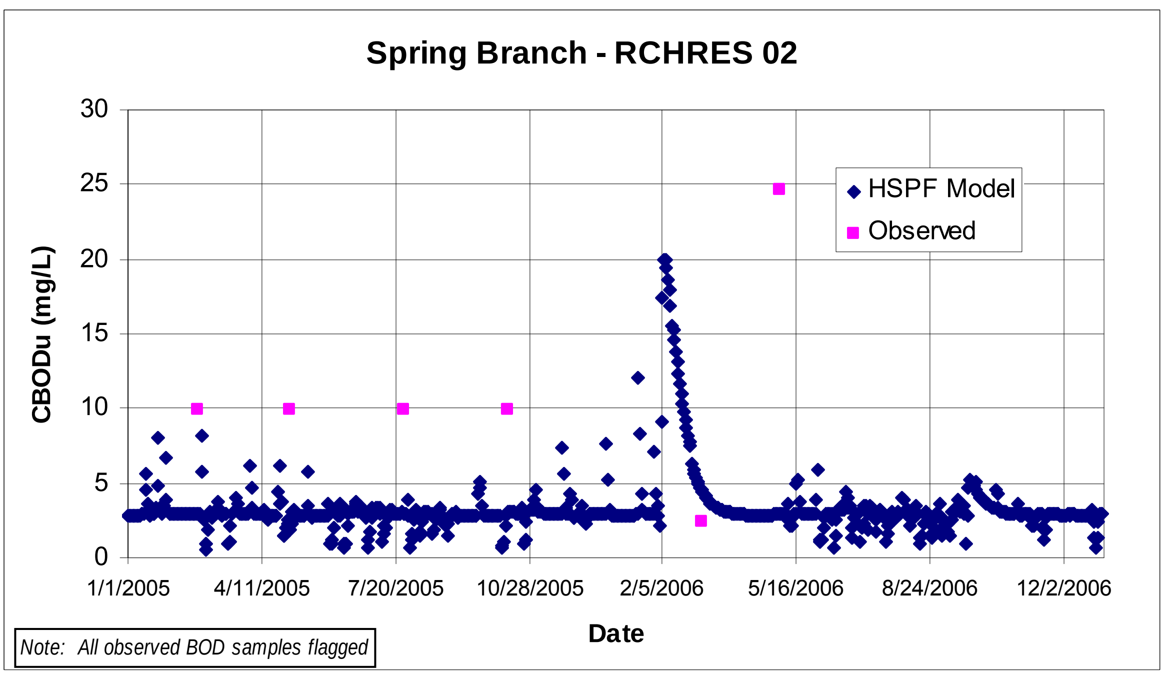


Figure 4-27 Measured and HSPF Modeled $CBOD_u$ in Spring Branch

Table 4-16 Range of Estimated Watershed Loading Rates for Spring Branch

Year	Commercial / Industrial	High Density Residential / Institutional	Medium Density Residential	Low Density Residential	Transportation / Utilities	Upland Forest / Cropland	Open Land/ Recreational	Wetlands
Phosphorus (lbs/ac/year)								
2000	0.45 to 0.84	0.31 to 0.71	0.33 to 0.59	0.12 to 0.20	0.45 to 0.84	0.04 to 0.06	0.04 to 0.06	0.04 to 0.06
2001	0.68 to 1.26	0.47 to 1.07	0.50 to 0.89	0.17 to 0.31	0.68 to 1.26	0.06 to 0.09	0.06 to 0.09	0.06 to 0.09
2002	0.85 to 1.57	0.58 to 1.34	0.63 to 1.11	0.22 to 0.38	0.85 to 1.57	0.08 to 0.11	0.08 to 0.11	0.08 to 0.11
2003	0.47 to 0.87	0.32 to 0.74	0.35 to 0.61	0.12 to 0.21	0.47 to 0.87	0.04 to 0.06	0.04 to 0.06	0.04 to 0.06
2004	0.98 to 1.81	0.67 to 1.54	0.72 to 1.27	0.25 to 0.44	0.98 to 1.81	0.09 to 0.13	0.09 to 0.13	0.09 to 0.13
2005	0.66 to 1.23	0.45 to 1.04	0.49 to 0.86	0.17 to 0.30	0.66 to 1.23	0.06 to 0.09	0.06 to 0.09	0.06 to 0.09
2006	0.70 to 1.30	0.48 to 1.11	0.52 to 0.91	0.18 to 0.32	0.70 to 1.30	0.06 to 0.09	0.06 to 0.09	0.06 to 0.09
Average	**0.45 to 0.84**	**0.31 to 0.71**	**0.33 to 0.59**	**0.12 to 0.20**	**0.45 to 0.84**	**0.04 to 0.06**	**0.04 to 0.06**	**0.04 to 0.06**
NO2+NO3 (lbs/ac/year)								
2000	3.75 to 9.04	0.51 to 1.07	1.18 to 2.24	0.41 to 0.77	3.75 to 9.04	0.01 to 0.07	0.01 to 0.07	0.01 to 0.07
2001	5.63 to 13.60	0.76 to 1.61	1.78 to 3.37	0.61 to 1.17	5.63 to 13.60	0.01 to 0.11	0.01 to 0.11	0.01 to 0.11
2002	7.04 to 16.99	0.95 to 2.02	2.22 to 4.21	0.77 to 1.46	7.04 to 16.99	0.01 to 0.14	0.01 to 0.14	0.01 to 0.14
2003	3.89 to 9.40	0.53 to 1.12	1.23 to 2.33	0.42 to 0.81	3.89 to 9.40	0.01 to 0.07	0.01 to 0.07	0.01 to 0.07
2004	8.11 to 19.57	1.09 to 2.32	2.55 to 4.85	0.88 to 1.68	8.11 to 19.57	0.01 to 0.16	0.01 to 0.16	0.01 to 0.16
2005	5.49 to 13.26	0.74 to 1.57	1.73 to 3.29	0.60 to 1.14	5.49 to 13.26	0.01 to 0.11	0.01 to 0.11	0.01 to 0.11
2006	5.82 to 14.06	0.79 to 1.67	1.83 to 3.48	0.63 to 1.20	5.82 to 14.06	0.01 to 0.11	0.01 to 0.11	0.01 to 0.11
Average	**3.75 to 9.04**	**0.51 to 1.07**	**1.18 to 2.24**	**0.41 to 0.77**	**3.75 to 9.04**	**0.00 to 0.07**	**0.00 to 0.07**	**0.00 to 0.07**
CBODu (lbs/ac/year)								
2000	46.10 to 68.15	37.40 to 72.60	21.97 to 32.43	7.59 to 11.21	46.10 to 68.15	5.31 to 24.98	5.31 to 24.98	5.31 to 24.98
2001	69.36 to 102.54	56.27 to 109.23	33.05 to 48.79	11.42 to 16.86	69.36 to 102.54	7.99 to 37.58	7.99 to 37.58	7.99 to 37.58
2002	86.66 to 128.11	70.30 to 136.47	41.29 to 60.96	14.27 to 21.06	86.66 to 128.11	9.98 to 46.95	9.98 to 46.95	9.98 to 46.95
2003	47.94 to 70.86	38.89 to 75.49	22.84 to 33.72	7.89 to 11.65	47.94 to 70.86	5.52 to 25.97	5.52 to 25.97	5.52 to 25.97
2004	99.79 to 147.51	80.94 to 157.14	47.54 to 70.19	16.43 to 24.25	99.79 to 147.51	11.49 to 54.06	11.49 to 54.06	11.49 to 54.06
2005	67.64 to 99.99	54.87 to 106.52	32.23 to 47.58	11.14 to 16.44	67.64 to 99.99	7.79 to 36.64	7.79 to 36.64	7.79 to 36.64
2006	71.67 to 105.95	58.14 to 112.87	34.15 to 50.42	11.80 to 17.42	71.67 to 105.95	8.25 to 38.83	8.25 to 38.83	8.25 to 38.83
Average	**31.59 to 46.70**	**25.62 to 49.74**	**15.05 to 22.22**	**5.20 to 7.68**	**31.59 to 46.70**	**3.64 to 17.11**	**3.64 to 17.11**	**3.64 to 17.11**
TKN (lbs/ac/year)								
2000	4.11 to 6.61	2.88 to 4.90	2.12 to 3.28	0.73 to 1.13	4.11 to 6.61	0.17 to 0.35	0.17 to 0.35	0.17 to 0.35
2001	6.19 to 9.95	4.33 to 7.37	3.19 to 4.94	1.10 to 1.71	6.19 to 9.95	0.26 to 0.52	0.26 to 0.52	0.26 to 0.52
2002	7.73 to 12.43	5.42 to 9.21	3.99 to 6.17	1.38 to 2.13	7.73 to 12.43	0.32 to 0.65	0.32 to 0.65	0.32 to 0.65
2003	4.28 to 6.88	3.00 to 5.09	2.21 to 3.41	0.76 to 1.18	4.28 to 6.88	0.18 to 0.36	0.18 to 0.36	0.18 to 0.36
2004	8.90 to 14.31	6.24 to 10.60	4.60 to 7.10	1.59 to 2.45	8.90 to 14.31	0.37 to 0.75	0.37 to 0.75	0.37 to 0.75
2005	6.04 to 9.70	4.23 to 7.19	3.11 to 4.82	1.08 to 1.66	6.04 to 9.70	0.25 to 0.51	0.25 to 0.51	0.25 to 0.51
2006	6.40 to 10.28	4.48 to 7.62	3.30 to 5.10	1.14 to 1.76	6.40 to 10.28	0.26 to 0.54	0.26 to 0.54	0.26 to 0.54
Average	**6.24 to 10.02**	**4.37 to 7.43**	**3.22 to 4.97**	**1.11 to 1.72**	**6.24 to 10.02**	**0.26 to 0.52**	**0.26 to 0.52**	**0.26 to 0.52**

Table 4-17 Simulated Watershed Annual Loading Rates for Spring Branch

Year	Commercial/Industrial	High Density Residential	Medium Density Residential	Low Density Residential	Transportation/ Utilities	Upland Forest/Cropland	Open Land/ Recreational	Wetlands	Total
Orthophosphorus (lb/acre/year)									
2000	0.52	0.52	0.46	0.14	0.76	0.05	0.03	0.04	2.52
2001	0.42	0.41	0.35	0.09	0.63	0.02	0.01	0.01	1.94
2002	0.53	0.52	0.47	0.15	0.75	0.07	0.03	0.05	2.57
2003	0.69	0.65	0.59	0.18	0.95	0.08	0.03	0.06	3.23
2004	0.68	0.7	0.68	0.3	0.94	0.16	0.06	0.14	3.66
2005	0.99	0.71	0.77	0.31	0.94	0.22	0.04	0.12	4.1
2006	0.57	0.56	0.48	0.12	0.84	0.03	0.02	0.02	2.64
Average	**0.59**	**0.53**	**0.49**	**0.15**	**0.77**	**0.08**	**0.02**	**0.04**	**2.67**
Nitrite-plus-Nitrate (lb/acre/year)									
2000	5.78	0.63	1.68	0.41	4.85	0.05	0.01	0.01	13.42
2001	4.36	0.46	1.27	0.28	4	0.02	0.01	0	10.4
2002	5.51	0.68	1.72	0.44	4.72	0.05	0.01	0.01	13.14
2003	7.11	0.73	2.08	0.51	5.99	0.05	0.01	0.01	16.49
2004	7.46	1.18	2.6	0.8	5.74	0.11	0.03	0.04	17.96
2005	6.95	1.05	2.39	0.7	5.66	0.09	0.02	0.03	16.89
2006	6.13	0.54	1.71	0.38	5.37	0.03	0.01	0.01	14.18
Average	**5.67**	**0.64**	**1.69**	**0.42**	**4.85**	**0.04**	**0.01**	**0.01**	**13.33**
$CBOD_u$ (lb/acre/year)									
2000	34.7	18.9	6.7	6.22	34.9	7.67	7.35	3.12	119.56
2001	28	13.7	3.14	3.04	28.1	3.54	3.96	1.01	84.49
2002	35.2	22.8	12.1	8.07	35.7	11.2	8.33	4.63	138.03
2003	44.9	29.6	16.3	9.12	45.4	12.9	11.3	5.35	174.87
2004	46.9	40.3	30.8	19.5	47.5	24.2	16.5	11.9	237.6
2005	53.9	63.4	61	22.9	55.1	34.1	15.7	10.6	316.7
2006	37.7	18.5	4.2	4.15	37.8	4.83	4.89	1.29	113.36
Average	**36.9**	**25.5**	**15.2**	**7.82**	**38.1**	**13.1**	**7.35**	**3.47**	147.44
TKN (lb/acre/year)									
2000	6.95	4.82	4.58	1.18	6.64	0.29	0.27	0.25	24.98
2001	5.23	3.84	3.74	0.88	5.21	0.14	0.15	0.08	19.27
2002	6.26	4.78	4.49	1.18	6.23	0.35	0.32	0.34	23.95
2003	7.9	5.93	5.66	1.43	7.86	0.38	0.45	0.4	30.01
2004	7.8	6.37	5.63	1.75	7.72	0.77	0.65	0.95	31.64
2005	7.64	6.09	5.48	1.63	7.55	0.82	0.61	0.79	30.61
2006	7.04	5.15	5.03	1.19	7.01	0.19	0.19	0.11	25.91
Average	**6.4**	**4.82**	**4.59**	**1.17**	**6.37**	**0.34**	**0.29**	**0.27**	24.25

Table 4-18 HSPF Simulated Total P Budget for Spring Branch

Calendar Year	Annual TP Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	868	38	198	0	-1096	8
2000	714	8	99	0	-815	5
2001	853	142	230	0	-1220	5
2002	1093	225	240	0	-1519	40
2003	1042	402	539	0	-2009	-26
2004	1151	1058	441	0	-2648	2
2005	960	7	136	0	-1097	6
2006	902	221	196	0	-1313	6
Average	948	263	260	0	-1465	6

Table 4-19 HSPF Simulated Total N Budget for Spring Branch

Calendar Year	Annual TN Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	12263	126	1412	0	-13786	15
2000	10011	28	701	0	-10738	2
2001	11844	490	1635	0	-14001	-32
2002	15036	783	1712	0	-17209	323
2003	14438	1378	3844	0	-20002	-342
2004	14143	3733	3144	0	-21067	-47
2005	13482	26	968	0	-14487	-11
2006	12169	782	1393	0	-14353	-9
Average	12923	918	1851	0	-15705	-13

Table 4-20 HSPF Simulated $CBOD_u$ Budget for Spring Branch

Calendar Year	Annual $CBOD_u$ Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	9454	2744	8957	0	-19400	1755
2000	7736	513	4449	0	-11551	1147
2001	9182	11477	10366	0	-28353	2672
2002	11617	18433	10855	0	-37320	3586
2003	11085	32521	24328	0	-63092	4842
2004	10953	89853	19903	0	-108848	11861
2005	10398	461	6145	0	-15491	1512
2006	9436	18640	8829	0	-34392	2513
Average	9983	21830	11729	0	-39806	3736

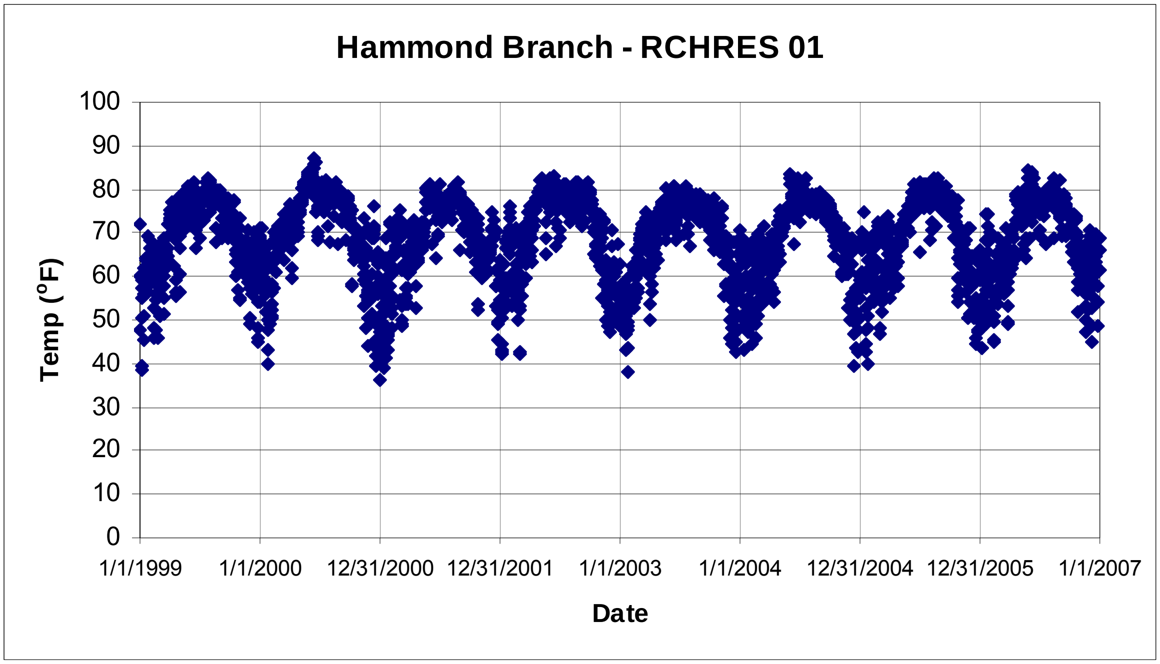


Figure 4-28 HSPF Modeled Water Temperature in Hammond Branch

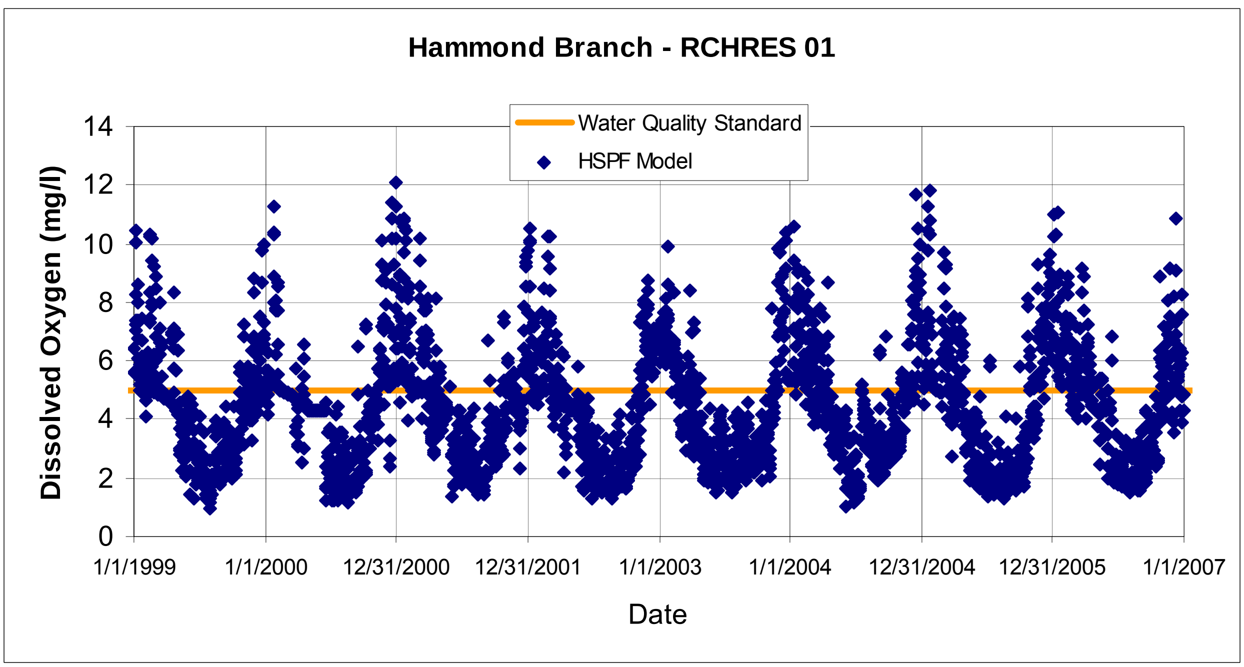


Figure 4-29 HSPF Modeled Dissolved Oxygen in Hammond Branch

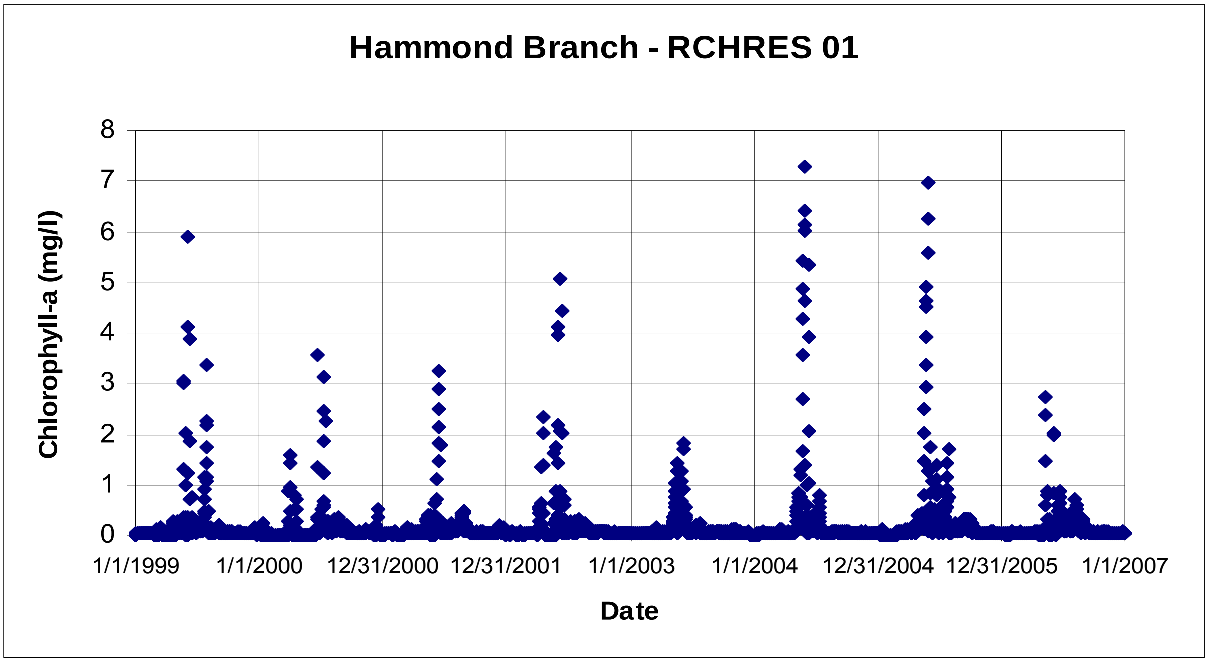


Figure 4-30 HSPF Modeled Chlorophyll-a in Hammond Branch

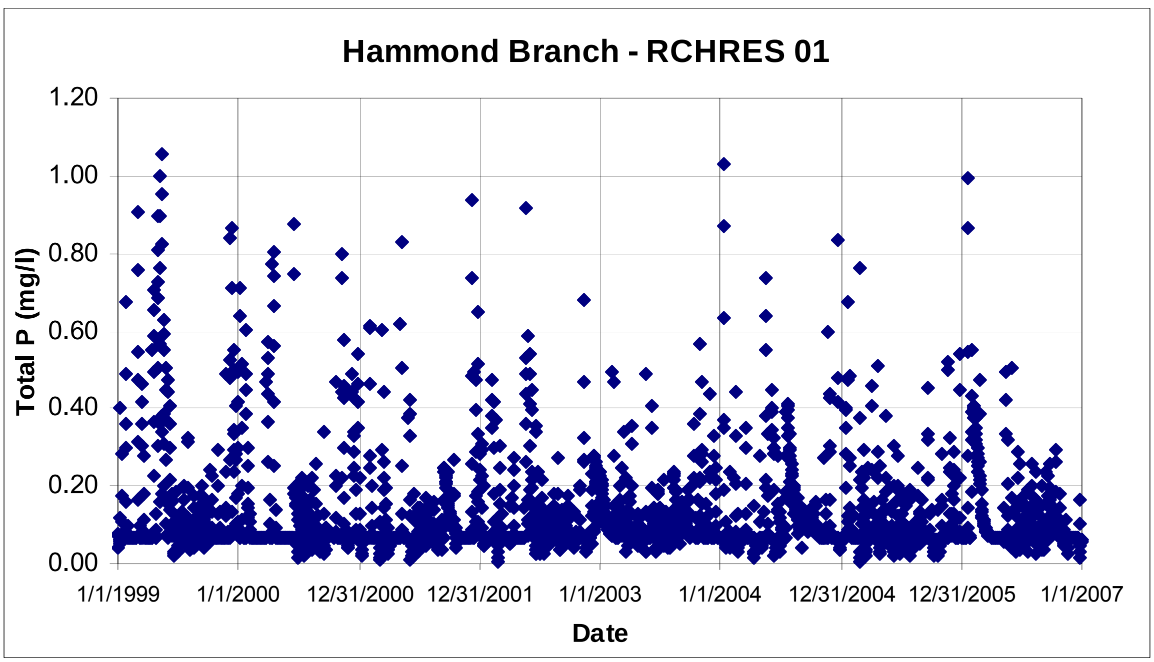


Figure 4-31 HSPF Modeled Total P in Hammond Branch

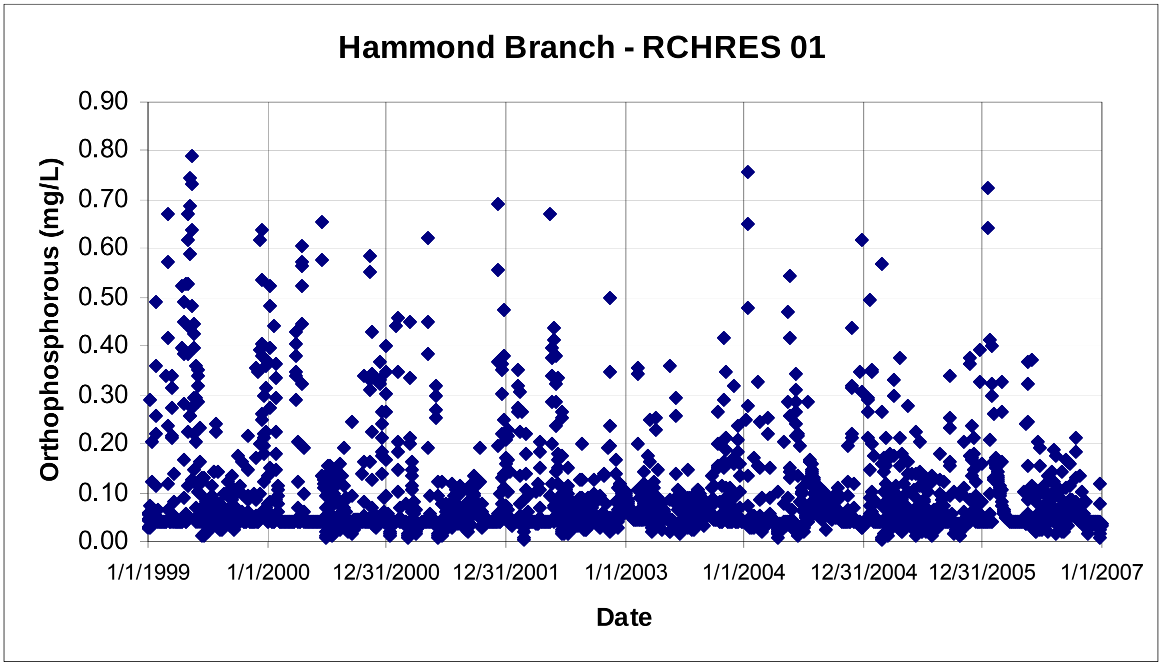


Figure 4-32 HSPF Modeled Orthophosphorus in Hammond Branch

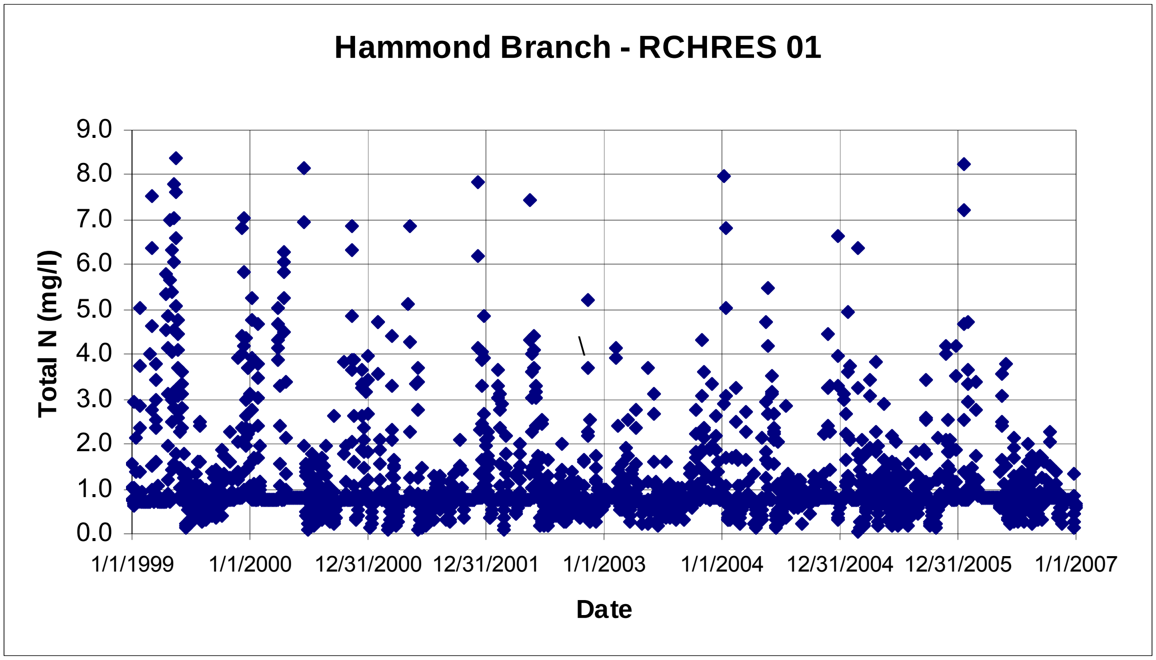


Figure 4-33 HSPF Modeled Total N in Hammond Branch

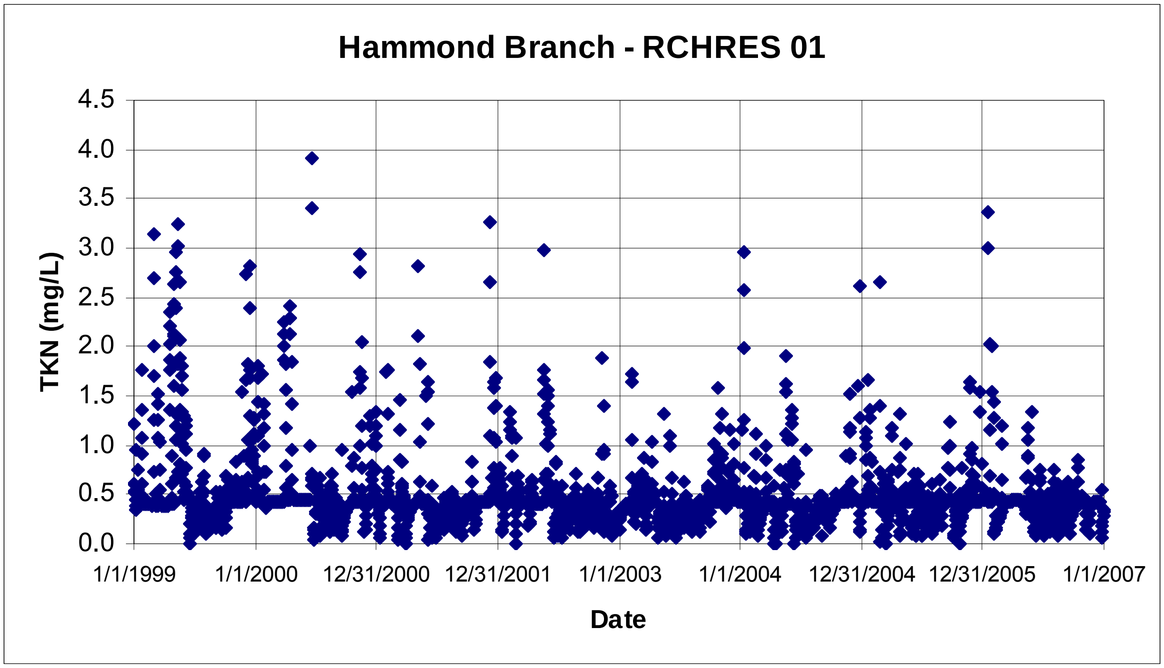


Figure 4-34 HSPF Modeled TKN in Hammond Branch

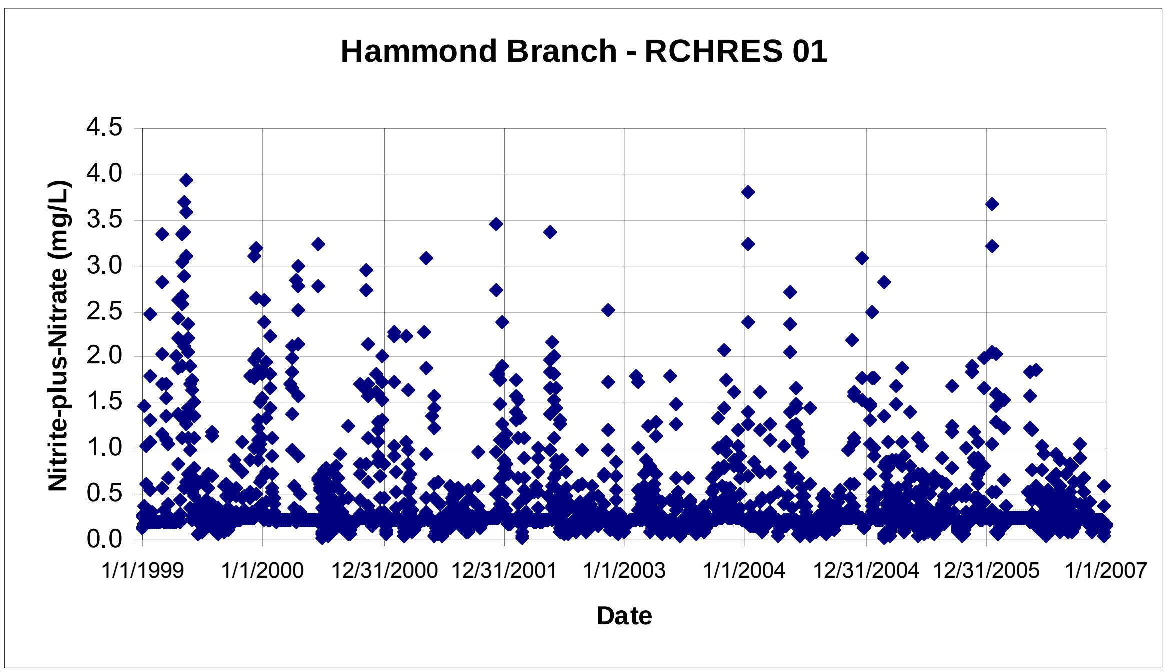


Figure 4-35 HSPF Modeled Nitrite-plus-Nitrate in Hammond Branch

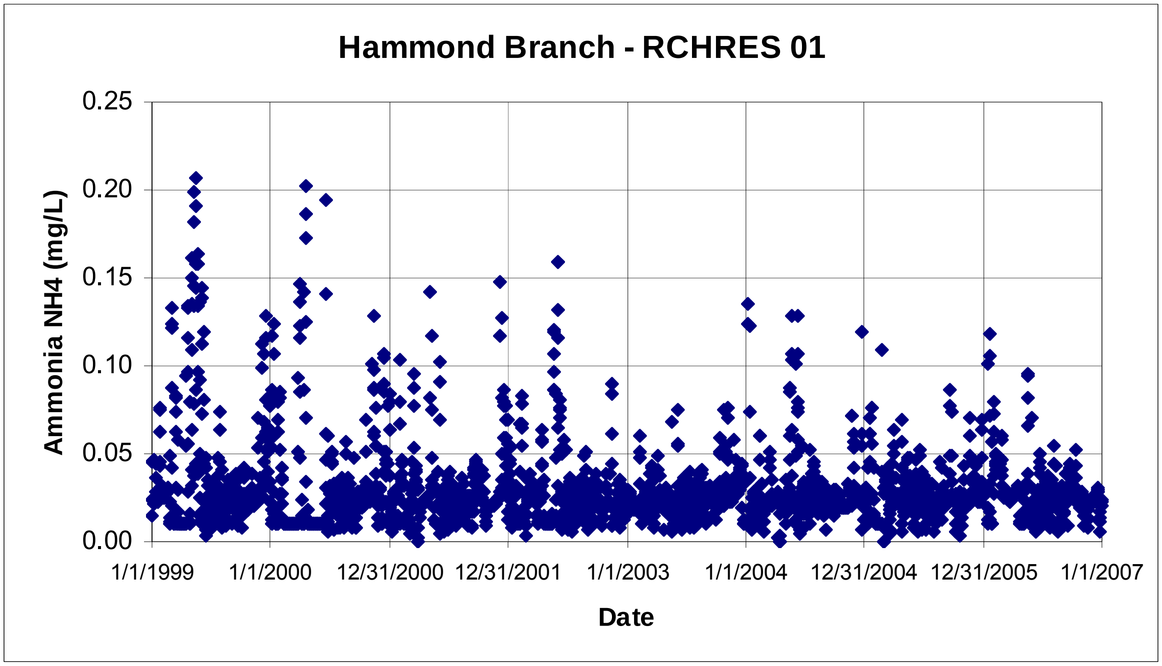


Figure 4-36 HSPF Modeled Ammonia (NH_4) in Hammond Branch

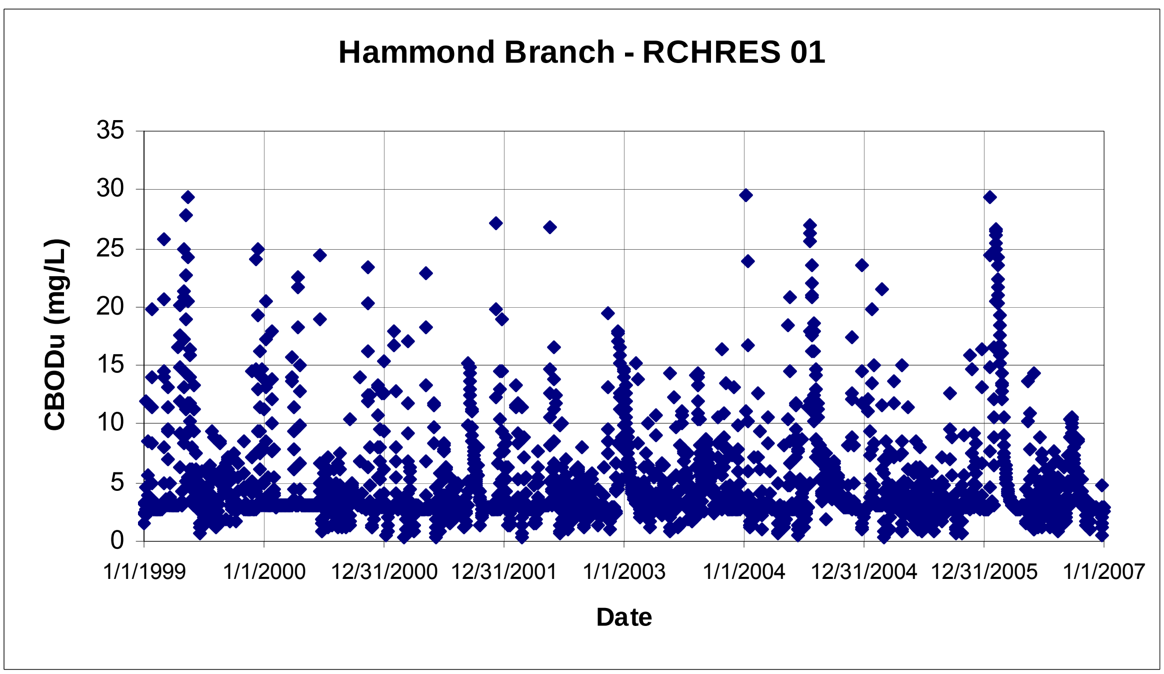


Figure 4-37 HSPF Modeled $CBOD_u$ in Hammond Branch

Table 4-21 Range of Estimated Watershed Loading Rates for Hammond Branch

Year	Commercial / Industrial	High Density Residential / Institutional	Medium Density Residential	Low Density Residential	Transportation / Utilities	Upland Forest / Cropland	Open Land/ Recreational	Wetlands
Phosphorus (lbs/ac/year)								
2000	0.25 to 0.46	0.17 to 0.39	0.18 to 0.32	0.06 to 0.11	0.25 to 0.46	0.02 to 0.03	0.02 to 0.03	0.02 to 0.03
2001	0.38 to 0.69	0.26 to 0.59	0.28 to 0.49	0.10 to 0.17	0.38 to 0.69	0.03 to 0.05	0.03 to 0.05	0.03 to 0.05
2002	0.47 to 0.87	0.32 to 0.74	0.34 to 0.61	0.12 to 0.21	0.47 to 0.87	0.04 to 0.06	0.04 to 0.06	0.04 to 0.06
2003	0.26 to 0.48	0.18 to 0.41	0.19 to 0.34	0.07 to 0.12	0.26 to 0.48	0.02 to 0.03	0.02 to 0.03	0.02 to 0.03
2004	0.54 to 1.00	0.37 to 0.85	0.40 to 0.70	0.14 to 0.24	0.54 to 1.00	0.05 to 0.07	0.05 to 0.07	0.05 to 0.07
2005	0.37 to 0.68	0.25 to 0.57	0.27 to 0.48	0.09 to 0.16	0.37 to 0.68	0.03 to 0.05	0.03 to 0.05	0.03 to 0.05
2006	0.39 to 0.72	0.26 to 0.61	0.29 to 0.50	0.10 to 0.17	0.39 to 0.72	0.03 to 0.05	0.03 to 0.05	0.03 to 0.05
Average	**0.38 to 0.70**	**0.26 to 0.59**	**0.28 to 0.49**	**0.10 to 0.17**	**0.38 to 0.70**	**0.03 to 0.05**	**0.03 to 0.05**	**0.03 to 0.05**
NO2+NO3 (lbs/ac/year)								
2000	2.57 to 6.20	0.35 to 0.74	0.81 to 1.54	0.28 to 0.53	2.57 to 6.20	0.01 to 0.05	0.01 to 0.05	0.01 to 0.05
2001	3.86 to 9.32	0.52 to 1.11	1.22 to 2.31	0.42 to 0.80	3.86 to 9.32	0.01 to 0.08	0.01 to 0.08	0.01 to 0.08
2002	4.82 to 11.65	0.65 to 1.38	1.52 to 2.89	0.53 to 1.00	4.82 to 11.65	0.01 to 0.09	0.01 to 0.09	0.01 to 0.09
2003	2.67 to 6.44	0.36 to 0.77	0.84 to 1.60	0.29 to 0.55	2.67 to 6.44	0.01 to 0.05	0.01 to 0.05	0.01 to 0.05
2004	5.56 to 13.41	0.75 to 1.59	1.75 to 3.33	0.61 to 1.15	5.56 to 13.41	0.01 to 0.11	0.01 to 0.11	0.01 to 0.11
2005	3.77 to 9.09	0.51 to 1.08	1.19 to 2.25	0.41 to 0.78	3.77 to 9.09	0.01 to 0.07	0.01 to 0.07	0.01 to 0.07
2006	3.99 to 9.63	0.54 to 1.14	1.26 to 2.39	0.44 to 0.83	3.99 to 9.63	0.01 to 0.08	0.01 to 0.08	0.01 to 0.08
Average	**3.89 to 9.39**	**0.53 to 1.12**	**1.23 to 2.33**	**0.43 to 0.81**	**3.89 to 9.39**	**0.01 to 0.08**	**0.01 to 0.08**	**0.01 to 0.08**
$CBOD_u$ (lbs/ac/year)								
2000	33.68 to 49.78	27.33 to 53.03	16.06 to 23.70	5.56 to 8.20	33.68 to 49.78	3.90 to 18.26	3.90 to 18.26	3.90 to 18.26
2001	50.67 to 74.89	41.10 to 79.77	24.15 to 35.65	8.36 to 12.33	50.67 to 74.89	5.85 to 27.46	5.85 to 27.46	5.85 to 27.46
2002	63.29 to 93.56	51.35 to 99.66	30.17 to 44.53	10.44 to 15.40	63.29 to 93.56	7.30 to 34.30	7.30 to 34.30	7.30 to 34.30
2003	35.02 to 51.76	28.41 to 55.14	16.70 to 24.64	5.78 to 8.53	35.02 to 51.76	4.05 to 18.98	4.05 to 18.98	4.05 to 18.98
2004	72.88 to 107.72	59.12 to 114.76	34.73 to 51.27	12.01 to 17.73	72.88 to 107.72	8.41 to 39.49	8.41 to 39.49	8.41 to 39.49
2005	49.41 to 73.03	40.08 to 77.79	23.55 to 34.76	8.15 to 12.02	49.41 to 73.03	5.71 to 26.78	5.71 to 26.78	5.71 to 26.78
2006	52.35 to 77.38	42.47 to 82.43	24.95 to 36.83	8.64 to 12.74	52.35 to 77.38	6.05 to 28.37	6.05 to 28.37	6.05 to 28.37
Average	**51.04 to 75.44**	**41.41 to 80.37**	**24.33 to 35.91**	**8.42 to 12.42**	**51.04 to 75.44**	**5.89 to 27.66**	**5.89 to 27.66**	**5.89 to 27.66**
TKN (lbs/ac/year)								
2000	1.71 to 2.75	1.20 to 2.04	0.88 to 1.36	0.31 to 0.47	1.71 to 2.75	0.07 to 0.15	0.07 to 0.15	0.07 to 0.15
2001	2.57 to 4.13	1.80 to 3.06	1.33 to 2.05	0.46 to 0.71	2.57 to 4.13	0.11 to 0.22	0.11 to 0.22	0.11 to 0.22
2002	3.21 to 5.16	2.25 to 3.83	1.66 to 2.56	0.57 to 0.89	3.21 to 5.16	0.13 to 0.27	0.13 to 0.27	0.13 to 0.27
2003	1.78 to 2.86	1.25 to 2.12	0.92 to 1.42	0.32 to 0.49	1.78 to 2.86	0.08 to 0.15	0.08 to 0.15	0.08 to 0.15
2004	3.70 to 5.95	2.59 to 4.41	1.91 to 2.95	0.66 to 1.02	3.70 to 5.95	0.15 to 0.31	0.15 to 0.31	0.15 to 0.31
2005	2.51 to 4.03	1.76 to 2.99	1.30 to 2.00	0.45 to 0.69	2.51 to 4.03	0.11 to 0.21	0.11 to 0.21	0.11 to 0.21
2006	2.66 to 4.27	1.86 to 3.16	1.37 to 2.12	0.48 to 0.73	2.66 to 4.27	0.11 to 0.22	0.11 to 0.22	0.11 to 0.22
Average	2.59 to 4.16	1.82 to 3.09	1.34 to 2.07	0.46 to 0.72	2.59 to 4.16	0.11 to 0.22	0.11 to 0.22	0.11 to 0.22

Table 4-22 Simulated Watershed Annual Loading Rates for Hammond Branch

Year	Commercial/Industrial	High Density Residential	Medium Density Residential	Low Density Residential	Transportation/ Utilities	Upland Forest/Cropland	Open Land/ Recreational	Wetlands	Total
Orthophosphorus (lb/acre/year)									
2000	0.49	0.28	0.34	0.12	0.52	0.04	0.04	0.02	1.85
2001	0.39	0.19	0.25	0.07	0.42	0.02	0.02	0.01	1.37
2002	0.51	0.37	0.38	0.14	0.51	0.05	0.05	0.03	2.04
2003	0.65	0.47	0.48	0.16	0.65	0.05	0.06	0.03	2.55
2004	0.7	0.67	0.61	0.28	0.65	0.1	0.09	0.08	3.18
2005	0.85	1.09	0.8	0.28	0.67	0.08	0.08	0.06	3.91
2006	0.52	0.25	0.33	0.1	0.56	0.03	0.03	0.01	1.83
Average	**0.56**	**0.46**	**0.43**	**0.13**	**0.53**	**0.04**	**0.04**	**0.02**	2.21
Nitrite-plus-Nitrate (lb/acre/year)									
2000	5.09	0.45	1.2	0.65	4.2	0.04	0.01	0.01	11.65
2001	4.16	0.27	0.87	0.39	3.41	0.02	0.01	0	9.13
2002	5.02	0.48	1.24	0.71	4.2	0.05	0.01	0.02	11.73
2003	6.35	0.55	1.49	0.79	5.31	0.05	0.01	0.02	14.57
2004	6.3	0.97	1.99	1.47	5.35	0.1	0.03	0.05	16.26
2005	6.39	0.81	1.83	1.21	5.62	0.08	0.02	0.04	16
2006	5.59	0.38	1.18	0.53	4.59	0.03	0.01	0.01	12.32
Average	**5.19**	**0.43**	**1.22**	**0.62**	**4.39**	**0.04**	**0.01**	**0.02**	**11.92**
$CBOD_u$ (lb/acre/year)									
2000	54.8	33.4	9.3	6.07	54.8	8.16	7.35	3.12	177
2001	44.5	24.7	3.98	2.86	44.5	3.63	3.96	1.01	129.14
2002	55.2	39.4	17.6	8.15	55.2	12.8	8.33	4.63	201.31
2003	70.1	50.2	22.6	9.28	69.8	14.9	11.3	5.35	253.53
2004	71.5	63.8	41.5	19.6	70.7	26.7	16.5	11.9	322.2
2005	77.7	91.9	77.3	22.9	75.3	38	15.7	10.6	409.4
2006	59.8	33.1	5.16	3.93	59.8	4.81	4.89	1.29	172.78
Average	**58.1**	**45.8**	**24.8**	**8.36**	**57.6**	**14.3**	**7.35**	**3.47**	**219.78**
TKN (lb/acre/year)									
2000	3.06	2.26	1.17	0.38	3.79	0.15	0.2	0.13	11.14
2001	2.07	1.82	0.83	0.18	2.8	0.07	0.07	0.04	7.88
2002	2.44	2.21	1.27	0.41	3.48	0.17	0.16	0.16	10.3
2003	3.09	2.79	1.38	0.44	4.32	0.19	0.18	0.18	12.57
2004	2.98	2.81	2.28	0.96	4.6	0.37	0.36	0.45	14.81
2005	2.94	2.74	2	0.79	4.37	0.34	0.26	0.34	13.78
2006	2.76	2.45	0.99	0.25	3.77	0.1	0.12	0.06	10.5
Average	**2.5**	**2.25**	**1.17**	**0.34**	**3.5**	**0.15**	**0.13**	**0.13**	**10.17**

Table 4-23 HSPF Simulated Total P Budget for Hammond Branch

Calendar Year	Annual TP Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	339	18	80	0	-437	0
2000	278	6	39	0	-323	0
2001	332	59	92	0	-484	-1
2002	425	94	96	0	-611	5
2003	406	164	215	0	-794	-8
2004	445	424	175	0	-1049	-5
2005	374	6	55	0	-435	0
2006	349	88	78	0	-516	-1
Average	369	107	104	0	-581	-1

Table 4-24 HSPF Simulated Total N Budget for Hammond Branch

Calendar Year	Annual TN Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	4803	79	555	0	-5444	-8
2000	3924	31	276	0	-4236	-5
2001	4644	225	642	0	-5521	-11
2002	5896	358	673	0	-6882	45
2003	5658	604	1505	0	-7847	-80
2004	5547	1533	1232	0	-8346	-35
2005	5284	34	382	0	-5706	-7
2006	4770	331	548	0	-5660	-12
Average	5066	399	726	0	-6205	-14

Table 4-25 HSPF Simulated $CBOD_u$ Budget for Hammond Branch

Calendar Year	Annual $CBOD_u$ Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	3291	1473	3573	0	-7965	372
2000	2640	486	1774	0	-4671	228
2001	3145	4908	4123	0	-11661	515
2002	3970	7909	4322	0	-15549	653
2003	3773	13578	9649	0	-26038	962
2004	3732	36245	7875	0	-45825	2027
2005	3543	507	2470	0	-6215	305
2006	3229	7549	3509	0	-13812	474
Average	3416	9082	4662	0	-16467	692

4.3.6 Water Quality – Lower Stevenson Creek

Figures 4-38 through **4-47** present the time series data for modeled constituents in Lower Stevenson Creek for the calibration and validation periods. No observed data were available for calibration, thus only the modeled water quality data are presented. Calibration focused on adjusting surface loading for the subwatersheds to match loadings estimated using representative Florida EMCs. These loadings were adjusted to reflect expected increased loadings from septic systems in the watershed. In addition, accumulation/washoff coefficients in the model were adjusted so that model annual loading was consistent with estimated watershed loads. These estimated watershed loadings were calculated using EMCs and assumptions documented in Section 4.7.2. Estimated watershed loads are shown in **Table 4-26**. The calibrated watershed loadings for Lower Stevenson Creek are presented in **Table 4-27**. Most annual average loads calibrated in the model are within the range of estimated loadings presented in Table 4-26. The only exceptions are phosphorus loads for the upland forest/cropland and open-land/recreational land uses, and $CBOD_u$ loads for the low density residential land use. However, it should be noted that the Stevenson Creek watershed is over 90% built-out, and that the upland forest/cropland and open land/recreational land use categories collectively constitute only 7.9% of the total Stevenson Creek watershed area. The low density residential land use category constitutes a mere 1.1% of the total Stevenson Creek watershed area (refer to Table 2-1 for land use distributions as derived from the 2004 FLUCCS data). Lastly, Chlorophyll-a concentrations in Lower Stevenson Creek reflect relatively high peaks during certain periods. These concentrations may potentially be reduced by incremental adjustments to the algal growth rate in HSPF, which should be investigated in further model refinements.

The HSPF simulated Total P, Total N, and $CBOD_u$ load budgets for the Lower Stevenson Creek reach are presented in **Table 4-28, Table 4-29, and Table 4-30,** respectively.

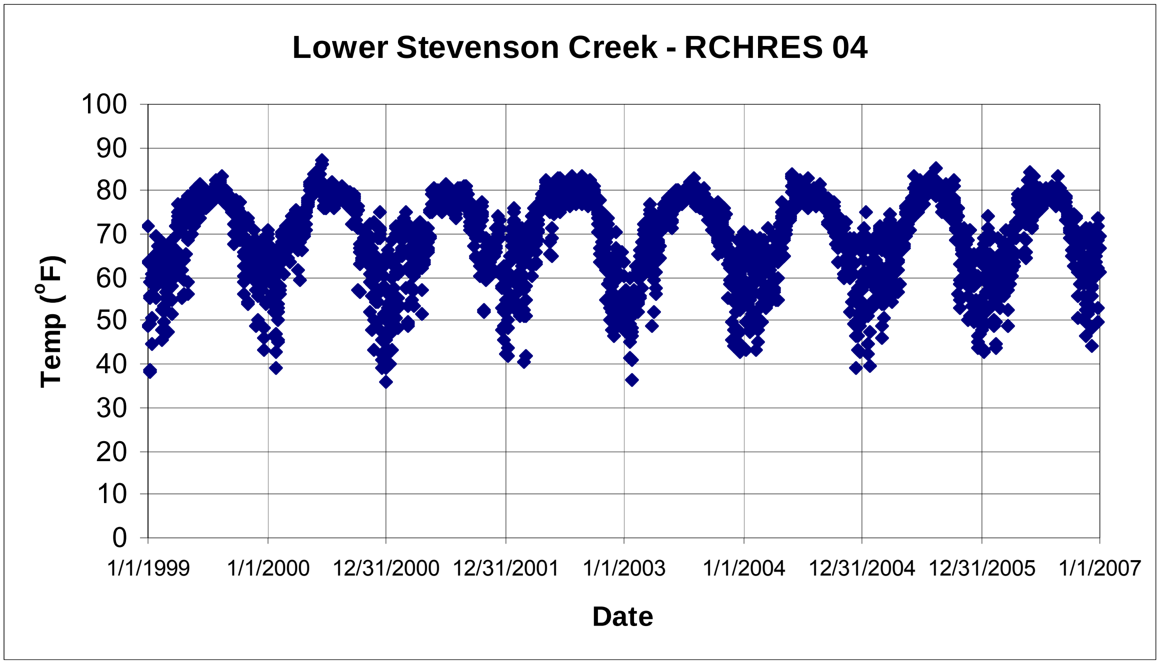


Figure 4-38 HSPF Modeled Water Temperature in Lower Stevenson Creek

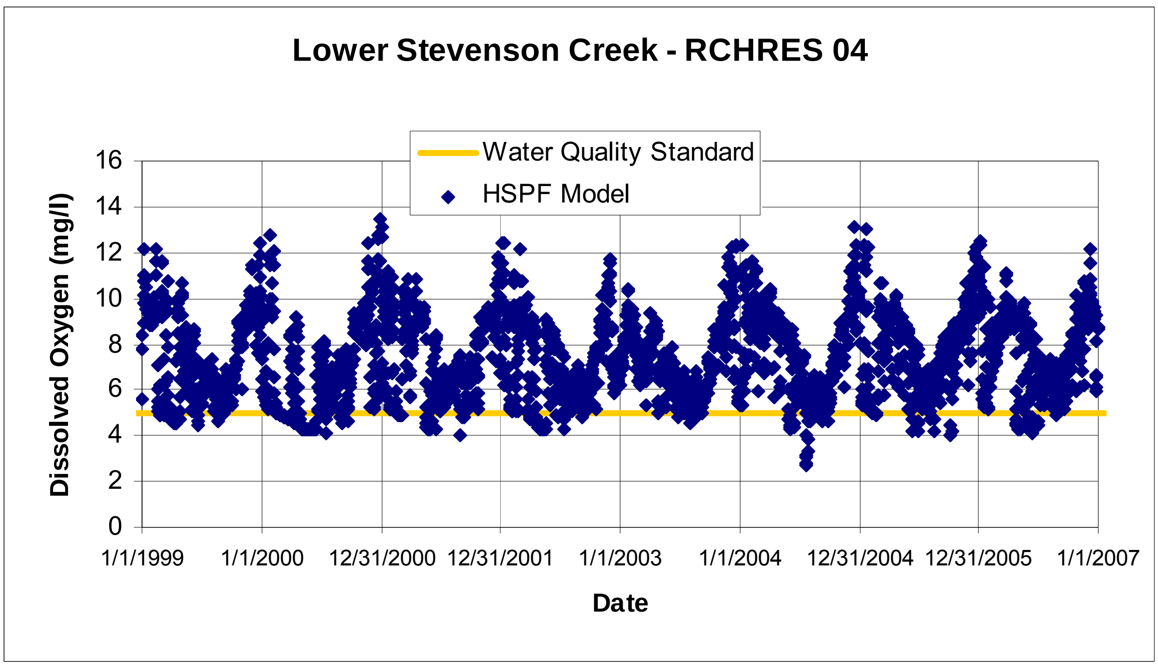


Figure 4-39 HSPF Modeled Dissolved Oxygen in Lower Stevenson Creek

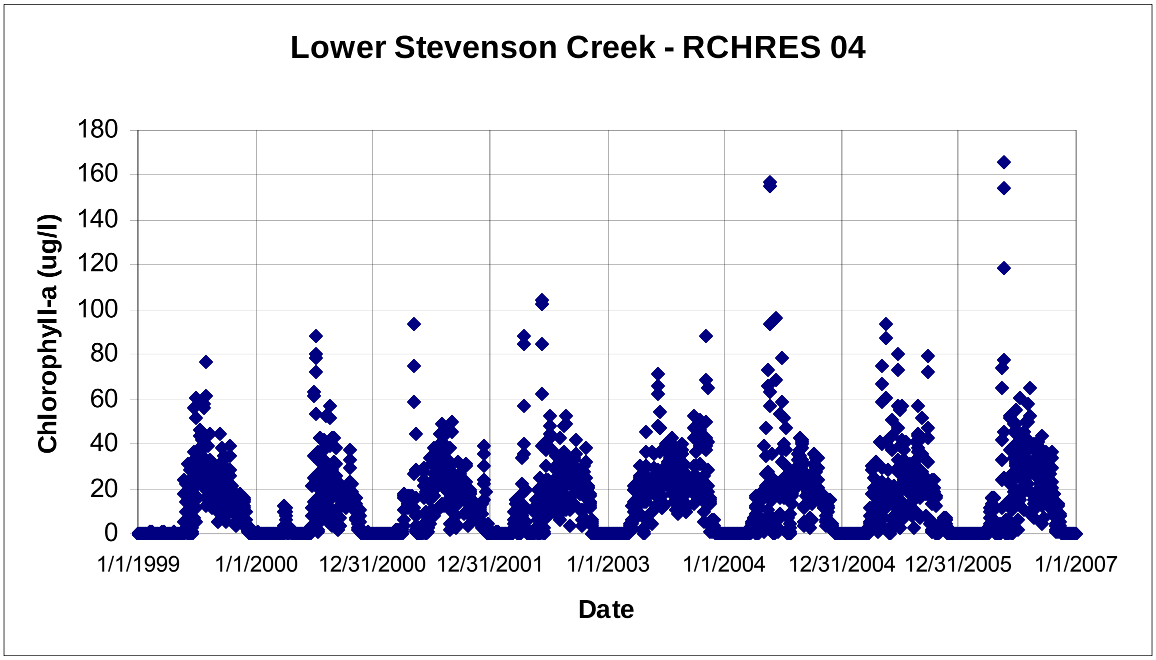


Figure 4-40 HSPF Modeled Chlorophyll-a in Lower Stevenson Creek

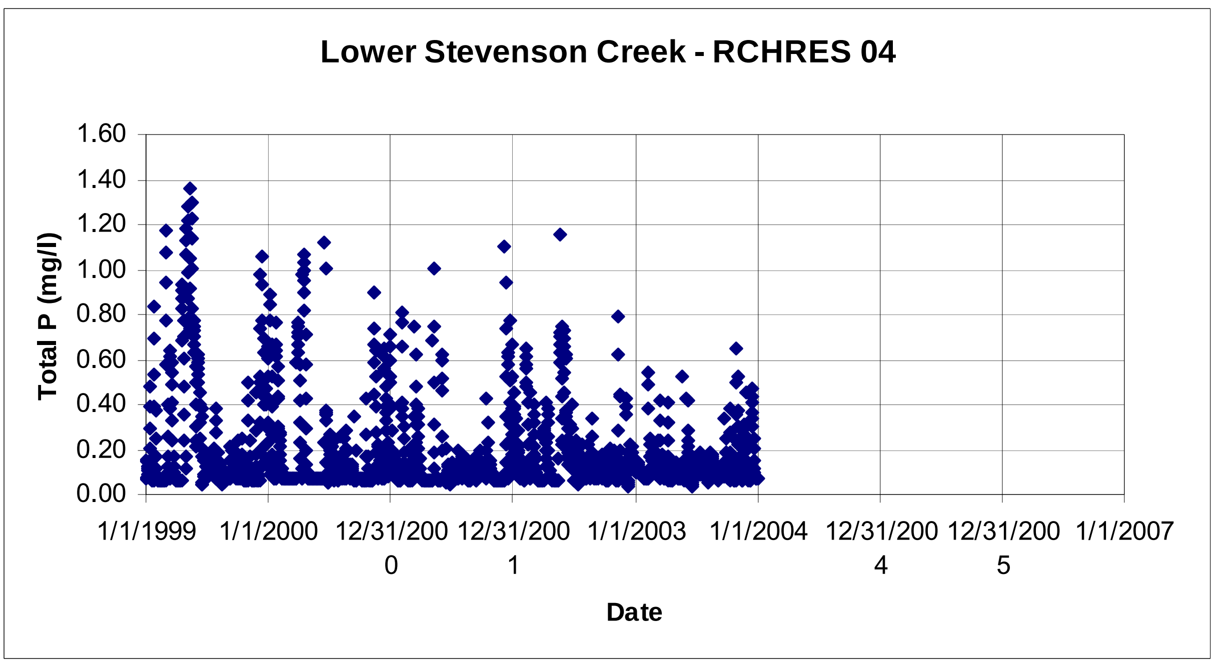


Figure 4-41 HSPF Modeled Total P in Lower Stevenson Creek

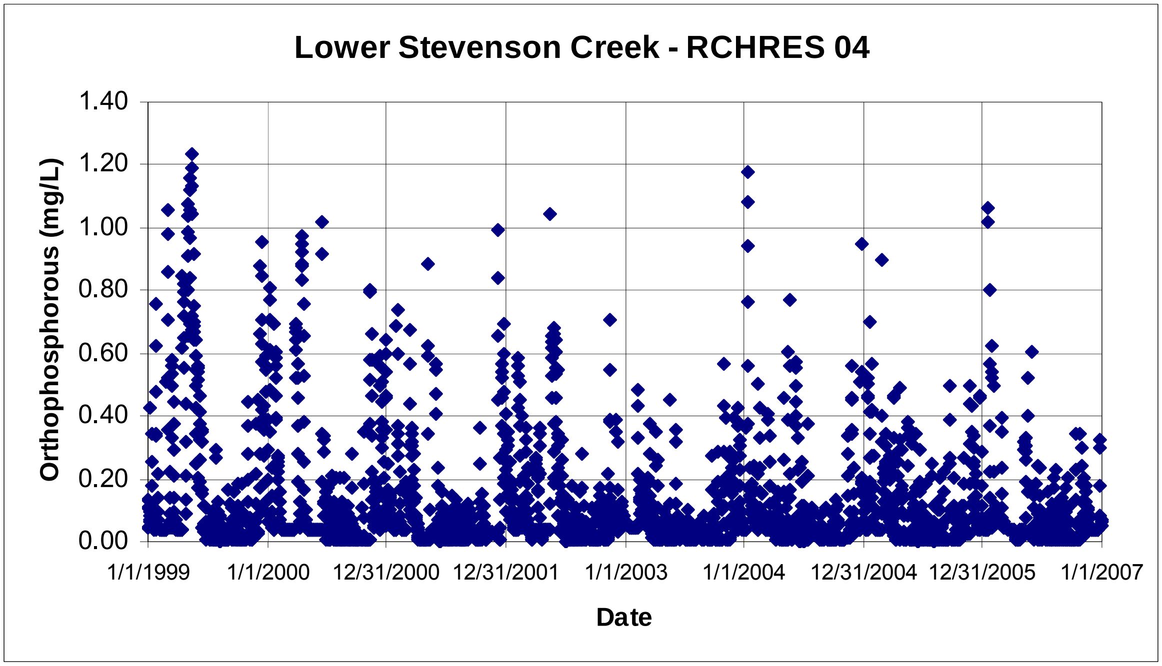


Figure 4-42 HSPF Modeled Orthophosphorus in Lower Stevenson Creek

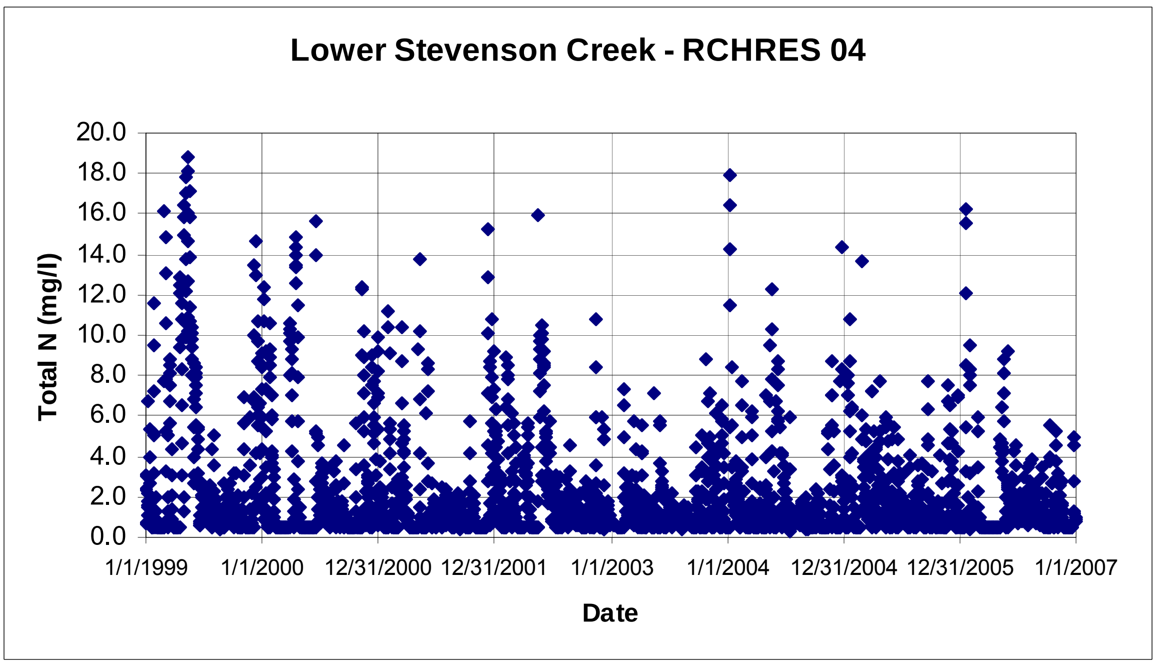


Figure 4-43 HSPF Modeled Total N in Lower Stevenson Creek

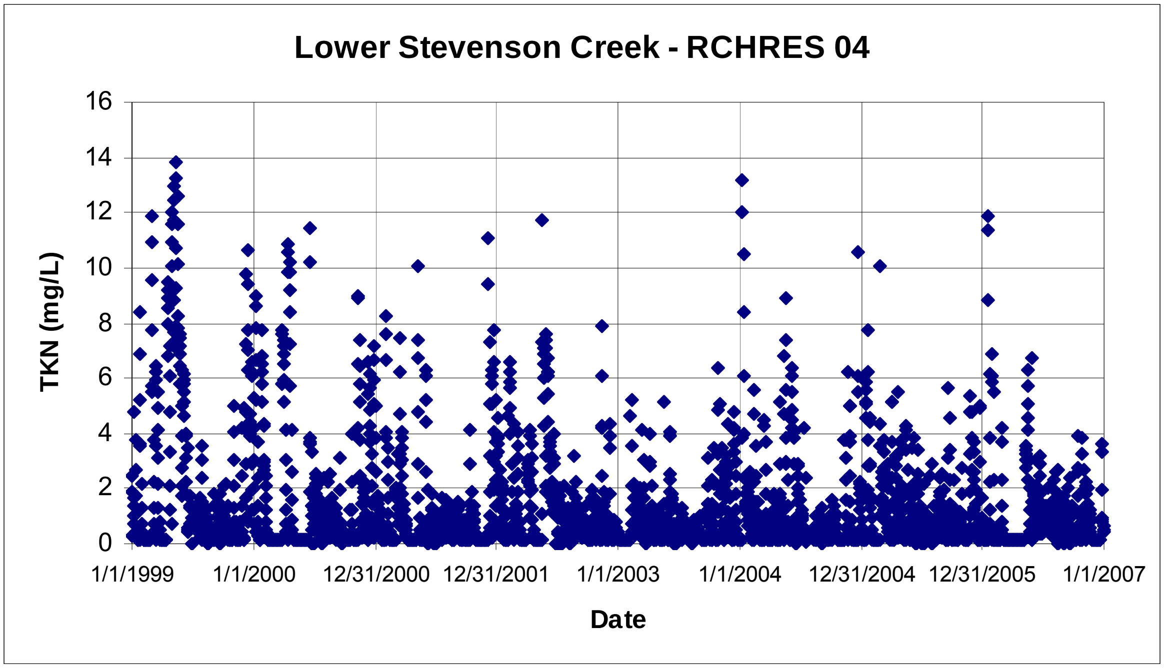


Figure 4-44 HSPF Modeled TKN in Lower Stevenson Creek

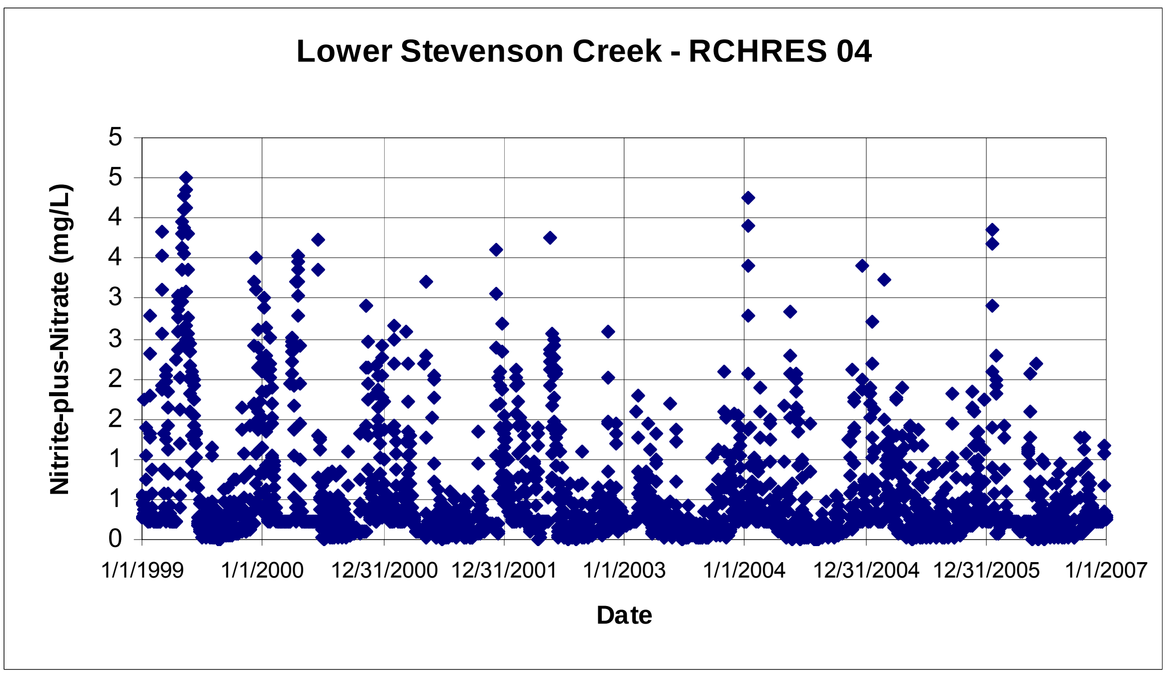


Figure 4-45 HSPF Modeled Nitrite-plus-Nitrate in Lower Stevenson Creek

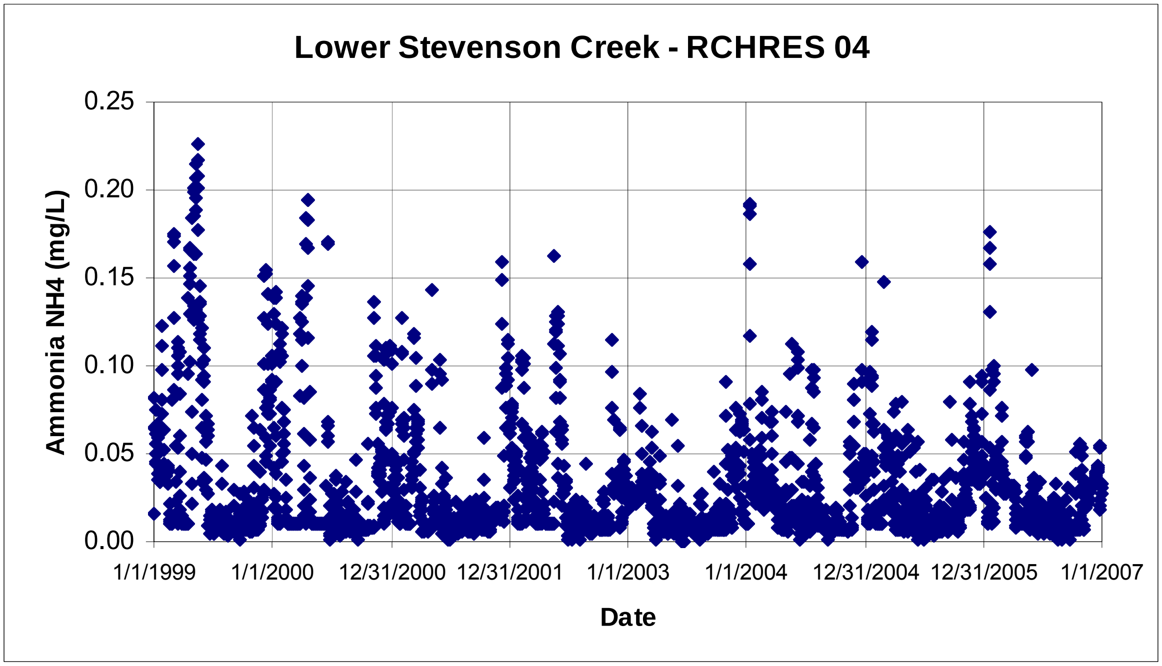


Figure 4-46 HSPF Modeled Ammonia (NH_4) in Lower Stevenson Creek

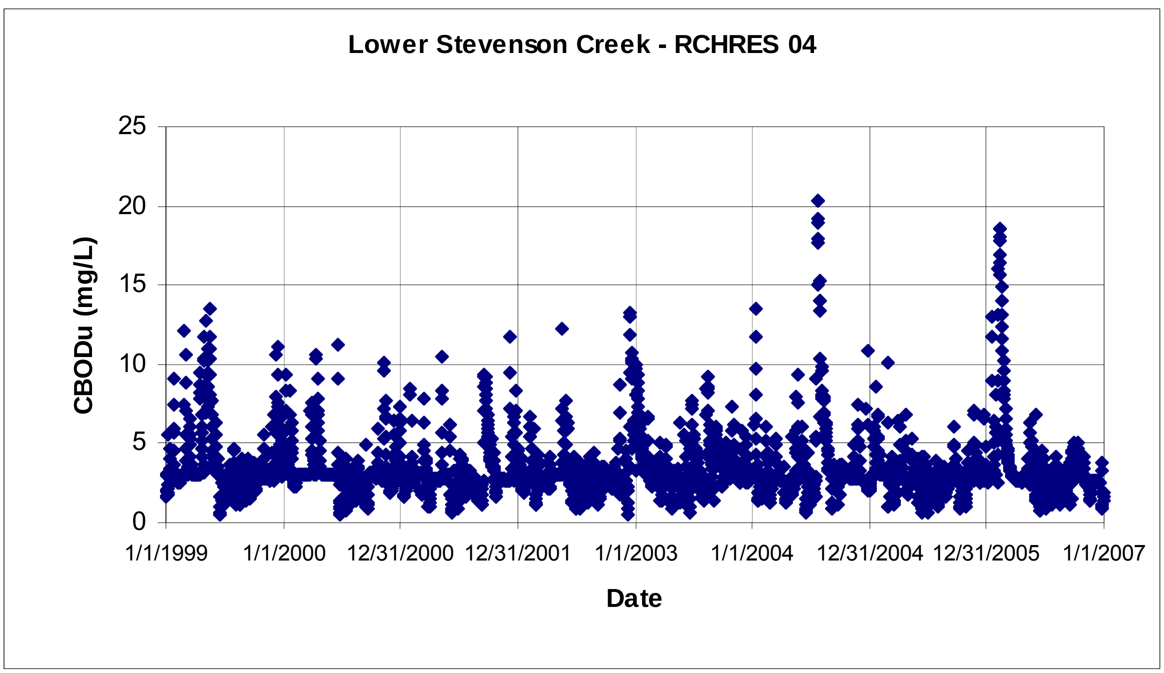


Figure 4-47 HSPF Modeled $CBOD_u$ in Lower Stevenson Creek

Table 4-26 Range of Estimated Watershed Loading for Lower Stevenson Creek

Year	Commercial / Industrial	High Density Residential / Institutional	Medium Density Residential	Low Density Residential	Transportation / Utilities	Upland Forest / Cropland	Open Land/ Recreational	Wetlands
Phosphorus (lbs/ac/year)								
2000	0.45 to 0.84	0.31 to 0.71	0.33 to 0.59	0.12 to 0.20	0.45 to 0.84	0.04 to 0.06	0.04 to 0.06	0.04 to 0.06
2001	0.68 to 1.26	0.47 to 1.07	0.50 to 0.89	0.17 to 0.31	0.68 to 1.26	0.06 to 0.09	0.06 to 0.09	0.06 to 0.09
2002	0.85 to 1.57	0.58 to 1.34	0.63 to 1.11	0.22 to 0.38	0.85 to 1.57	0.08 to 0.11	0.08 to 0.11	0.08 to 0.11
2003	0.47 to 0.87	0.32 to 0.74	0.35 to 0.61	0.12 to 0.21	0.47 to 0.87	0.04 to 0.06	0.04 to 0.06	0.04 to 0.06
2004	0.98 to 1.81	0.67 to 1.54	0.72 to 1.27	0.25 to 0.44	0.98 to 1.81	0.09 to 0.13	0.09 to 0.13	0.09 to 0.13
2005	0.67 to 1.23	0.45 to 1.05	0.49 to 0.86	0.17 to 0.30	0.67 to 1.23	0.06 to 0.09	0.06 to 0.09	0.06 to 0.09
2006	0.71 to 1.30	0.48 to 1.11	0.52 to 0.92	0.18 to 0.32	0.71 to 1.30	0.06 to 0.09	0.06 to 0.09	0.06 to 0.09
Average	**0.45 to 0.84**	**0.31 to 0.71**	**0.33 to 0.59**	**0.12 to 0.20**	**0.45 to 0.84**	**0.04 to 0.06**	**0.04 to 0.06**	**0.04 to 0.06**
NO2+NO3 (lbs/ac/year)								
2000	3.75 to 9.05	0.51 to 1.08	1.19 to 2.25	0.42 to 0.78	3.75 to 9.05	0.01 to 0.08	0.01 to 0.08	0.01 to 0.08
2001	5.64 to 13.61	0.77 to 1.62	1.78 to 3.38	0.62 to 1.17	5.64 to 13.61	0.02 to 0.12	0.02 to 0.12	0.02 to 0.12
2002	7.05 to 17.00	0.96 to 2.03	2.23 to 4.22	0.78 to 1.46	7.05 to 17.00	0.02 to 0.14	0.02 to 0.14	0.02 to 0.14
2003	3.90 to 9.41	0.54 to 1.13	1.24 to 2.34	0.43 to 0.81	3.90 to 9.41	0.01 to 0.08	0.01 to 0.08	0.01 to 0.08
2004	8.11 to 19.58	1.10 to 2.33	2.56 to 4.86	0.89 to 1.69	8.11 to 19.58	0.02 to 0.16	0.02 to 0.16	0.02 to 0.16
2005	5.50 to 13.27	0.75 to 1.58	1.74 to 3.30	0.61 to 1.15	5.50 to 13.27	0.02 to 0.11	0.02 to 0.11	0.02 to 0.11
2006	5.83 to 14.06	0.80 to 1.68	1.84 to 3.49	0.64 to 1.21	5.83 to 14.06	0.02 to 0.12	0.02 to 0.12	0.02 to 0.12
Average	**3.75 to 9.04**	**0.51 to 1.07**	**1.18 to 2.24**	**0.41 to 0.77**	**3.75 to 9.04**	**0.00 to 0.07**	**0.00 to 0.07**	**0.00 to 0.07**
Ultimate $CBOD_u$ (lbs/ac/year)								
2000	46.22 to 68.27	37.52 to 72.72	22.08 to 32.55	7.71 to 11.32	46.22 to 68.27	5.43 to 25.09	5.43 to 25.09	5.43 to 25.09
2001	69.48 to 102.65	56.38 to 109.35	33.16 to 48.91	11.54 to 16.98	69.48 to 102.65	8.10 to 37.69	8.10 to 37.69	8.10 to 37.69
2002	86.78 to 128.22	70.41 to 136.59	41.40 to 61.08	14.38 to 21.18	86.78 to 128.22	10.09 to 47.06	10.09 to 47.06	10.09 to 47.06
2003	48.05 to 70.98	39.00 to 75.61	22.96 to 33.84	8.01 to 11.77	48.05 to 70.98	5.64 to 26.09	5.64 to 26.09	5.64 to 26.09
2004	99.90 to 147.63	81.06 to 157.26	47.66 to 70.31	16.54 to 24.37	99.90 to 147.63	11.60 to 54.17	11.60 to 54.17	11.60 to 54.17
2005	67.76 to 100.11	54.99 to 106.64	32.34 to 47.70	11.25 to 16.56	67.76 to 100.11	7.91 to 36.76	7.91 to 36.76	7.91 to 36.76
2006	71.79 to 106.07	58.25 to 112.98	34.26 to 50.53	11.92 to 17.54	71.79 to 106.07	8.37 to 38.94	8.37 to 38.94	8.37 to 38.94
Average	**31.59 to 46.70**	**25.62 to 49.74**	**15.05 to 22.22**	**5.20 to 7.68**	**31.59 to 46.70**	**3.64 to 17.11**	**3.64 to 17.11**	**3.64 to 17.11**
TKN (lbs/ac/year)								
2000	4.12 to 6.62	2.89 to 4.91	2.13 to 3.29	0.74 to 1.14	4.12 to 6.62	0.18 to 0.36	0.18 to 0.36	0.18 to 0.36
2001	6.20 to 9.96	4.34 to 7.38	3.20 to 4.95	1.11 to 1.72	6.20 to 9.96	0.26 to 0.53	0.26 to 0.53	0.26 to 0.53
2002	7.74 to 12.44	5.42 to 9.22	4.00 to 6.18	1.39 to 2.14	7.74 to 12.44	0.33 to 0.66	0.33 to 0.66	0.33 to 0.66
2003	4.29 to 6.89	3.00 to 5.10	2.22 to 3.42	0.77 to 1.19	4.29 to 6.89	0.19 to 0.37	0.19 to 0.37	0.19 to 0.37
2004	8.91 to 14.32	6.24 to 10.61	4.60 to 7.11	1.60 to 2.46	8.91 to 14.32	0.38 to 0.76	0.38 to 0.76	0.38 to 0.76
2005	6.04 to 9.71	4.24 to 7.20	3.12 to 4.82	1.09 to 1.67	6.04 to 9.71	0.26 to 0.52	0.26 to 0.52	0.26 to 0.52
2006	6.40 to 10.29	4.49 to 7.63	3.31 to 5.11	1.15 to 1.77	6.40 to 10.29	0.27 to 0.55	0.27 to 0.55	0.27 to 0.55

Average	6.24 to 10.03	4.38 to 7.44	3.23 to 4.98	1.12 to 1.73	6.24 to 10.03	0.27 to 0.53	0.27 to 0.53	0.27 to 0.53

Table 4-27 Simulated Watershed Annual Loading Rates for Lower Stevenson Creek

Year	Commercial/Industrial	High Density Residential	Medium Density Residential	Low Density Residential	Transportation/ Utilities	Upland Forest/Cropland	Open Land/ Recreational	Wetlands	Total
Orthophosphorus (lb/acre/year)									
2000	0.52	0.52	0.46	0.14	0.76	0.05	0.03	0.04	2.52
2001	0.42	0.41	0.35	0.09	0.63	0.02	0.01	0.01	1.94
2002	0.53	0.52	0.47	0.15	0.75	0.07	0.03	0.05	2.57
2003	0.7	0.65	0.59	0.18	0.95	0.08	0.03	0.06	3.24
2004	0.68	0.7	0.68	0.3	0.94	0.16	0.06	0.14	3.66
2005	1.01	0.71	0.78	0.31	0.94	0.22	0.04	0.12	4.13
2006	0.57	0.56	0.48	0.12	0.84	0.03	0.02	0.02	2.64
Average	**0.61**	**0.53**	**0.49**	**0.15**	**0.78**	**0.08**	**0.02**	**0.04**	**2.7**
Nitrite-plus-Nitrate (lb/acre/year)									
2000	5.78	0.63	1.68	0.41	4.85	0.05	0.01	0.01	13.42
2001	4.36	0.46	1.26	0.28	4	0.02	0.01	0	10.39
2002	5.51	0.68	1.71	0.44	4.72	0.05	0.01	0.01	13.13
2003	7.11	0.73	2.07	0.51	5.99	0.05	0.01	0.01	16.48
2004	7.46	1.17	2.59	0.79	5.74	0.11	0.03	0.04	17.93
2005	6.95	1.04	2.38	0.7	5.66	0.09	0.02	0.03	16.87
2006	6.13	0.54	1.71	0.38	5.37	0.03	0.01	0.01	14.18
Average	**5.67**	**0.64**	**1.68**	**0.41**	**4.85**	**0.04**	**0.01**	**0.01**	**13.31**
$CBOD_u$ (lb/acre/year)									
2000	34.7	19	6.79	6.21	34.9	7.7	7.35	3.12	119.77
2001	28	13.7	3.14	3.02	28.1	3.54	3.96	1.01	84.47
2002	35.3	23	12.4	8.09	35.8	11.3	8.33	4.63	138.85
2003	45	29.9	16.7	9.15	45.5	13	11.3	5.35	175.9
2004	47.1	40.8	31.5	19.5	47.7	24.4	16.5	11.9	239.4
2005	54.2	64.3	62.2	23	55.4	34.4	15.7	10.6	319.8
2006	37.7	18.5	4.2	4.13	37.8	4.82	4.89	1.29	113.33
Average	**37**	**26**	**15.8**	**7.87**	**38.3**	**13.2**	**7.35**	**3.47**	**148.99**
TKN (lb/acre/year)									
2000	6.95	4.81	4.58	1.18	6.64	0.29	0.27	0.25	24.97
2001	5.23	3.84	3.74	0.88	5.21	0.14	0.15	0.08	19.27
2002	6.26	4.78	4.49	1.18	6.23	0.35	0.32	0.34	23.95
2003	7.9	5.92	5.66	1.43	7.86	0.38	0.45	0.4	30
2004	7.8	6.36	5.63	1.75	7.72	0.77	0.65	0.95	31.63
2005	7.63	6.08	5.48	1.62	7.55	0.82	0.61	0.79	30.58
2006	7.04	5.15	5.03	1.19	7.01	0.19	0.19	0.11	25.91
Average	**6.4**	**4.82**	**4.59**	**1.16**	**6.37**	**0.34**	**0.29**	**0.27**	**24.24**

Table 4-28 HSPF Simulated Total P Budget for Lower Stevenson Creek

Calendar Year	Annual TP Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	211	31	48	0	-290	-1
2000	172	7	23	0	-203	0
2001	207	86	54	0	-348	-1
2002	265	119	57	0	-442	-1
2003	254	213	129	0	-600	-3
2004	263	467	100	0	-834	-4
2005	231	7	33	0	-272	-1
2006	218	136	44	0	-400	-1
Average	228	133	61	0	-424	-2

Table 4-29 HSPF Simulated Total N Budget for Lower Stevenson Creek

Calendar Year	Annual TN Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	1596	87	536	0	-2228	-8
2000	1298	23	265	0	-1591	-6
2001	1508	241	611	0	-2373	-12
2002	1884	337	648	0	-2883	-14
2003	1793	594	1462	0	-3872	-23
2004	1811	1322	1130	0	-4293	-31
2005	1687	22	373	0	-2091	-8
2006	1567	389	496	0	-2465	-13
Average	1643	377	690	0	-2725	-14

Table 4-30 HSPF Simulated $CBOD_u$ Budget for Lower Stevenson Creek

Calendar Year	Annual $CBOD_u$ Load (pounds per year)					
	Inflow from Runoff	Inflow from Interflow	Inflow from Baseflow	Stream Surface Rainfall	Reach Outflow	Change in Reach Mass
1999	6324	1972	2133	0	-9847	582
2000	5168	513	1051	0	-6340	392
2001	6127	5496	2425	0	-13335	712
2002	7753	7679	2574	0	-17304	701
2003	7394	13515	5785	0	-25468	1227
2004	7285	30308	4460	0	-40739	1314
2005	6945	492	1492	0	-8433	496
2006	6291	8933	1964	0	-16483	705
Average	6661	8614	2736	0	-17244	766

4.4 HSPF Flow and Loads to Tidal Stevenson Creek

Table 4-31 presents a summary of model results for each sub-watershed that discharges to tidal Stevenson Creek (i.e., Lower Stevenson Creek). The data in the table include the average annual unit flow (inches per year over the subwatershed), load (pounds per acre per year), and flow-weighted concentration (milligrams per liter). The subwatersheds having the highest levels of urban development (e.g., Upper Stevenson Creek) have the highest unit loads.

4.5 HSPF Model Sensitivity

This section presents a discussion of model sensitivity to various parameters observed during calibration of the HSPF model.

4.5.1 Streamflow Rate

As noted previously, a large effort was invested to improve the HSPF simulated streamflow rates. During the course of the model calibration, most model parameters that are relevant to streamflow rate were found to be relatively insensitive, that is, large variations in the parameters magnitudes resulted in very small streamflow rate variations. For example, variations of up to 50% in soil infiltration capacity resulted in an average of 3% difference in streamflow rate.

Percent impervious cover, on the other hand, was a sensitive parameter. Reductions of impervious cover by 20% yielded similar reductions in peak flow. Although percent impervious cover was a fairly sensitive parameter, its use to adjust model results was limited for two reasons: (1) land use is well characterized in the Stevenson Creek Watershed and thus is not subject to significant adjustments and (2) percent impervious cover is specified by the FDEP TMDL protocol and thus can only be adjusted within the range in the protocol. Thus, as mentioned previously, the percent impervious cover was pushed to the minimum allowed by the FDEP TMDL protocol to minimize the peak flows from the watershed to the greatest extent practicable.

Table 4-31 Average Annual Flows and Loads from Stevenson Creek Sub-watersheds

Constituent	Units	Subwatershed			
		Hammond Branch	Spring Branch	Upper Stevenson Creek	Lower Stevenson Creek
Flow	inches/yr	21.1	20.9	23.7	21.5
$CBOD_u$	lb/ac/yr	34.79	23.54	38.04	23.02
	mg/l	5.97	4.09	5.84	3.89
DO	lb/ac/yr	23.34	22.92	34.11	36.73
	mg/l	4.01	3.98	5.24	6.21
Ammonia	lb/ac/yr	0.14	0.12	0.36	0.12
	mg/l	0.02	0.02	0.06	0.02
Nitrite-plus-Nitrate	lb/ac/yr	1.80	2.02	3.05	1.75
	mg/l	0.31	0.35	0.47	0.30
TKN	lb/ac/yr	1.91	4.82	4.28	5.45
	mg/l	0.33	0.84	0.66	0.92
Total P	lb/ac/yr	0.79	0.77	1.06	0.84
	mg/l	0.14	0.13	0.16	0.14
Total N	lb/ac/yr	5.16	7.94	9.16	8.95
	mg/l	0.89	1.38	1.41	1.51
Chlorophyll-a	lb/ac/yr	0.69	14.65	32.52	84.10
	mg/l	0.12	2.54	4.99	14.22
Orthophosphorous	lb/ac/yr	0.47	0.52	0.65	0.47
	mg/l	0.08	0.09	0.10	0.08

4.5.2 Water Quality

Numerous water quality parameters were used to calibrate the HSPF model to observed in-stream nutrients, chlorophyll-a, $CBOD_u$ and DO concentrations. During the course of the model calibration, several parameters were found to be useful in adjusting water quality parameters, including watershed loadings, sediment oxygen demand (SOD), and the algal growth rate. These parameters were the focus of the calibration process and the impact of changing these parameters is as follows:

- Watershed loadings were found to be fairly sensitive and useful for matching estimated watershed loads and in-stream water quality concentrations. For example, reductions in pervious and impervious watershed loadings by 50% resulted in in-stream $CBOD_u$ concentration reductions on average by 30%. Similar results were seen for other nutrient species, such as orthophosphorous, nitrate-plus-nitrite, TKN, and ammonia.
- SOD is another parameter that was found to be fairly sensitive through the course of model calibration. For example, increases in the SOD rate by 10% for reach 3 (i.e., Upper Stevenson Creek) resulted in increased DO concentrations by approximately 2%. Larger increases would result in even higher DO concentrations.
- The algal growth rate was a parameter that was found to be extremely sensitive for chlorophyll-a concentrations. During the calibration, increases of around 50% resulted in significantly more in-stream chlorophyll-a, with typical increases exceeding 1,000%. Thus, this parameter was key in calibrating chlorophyll-a.

4.6 EFDC MODEL DEVELOPMENT

The following summarizes the development of the site-specific hydrodynamic and water quality model of the tidally influenced region of Stevenson Creek. The Environmental Fluid Dynamic Code (EFDC) (Hamrick, 1996) model was set-up, refined, calibrated, and validated to available observed data. The EFDC pre- and post-processing utility used for this study is EFDC_Explorer (Craig, 2004).

4.6.1 Grid Development

Grid development is a critical component of any hydrodynamic modeling study. A model grid is the result of a balance of spatial resolution, site conceptual model and modeling objectives against the computational time and resources. High resolution grids can produce excellent horizontal and vertical detail but if the run times are excessive then the modeling study will fail due to the inability to produce enough runs to obtain good calibration, verification and target scenarios.

In order to test the appropriate grid resolution for Stevenson Creek, a number of grids were developed. The final grid contained 241 horizontal grid cells. The grid was developed using the Delft RGFGrid (Delft, 2006) program. The grid created by RGFGrid was configured for EFDC by importing the GRD file into EFDC_Explorer . Final minor editing to the grid was performed using EFDC_Explorer. **Figure 4-48** provides a plot of the final grid for the Stevenson Creek EFDC model and shows some of the IJ indices for reference. The final grid represents a balance between the grid resolution needed for the TMDL and the computational resources required.

This grid incorporates the comments received from FDEP and addresses all of the critical components needed for the Stevenson Creek water quality modeling. Water quality simulations for the fresh water tributaries to the tidal zone of Stevenson Creek were addressed by the HSPF model component. HSPF provided the water quality loadings at the boundaries of the Stevenson Creek EFDC model.

The EFDC model grid was configured with 4 vertical layers to address the density dependent dynamics due to salinity and temperature profiles. Each layer represents 25% of the water depth for each cell.

4.6.2 Bathymetry

Bathymetric data are required to build the receiving water quality model of Stevenson Creek. The bathymetry of a system has significant impacts on the simulation results. Bathymetric data were obtained from two main data sources. The primary data were collected in 2001 for the US Army Corps of Engineers (USACE) dredging project (Johnson MacAdams, 2001). A second source of data was NOAA NOS bathymetry data (http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html) for the Clearwater Harbor portion of the model domain. These data were obtained and converted to common horizontal (UTM NAD83 meters) and vertical (mean low water (MLW) in meters) datums. **Figure 4-49** shows the composite data for the model domain. Each XYZ data point was plotted as a small colored symbol. The color of the symbol represents the elevation of the data point.

No bathymetric data was available for the short section of Stevenson Creek above the Marshall AWWTP. A distance of about 1200 feet was estimated using a bottom slope of 0.0001 from the last cell that contained measured bathymetry. The final bathymetry interpolated onto the final grid is shown in **Figure 4-50**.

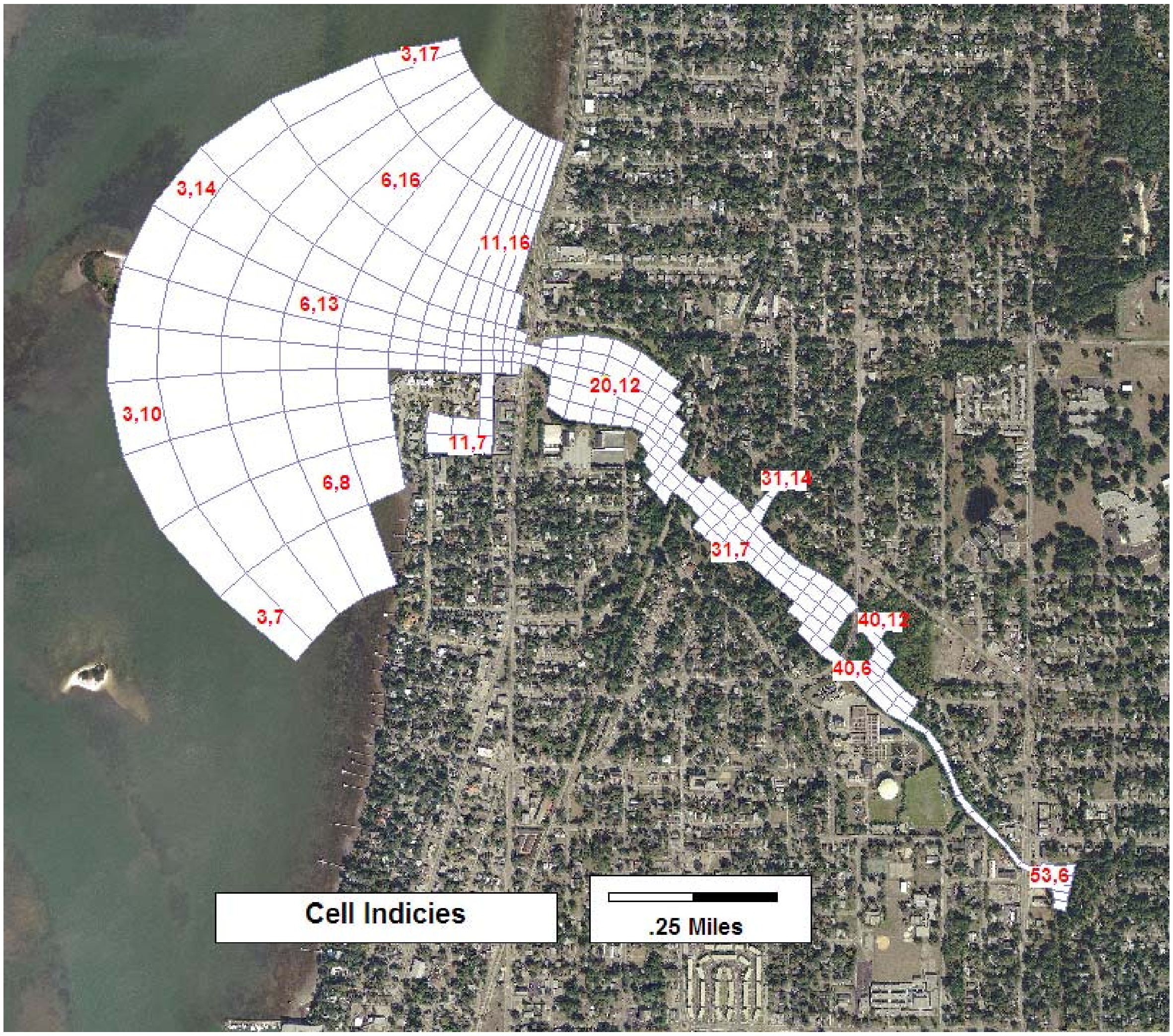


Figure 4-48 Stevenson Creek EFDC Model Grid with Cell Indices.

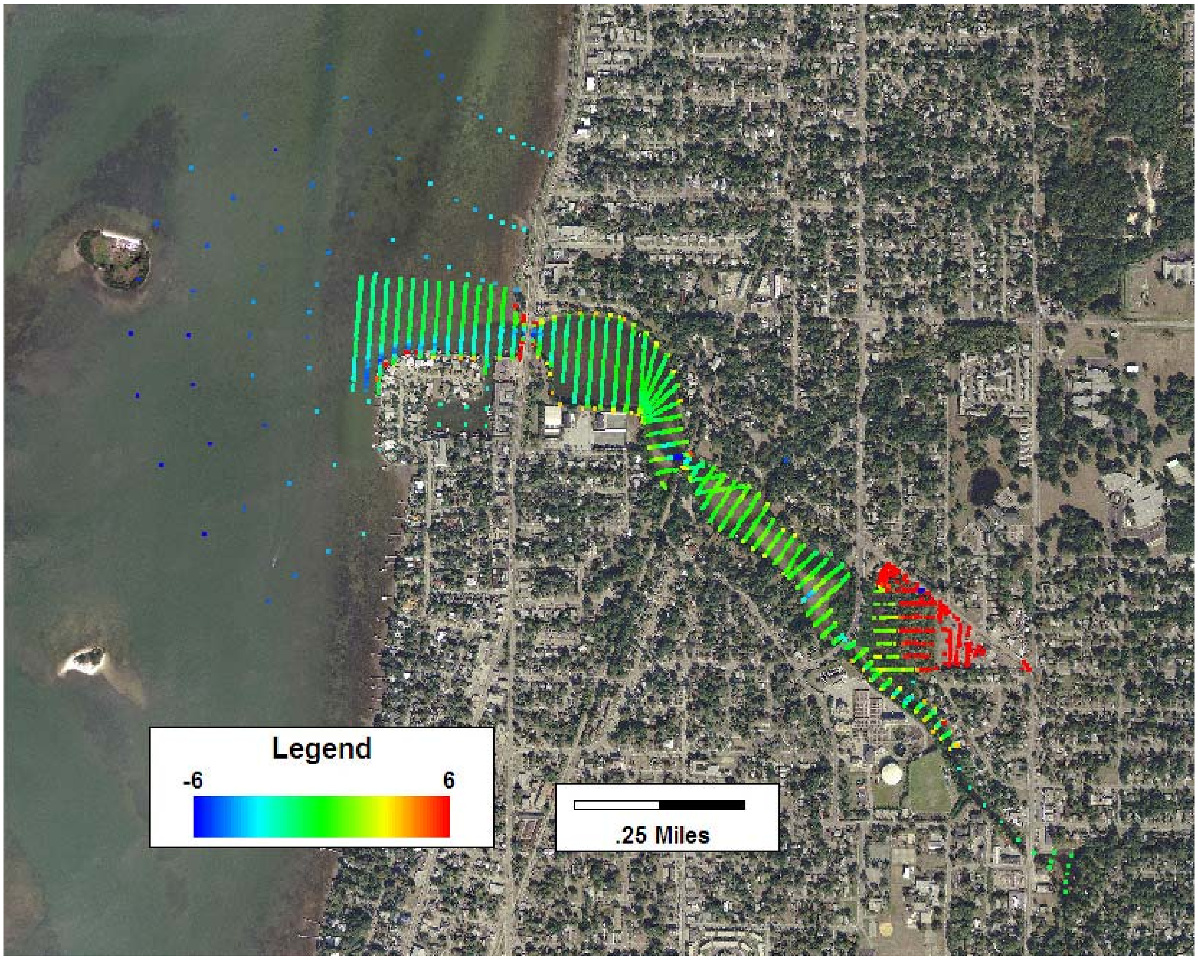


Figure 4-49 Map of the Bathymetric Data (datum: MLW) for the Stevenson Creek and Coastal Region.

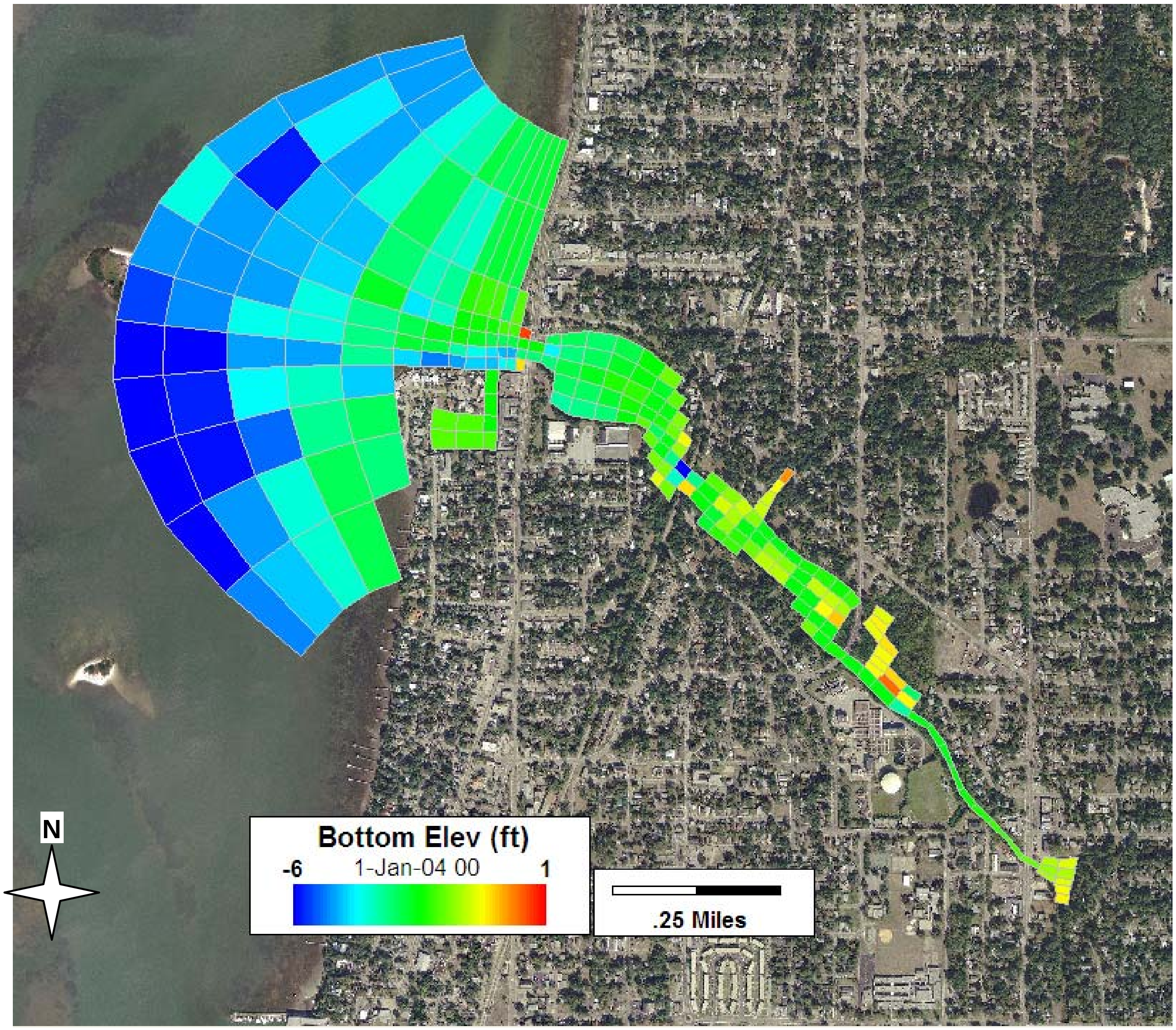


Figure 4-50 Lower Stevenson Creek Model Bathymetry (MLW).

4.6.3 Boundary Conditions

Once the final grid and bathymetry were determined, the boundary conditions were assigned to the appropriate grid cells based on location and type. The Stevenson Creek model used only two boundary types; open boundaries used for tidal forcings and specified flow boundaries. **Figure 4-51** shows the EFDC model grid with the boundary condition locations identified and labeled by boundary group. An EFDC boundary group is defined as a collection of one or more EFDC model cells that comprise one logical inflow/forcing (e.g. a single river's inflow distributed across several river cells).

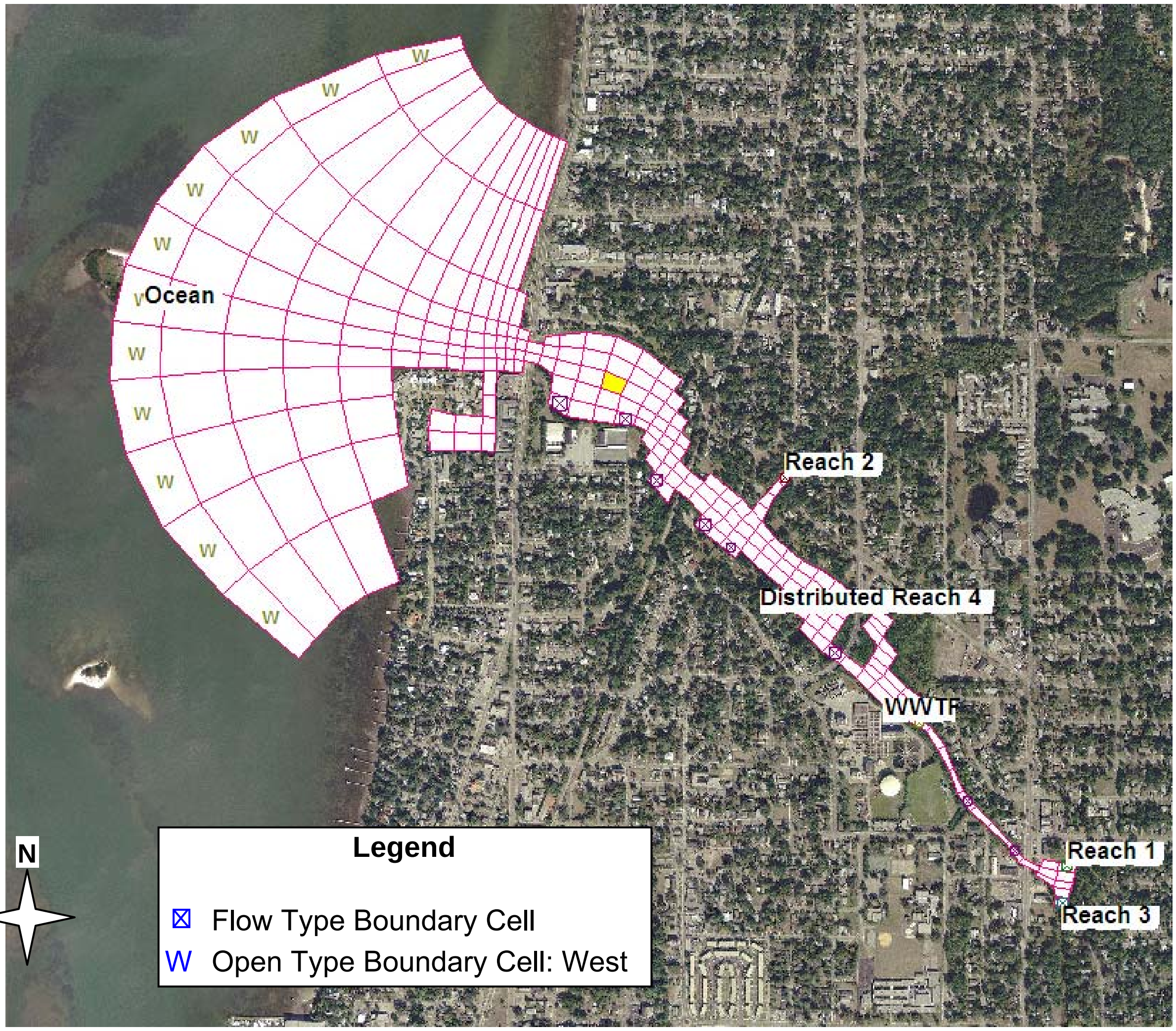


Figure 4-51 Stevenson Creek Boundary Conditions Location Map.

Flow Boundaries

The HSPF model results presented earlier provided the watershed generated inflows and pollutant loadings to Stevenson Creek. In addition to the watershed loadings, the Marshall Advanced Waste Water Treatment Plant (AWWTP) provides pollutant loadings to this region of Stevenson Creek.

The following summarizes the EFDC flow boundary groups' linkage to the HSPF results:

Reach 1 → Upstream East direct runoff (Hammond Branch)

Reach 2 → Middle north-east direct runoff (Spring Branch)

Reach 3 → Upstream South direct runoff (Upper Stevenson Creek)

Reach 4 → Distributed inflows from the Lower Stevenson Creek sub-watershed

WWTF → Effluent flows and pollutant loadings from the Marshall AWWTP

The use of simulated flows is necessary to provide complete temporal and spatial coverage for all of the incoming flows for the simulation periods of interest. It should be noted, however, that the EFDC model is being calibrated to measured water quality data in the bayou but the EFDC model is being driven with simulated flows. This standard approach causes differences in the actual versus simulated flows and loadings. These differences in the loadings produced differences in the computed water quality of the receiving stream.

Open Boundary

An open boundary was set for the cells along the western edge of the model that corresponds to Clearwater Harbor (see Figure 4-51). The "W" label identifies the open ocean boundary as a "West" open boundary, in relation to the EFDC IJ map.

The hydrodynamic forcings at this boundary were set using model results from a large scale model of Clearwater Harbor and St. Josephs Sound. Water levels, temperature and salinity used for this boundary condition were derived from this large scale model. **Appendix A** contains a brief description of the Clearwater Harbor and St. Josephs Sound model.

The water quality data at the open boundary of Stevenson Creek was defined using the observed water quality data at the Clearwater Harbor Station, North (Station ID W2) (Pinellas County water quality database).

Summary of Boundary Condition Impacts

In general, the boundary condition impacts in the model are as follows:

- The tidal portion of Stevenson Creek is relatively short (about 7500 ft). With a daily tide fluctuation magnitude of up to 5 feet, the hydrodynamic regime of the tidal creek is controlled by the tidal boundary.
- During the dry season (typically November through May), the hydrodynamics and water quality are largely controlled by the open ocean boundary and wastewater discharge from the Marshall Street AWWTP.
- During the wet season and other wet-weather periods, the freshwater reaches (HSPF reaches 1-4) have greater impact in the tidal creek.

4.6.4 Available Data for Calibration/Validation

The data needed for calibration of a model is slightly different than that needed for definition of boundary conditions. The model boundaries must have data or a defensible approach (e.g. the HSPF simulation results used for this study) for all boundaries for the entire period of the simulation. However, for calibration, the data can be either sparse or robust, but it must be internal to the model domain, or at least not negatively impacted by a boundary condition. For Stevenson Creek, there are several stations that meet the various data requirements for calibration and validation of the EFDC water quality model. The following list summarizes the specific data sources used for this study:

Tide Signal Calibration: Relative water depth in Stevenson Creek at Harrison, Pinellas and Douglas bridges collected by the USACE during the period of 25th through the 26th of June 2002 (personal communication with the USACE).

Hydrodynamic and Water Quality Calibration: Data was collected at a number of stations along Stevenson Creek and up some of the tributaries by the FDEP Southwest District office. The four stations that were used were TP282 (ID , TP283, TP284 and TP285 . See Section 4.12.2 for more information.

Hydrodynamic and Water Quality Validation: Data from two of the Pinellas County water quality data monitoring program stations was used. The two stations were AMB 18-1 just below the Marshall Street AWWTP outfall and 21FLPDEM AMB 15-1 at the mouth of Spring Branch.

4.6.5 Model Comparison Statistics

The model-data comparison statistic selected for the calibration and validation was the Root Mean Square (RMS) error.

The RMS is calculated by the following:

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

Where:

O – The observed value,

X – The corresponding model value in space and time, and

N – The number of valid data/model pairs.

4.7 EFDC Model Calibration

The primary period selected for water quality model calibration was from January 1, 2004 to December 26, 2004. This period has an adequate set of salinity, temperature, meteorology, and water quality data for setting boundary conditions and calibrating the model.

A secondary calibration period was used in addition to the 2004 primary period. There are no tide or water level gages within the tidally influenced region of Stevenson Creek. However, the USACE collected a short record of relative water depths on the June 25-26, 2002. These data were used to calibrate the tidal fluctuations and supplement the limited data set.

The model initial conditions and boundary conditions are discussed in Section 4.11.1. The EFDC hydrodynamic and water quality model calibration results are presented in Sections 4.11.2 and 4.11.3.

4.7.1 Boundary Conditions

The EFDC model boundary condition locations are shown in Figure 4-51.

<u>Flow Type Boundary Conditions</u>

Using the HSPF model results and the EFDC model boundary definitions presented earlier, flow, temperature and salinity time series were generated for the EFDC hydrodynamic model. An example of the HSPF flow results, the flows for the calibration period of January 2004 to December 2004 are shown in **Figure 4-52**.

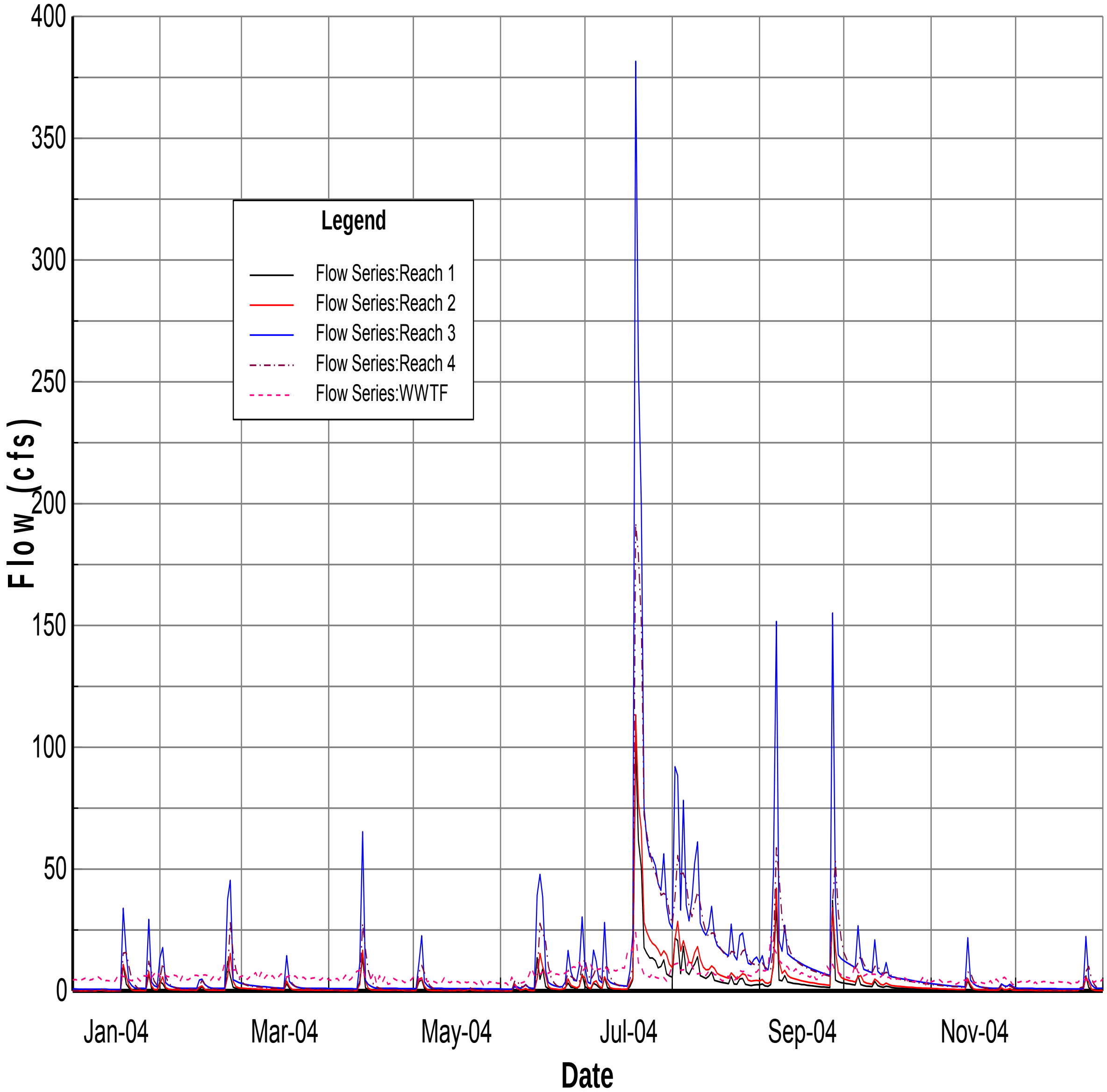


Figure 4-52 Stevenson Creek HSPF Flow Derived and Wastewater Discharged Data Boundary Conditions.

The total TP, TN, and TOC mass loadings contributed by the flow type boundary groups (the stream reaches and the WWTP) are given in **Table 4-32**. Mass loading time-series are presented in **Figures 4-53**, **4-54** and **4-55**.

Table 4-32 Summary of 2004 nutrient mass loadings by boundary group.

Boundary Group	Total P (Tons)			Total N (Tons)			Total C (Tons)		
	HSPF	EFDC	Percent Difference (%)	HSPF	EFDC	Percent Difference (%)	HSPF	EFDC	Percent Difference (%)
Reach 1 (Hammond Branch)	0.44	0.44	-0.043	2.23	2.23	-0.030	97.13	97.17	0.045
Reach 2 (Spring Branch)	0.52	0.52	-0.122	4.13	4.12	-0.295	100.87	100.99	0.120
Reach 3 (Upper Stevenson)	2.33	2.33	-0.007	15.58	15.58	0.006	498.74	498.84	0.020
Reach 4 (Lower Stevenson)	1.33	1.33	-0.060	10.69	10.68	-0.043	229.57	229.67	0.043
Total Watershed Load	**4.63**	**4.63**	**-0.038**	**32.62**	**32.60**	**-0.050**	**926.31**	**926.67**	**0.039**
Marshall St. AWWTP	1.33			14.82			22.19		

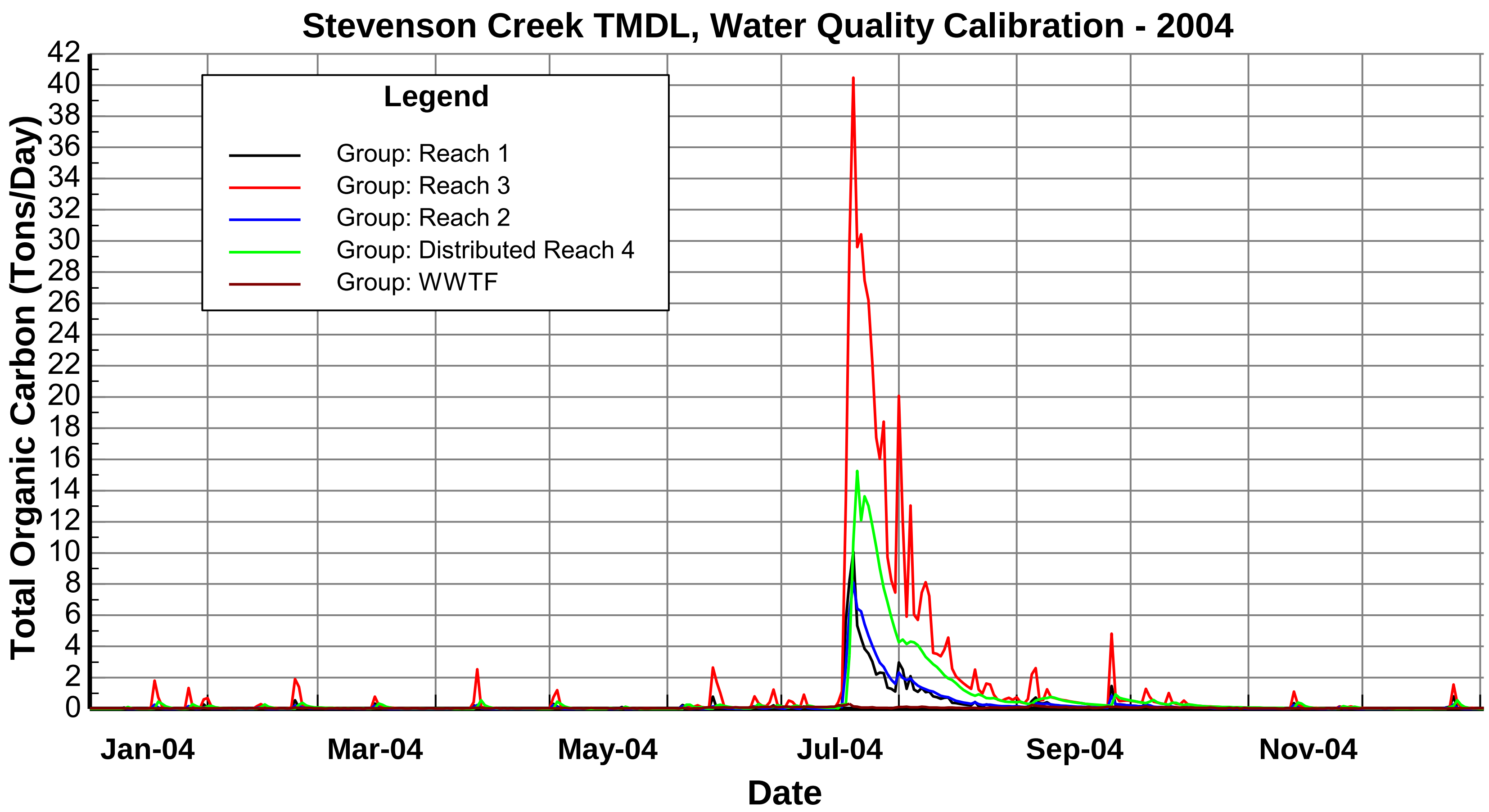


Figure 4-53 Total Organic Carbon Mass Loading by Boundary Group.

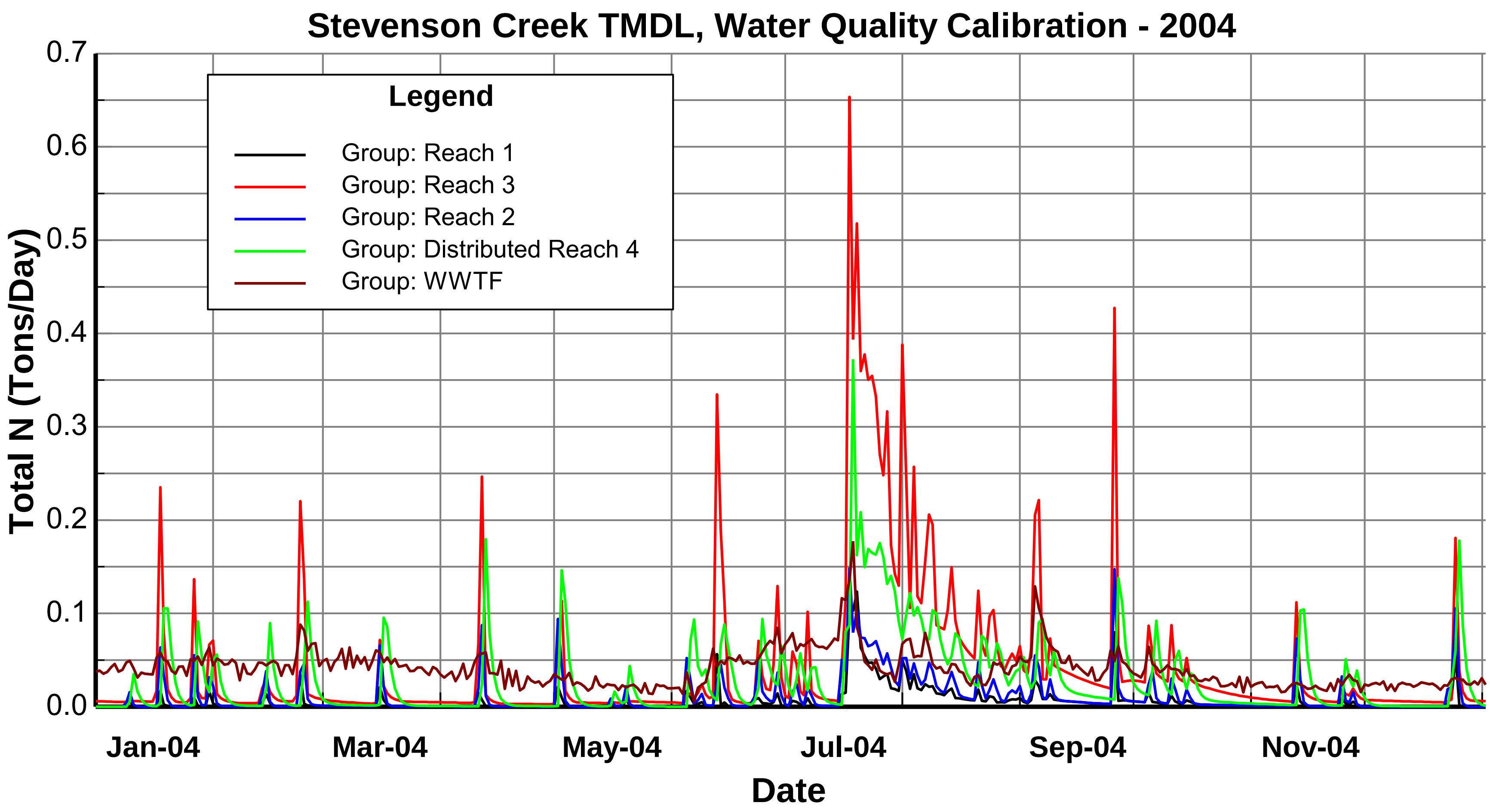


Figure 4-54 Total Nitrogen Mass Loading by Boundary Group.

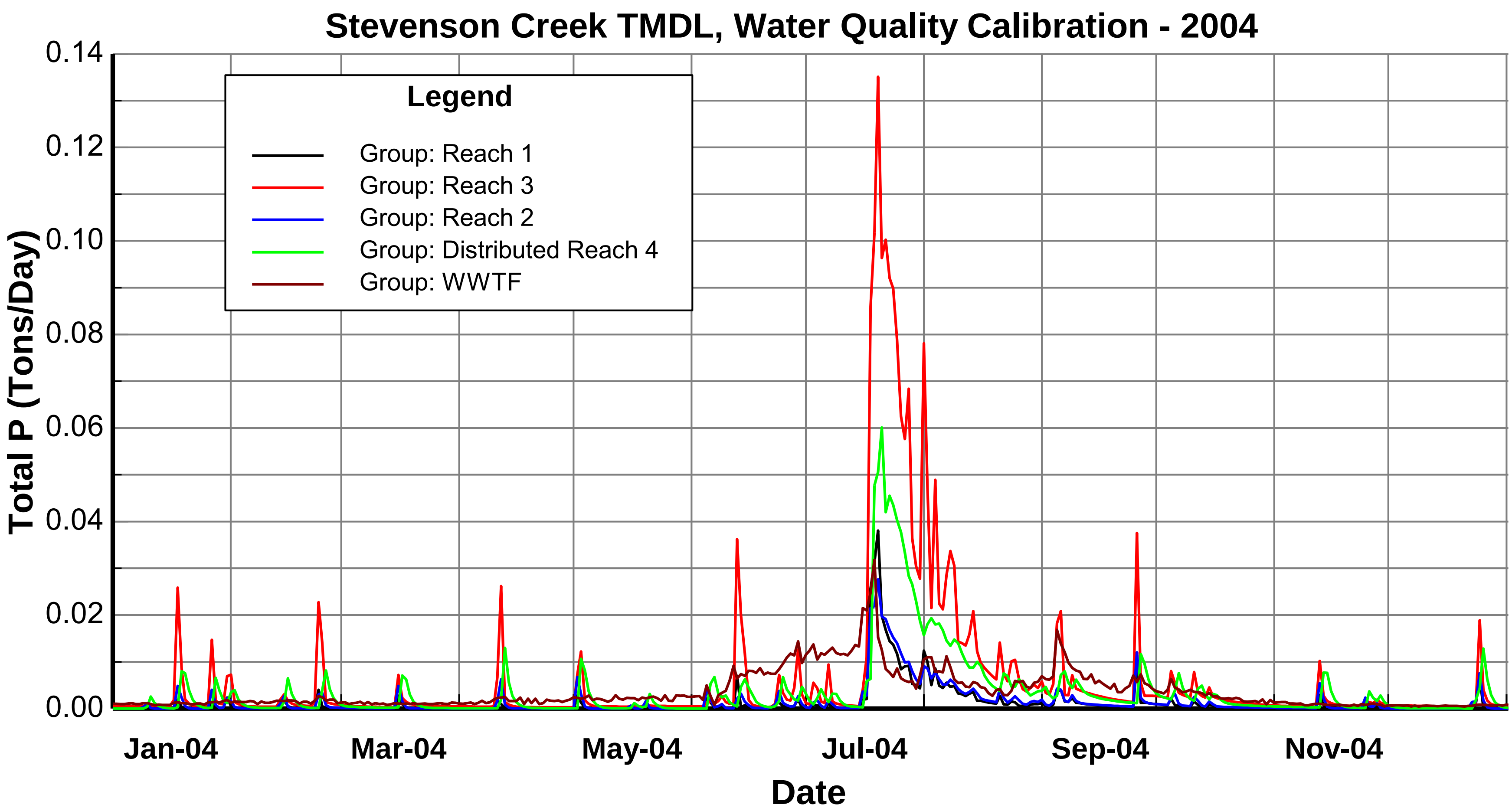


Figure 4-55 Total Phosphorus Mass Loading by Boundary Group.

Open Boundary Conditions

The open boundary of the Stevenson Creek model for water levels, salinity and temperature was defined using the large scale model (**Appendix A**). The time series of water levels for the calibration period of from January 2004 to December 2004, is shown in **Figure 4-56**.

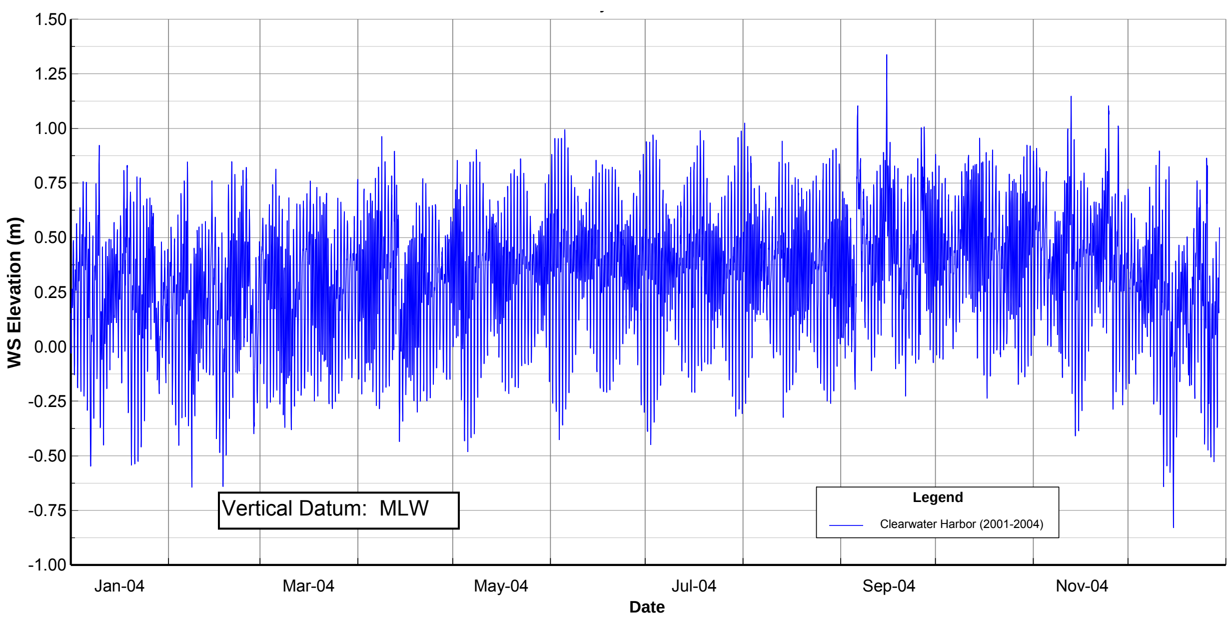


Figure 4-56 Clearwater Harbor Open Boundary Tide Series.

Atmospheric and Wind Boundary Conditions

Winds and atmospheric conditions are incorporated into a hydrodynamic model to address wind mixing, wind derived currents, and surface heat exchange. For some periods of time, winds may be the dominant forcing for flows, especially for the surface layer. Winds are entered into the EFDC model via the WSER.INP file. This file has been constructed for the simulation periods of interest using the complete set of data collected at the St. Petersburg/Clearwater International Airport.

The atmospheric conditions of temperature, humidity, rainfall, evaporation, barometric pressure, solar radiation and cloud cover are important for the heat sub-model within EFDC. These data are entered into EFDC via the ASER.INP file. This file has been constructed for the simulation periods of interest.

Figure 4-57 provides an hour by hour summary of the winds and air temperature for the year 2004. Each bar is one record/hour. The length of the bar is scaled to wind speed, the bar direction reflects the wind direction (wind towards) and the color represents the dry bulb air temperature. **Figure 4-58** shows a summary of the wind data as a wind rose for 2004.

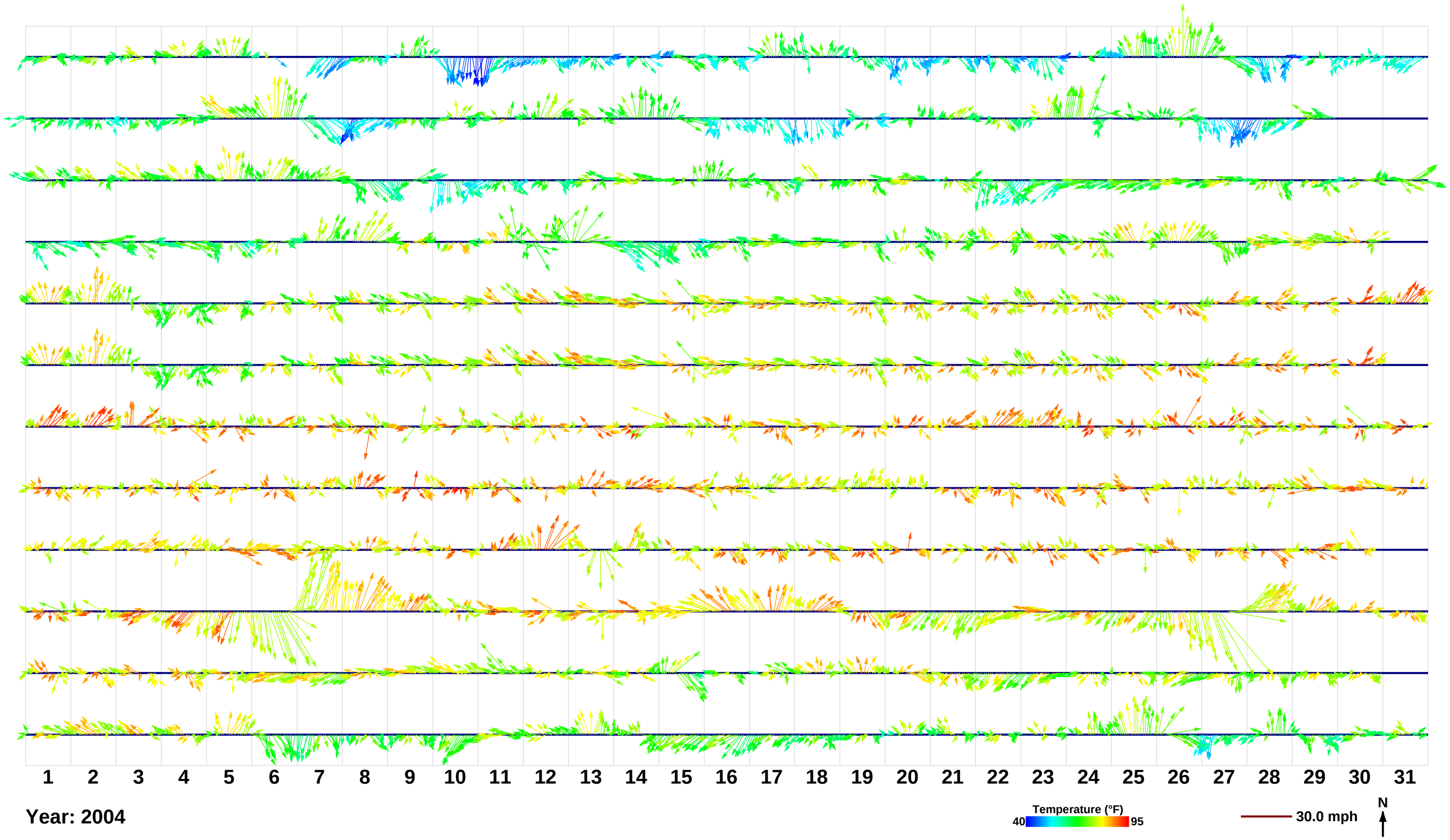


Figure 4-57 Wind Speed, Direction and Dry Bulb Air Temperature Summarized for 2004

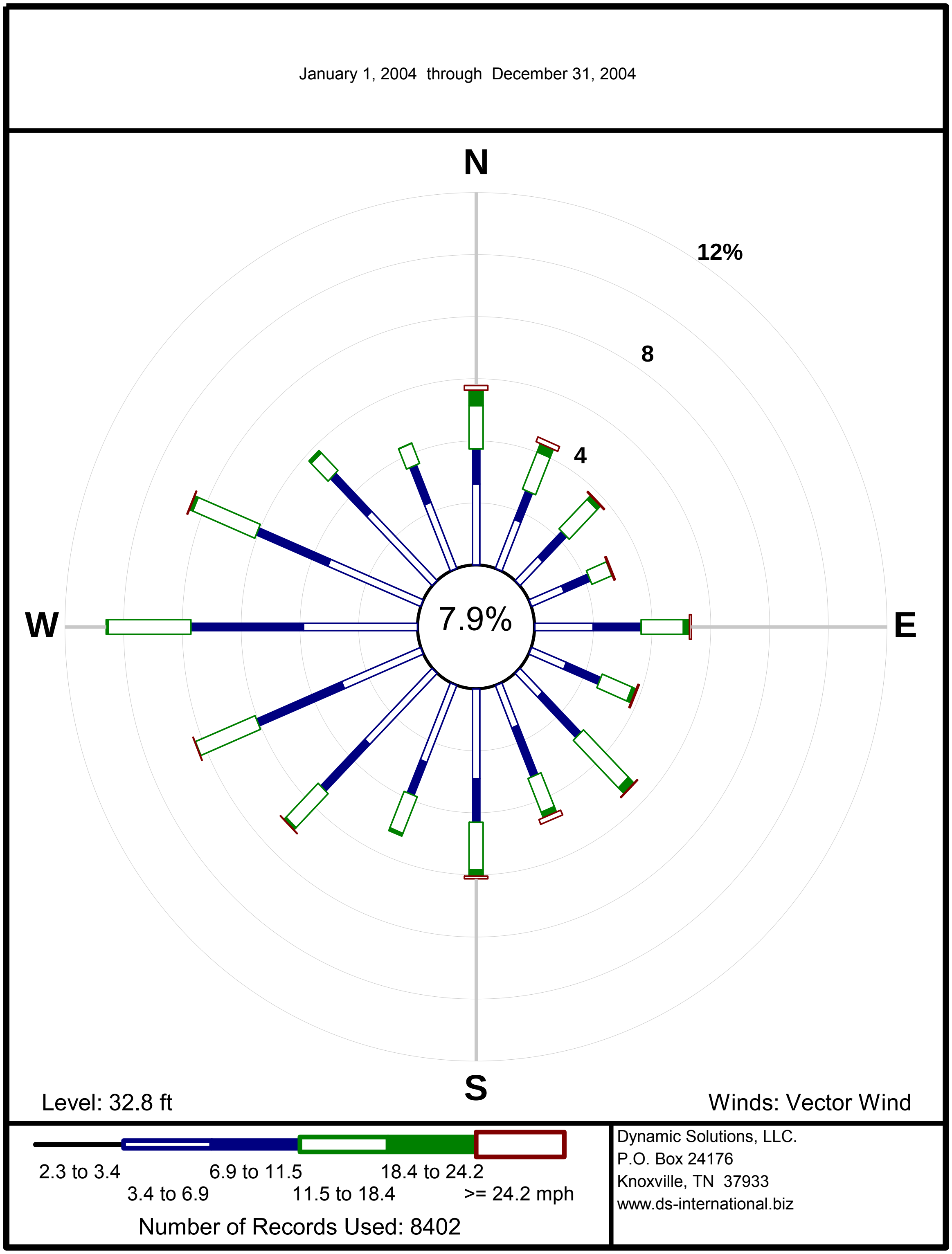


Figure 4-58 St. Petersburg/Clearwater International Airport Station Wind Rose for the Year 2004.

4.7.2 Calibration: Tide Signal

The first step in calibrating a hydrodynamic model is to obtain a satisfactory match to volumes and/or levels, depending on the system. For an open system like Stevenson Creek the critical parameters needed for water level calibration are tidal forcings, river flows and wind stresses. These boundary conditions were described in the prior section. The next component needed is measured tides inside (or at upstream boundaries like the Stevenson Creek) of the model domain.

As mentioned earlier, there are no long term water level records for Stevenson Creek. Fortunately, the USACE conducted a short field program as part of their work on Stevenson Creek (Personal communication, 2007) where they collected stage over a two day period at three stations (**Figure 4-59)**. The period of data collection was 25-Jun-2002 through 26-Jun-2002. Therefore, the tide signal calibration period will correspond to that period.

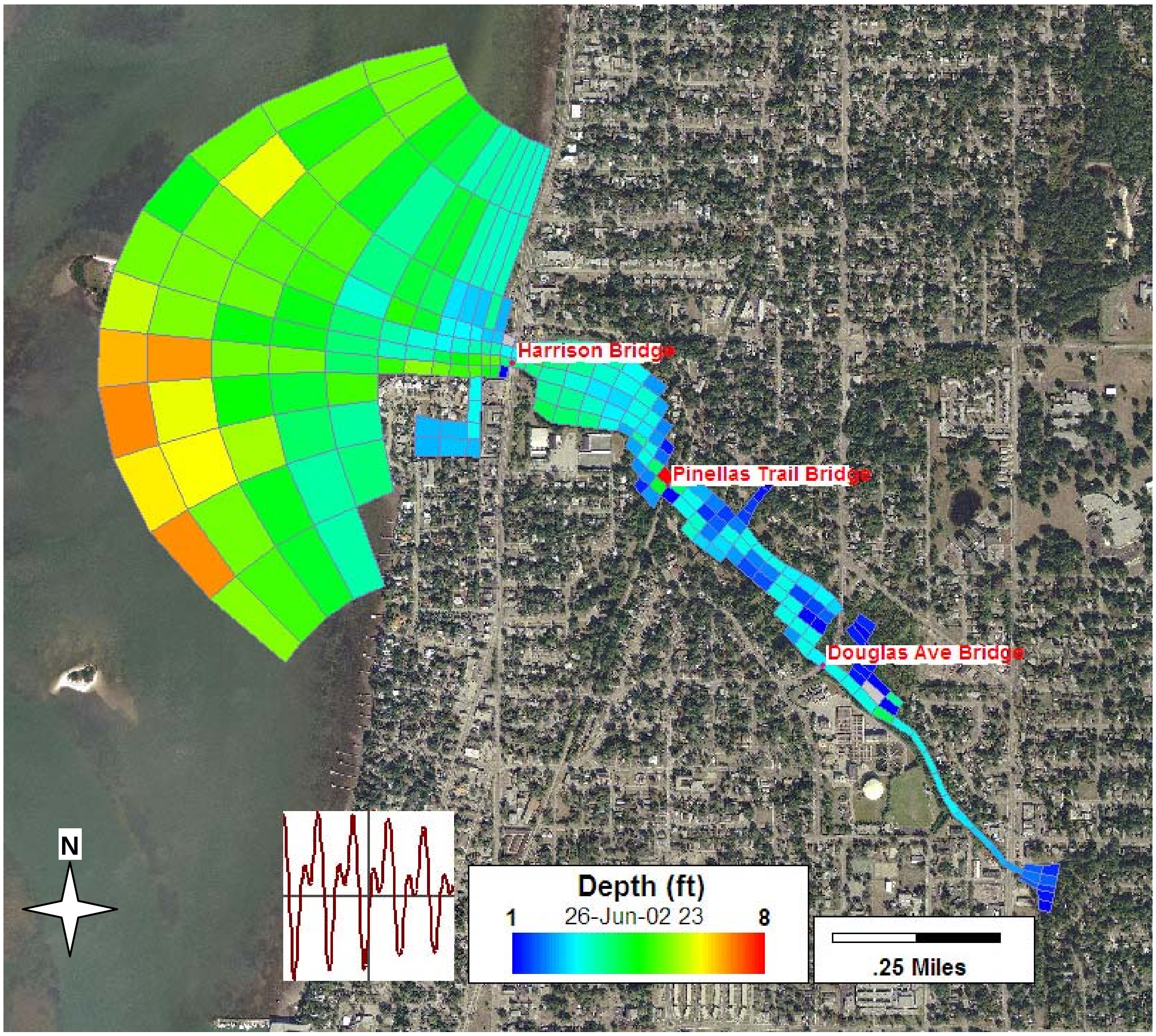


Figure 4-59 Stevenson Creek Water Depths with Tide Signal Calibration Stations (26-Jun-2002).

A model covering the period of the measured stages was constructed. The actual start time of the model was two weeks prior to the calibration period to allow adequate time for the model results to not be impacted by the initial conditions. The flow boundaries and the open boundary were set for this period using the approaches outlined for the main calibration effort.

A 2D snapshot of the computed water depths for Stevenson Creek is shown in **Figure 4-59**. The cells shown as grey indicate that those cells are "dry" at the time of indicated in plot. Depending on the tidal forcings, some cells become "dry" and then reactivate when the tide levels come back up. In the model, this process is referred to as "wetting and drying".

Figures 4-60 through **4-62** provide plots of the tide calibration showing model (blue line) versus data (green solid circle). The EFDC modeled-simulated water surface elevations were considered acceptable.

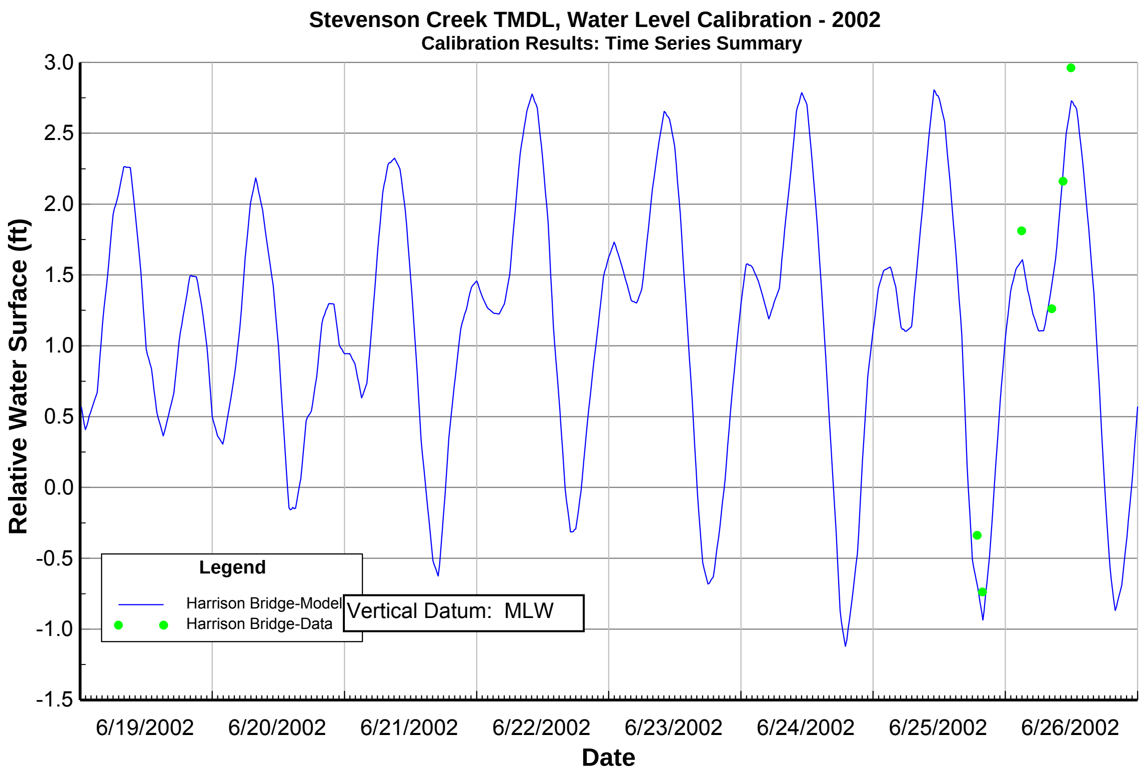


Figure 4-60 Stevenson Creek Tide Signal Calibration: Harrison Bridge.

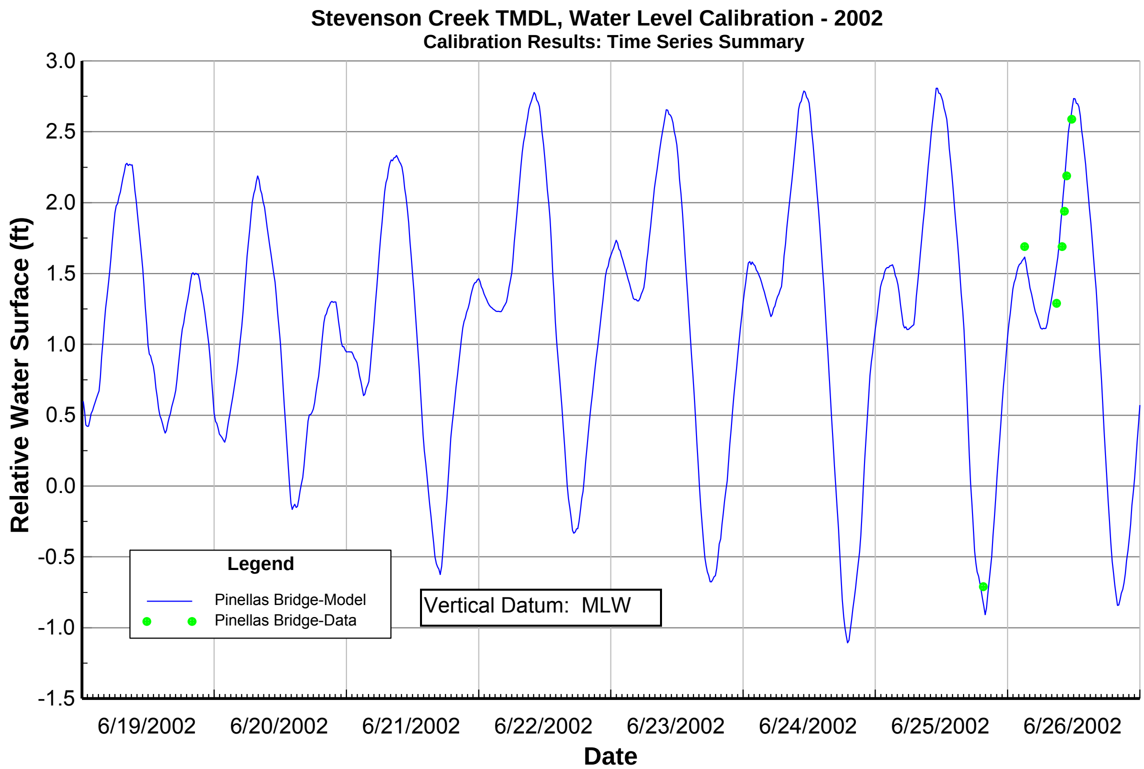


Figure 4-61 Stevenson Creek Tide Signal Calibration: Pinellas Bridge.

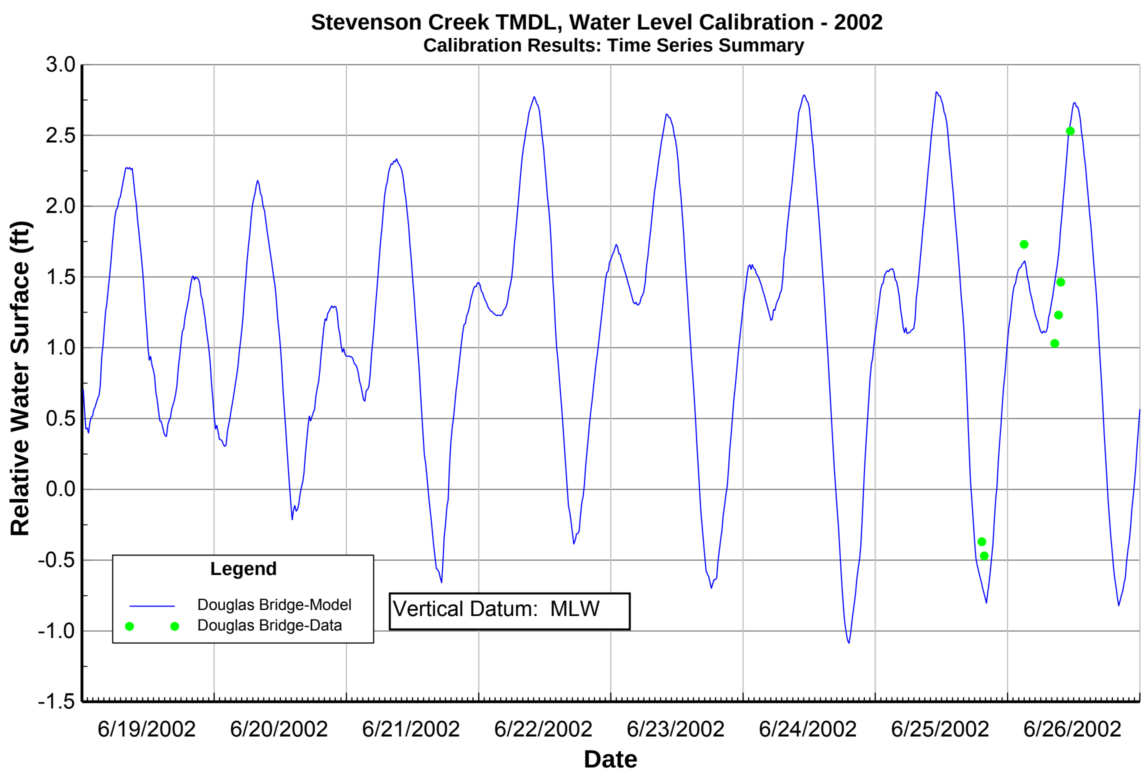


Figure 4-62 Stevenson Creek Tide Signal Calibration: Douglas Bridge.

4.7.3 Calibration: Hydrodynamics

The source of the data for calibration period of 2004 was from a sampling program by the FDEP Southwest District office. The stations with their full station names and ID's are listed below:

- TP283: → TP283-Stevenson Creek, 27592358247432
- TP284: → TP284-Stevenson Creek, 27591358247312
- TP282: → TP282-Stevenson Creek, 27585948247171
- TP285: → TP285-Stevenson Creek, 27584438247015

These data were stored on the Florida STORET database with a data source ID of STORET_21FLTPA. They start just inside the mouth of Stevenson Creek at Harrison Bridge with TP283. Then, in order moving upstream, the stations are TP284 at Pinellas Bridge; TP282 at Douglas Bridge and TP285 at N Betty Drive Bridge. The locations of the stations are shown on **Figure 4-63**.

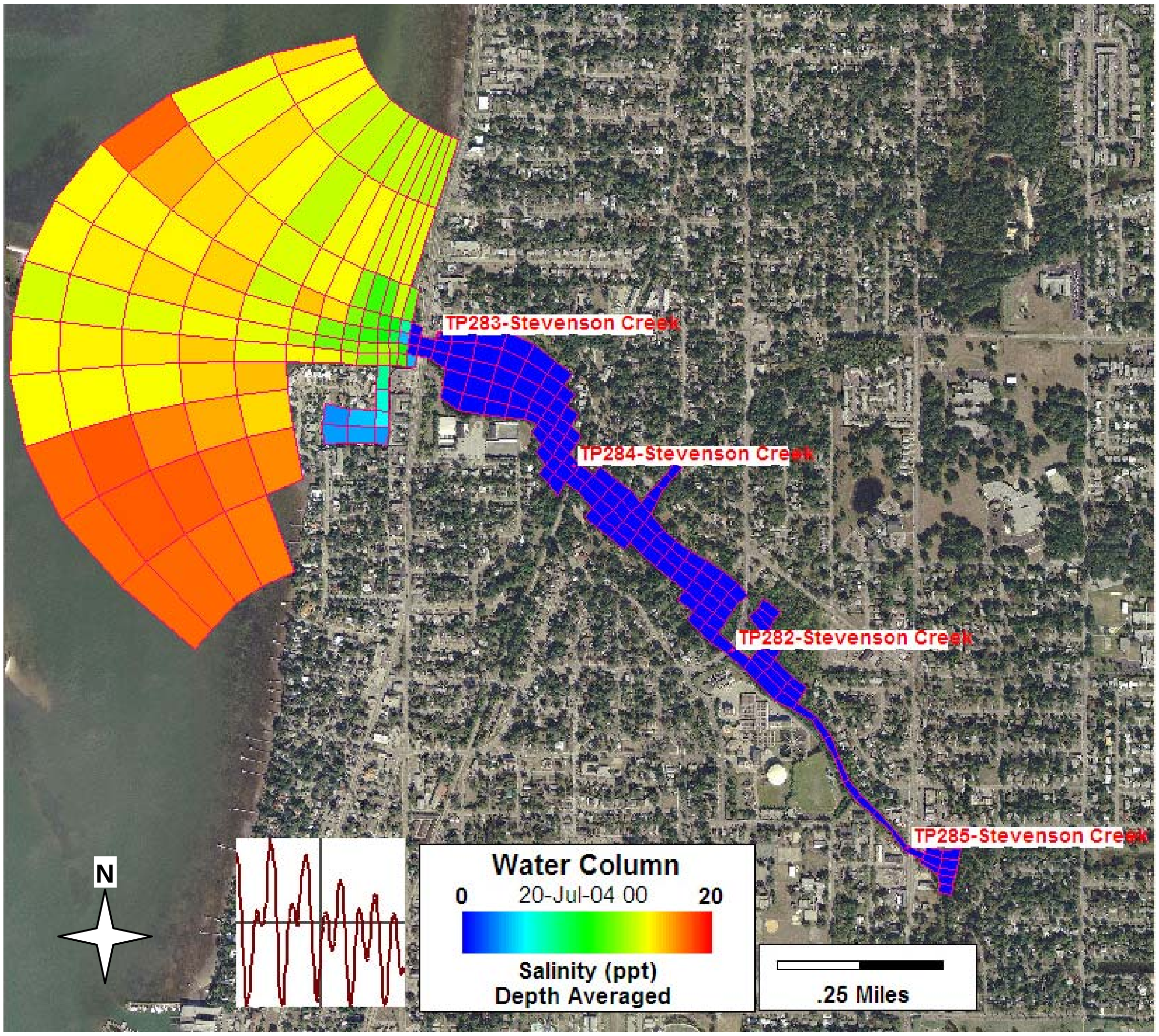


Figure 4-63 Model Domain Salinity with FDEP Stations Used for Calibration.

Tide Signal Calibration

There are no tide level data for Stevenson Creek for the period of calibration. Therefore, the tide levels were evaluated only on a qualitative basis (i.e. are the computed tide levels reasonable?). **Figure 4-64** shows a time series water surface elevations for a cell located just upstream of the Pinellas Bridge (IJ Map coordinates of I=29 and J=6). As expected, this series is very close to the open boundary forcing at the Clearwater Harbor boundary.

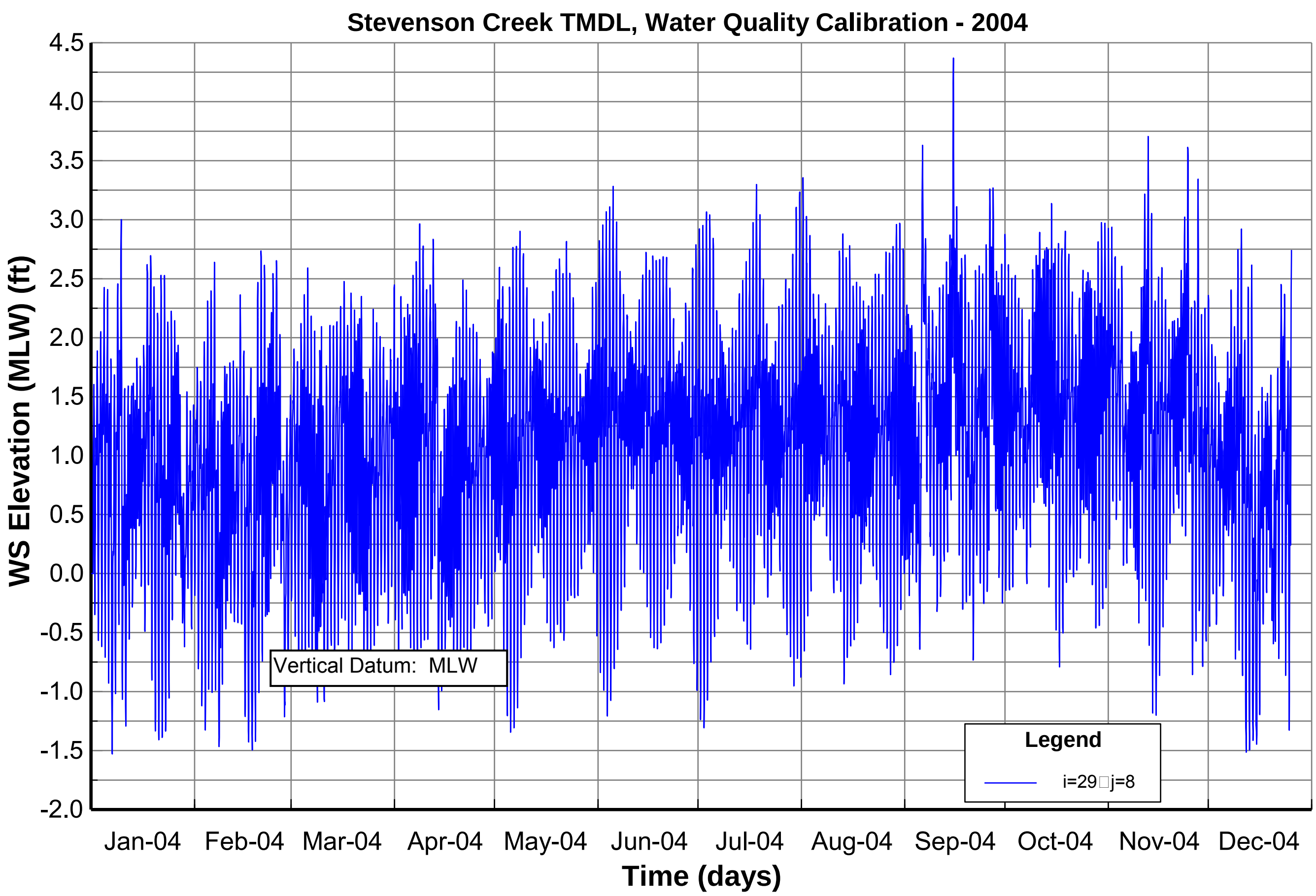


Figure 4-64 Modeled Upper Stevenson Creek Water Surface (MLW) Elevations for the Calibration Period.

Velocity Patterns

There are no data to perform calibration on either 2D or 3D velocities generated by the EFDC model. However, the simulated velocities were evaluated to see if the general patterns fit the conceptual understanding of flow in Stevenson Creek. As an example **Figures 4-65** (ebb tide) and **4-66** (flood tide) are shown.

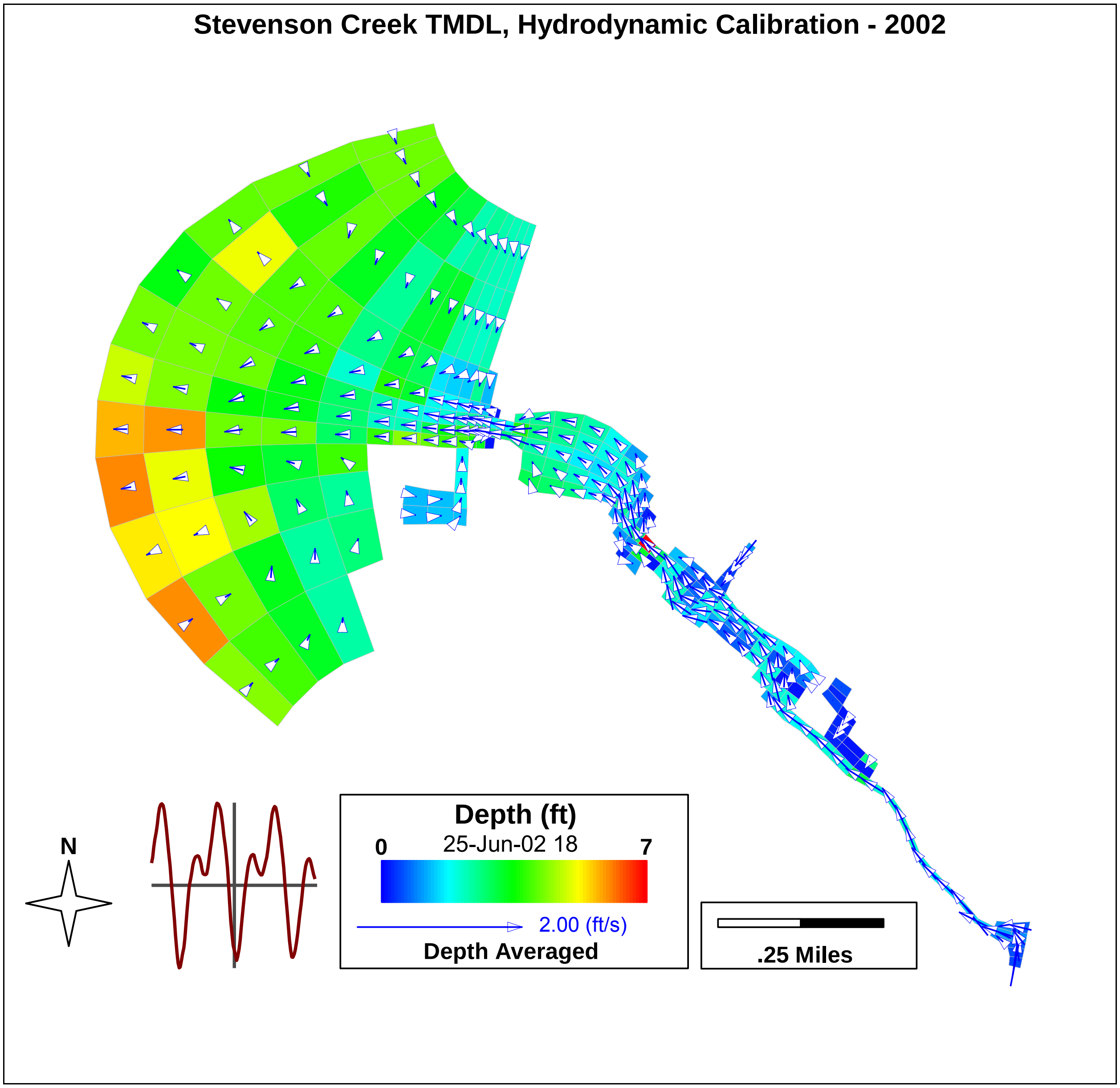


Figure 4-65 Stevenson Creek Hydrodynamic Calibration: Ebb Flow Velocity Pattern Example.

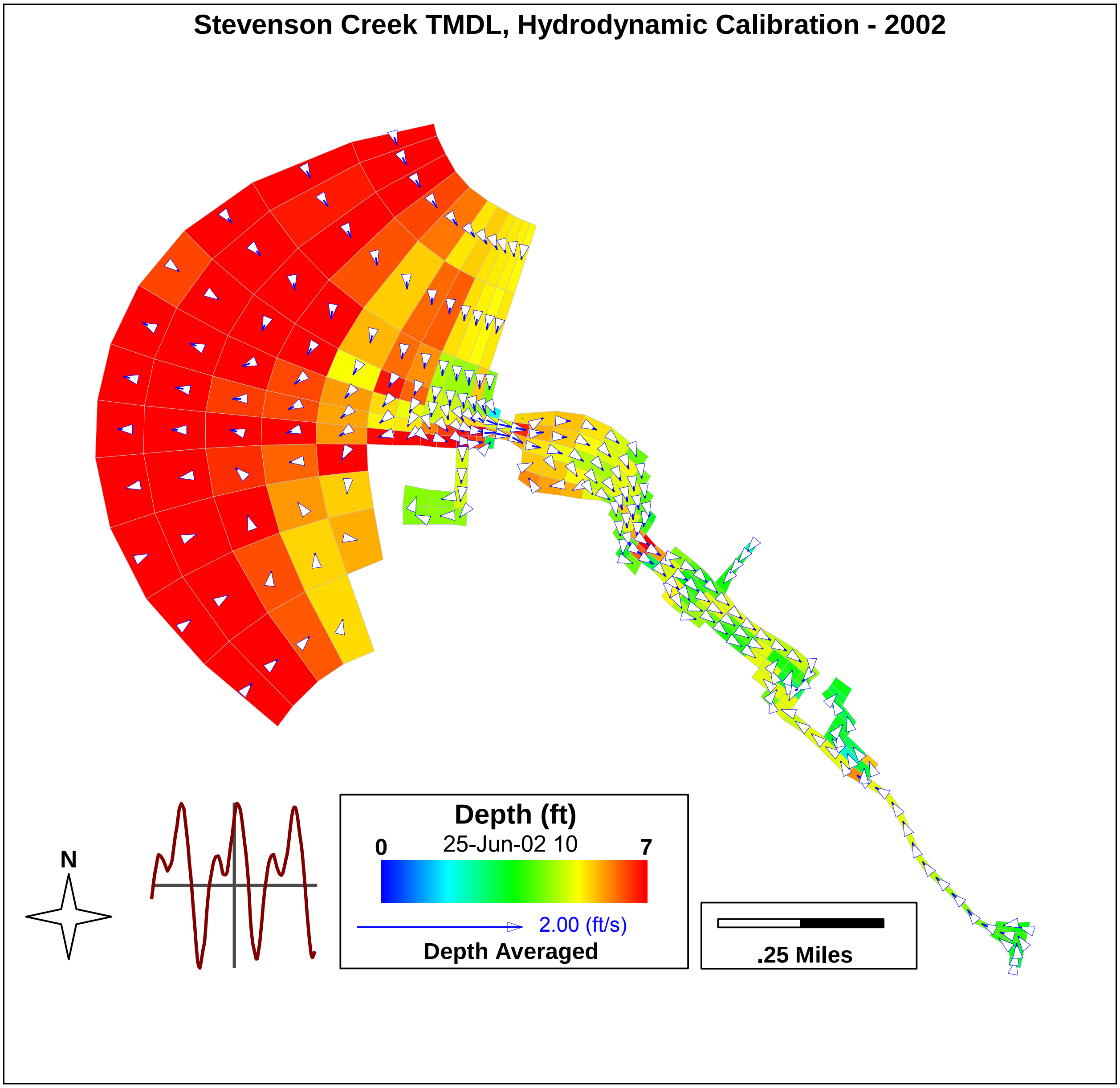


Figure 4-66 Stevenson Creek Hydrodynamic Calibration: Flood Flow Velocity Pattern Example.

Salinity Calibration

The salinity and temperature data used for the hydrodynamic model calibration data was developed from the Florida STORET database. The stations where data were available and used for calibration were previously shown in **Figure 4-63**.

Figures 4-67 through **4-70** show the salinity calibration results (for the surface water layer).

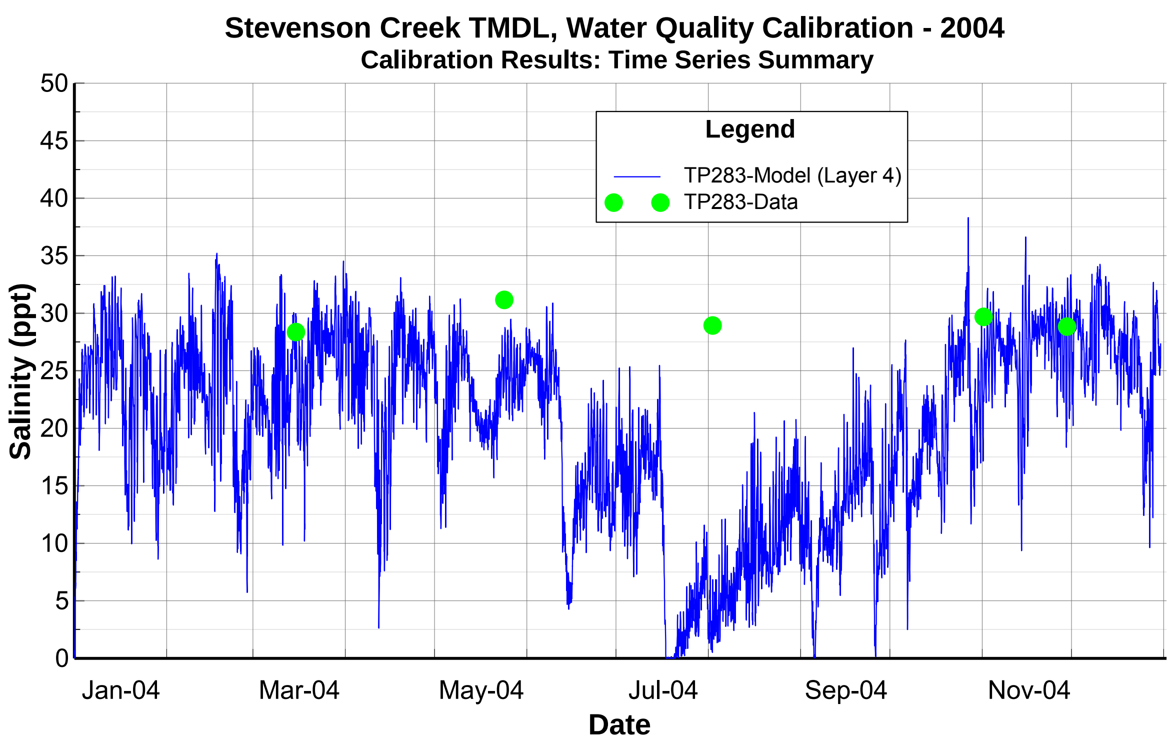


Figure 4-67 Stevenson Creek 2004 Salinity Calibration: TP283.

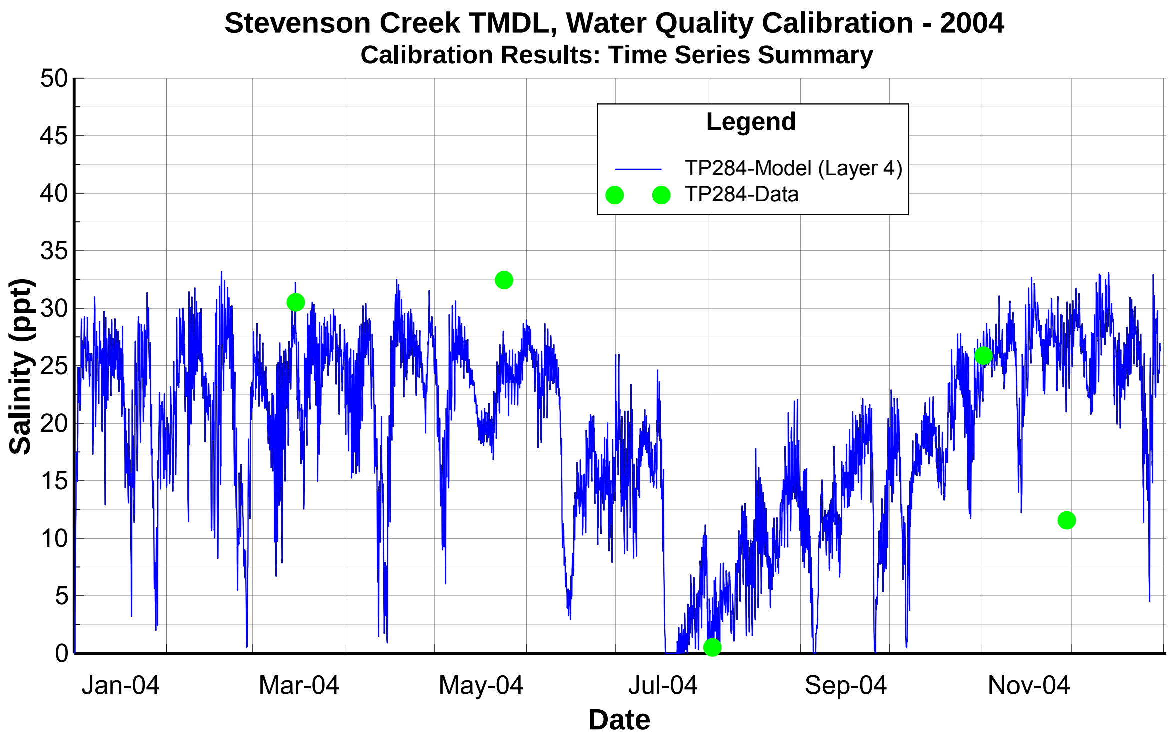


Figure 4-68 Stevenson Creek 2004 Salinity Calibration: TP284.

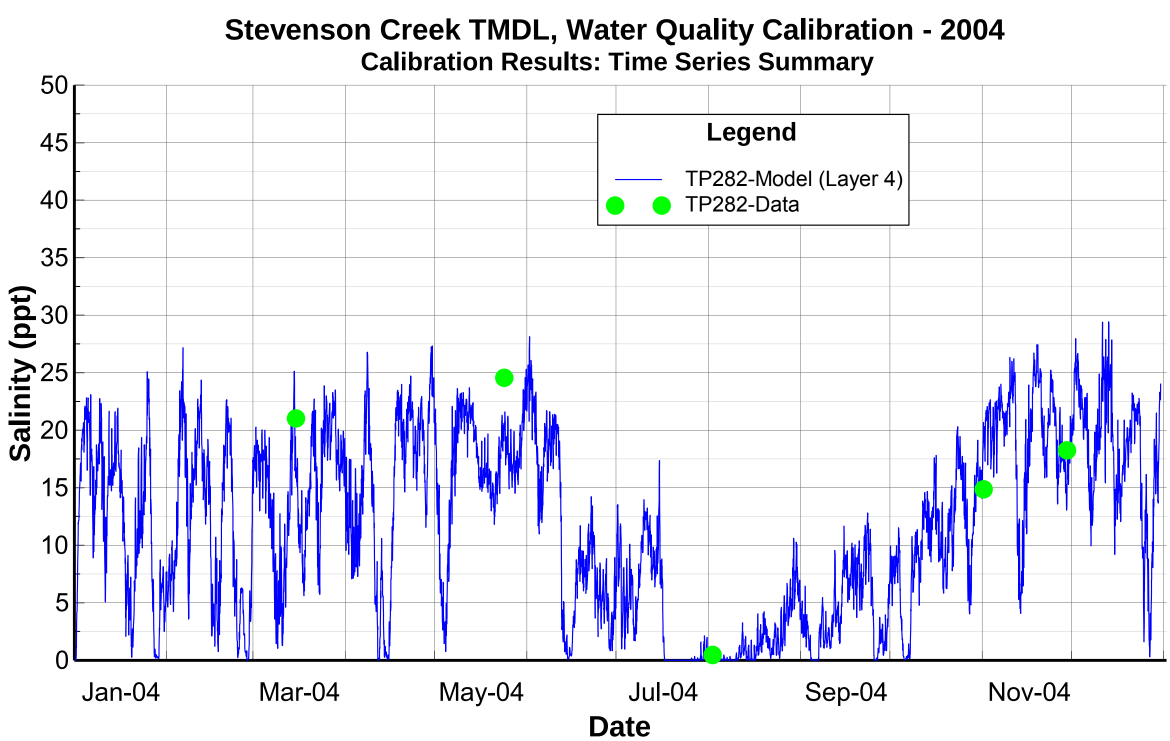


Figure 4-69 Stevenson Creek 2004 Salinity Calibration: TP282.

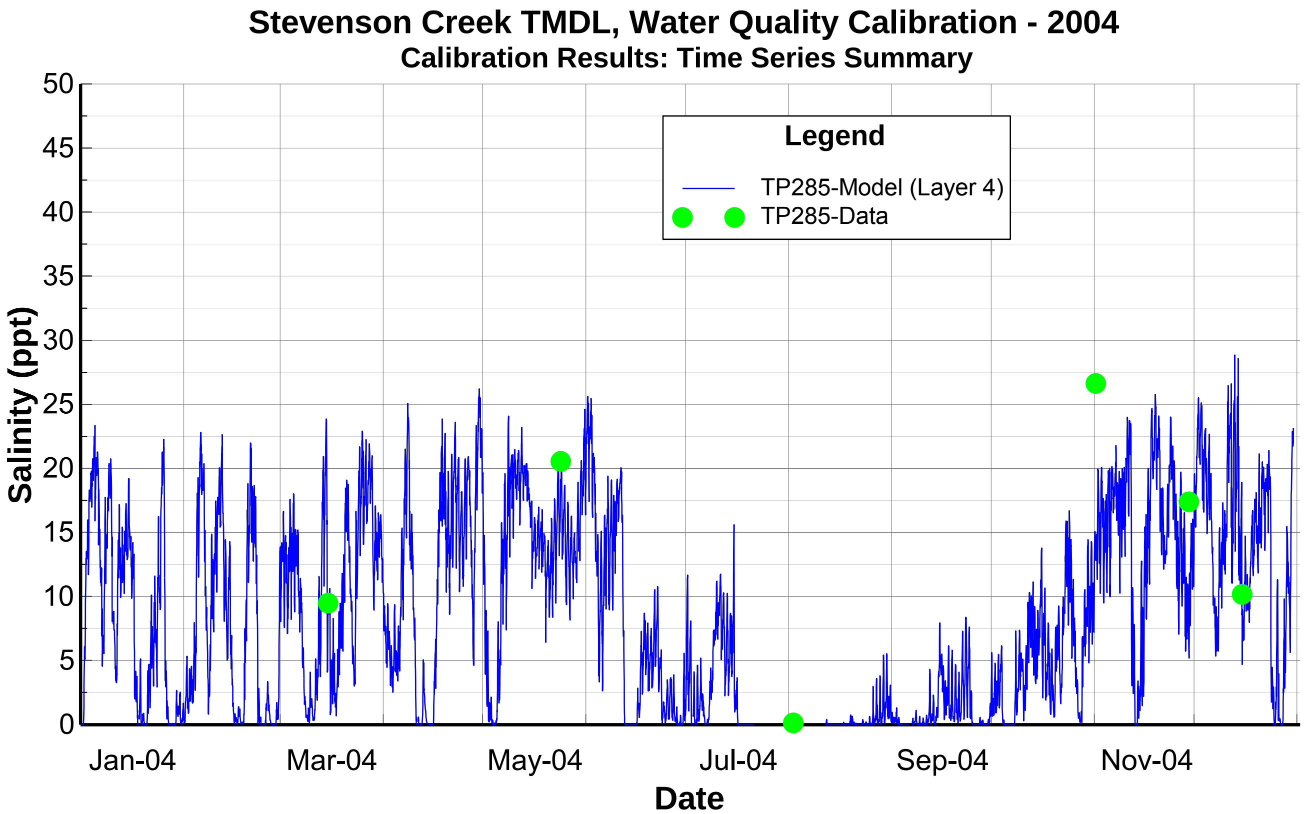


Figure 4-70 Stevenson Creek 2004 Salinity Calibration: TP285.

Water Temperature Calibration

The salinity and temperature data used for the hydrodynamic model calibration data was developed from the Pinellas County data base. The stations where data were available and used for calibration were previously shown in Figure 4-63.

Figures 4-71 through **4-74** show the Temperature calibration results. The comparison between model results and observed data for water temperature was considered good.

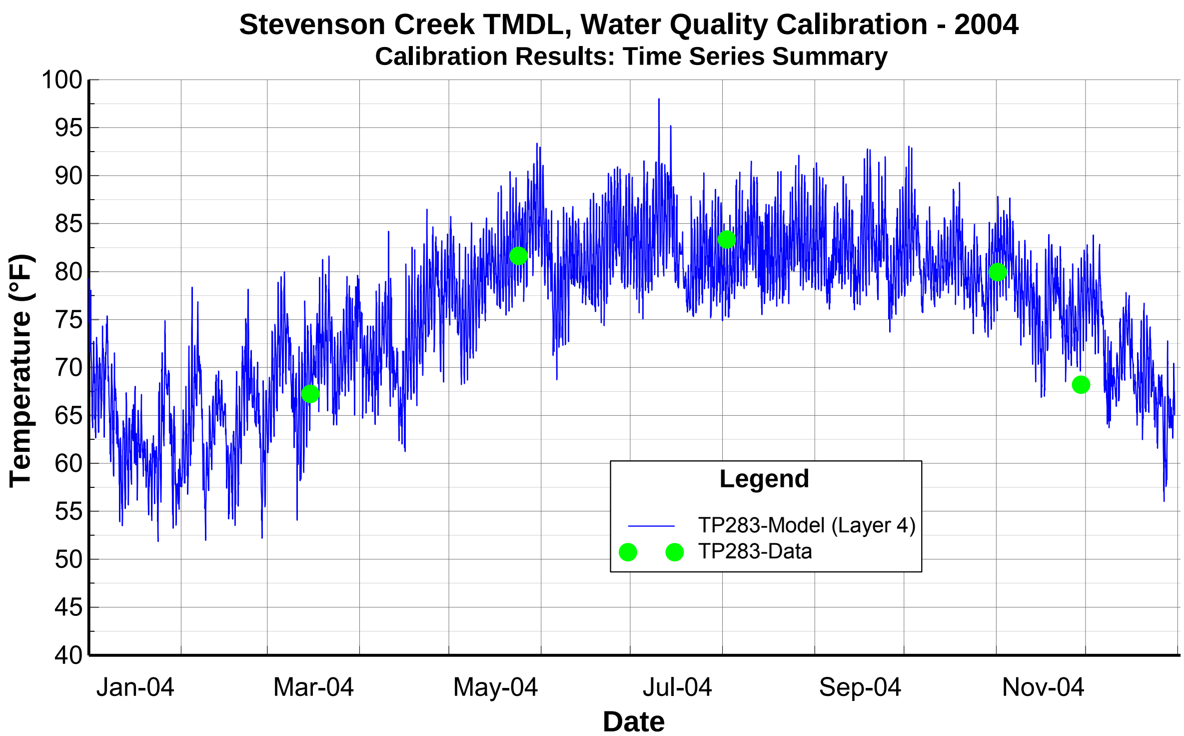


Figure 4-71 Stevenson Creek 2004 Water Temperature Calibration: TP283.

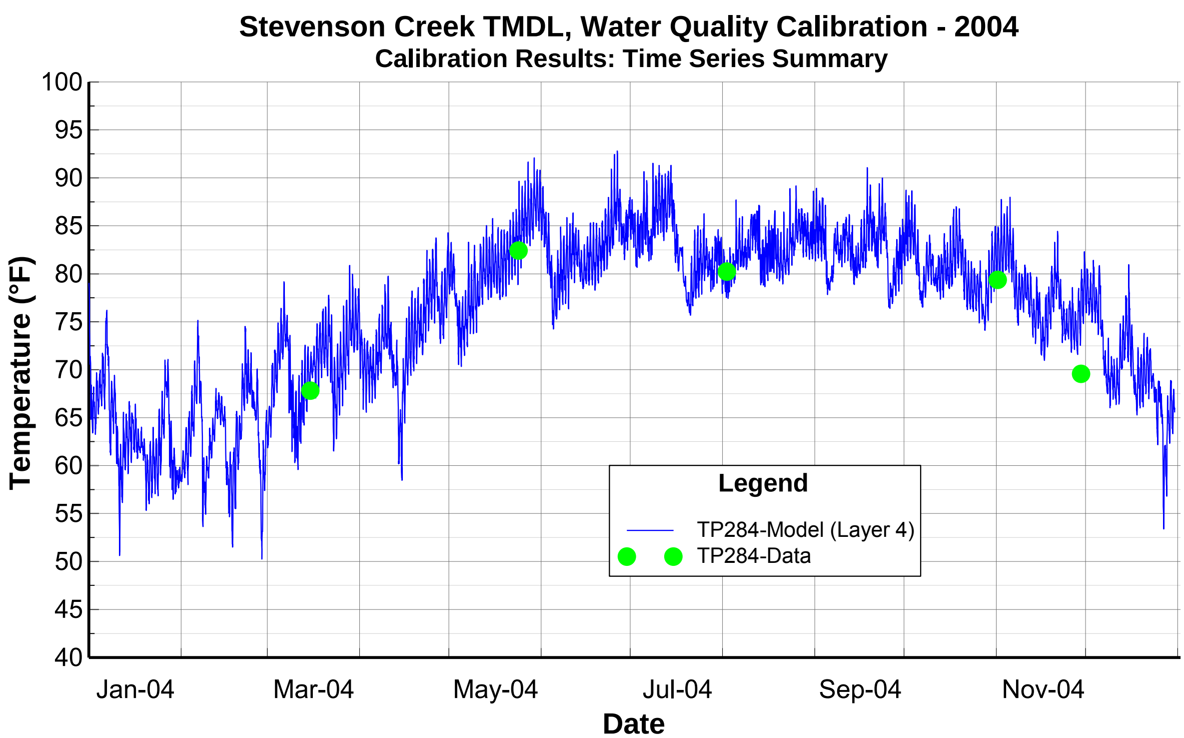


Figure 4-72 Stevenson Creek 2004 Water Temperature Calibration: TP284.

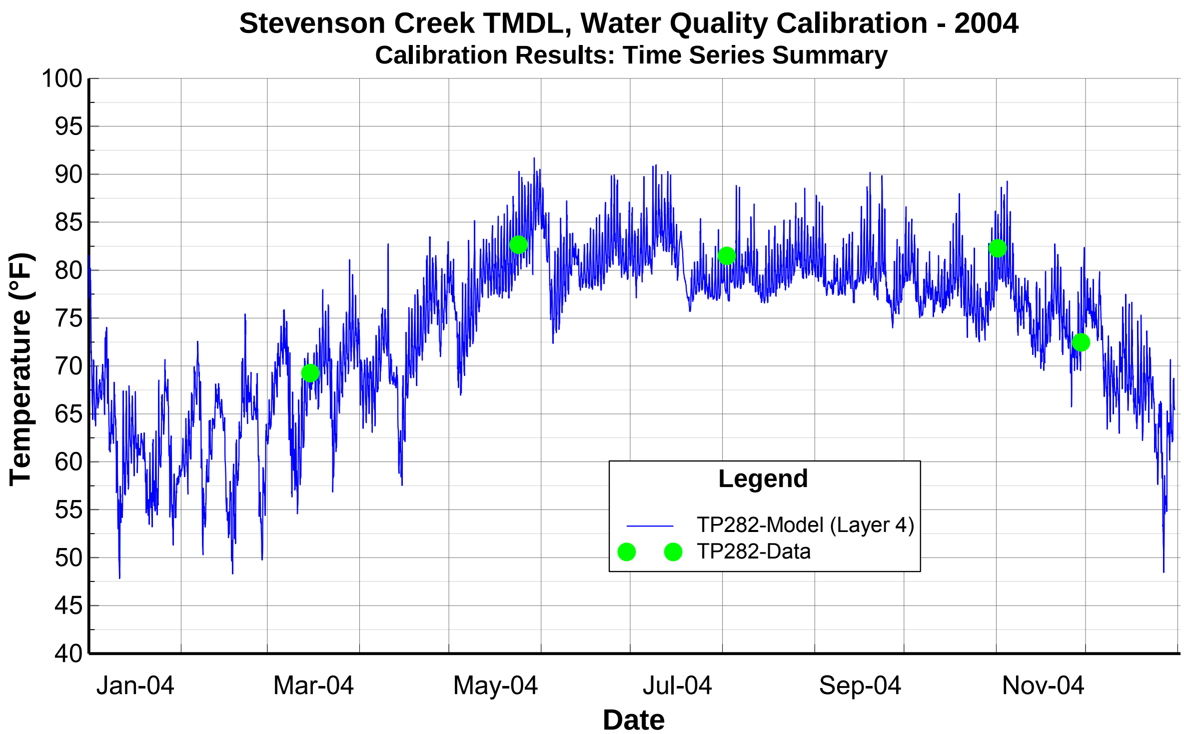


Figure 4-73 Stevenson Creek 2004 Water Temperature calibration: TP282.

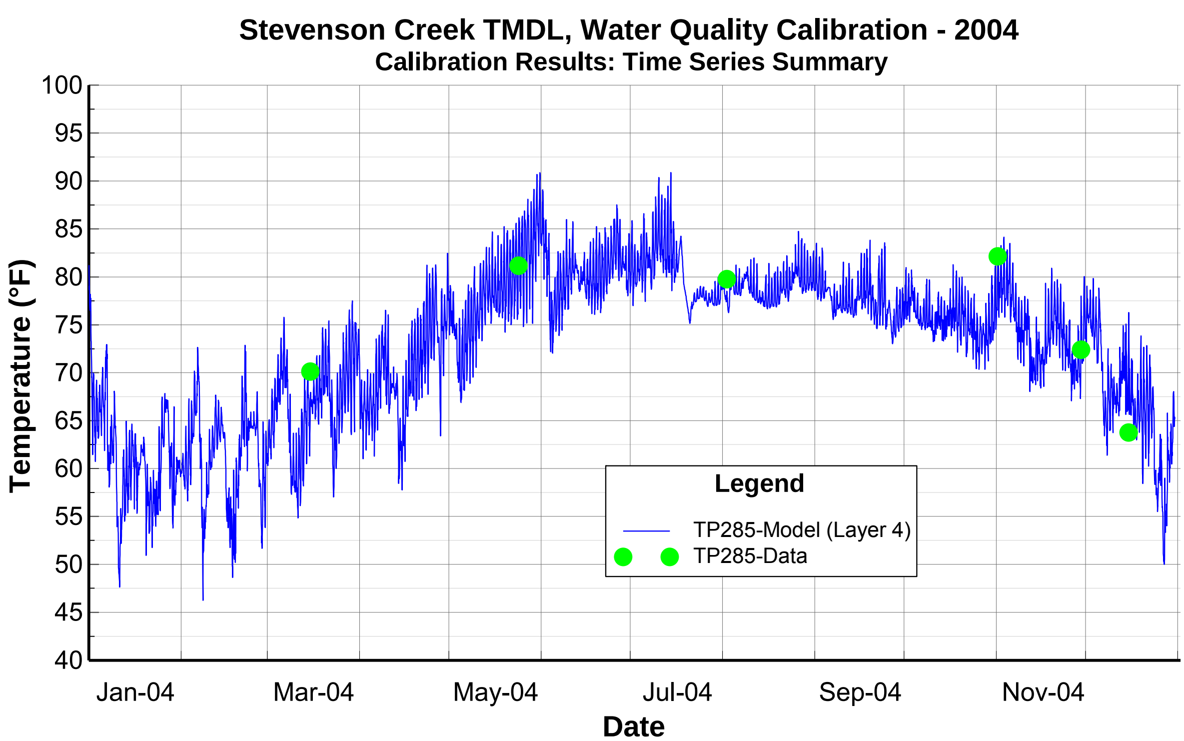


Figure 4-74 Stevenson Creek 2004 Water Temperature Calibration: TP285.

Summary Statistics

Tables 4-33, 4-34 and **4-35** provide summaries of the calibration statistics for water surface elevations, salinity and temperature, respectively. The error statistic presented in these tables is the RMS (see Section 4.10.5).

Upon reviewing the calibration plots and the RMS errors, the salinity and temperature calibrations were judged to be good and sufficiently representative of Stevenson Creek. Therefore, the model was considered calibrated for salinity and temperature.

4.7.4 Calibration: Water Quality

Once the hydrodynamic model was calibrated (see Section 4.11.3) for the temperature, salinity and flows, the water quality model was calibrated. The calibration period for water quality was the same as for the calibration period for the temperature and salinity. The boundary conditions for the watershed inflows were provided by the HSPF simulation results. The water quality model used for this application is the coupled water quality model internal to EFDC (Park, et.al., 1995), sometime referred to as HEM-3D.

EFDC/HEM-3D provides several kinetic options. For Stevenson Creek, the kinetic option 1 was used. This essentially mimics the CE-QUAL-ICM (Cerco & Cole, 1994) kinetics. This option has been the most tested and stable of the EFDC water quality kinetic options. **Table 4-36** provides a list of the EFDC water quality parameters that are simulated with this kinetic option. Within this option, the user can activate or inactivate the kinetics and transport of individual parameters. Table 4-36 also shows which parameters were used for this application.

The Green Algae parameter was used to lump all algal groups and their dynamics into a single compartment. While this simplification has some obvious problems with representing a complex mixture of plankton and zooplankton, it was decided that this approach should be representative for the Stevenson Creek water quality model for TMDL applications.

The water quality parameters needed by the EFDC model were all initialized with the defaults as indicated in the user's manual (Park, et.al., 1995). These defaults are mostly identical to the factors determined in the Chesapeake Bay CE-QUAL-ICM application and reported in the ICM user's manual (Cerco & Cole, 1994).

Boundary Conditions

As in the hydrodynamic model the water quality model boundary conditions for the flow type boundaries has been derived from the calibrated HSPF model and the Marshall AWWTP. **Table 4-37** provides a listing of the water quality parameters supplied by the HSPF model.

Table 4-33 Calibration Period Summary Statistics for Relative Water Surface (ft).

Station ID	Starting Date/Time	Ending Date/Time	# Pairs	RMS	Data Average	Model Average
Harrison Bridge	25-Jun-02 18:55	26-Jun-02 11:55	6	0.22	1.2	1.1
Pinellas Bridge	25-Jun-02 19:38	26-Jun-02 11:39	7	0.19	1.5	1.6
Douglas Bridge	25-Jun-02 19:20	26-Jun-02 11:25	7	0.32	1.0	1.1
Composite	Varies	Varies	**20**	**0.25**		

Table 4-34 Calibration Period Summary Statistics for Salinity (PPT).

Station ID	Layer/ Type	Starting Date/Time	Ending Date/Time	# Pairs	RMS	Data Average	Model Average
TP283	4	15-Mar-04 12:00	29-Nov-04 12:00	5	10.77	29.4	22.1
TP284	4	15-Mar-04 12:00	29-Nov-04 12:00	5	7.96	20.2	22.7
TP282	4	15-Mar-04 12:00	29-Nov-04 12:00	5	3.89	15.8	14.3
TP285	4	15-Mar-04 12:00	15-Dec-04 12:00	6	7.59	14.0	9.2
Composite	4	Varies	Varies	**21**	**7.55**		

Table 4-35 Calibration Period Summary Statistics for Temperature (°F).

Station ID	Layer/ Type	Starting Date/Time	Ending Date/Time	# Pairs	RMS	Data Average	Model Average
TP283	4	15-Mar-04 12:00	29-Nov-04 12:00	5	6.47	76.1	80.7
TP284	4	15-Mar-04 12:00	29-Nov-04 12:00	5	4.80	75.9	79.6
TP282	4	15-Mar-04 12:00	29-Nov-04 12:00	5	2.59	77.6	78.7
TP285	4	15-Mar-04 12:00	15-Dec-04 12:00	6	5.60	74.9	77.5
Composite	4	Varies	Varies	**21**	**4.87**		

Table 4-36 EFDC Water Quality Modeled Parameters for Kinetic Option 1.

Code	EFDC Parameter	EFDC Parameter Code	Used in Stevenson Creek Model
1	Cyanobacteria	CHC	No
2	Diatoms	CHD	No
3	Green Algae	CHG	Yes
4	Refractory Particulate Organic Carbon	ROC	Yes
5	Labile Particulate Organic Carbon	LOC	Yes
6	Dissolved Organic Carbon	DOC	Yes
7	Refractory Particulate Organic Phosphorus	ROP	Yes
8	Labile Particulate Organic Phosphorus	LOP	Yes
9	Dissolved Organic Phosphorus	DOP	Yes
10	Total Phosphate	P4D	Yes
11	Refractory Particulate Organic Nitrogen	RON	Yes
12	Labile Particulate Organic Nitrogen	LON	Yes
13	Dissolved Organic Nitrogen	DON	Yes
14	Ammonia Nitrogen	NHX	Yes
15	Nitrate Nitrogen	NOX	Yes
16	Particulate Biogenic Silica	SUU	No
17	Dissolved Available Silica	SAA	No
18	Chemical Oxygen Demand	COD	No
19	Dissolved Oxygen	DOX	Yes
20	Total Active Metals	TAM	No

Table 4-37 HSPF simulated water quality parameters.

Parameter	Abbrev-iation	Units
Flow	Q	CFS
Water Temperature	T	°C
Total Nitrogen	TN	mg-l N
Nitrate-Nitrite	NOX	mg-l N
Ammonia	NH3	mg-l N
Total Phosphorus	TP	mg/l P
Ortho Phosphorus	orthoP	mg/l P
Biochemical Oxygen Demand (Carbonaceous-Ult)	$CBOD_u$	mg/l O
Dissolved Oxygen	DO	mg/l O
Chlorophyll a	Chl-A	μm/l

These HSPF and AWWTP water quality parameters were then mapped into the appropriate EFDC water quality parameter in order to build the boundary loadings file for all 21 constituents. **Table 4-38** lists the factors used for this study. These factors were based on literature (Chapra, 2000, Weitzel, 1983), a report on nutrient loadings by HSPF (Hendrickson, 2007), analysis of the FDEP data for 2004 and professional judgment. Using these factors, the fourteen water quality constituents loads for each tributary to the EFDC boundary conditions were constructed.

An example of the generated boundary condition time series for the water quality constituents is provided in **Figure 4-75**. This plot shows the parameters for Reach 1 (Hammond Branch). For visual clarity, only a subset of the parameters is shown. The other HSPF derived flow boundaries have similar patterns and magnitudes for their pollutant loads.

Table 4-38 HSPF/WWTP to EFDC factors and splits.

HSPF Factors			WWTP Factors			
HSFP Parameter	**Inter-mediate**	**Multiplier Factor**	**Monitoring Parameter**	**Inter-mediate**	**Multiplier Factor**	**EFDC Parameter Code**
-		-				CHC
-		-				CHD
Chla		0.065				CHG
BODult	TOC[1]	0.25	BOD5	TOC[4]	0.10	ROC
BODult	TOC[1]	0.40	BOD5	TOC[4]	0.27	LOC
BODult	TOC[1]	0.35	BOD5	TOC[4]	0.63	DOC
TP	TORP[2]	0.10	TP	TORP[5]	0.13	ROP
TP	TORP[2]	0.37	TP	TORP[5]	0.29	LOP
TP	TORP[2]	0.53	TP	TORP[5]	0.58	DOP
PO4		1.00	TP		0.50	P4D
TKN	TORN[3]	0.30	TN	TORN[6]	0.16	RON
TKN	TORN[3]	0.35	TN	TORN[6]	0.28	LON
TKN	TORN[3]	0.35	TN	TORN[6]	0.56	DON
NHX		1.00	TN		0.10	NHX
NOX		1.00	TN		0.60	NOX
-		-				SUU
-		-				SAA
-		-				COD
DO		1.00			1.00	DOX
-		-				TAM
FC		1.00			1.00	FCB

[1]TOC/BODult = 4.13 (mg/l TOC) / (mg/l BOD), computed from measured data for Stevenson Creek, 2004
[2]TORP = TP – PO4
[3]TORN = TN – NHX – NOX
[4]TOC/BOD5 = 2.10 (mg/l O) / (mg/l C) for WWTP effluents
[5]TORP = 0.50 * TP
[6]TORN = 0.30 * TN

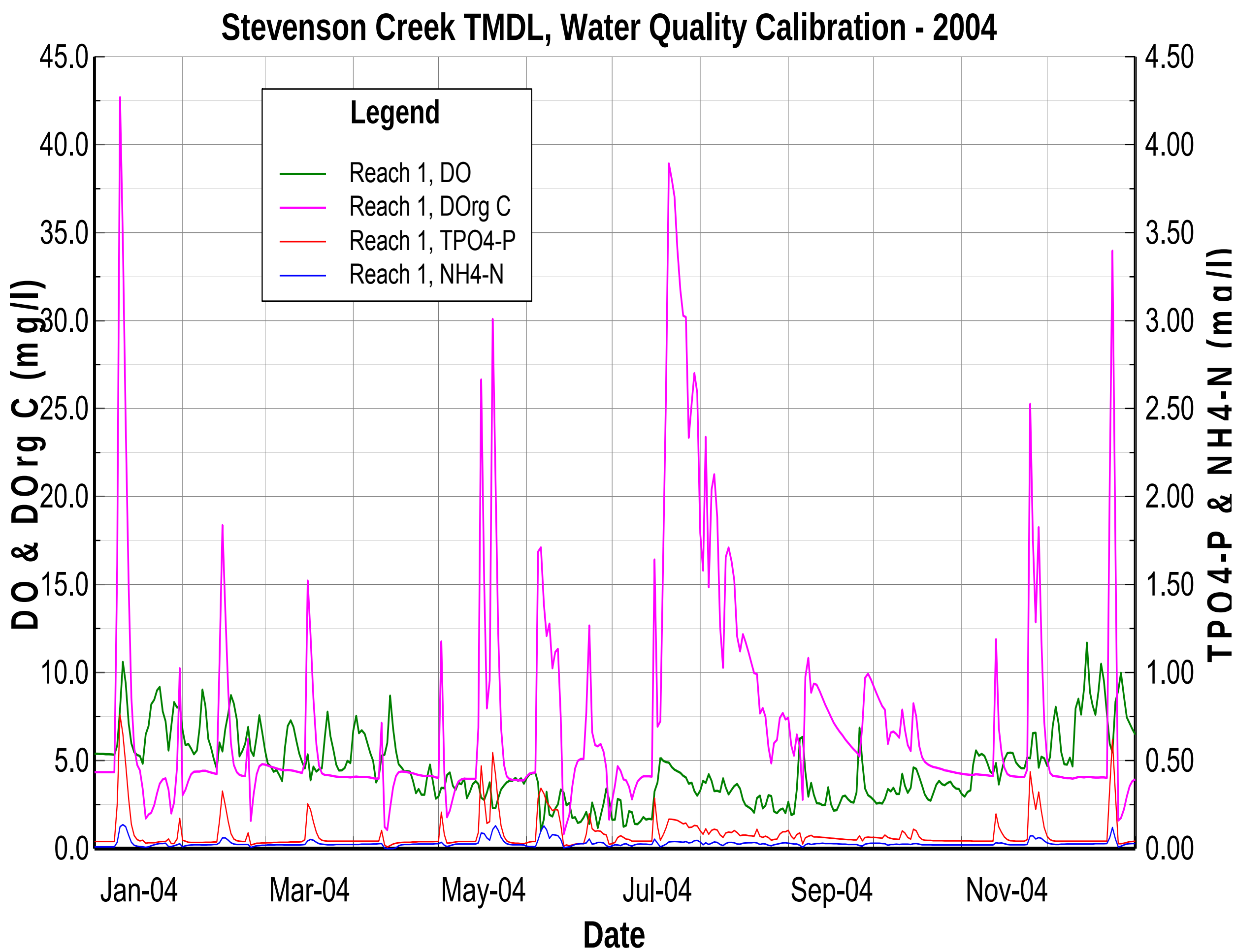


Figure 4-75 Time Series Plot of Selected EFDC Water Quality Parameter Concentrations for Reach 1 (Hammond Branch)

Water Column/Sediment Interactions
The EFDC water quality model currently has three options for defining the sediment/water column interactions for water quality parameters. They are:

- Spatially and Temporally Constant Fluxes
- Spatially and Temporally Variable Fluxes
- Full Sediment Diagenesis

The water quality parameters that have an interaction with the sediments are phosphate, ammonia, nitrate, silica, chemical oxygen demand and oxygen (i.e. sediment oxygen demand). The first two options require the fluxes to be set to some predefined flux rate in g/m^2/day. The full diagenesis (Park, et al, 1995 & DiToro, 2001) option uses a sediment diagenesis sub-model to compute the fluxes from some basic physical properties and typical/reference rates and factors. While this option has been used with some success in other EFDC applications, it does require some basic sediment nutrient data. These data were not available for this application. Therefore, the option chosen was to assign spatially varying, temporally constant nutrient fluxes (i.e., steady-state).

In order to define benthic flux zones, three things must be specified for each cell. There are:

- A sand zone
- A mud zone
- A percent mud of the cell's bottom.

A simple approach was used for this application. Only one sand zone and one mud zone was defined and the mud/sand splits were largely defined by the cell's location. For all of the open water cells near the open boundary the cells were assigned with mostly sandy bottoms. For the cells inside lower Stevenson Creek the cells were assigned with mostly mud bottoms. **Table 4-39** provides a summary of the fluxes assigned to the mud and sand zones. The sign convention for the fluxes is positive into the water column and negative out of the water column.

Table 4-39 Fluxes assigned to the mud and sand zones

	Benthic Flux Rates ($g/m^2/day$)					
Benthic Zone	Phosphate	Ammonia	Nitrate	Silica	COD	SOD
Sand	0.01	0.005	0	0	0	-0.25
Mud	0.01	0.010	0	0	0	-3.0

Water Quality Data Used For Calibration

Water quality data from the four monitor stations, TP282, TP283, TP284 and TP285 (see **Figure 4-63)** were used for calibration. The EFDC water quality parameter correspondence to the water quality data collected for these stations is shown in **Table 4-40**.

Table 4-40 EFDC parameter to FDEP data correspondence used for calibration.

Derived Data From	Corresponding EFDC Parameter(s)
Dissolved Oxygen	Dissolved Oxygen (DOX)
Chlorophyll a	Green Algae (CHG)[1]
Total Organic Carbon	Sum of DOC, LPOC and RPOC fractions
Total Phosphorus	Sum of DOP, LPOP and RPOP fractions and Total Phosphate (P4D)
Orthophosphate	Total Phosphate (P4D)
Total Nitrogen	Sum of DON, LPON and RPON fractions, Nitrate-Nitrite (NOX) and Ammonia (NHX)
Total Organic Nitrogen	Sum of DON, LPON and RPON fractions
Nitrate-Nitrite Nitrogen	Nitrate-Nitrite (NOX)
Ammonia Nitrogen	Ammonia (NHX)

[1] Algae concentration converted to Chlorophyll a by the ratio 0.065 mg C/μg Chla.

Water Quality Calibration Results

Figures 4-76 through **4-83** provide time series comparisons of the model versus measured dissolved oxygen and Chlorophyll a, respectively, at the four monitoring stations. A complete set of calibration time series plots are included in **Appendix B**. Also included in **Appendix B** are the station by station calibration statistics. **Table 4-41** contains a summary of the calibration statistics for the calibration parameters.

Table 4-41 Summary of the Stevenson Water Quality Statistics: Calibration Period.

Parameter	# of Data/ Model Pairs	RMS	Data Average (mg/l)	Model Average (mg/l)
Dissolved Oxygen	26	1.63	5.00	4.71
Total Phosphate	26	0.072	0.102	0.061
Total Phosphorus	26	0.306	0.31	0.095
Ammonia Nitrogen	26	0.055	0.068	0.026
Nitrate Nitrogen	26	0.23	0.222	0.252
Total Organic Carbon	25	14.23	7.72	12.13
Chlorophyll a	26	72.0	48.8	11.1
Total Nitrogen	25	1.73	1.93	0.93
Total Organic Nitrogen	26	1.64	1.63	0.63
Total Organic Phosphorus	26	0.281	0.208	0.034

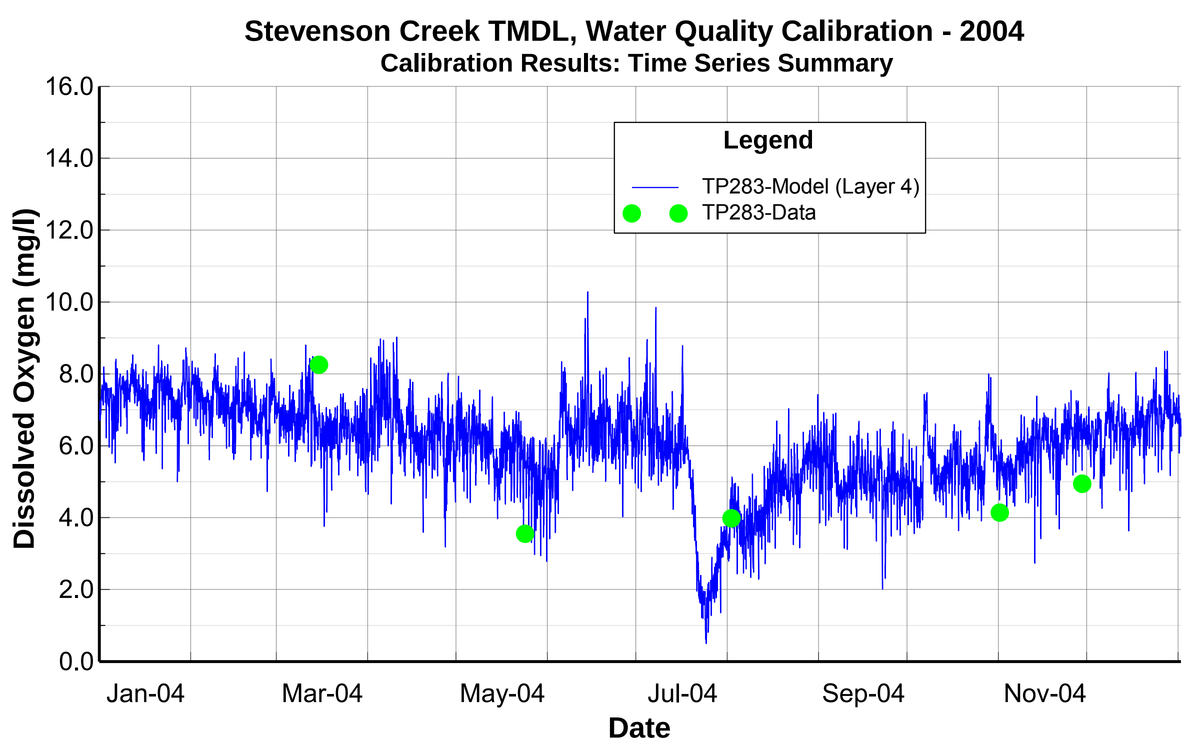


Figure 4-76 Stevenson Creek Water Quality Calibration: Dissolved Oxygen, TP283.

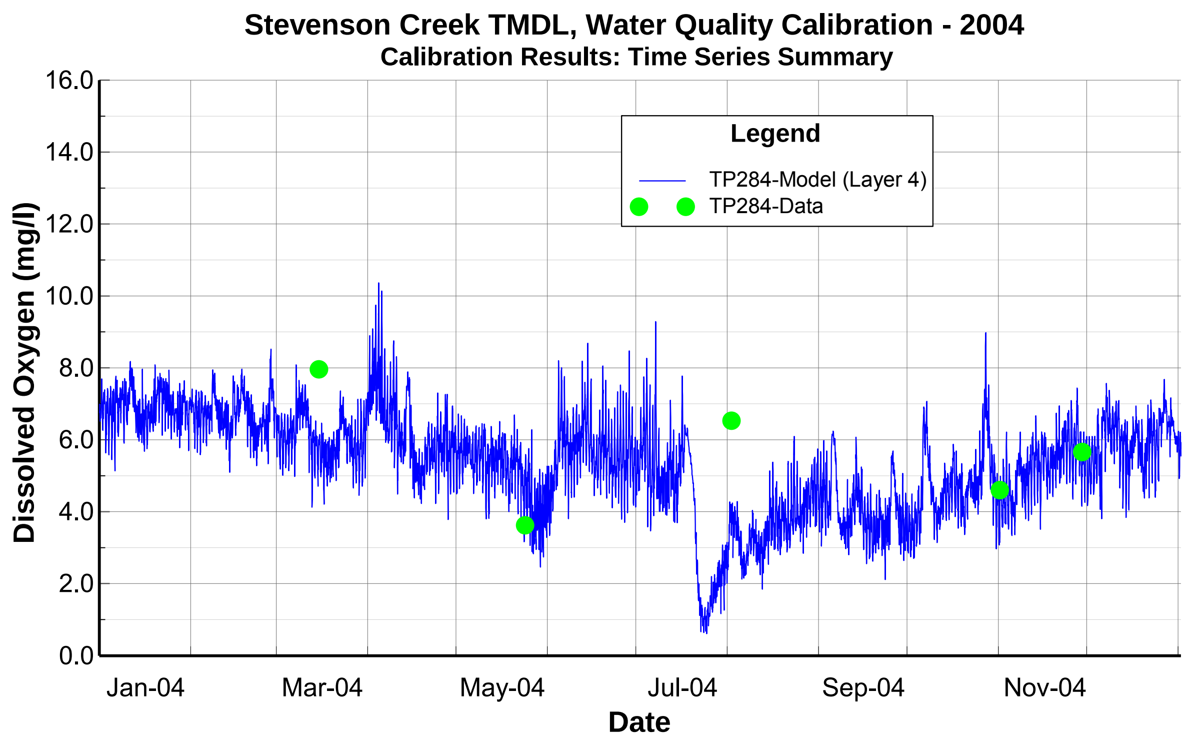


Figure 4-77 Stevenson Creek Water Quality Calibration: Dissolved Oxygen, TP284.

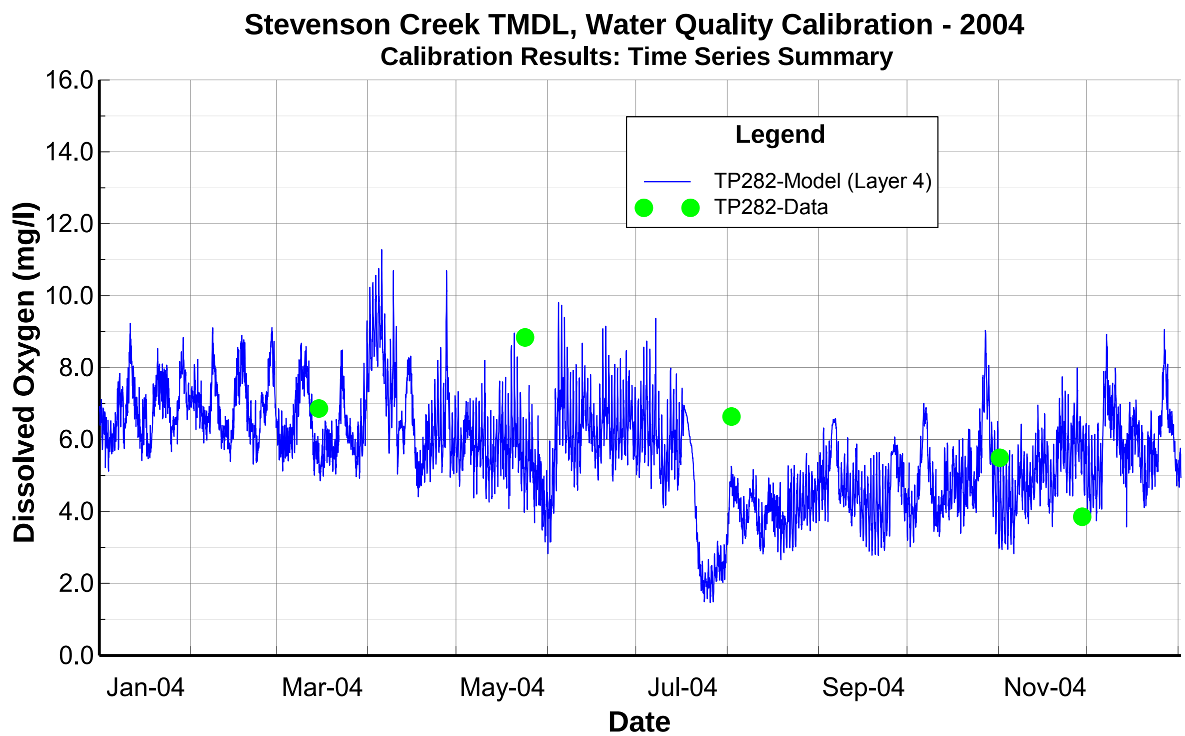


Figure 4-78 Stevenson Creek Water Quality Calibration: Dissolved Oxygen, TP282.

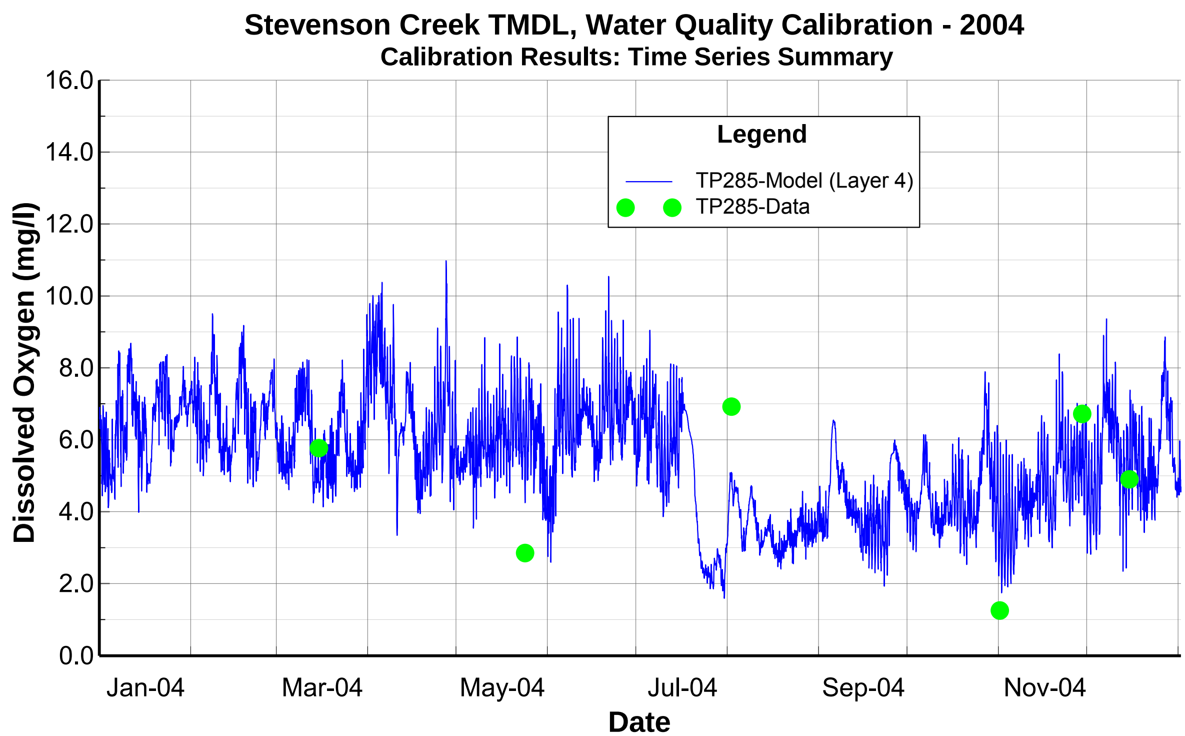


Figure 4-79 Stevenson Creek Water Quality Calibration: Dissolved Oxygen, TP285.

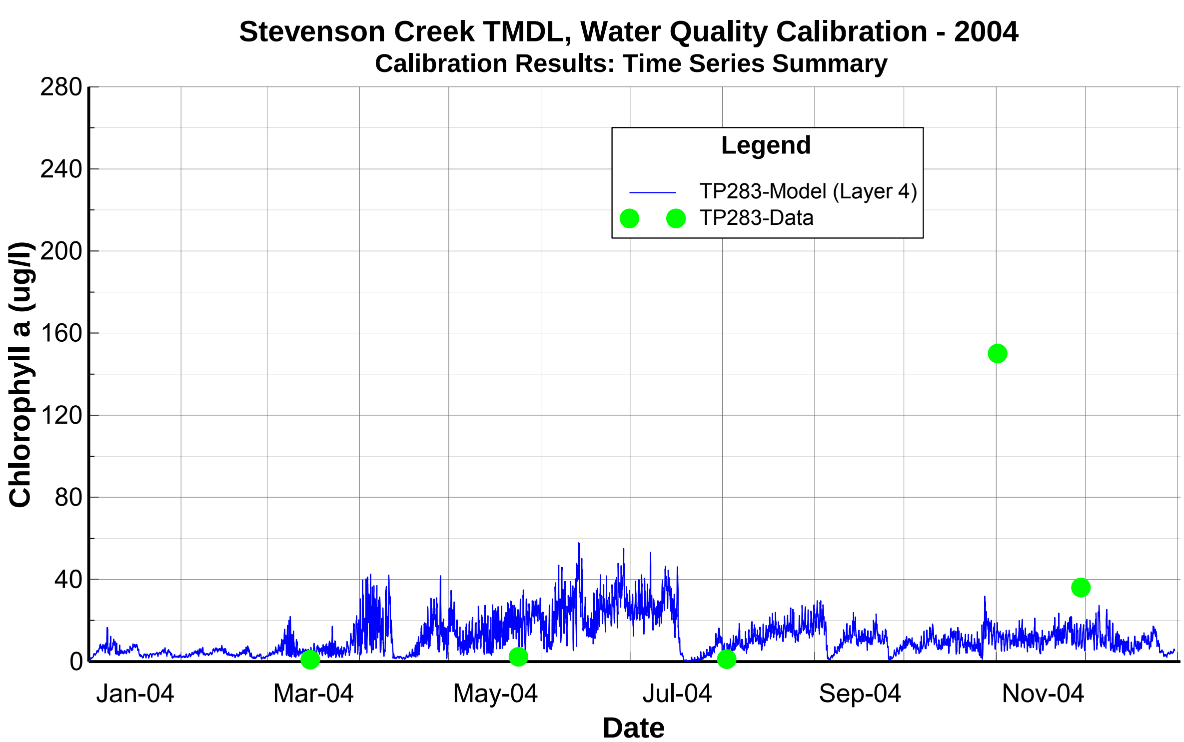


Figure 4-80 Stevenson Creek Water Quality Calibration: Chlorophyll a, TP283.

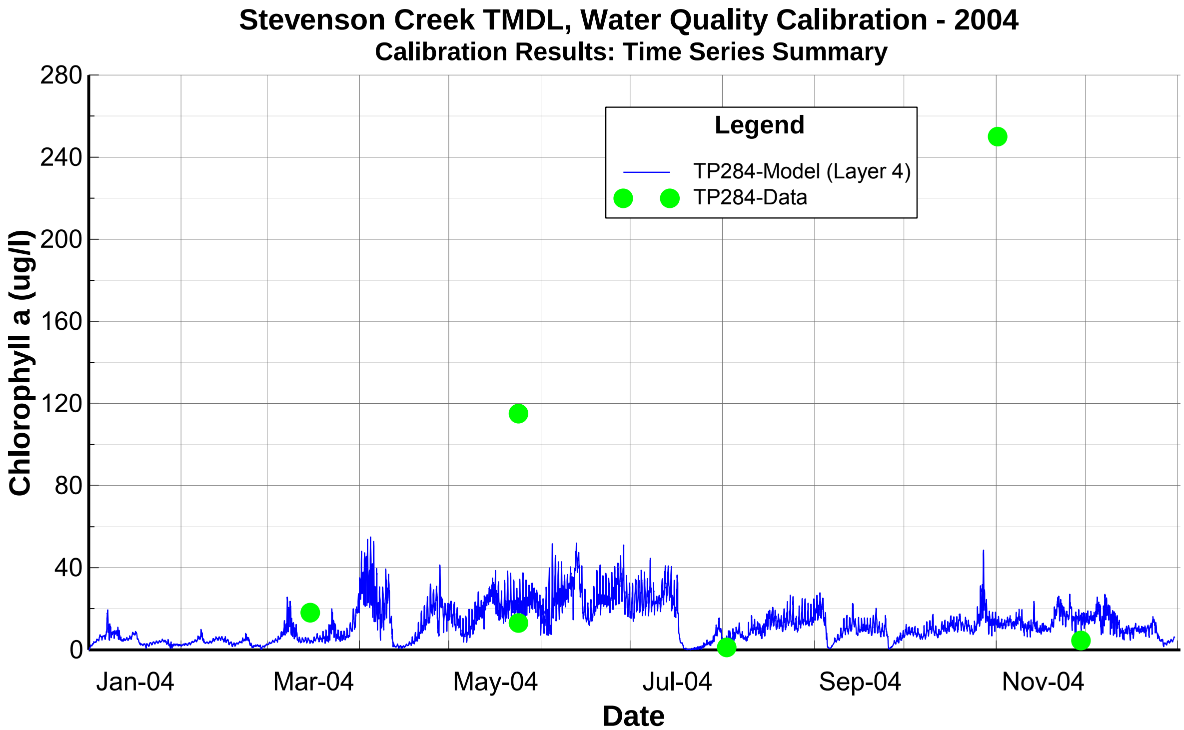


Figure 4-81 Stevenson Creek Water Quality Calibration: Chlorophyll a, TP284

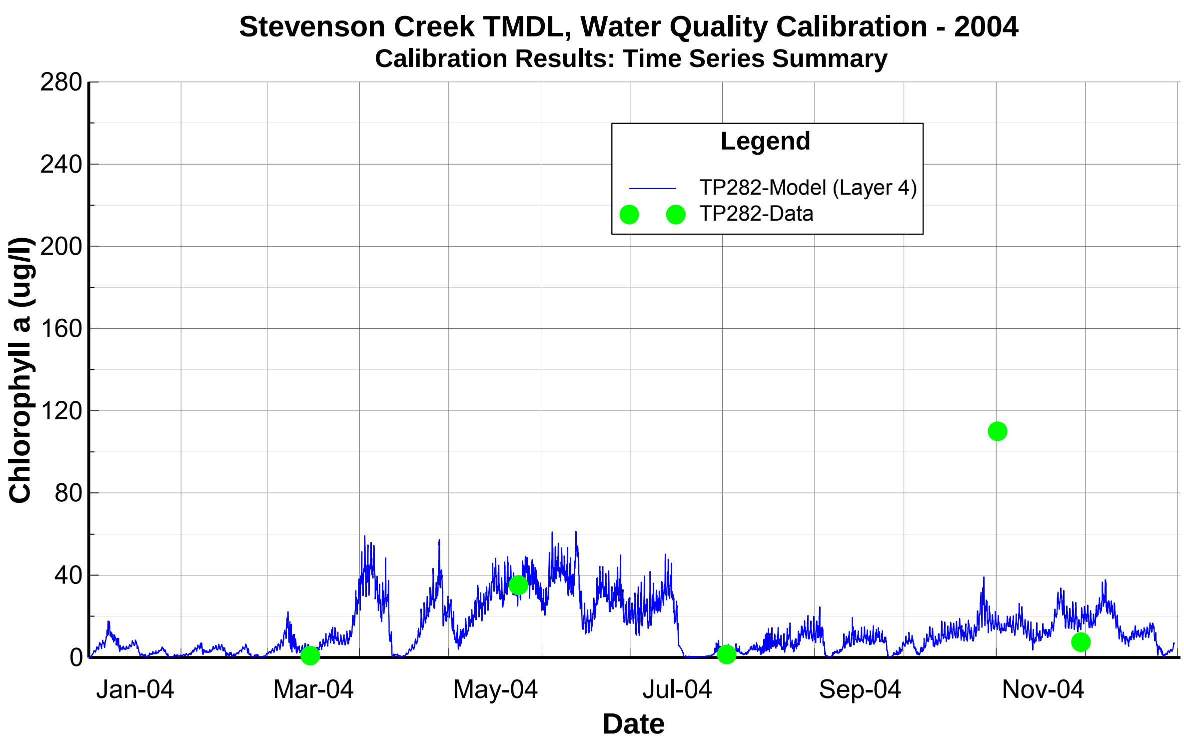


Figure 4-82 Stevenson Creek Water Quality Calibration: Chlorophyll a, TP282

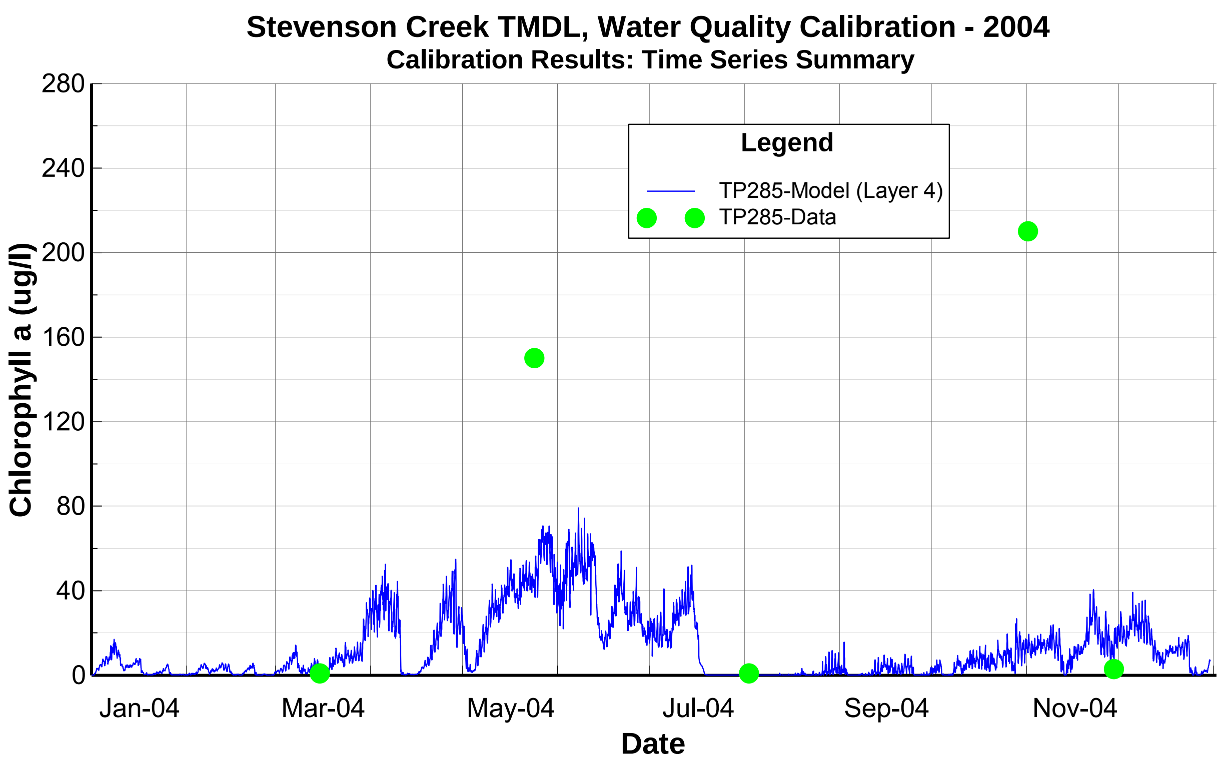


Figure 4-83 Stevenson Creek Water Quality Calibration: Chlorophyll a, TP285

EFDC_Explorer provides a large number of views to present the model results. This is very useful for interpretation of model results and scenario analysis. As examples, **Figures 4-84**, **4-85** and **4-86** show one plan view and two longitudinal (vertical slice along a user defined line) profile plots. **Figure 4-84** and **4-85** show the dissolved oxygen for the dates of March 13, 2004 and June 21, 2004. **Figure 4-86** shows the Total Phosphate profile for that same time as the DO profile (**Fig. 4-85**). The dotted line through the model (**Fig. 4-84**) shows the location of the longitudinal profiles.

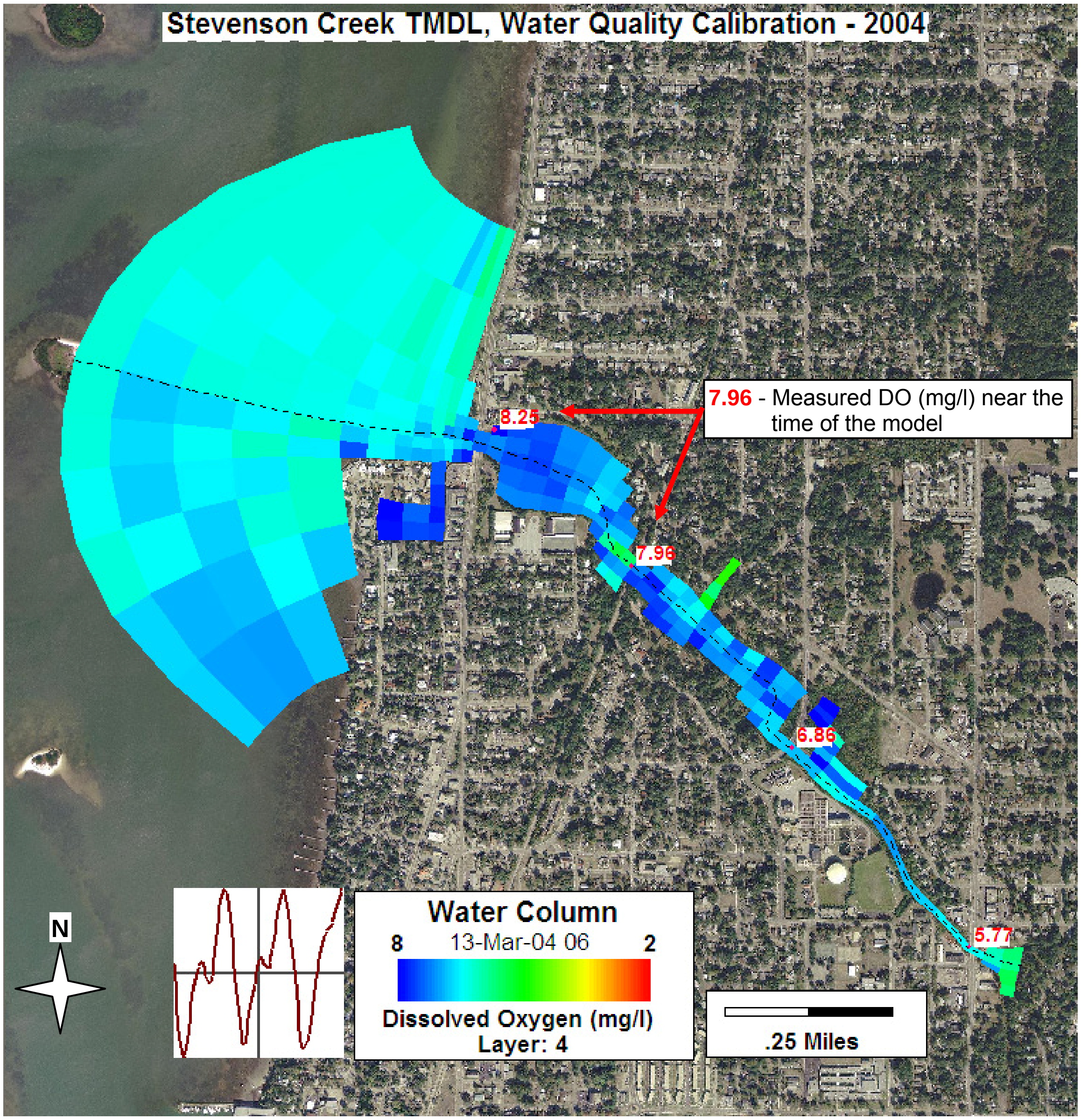


Figure 4-84 Plan View of Dissolved Oxygen March 13, 2004 (Surface Layer, K=4).

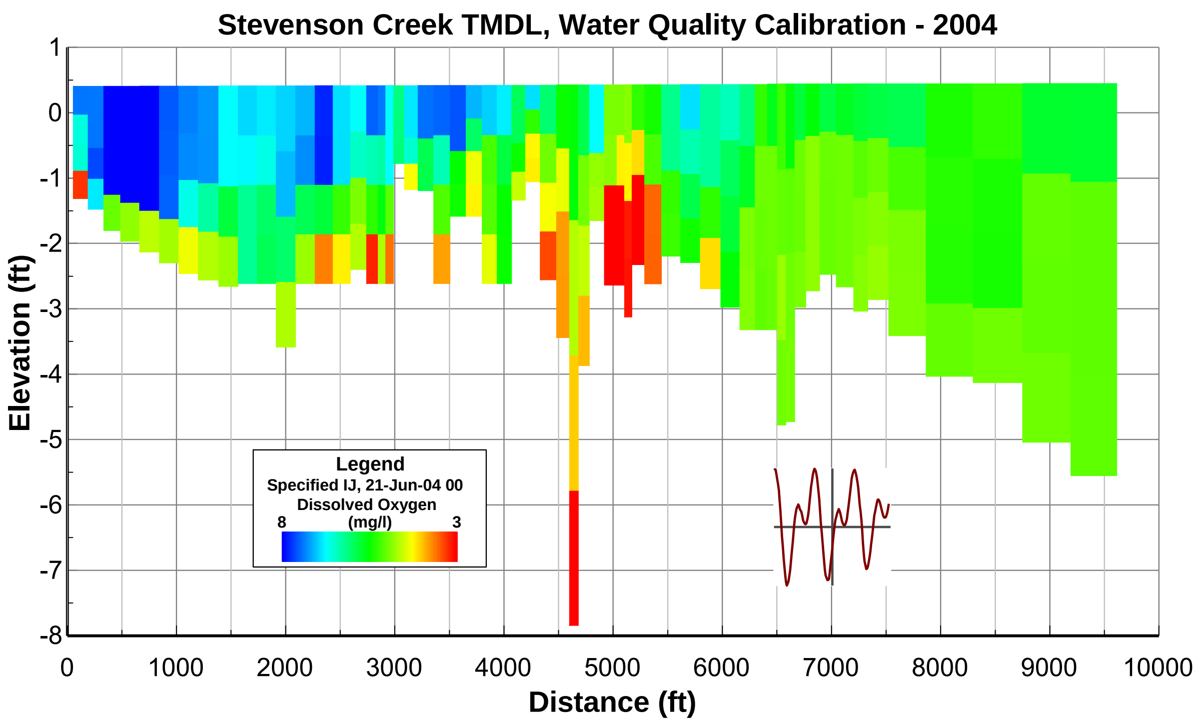


Figure 4-85 Longitudinal Profile of Dissolved Oxygen on June 21, 2004.

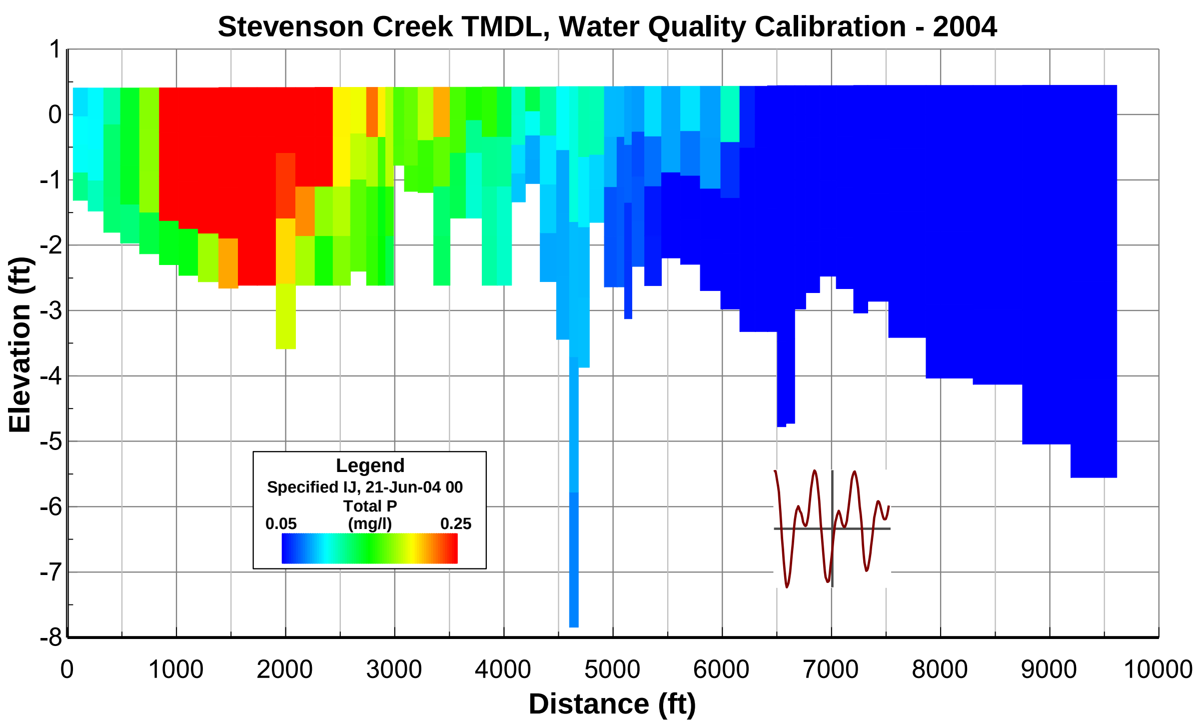


Figure 4-86 Longitudinal Profile of Total Phosphate on June 21, 2004.

In general it can be seen that the model does a good job of reproducing the water quality seasonal trends in Stevenson Creek. Therefore the model was considered calibrated for hydrodynamics and water quality.

4.7.5 Summary of Calibration Parameters

The initial water quality parameters were set to their defaults (Park, et.al., 1995). During the calibration process several of these factors were adjusted. **Table 4-42** summarizes the water quality factors adjusted and the final values used. All of these factors are within typical ranges.

Table 4-42 Adjusted water quality parameters for calibration.

Parameter	Initial	Final
Reaeration Factor	1.0	0.5
Green Algae Growth Rate	2.5	3.3
Green Algae Upper Bound Optimal Temperature (°C)	25	26
Green Algae Lower Bound Optimal Temperature (°C)	28	30
Green Algae Settling Rate (m/day)	0.1	0.025
Labile Organic Material Settling (m/day)	1	.25
Refractory Organic Material Setting (m/day)	1	.25
Dissolved Organic Carbon Heterotrophic Respiration (/day)	.01	.1
Refractory Organic Carbon Dissolution Rate (/day)	.005	.01
Background Light Extinction Factor	0.45	1.5

4.8 EFDC Model Validation

The period selected for model validation was a four year period ranging from January 1, 1999 to December 31, 2002. The data used for the validation effort was from the Pinellas County water quality monitoring program. There are two stations of use for the tidally impacted area of Stevenson Creek. They are 21FLPDEM AMB 18-1 and 21FLPDEM AMB 15-1. **Figure 4-87** shows the location of the validation stations overlaid on a plot of the water depths at midnight August 11, 2002.

As with the calibration period, this period has good overlap of the salinity, temperature, meteorology, and water quality data for both the boundary conditions and for validation comparison data. Section 4.12.1 summarizes the data input for initial and boundary conditions, and Section 4.12.2 summarizes the EFDC model validation results.

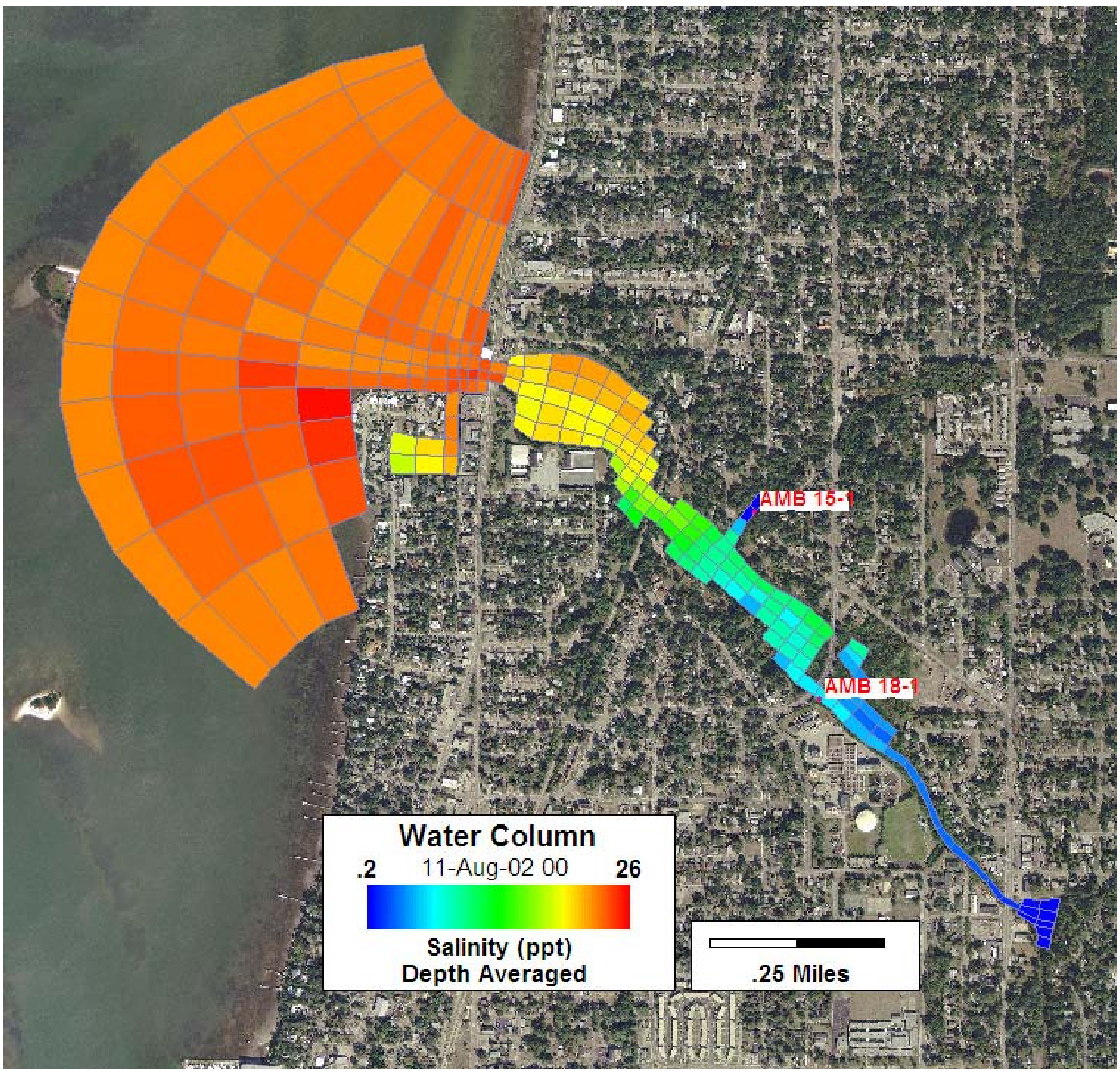


Figure 4-87 Stevenson Creek depth averaged salinity (11-Aug-02) with validation stations.

4.8.1 Boundary Conditions

The EFDC model boundary condition locations were previously shown in **Figure 4-51**. The location and types of boundary conditions did not change from the calibration period. What did change was the boundary condition forcings. The boundary conditions reflect the validation period.

Flow Boundaries

As an example of the flow boundaries for the validation period, **Figure 4-88** shows the HSPF flows for Reach 1(Hammond Branch) and Reach 2 (Spring Branch). **Figure 4-88** also shows the flows from the Marshall WWTP as a comparison.

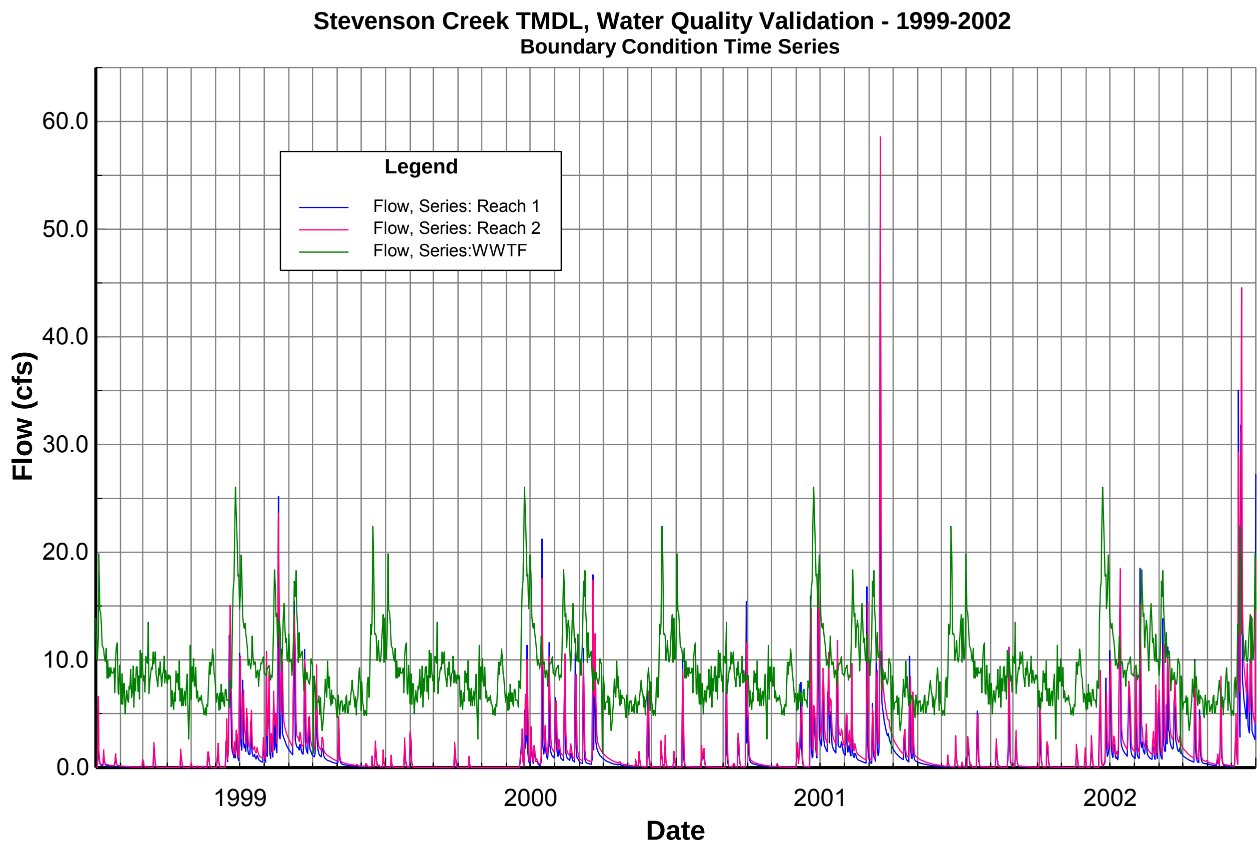


Figure 4-88 Stevenson Creek HSPF and AWWTP Flows for the Validation Period.

Open Boundary Conditions

The same approach used for the calibration period was used for the validation period. The water levels, temperatures and salinities were extracted from the large scale model (**Appendix A**). Water quality parameters were taken from the Clearwater Harbor, North (Station ID W2). The time series of water surface elevation for the validation period of January 1999 to December 2002, is shown in **Figure 4-89**.

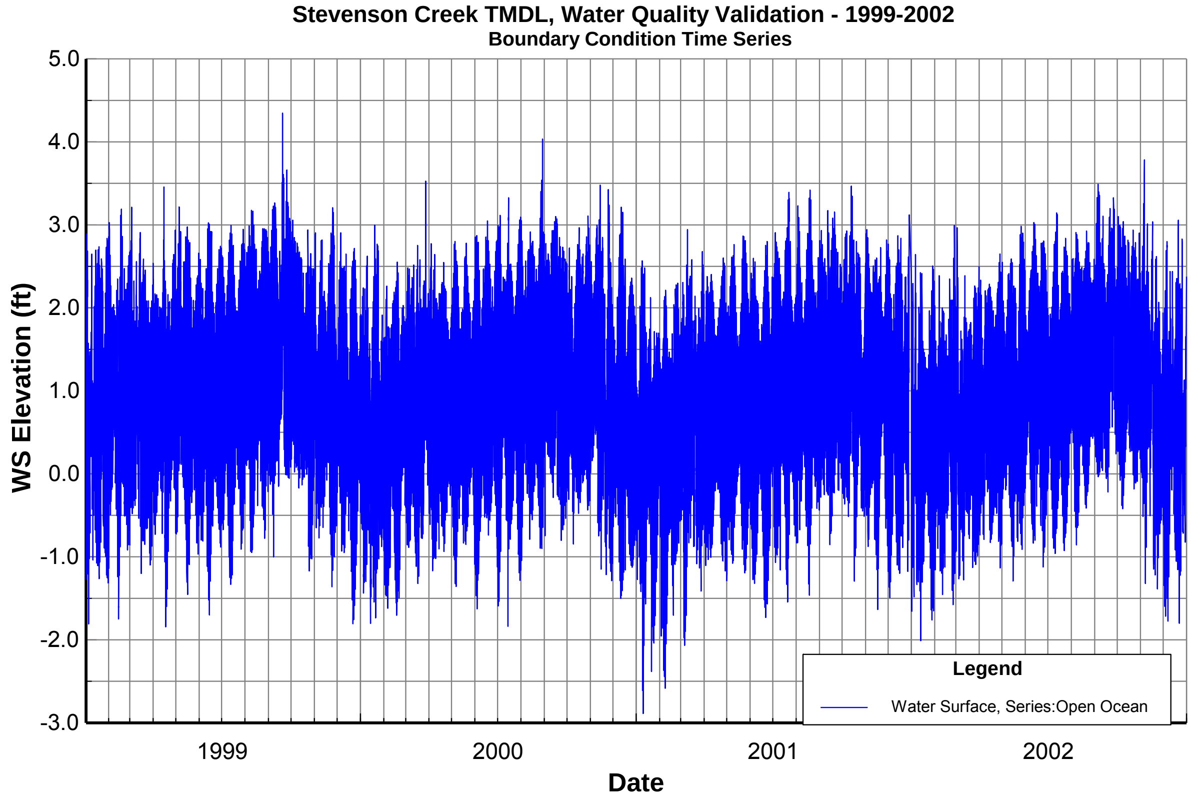


Figure 4-89 Clearwater Harbor Open Boundary Tide Series for the Validation Period.

Atmospheric and Wind Boundary Conditions

Winds (WSER.INP) and atmospheric (ASER.INP) boundary condition files have been developed using the St. Petersburg/Clearwater International Airport. As an example of this meteorological data, **Figure 4-90** provides an hour by hour summary of the winds and air temperature for 1999. **Figure 4-91** shows a summary of the wind data as a wind rose for entire validation period of 1999-2002.

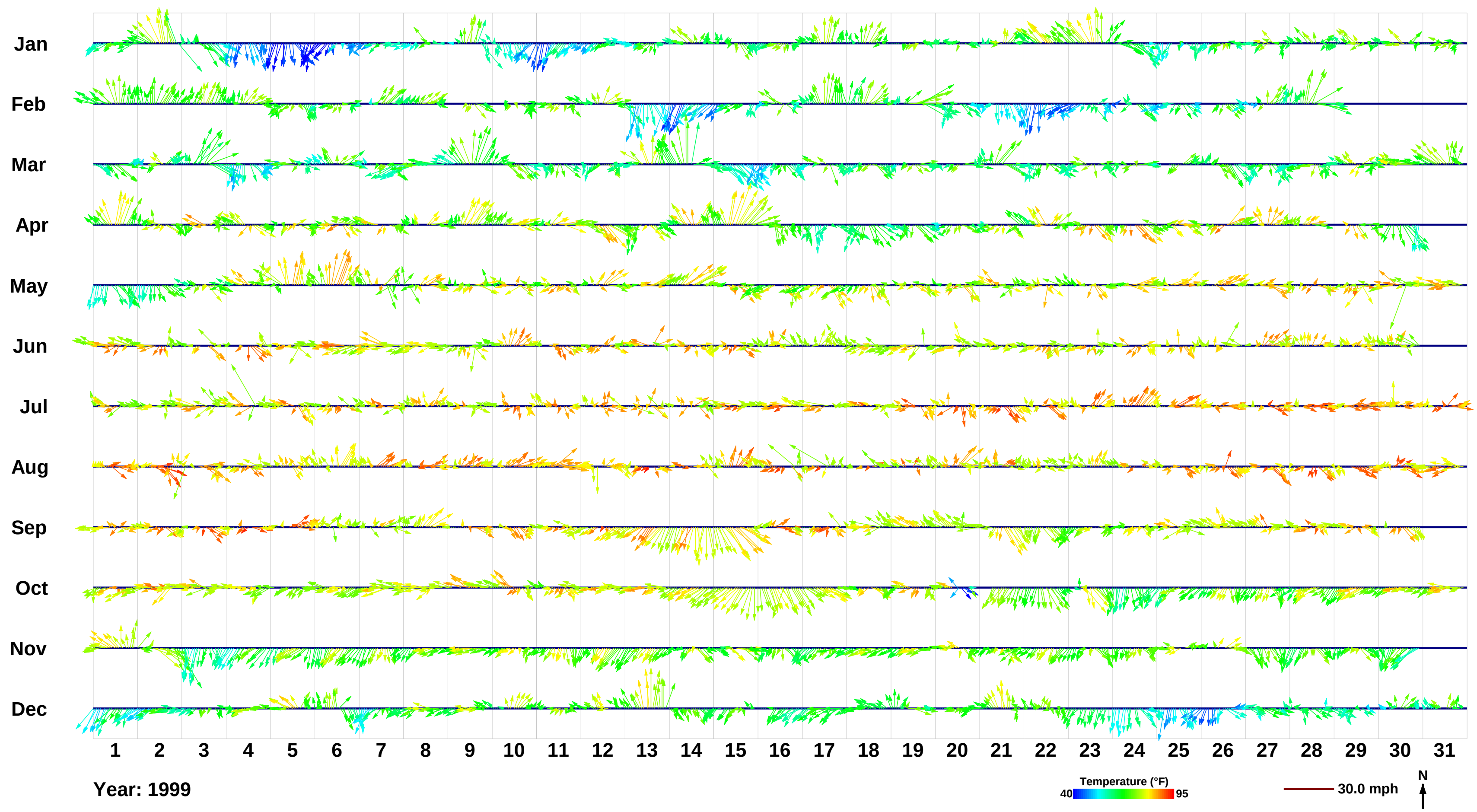


Figure 4-90 Wind Speed, Direction and Dry Bulb Air Temperature Summarized for 1999

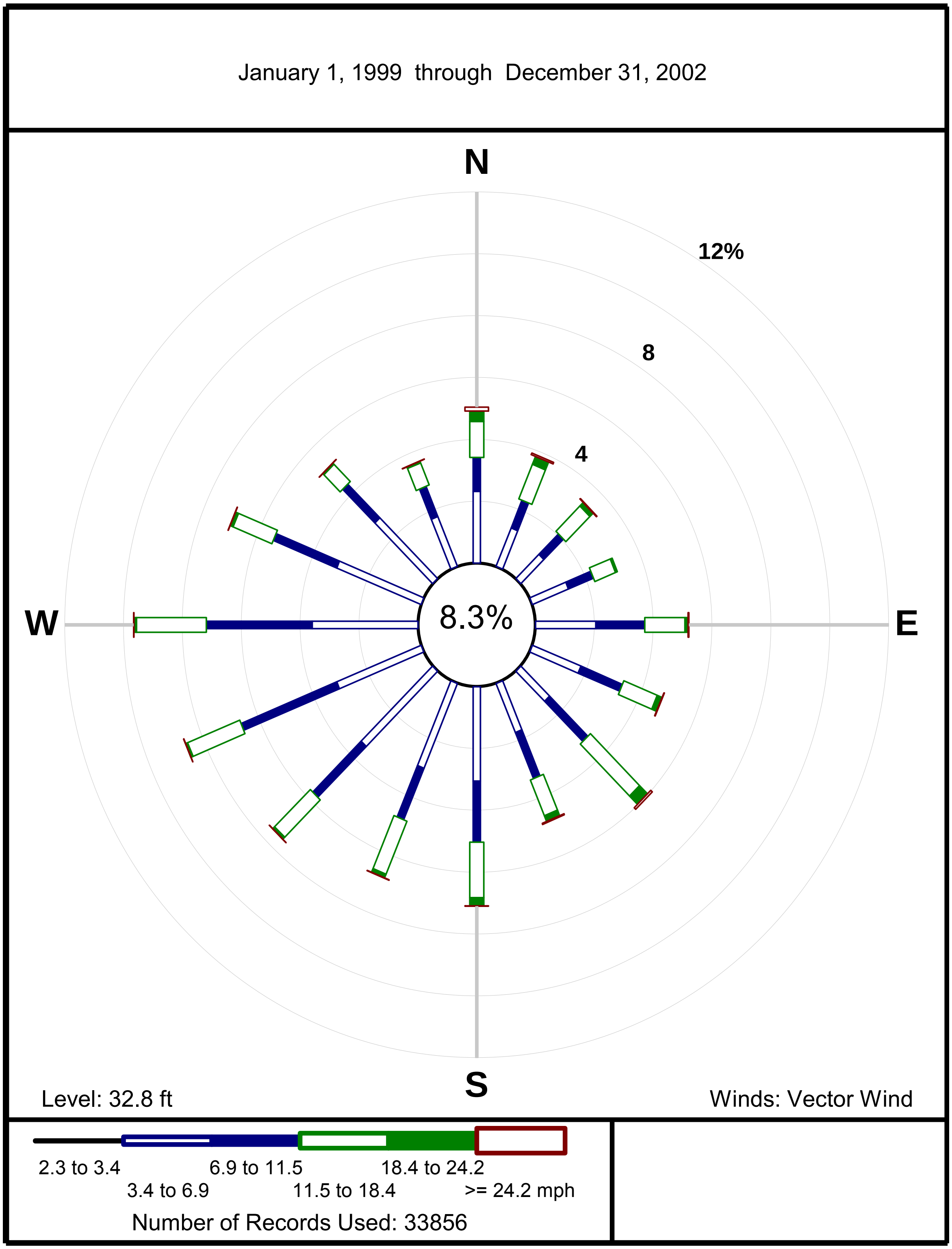


Figure 4-91 Clearwater Harbor, North Station Wind Rose for the Year 1999-2002

4.8.2 Validation: Hydrodynamics

Tide Signal Validation

There were no data for tide signal calibration inside the Bay for the validation period. Based on the calibration results it is expected that the tide signal propagation into and up Stevenson Creek will be representative of the validation conditions.

Salinity Validation

The salinity & temperature data used for the water quality model validation data were developed from the Pinellas County database. Water quality data are available for stations AMB 18-1 and AMB 15-1 for the validation period. The stations are shown in Figure 4-87.

A plan view of the surface layer salinities for a snapshot in time where measured salinities were available is shown in **Figure 4-92**. **Figures 4-93** to **4-96** show the salinity validation results for Station AMB15-1 and AMB18-1. Overall trends in salinity of the model for the surface layer are underestimated, and are overestimated for the bottom layer.

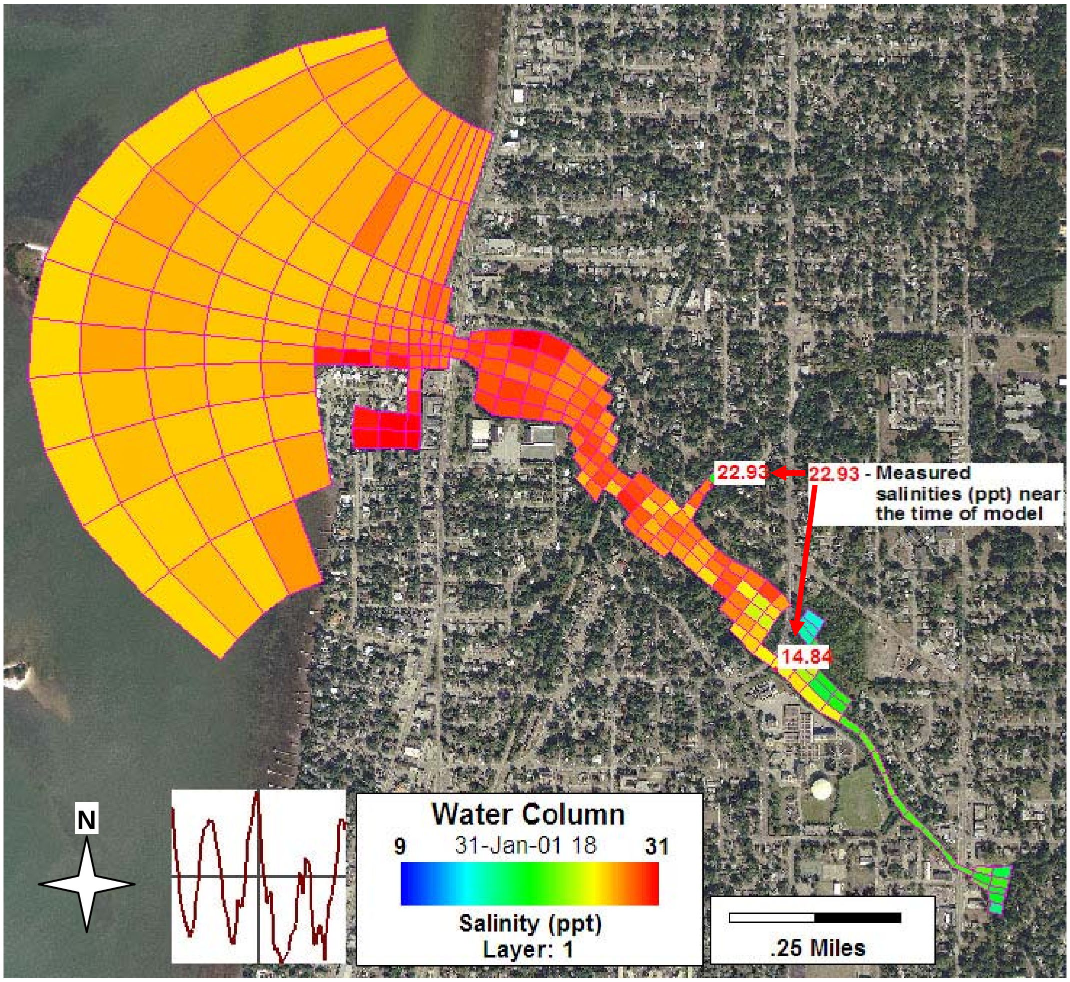


Figure 4-92 Model Domain Salinity for the Surface Layer on 31 March, 2001.

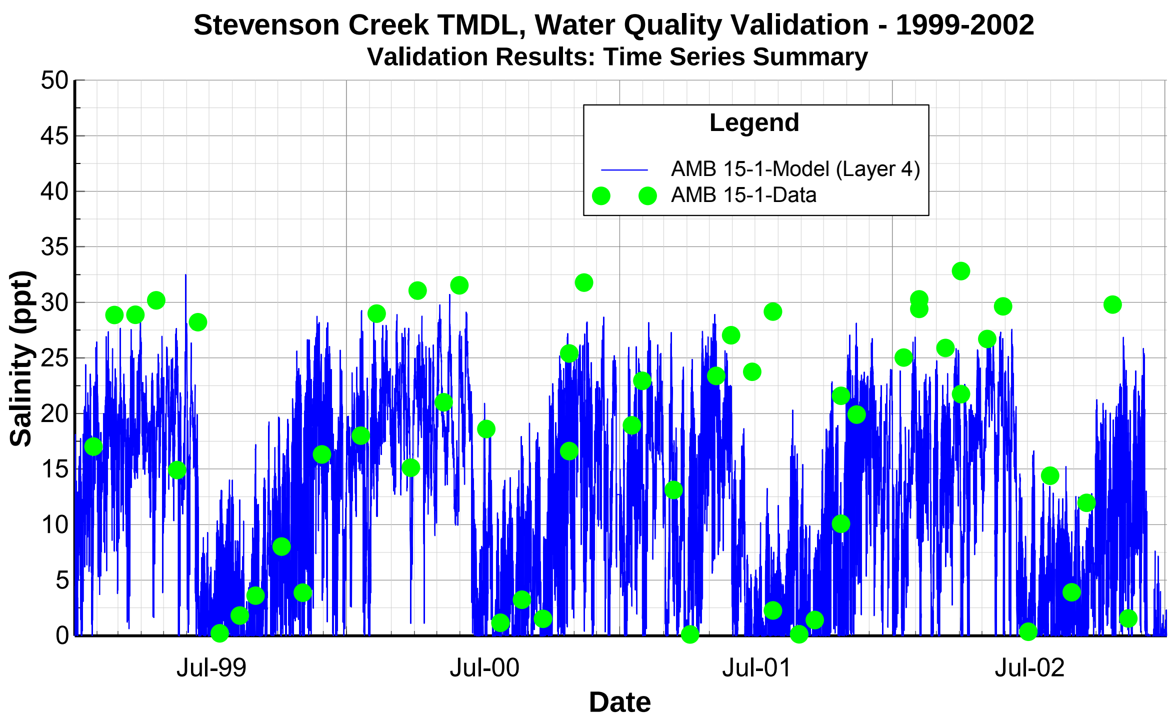


Figure 4-93 Stevenson Creek 1999-2002 Salinity Validation-Surface Layer: AMB 15-1.

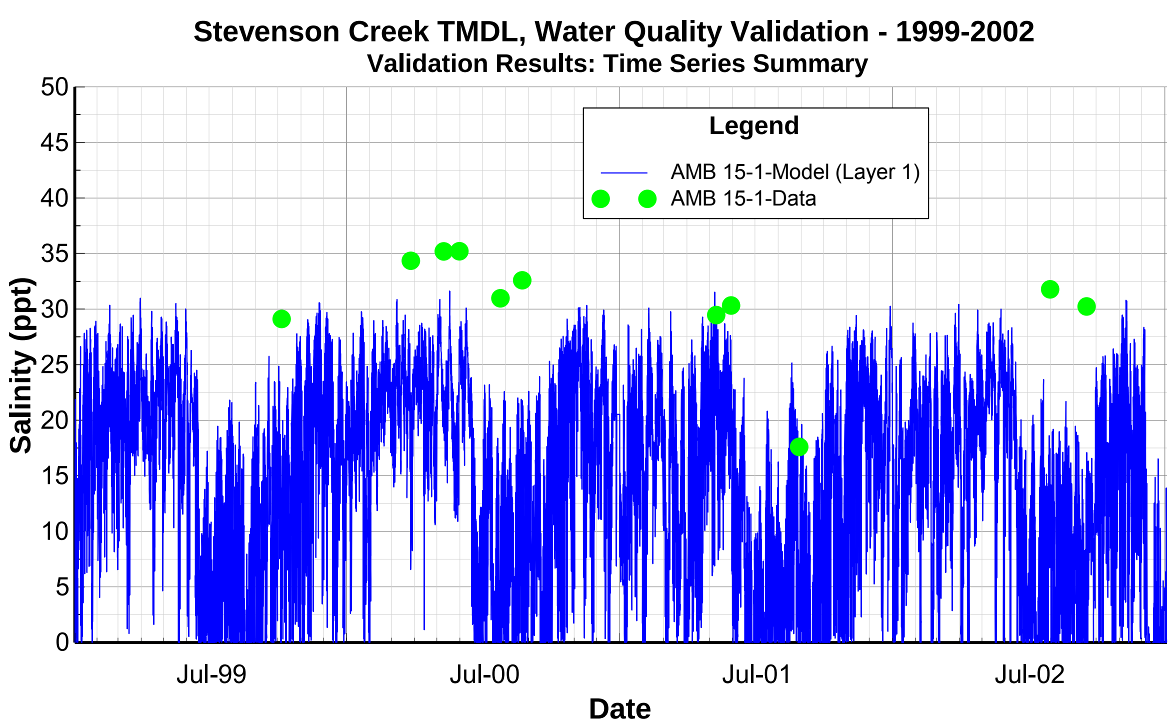


Figure 4-94 Stevenson Creek 1999-2002 Salinity Validation-Bottom Layer: AMB 15-1.

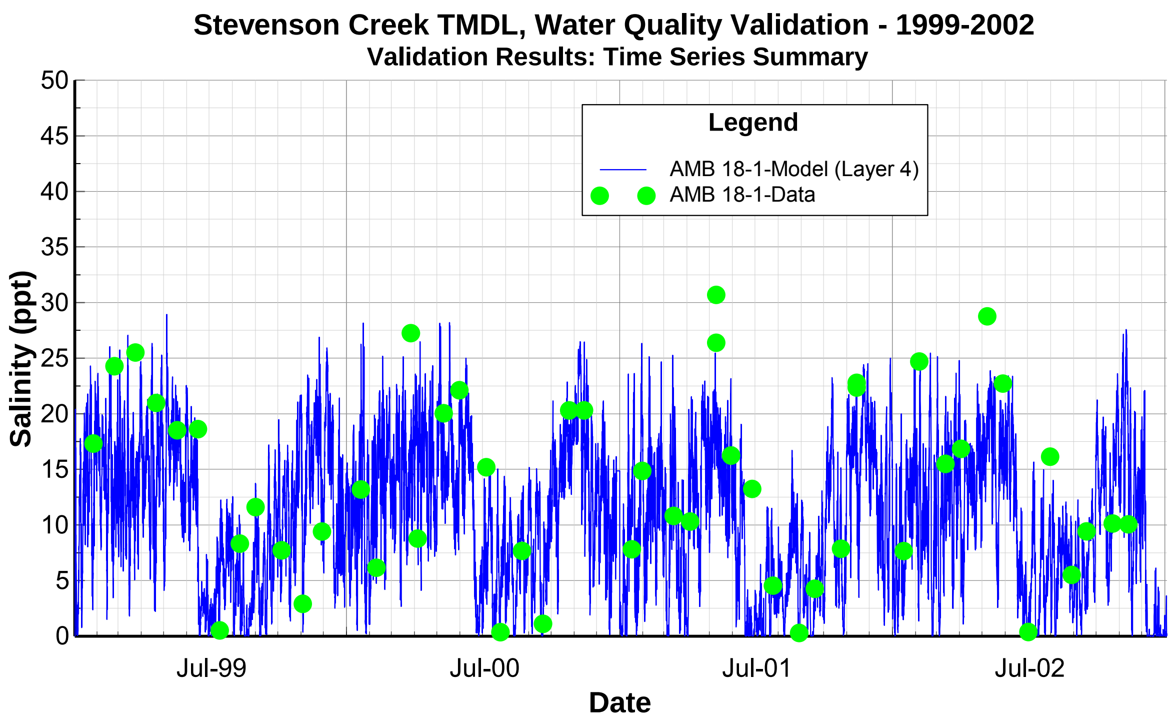


Figure 4-95 Stevenson Creek 1999-2002 Salinity Validation-Surface Layer: AMB 18-1.

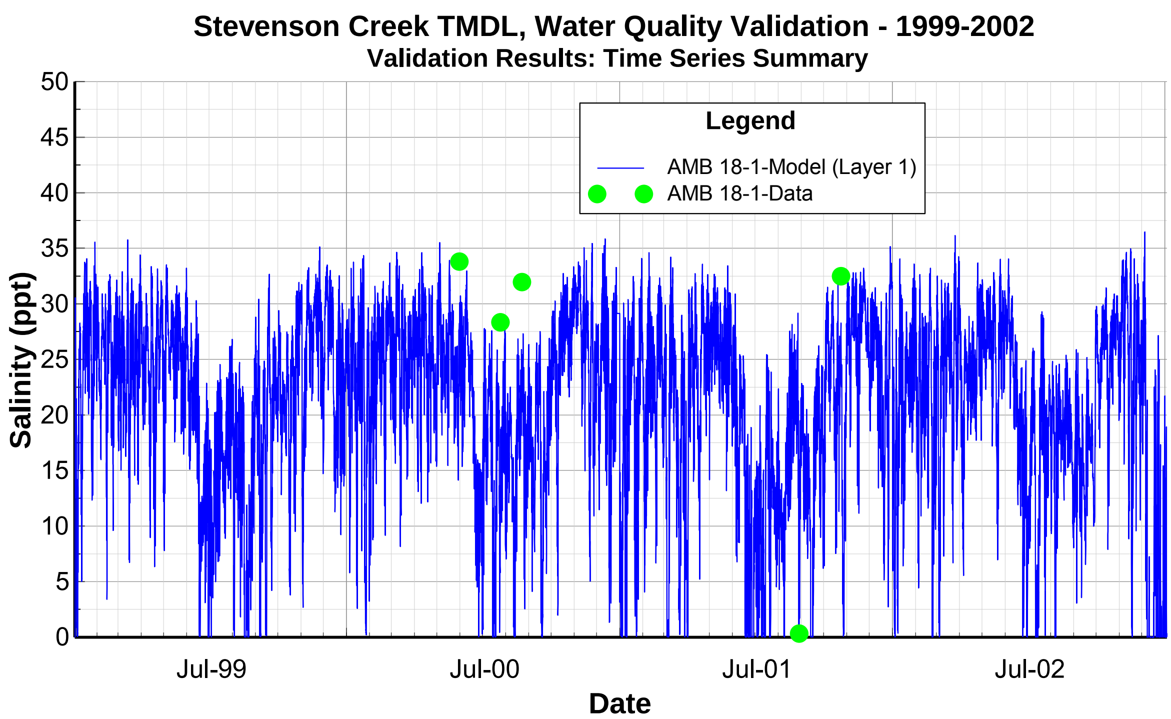


Figure 4-96 Stevenson Creek 1999-2002 Salinity Validation-Bottom Layer: AMB 18-1.

Water Temperature Validation

As mentioned previously, the salinity & temperature data used for the water quality model validation data were developed from the Pinellas County database. Water quality data are available for stations AMB 18-1 and AMB 15-1 for the validation period. The stations are shown in Figure 4-87.

Figures 4-97 to **4-100** show the temperature validation results. The model versus data comparison for water temperature was considered excellent.

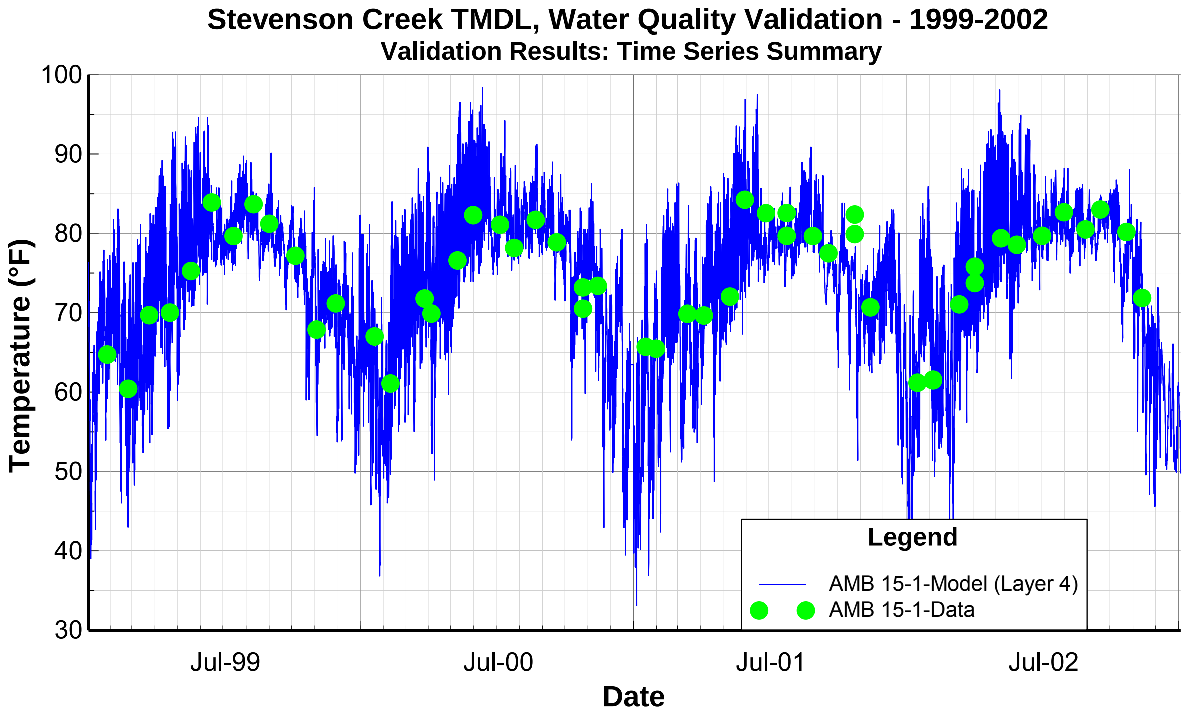


Figure 4-97 Stevenson Creek 1999-2002 Water Temperature Validation-Surface Layer: AMB 15-1

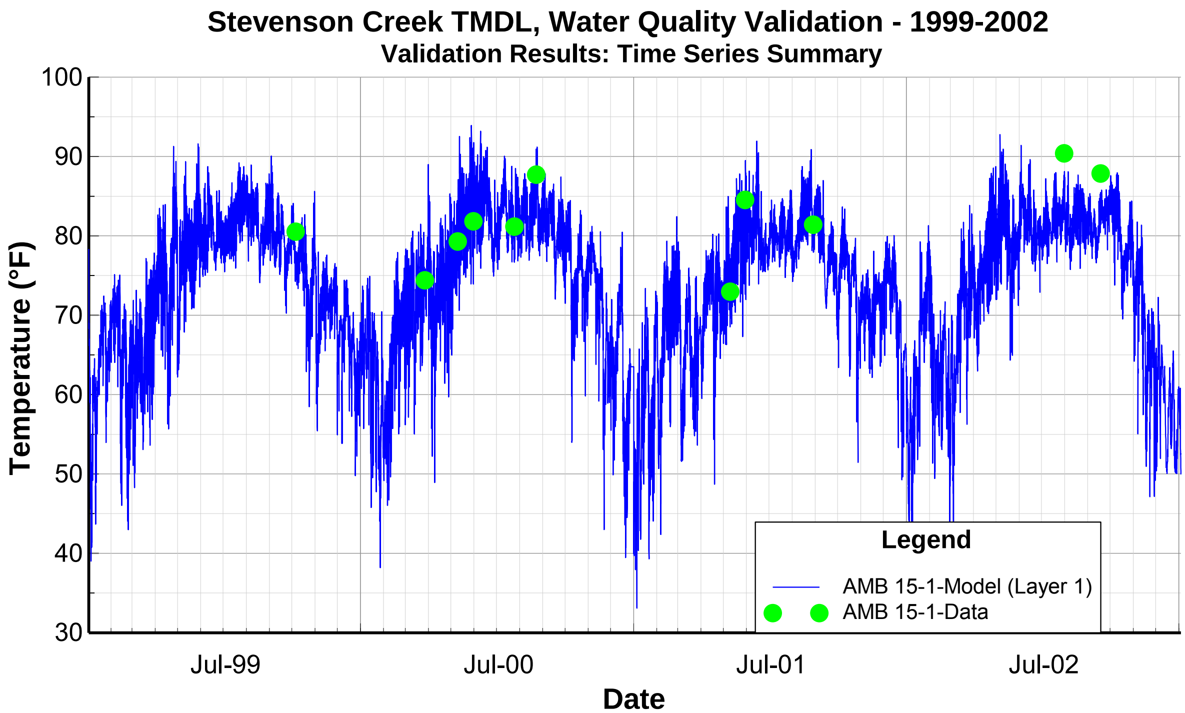


Figure 4-98 Stevenson Creek 1999-2002 Water Temperature Validation-Bottom Layer: AMB 15-1.

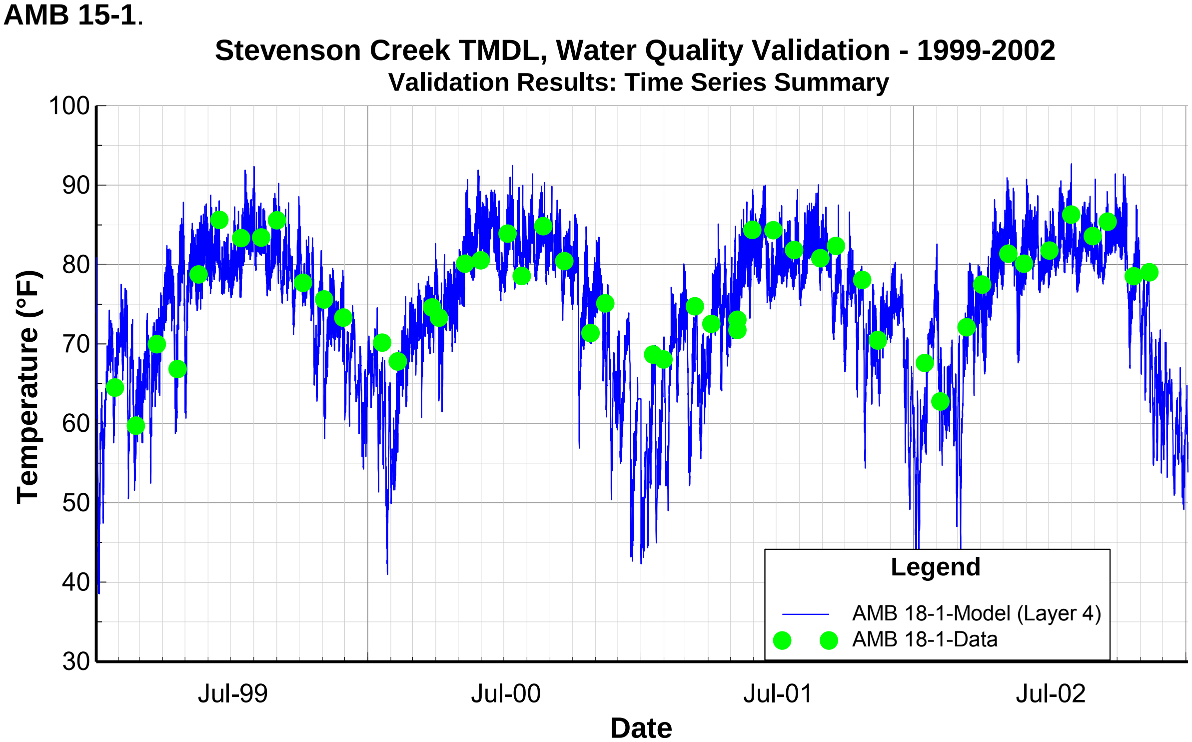


Figure 4-99 Stevenson Creek 1999-2002 Water Temperature Validation-Surface Layer: AMB 18-1.

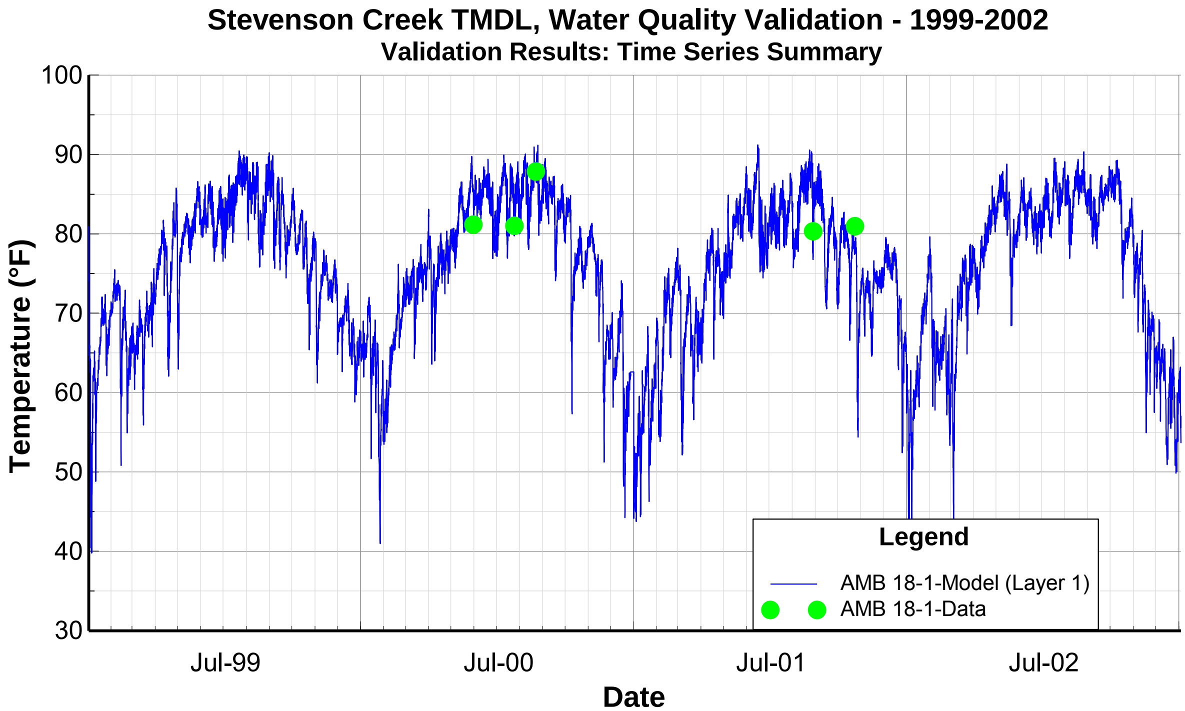


Figure 4-100 Stevenson Creek 1999-2002 Water Temperature Validation-Bottom Layer: AMB 18-1

Summary Statistics

Tables 4-43 and **4-44** provide summaries of the validation statistics for salinity and temperature, respectively. It is can be noted that the bottom temperatures are higher than that of the surface for both the measurements and the model. This is due to the differences in the sample numbers and sample periods, i.e. the bottom temperatures were only measured in the summer.

Table 4-43 Validation Period Summary Statistics for Salinity (PPT).

Station ID	Layer/ Type	Starting Date/Time	Ending Date/Time	# Pairs	RMS	Data Average	Model Average
AMB 15-1	Top	27-Jan-1999 8:59	13-Nov-2002 9:06	53	12.5	17.4	11.0
AMB 15-1	Bottom	6-Oct-1999 8:24	18-Sep-2002 9:14	11	13.4	30.6	18.0
AMB 18-1	Top	27-Jan-1999 8:42	13-Nov-2002 8:51	50	5.9	13.8	11.5
AMB 18-1	Bottom	31-May-2000 9:46	24-Oct-2001 8:43	5	6.7	25.4	20.1

Table 4-44 Validation Period Summary Statistics for Temperature (°F).

Station ID	Layer/ Type	Starting Date/Time	Ending Date/Time	# Pairs	RMS	Data Average	Model Average
AMB 15-1	Top	27-Jan-1999 8:59	13-Nov-2002 9:06	53	3.1	74.6	74.1
AMB 15-1	Bottom	6-Oct-1999 8:24	18-Sep-2002 9:14	11	2.2	82.0	80.5
AMB 18-1	Top	27-Jan-1999 8:42	13-Nov-2002 8:51	50	4.4	76.4	73.7
AMB 18-1	Bottom	31-May-2000 9:46	24-Oct-2001 8:43	5	2.4	82.3	82.1

4.8.3 Validation: Water Quality

Data for Validation

The data used for the water quality model validation data were developed from the Pinellas County database. Water quality data are available for the same stations used for the hydrodynamic calibration, i.e. stations AMB 18-1 and AMB 15-1. The stations are shown in Figure 4-87. The EFDC water quality parameter correspondence to the water quality data collected for these stations is shown in **Table 4-45**.

Table 4-45 EFDC parameter – Pinellas County data correspondence used for validation.

Derived Data From	Corresponding EFDC Parameter(s)
Dissolved Oxygen	Dissolved Oxygen (DOX)
Chlorophyll a	Green Algae (CHG)
Total Organic Carbon	Sum of DOC, LPOC and RPOC fractions
Total Phosphorus	Sum of DOP, LPOP and RPOP fractions and Total Phosphate (P4D)
Orthophosphate	Total Phosphate (P4D)
Total Nitrogen[1]	Sum of DON, LPON and RPON fractions, Nitrate-Nitrite (NOX) and Ammonia (NHX)
Nitrate-Nitrite Nitrogen	Nitrate-Nitrite (NOX)
Ammonia Nitrogen	Ammonia (NHX)

[1]Derived from summing TKN and NOX results.

Water Quality Validation Results

Figures 4-101 through **4-106** provide time series comparisons of the model versus measured dissolved oxygen and Chlorophyll a, respectively, at the two monitoring stations. A complete set of calibration time series plots are included in **Appendix C**. Also included in **Appendix C** are the station by station calibration statistics. **Table 4-46** provides summaries of the validation statistics for all validated water quality parameters.

The DO results for the validation run suggests that the model over predicts. For Chlorophyll a, the model reproduces the general seasonal trends but misses the large blooms that seem to occur every year.

Table 4-46 Water quality summary statistics for the validation period.

Parameter	Layer	# of Data/ Model Pairs	RMS	Data Average (mg/l)	Model Average (mg/l)
		AMB 15-1			
	Surface	52	2.46	2.968	4.560
Dissolved Oxygen	Bottom	11	1.28	1.657	1.085
Total Phosphate	Surface	48	0.113	0.134	0.130
Total Phosphorus	Surface	48	0.195	0.250	0.176
Ammonia Nitrogen	Surface	42	0.104	0.114	0.032
Nitrate Nitrogen	Surface	48	0.439	0.178	0.409
Total Organic Carbon	Surface	45	15.219	14.694	8.247
Chlorophyll a	Surface	48	75.956	28.554	9.609
Total Nitrogen	Surface	42	1.633	1.083	1.584
Total Organic Nitrogen	Surface	42	1.231	0.788	1.107
Total Organic Phosphorus	Surface	48	0.153	0.116	0.046
		AMB 18-1			
	Surface	49	2.10	4.24	5.83
Dissolved Oxygen	Bottom	5	0.96	2.23	2.3
Total Phosphate	Surface	47	0.067	0.159	0.150
Total Phosphorus	Surface	47	0.139	0.284	0.252
Ammonia Nitrogen	Surface	37	0.16	0.12	0.066
Nitrate Nitrogen	Surface	47	0.312	0.447	0.541
Total Organic Carbon	Surface	44	31.98	29.36	7.37
Chlorophyll a	Surface	95	57.82	28.16	11.56
Total Nitrogen	Surface	47	0.708	1.537	1.198
Total Organic Nitrogen	Surface	37	0.417	0.877	0.614
Total Organic Phosphorus	Surface	47	0.134	0.125	0.102

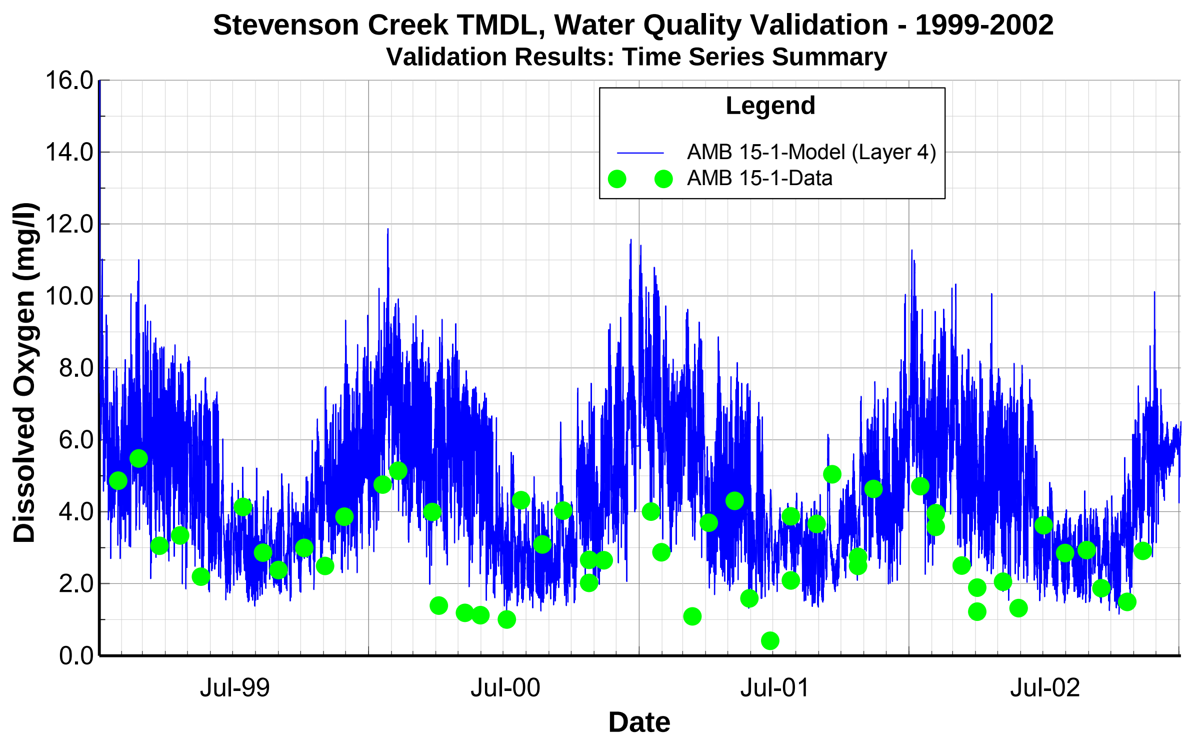


Figure 4-101 Stevenson Creek 1999-2002 Dissolved Oxygen Validation-Surface Layer: AMB 15-1.

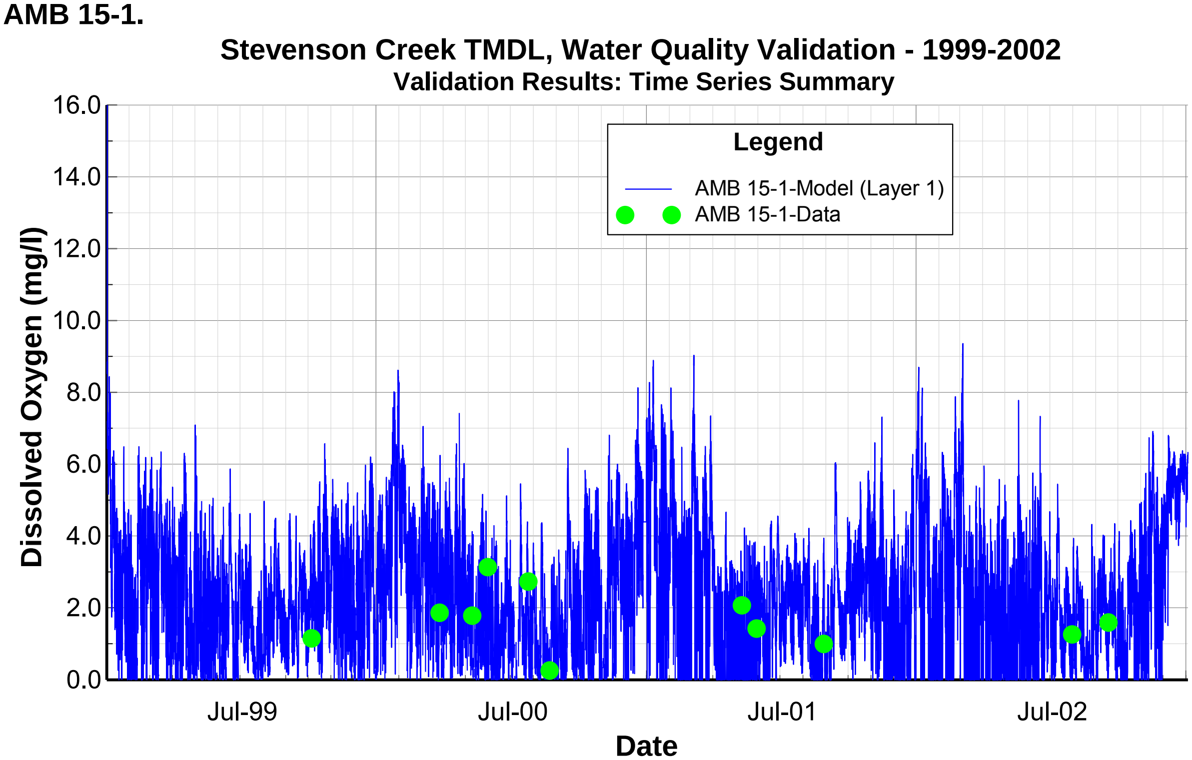


Figure 4-102 Stevenson Creek 1999-2002 Dissolved Oxygen Validation-Bottom Layer: AMB 15-1.

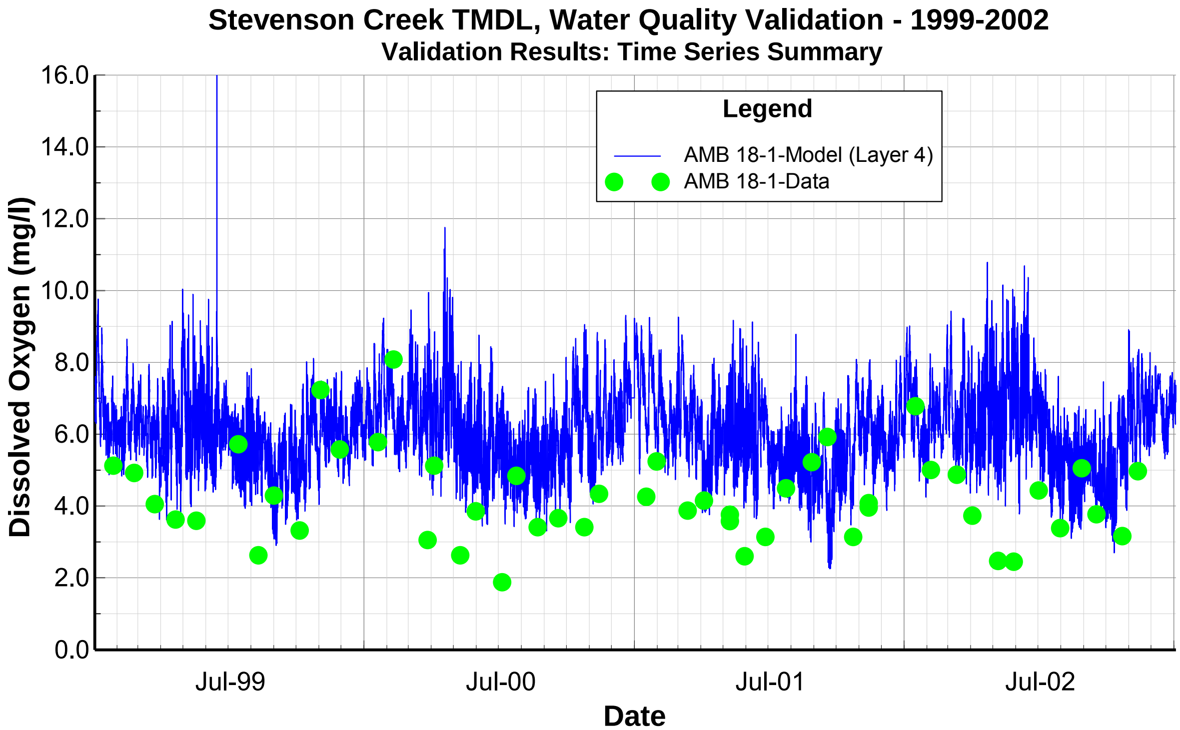


Figure 4-103 Stevenson Creek 1999-2002 Dissolved Oxygen Validation-Surface Layer: AMB 18-1.

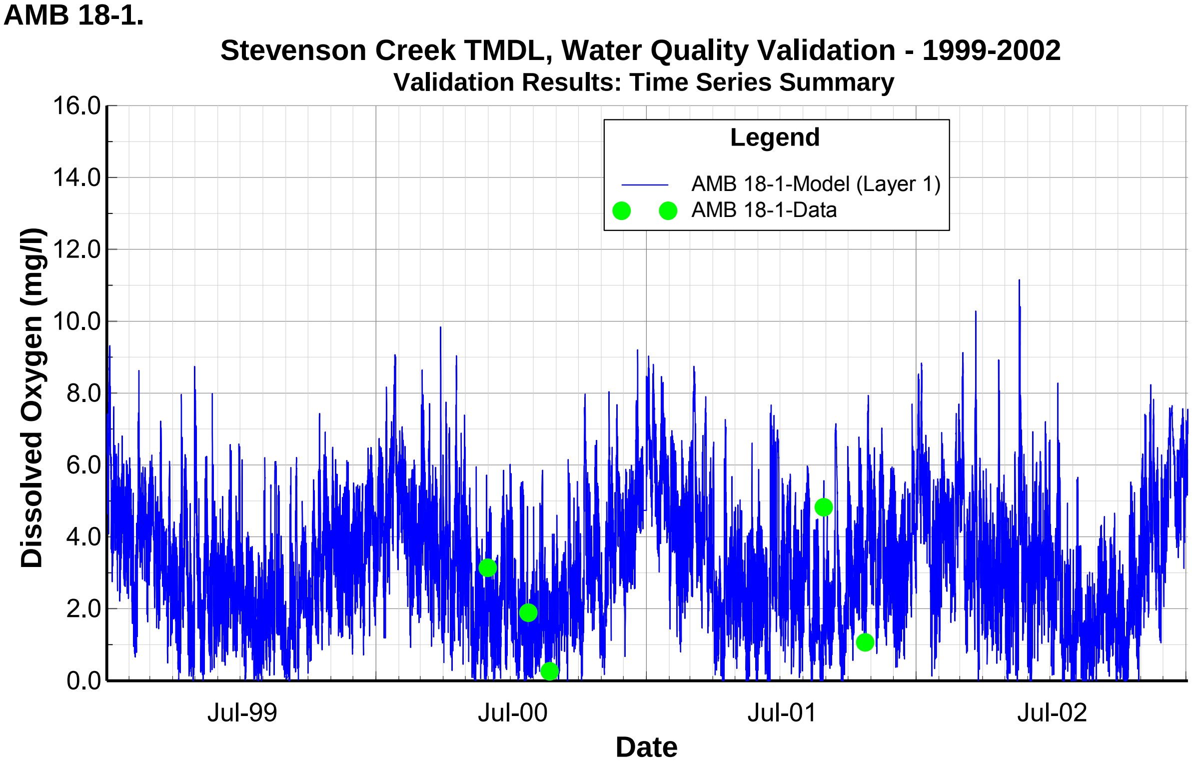


Figure 4-104 Stevenson Creek 1999-2002 Dissolved Oxygen Validation-Bottom Layer: AMB 18-1.

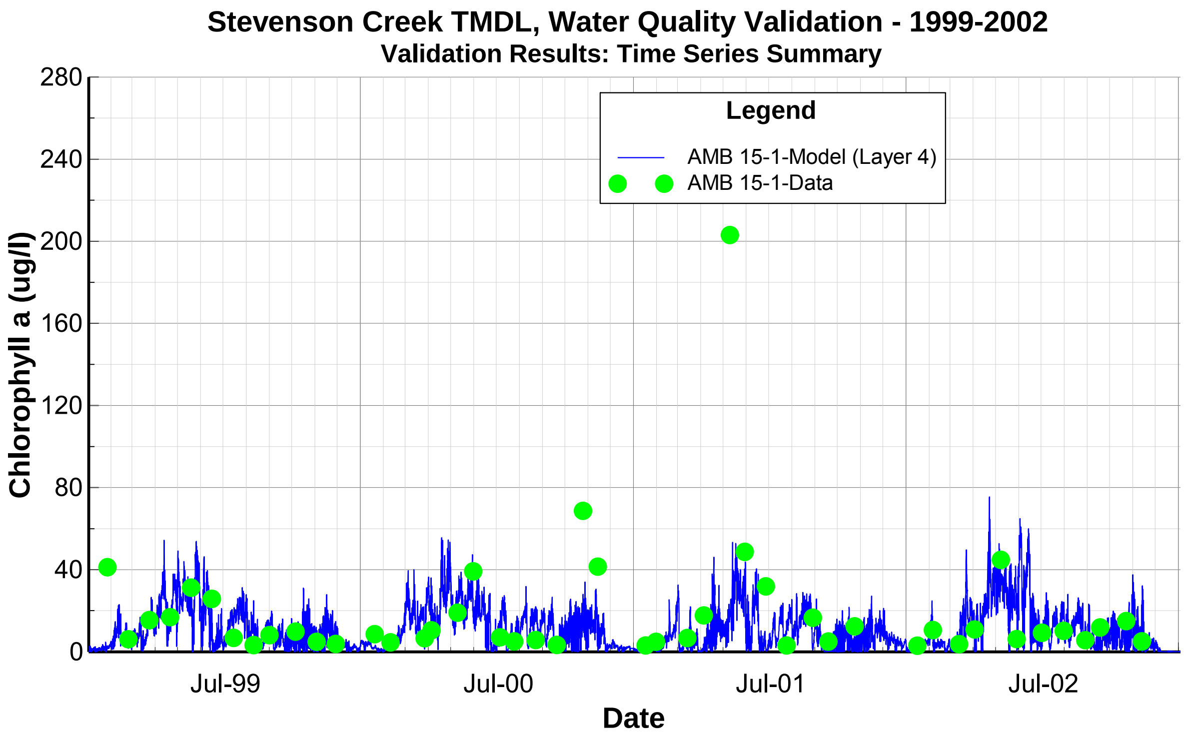


Figure 4-105 Stevenson Creek 1999-2002 Chlorophyll a Validation-Surface Layer: AMB 15-1.

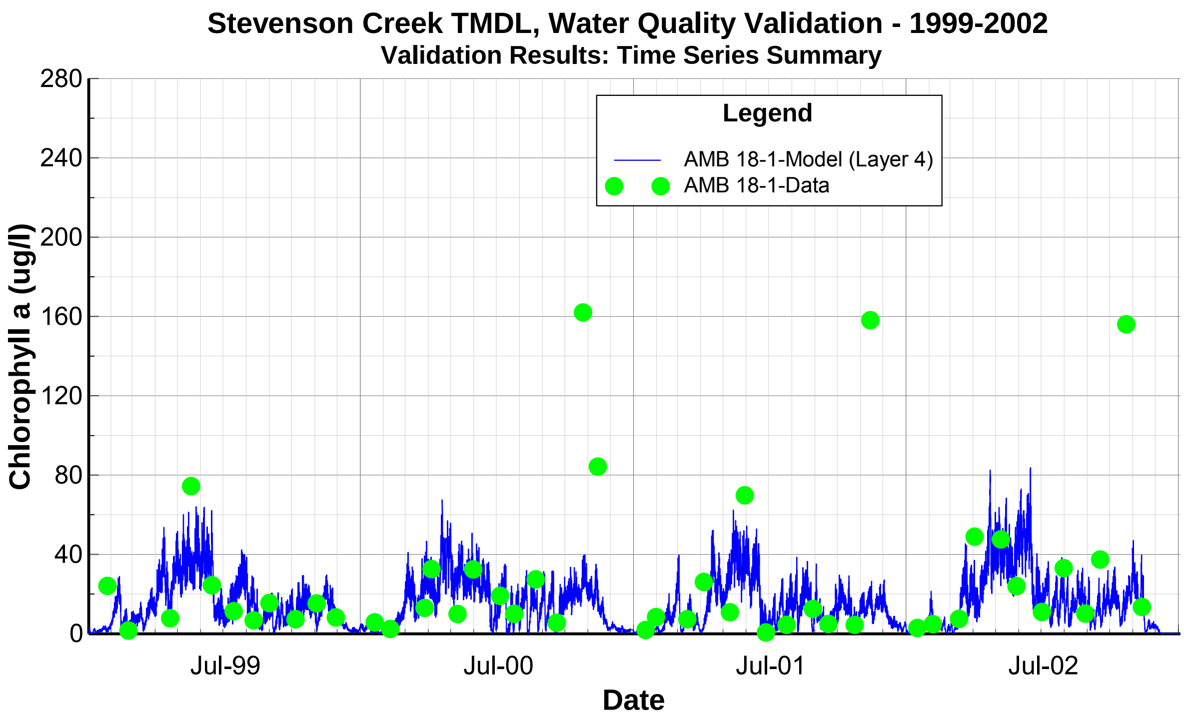


Figure 4-106 Stevenson Creek 1999-2002 Chlorophyll a Validation-Surface Layer: AMB 18-1.

From a review of the validation plots and statistics it can be seen that the validation period did not provide as good as a fit to the data as the calibration period. The cause of this can be due to a large number of factors. A few of these factors were briefly investigated.

- It should be noted that the data source for the validation period was different from calibration period. Depending on the details of sampling location, sampling procedure, sample handling and laboratory analysis results can vary. Looking at the data provides some indication of data variability. **Figure 4-107** shows a time series of BOD results from the two stations in Stevenson Creek that were very close to each other, TP-282 and AMB 18-1. The BOD data for TP282 was BOD ultimate while the BOD data for 18-01 was a 5 day BOD. Normally BODult is 2 to 3 times higher than BOD5. However, **Figure 4-107** shows that the BOD5 are as high or higher than the BODult results. This could be due to changes in the loadings or other environmental and/or sampling and analysis differences. Whatever the cause of the differences, the issue for the validation period is that the data clearly represent a different condition than what was calibrated to.

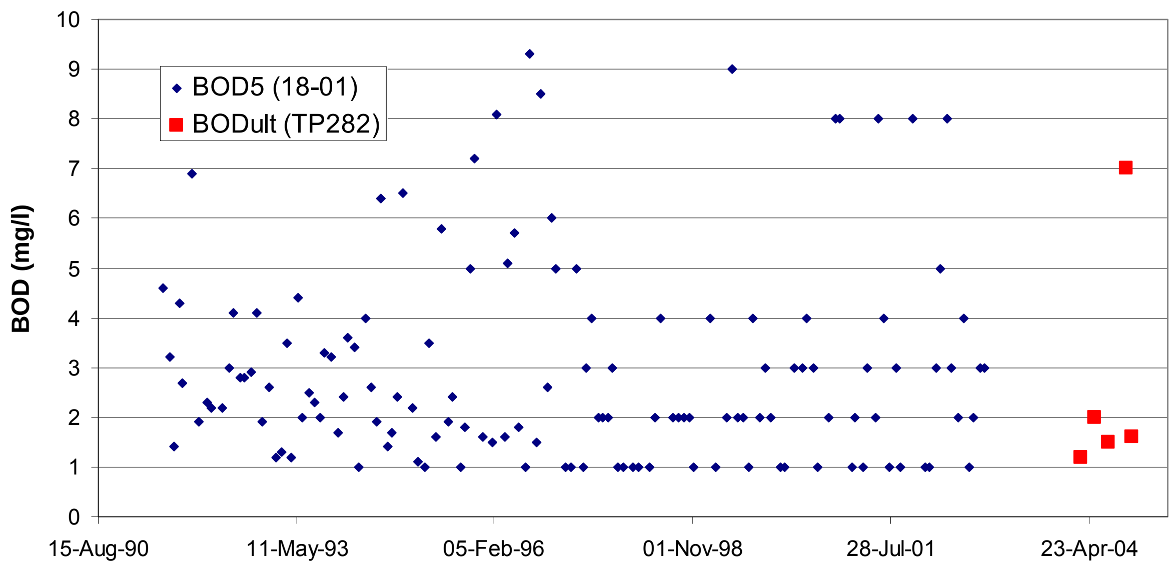


Figure 4-107 BOD Sampling Results for TP282 and AMB 18-1 from 1991-2004.

- A similar analysis was made using the dissolved oxygen results for the two stations. **Figure 4-108** shows the results of that comparison. While the TP282 data is limited, it does suggest that the waters at these two stations are different.

- To understand why the DO was significantly different between the two nearby stations, a telephone call was made to Pinellas County staff. The staff person indicated that the AMB 18-1 station is sitting over a large area of organic sediments and is fairly shallow. Given that the AMB 18-1 station is in the same EFDC model cell as TP282 from the calibration and the calibration results were more in line with the data (see **Fig. 4-78**), it is thought that the coarseness of the model grid will not be able to reflect this variability seen in the data.

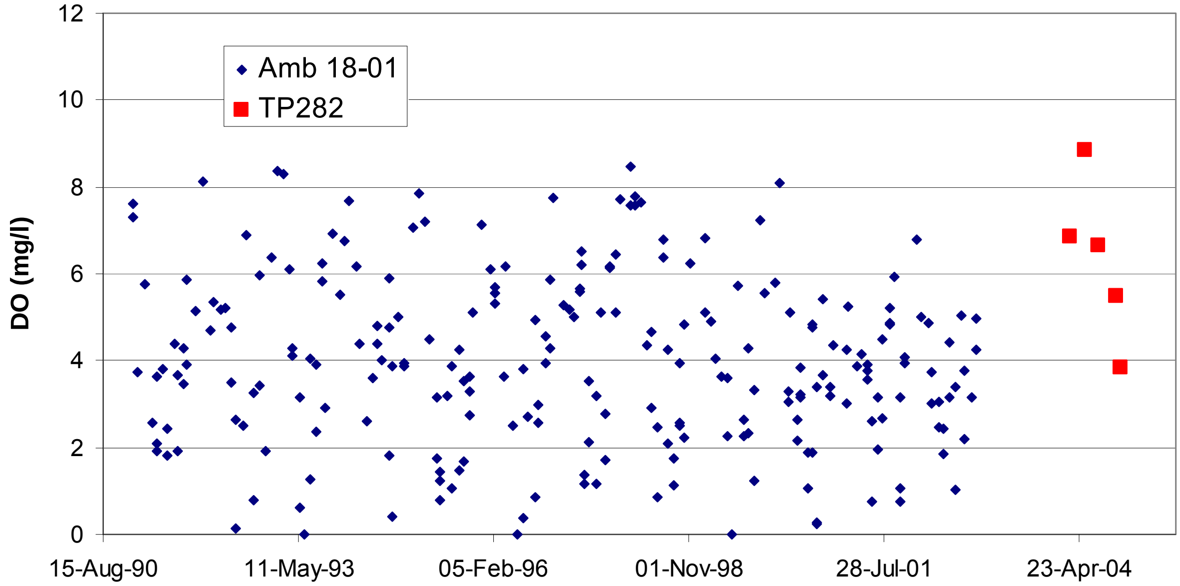


Figure 4-108 DO Sampling Results for TP282 and AMB 18-1 from 1991-2004.

4.9 Parameter Sensitivity During Model Development

A sensitivity analysis was carried out after the model calibration/validation process. The base model used for this analysis was the calibrated model (ID Run35) for the year 2004. Sixteen runs with different parameter values **(Table 4-47)** were carried out to investigate the model sensitivity.

Only those cells that are actually make up the Stevenson Creek tidal area were used to compute the average value reported for each run. **Figure 4-109** shows the Stevenson Creek model grid with a polygon overlaid on the grid. Only the cells inside the polygon were used for the computations.

Table 4-48 summarizes the 2004 average water quality values over the upstream area ("area-average" for short) from the Harrison Bridge for 6 water quality parameters. **Table 4-49** presents the relative change of the "area-average" water quality compared to the reference calibrated model Run35. Similar comparisons were made for the calibration data of stations TP282, TP283, TP284 and TP285. These comparisons were made relative to the RMS values of the calibrated model. The results of these comparisons are presented in **Tables 4-50** and **4-51**.

For the parameters varied and for the range of variation, the model was not very sensitive to any of the parameters. Changing the algal growth rate had some of the largest relative impacts. Raising the growth rate improved the Chlorophyll a RMS but negatively impacted the DO and nutrient RMS's. SOD also had a significant impact on DO and, to a lesser degree on the nutrients.

Table 4-47 Runs with different parameter values

Parameters	Ref case: Run35	Values changed 50%		Values changed 200%	
		Run ID	Value	Run ID	Value
Maximum growth Rate for Greens (1/day):	3.3	Run35-11A	1.65	Run35-11B	6.6
Predation Rate on Greens (1/day):	0.05	Run35-12A	0.025	Run35-12B	0.10
Basal Metabolism Rate for Greens (1/day):	0.01	Run35-13A	0.005	Run35-13B	0.02
Background Light Extinction Coefficient (1/m):	1.5	Run35-14A	0.75	Run35-14B	3.00
Settling velocity for Greens (m/day):	0.025	Run35-15A	0.0125	Run35-15B	0.05
Reaeration Rate Constant (3.933 for OConnor-Dobbins; 5.32 for Owen-Gibbs):	1.0	Run35-21A	0.5	Run35-21B	2.0
SOD	-3.0	Run35-22A	-1.5	Run35-22B	-6.0
Maximum Nitrification Rate (gN/m3/day):	0.07	Run35-23A	0.035	Run35-23B	0.140

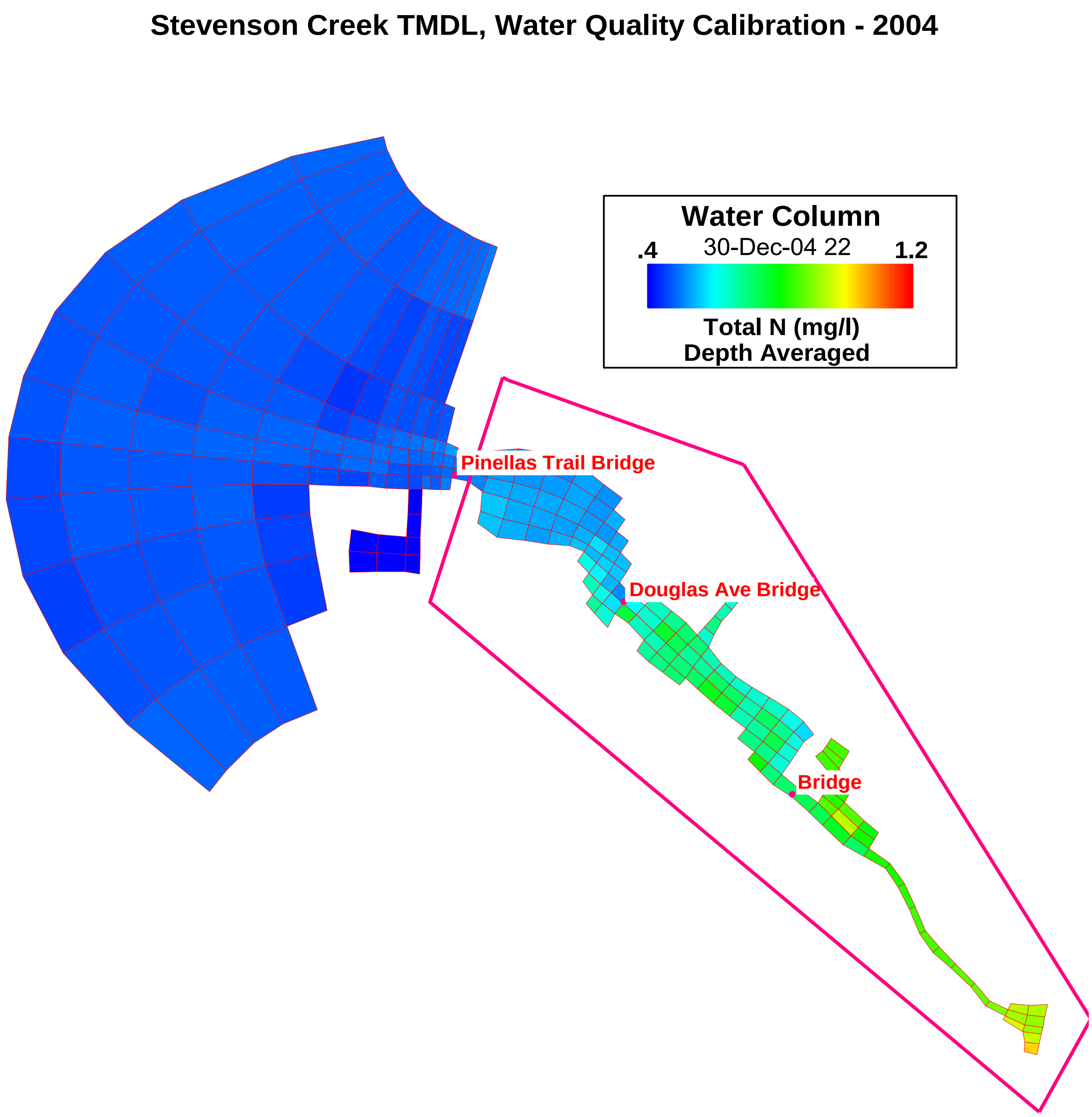


Figure 4-109 Stevenson Creek Model Cells Used for the Sensitivity Analysis.

Table 4-48 Area-averaged water quality results with respect to the parameter changes.

Parameters	Ref Value	Cases	Value	Chl-a	DO	NO3	TP	TN	TPO4
				Run35 (Ref run)					
				9.35	**5.53**	**0.13**	**0.10**	**0.86**	**0.070**
Maximum growth Rate for Greens (1/day)	**3.300**	Run35-11A	**1.650**	4.46	5.04	0.16	0.11	0.91	0.078
		Run35-11B	**6.6**	15.24	6.03	0.07	0.09	0.80	0.059
Predation Rate on Greens (1/day)	**0.050**	Run35-12A	**0.025**	10.03	5.56	0.12	0.10	0.86	0.069
		Run35-12B	**0.100**	8.10	5.46	0.13	0.10	0.87	0.071
Basal Metabolism Rate for Greens (1/day)	**0.010**	Run35-13A	**0.005**	9.49	5.54	0.13	0.10	0.86	0.069
		Run35-13B	**0.020**	9.09	5.50	0.13	0.10	0.87	0.070
Background Light Extinction Coefficient (1/m)	**1.500**	Run35-14A	**0.750**	10.93	5.67	0.11	0.10	0.85	0.067
		Run35-14B	**3.000**	6.17	5.24	0.15	0.11	0.90	0.075
Settling velocity for Greens (m/day)	**0.025**	Run35-15A	**0.013**	9.56	5.53	0.13	0.10	0.91	0.069
		Run35-15B	**0.050**	8.93	5.42	0.14	0.11	0.91	0.070
SOD	**-3.000**	Run35-22A	**-1.500**	9.45	7.32	0.20	0.09	1.15	0.069
		Run35-22B	**-6.000**	9.21	4.56	0.19	0.10	1.08	0.070
Reaeration Rate Constant (3.933 for OConnor-Dobbins; 5.32 for Owen-Gibbs)	**1.000**	Run35-21A	**0.500**	9.32	5.14	0.13	0.10	0.86	0.070
		Run35-21B	**2.000**	9.39	5.97	0.13	0.10	0.86	0.070
Maximum Nitrification Rate (gN/m3/day)	**0.07**	Run35-23A	**0.035**	9.22	4.56	0.12	0.10	1.08	0.070
		Run35-23B	**0.140**	9.09	5.50	0.13	0.10	0.87	0.070

Table 4-49 Area-averaged water quality results with respect to the parameter changes, relative to the base case.

Parameters	Ref Value	Cases	Value	Chl-a	DO	NO3	TP	TN	TPO4
Maximum growth Rate for Greens (1/day)	**3.300**	Run35-11A	**1.650**	-52.32	-8.73	23.28	7.59	5.61	12.16
		Run35-11B	**6.6**	63.03	9.12	-43.10	-9.89	-6.96	-14.83
Predation Rate on Greens (1/day)	**0.050**	Run35-12A	**0.025**	7.25	0.54	-1.94	-1.06	-0.70	-0.94
		Run35-12B	**0.100**	-13.38	-1.21	3.53	1.80	1.23	1.67
Basal Metabolism Rate for Greens (1/day)	**0.010**	Run35-13A	**0.005**	1.47	0.30	-0.44	-0.24	-0.17	-0.17
		Run35-13B	**0.020**	-2.76	-0.47	0.82	0.51	0.26	0.31
Background Light Extinction Coefficient (1/m)	**1.500**	Run35-14A	**0.750**	16.88	2.52	-10.75	-2.36	-1.94	-3.41
		Run35-14B	**3.000**	-34.05	-5.16	16.63	5.01	3.95	7.19
Settling velocity for Greens (m/day)	**0.025**	Run35-15A	**0.013**	2.30	0.16	-0.59	-0.13	-0.10	-0.25
		Run35-15B	**0.050**	-4.47	-0.24	1.26	0.25	0.23	0.54
SOD	**-3.000**	Run35-22A	**-1.500**	1.13	14.27	2.16	-11.60	0.31	-0.21
		Run35-22B	**-6.000**	-1.47	-17.48	-4.75	0.34	-0.53	0.45
Reaeration Rate Constant (3.933 for OConnor-Dobbins; 5.32 for Owen-Gibbs)	**1.000**	Run35-21A	**0.500**	-0.35	-6.91	-0.80	0.06	-0.10	0.06
		Run35-21B	**2.000**	0.41	8.05	1.24	0.02	0.17	-0.04
Maximum Nitrification Rate (gN/m3/day)	**0.07**	Run35-23A	0.035	-1.43	-6.91	-5.09	0.21	-0.54	0.44
		Run35-23B	0.140	-2.76	-0.47	0.82	0.51	0.26	0.31

Table 4-50 Composite TP282-TP285 RMS's of the water quality parameters used for the sensitivity analysis.

Parameters	Cases	Value	CHLA	DO	NO3	TP	TN	TPO4
Maximum growth Rate for Greens (1/day)	Run35-11A	1.650	83.137	1.695	0.255	0.323	1.794	0.054
	Base	**3.300**	**80.007**	**1.663**	**0.260**	**0.326**	**1.821**	**0.054**
	Run35-11B	6.600	78.246	1.616	0.277	0.330	1.846	0.055
Predation Rate on Greens (1/day)	Run35-12A	0.025	79.485	1.648	0.263	0.327	1.825	0.054
	Base	**0.050**	**80.007**	**1.663**	**0.260**	**0.326**	**1.821**	**0.054**
	Run35-12B	0.100	80.882	1.656	0.259	0.325	1.812	0.054
Basal Metabolism Rate for Greens (1/day)	Run35-13A	0.005	79.927	1.665	0.260	0.327	1.822	0.054
	Base	**0.010**	**80.007**	**1.663**	**0.260**	**0.326**	**1.821**	**0.054**
	Run35-13B	0.020	80.191	1.644	0.262	0.326	1.819	0.055
Background Light Extinction Coefficient (1/m)	Run35-14A	0.750	78.915	1.732	0.266	0.328	1.833	0.055
	Base	**1.500**	**80.007**	**1.663**	**0.260**	**0.326**	**1.821**	**0.054**
	Run35-14B	3.000	81.935	1.662	0.254	0.324	1.802	0.054
Settling velocity for Greens (m/day)	Run35-15A	0.0125	79.887	1.661	0.264	0.326	1.822	0.055
	Base	**0.025**	**80.007**	**1.663**	**0.260**	**0.326**	**1.821**	**0.054**
	Run35-15B	0.050	80.156	1.643	0.261	0.326	1.821	0.054
SOD	Run35-22A	-1.500	79.843	1.737	0.259	0.326	1.819	0.054
	Base	-3.000	**80.007**	**1.663**	**0.260**	**0.326**	**1.821**	**0.054**
	Run35-22B	-6.000	80.095	1.912	0.263	0.326	1.824	0.054
Reaeration Rate Constant (3.933 for OConnor-Dobbins; 5.32 for Owen-Gibbs)	Run35-21A	0.500	80.028	1.751	0.262	0.327	1.822	0.054
	Base	**1.000**	**80.007**	**1.663**	**0.260**	**0.326**	**1.821**	**0.054**
	Run35-21 B	2.000	79.940	1.702	0.263	0.327	1.821	0.055
Maximum Nitrification Rate (gN/m3/day)	**Run35-23A**	0.035	80.132	1.903	0.259	0.326	1.823	0.054
	Base	**0.070**	**80.007**	**1.663**	**0.260**	**0.326**	**1.821**	**0.054**
	Run35-23B	0.140	80.112	1.921	0.261	0.326	1.821	0.054

Table 4-51 Composite TP282-TP285 relative RMS's of the water quality parameters used for the sensitivity analysis.[1]

Parameters	Run35	Run35-11A	Run35-11B	Run35-12A	Run35-12B	Run35-13A	Run35-13B	Run35-14A	Run35-14B	Run35-15A	Run35-15B	Run35-21A	Run35-21B	Run35-22A	Run35-22B	Run35-23A	Run35-23B
Salinity	1	1.003	1.001	1.002	1.008	1.003	1.002	0.997	1.004	1.008	1.005	1.003	1.004	1.000	1.005	0.999	1.005
Temperature	1	0.953	0.974	0.974	0.974	0.991	0.969	1.022	0.950	0.947	0.949	0.927	0.956	1.005	0.960	1.000	1.012
Refractory POC	1	1.001	0.998	0.999	0.998	0.999	0.999	0.999	1.001	1.000	0.999	0.999	1.000	1.000	0.999	0.999	0.999
Labile POC	1	1.000	0.998	0.999	0.998	1.000	0.999	0.999	1.001	0.999	0.999	0.999	1.000	1.000	0.999	0.999	1.000
Dis Org Carbon	1	1.000	0.998	0.999	1.000	1.000	0.999	0.999	1.000	1.000	0.999	0.999	1.000	0.999	1.001	1.000	1.001
Ref Part Org Phosphorus	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Lab Part Org Phosphorus	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Dis Org Phosphorus	1	1.006	1.000	1.006	1.000	1.006	1.000	1.000	1.006	1.000	1.006	1.006	1.000	1.000	1.000	1.006	1.000
Total Phosphate	1	0.982	1.018	1.000	1.000	1.000	1.000	1.000	0.982	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ref Part Org Nitrogen	1	1.000	0.998	1.000	0.996	1.000	0.998	0.998	1.000	0.998	0.998	0.998	0.998	1.000	0.998	1.000	0.998
Lab Part Org Nitrogen	1	1.000	0.998	1.002	0.995	1.000	0.998	0.998	1.002	0.998	0.998	0.998	0.998	1.000	0.998	1.000	0.998
Dis Org Nitrogen	1	1.002	0.998	1.000	0.998	1.000	0.998	0.998	1.002	0.998	1.000	1.000	0.998	1.000	0.998	1.000	0.998
Ammonia Nitrogen	1	0.755	1.265	0.980	0.959	1.000	0.959	1.143	0.816	0.959	0.959	0.959	0.959	1.000	0.959	0.980	1.000
Nitrate Nitrogen	1	0.981	1.069	1.012	0.996	1.004	1.008	1.023	0.977	1.015	1.004	1.008	1.012	0.996	1.015	1.000	1.004
DO	1	1.019	0.978	0.994	0.996	1.002	0.991	1.045	0.996	1.001	0.990	1.056	1.033	1.058	1.155	1.145	1.157
Total N	1	0.985	1.014	1.002	0.995	1.001	0.999	1.007	0.990	1.001	1.000	1.001	0.999	0.999	1.001	1.001	0.999
Total P	1	0.988	1.012	1.003	0.997	1.000	1.000	1.006	0.991	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Chlorophyll a	1	1.038	0.979	0.994	1.011	0.999	1.002	0.987	1.023	0.999	1.002	1.000	0.999	0.998	1.001	1.002	1.001
Average	1	0.984	1.017	0.998	0.996	1.000	0.996	1.012	0.986	0.996	0.995	0.997	0.998	1.003	1.005	1.007	1.010

[1]Based on composite statistics for the stations TP282, TP283, TP284 and TP285 and relative the to calibrated model (ID:Run35).

4.10 Water Quality Conclusions and Recommendations

The Stevenson Creek linked HSPF and EFDC models have been calibrated and validated for flow, hydrodynamics, and water quality and is considered ready for TMDL scenario applications.

4.10.1 HSPF Model Recommendations

Based upon the data and model uncertainty, the following recommendations are made to improve the accuracy of the HSPF model:

- Physical data needs:
  - More detailed directly connected impervious area estimates
  - Improved BMP evaluations including windshield surveys of the watersheds to confirm

- Hydrologic data needs:
  - Longer period of record at the Upper Stevenson Creek flow gage
  - Flow monitoring at other locations in the watershed, such as Hammond Branch and Spring Branch

- Water Quality data needs:
  - Longer period of record for all water quality constituents
  - Targeted sampling during rain conditions to improve runoff simulations
  - Additional water quality data for Hammond Branch
  - Long-term DO monitoring to provide better calibration record and capture seasonal variations more thoroughly
  - Quantify SOD rates in the reaches

4.10.2 EFDC Model Recommendations

The following recommendations were made for the future Stevenson Creek EFDC hydrodynamic and water quality model improvements:

- Collect sediment samples for TOC, TON and TOP to enable the use of the full sediment diagenesis sub-model in EFDC to represent the spatial temporal variations in nutrient fluxes. This is especially important in the areas downstream of the WWTF and in the transition zones from free flowing to tidally influence waters for each tributary.
- Confirm the bathymetry data's datum relative to the Clearwater Beach MTL and extend the bathymetry up to the upper section of the model
- Obtain a short time series of water surface elevations in near the Marshall WWTF. These elevations must be tied in to NAVD88 so the data can be related to the Clearwater Beach tide data.
- Collect data (water column and sediment fluxes) to evaluate the impacts of the planned dredging activities on Stevenson Creek and then recalibrate the model.
- Any enhancements to the HSPF calibration will have direct positive impacts on the Stevenson Creek hydrodynamic water quality model.

Section 5
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Appendix A
Clearwater Harbor and St. Joseph Sound Hydrodynamic Model

Appendix A
Clearwater Harbor and St. Joseph Sound Hydrodynamic Model

This Appendix summarizes the development of the site-specific hydrodynamic model of St. Joseph Sound/Clearwater Harbors Hydrodynamic Model:

A.1 Bathymetry

NOAA NOS bathymetry data (http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html) was obtained and processed. This data set contained two main groupings of raw soundings data. The first group consisted of surveys conducted prior to 1960. During that time the survey covered an area near the shoreline and Clearwater Beach. The second group of raw sounding data was taken from more recent surveys conducted during the period from 1972-1980. This data covered an area from Clearwater Beach to the area about 10 miles from the coast line. The bathymetric data was integrated with the recent satellite images of Clearwater Harbor to reflect the more recent changes.

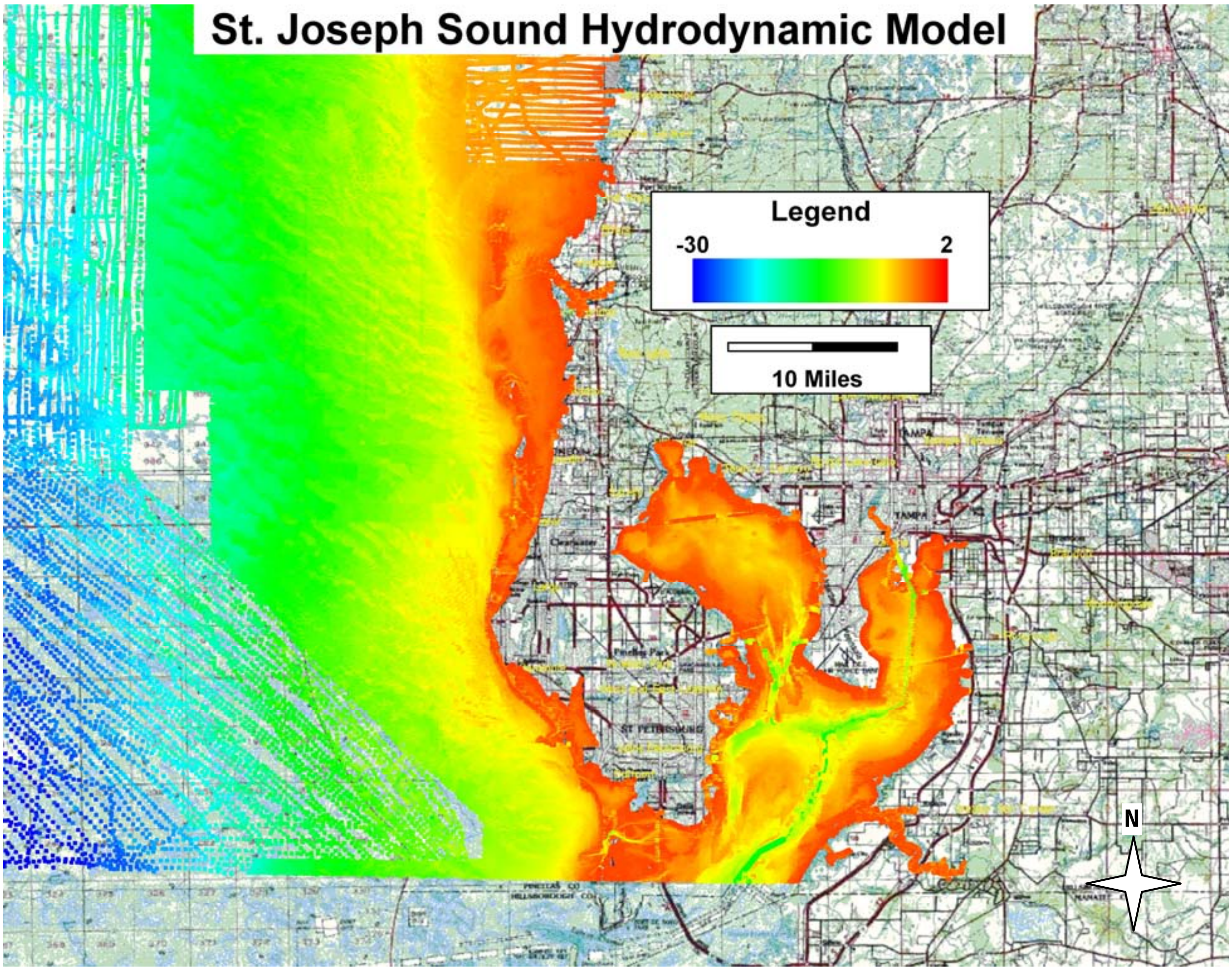

Figure A-1 Map of the bathymetric data for the St. Joseph Sound coastal region.

The final data set contained more than 180 000 data points. **Figure A-1** shows the soundings overlaid on the USGS 100K scale topographical map.

A.2 Grid Development

In order to test the appropriate grid resolution for the St. Joseph Sound model, a number of grid alternatives were developed. **Figure A-2** provides a plot of the final grid. The grid has 3204 horizontal cells and four vertical layers. The grid was developed using the Delft RGFGrid program. The grid created by RGFGrid was then configured for EFDC by importing the GRD file into EFDC_Explorer. Final minor editing to the grid was performed using EFDC_Explorer. The total grid covered an area of about 10 miles by 55 miles.

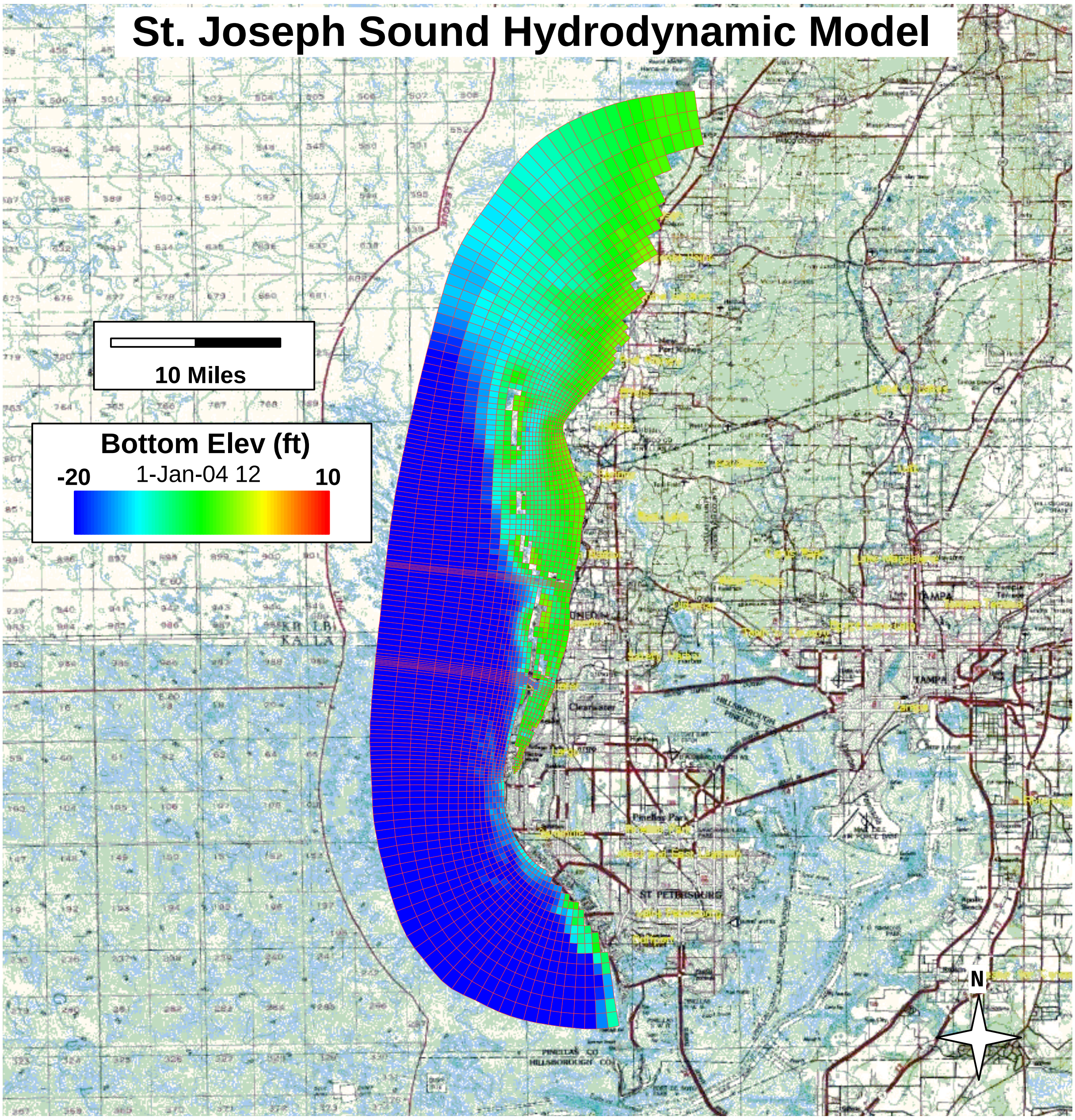

Figure A-2 Final Grid with bathymetry (vertical datum: mean low water (MLW)).

Figure A-3 shows the grid with some cells labeled with the EFDC's grid numbering scheme of I (generally the X/Easting component) and the J (generally the Y/Northing component). The Gulf of Mexico is located along the model boundary with the smallest Js at the southern point near Saint Petersburg and the northern point of Hemando Beach with the largest J of the active cells. The EFDC model grid was configured with four layers to address the density dependent dynamics due to salinity and temperature profiles.

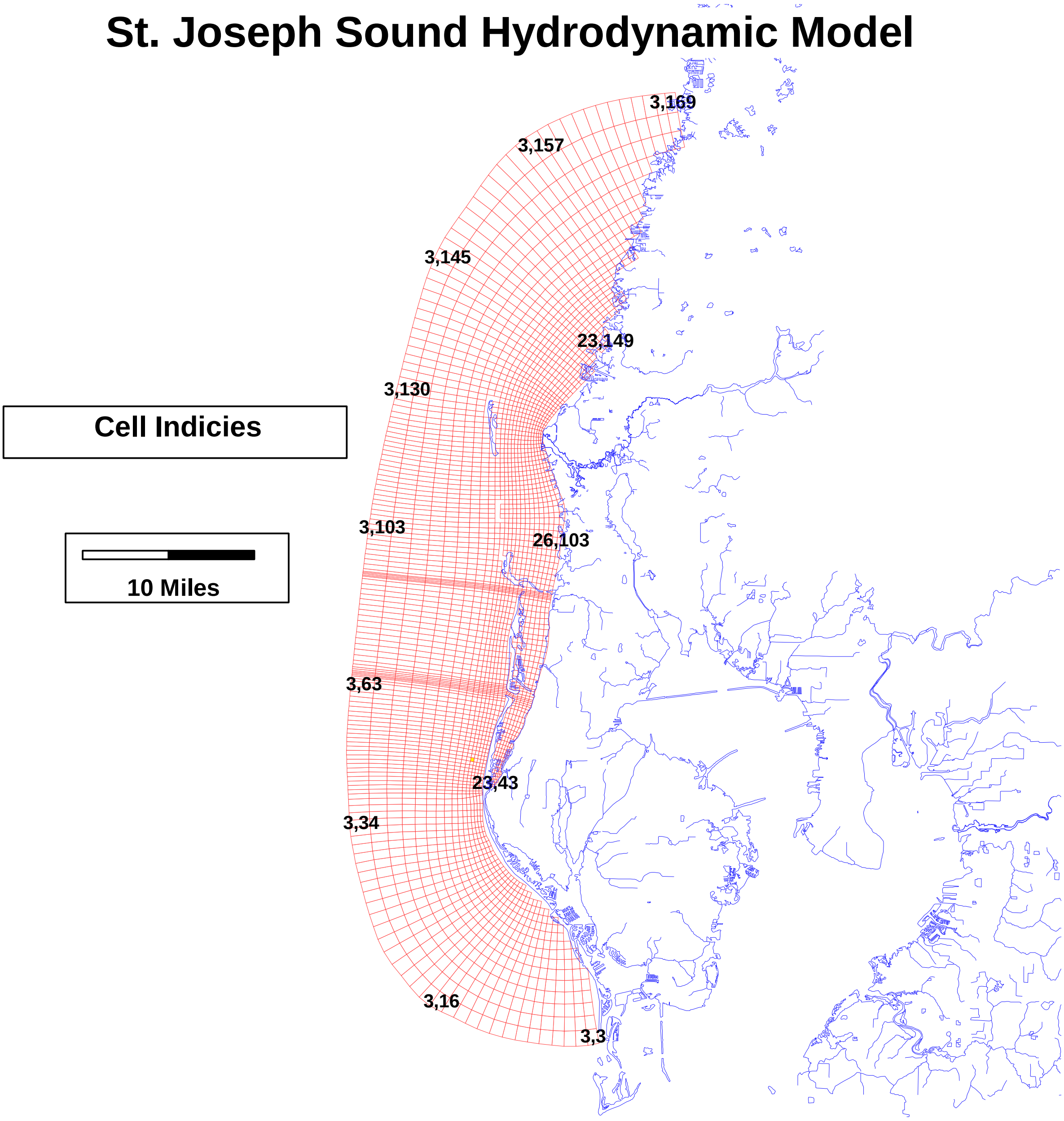

Figure A-3 Model domain with cell indices.

A.3 Model Calibrations

The period selected for model calibration was from January 1, 2002 to December 30, 2002. During this period, several overlaps in the salinity, temperature, and water level records for calibration comparison data exist. The following section summarizes the model's initial and boundary conditions. A summary of the EFDC model calibration results follows the discussion of the model setup and verification.

A.3.1 Boundary Condition

The EFDC model boundary condition locations are shown in **Figure A-4**. Two types of boundary were specified in the model: runoff from inland areas that drain into the sea along the coastline and the open sea tidal boundary.

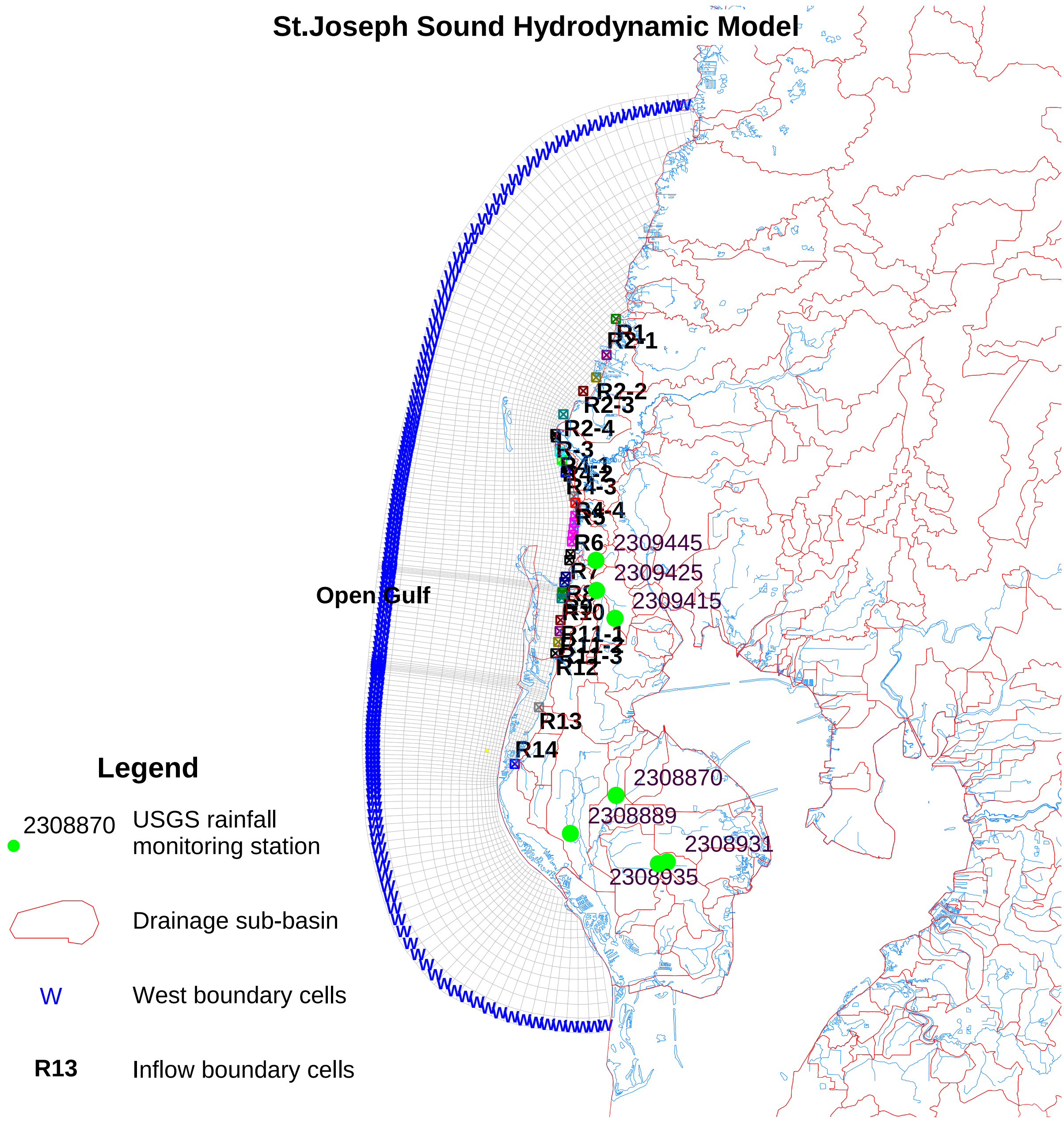

Figure A-4 St. Joseph Sound Model boundary conditions location map.

Flow Boundary Conditions

Runoff for each zone along the coastline was estimated by multiplying an average monthly flow rate from the seven USGS stations (**Table A-1**) with the drainage area of the region. Most necessary data at these stations are available from 1984 to 2007, with the exception of

Lake Seminole Outlet (USGS 02308889) from 08/01/1950 to 09/30/1971. http://waterdata.usgs.gov/nwis/monthly?referred_module=sw&search_site_no=02308889&format=sites_selection_links). The results are shown in **Table A-2**. In this table and in **Figure A-4**, each runoff was labeled as R1, R2, etc. For all flow, water was considered as fresh with salinity 0 ppt and the inland historic water temperature data from Klosterman Bayou was used.

Table A-1 Runoff Coefficient (cfs/mile^2)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
02309445	26.78	24.87	24.19	14.76	111.64	94.85	86.45	112.35	24.78	14.97	68.21	36.71
02309425	75.34	83.06	71.99	68.93	38.81	137.34	253.02	216.03	229.73	91.41	54.56	110.16
02309415	28.18	45.68	32.18	30.53	22.58	98.58	165.10	114.90	112.65	44.20	27.65	50.73
02308870	32.86	50.94	44.70	40.69	20.07	113.48	146.41	175.60	132.93	26.76	23.13	61.80
02308889	24.03	29.91	52.38	19.10	6.65	14.35	33.86	87.28	75.36	27.89	12.12	16.55
02308931	31.58	41.83	29.55	16.45	42.43	56.23	90.00	82.75	66.00	32.25	25.18	23.88
02308935	35.70	38.09	57.55	32.82	31.78	69.50	101.73	127.09	164.55	56.93	39.17	49.17
Monthly Average	36.35	44.91	44.65	31.90	39.13	83.47	125.22	130.86	115.14	42.06	35.72	49.86
Minimum	24.03	24.87	24.19	14.76	6.65	14.35	33.86	82.75	24.78	14.97	12.12	16.55
Maximum	75.34	83.06	71.99	68.93	111.64	137.34	253.02	216.03	229.73	91.41	68.21	110.16
Median	31.58	41.83	44.70	30.53	31.78	94.85	101.73	114.90	112.65	32.25	27.65	49.17

Table A-2 Estimated flow rate along St. Joseph Sound Hydrodynamic Model (cfs)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
R1	1609	1987	1976	1411	1732	3694	5541	5790	5095	1861	1580	2206
R2	532	657	653	466	572	1221	1831	1913	1684	615	522	729
R3	2079	2568	2553	1824	2238	4773	7161	7483	6585	2405	2043	2851
R4	62	77	77	55	67	143	215	224	197	72	61	85
R5	96	119	118	85	104	221	332	347	305	112	95	132
R6	150	185	184	131	161	344	516	539	474	173	147	205
R7	47	44	43	26	197	167	153	198	44	26	120	65
R8	71	88	87	62	77	163	245	256	225	82	70	97
R9	702	793	678	648	372	1341	2449	2057	2175	865	518	1039
R10	57	71	70	50	61	131	197	205	181	66	56	78
R11	74	91	90	65	79	169	254	265	233	85	72	101
R12	342	423	420	300	368	786	1179	1232	1084	396	336	469
R13	61	75	75	54	66	140	210	220	193	71	60	84
R14	171	211	210	150	184	392	588	615	541	198	168	234

Open Boundary Conditions

The open sea boundary was indicated by index "W", which is located along the western side of the computational domain. Here the water levels and temperatures recorded at tidal station Clear Water Beach (ID: 8726724) (http://tidesandcurrents.noaa.gov/index.shtml) were used. An example time series for the calibration period of January 2002 to December 2002 is shown in **Figure A-5** with reference level MLW. Along the open sea boundary condition, a constant salinity of 34 ppt was maintained over the entire time.

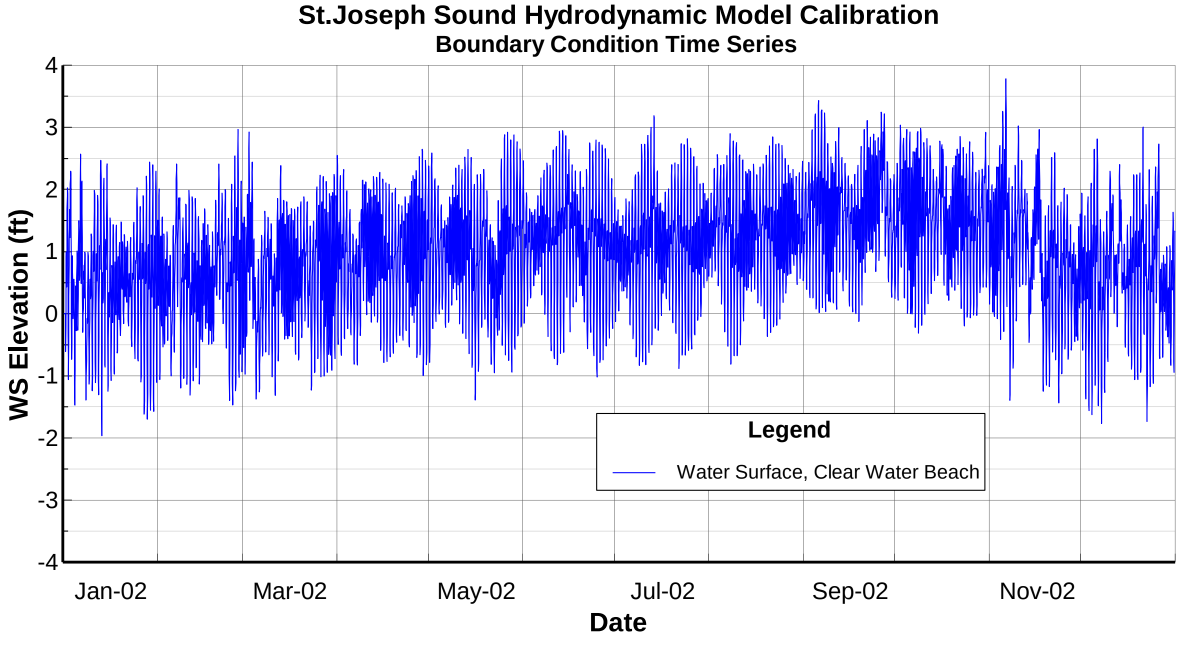

Figure A-5 St. Joseph Sound open boundary tide series based on Clear Water Beach gage.

A.3.2 Hydrodynamic Model Calibration

Tide Signal Calibration

Figure A-6 presents a plot of the tide calibration showing the model (in blue) versus the observed data (in green). While a complete 360-day period was simulated, only the period where there were data is shown. The comparison of modeled water surface and the observed data was considered acceptable.

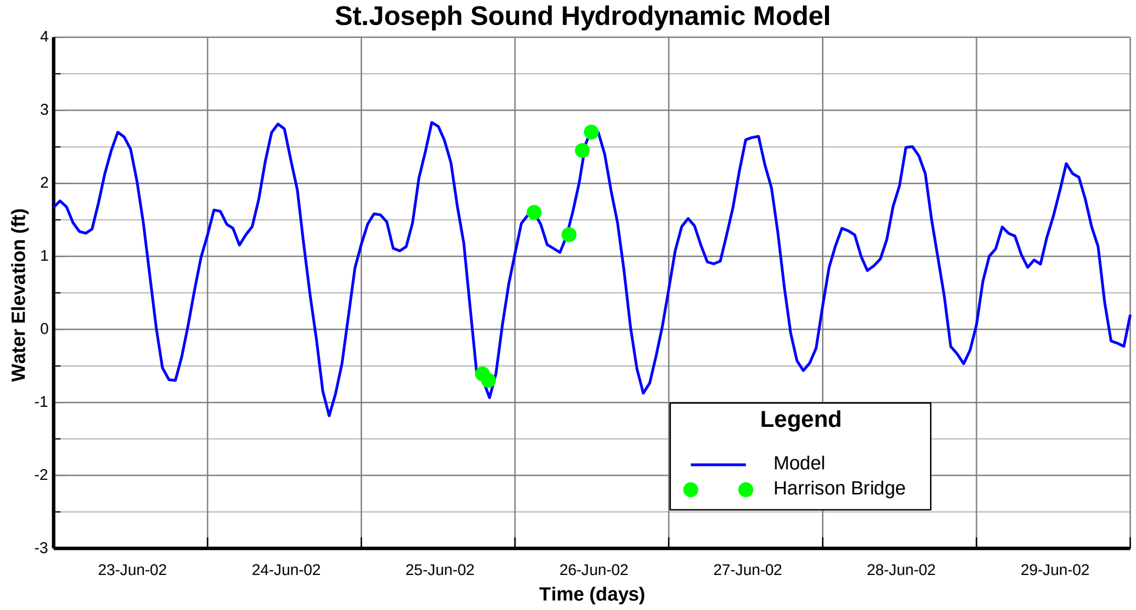

Figure A-6 Clearwater Harbor tide signal calibration: North Ft Harrison Bridge.
(Sample Data Source: Storage Data Base SWFWMD)

Salinity Calibration

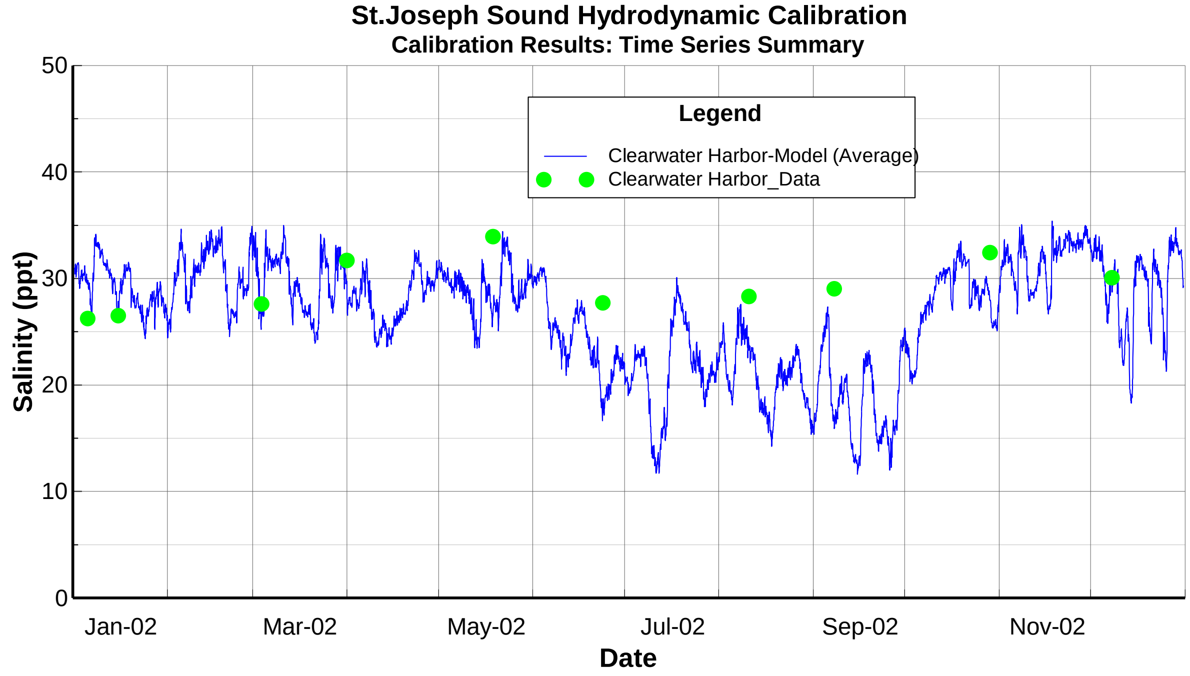

Figure A-7 Clearwater Harbor 2002 salinity calibration.
(Sample Data Source: Storage Data Base SWFWMD)

Figure A-7 shows the salinity calibration results. Overall, the model does a good job of representing the salinity trends.

Water Temperature Calibration

Figure A-8 shows the Temperature calibration results. The model versus data comparison for water temperature was considered good.

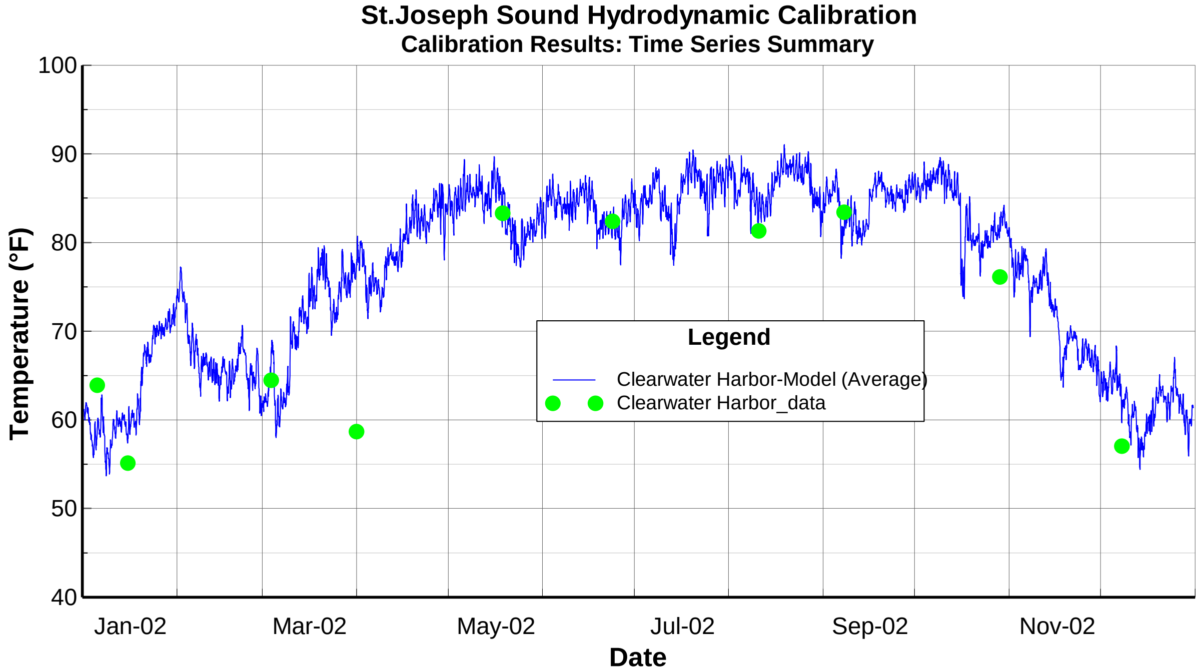

Figure A-8 Clearwater Harbor 2002 water temperature calibration.
(Sample Data Source: Storage Data Base SWFWMD)

Further, the model was used to calculate hydrodynamic flow, water temperature and salinity for a period from 1999 to December 31, 2006. In all calculations, boundary conditions were specified in a similar way to the calibration period. The water level and temperature recorded at tidal station Clear Water Beach (ID: 8726724) were used for the open sea boundary and flow rates from **Table A-2** for runoff along the coastline.

The results of these simulations at the mouth of Stevenson Creek and Klosterman Bayou were used as boundary conditions for respective hydrodynamic and water quality models.

Appendix B
EFDC Model Calibration Dataset

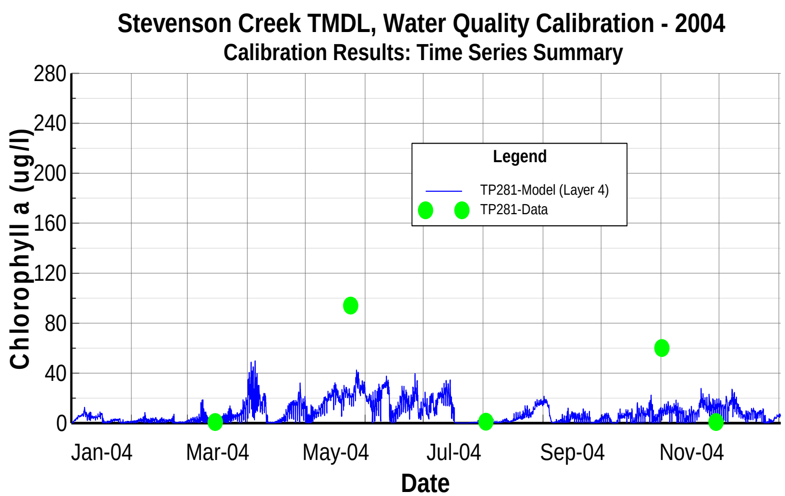

Figure B-1 Stevenson Creek Water Quality Calibration: Chlorophyll a, TP281

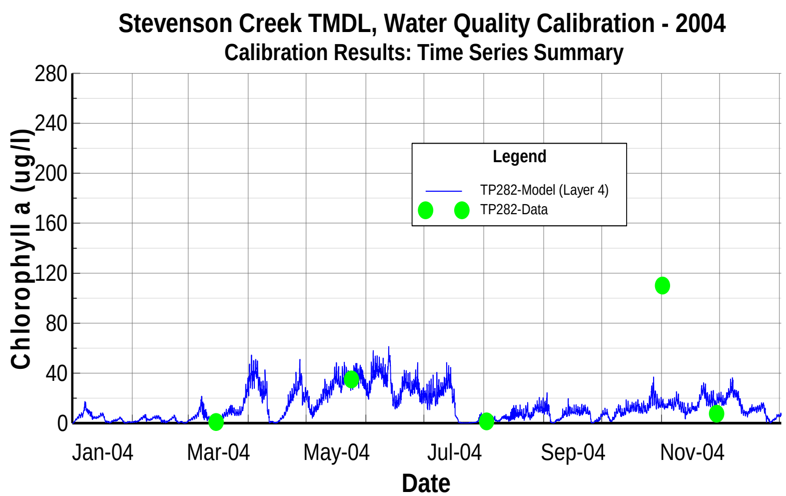

Figure B-2 Stevenson Creek Water Quality Calibration: Chlorophyll a, TP282

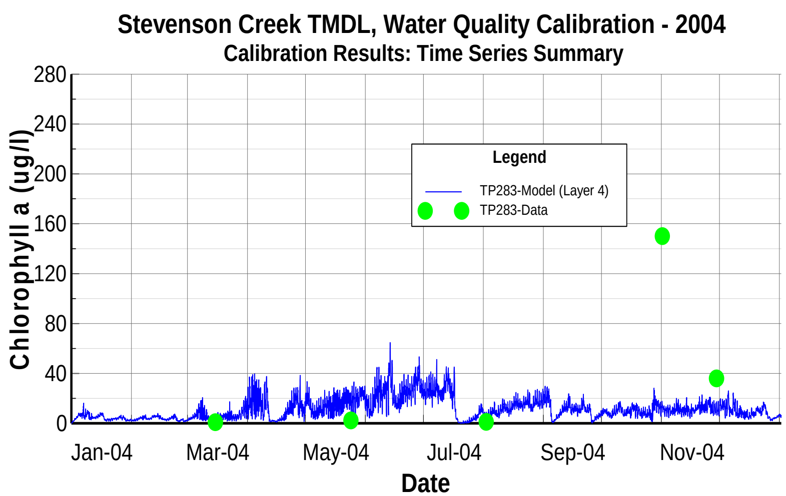

Figure B-3 Stevenson Creek Water Quality Calibration: Chlorophyll a, TP283

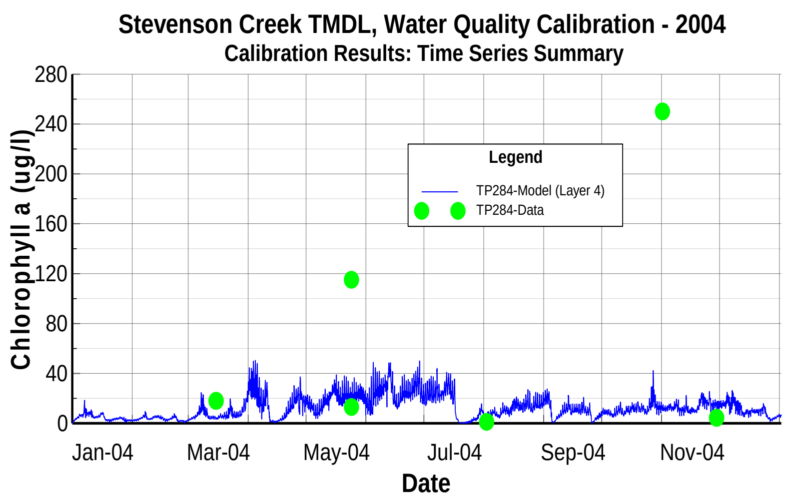

Figure B-4 Stevenson Creek Water Quality Calibration: Chlorophyll a, TP284

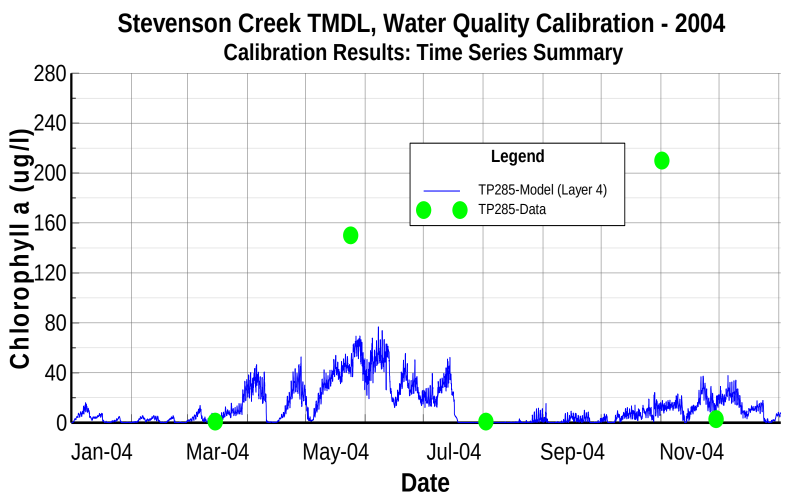

Figure B-5 Stevenson Creek Water Quality Calibration: Chlorophyll a, TP285

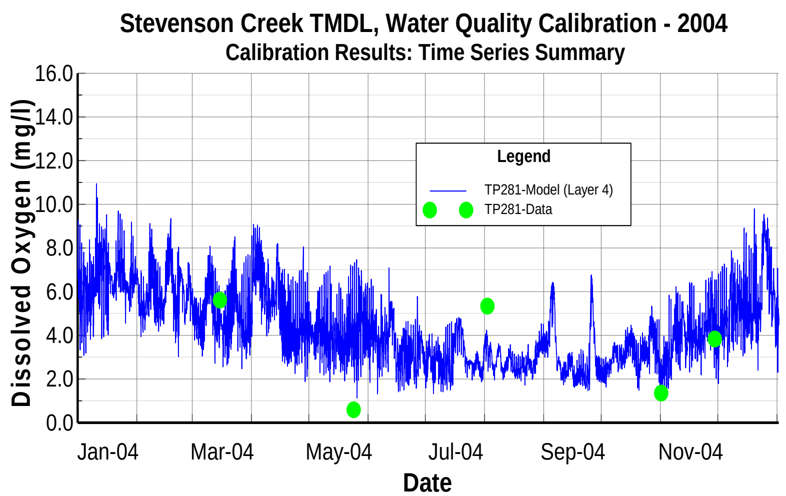

Figure B-6 Stevenson Creek Water Quality Calibration: Dissolved Oxygen, TP281

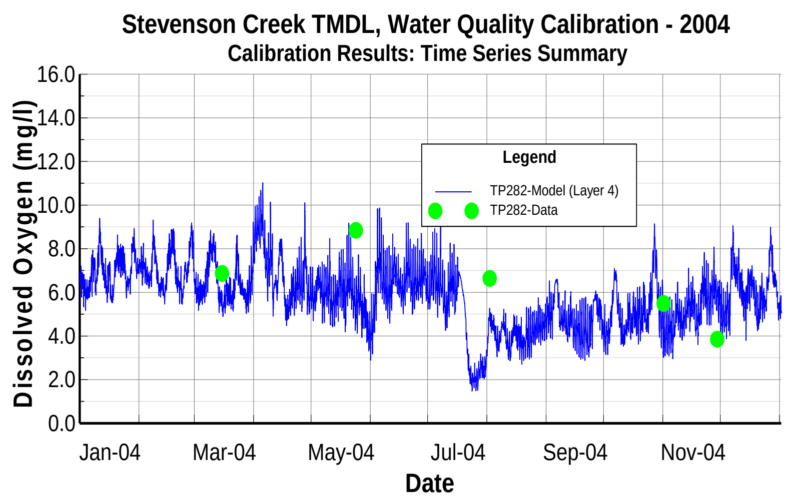

Figure B-7 Stevenson Creek Water Quality Calibration: Dissolved Oxygen, TP282

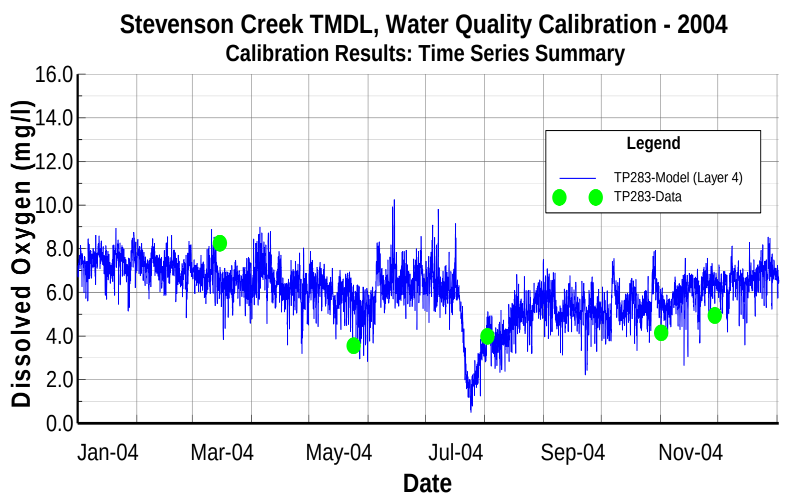

Figure B-8 Stevenson Creek Water Quality Calibration: Dissolved Oxygen, TP283

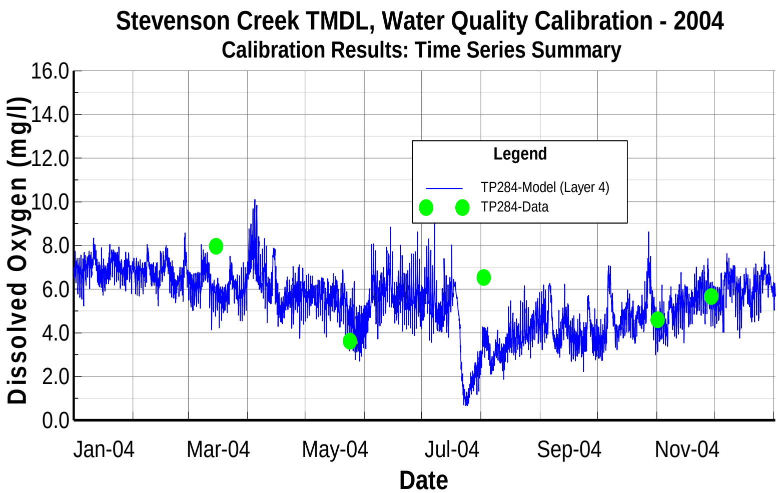

Figure B-9 Stevenson Creek Water Quality Calibration: Dissolved Oxygen, TP284

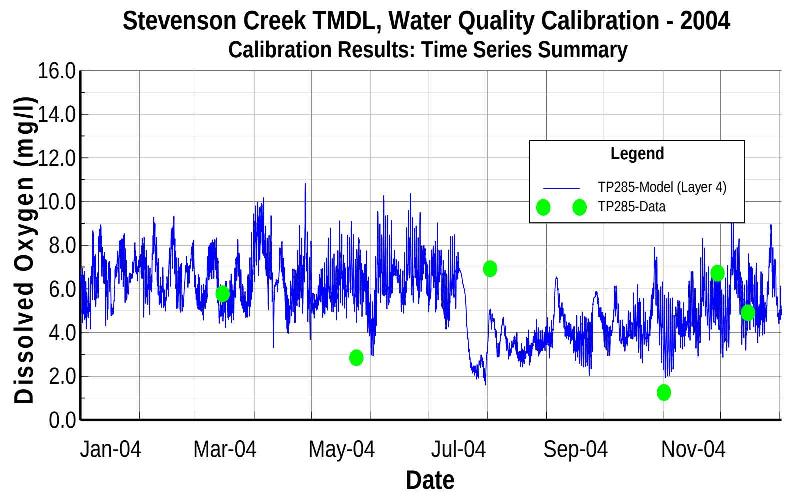

Figure B-10 Stevenson Creek Water Quality Calibration Dissolved Oxygen, TP285

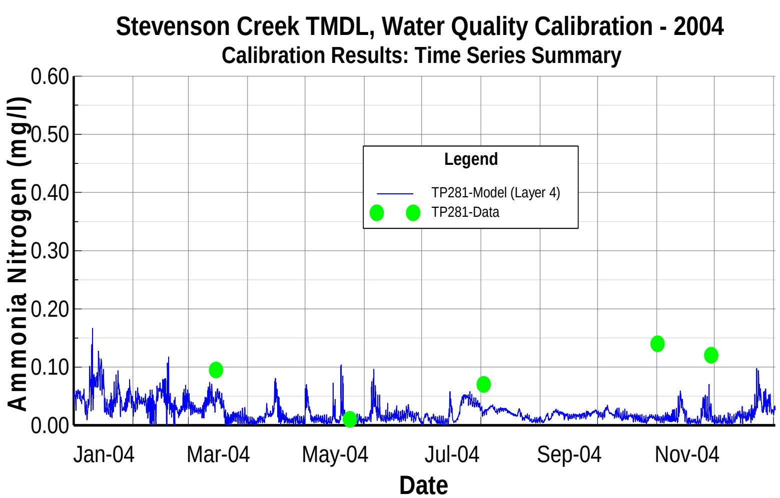

Figure B-11 Stevenson Creek Water Quality Calibration: Ammonia Nitrogen, TP281

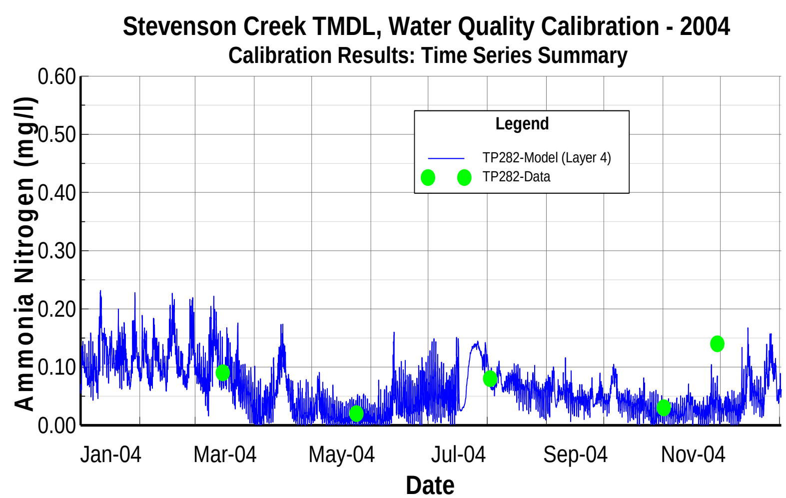

Figure B-12 Stevenson Creek Water Quality Calibration: Ammonia Nitrogen, TP282

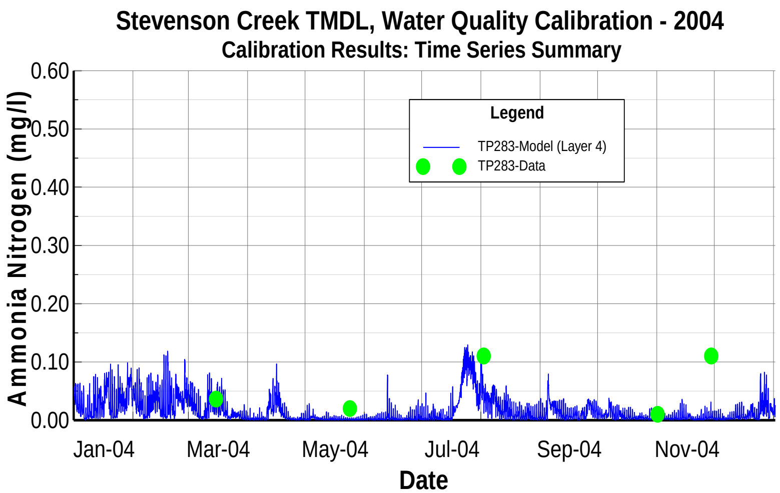

Figure B-13 Stevenson Creek Water Quality Calibration: Ammonia Nitrogen, TP283

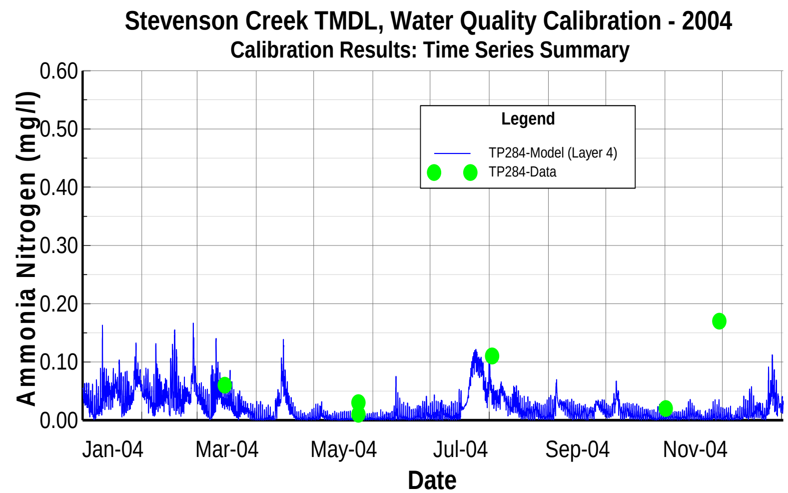

Figure B-14 Stevenson Creek Water Quality Calibration: : Ammonia Nitrogen, TP284

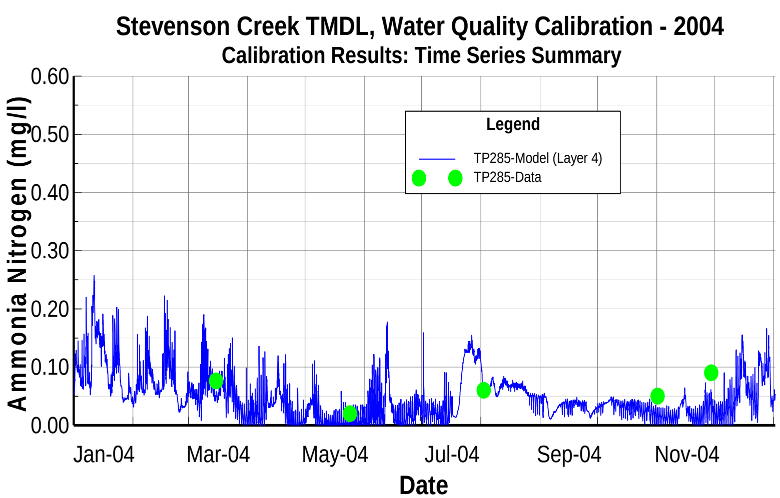

Figure B-15 Stevenson Creek Water Quality Calibration: : Ammonia Nitrogen, TP285

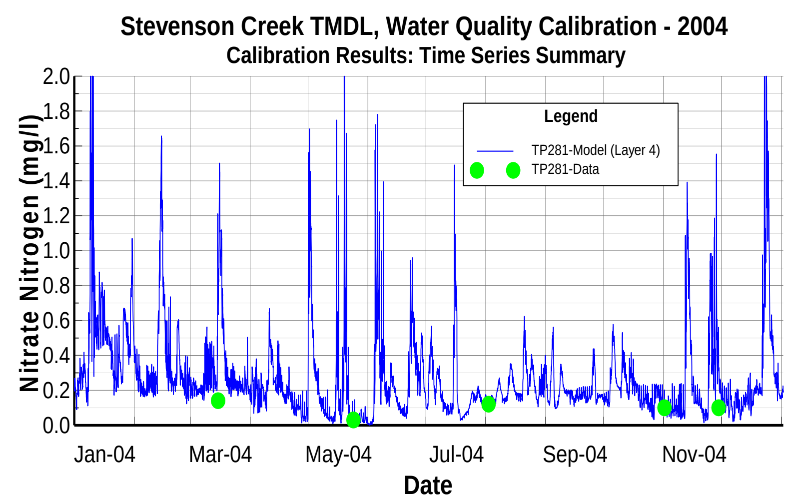

Figure B-16 Stevenson Creek Water Quality Calibration: Nitrate Nitrogen, TP281

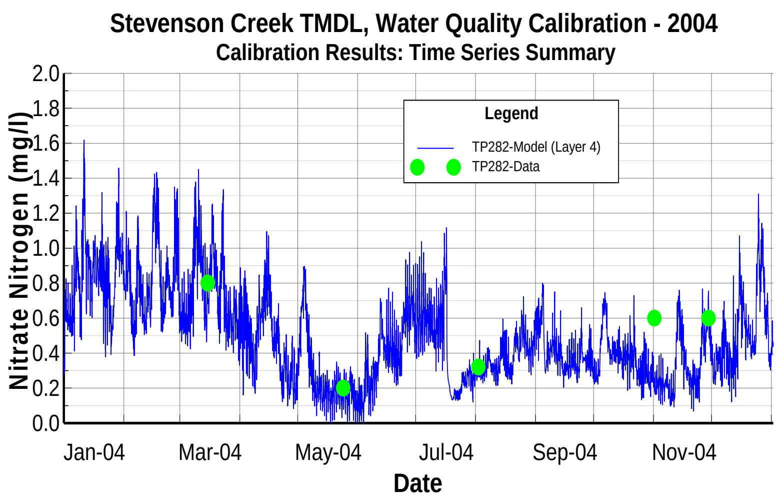

Figure B-17 Stevenson Creek Water Quality Calibration: Total : Nitrate Nitrogen, TP282

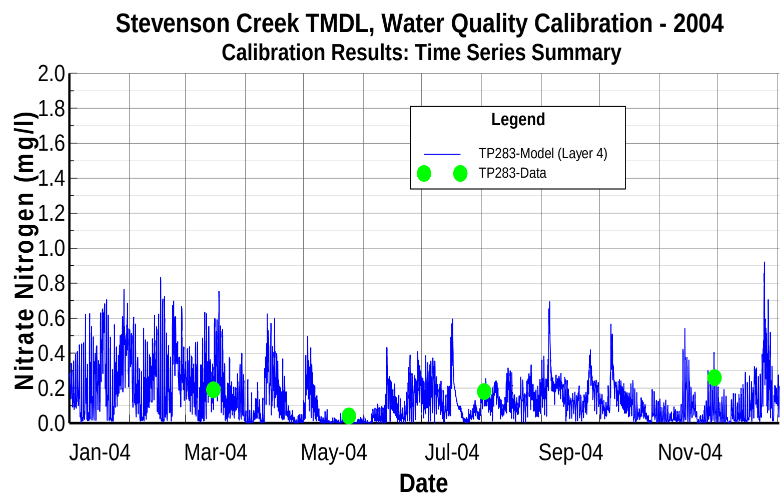

Figure B-18 Stevenson Creek Water Quality Calibration: Total : Nitrate Nitrogen, TP283

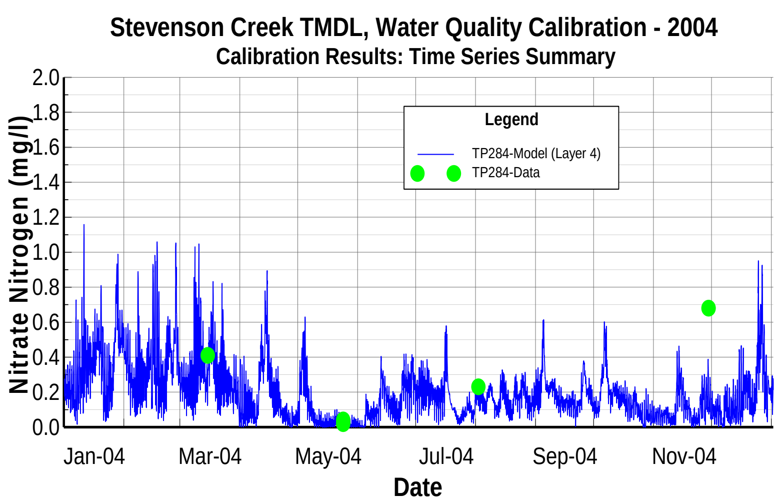

Figure B-19 Stevenson Creek Water Quality Calibration: Total : Nitrate Nitrogen, TP284

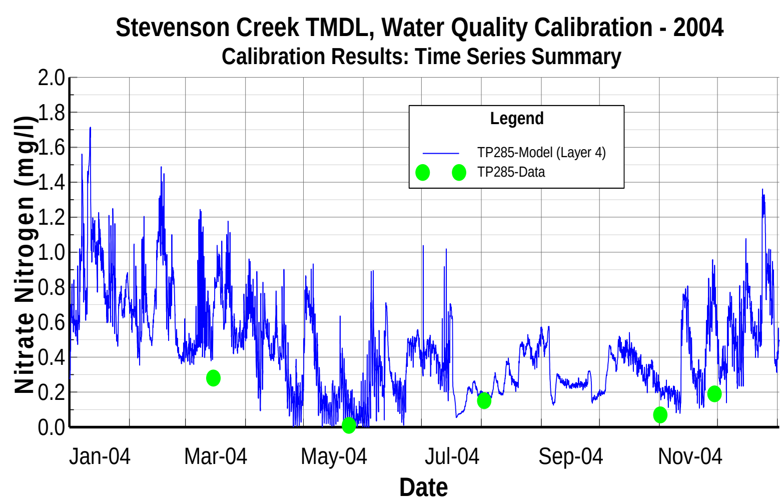

Figure B-20 Stevenson Creek Water Quality Calibration: Total : Nitrate Nitrogen, TP285

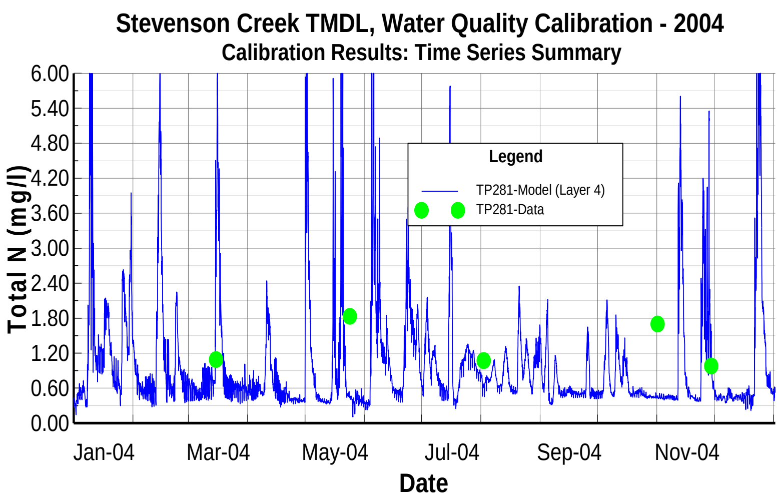

Figure B-21 Stevenson Creek Water Quality Calibration: Total Organic Nitrogen, TP281

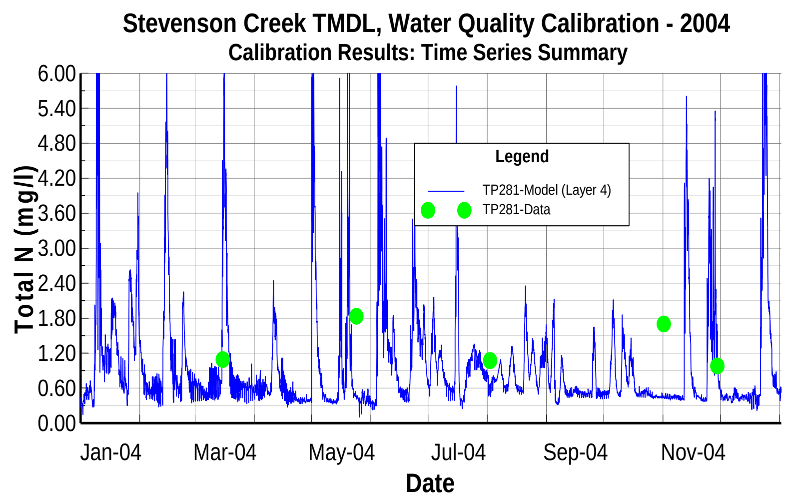

Figure B-22 Stevenson Creek Water Quality Calibration: Total Organic Nitrogen, TP282

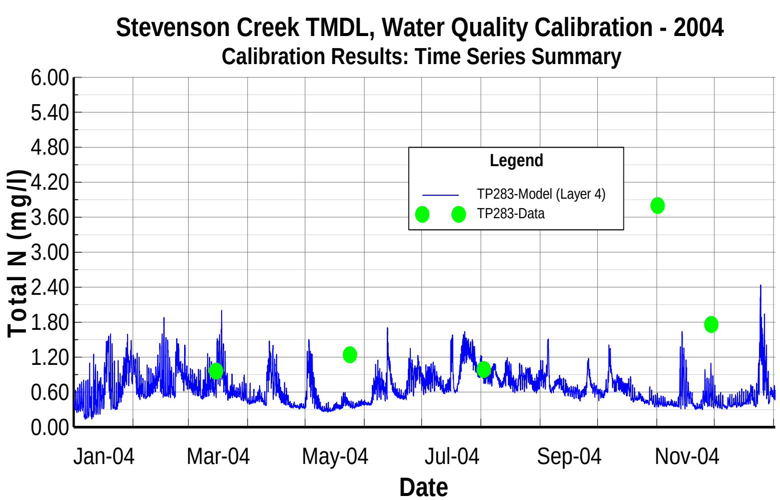

Figure B-23 Stevenson Creek Water Quality Calibration: Total Organic Nitrogen, TP283

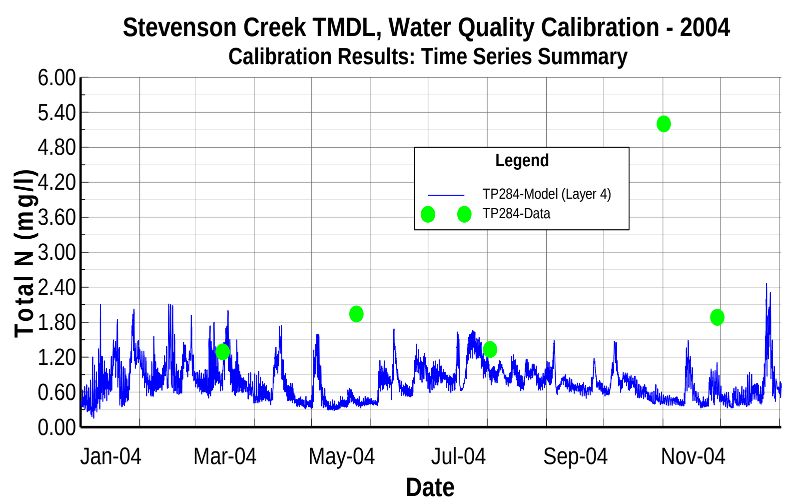

Figure B-24 Stevenson Creek Water Quality Calibration: Total Organic Nitrogen, TP284

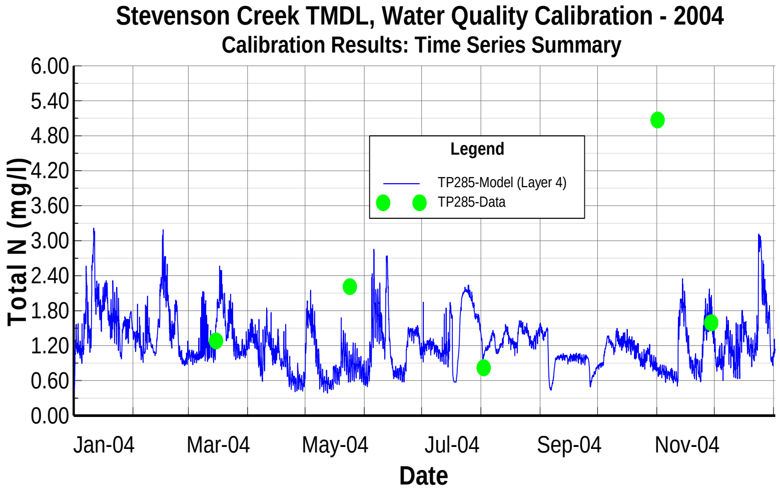

Figure B-25 Stevenson Creek Water Quality Calibration: Total Organic Nitrogen, TP285

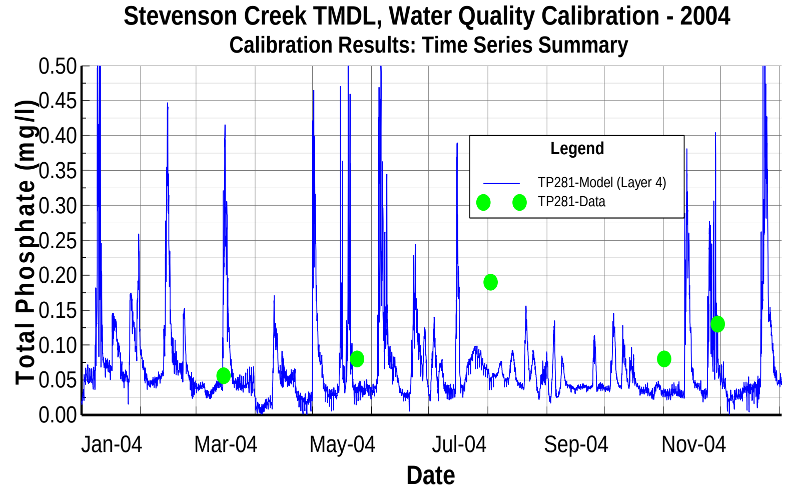

Figure B-26 Stevenson Creek Water Quality Calibration: Total Phosphate, TP281

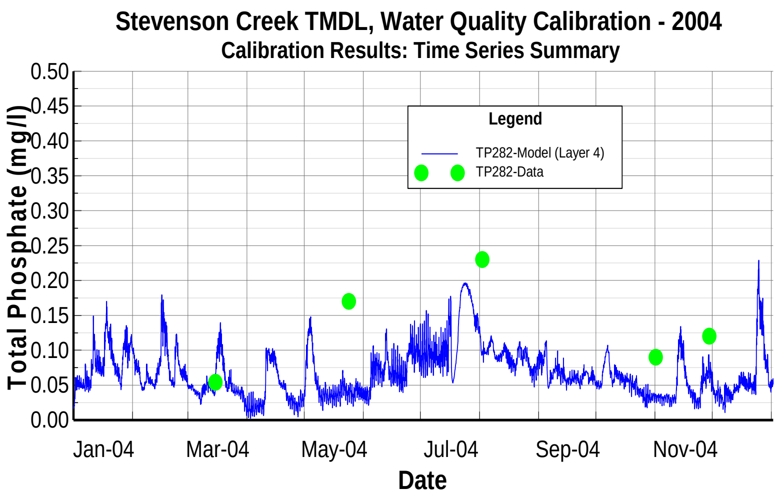

Figure B-27 Stevenson Creek Water Quality Calibration: Total Phosphate, TP282

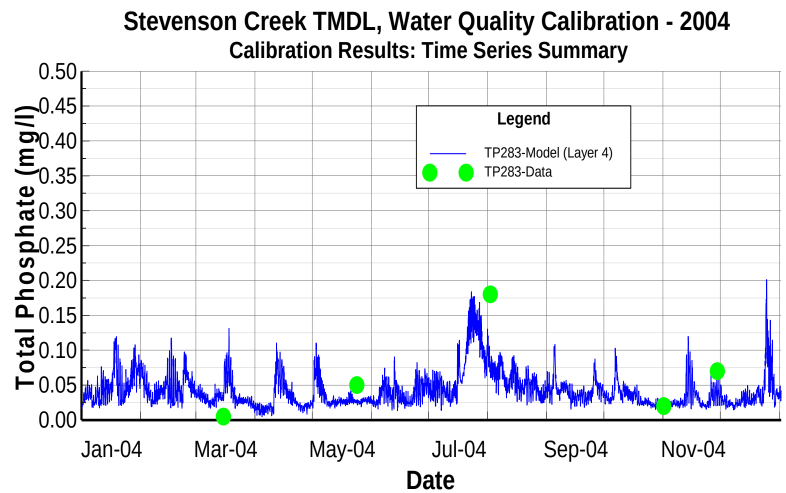

Figure B-28 Stevenson Creek Water Quality Calibration: Total Phosphate, TP283

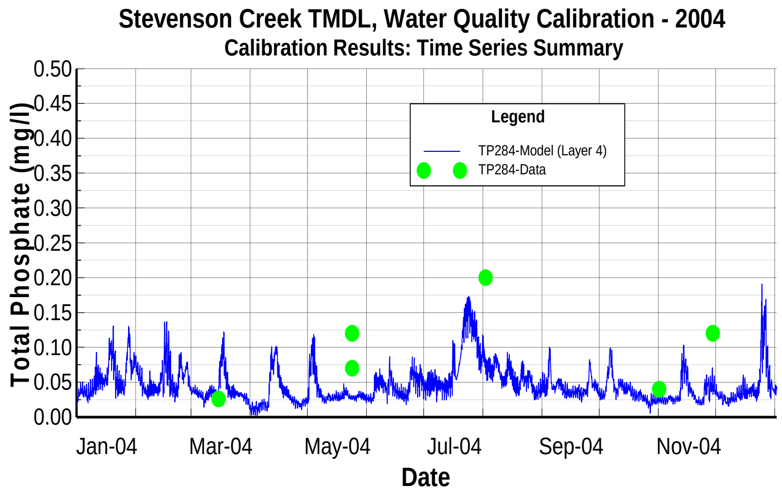

Figure B-29 Stevenson Creek Water Quality Calibration: Total Phosphate, TP284

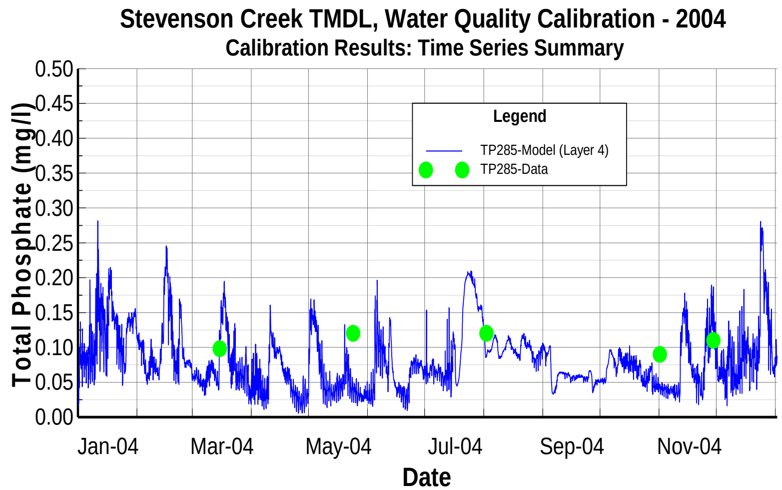

Figure B-30 Stevenson Creek Water Quality Calibration: Total Phosphate, TP285

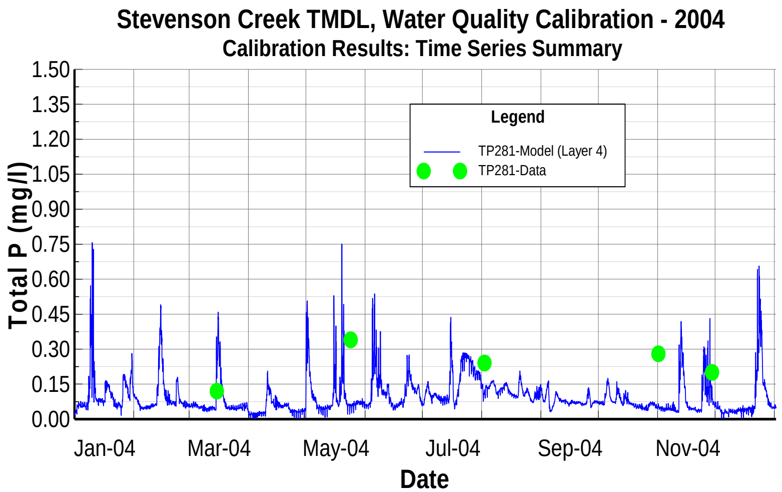

Figure B-31 Stevenson Creek Water Quality Calibration: Total Organic Phosphorus, TP281

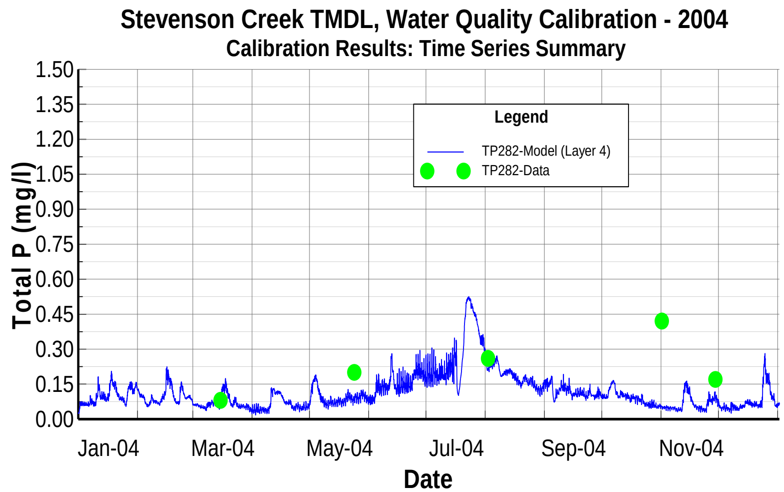

Figure B-32 Stevenson Creek Water Quality Calibration: Total Organic Phosphorus, TP282

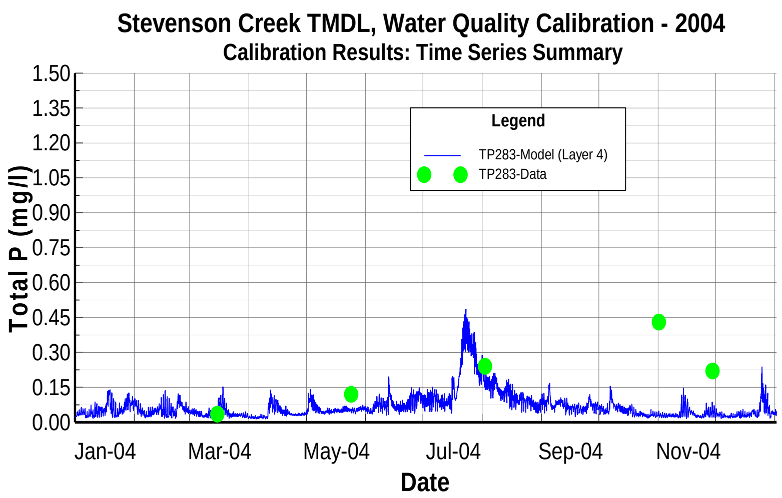

Figure B-33 Stevenson Creek Water Quality Calibration: Total Organic Phosphorus, TP283

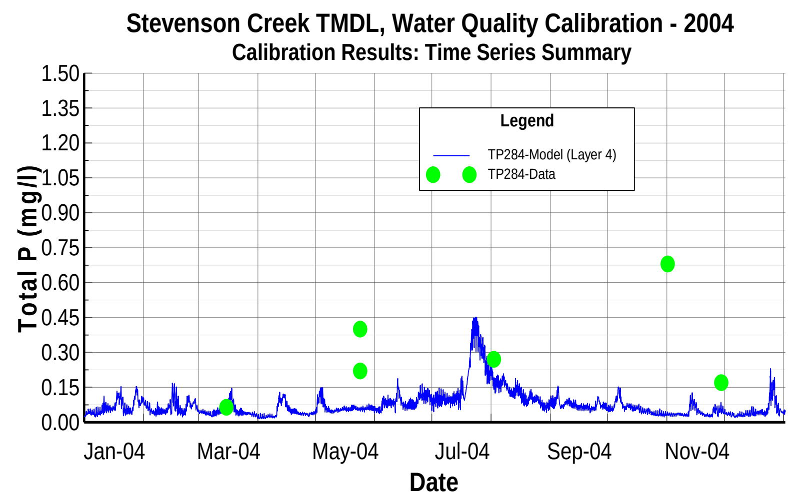

Figure B-34 Stevenson Creek Water Quality Calibration: Total Organic Phosphorus, TP284

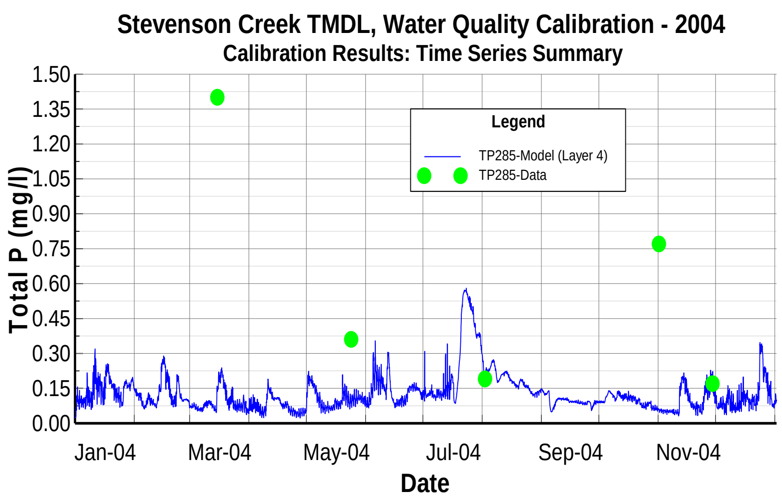

Figure B-35 Stevenson Creek Water Quality Calibration: Total Organic Phosphorus, TP285

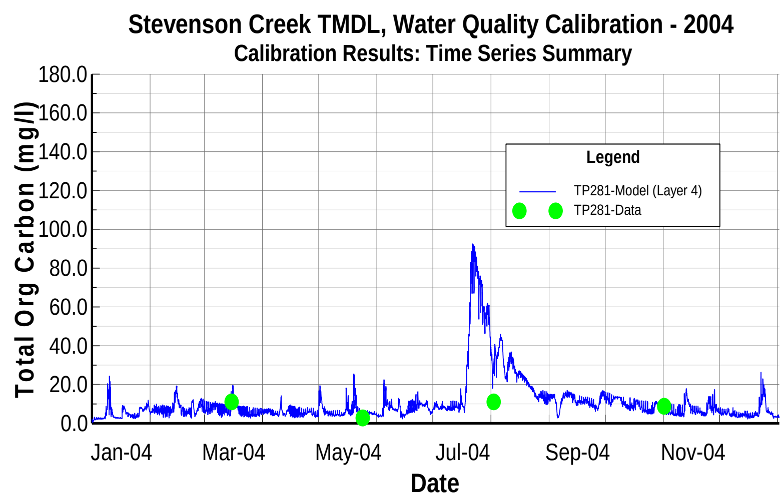

Figure B-36 Stevenson Creek Water Quality Calibration: Total Organic Carbon, TP281

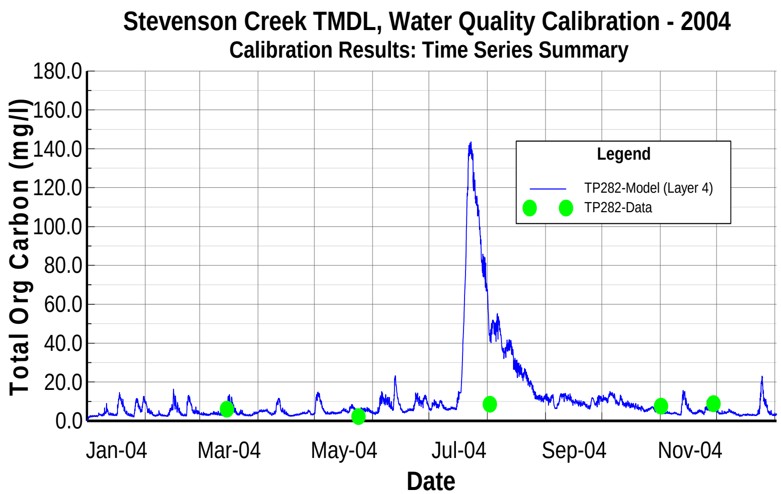

Figure B-37 Stevenson Creek Water Quality Calibration: Total Organic Carbon, TP282

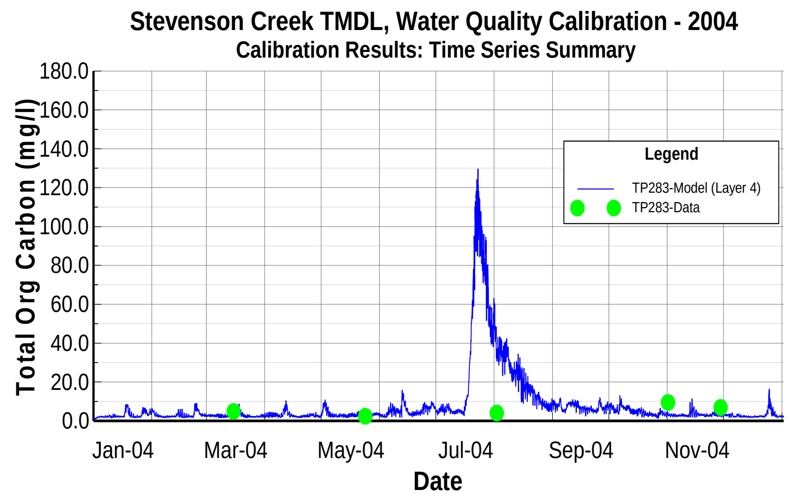

Figure B-38 Stevenson Creek Water Quality Calibration: Total Organic Carbon, TP283

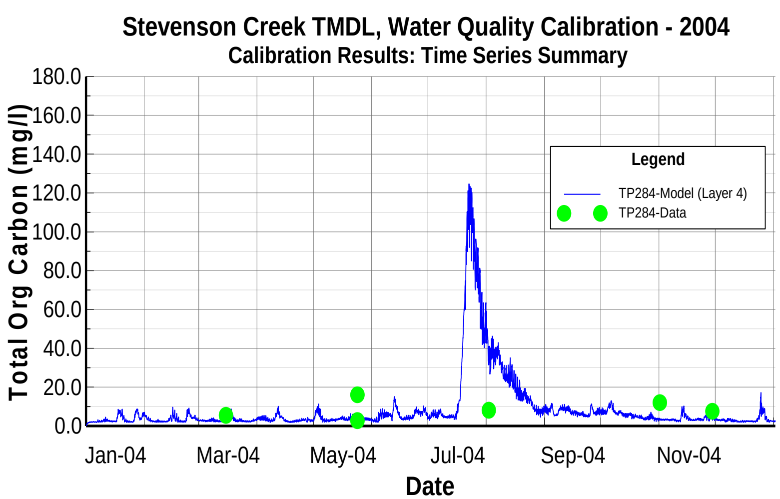

Figure B-39 Stevenson Creek Water Quality Calibration: Total Organic Carbon, TP284

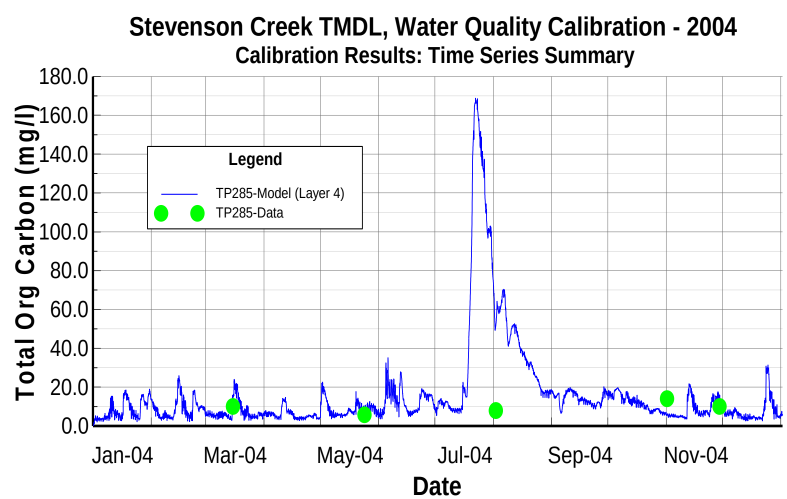

Figure B-40 Stevenson Creek Water Quality Calibration: Total Organic Carbon, TP285

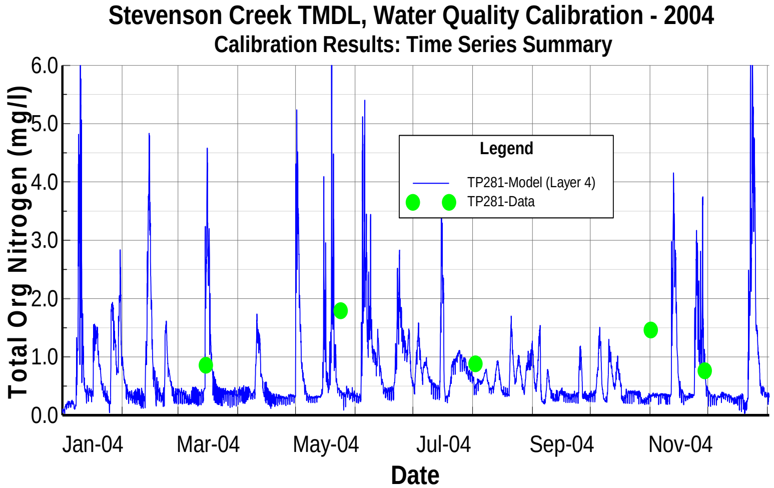

Figure B-41 Stevenson Creek Water Quality Calibration: Total Nitrogen, TP281

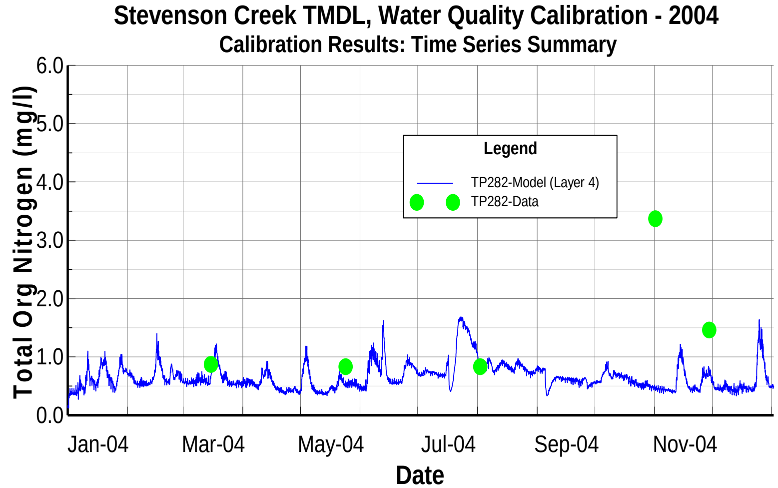

Figure B-42 Stevenson Creek Water Quality Calibration: Total Nitrogen, TP282

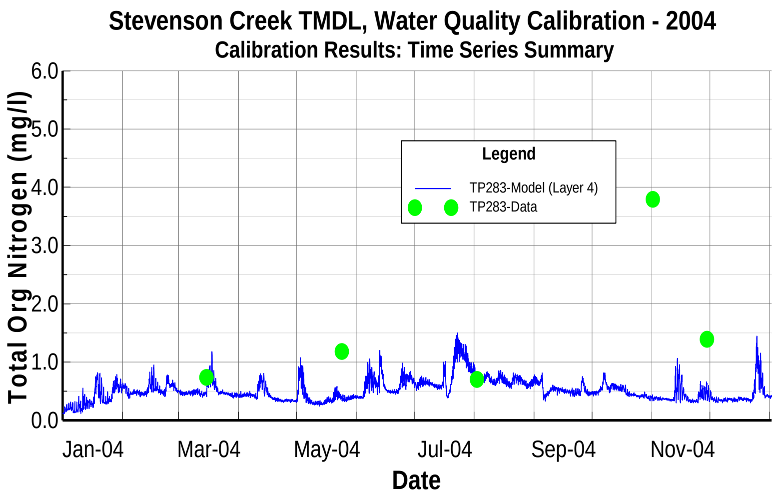

Figure B-43 Stevenson Creek Water Quality Calibration: Total Nitrogen, TP283

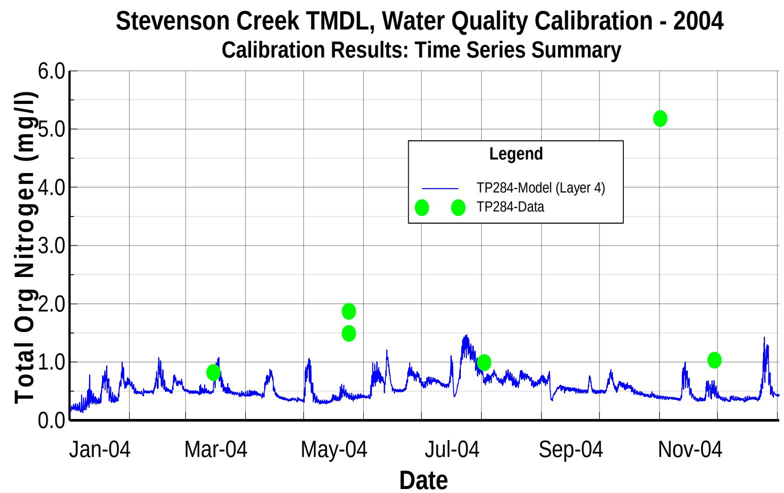

Figure B-44 Stevenson Creek Water Quality Calibration: Total Nitrogen, TP284

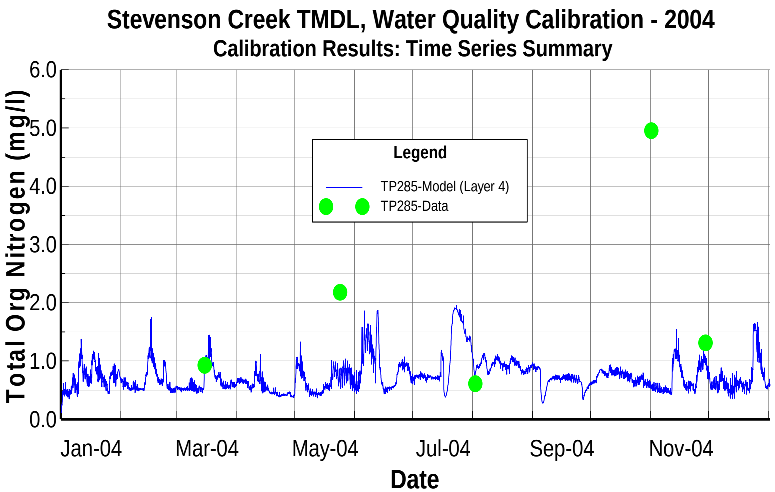

Figure B-45 Stevenson Creek Water Quality Calibration: Total Nitrogen, TP285

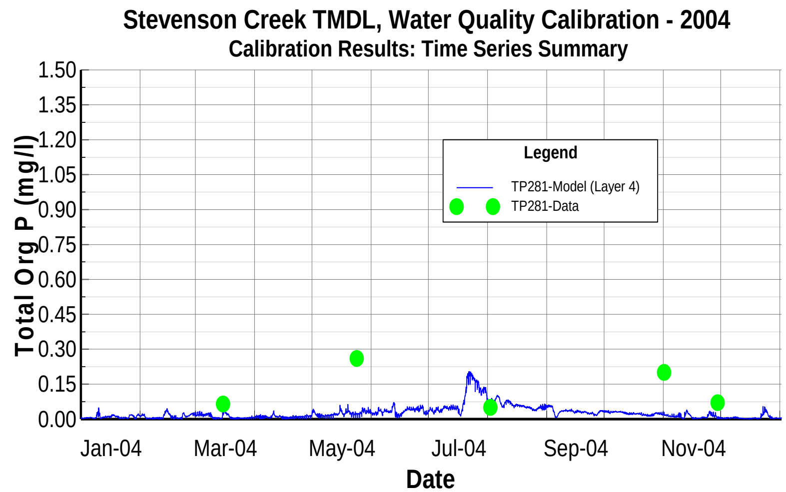

Figure B-46 Stevenson Creek Water Quality Calibration: Total Phosphorus, TP281

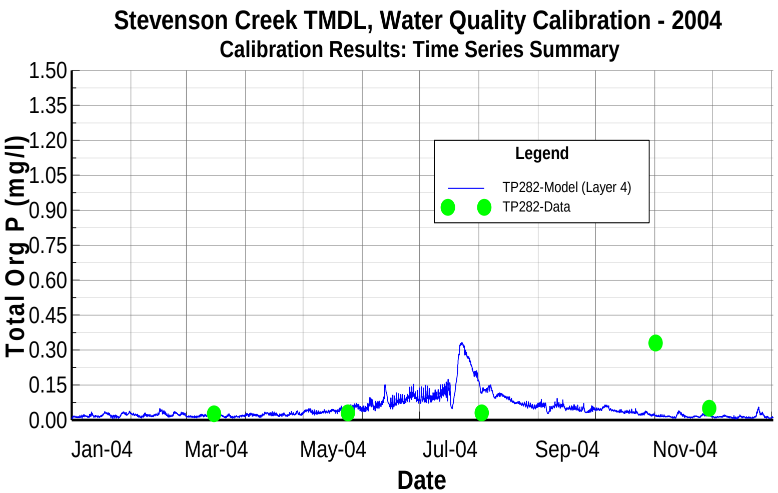

Figure B-47 Stevenson Creek Water Quality Calibration: Total Phosphorus, TP282

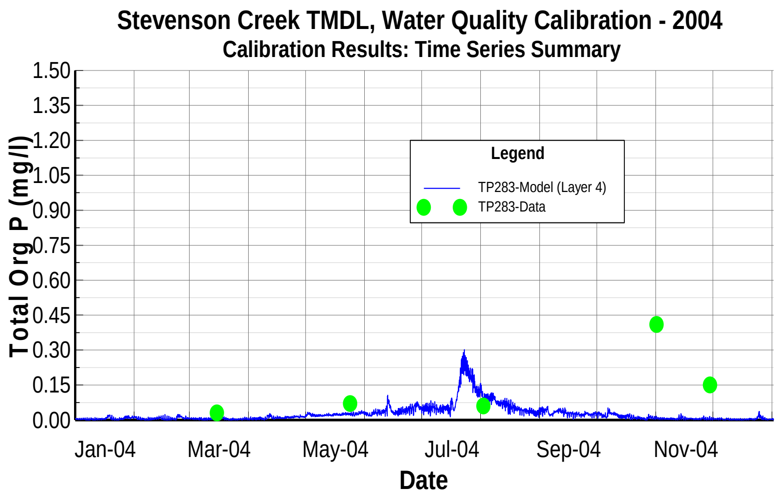

Figure B-48 Stevenson Creek Water Quality Calibration: Total Phosphorus, TP283

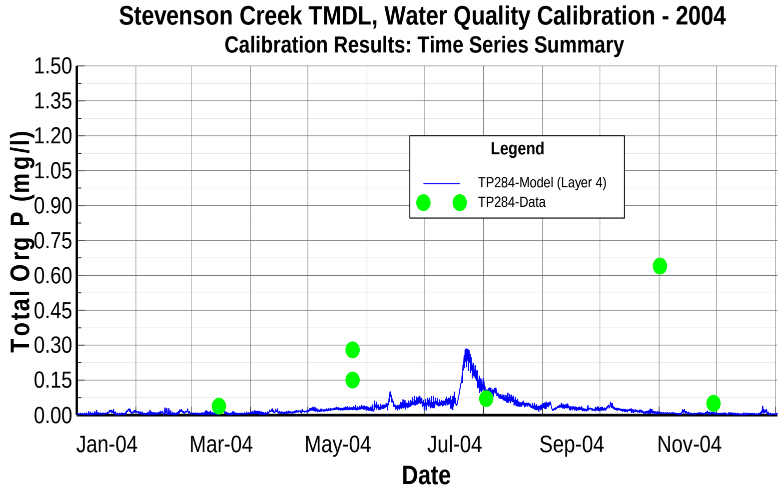

Figure B-49 Stevenson Creek Water Quality Calibration: Total Phosphorus, TP284

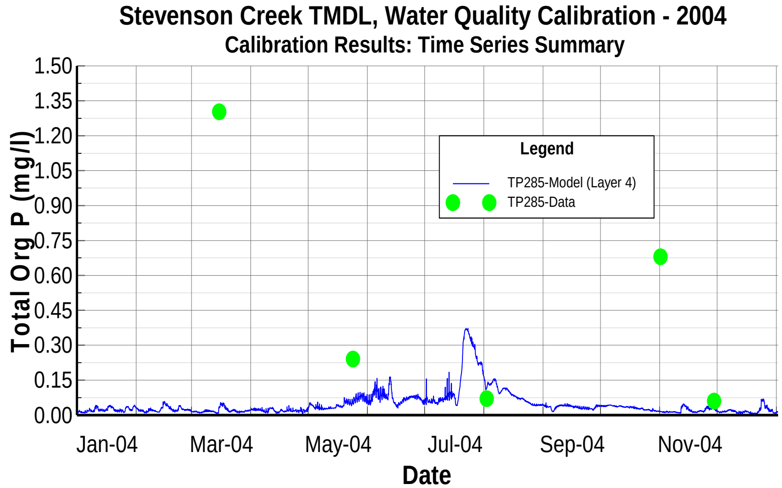

Figure B-50 Stevenson Creek Water Quality Calibration: Total Phosphorus, TP285

EFDC Model Run - Time Series Statistics

Station ID	Layer/ Type	Starting Date/Time	Ending Date/Time	# Pairs	RMS (mg/l)	Data Average (mg/l)	Model Average (mg/l)
		Stevenson Creek TMDL, Water Quality Calibration - 2004					
		Nitrate Nitrogen (mg/l)					
TP283	Layer 4	15-Mar-04	29-Nov-04	5	0.094	0.134	0.080
TP284	Layer 4	15-Mar-04	29-Nov-04	6	0.228	0.230	0.106
TP281	Layer 4	15-Mar-04	29-Nov-04	5	0.274	0.098	0.272
TP282	Layer 4	15-Mar-04	29-Nov-04	5	0.175	0.504	0.411
TP285	Layer 4	15-Mar-04	29-Nov-04	5	0.380	0.140	0.422
		Ammonia Nitrogen (mg/l)					
TP283	Layer 4	15-Mar-04	29-Nov-04	5	0.060	0.057	0.010
TP284	Layer 4	15-Mar-04	29-Nov-04	6	0.076	0.067	0.013
TP281	Layer 4	15-Mar-04	29-Nov-04	5	0.078	0.087	0.022
TP282	Layer 4	15-Mar-04	29-Nov-04	5	0.035	0.072	0.051
TP285	Layer 4	15-Mar-04	29-Nov-04	5	0.024	0.059	0.038
		Dissolved Oxygen (mg/l)					
TP283	Layer 4	15-Mar-04	29-Nov-04	5	1.112	4.972	5.492
TP284	Layer 4	15-Mar-04	29-Nov-04	5	1.758	5.674	4.648
TP281	Layer 4	15-Mar-04	29-Nov-04	5	1.545	3.342	3.607
TP282	Layer 4	15-Mar-04	29-Nov-04	5	2.175	6.336	5.134
TP285	Layer 4	15-Mar-04	29-Nov-04	5	1.574	4.735	4.687
		Total Phosphate (mg/l)					
TP283	Layer 4	15-Mar-04	29-Nov-04	5	0.052	0.065	0.039
TP284	Layer 4	15-Mar-04	29-Nov-04	6	0.077	0.096	0.039
TP281	Layer 4	15-Mar-04	29-Nov-04	5	0.086	0.107	0.078
TP282	Layer 4	15-Mar-04	29-Nov-04	5	0.090	0.133	0.061
TP285	Layer 4	15-Mar-04	29-Nov-04	5	0.055	0.108	0.094
		Total P (mg/l)					
TP283	Layer 4	15-Mar-04	29-Nov-04	5	0.199	0.209	0.063
TP284	Layer 4	15-Mar-04	29-Nov-04	6	0.315	0.301	0.064
TP281	Layer 4	15-Mar-04	29-Nov-04	5	0.176	0.236	0.106

EFDC Model Run - Time Series Statistics

Station ID	Layer/ Type	Starting Date/Time	Ending Date/Time	# Pairs	RMS (mg/l)	Data Average (mg/l)	Model Average (mg/l)
Stevenson Creek TMDL, Water Quality Calibration - 2004							
TP282	Layer 4	15-Mar-04	29-Nov-04	5	0.177	0.226	0.105
TP285	Layer 4	15-Mar-04	29-Nov-04	5	0.659	0.578	0.144
Chlorophyll a (ug/l)							
TP283	Layer 4	15-Mar-04	29-Nov-04	5	62.025	38.030	10.315
TP284	Layer 4	15-Mar-04	29-Nov-04	6	105.830	66.917	10.987
TP281	Layer 4	15-Mar-04	29-Nov-04	5	40.232	31.360	8.906
TP282	Layer 4	15-Mar-04	29-Nov-04	5	43.347	30.930	13.140
TP285	Layer 4	15-Mar-04	29-Nov-04	5	101.904	72.900	12.084
Total N (mg/l)							
TP283	Layer 4	15-Mar-04	29-Nov-04	5	1.644	1.750	0.549
TP284	Layer 4	15-Mar-04	29-Nov-04	5	2.326	2.328	0.649
TP281	Layer 4	15-Mar-04	29-Nov-04	5	1.121	1.334	1.100
TP282	Layer 4	15-Mar-04	29-Nov-04	5	1.518	2.048	1.082
TP285	Layer 4	15-Mar-04	29-Nov-04	5	2.020	2.194	1.250
Total Org C (mg/l)							
TP283	Layer 4	15-Mar-04	29-Nov-04	5	12.597	5.480	8.675
TP284	Layer 4	15-Mar-04	29-Nov-04	6	12.383	8.617	8.185
TP281	Layer 4	15-Mar-04	1-Nov-04	4	10.010	8.350	12.900
TP282	Layer 4	15-Mar-04	29-Nov-04	5	15.046	6.600	12.699
TP285	Layer 4	15-Mar-04	29-Nov-04	5	20.626	9.520	19.133
Total Org N (mg/l)							
TP283	Layer 4	15-Mar-04	29-Nov-04	5	1.623	1.559	0.459
TP284	Layer 4	15-Mar-04	29-Nov-04	6	2.113	1.897	0.487
TP281	Layer 4	15-Mar-04	29-Nov-04	5	0.963	1.149	0.807
TP282	Layer 4	15-Mar-04	29-Nov-04	5	1.351	1.472	0.620
TP285	Layer 4	15-Mar-04	29-Nov-04	5	2.071	1.995	0.790
Total Org P (mg/l)							
TP283	Layer 4	15-Mar-04	29-Nov-04	5	0.192	0.144	0.024

EFDC Model Run - Time Series Statistics

Stevenson Creek TMDL, Water Quality Calibration - 2004							
Station ID	**Layer/ Type**	**Starting Date/Time**	**Ending Date/Time**	**# Pairs**	**RMS (mg/l)**	**Data Average (mg/l)**	**Model Average (mg/l)**
TP284	Layer 4	15-Mar-04	29-Nov-04	6	0.284	0.205	0.025
TP281	Layer 4	15-Mar-04	29-Nov-04	5	0.137	0.129	0.028
TP282	Layer 4	15-Mar-04	29-Nov-04	5	0.146	0.093	0.044
TP285	Layer 4	15-Mar-04	29-Nov-04	5	0.647	0.470	0.050

Appendix C
EFDC Model Validation Dataset

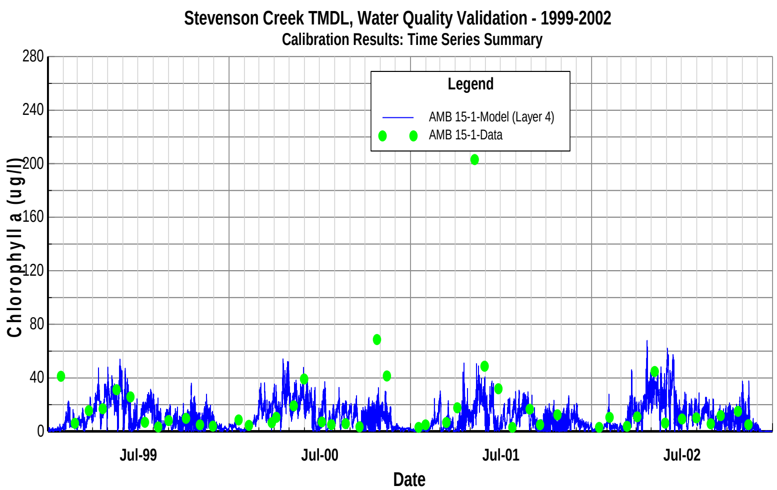

Figure C-1 Stevenson Creek Water Quality Validation: Chlorophyll a, AMB 15-1

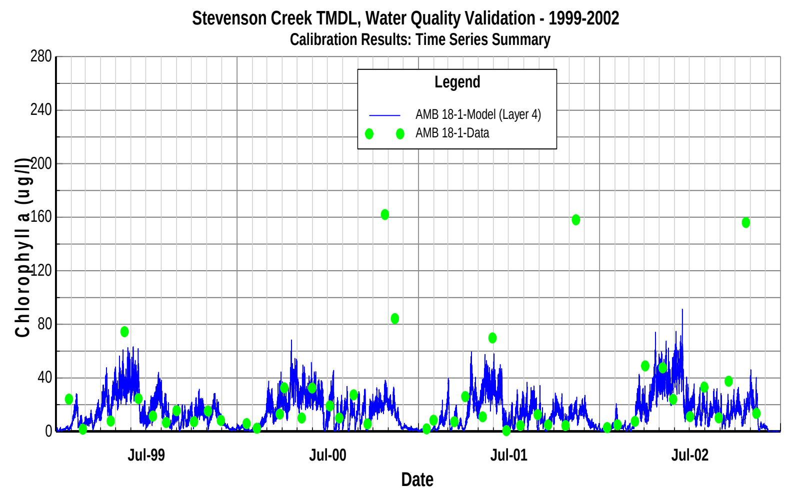

Figure C-2 Stevenson Creek Water Quality Validation: Chlorophyll a, AMB 18-1

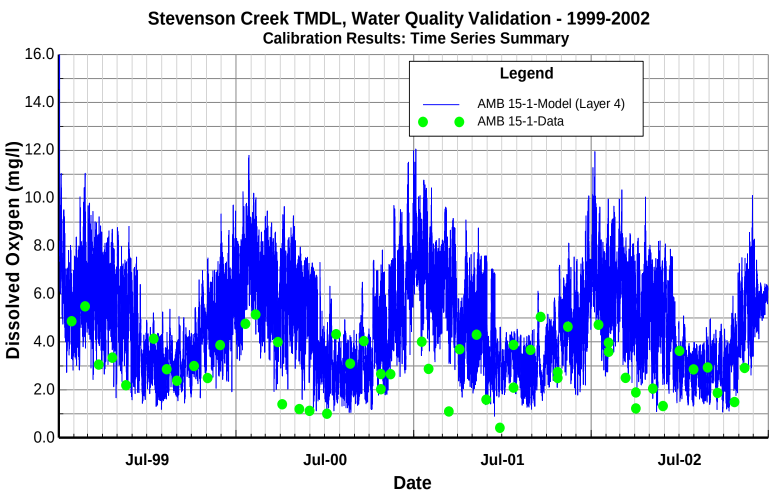

Figure C-3 Stevenson Creek Water Quality Validation: Dissolved Oxygen, Bottom layer: AMB 15-1

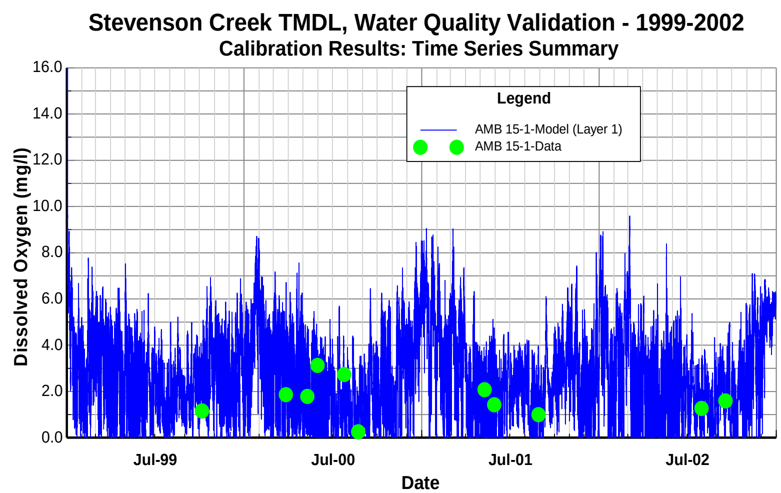

Figure C-4 Stevenson Creek Water Quality Validation: Dissolved Oxygen, Surface layer: AMB 15-1

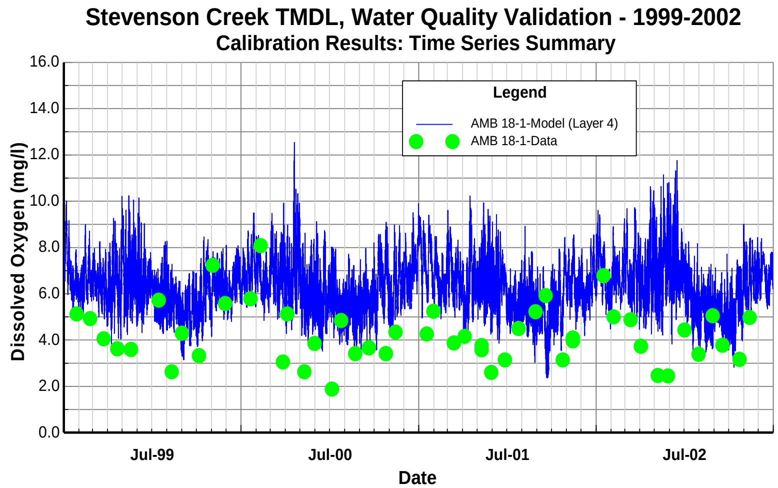

Figure C-5 Stevenson Creek Water Quality Validation: Dissolved Oxygen, Bottom layer: AMB 18-1

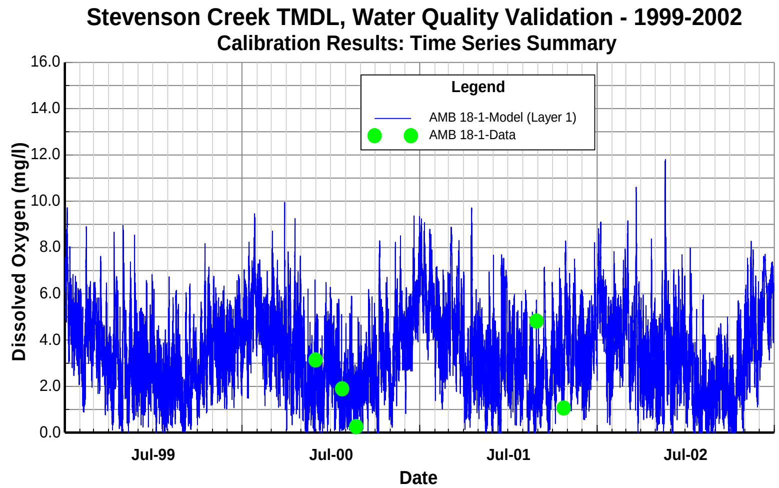

Figure C-6 Stevenson Creek Water Quality Validation: Dissolved Oxygen, Surface layer: AMB 18-1

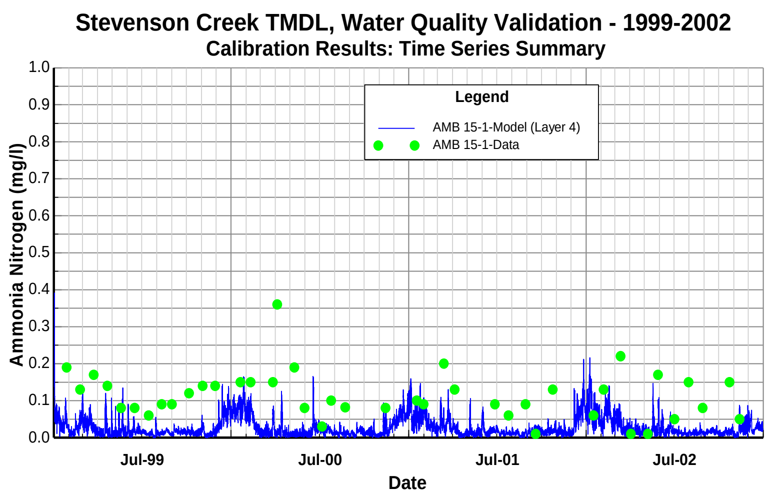

Figure C-7 Stevenson Creek Water Quality Validation: Ammonia Nitrogen, AMB 15-1

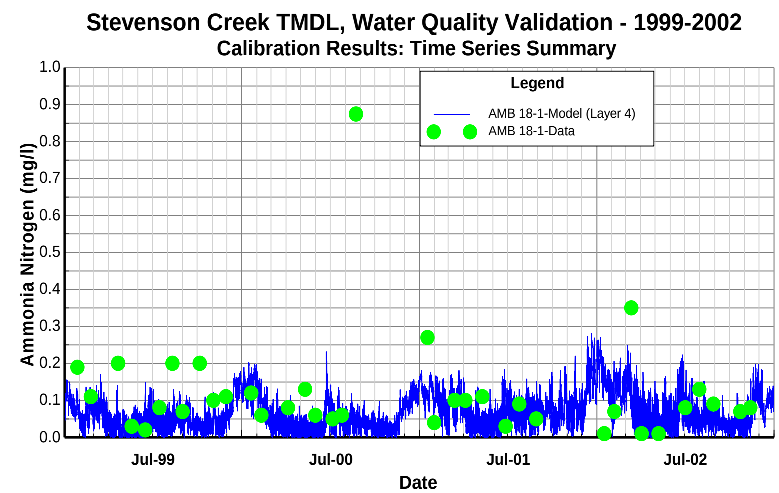

Figure C-8 Stevenson Creek Water Quality Validation: Ammonia Nitrogen, AMB 18-1

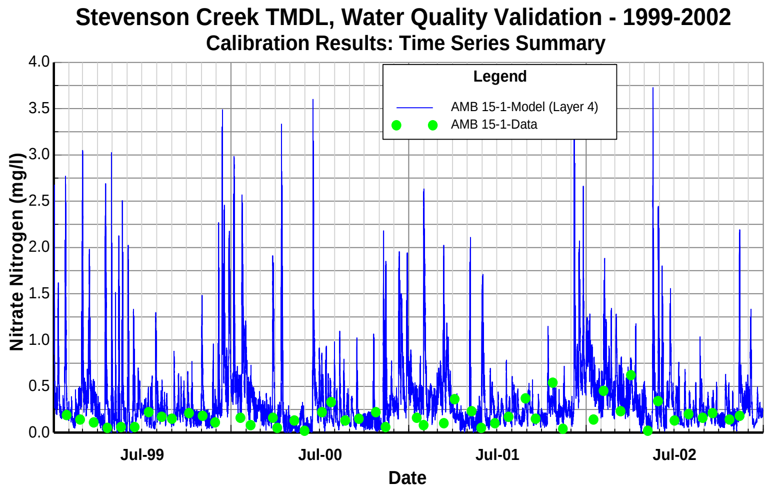

Figure C-9 Stevenson Creek Water Quality Validation: Nitrate Nitrogen, AMB 15-1

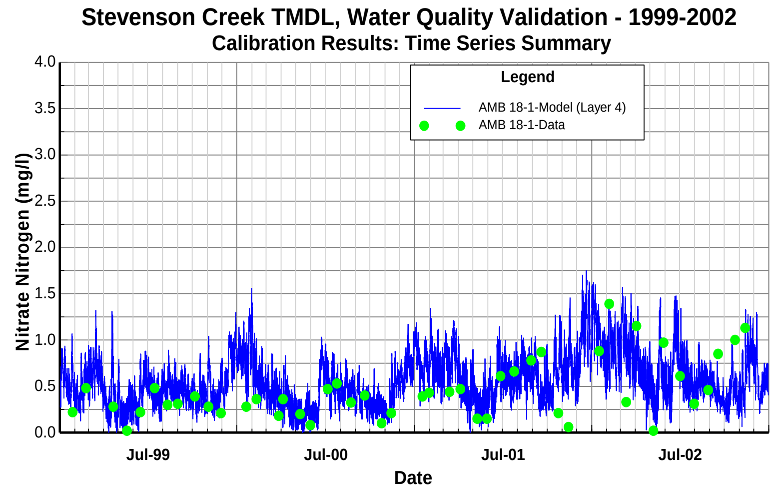

Figure C-10 Stevenson Creek Water Quality Validation: Nitrate Nitrogen, AMB 18-1

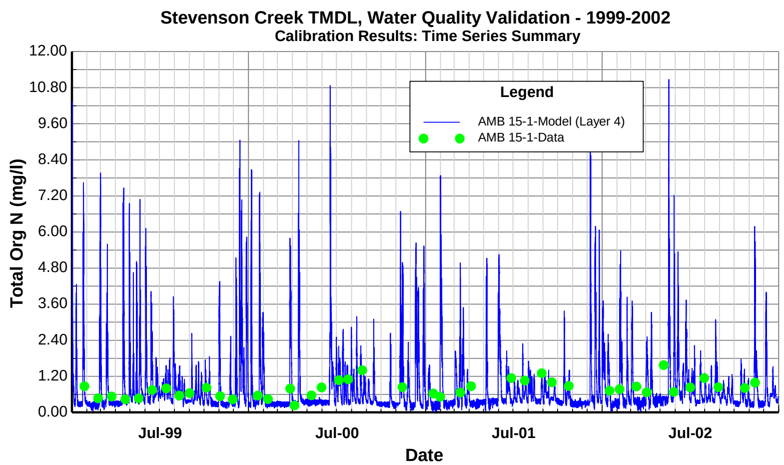

Figure C-11 Stevenson Creek Water Quality Validation: Total Organic Nitrogen, AMB 15-1

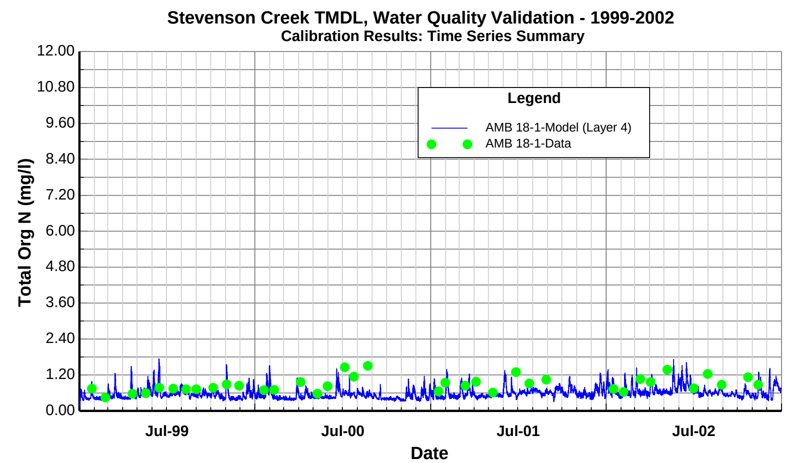

Figure C-12 Stevenson Creek Water Quality Validation: Total Organic Nitrogen, AMB 18-1

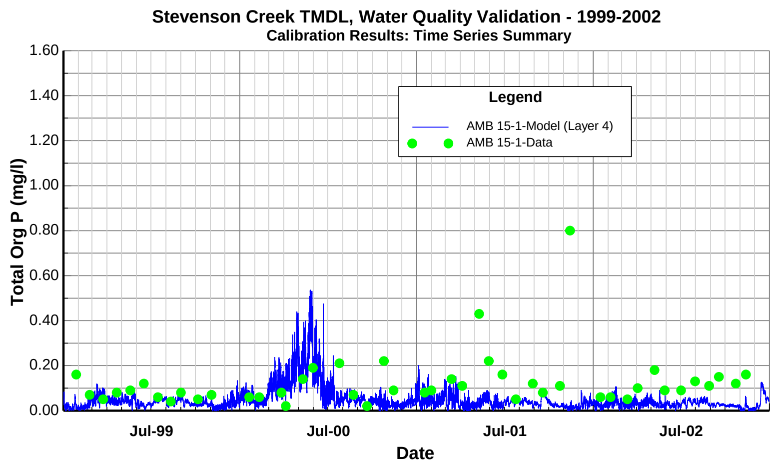

Figure C-13 Stevenson Creek Water Quality Validation: Total Organic Phosphorus, AMB 15-1

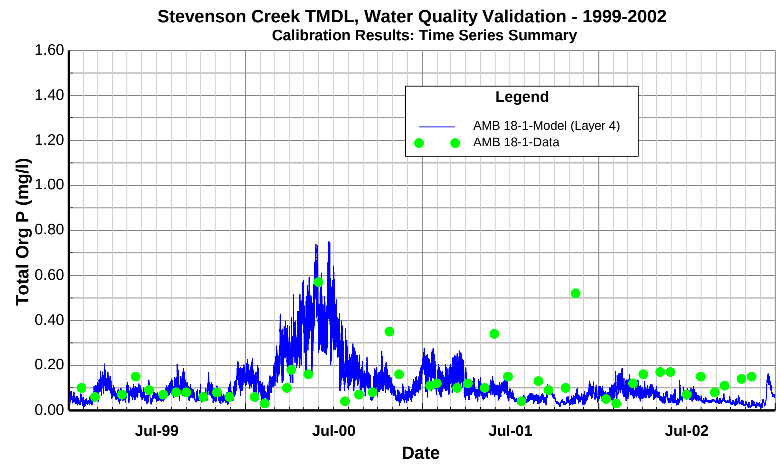

Figure C-14 Stevenson Creek Water Quality Validation: Total Organic Phosphorus, AMB 18-1

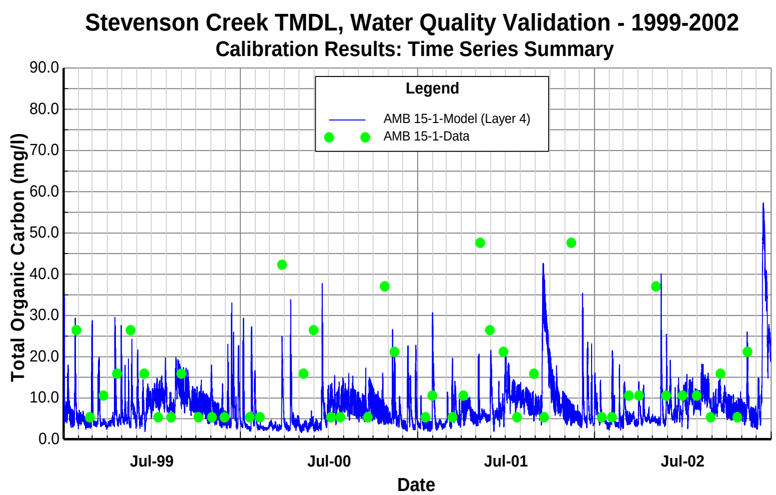

Figure C-15 Stevenson Creek Water Quality Validation: Total Organic Carbon, AMB 15-1

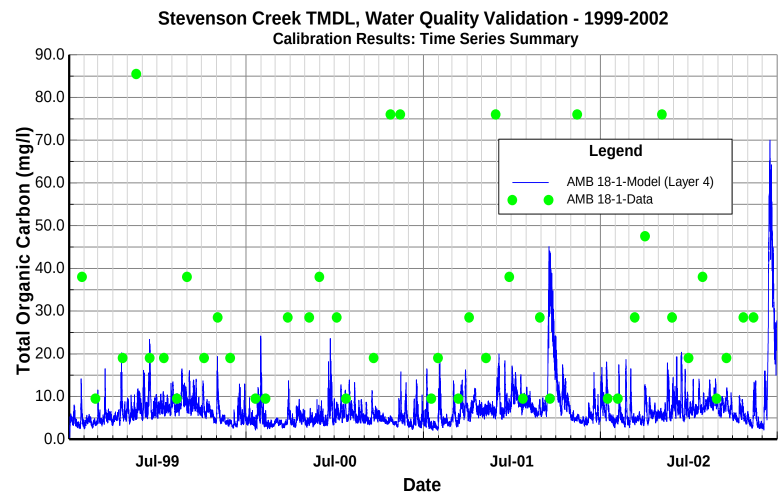

Figure C-16 Stevenson Creek Water Quality Validation: Total Organic Carbon, AMB 18-1

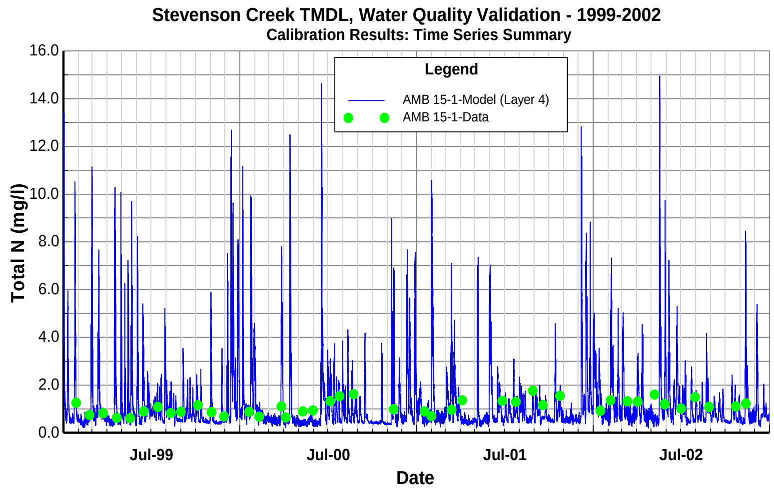

Figure C-17 Stevenson Creek Water Quality Validation: Total Nitrogen, AMB 15-1

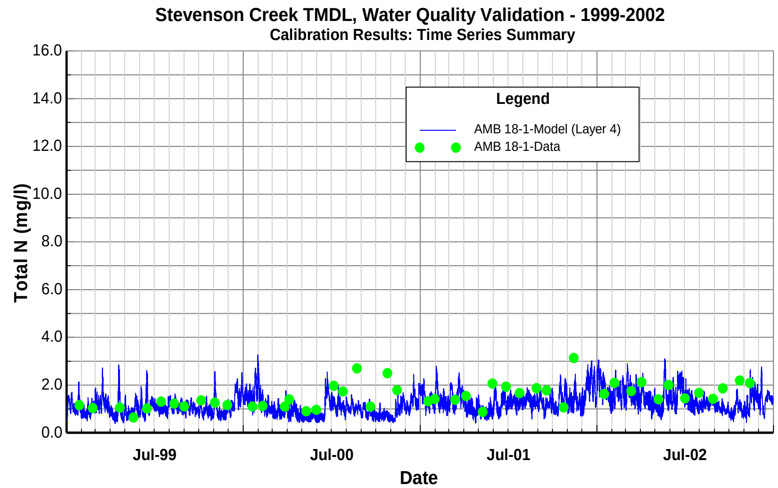

Figure C-18 Stevenson Creek Water Quality Validation: Total Nitrogen, AMB 18-1

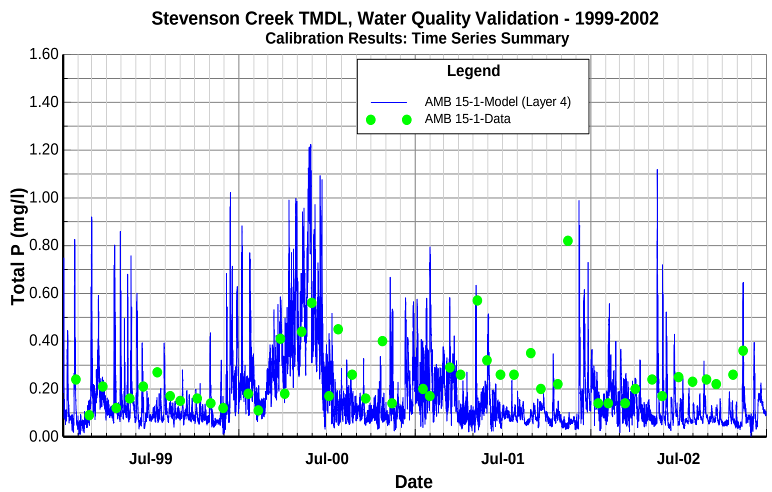

Figure C-19 Stevenson Creek Water Quality Validation: Total Phosphorus, AMB 15-1

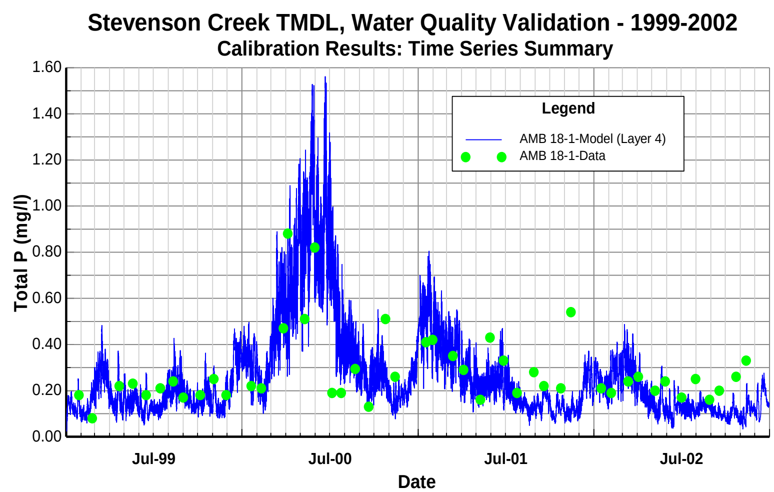

Figure C-20 Stevenson Creek Water Quality Validation: Total Phosphorus, AMB 18-1

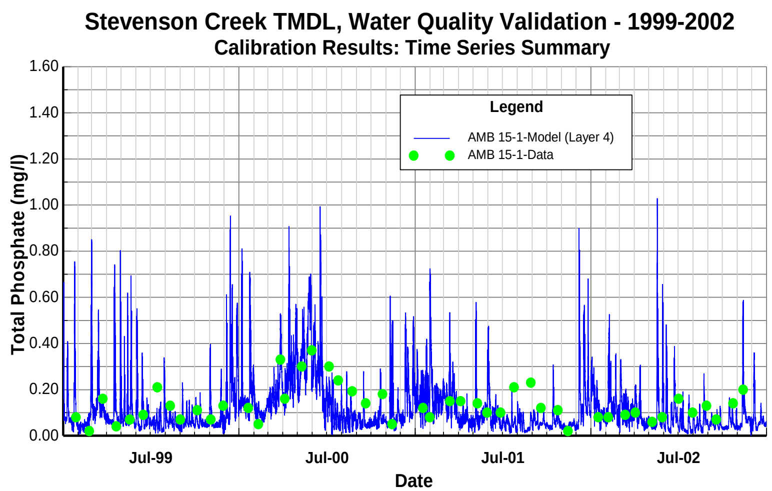

Figure C-21 Stevenson Creek Water Quality Validation: Total Phosphate, AMB 15-1

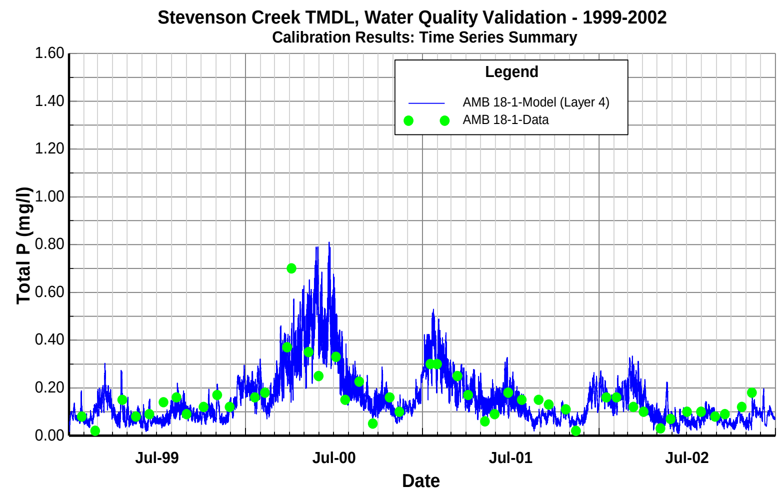

Figure C-22 Stevenson Creek Water Quality Validation: Total Phosphate, AMB 18-1

EFDC Model Run - Time Series Statistics

Stevenson Creek TMDL, Water Quality Validation - 1999-2002

Station ID	Layer/ Type	Starting Date/Time	Ending Date/Time	# Pairs	RMS (mg/l)	Data Average (mg/l)	Model Average (mg/l)
Chlorophyll a (µg/l)							
AMB 15-1	Layer 4	1/27/1999 8:59	11/13/2002 9:06	48	75.956	28.554	9.609
AMB 18-1	Layer 4	1/27/1999 8:42	11/13/2002 8:51	47	39.304	27.749	13.551
Dissolved Oxygen (mg/l)							
AMB 15-1	Layer 4	1/27/1999 8:59	11/13/2002 9:06	53	2.490	2.912	4.545
AMB 15-1	Layer 1	10/6/1999 8:24	9/18/2002 9:14	11	1.275	1.657	1.085
AMB 18-1	Layer 4	1/27/1999 8:42	11/13/2002 8:51	50	2.271	4.152	5.843
AMB 18-1	Layer 1	5/31/2000 9:46	10/24/2001 8:43	5	0.964	2.234	2.296
Ammonia Nitrogen (mg/l)							
AMB 15-1	Layer 4	1/27/1999 8:59	11/13/2002 9:06	42	0.104	0.114	0.032
AMB 18-1	Layer 4	1/27/1999 8:42	11/13/2002 8:51	37	0.160	0.120	0.066
Nitrate Nitrogen (mg/l)							
AMB 15-1	Layer 4	1/27/1999 8:59	11/13/2002 9:06	48	0.439	0.178	0.409
AMB 18-1	Layer 4	1/27/1999 8:42	11/13/2002 8:51	47	0.312	0.447	0.541
Total Org C (mg/l)							
AMB 15-1	Layer 4	1/27/1999 8:59	11/13/2002 9:06	45	15.219	14.694	8.247

EFDC Model Run - Time Series Statistics

Stevenson Creek TMDL, Water Quality Validation - 1999-2002

Station ID	Layer/ Type	Starting Date/Time	Ending Date/Time	# Pairs	RMS (mg/l)	Data Average (mg/l)	Model Average (mg/l)
AMB 18-1	Layer 4	1/27/1999 8:42	11/13/2002 8:51	44	31.978	29.362	7.370
Total N (mg/l)							
AMB 15-1	Layer 4	1/27/1999 8:59	11/13/2002 9:06	42	1.633	1.083	1.584
AMB 18-1	Layer 4	1/27/1999 8:42	11/13/2002 8:51	47	0.708	1.537	1.198
Total P (mg/l)							
AMB 15-1	Layer 4	1/27/1999 8:59	11/13/2002 9:06	48	0.195	0.250	0.176
AMB 18-1	Layer 4	1/27/1999 8:42	11/13/2002 8:51	47	0.139	0.284	0.252
Total Phosphate (mg/l)							
AMB 15-1	Layer 4	1/27/1999 8:59	11/13/2002 9:06	48	0.113	0.134	0.130
AMB 18-1	Layer 4	1/27/1999 8:42	11/13/2002 8:51	47	0.067	0.159	0.150
Total Org N (mg/l)							
AMB 15-1	Layer 4	1/27/1999 8:59	11/13/2002 9:06	42	1.231	0.788	1.107
AMB 18-1	Layer 4	1/27/1999 8:42	11/13/2002 8:51	37	0.417	0.877	0.614
Total Org P (mg/l)							
AMB 15-1	Layer 4	1/27/1999 8:59	11/13/2002 9:06	48	0.153	0.116	0.046
AMB 18-1	Layer 4	1/27/1999 8:42	11/13/2002 8:51	47	0.134	0.125	0.102