MODEL SETUP AND CALIBRATION FOR MCKAY BAY

March 2013

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1.0 Introduction

The United States Environmental Protection Agency (EPA) published a proposed Total Maximum Daily Load (TMDL) for nutrients and dissolved oxygen (DO) in Ybor City Drain (WBID 1584A) and McKay Bay (WBID 1584B) in October 2010 (EPA, 2010). The report provided a proposed TMDL for total nitrogen to address impairment of nutrients and DO for McKay Bay and nutrients for Ybor City Drain.

This technical memorandum provides a summary of the model setup and calibration of the Environmental Fluid Dynamics Code (EFDC) and Water Quality Analysis Simulation Program (WASP), models for McKay Bay and the Tampa Bypass Canal (TBC) or Tidal Palm River. The model system will be utilized to assess the changes in water quality response within McKay Bay and the TBC under specified load conditions in order to identify the allowable loads that will utilized to develop a TMDL. This is part of a project being completed for a group of stakeholders including the City of Tampa, the Florida Department of Transportation, Hillsborough County, and Tampa Bay Water, aimed at developing a hydrodynamic and water quality model for use in TMDL development for the McKay Bay system.

This task includes set up and calibration of the EFDC hydrodynamic model and the set up and calibration of the WASP water quality model. Following this effort, the calibrated models will be utilized to assess allowable loading.

2.0 Hydrodynamic Model Development

This section provides a description of the EFDC hydrodynamic model. It also describes the model setup and calibration.

2.1 EFDC Model Description and Configuration

The EFDC is a general purpose modeling package for simulating two- and three-dimensional flow, transport and biogeochemical processes in surface water systems including: rivers, lakes, estuaries, reservoirs, wetlands and near shore to shelf scale coastal regions. The EFDC model was originally developed by Dr. John Hamrick at the Virginia Institute of Marine Science and is considered public domain software. EFDC is currently supported by Tetra Tech for the EPA Office of Research and Development (ORD), EPA Region 4, and EPA Headquarters.

As described by Hamrick (1992) and Tetra Tech (2002, 2006a, 2006b, 2006c, 2006d), the physics of the EFDC model, and many aspects of the computational scheme, are equivalent to the widely used Blumberg-Mellor model. The EFDC model solves the three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motions for a variable density fluid. Dynamically coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved. The two turbulence parameter transport equations implement the Mellor-Yamada level 2.5 turbulence closure scheme. The EFDC model uses a stretched or sigma vertical coordinate, and curvilinear orthogonal horizontal coordinates.

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

For this project, EFDC is configured as a three-dimensional model to simulate the water levels, transport, temperature, and salinity in the estuary. This information is saved to a binary output file (HYD file) that provides input to the WASP water quality model. The particular version of EFDC and program executable used for the study was provided by Tim Wool at EPA Region IV.

2.2 Model Grid and Bathymetry

A boundary-fitted curvilinear grid was developed to adequately represent the complex shorelines in McKay Bay, the TBC and within Hillsborough Bay. The model was extended into Hillsborough Bay in order to assure that model boundaries are well away from the areas of interest for determination of the TMDL. The model grid, shown in Figure 2-1, includes 160 horizontal grid cells covering Hillsborough Bay, East Bay, McKay Bay and Palm River.

The bathymetric data used to determine the grid bottom elevation was assembled from several sources, including:

1. National Ocean Service (NOS) hydrographic survey data from 1957, 1996 and 2004;
2. Hillsborough County LiDAR data for shallow intertidal areas;
3. SWFWMD survey data in the McKay Bay area; and
4. USACE survey data in the federal navigation channel.

The data were processed as follows:

1. Vertical datum adjustments were applied to correct to NAVD88;
2. Older data were removed in overlapping areas;
3. The data were merged to create a single bathymetry data set;
4. The data were interpolated onto a square grid using an inverse distance interpolation method. This was done to eliminate over-weighting dense data sets,

such as USACE channel surveys when the results were interpolated onto the model grid.

5. The square grid data was then interpolated onto the model grid using the WQGRID software depth interpolation (which averages all depth points that fall within each grid cell area).
6. After the data were interpolated onto the model grid, a minimum elevation of -1.1 m NAVD88 was applied. This was done to keep all of the grid cells wet at low tide.

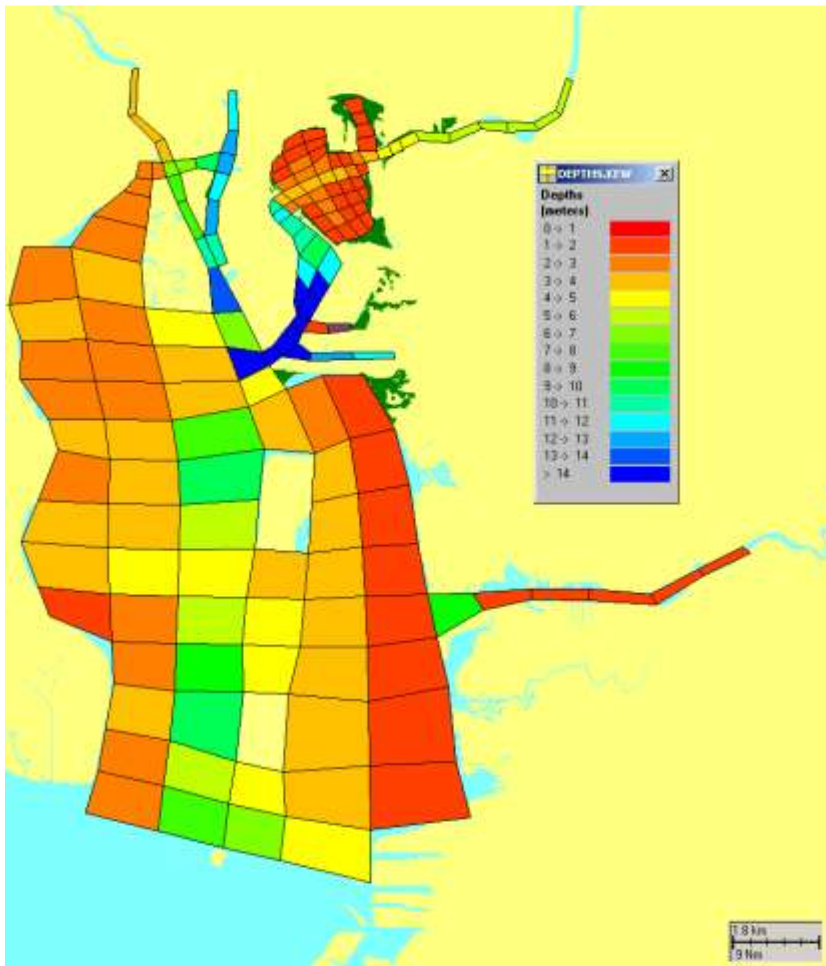


Figure 2-1. Model grid and depths

2.3 Calibration Period

The calibration period was selected as the five year period from January 2003 through December 2007. This period includes flow, load, meteorological, and in-stream water quality conditions that are representative of the range of conditions that occur in McKay Bay and the Palm River. This period includes conditions with the zero base flow as established by the current Minimum Flows and Levels (MFL) for the TBC discharge at S-160, beginning in July 2007. It also includes the preceding conditions with higher flows. Most importantly, this period represents the most up to date loadings that are available for the system, including the loadings used as part of the five-year renewal of the Tampa Bay Reasonable Assurance (RA) which was recently approved by order of the FDEP Secretary (TBNMC, 2010).

2.4 Boundary Inputs and Coefficients

The circulation, salinity and temperature in the modeling domain are driven by boundary inputs. Three types of boundary conditions are required for the McKay Bay EFDC model. These include, tributary and lateral freshwater inflows including temperature, tidal (water level) open boundary conditions at the Hillsborough Bay entrance along with salinity and temperature, and meteorological conditions (wind, rainfall, solar radiation, etc) at the water surface. The following provides an overview of the data used for each.

Tributary and Lateral Inflows

Three primary tributary inflows are included within the model, these are; the Alafia River, the Tampa Bypass Canal (TBC) at structure S-160, and the Hillsborough River. The flows for these three inputs were generated from measured data from the following sources:

- Alafia River – flow directly input from the USGS gage 02301500 (ALAFIA RIVER AT LITHIA FL)
- Hillsborough River – flow is the summation of three measurements, these are USGS gage 02304500 (HILLSBOROUGH RIVER NEAR TAMPA FL), USGS gage 02306000 (SULPHUR SPRINGS AT SULPHUR SPRINGS FL), and Sulphur Springs diversion flows
- Tampa Bypass Canal - flow measured by Tampa Bay Water at the S-160 structure

Lateral inflows from the surrounding watershed were provided by the watershed loading model at the locations shown in Figure 2-2. Model inflows are listed in Table 2-1, along with the EFDC cell index and a description of the inflow type (e.g., river inflows, Non Point Source (NPS) inflows and point source discharges). The freshwater inflows represent the ungaged flows to McKay Bay. These were taken from a study performed for the SWFWMD by HSW (HSW, 2004). Attachment A presents the inflows used in the model including the gaged and ungaged flows. Salinity at all of these boundaries was set to zero.

Open Boundary Conditions

The hydrodynamic model requires input tides and salinity concentrations at the open boundary, which is located at the entrance to Hillsborough Bay. The input tides for the boundary were developed by interpolating water surface elevations measured by two NOAA gages located at the St. Petersburg pier and at the McKay Bay entrance (Figure 2-3). The measured gage data were first low-pass filtered using a two-hour filter to remove high frequency variations (e.g., wind wave or other non-tidal high frequency effects).

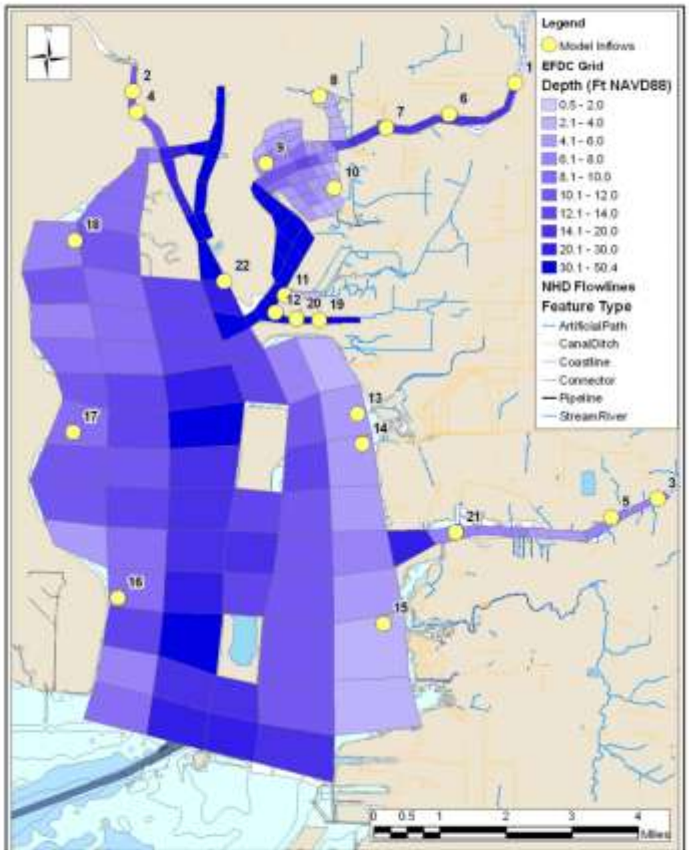


Figure 2-2. Model freshwater and load input locations

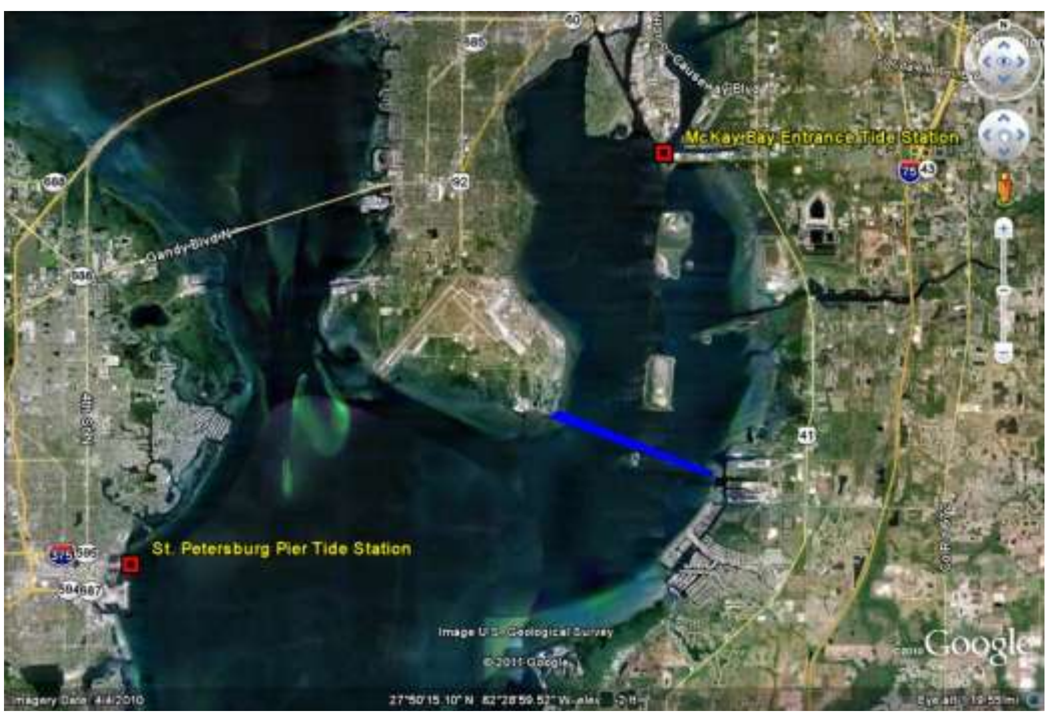


Figure 2-3. Location of St. Petersburg Pier and McKay Bay Entrance Tide Stations.

Table 2-1. List of model inflows, including cell indices and description

Inflow	I	J	Description
1	34	19	S-160, Falkenburg WWTF, Palm River NPS, Trademark Nitrogen and Tampa Bay Water
2	10	22	Hillsborough River
3	18	7	Alafia River
4	10	21	Hillsborough River - Ungaged flows
5	17	7	Alafia River - Ungaged flows
6	31	19	McKay Bay NPS
7	29	19	McKay Bay NPS
8	25	23	McKay Bay NPS
9	19	20	McKay Bay NPS
10	22	15	McKay Bay NPS
11	33	7	McKay Bay NPS
12	30	7	Hillsborough Bay NPS
13	12	10	Hillsborough Bay NPS
14	12	9	Hillsborough Bay NPS
15	12	5	Hillsborough Bay NPS
16	8	6	Hillsborough Bay NPS
17	7	10	Hillsborough Bay NPS
18	7	15	Hillsborough Bay NPS
19	33	6	Kinder Morgan (formerly Pakhoed Dry Bulk)
20	30	6	Kinder Morgan Hartford Terminal (formerly Nitram), Kinder Morgan Port Sutton (formerly IMC Port Sutton)
21	14	7	Mosaic Fertilizer Riverview Chemical Complex (NPDES # FL0000761)
22	10	15	Howard F Curren WWTF

The upper plot in Figure 2-4 shows the filtered tidal signals at the St Pete pier and at the McKay Bay entrance, along with the interpolated value used for the model input water levels (the PSER.INP file). The McKay Bay signal shows some amplification of the tidal signal. The bottom plot in Figure 2-4 shows the boundary water levels for the entire simulation period. The boundary salinity and temperature were based on observed values at EPC Station 80 in Hillsborough Bay. Attachment B presents the open boundary salinity and temperature inputs derived from the EPC Station 80 data.

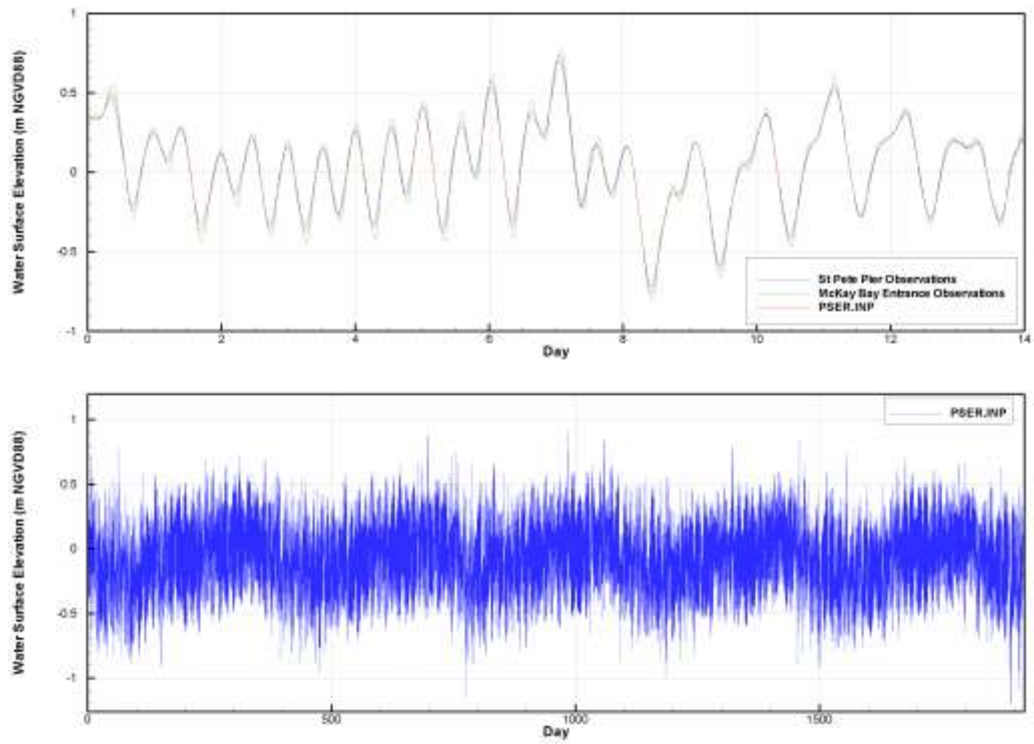


Figure 2-4. Observed tides at St. Petersburg Pier and McKay Bay entrance gages (top plot) and model open boundary water levels (bottom plot)

Meteorological Conditions

Atmospheric data consists of wind speed, wind direction, air temperature, atmospheric pressure, relative humidity, rainfall, solar radiation, evaporation, and cloud cover. Hourly wind speed, wind direction, air temperature, atmospheric pressure, relative humidity and cloud cover were obtained from the National Oceanic and Atmospheric Administration/National Climate Data Center (NOAA NCDC) station at the Tampa International Airport. Daily estimates of rainfall were derived from 18 National Weather Service stations in the area based on inverse distance squared weighting algorithm (Zarbock et al., 1994). Daily evaporation was computed using a bulk aerodynamic formula with data obtained from the NOAA NCDC. Hourly estimates of solar radiation were obtained from the Florida Automated Weather Network (FAWN) station at Dover, FL. Dover, FL is located approximately 15 miles east of McKay Bay and is within the Hillsborough River Watershed. The meteorologic data are presented within Attachment C.

2.5 Model Calibration Results

The EFDC model calibration included comparisons of simulation results to observed water levels, salinities and temperatures. Figure 2-5 presents the locations of the stations used in the model comparisons for the hydrodynamics and the water quality.

Figure 2-5. Hydrodynamic and Water Quality Data Station Locations

Two different data sets were used for the model comparisons. The first data set comes from Hillsborough Counties long-term monitoring program in which they maintain fixed station sampling at four locations within East Bay, McKay Bay, and the Palm River. These are Stations EPC-54, EPC-58, EPC-109, and EPC-110. EPC-58 is located within McKay Bay while EPC-109 is located upstream within the Palm River. EPC-110 is the most upstream station and is located immediately downstream of the S-160 structure. EPC-52 is located within Hillsborough Bay near the entrance to East Bay.

The other data set is the HBMP data collected by Tampa Bay Water. This data is collected using a stratified random sampling approach within specified strata. The green dots in Figure 2-5 represent the locations where samples have been collected under this program. The HBMP data are utilized to provide additional comparisons for the water quality calibration.

Water Levels

The hydrodynamic model calibration included comparison to observed water levels at the gage at the McKay Bay entrance. As this station was also used in the development of the boundary condition (interpolation between the St. Pete and McKay Bay entrance gage), the comparison provides an assessment of whether or not the amplification seen between the St. Pete and McKay Bay gages is seen moving up from the boundary at the entrance to Hillsborough Bay is simulated. No other data of water level time series were available in McKay Bay or the Palm River.

The observed and model simulated water levels for 2003 are shown in Figure 2-6 (plots for 2004 through 2007 are provided in Attachment D). The model results show excellent agreement between the simulated and observed water levels at the McKay Bay entrance. As shown in Table 2-2, the absolute mean error for this station is only 0.02 m (0.07 ft) and the relative RMSE is only 1 percent.

The water level boundary was modified to exclude extreme low tide conditions below -0.75 m (-2.5 ft) NAVD88. This was done to improve model stability and avoid model grid cells from drying out. As noted in Section 2.2, the model grid used a minimum depth of -1.1 m (-3.6 ft) NAVD88 to avoid grid cells from drying out. A lower minimum depth would have been required if the boundary water levels were not modified to remove extreme low values (i.e., a minimum depth of -2 m (-6.6 ft) would be necessary for the model grid). The minimum water level values removed from the record occurred infrequently and primarily as a result of meteorological conditions (i.e., wind and pressure effects on bay water levels). This boundary modification does not affect the critical conditions when lowest DO concentrations in McKay Bay occur.

Salinity

The salinity calibration included model comparisons to observed salinity at EPC Stations 52, 54, 58, and 109. These include comparisons to samples taken near the water surface and near the estuary bottom. An additional station (EPC station 110) was also available, but as this station is immediately adjacent to the upstream boundary condition, it was not deemed necessary for model calibration.

The observed and model simulated salinities for 2003 through 2007 are shown in Figure 2-7 (yearly plots are provided in Attachment D). As shown in Table 2-3, the model salinities are in relatively good agreement with the observed data. Mean Errors are on the order of 1 to 3 ppt with the model underpredicting salinities on average. Root Mean Squared errors (RMS) are between 2 and 4 ppt with percent errors ranging from 7% up to 14%. Overall the model appears to underpredict the levels of salinity in the system with a good portion of that error coming from the simulation of levels within Hillsborough Bay. If the error at the entrance to McKay Bay were at 0%, the error propagating into East Bay and through McKay Bay up to the Palm River would be near 7% at a maximum. One area where the model appears to miss some of the level of stratification is within the Palm River under large flow events, where the model responds both in the surface and bottom to the flows, while in the data some level of stratification remains. Overall the salinity calibrations provide confidence that the transport of mass within the hydrodynamic model (which is transferred to the WQ model) is reasonably accurate.

Temperature

Similar to salinity, the temperature calibration included model comparisons to observed temperatures at EPC Stations 52, 54, 58, and 109, including comparisons to samples taken near the water surface and near the estuary bottom.

The observed and model simulated temperatures are shown in Figure 2-8 for 2003 through 2007 for all stations (yearly plots are provided in Attachment D). The model results show overall good agreement between the simulated and observed temperatures at all four stations. The model reproduces the seasonal variation in temperature shown by the data. The simulation time series is at a much higher frequency (daily) than the observation data (monthly discrete samples), and therefore the simulation time series shows a wider range of variation than the observed data. As shown in Table 2-4, the relative RMSE errors are all at or less than 5% with the model slightly underpredicting the overall temperature (generally less than 1 degree).

Table 2-2. Summary water level statistics

Gage	Model				Observed				Mean error	Abs mean error	RMSE	Relative RMSE[1] (%)
	10th prc	median	mean	90th prc	10th prc	median	mean	90th prc				
NOS Station	-0.417	-0.020	-0.038	0.309	-0.442	-0.030	-0.050	0.312	0.01	0.02	0.04	1%

[1] Relative RMSE = RMSE / range of observations

Table 2-3. Summary salinity statistics

EPC Station	Model				Observed				Mean error	Abs mean error	RMSE	Relative RMSE (%)
	10th prc	median	mean	90th prc	10th prc	median	mean	90th prc				
52 surface	16.8	23.0	22.6	27.8	14.9	25.4	23.8	29.3	-1.2	2.2	2.8	9%
52 Bottom	18.5	23.7	23.6	28.7	20.4	25.7	25.4	29.6	-1.8	1.8	2.2	7%
54 surface	13.7	22.2	21.2	27.1	13.6	23.9	22.4	29.0	-1.2	2.4	2.9	9%
54 bottom	18.9	24.0	23.9	29.0	20.0	25.6	25.2	30.1	-1.3	1.9	2.3	7%
58 surface	10.2	20.5	19.0	25.6	12.9	23.5	21.6	27.9	-2.6	2.8	3.4	11%
58 bottom	17.6	23.2	22.9	28.1	19.5	25.4	24.8	29.4	-2.0	2.1	2.6	8%
109 surface	9.2	18.9	17.4	23.9	11.6	20.5	19.3	26.6	-1.9	3.0	3.8	14%
109 bottom	13.4	21.3	20.4	26.2	17.6	22.6	22.7	27.4	-2.3	2.9	4.0	14%

Table 2-4. Summary temperature statistics

EPC Station	Model				Observed				Mean error	Abs mean error	RMSE	Relative RMSE (%)
	10th prc	median	mean	90th prc	10th prc	median	mean	90th prc				
52 surface	17.9	25.8	25.2	31.2	18.0	26.3	25.5	31.6	-0.4	1.1	1.4	4%
52 Bottom	16.9	24.4	24.0	29.8	17.4	24.7	24.5	30.1	-0.5	1.0	1.2	4%
54 surface	16.2	24.1	23.8	30.2	17.1	25.0	24.0	29.5	-0.3	1.0	1.3	4%
54 bottom	16.9	24.5	23.8	29.9	17.1	24.9	24.0	30.3	-0.2	0.8	1.0	3%
58 surface	16.4	23.8	23.6	29.9	17.5	24.4	24.2	29.8	-0.6	1.1	1.5	5%
58 bottom	16.6	23.7	23.7	29.9	17.3	24.8	24.4	30.3	-0.7	1.0	1.3	4%
109 surface	16.1	23.2	23.2	29.5	16.5	25.4	23.9	29.4	-0.8	1.1	1.4	4%
109 bottom	16.7	23.4	23.7	29.9	16.9	25.3	24.4	30.5	-0.8	1.2	1.5	5%

Figure 2-6. Observed and simulated 2003 water levels

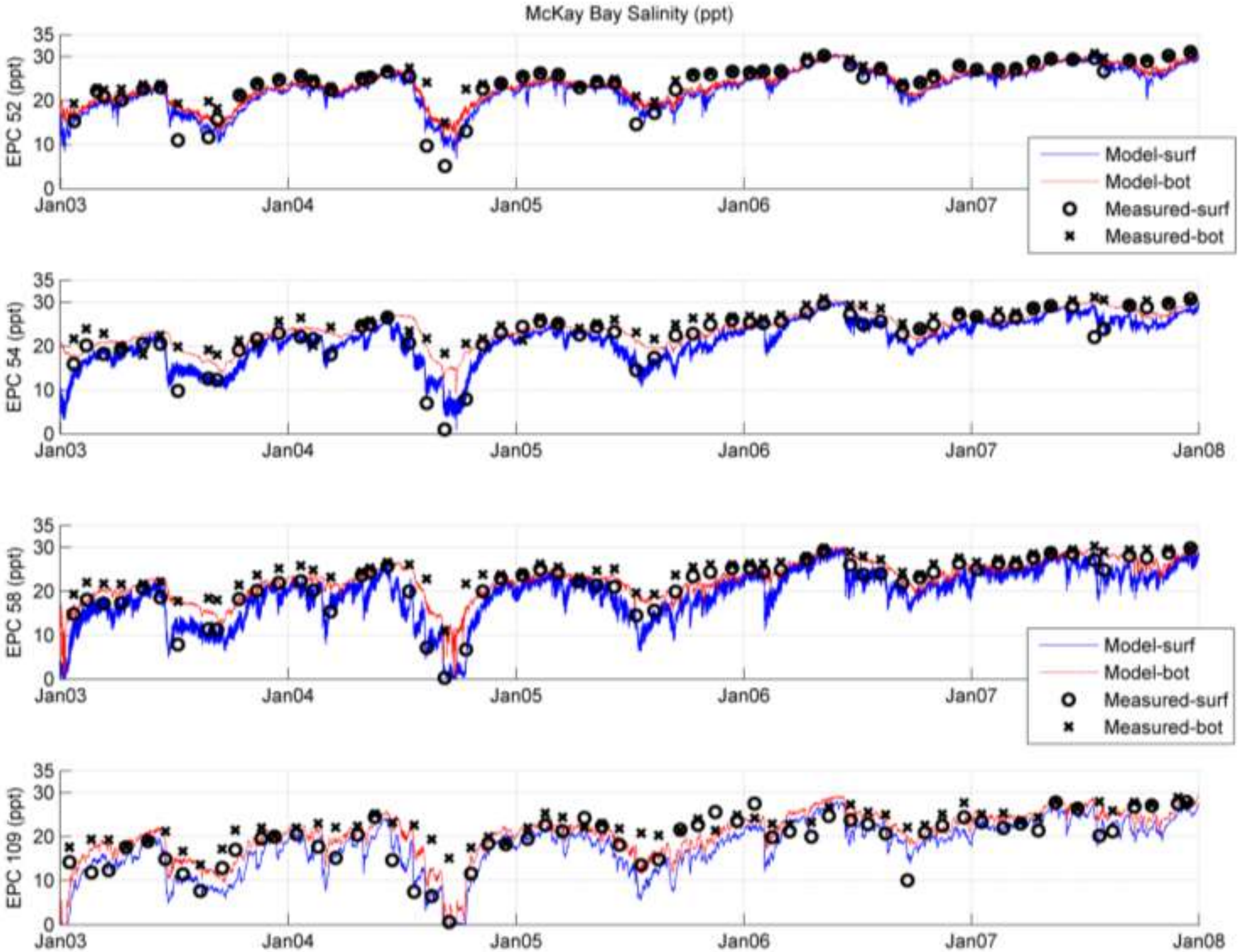


Figure 2-7. Observed and simulated salinities

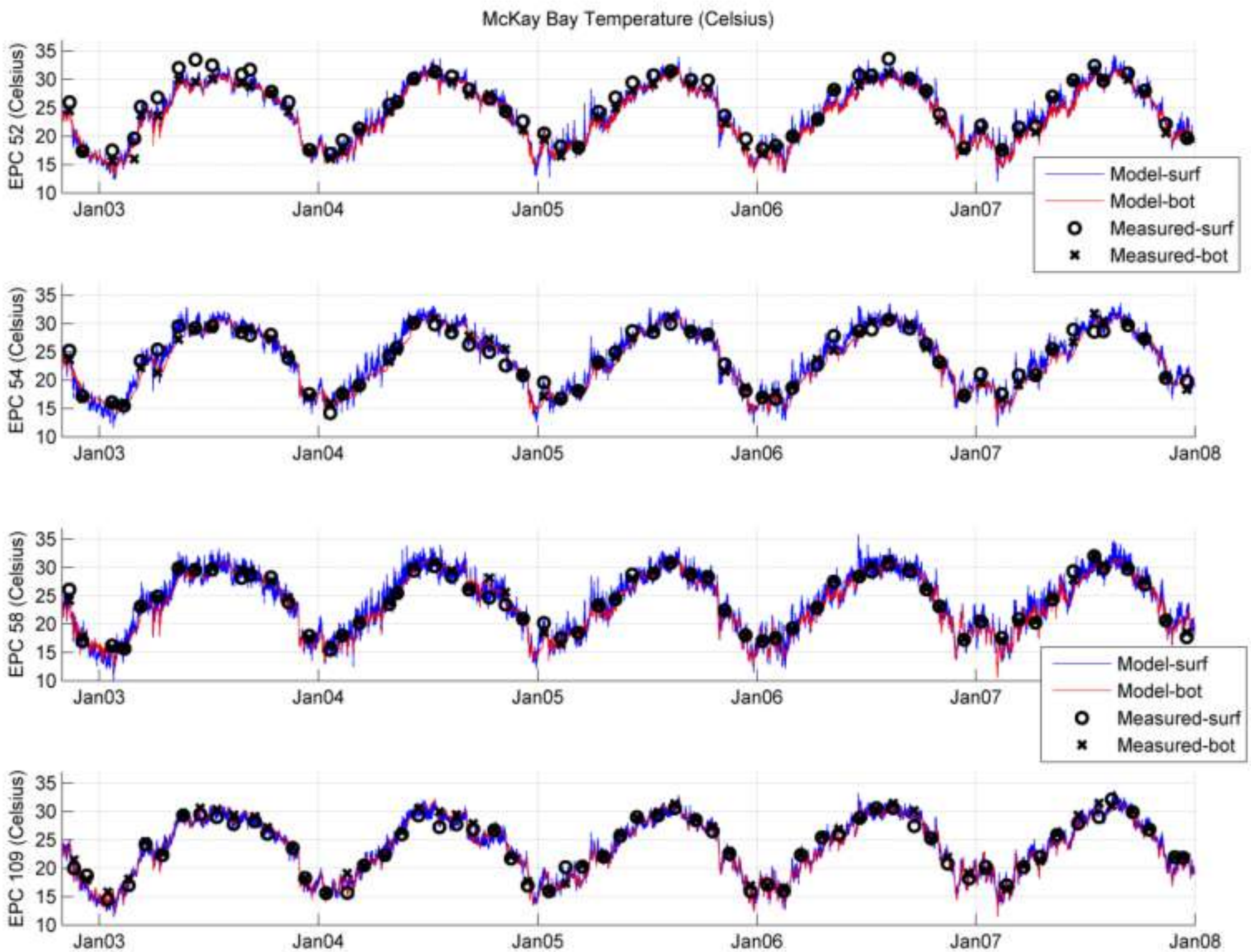


Figure 2-8. Observed and simulated temperatures

The model does slightly over predict temperature, in general (the mean error is about 0.5 degree C), but this error is small. Overall, the model is reasonably calibrated for temperature for the purpose of simulating McKay Bay water quality. Attachment D provides the yearly plots of simulated versus measured temperature to allow for a larger time scale to view the comparisons.

3.0 Water Quality Model Development

This section describes the water quality model configuration, inputs, and calibration results.

3.1 WASP Model Description and Configuration

The model used for this study is WASP version 7.5. This model was developed by the EPA and is freely available via download from its website. WASP has a long history of application to various problems. Numerous applications have been validated with field data, or verified by model experiments and reviewed by independent experts.

As mentioned previously, the WASP model utilizes the hydrodynamics, temperature, salinity and transport output from the EFDC model saved to a binary HYD linkage file. Within EFDC, the option exists to pass any increment of hydrodynamic data to WASP, i.e., at each time step of EFDC or at some alternate number of time steps greater than 1. This function is driven by the variable NTSMMT. Based on tests performed on the WASP model continuity, it was determined that at higher levels of NTSMMT, significant continuity errors were introduced. Therefore, for the simulations presented, the NTSMMT value was set to 1 with a time step of 60 seconds.

For this study, the nutrient enrichment, eutrophication, and DO depletion processes are simulated using WASP's EUTRO program. Several physical-chemical processes can affect the transport and interaction among nutrients, phytoplankton, carbonaceous material, and DO in the aquatic environment. Figure 3-1 presents principal kinetic interactions for the nutrient cycles and DO. The model was implemented with intermediate-level eutrophication kinetics to simulate growth and death of phytoplankton interacting with the nitrogen and phosphorus cycles and DO balance. Growth can be limited by the availability of inorganic nitrogen, inorganic phosphorus, and light.

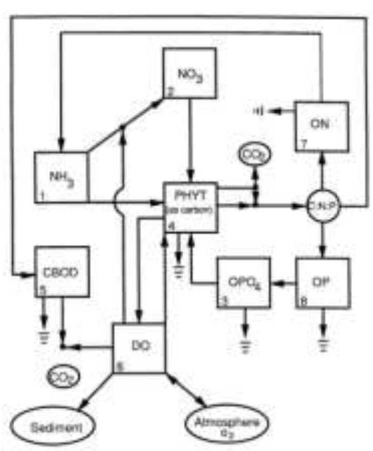


Figure 3-1. EUTRO State Variable Interactions (Wool et al., 2001)

3.2 Boundary Inputs and Coefficients

The WASP model set up requires input boundary loads or concentrations and input model coefficients. This model was set up to use observed concentrations from EPC Station 80 (located near the Hillsborough Bay entrance) to provide the input boundary concentrations at the model open boundary. Attachment B provides the concentration boundary conditions used for the open boundary based on the data from EPC Station 80.

The WASP model allows for a separate ASCII format nonpoint source load file (NPS file) to specify the input mass loading rates for the system variables. This method was used to specify not only the nonpoint source loadings, but it was also used to specify the inflow loads at S-160, the Alafia River and the Hillsborough River. The inflow concentration fields in the WASP model interface were not used to specify the tributary loads (in this case, using the NPS file is less cumbersome than specifying the river inflow concentrations manually in the interface).

For the open tidal boundary, time series of concentrations were input based upon data from EPC station 80. The time series utilized are presented in Attachment B.

For the three primary tributary inputs, the loads were derived based upon available data, i.e. measured concentrations in the vicinity of the gaged flows. To derive the daily loads, the daily measured flows are multiplied by the measured concentration data (on days where measurements are available) or by interpolated (between the measured points) concentrations (on days where no measurements are available). Attachment E provides the time series of loads that match up with the input locations outlined in Table 2-1 and plotted on Figure 2-2.

The ungaged loads come from work conducted by Janicki Environmental and HSW to define loads from 1993 to 2007 for the Tampa Bay Estuary Program (Poe et al., 2005; Janicki Environmental, 2008). These loads have been evaluated and approved by FDEP and EPA through the Tampa Bay Reasonable Assurance Program. Attachment E provides the time series of the ungaged loads.

The meteorologic data used for the input are presented within Attachment C.

Once the boundary conditions were prescribed, the model was run through numerous iterations with varying model input coefficients in order to achieve the best overall calibration possible with specific focus on the area of interest (McKay Bay). The final model coefficients utilized to develop the calibration presented in Section 3.3 are listed in Table 3-1.

The SOD varies spatially in the model. In general, the SOD distribution was selected based on the depth characteristics (very shallow areas exposed to high light intensity have low SOD) and expected depositional areas (e.g., the dredged port navigation channel in East Bay is a deep area that is a depositional environment that will exhibit high SOD). The SOD values were then adjusted as part of the calibration process. The resulting SOD distribution is as follows:

- Hillsborough Bay: 0.5 $g/m^2/d$

- Tampa Bypass Canal: 1.0 g/m^2/d
- McKay Bay channel: 1.1 g/m^2/d
- McKay Bay intertidal and shallow flats: 0 g/m^2/d
- East Bay: 3.0 g/m^2/d

Table 3-1. WASP model constants		
Constant	Used	Model Value
Global Constants		
Atmospheric Deposition of Nitrate (mg/m^2-day)	Yes	2
Atmospheric Deposition of Ammonia (mg/m^2-day)	No	0
Atmospheric Deposition of Orthophosphate (mg/m^2-day)	No	0
Atmospheric Deposition of BOD1 (Ultimate) (mg/m^2-day)	No	0
Atmospheric Deposition of Organic Nitrogen (mg/m^2-day)	No	0
Atmospheric Deposition of Organic Phosphorus (mg/m^2-day)	No	0
Ammonia		
Nitrification Rate Constant @20°C (per day)	Yes	0.08
Nitrification Temperature Coefficient	Yes	1.08
Half Saturation Constant for Nitrification Oxygen Limit (mg O/L)	Yes	2
Minimum Temperature for Nitrification Reaction, °C	No	0
Ammonia Partition Coefficient to Water Column Solids, L/kg	No	0
Ammonia Partition Coefficient to Benthic Solids, L/kg	No	0
Nitrate		
Denitrification Rate Constant @20°C (per day)	Yes	0.1
Denitrification Temperature Coefficient	Yes	1.08
Half Saturation Constant for Denitrification Oxygen Limit (mg O/L)	Yes	0.1
Organic Nitrogen		
Dissolved Organic Nitrogen Mineralization Rate Constant @20°C (per day)	Yes	0.07
Dissolved Organic Nitrogen Mineralization Temperature Coefficient	Yes	1.08
Organic Nitrogen Decay Rate Constant in Sediments @20°C (per day)	No	0.03
Organic Nitrogen Decay in Sediment Temperature Coefficient	No	1.07
Fraction of Phytoplankton Death Recycled to Organic Nitrogen	Yes	0.5
Orthophosphate		
Orthophosphate Partition Coefficient to Water Column Solids, L/kg	No	0
Orthophosphate Partition Coefficient to Benthic Solids, L/kg	No	0
Organic Phosphorus		
Mineralization Rate Constant for Dissolved Organic P @20°C (per day)	Yes	0.05
Dissolved Organic Phosphorus Mineralization Temperature Coefficient	Yes	1.07
Organic Phosphorus Decay Rate Constant in Sediments @20°C (per day)	No	0
Organic Phosphorus Decay in Sediments Temperature Coefficient	No	0
Fraction of Phytoplankton Death Recycled to Organic Phosphorus	Yes	0.1

Table 3-1. WASP model constants		
Constant	Used	Model Value
Phytoplankton		
Phytoplankton Maximum Growth Rate Constant @20°C (per day)	Yes	2
Phytoplankton Growth Temperature Coefficient	Yes	1.07
Include Algal Self Shading Light Extinction in Steele (0=Yes, 1=No)	No	0
Exponent for Self Shading (Mult * TCHLA^Exp)	No	0
Multiplier for Self Shading (Mult * TCHLA^Exp)	No	0
Phytoplankton Self Shading Extinction (Dick Smith Formulation)	No	0
Phytoplankton Carbon to Chlorophyll Ratio	Yes	20
Phytoplankton Half-Saturation Constant for Nitrogen Uptake (mg N/L)	Yes	0.02
Phytoplankton Half-Saturation Constant for Phosphorus Uptake (mg P/L)	Yes	0.001
Phytoplankton Endogenous Respiration Rate Constant @20°C (per day)	Yes	0.15
Phytoplankton Respiration Temperature Coefficient	Yes	1.08
Phytoplankton Death Rate Constant (Non-Zooplankton Predation) (per day)	Yes	0.02
Phytoplankton Zooplankton Grazing Rate Constant (per day)	No	0
Nutrient Limitation Option	No	0
Phytoplankton Decay Rate Constant in Sediments (per day)	No	0
Phytoplankton Temperature Coefficient for Sediment Decay	No	0
Phytoplankton Phosphorus to Carbon Ratio	Yes	0.07
Phytoplankton Nitrogen to Carbon Ratio	Yes	0.3
Phytoplankton Half-Sat. for Recycle of Nitrogen and Phosphorus (mg Phyt C/L)	Yes	1
Light		
Percent Light to Define Photic Zone	No	0
Light Option (1 uses input light; 2 uses calculated diel light)	Yes	1
Phytoplankton Maximum Quantum Yield Constant	Yes	720
Phytoplankton Optimal Light Saturation	Yes	200
Background Light Extinction Multiplier	Yes	1
Detritus & Solids Light Extinction Multiplier	No	0
DOC Light Extinction Multiplier	Yes	0.35
DOC(1) Light Extinction Multiplier	No	0
DOC(2) Light Extinction Multiplier	No	0
DOC(3) Light Extinction Multiplier	No	0
Dissolved Oxygen		
Waterbody Type Used for Wind Driven Reaeration Rate	Yes	2
Calc Reaeration Option (0=Covar, 1=O'Connor, 2=Owens, 3=Churchill, 4=Tsivoglou)	Yes	0
Global Reaeration Rate Constant @ 20°C (per day)	No	0
Elevation above Sea Level (meters) used for DO Saturation	Yes	0
Reaeration Option (Sums Wind and Hydraulic Ka)	No	0
Minimum Reaeration Rate, per day	No	0
Theta -- Reaeration Temperature Correction	Yes	1.024
Oxygen to Carbon Stoichiometric Ratio	Yes	2.67
Use (1 - On, 0 - Off) Total Depth of Vertical Segments in Reaeration Calculation	No	0
Light Threshold at Bottom to Inhibit SOD (ly/Day)	Yes	35

Table 3-1. WASP model constants		
Constant	Used	Model Value
CBOD		
BOD (1) Decay Rate Constant @20°C (per day)	Yes	0.04
BOD (1) Decay Rate Temperature Correction Coefficient	Yes	1.047
BOD (1) Decay Rate Constant in Sediments @20°C (per day)	No	0
BOD (1) Decay Rate in Sediments Temperature Correction Coefficient	No	0
BOD (1) Half Saturation Oxygen Limit (mg O/L)	Yes	0.5
Fraction of Detritus Dissolution to BOD (1)	Yes	1
Fraction of BOD (1) Carbon Source for Denitrification	Yes	0.1
Detritus		
Detritus Dissolution Rate (1/day)	No	0
Temperature Correction for detritus dissolution	No	0
SOD		
SOD Temperature Correction Coefficient	Yes	1.09

3.3 Model Calibration Results

The model calibration results for TN, TP, nutrient species, BOD, chlorophyll-a, and dissolved oxygen at EPC Station 58 (McKay Bay) are shown in Figures 3-2 through 3-19. The model calibration results for EPC Stations 52 (Hillsborough Bay), 54 (East Bay), and 109 (Palm River), and the HNTB data are included in Attachment F. The data are presented as raw time series comparisons as well as annual average comparisons. For the annual averages, only simulation data from the day the measurements used in the average are utilized to calculate the simulated annual averages.

The time series comparison plots show the time series of semidiurnal output from the model and discrete EPC monthly sampling data. The plots also include comparison of annual mean concentrations. For CBOD, the measured data was converted to an ultimate CBOD (CBODu) using a multiplier (i.e., the f-ratio) of 5.42 based on the oxidation rate used in the model (0.04 day^{1}).

For the calibration the key areas of interest are McKay Bay and the Palm River, but the model simulated all of Hillsborough Bay in order to avoid potential boundary interference issues. Therefore the first step in a calibration discussion is to identify how the model simulations are performing at the entrance to the East Bay/McKay Bay system, specifically in regard to our key causative parameters, nitrogen, phosphorus, and BOD. This is because errors in this boundary will propagate into the system and create errors in our simulation within McKay Bay. The first series of plots in Attachment F present the results from EPC Station 52 at the entrance (see Figure 2-5). For TN the results show good agreement in the overall magnitude and patterns in the data. At times there are some fairly high concentrations simulated in the Bay, especially in 2004 and 2006. The data do show in 2004 that the high levels were measured, but the highest of those in 2006 are not seen in the data. Examination of the species shows that the Organic Nitrogen results are similar which is to be expected as the majority of the nitrogen (nearly 80 to

90 percent) is Organic. For the ammonia, the simulations do not show some of infrequent higher events seen, but do capture the overall level. For the nitrate-nitrite, the model seems high in the initial years but seems to balance out in the later years. This is mostly a function of some significant nitrate-nitrite loads coming from the point sources in the area. The loads are all assumed to reach the bay without any losses, this may not be fully accurate. The overall patterns and magnitude of the Organic Phosphorus and the PO4 are reasonable. As the system is nitrogen limited the phosphorus result are less significant. For the BOD the model under predicts the overall levels especially in the latter years. For the surface and bottom DO the overall patterns and levels are reasonable, although the surface values in the model are low.

Finally, Chl a levels and patterns are reasonable although some of the higher values are not simulated.

The second series of plots in Attachment F present the results from EPC Station 54 which is within East Bay. For TN the key issue is that there are two periods where the model significantly over predicts the TN levels in 2004 and 2006. This comes primarily from overprediction of the Organic Nitrogen levels. These results are higher than those seen at Station 52 indicating a local source as the cause, the data do not reflect this condition. Unlike Station 52, the results for the BOD show the model predicting levels similar to those measured although at times the results are high. For the surface and bottom DO the overall patterns and magnitudes are reasonably simulated although the model misses some lower DO values in 2003, 2004, and 2005. The Chl a levels seem reasonable, although in 2007 at the time of one of the overpredictions of TN and Organic Nitrogen, the Chl a simulations are high.

Figures 3-2 through 3-19 present the results at the key station EPC-58 in McKay Bay. For the TN and the nitrogen species, the model is overall capturing the magnitudes and patterns reasonably well at this station. While the nitrate-nitrite results seem high when looking at the raw data plots, the annual averages appear to indicate that this is not the case. For the BOD simulations, while the raw data plots would indicate the model is simulating similar levels, the annual averages indicate the model is significantly under predicting the BOD levels in the system. For the surface and bottom DO the model is capturing the magnitude and patterns very well. Given what appears to be an under prediction of the BOD levels, this indicates that SOD and local hydrology play a more significant role in the DO levels. Finally the magnitude and patterns for the Chl a are captured well by the model.

The third series in Attachment F presents the results at EPC-109. The simulations show reasonable predictions of the TN and TP levels although not as good as that seen in McKay Bay. One point to note is that in 2003 and 2004 the data show elevated TN levels at 109 on an annual average basis in comparison to EPC-58 down in McKay Bay. In 2005, 2006, and 2007 this is not the case. This pattern is not seen in the model simulations and this reflects in the dissolved oxygen and Chl a simulations.

In addition to the EPC data, the model results were also compared to the HBMP monitoring data for the McKay Bay stratum (this segment is labeled as MBC in the database). The HBMP monitoring uses a stratified random sampling approach which samples within a selected stratum. The MBC data comes from the McKay Bay area sampled. The HBMP measurements include many spatial locations within each of the strata. In order to compare the water quality data to the model results, the HBMP water quality data were averaged within the strata and compared to the average of all 39 model grid cells within the McKay Bay stratum (for the model surface layer). The data were also time averaged using a geometric mean. The final series in Attachment F present the HBMP comparisons. The HBMP data do not show the same pattern as that seen in the EPC data for TN and Chl a. For the years 2005 to 2007 the HNTB data show higher TN levels and lower Chl a levels. As the model was primarily calibrated to the EPC data, this pattern is not seen in the model.

Finally, for the dissolved oxygen, the determination of compliance is based upon the percent of time the system is below the threshold of 4.0 mg/L (the marine DO standard). By combining the HBMP data along with the EPC data, there are a significant number of samples for analyses. Using these data, determinations were made on the percent of DO values below the 4.0 mg/L threshold. The model results were similarly processed and the results of the comparisons are presented in Table 3-2. The results show that the general range of percentages in McKay Bay and the Palm River are consistent between the measured data and the model simulations. Specifically the relative differences between the Palm River and McKay Bay are simulated well. Based upon this comparison the model is reasonably simulating this aspect of the system.

Table 3-2. Comparison of simulated versus measured percent DO below 4.0 mg/L in McKay Bay and Palm River.

Area			Year				
			2003	2004	2005	2006	2007
McKay Bay	Data	Freq	1338	1284	1250	1286	1312
		# < 4mg/l	204	218	177	107	147
		% < 4mg/l	15.2%	17.0%	14.2%	8.3%	11.2%
	Model	Freq	1423500	1427868	1423500	1422096	1422252
		# < 4mg/l	212913	233048	103164	166058	193958
		% < 4mg/l	15.0%	16.3%	7.2%	11.7%	13.6%
Palm River	Data	Freq	1570	1571	1701	1576	1601
		# < 4mg/l	817	741	808	609	590
		% < 4mg/l	52.0%	47.2%	47.5%	38.6%	36.9%
	Model	Freq	328500	329508	328500	328176	328212
		# < 4mg/l	161300	155666	138382	135641	152161
		% < 4mg/l	49.1%	47.2%	42.1%	41.3%	46.4%

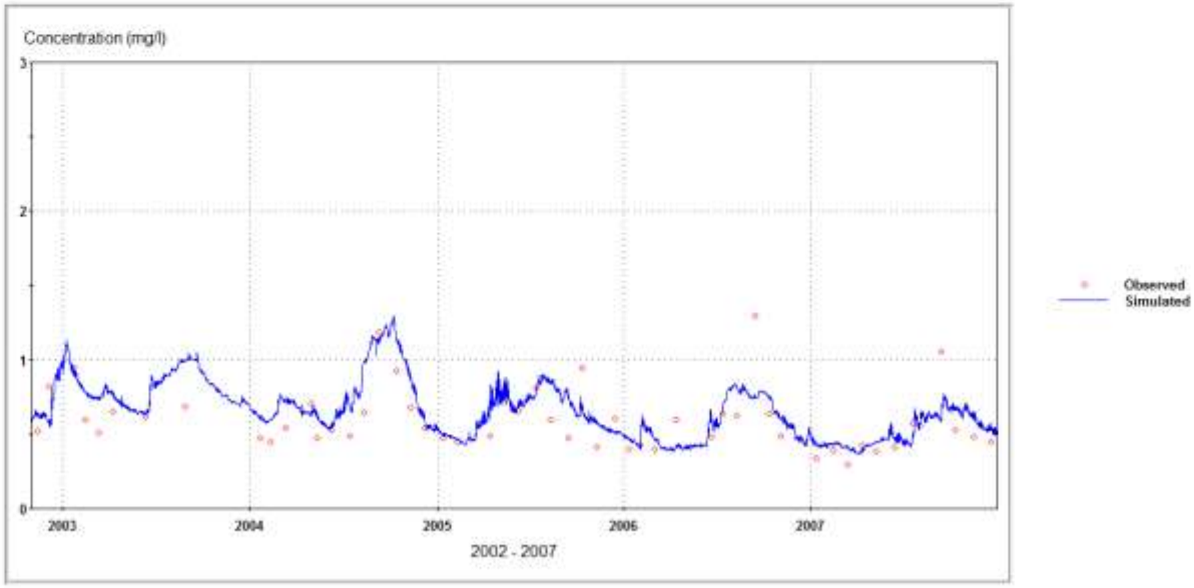


Figure 3-2. Simulated and observed TN at EPC 58

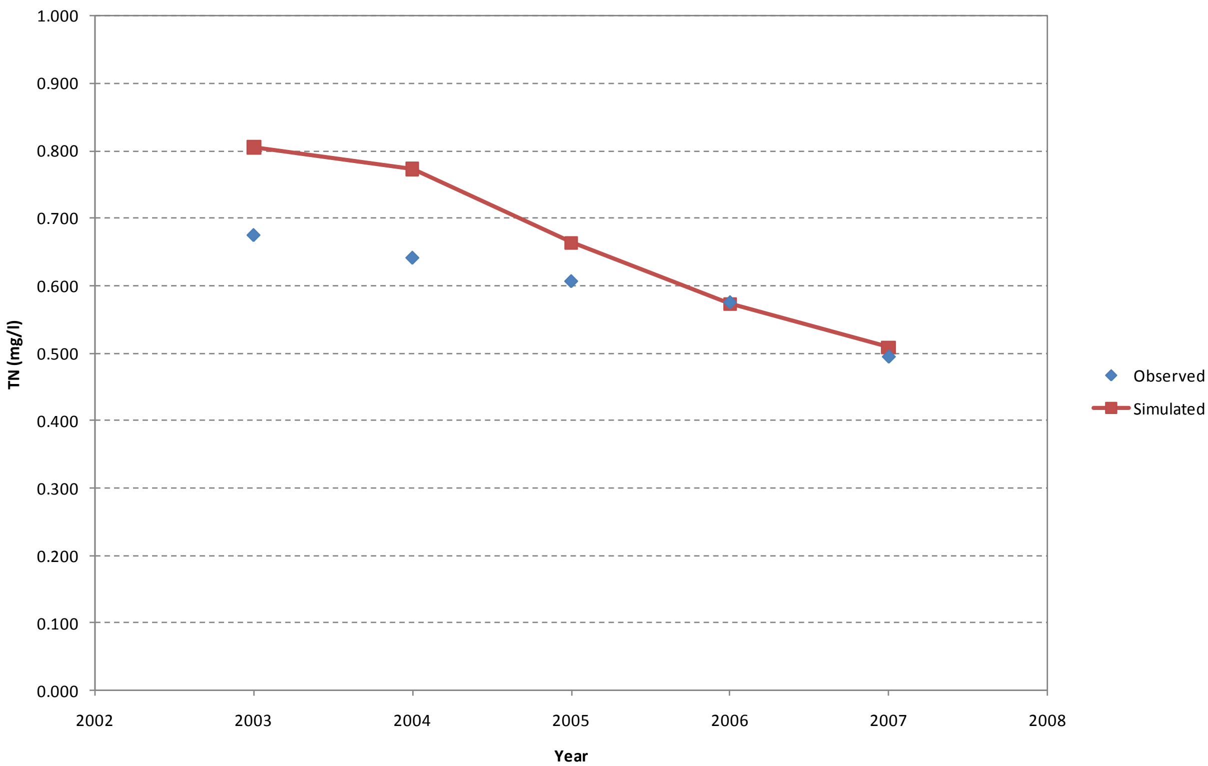


Figure 3-3. Simulated and observed annual mean TN at EPC 58

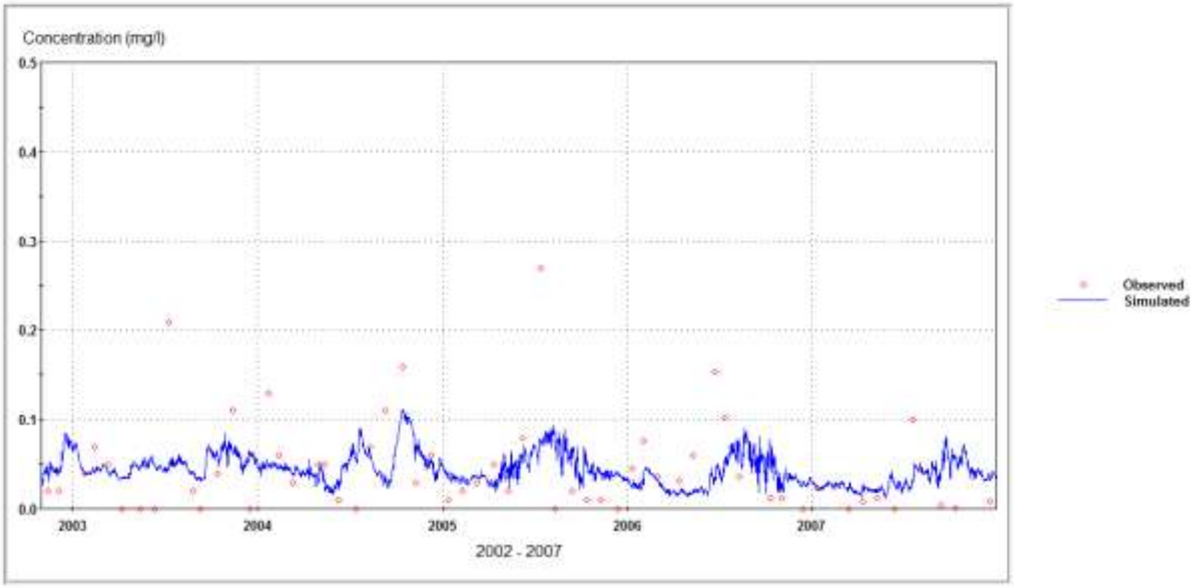


Figure 3-4. Simulated and observed NH3 at EPC 58

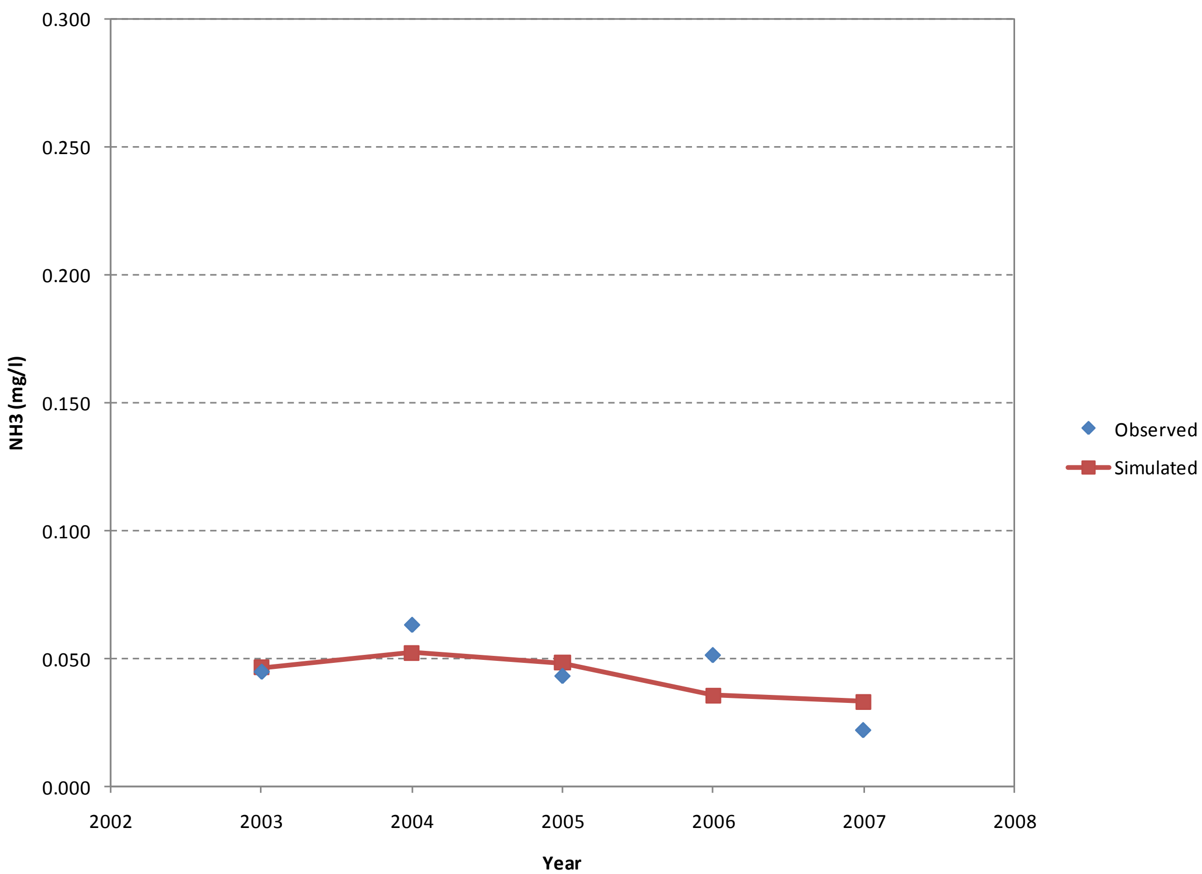


Figure 3-5. Simulated and observed annual mean NH3 at EPC 58

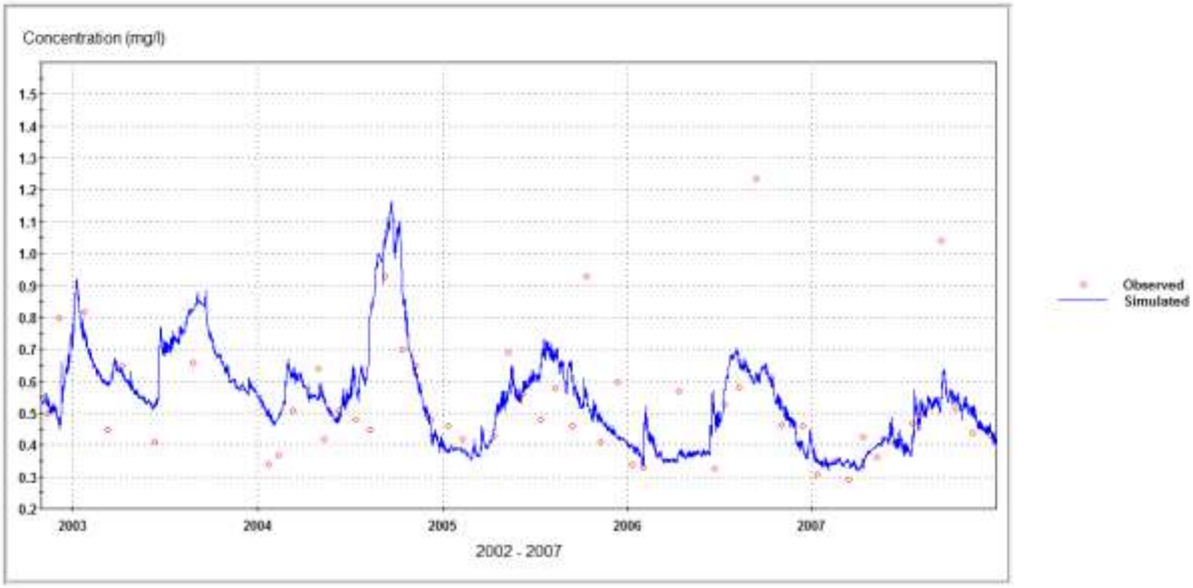


Figure 3-6. Simulated and observed Organic Nitrogen at EPC 58

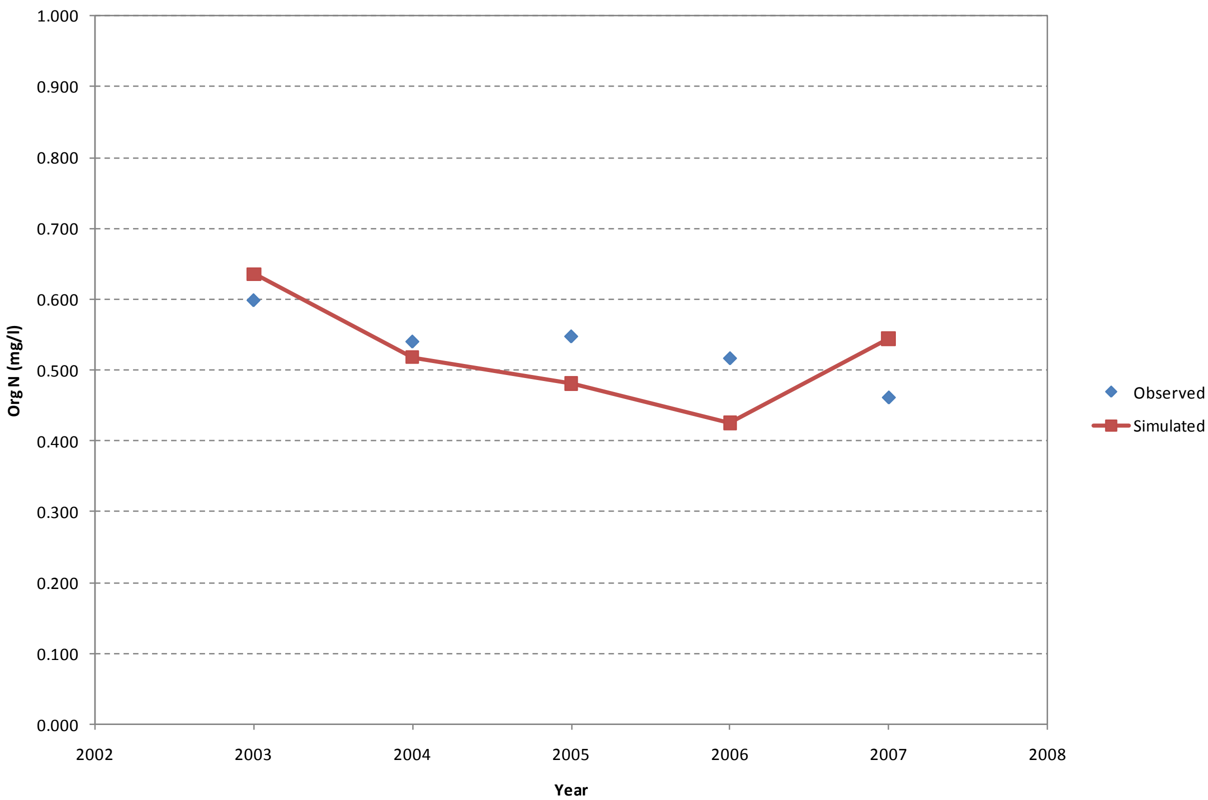


Figure 3-7. Simulated and observed annual mean Organic Nitrogen at EPC 58

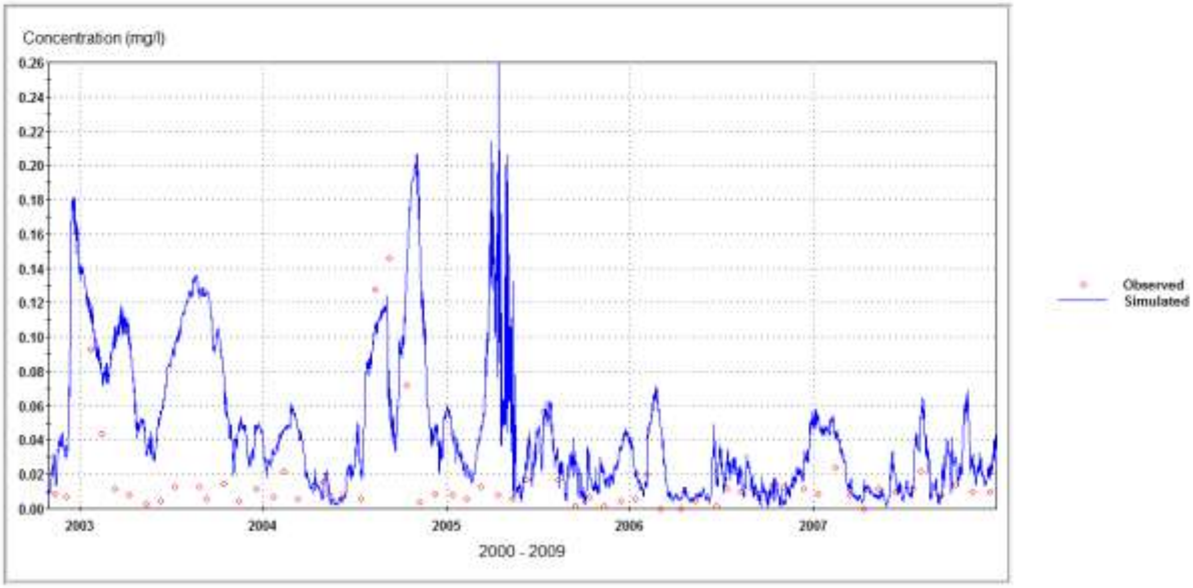


Figure 3-8. Simulated and observed NO2/NO3 at EPC 58

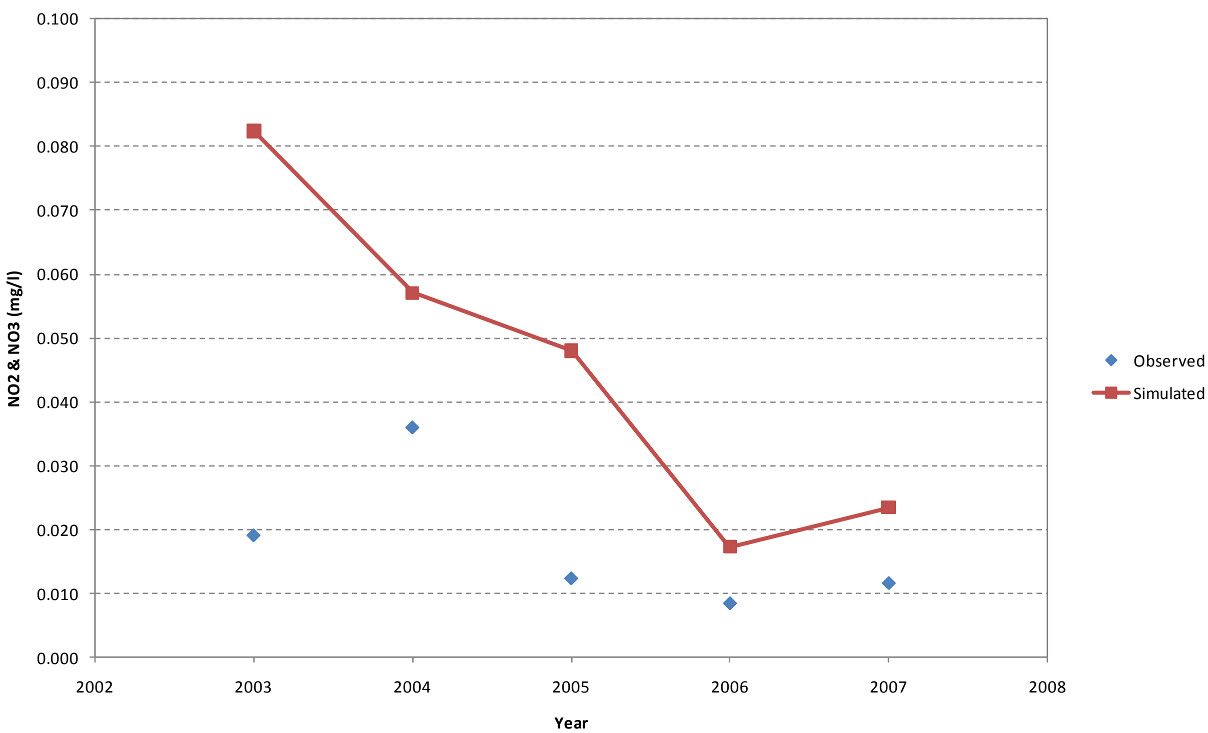


Figure 3-9. Simulated and observed annual mean NO2/NO3 at EPC 58

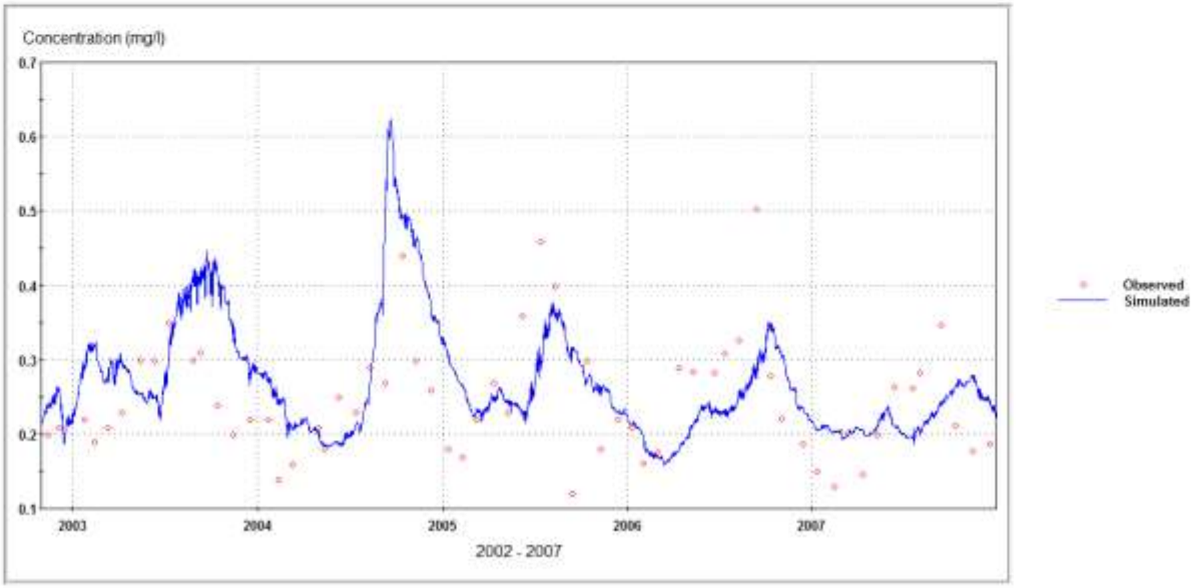


Figure 3-10. Simulated and observed TP at EPC 58

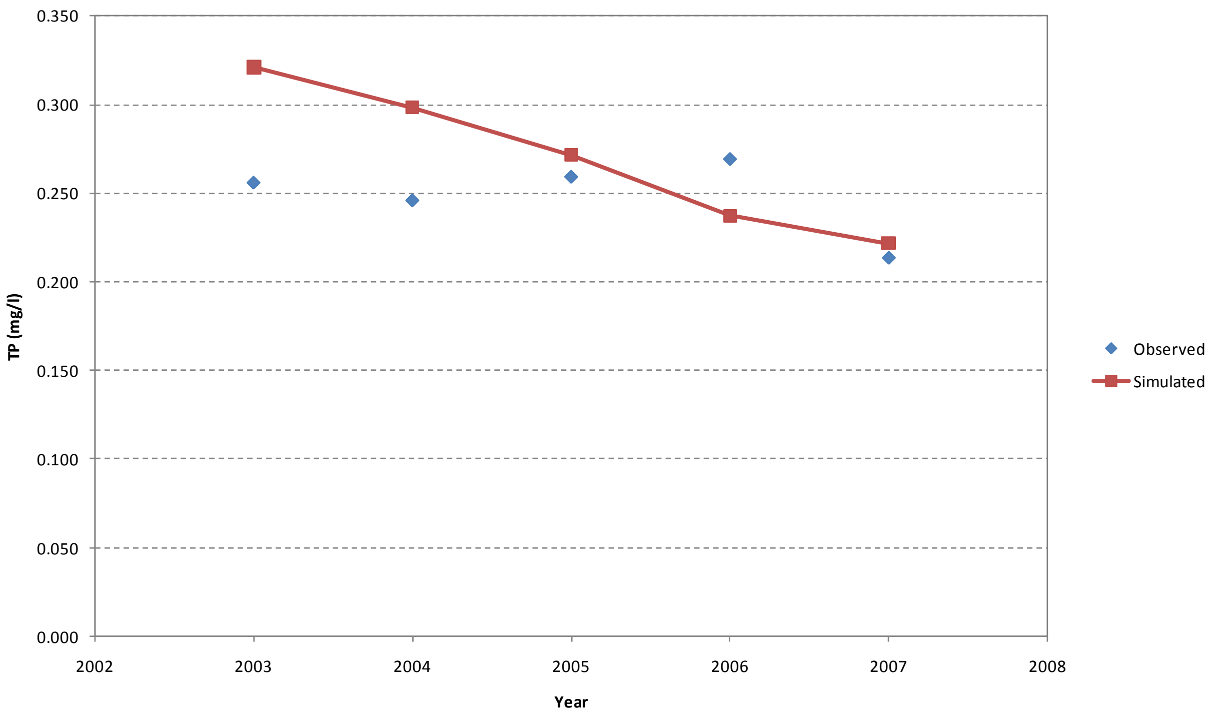


Figure 3-11. Simulated and observed annual mean TP at EPC 58

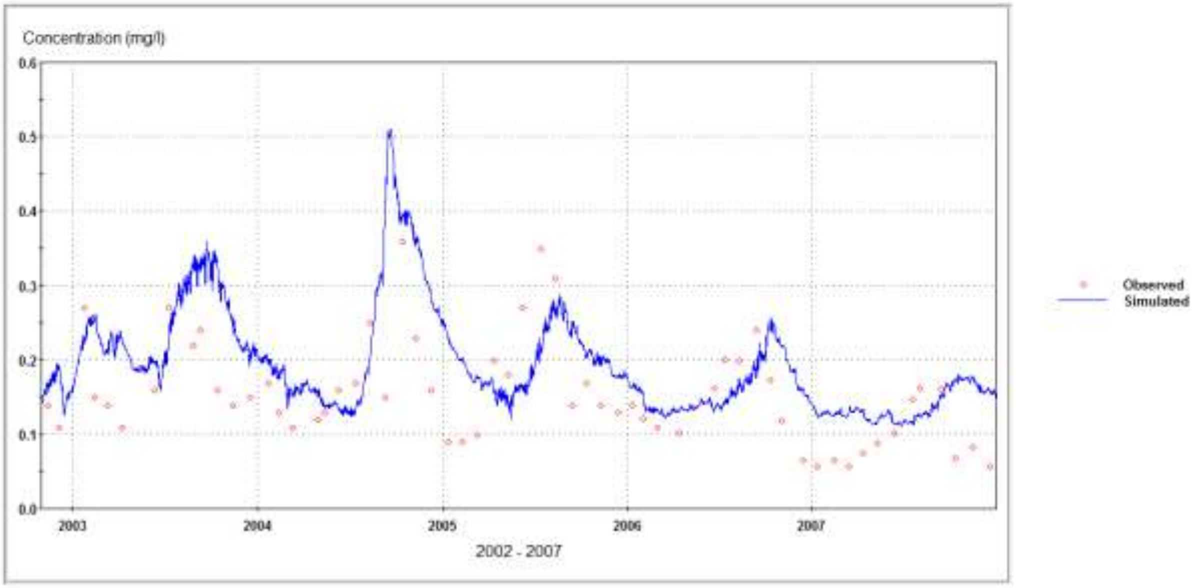


Figure 3-12. Simulated and observed PO4 at EPC 58

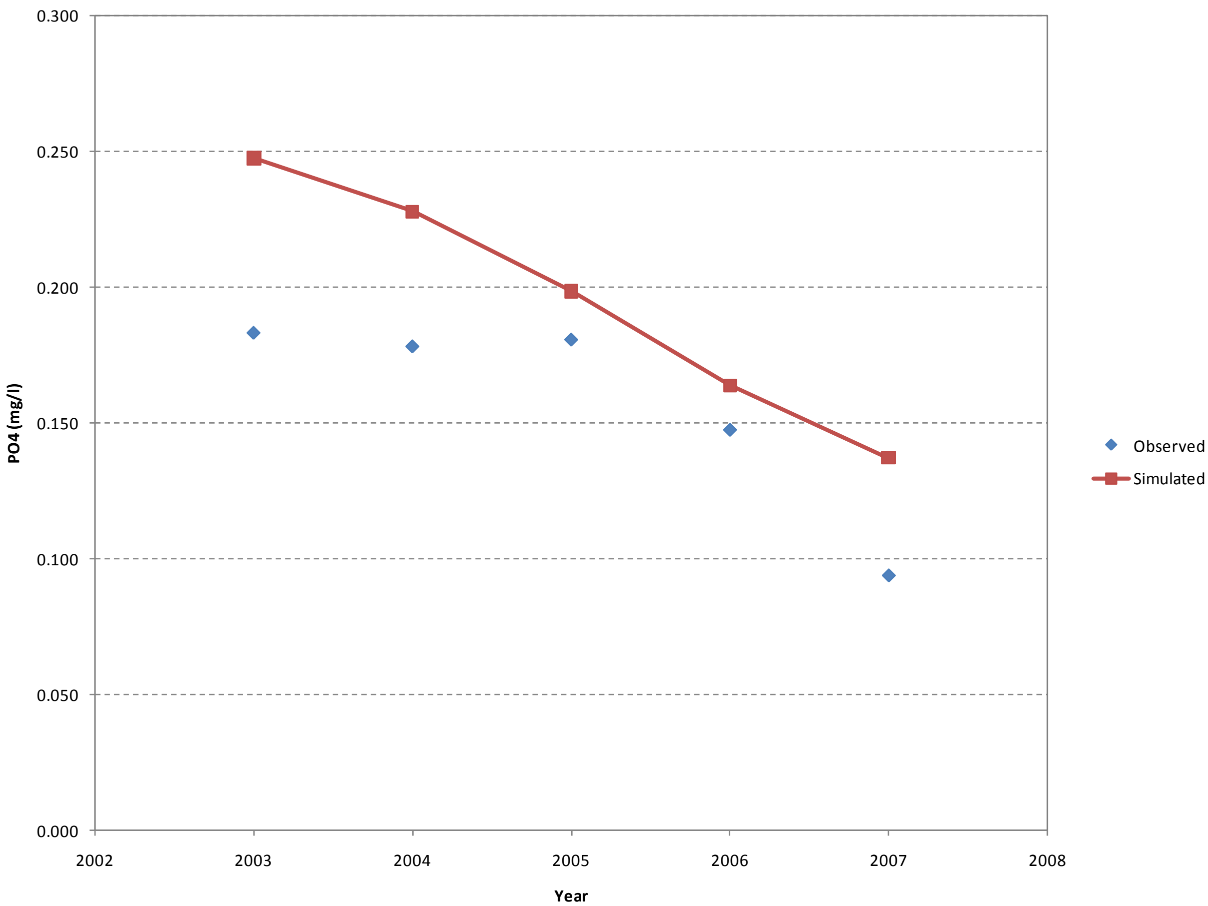


Figure 3-13. Simulated and observed annual mean PO4 at EPC 58

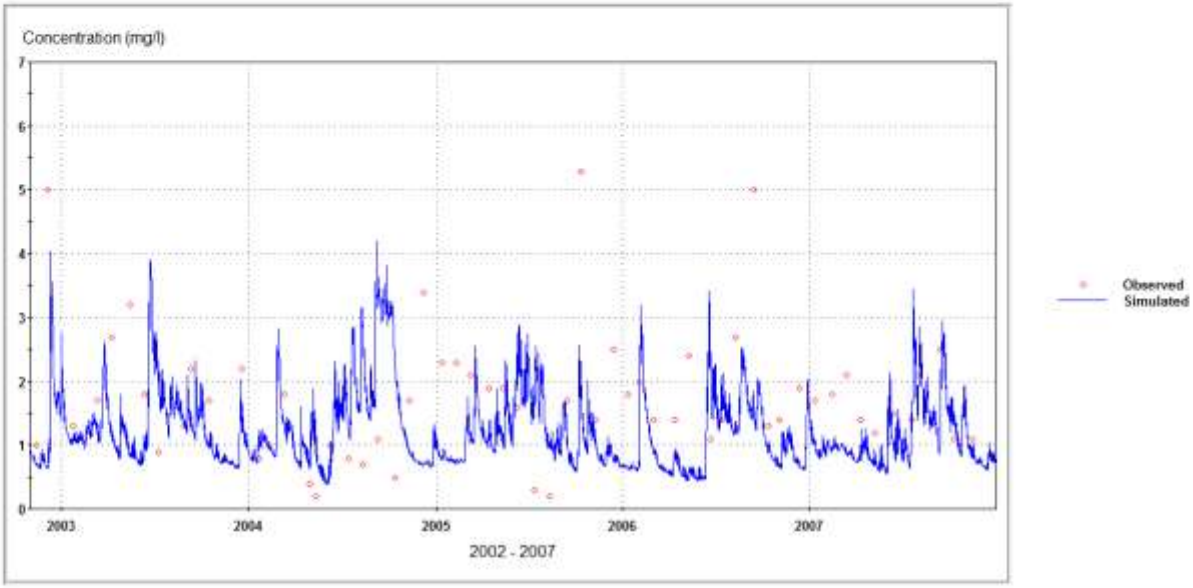


Figure 3-14. Simulated and observed BOD5 at EPC 58

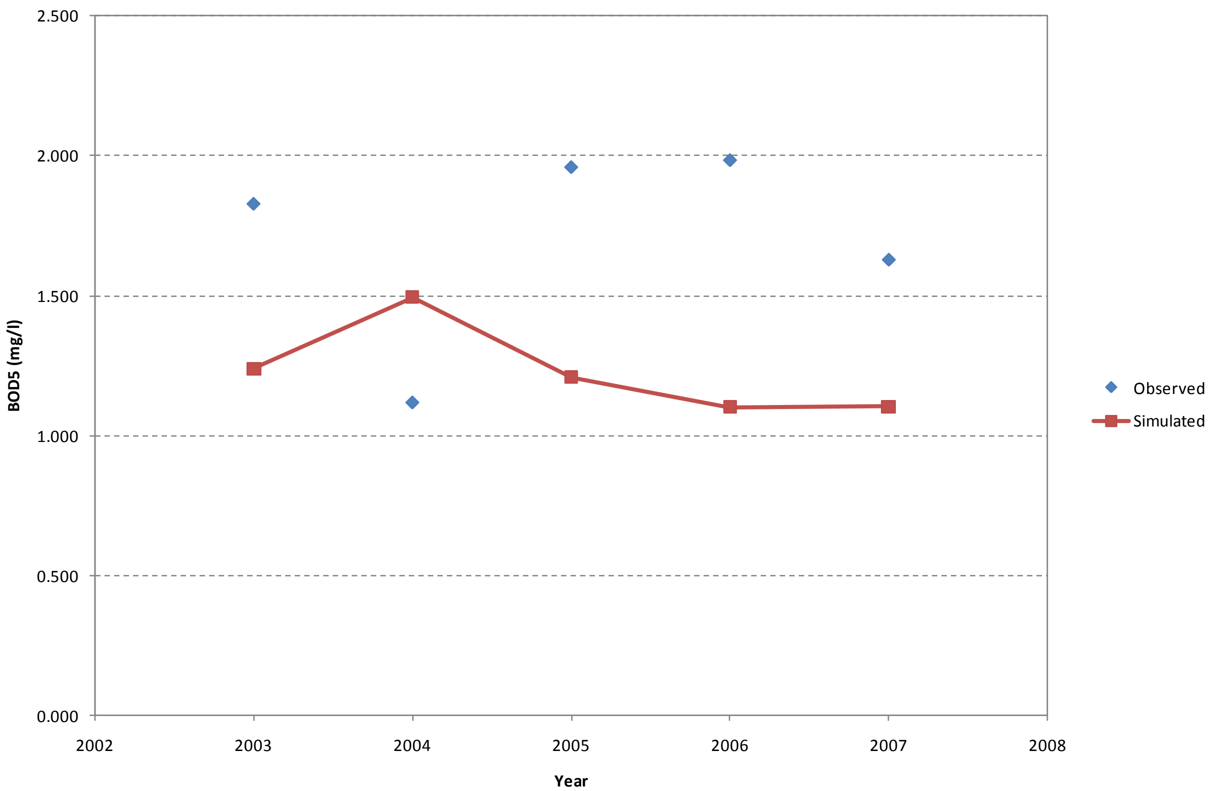


Figure 3-15. Simulated and observed annual mean BOD5 at EPC 58

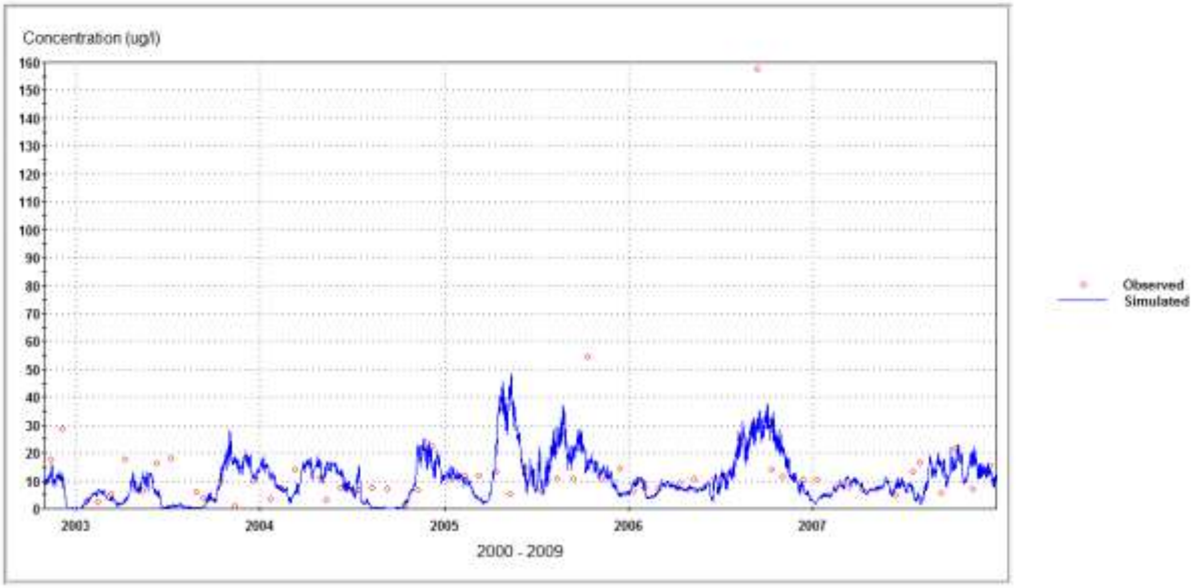


Figure 3-16. Simulated and observed Chlorophyll-a at EPC 58

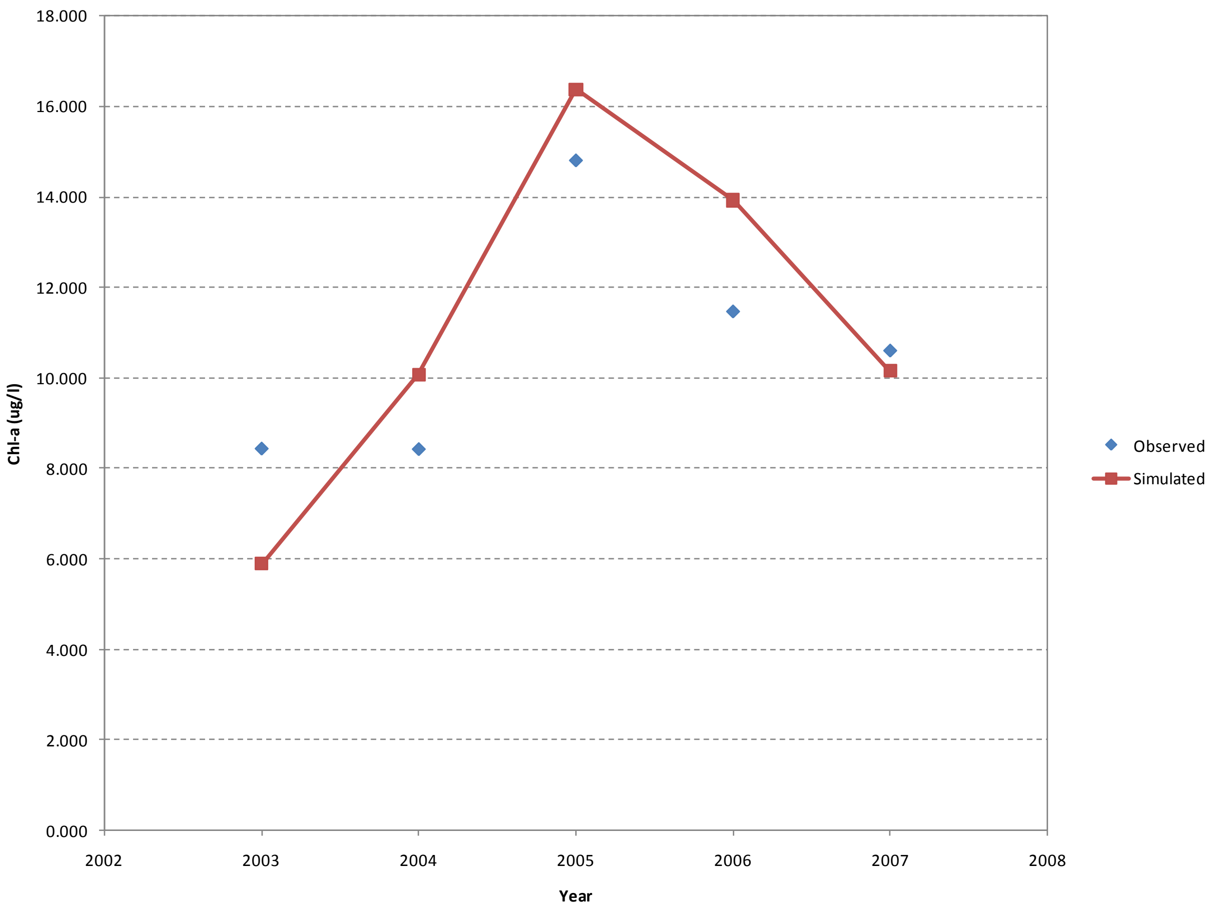


Figure 3-17. Simulated and observed annual mean Chlorophyll-a at EPC 58

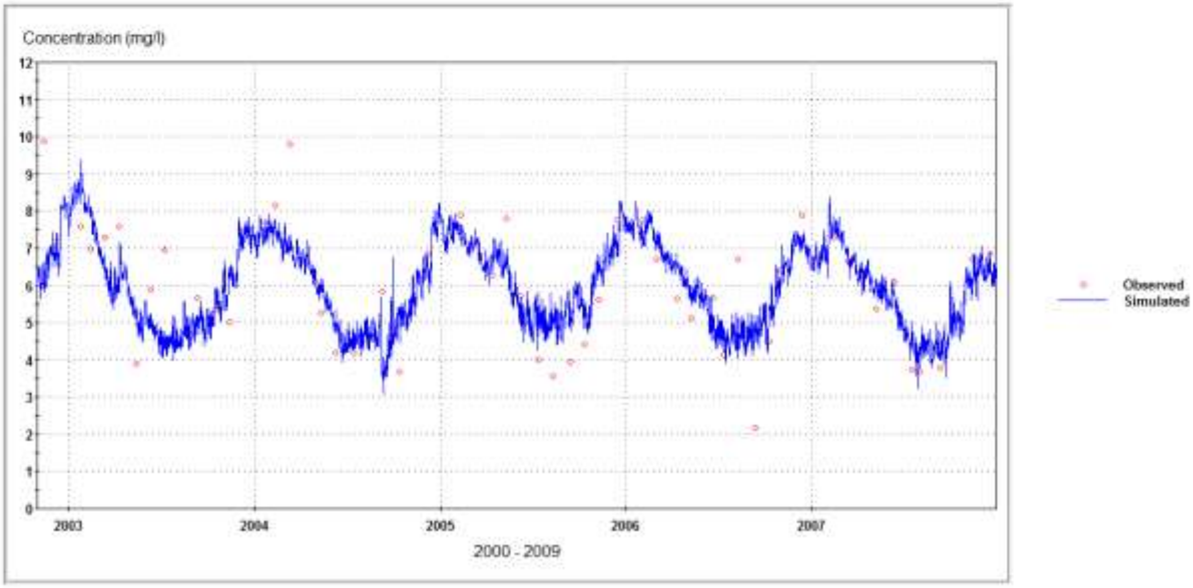
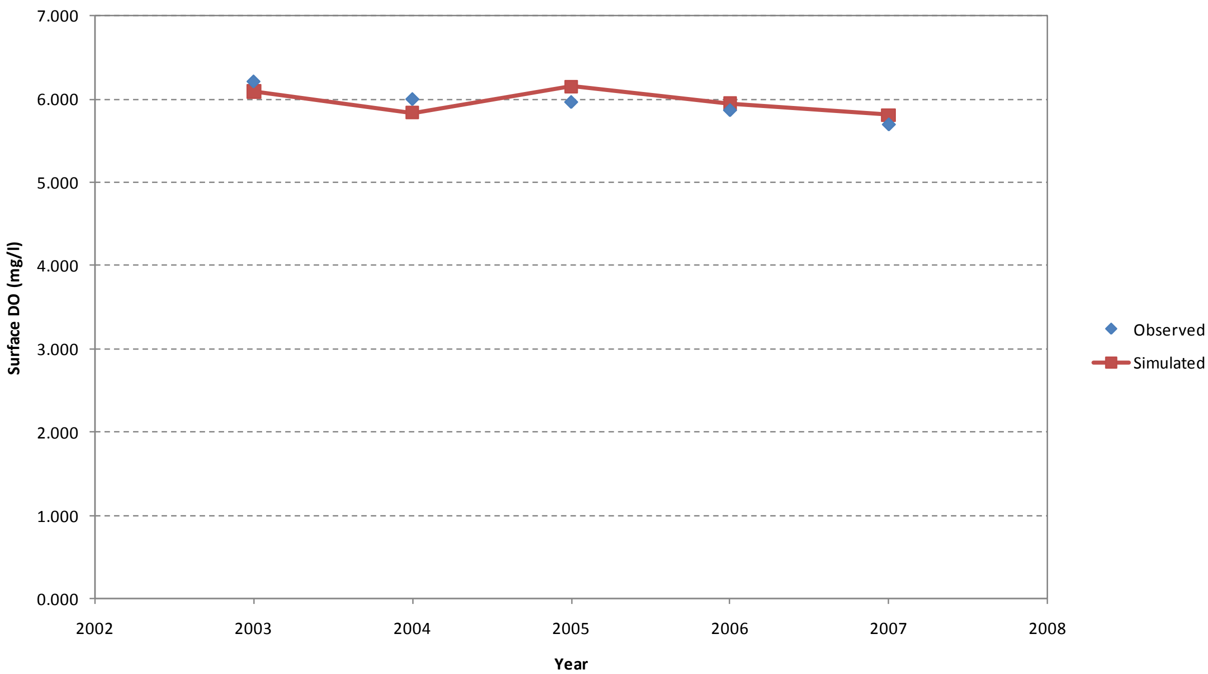
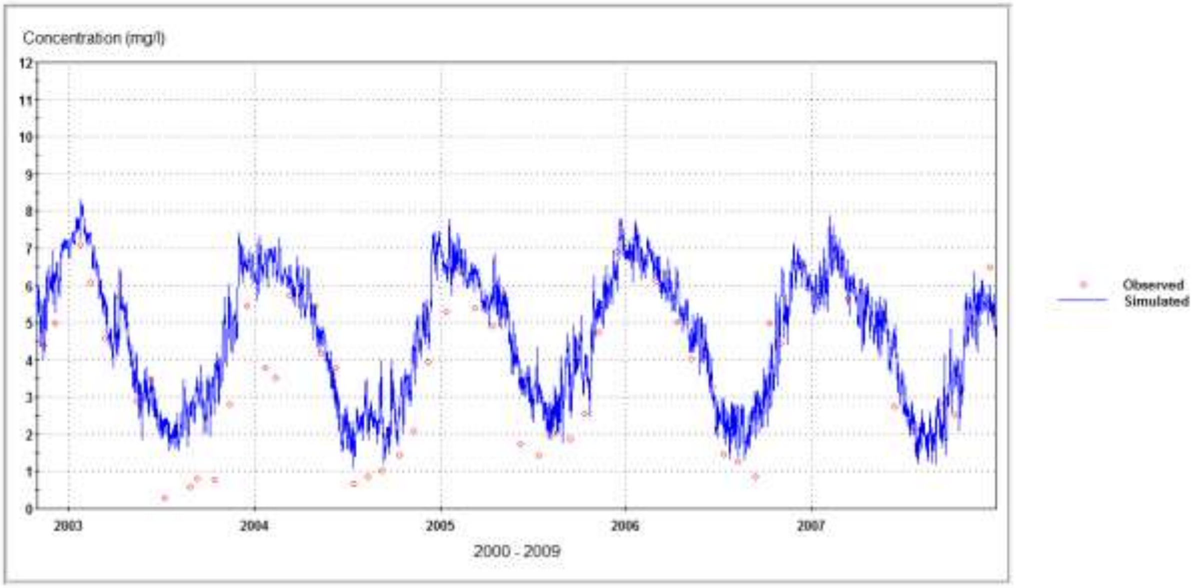


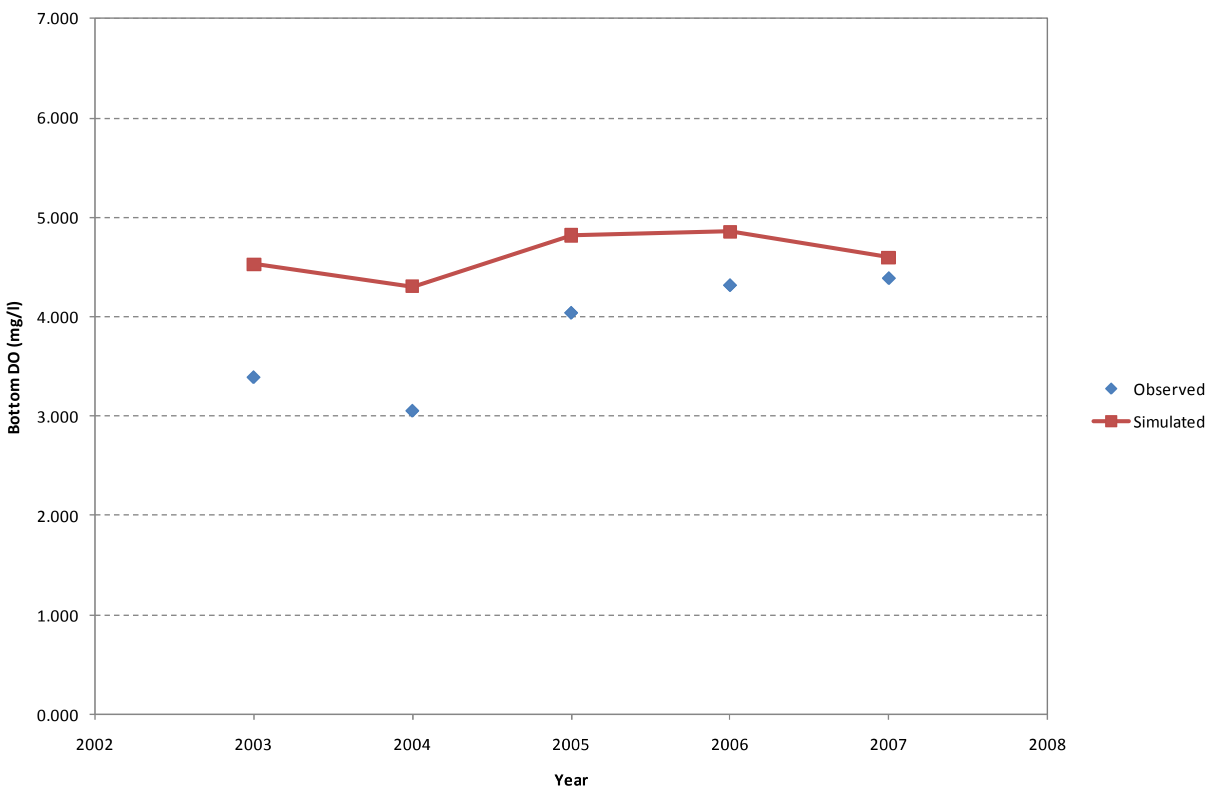
Figure 3-18. Simulated and observed surface DO at EPC 58



3-19. Simulated and observed annual mean surface DO at EPC 58



3-20. Simulated and observed bottom DO at EPC 58



3-21. Simulated and observed annual mean bottom DO at EPC 58

4.0 Conclusions

Based on the results of the model to data comparisons, it is determined that overall the model is reasonably simulating the key processes in McKay Bay and the Palm River for the time scales and methods of compliance assessment to be utilized in the TMDL. Based upon the analyses of the data presented within the TMDL report, the primary aspect of the model for use is its simulation of the dissolved oxygen conditions. Based upon the model to data comparisons, the model as presently calibrated is accurately simulating the temporal and spatial variations in the DO conditions as well as the percent of values below the 4.0 mg/L threshold.

5.0 References

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