Crystal Watershed

Modeling Report

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1.0 INTRODUCTION

Excess inputs of nitrogen and phosphorus (nitrogen/phosphorus pollution) in surface waters can be harmful in aquatic ecosystems by directly producing excess plant and algal growth, and indirectly leading to reduced clarity, reduced oxygen levels as the algae and plants decompose, and decreased biodiversity. Primary sources of nitrogen and phosphorus to aquatic ecosystems include waste water and sewage effluent, atmospheric deposition, landfill leachate, fossil fuel combustion, and runoff from commercial fertilizer and manure applications.

Nitrogen/phosphorus pollution contributes significant loadings of nitrogen and phosphorus to waters of the United States and is one of the leading causes of water quality degradation. Many of our nation's waters, including rivers, canals, lakes, estuaries, and coastal marine waters, are affected by nitrogen/phosphorus pollution. There is increasing evidence of nitrogen/phosphorus pollution in Florida's waters and clear, widespread indications of the resulting adverse effects on aquatic life in those waters.

The EPA is seeking to improve and enhance protection of aquatic life from the detrimental effects of nitrogen/phosphorus pollution through the implementation of Total Maximum Daily Loads (TMDLs). To aid in the development of TMDLs, watershed models throughout the state of Florida have been developed. The Crystal watershed is located in the central region of the Florida peninsula and drains into the Gulf of Mexico (Figure 1.0-1). The Crystal watershed has a mix of forested, wetland, agricultural, and urban land with flat topography. Most of the developed land is located in southern portion of the watershed.

This report documents the development and calibration of the Crystal watershed model that will be used to simulate watershed flows, temperature, dissolved oxygen, sediment, and nutrient loadings entering Florida estuaries.

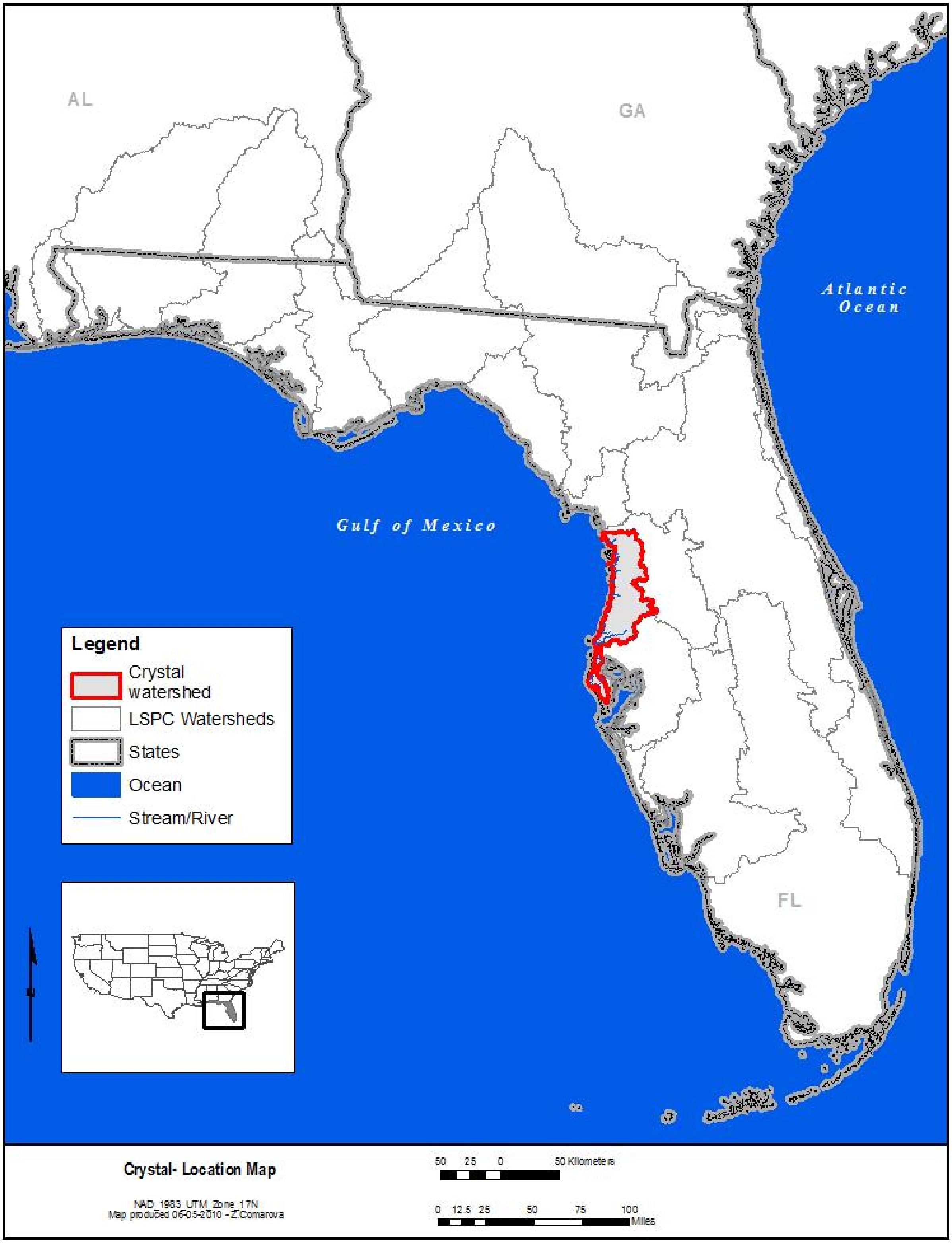

Figure 1.0-1 Location of the Crystal watershed

2.0 LSPC WATERSHED MODEL

2.1 LSPC Watershed Model

The Loading Simulation Program C++ (LSPC) was used to represent the hydrological and water quality conditions in the Crystal watershed. LSPC is a comprehensive data management and modeling system that is capable of representing loading, both flow and water quality from nonpoint and point sources, and simulating in-stream processes. It is capable of simulating flow, sediment, metals, nutrients, pesticides, and other conventional pollutants, as well as temperature and pH for waterbodies and pervious and impervious lands. LSPC was configured to simulate the watershed as a series of hydrologically connected sub-watersheds.

LSPC is a version of the Hydrologic Simulation Program-Fortran (HSPF) model that has been ported to the C++ programming language to improve efficiency and flexibility. LSPC integrates a geographic information system (GIS), comprehensive data storage and management capabilities, the original HSPF algorithms, and a data analysis/post-processing system into a convenient PC-based windows interface. LSPC's algorithms are identical to a subset of those in the HSPF model. LSPC is currently maintained by the EPA Office of Research and Development in Athens, Georgia. The LSPC system is based on the Mining Data Analysis System (MDAS), with modifications for non-mining applications such as nutrient and fecal coliform modeling. The system uses a Microsoft Access database to manage model data and weather text files, which are used to simulate the watersheds. MDAS was developed by EPA Region 3 through mining TMDL applications.

2.2 Integration of LSPC with Other Models

The outputs from the LSPC watershed models will be used as inputs for simulation models of Florida estuaries, which will be modeled using Environmental Fluid Dynamics Code (EFDC) and Water Quality Analysis Simulation Program Version 7.3 (WASP7) in order to model hydrology and water quality in Florida estuaries. EFDC is a hydrodynamic modeling package used for simulating one-dimensional, two-dimensional, and three-dimensional flow and transport in surface water systems, such as reservoirs and estuaries. WASP7 is a water quality modeling package used for simulating various processes such as eutrophication, sediment diagenesis, multiple BOD components, and toxicants. EFDC will be used to simulate the hydrodynamics (velocity, temperature, etc) in the Florida estuaries, while WASP7 will be used to simulate water quality processes in the Florida estuaries. LSPC will provide flows to the EFDC estuary models and water quality concentrations to WASP7 estuary models. EFDC and WASP7 are linked through a hydrodynamic linkage file. Figure 2.2-1 shows how the 3 models will interact with one another.

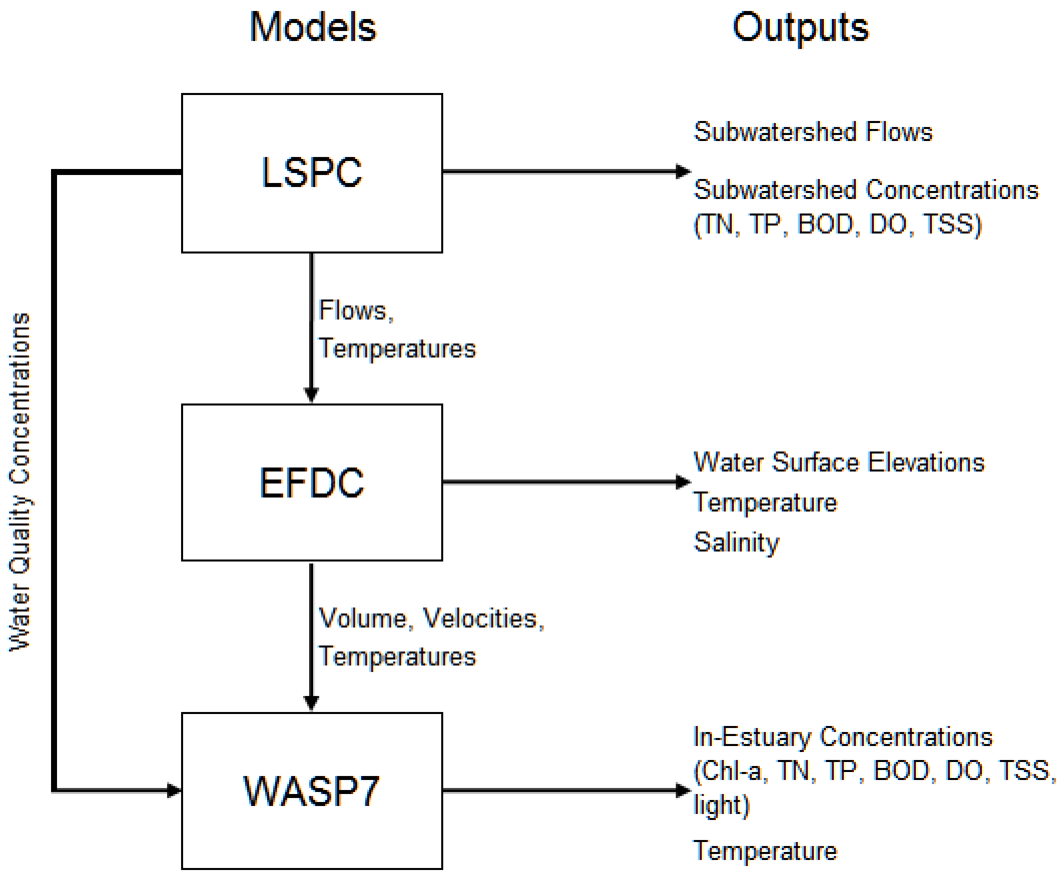

Figure 2.2-1 Linkage between LSPC, EFDC, and WASP7 models

3.0 WATERSHED MODEL DEVELOPMENT

3.1 Overview

The Crystal watershed model represented the variability of nonpoint source contributions through dynamic representation of hydrology and land practices. The watershed model included all point source contributions. Key components of the watershed modeling included:

- Watershed Segmentation (Section 3.2)
- Simulation Period (Section 3.3)
- Soils (Section 3.4)
- Meteorological Data (Section 3.5)
- Reach Characteristics (Section 3.6)
- Land Use Representation (Section 3.7)
- Point Source Discharges (Section 3.8)
- Municipal and Industrial Water Withdrawals (Section 3.9)
- Natural Springs (3.10)
- Hydrologic Representation (section 4.1)
- Observed Flow Data (Section 4.2)
- Hydrology Model Calibration and Validation (Sections 4.3)
- Hydrology Model Calibration and Validation Results (Section 4.4)
- Water Quality Model Overview (Section 5.1)
- Modeled Parameters (Section 5.2)
- Observed Water Quality Data (Section 5.3)
- Temperature Representation (Section 5.4)
- Dissolved Oxygen and Biological Oxygen Demand Representation (Section 5.5)
- Sediment Representation (Section 5.6)
- Nutrient Representation (Section 5.7)
- Water Quality Model Calibration and Validation (Section 5.8)
- Water Temperature Model Calibration and Validation (Section 5.9)
- Dissolved Oxygen and Biological Oxygen Demand Model Calibration and Validation Results (Section 5.10)
- Sediment Model Calibration and Validation Results (Section 5.11)
- Nutrients Model Calibration and Validation Results (Section 5.12)
- Nutrient Model Loading Analysis Results (Section 5.13)

The hydrologic representation and the hydrology calibration and validation and results are presented in Chapter 4. The water quality representation and the water quality calibration and validation and results are presented in Chapter 5.

3.2 Watershed Segmentation

In order to evaluate the contributing sources to a waterbody and to represent the spatial variability of these sources within the watershed model, the contributing drainage area was represented by a series of sub-watersheds. The sub-watersheds were developed using the Florida 12-digit hydrologic unit code (HUC12) watershed data layer that was provided by the Florida Department of Environmental Protection and the United States Geological Survey (USGS) National Hydrograph Dataset (NHD) catchments (Figure 3.2-1).

The elevation-derived NHD catchments are considered more accurate than the topographic-derived HUC12 watersheds, and were therefore used to develop the watershed and sub-watershed boundaries. However, the large numbers of NHD catchments in the watersheds were impractical for the LSPC modeling purposes. The NHD catchments were therefore grouped into larger HUC12 sized watersheds, effectively re-shaping the boundary of each HUC12 watershed. The revised HUC12 watersheds were further refined as needed to create a series of hydrologically connected sub-watersheds for LSPC (Figure 3.2-2).

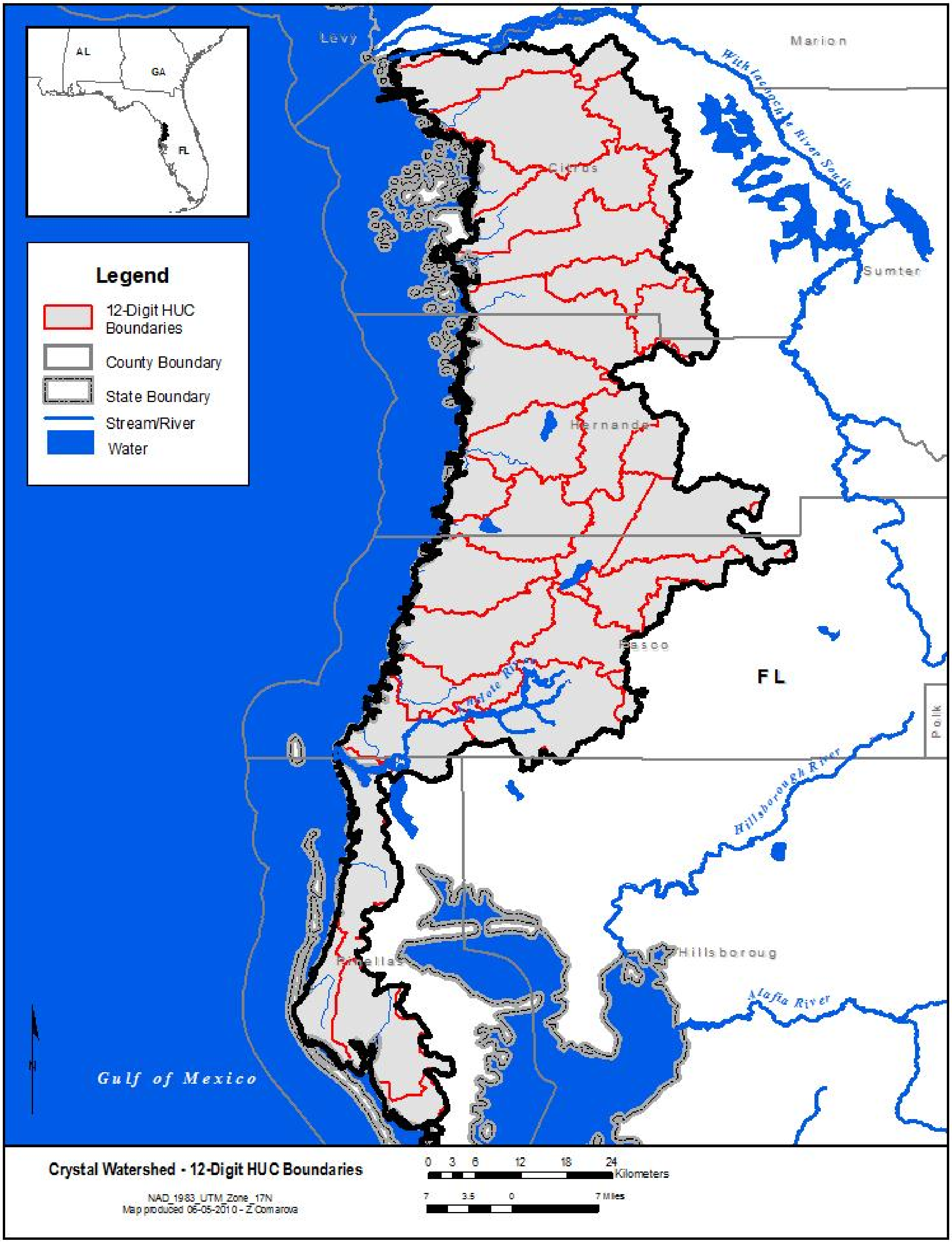

Figure 3.2-1 FDEP 12-Digit HUC coverage for the Crystal watershed

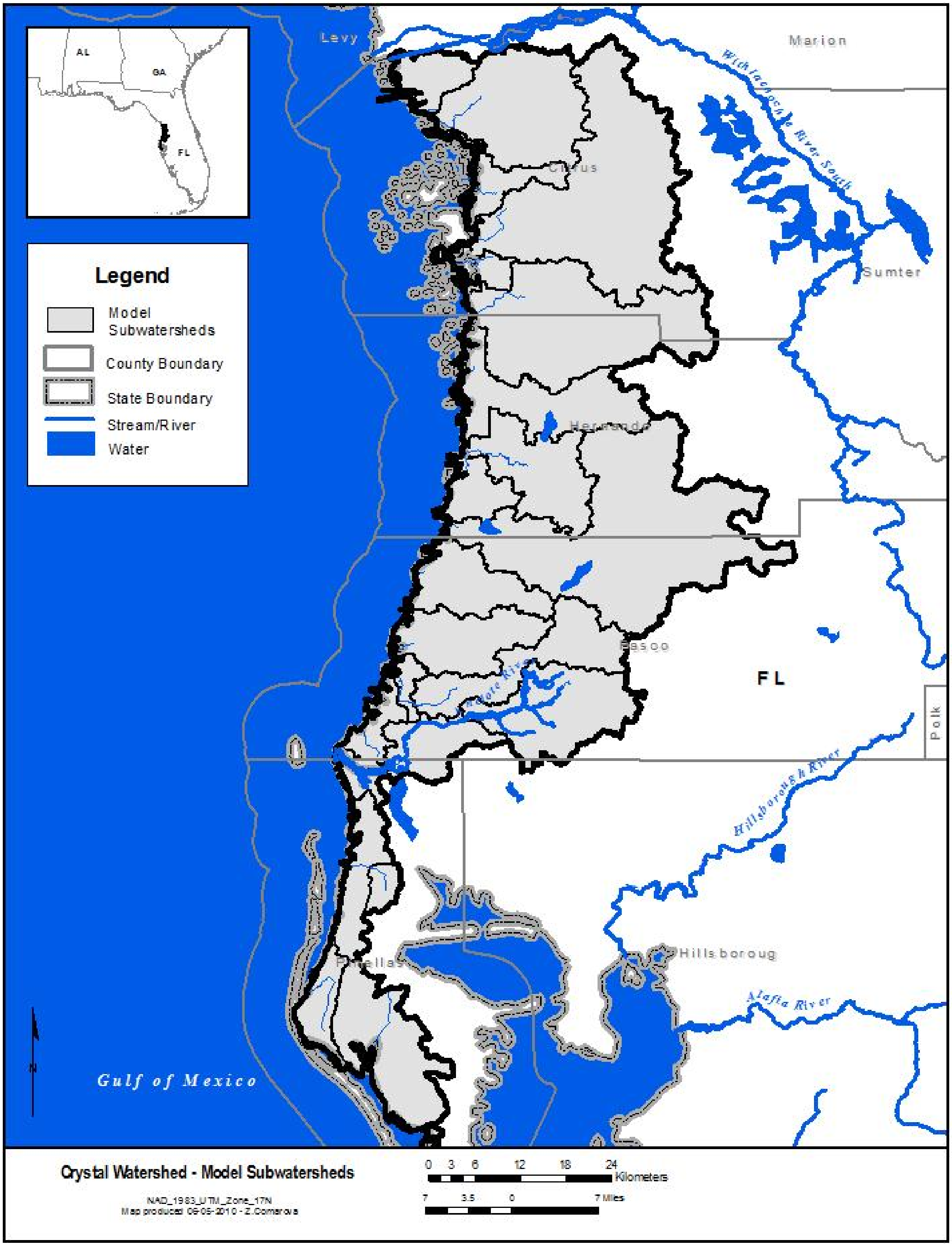

Figure 3.2-2 Sub-Delineated 12-Digit HUC coverage for the Crystal watershed

3.3 Simulation Period

The US Geological Survey (USGS) recommends looking at a minimum of a 10-year time period for hydrology calibrations. This is due to the fact that over a 10-year period, a variety of hydrological conditions will exist, and a model that is calibrated over this time period will have a greater chance of success in predicting future hydrological conditions. The LSPC model was simulated for a 13-year period from January 1, 1997 through December 31, 2009 and included low, normal, and high flow years. To ensure that the model outputs were not impacted by the initial model conditions, the model was run for a full year of “spin up” (1996) before the simulation period began (1997-2009). The LSPC watershed hydrology and water quality model was calibrated and validated to data collected from 1997 through 2009.

3.4 Soils

Soil data for the Florida watersheds was obtained from the Soil Survey Geographic Database (SSURGO). The database was produced and distributed by the Natural Resources Conservation Service (NRCS) - National Cartography and Geospatial Center (NCGC). The SSURGO data was used to determine the total area that each hydrologic soil group covered within each sub-watershed. The sub-watersheds were represented by the hydrologic soil group that had the highest percentage of coverage within the boundaries of the sub-watershed. All four soil types along with one combination soils type were found within the Crystal watershed:

Group A Soils	Have high infiltration rates and consist of soils that are deep and well drained to excessively drained and are often sandy with coarse textures.
Group B Soils	Have moderate infiltration rates when wet and consist chiefly of soils that are moderately deep to deep, moderately well to well drained, and moderately fine to moderately course textures.
Group C Soils	Have slow infiltration rates and are soils with layers impeding downward movement of water, or soils that have moderately fine or fine textures.
Group D Soils	Have very slow infiltration rates and have soils that are clayey and impede downward movement of water, or can be shallow soils over an impervious layer. Soils have a high water table.

The combination soil group, B/D, is a combination of drained soils and undrained soils with the potential to be drained. When fully drained, the soils would be classified as their primary designation, or the first soil group in the combination group, i.e. B/D would be classified as B. In the Crystak watershed model, combination soil classes were designated as their primary classification. To assign a hydrologic soil group to each sub-watershed, the total area of each hydrologic soil group within each sub-watershed was determined. The sub-watersheds were represented by the hydrologic soil group that had the highest percent of coverage. Figure 3.4-1 shows the different soil types that are within the Crystak watershed, and Table 3.4-1 shows the number of subwatersheds assigned to each hydrologic soil group.

Table 3.4-1 Number of subwatersheds assigned to each hydrologic soil group in the Crystal watershed model

Hydrologic Soil Group	Number of Subwatersheds
A	9
B	7
C	4
D	2

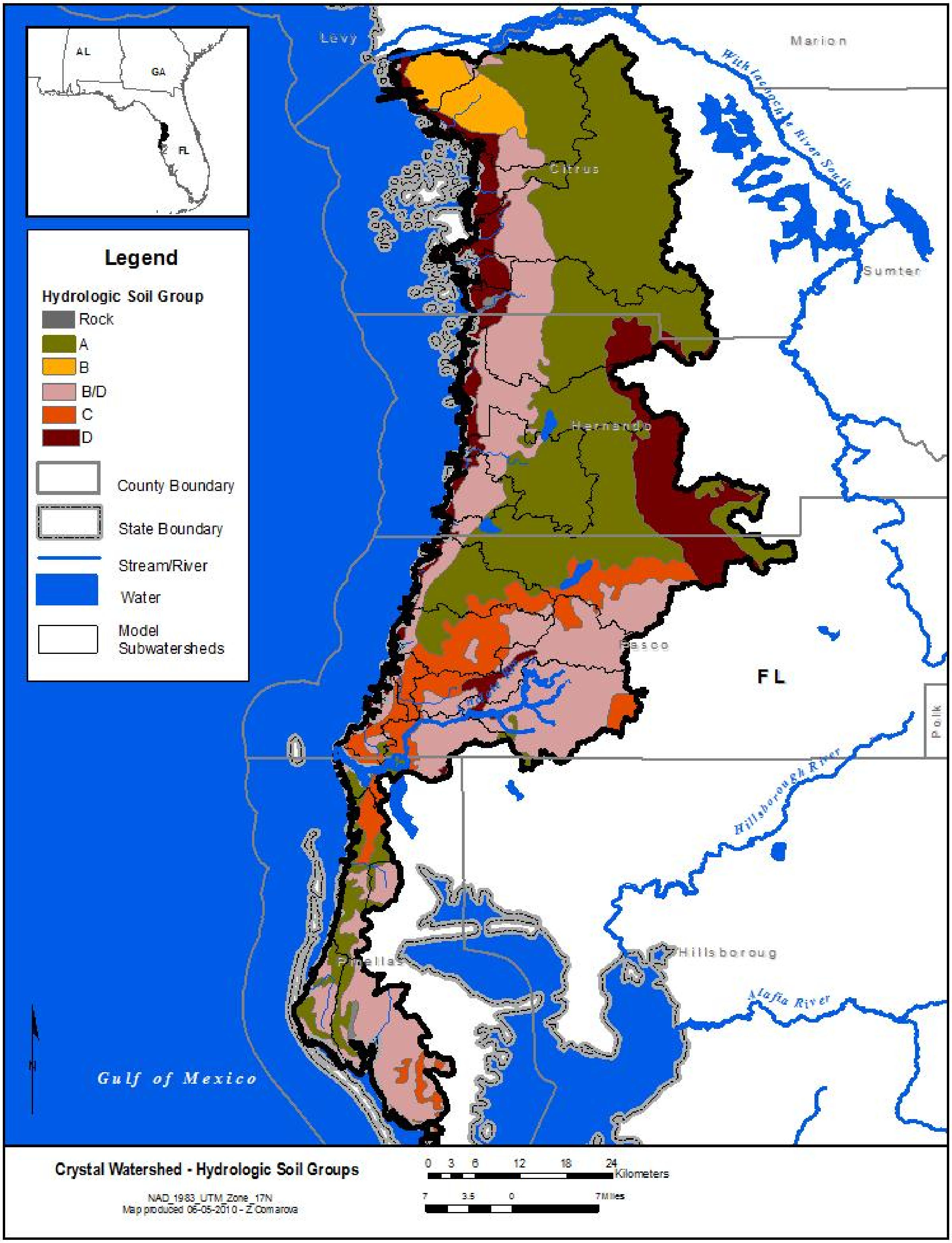

Figure 3.4-1 SSURGO soils coverage for the Crystal watershed

3.5 Meteorological Data

Nonpoint source loadings and hydrological conditions are dependent on weather conditions. Hourly data from weather stations within the boundaries of, or in close proximity to, the sub-watersheds were applied to the watershed model. A weather data forcing file was generated in ASCII format (*.air) for each meteorological station used in the hydrological evaluations in LSPC. Each meteorological station file contained atmospheric data used in modeling the hydrological processes. These data included precipitation, air temperature, dew point temperature, wind speed, cloud cover, evaporation, and solar radiation. These data are used directly, or calculated from the observed data.

Weather data forcing files were developed for 2 stations in the Crystal watershed. The primary source of rainfall data were Summary of the Day (SOD) which were obtained from the Florida State Climate Center (FSCC). The SOD data were daily precipitation, daily maximum air temperature, and daily minimum air temperature. Surface Airways (SA) stations were also used to develop forcings for meteorological constituents. The SA data were obtained from the National Climate Data Center (NCDC), which were hourly records of precipitation, dew point temperature, air temperature, relative humidity, wind speed, wind direction, atmospheric pressure, and sky condition.

Meteorological stations were assigned to sub-watersheds using a Thiessen polygon. If a particular watershed was intersected by the polygon boundary, it was assigned to the meteorological station that had the greatest area covered by that stations polygon. In some watersheds there were few or no weather stations located within the boundaries, at which point adjacent weather stations were used. The meteorological stations used for the Crystal watershed model are listed in Table 3.5-1 and shown in Figure 3.5-1.

Table 3.5-1 Meteorological stations used in the Crystal watershed model

Station ID	LSPC ID	Station Name	Elevation	County	Latitude	Longitude
088824	1	Tarpon Springs SWG Plant	8	Pinellas, FL	28.1500	-82.7500
089430	2	Weeki Wachee	20	Hernando, FL	28.5175	-82.5756

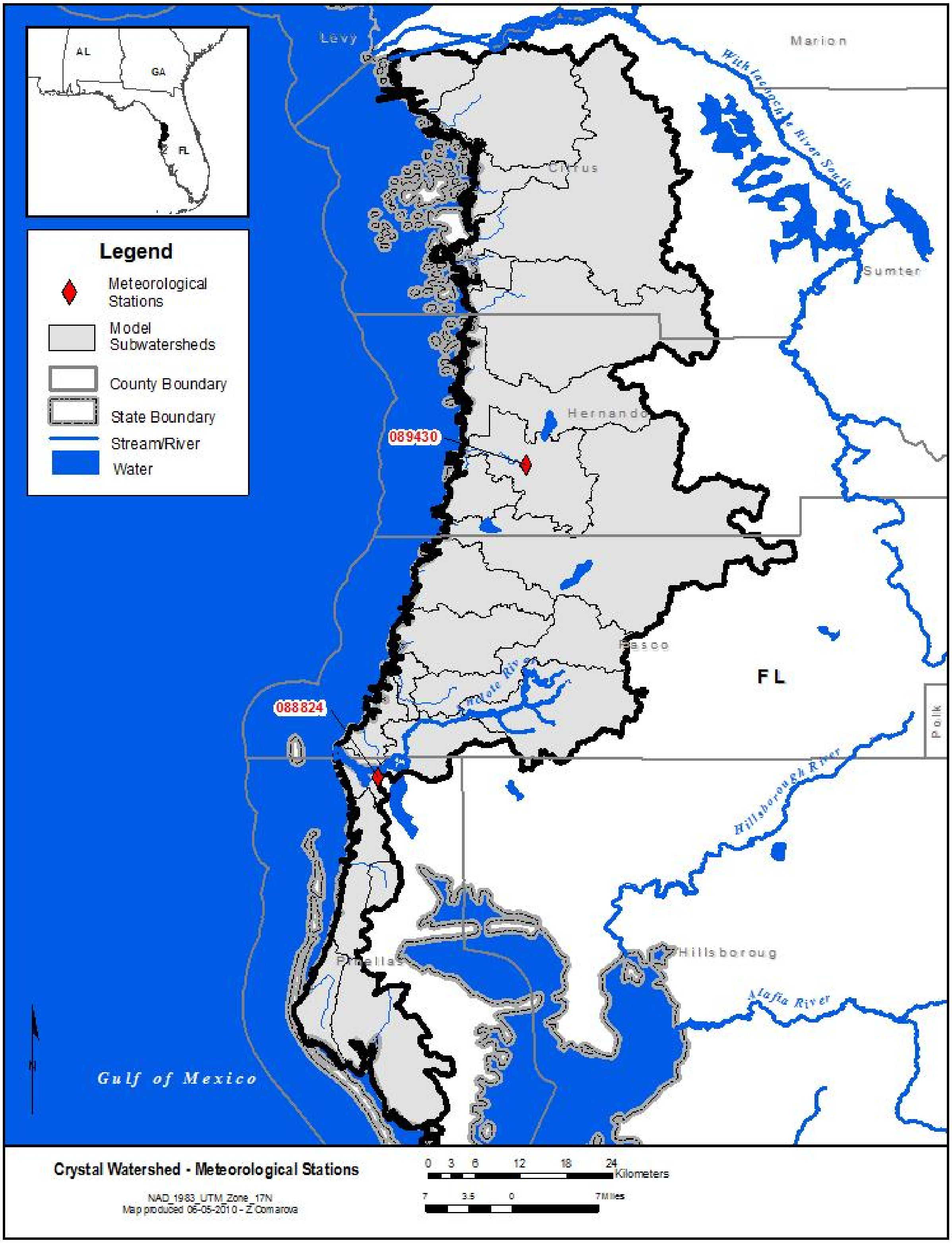

Figure 3.5-1 Location of meteorological stations used in the Crystal watershed model

3.6 Reach Characteristics

The LSPC model must have a representative reach defined for each sub-watershed, and the main channel stem within each sub-watershed was used as the representative reach. The characteristics for each reach include the length and slope of the reach, the channel geometry and the connectivity between the sub-watersheds. Length and slope data for each reach was obtained using the USGS National Elevation Dataset (NED) Digital Elevation Maps (DEM), and the USGS National Hydrography Dataset (NHD) (Figure 3.6-1).

Each representative reach in LSPC was assumed to be a completely mixed, one-dimensional segment with a trapezoidal cross section. Input parameters for the reaches include initial depth, length, depth, width, slope, Manning's roughness coefficient, and coefficients to describe the shape of the stream channel. The channel geometry is described by a bank full width and depth (the main channel), a bottom width factor (r1), a flood plain width factor (w1) and slope of the flood plain (r2) (Figure 3.6-2).

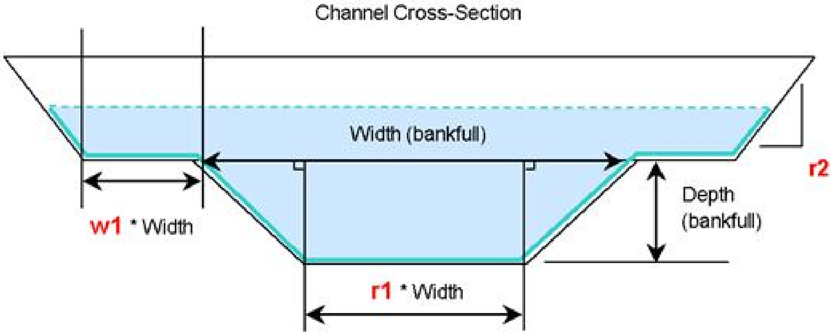

Figure 3.6-2 Stream channel representation in the LSPC model

LSPC takes the attributes supplied for each reach and develops a function table (FTABLE). The FTABLE describes the hydrology, of a river reach or reservoir segment, by defining the functional relationship between water depth, surface area, water volume, and outflow in the segment. The assumption of a fixed depth, area, volume, outflow relationship rules out cases where the flow reverses direction or where one reach influences another upstream of it in a time-dependent way. The routing technique falls in the class known as "storage routing" or "kinematic wave" methods. In these methods, momentum is not considered (EPA 2007).

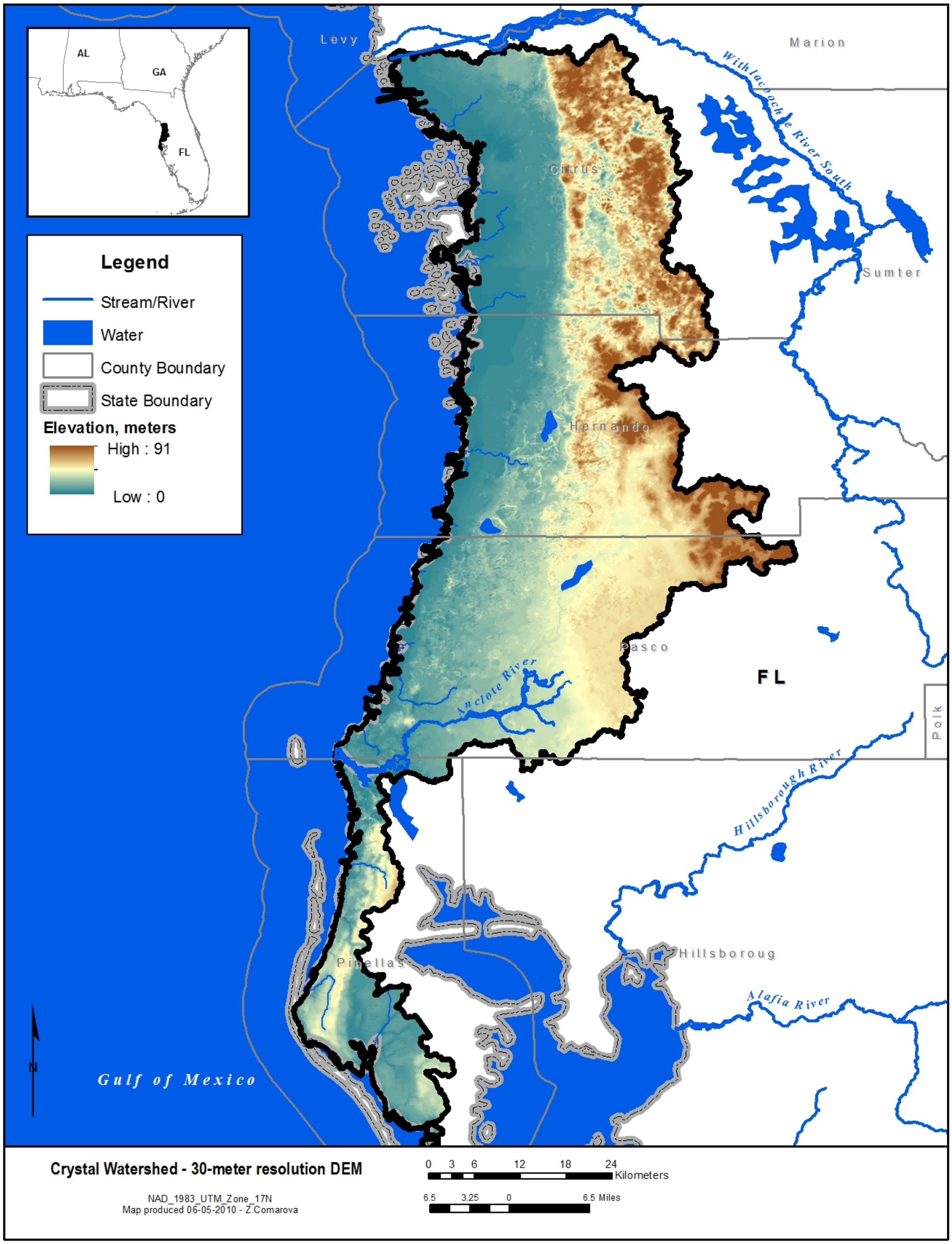

Figure 3.6-1 USGS NED DEM of the Crystal watershed

3.7 Land Use Representation

The watershed model uses land use data as the basis for representing hydrology and nonpoint source loadings. The FDEP Level III Florida Land Use and the National Landuse Coverage Dataset (NLCD) were used to develop the watershed land use representation. The FDOT coverages were used as the primary coverage, and the Southwest Florida Watershed Management Distric (SWFWMD) was used as the primary coverage for the Crystal watershed (Figure 3.7-1). When available, the land cover classification, identified as LUCODE or Secondary classification in the coverages, was used to develop the land use representation coverage for the Florida models. According to the SJRWMD metadata:

> "Each feature is required to have two attributes, one emphasizing land cover (LCCODE) and the second land use (LUCODE). In most cases, these two values are the same. They differ in a minority of cases where separate cover and use values are required in order to adequately describe the mapping unit. The result is a map with dual codes. The LCCODE attribute can be used (mapped, queried, etc.) alone for a land cover emphasis; LUCODE can be used alone for a land use emphasis; or both can be used together." (SJRWMD 2006).

Differences between the land use and land cover codes occur in low density rural developments and surface water structures.

The coverages utilized a variety of land use classes, and the FDEP coverages were grouped and reclassified into 18 land use categories: beaches/dune/mud, open water, utility swaths, developed open space, developed low intensity, developed medium intensity, developed high intensity, clear-cut/sparse, quarries/strip mines, deciduous forest, evergreen forest, mixed forest, golf courses, pasture, row crop, forested wetland, non-forested wetland (salt/brackish), and non-forested wetland (freshwater) (Table 3.7-1). The GLUT and NLCD datasets were then reclassified into the same land use categories. For the LSPC simulation, similar land use classes were grouped together into reduced modeling categories, i.e., deciduous forest, evergreen forest and mixed forest were grouped together into a unit named forest. The Crystal watershed land use coverage is shown in Figure 3.7-1.

The LSPC model requires division of land uses in each sub-watershed into separate pervious and impervious land units. The NLCD 2006 percent impervious coverage was used as the impervious layer. The datasets was intersected with the land use cover layer in ArcGIS. Any impervious areas associated with utility swaths, developed open space, and developed low intensity, were grouped together and placed into a new land use category named *low intensity development impervious*. Impervious areas associated with medium intensity development and high intensity development were kept separate and placed into two new categories for *medium intensity development impervious* and *high intensity development impervious*, respectively. Finally, any impervious area not already accounted for in the three developed impervious categories, were grouped together into a fourth new category for all remaining impervious land use. The reduced modeling units and their corresponding classifications are presented in Table 3.7-2, and the Crystal land use and impervious coverages are shown in Figures 3.7-2 and 3.7-3. The Crystal watershed land use breakdown is presented in Table 3.7-3.

Table 3.7-1 FDEP land use representation re-classification

FDEP Value	FDEP Description	Geoprocessed Land Use Code	Geoprocessed Land Use Description
71	BEACHES OTHER THAN SWIMMING BEACHES	7	Beaches/Dunes/Mud
72	SAND OTHER THAN BEACHES	7	Beaches/Dunes/Mud
75	SAND OTHER THAN BEACHES	7	Beaches/Dunes/Mud
51	STREAMS AND WATERWAYS	11	Open Water
52	LAKES	11	Open Water
53	RESERVOIRS	11	Open Water
54	BAYS AND ESTUARIES	11	Open Water
55	MAJOR SPRINGS	11	Open Water
56	SLOUGH WATERS	11	Open Water
57	GULF OF MEXICO	11	Open Water
87	UTILITIES (Surface Water Collection Systems - non-wastewater)	11	Open Water
83	UTILITIES (Elec. Power, Oil, Water, and Gas transmission lines)	20	Utility Swaths
18	RECREATIONAL	21	Developed, Open Space
19	OPEN LAND	21	Developed, Open Space
11	RESIDENTIAL LOW DENSITY < 2 DWELLING UNITS	22	Developed, Low Intensity
12	RESIDENTIAL MED DENSITY 2->5 DWELLING UNIT	23	Developed, Medium Intensity
13	RESIDENTIAL HIGH DENSITY	24	Developed, High Intensity
14	COMMERCIAL AND SERVICES	24	Developed, High Intensity
15	INDUSTRIAL	24	Developed, High Intensity
17	INSTITUTIONAL	24	Developed, High Intensity
81	TRANSPORTATION	24	Developed, High Intensity
82	COMMUNICATIONS	24	Developed, High Intensity
83	UTILITIES (Power Plants, Water and Wastewater Plants)	24	Developed, High Intensity
31	HERBACEOUS	31	Clearcut/Sparse
32	SHRUB AND BRUSHLAND	31	Clearcut/Sparse
33	MIXED RANGELAND	31	Clearcut/Sparse
16	EXTRACTIVE	33	Quarries/Strip Mines
74	DISTURBED LAND	33	Quarries/Strip Mines
42	UPLAND HARDWOOD FORESTS - PART 1	41	Deciduous Forest
41	UPLAND CONIFEROUS FOREST	42	Evergreen Forest
44	TREE PLANTATIONS	42	Evergreen Forest
43	HARDWOOD CONIFER MIXED	43	Mixed Forest

FDEP Value	FDEP Description	Geoprocessed Land Use Code	Geoprocessed Land Use Description
73	GOLF COURSES	73	Golf Courses
21	CROPLAND AND PASTURELAND	80	Pasture
23	FEEDING OPERATIONS	80	Pasture
25	SPECIALTY FARMS	80	Pasture
26	OTHER OPEN LANDS <RURAL>	80	Pasture
21	ROW CROPS	83	Row Crop
22	TREE CROPS	83	Row Crop
24	NURSERIES AND VINEYARDS	83	Row Crop
61	WETLAND HARDWOOD FORESTS	91	Forested Wetland
62	WETLAND CONIFEROUS FORESTS	91	Forested Wetland
63	WETLAND FORESTED MIXED	91	Forested Wetland
66	SALT FLATS	92	Non-forested Wetland (Salt/Brackish)
64	VEGETATED NON-FORESTED WETLANDS	93	Non-forested Wetland (Freshwater)
65	NON-VEGETATED WETLANDS	93	Non-forested Wetland (Freshwater)

Table 3.7-2 LSPC land use representation

LSPC Land Use ID	LSPC Land Use Description	Geoprocessed Land Use Code	Geoprocessed Land Use Description
1	Beach	7	Beach/Dunes/Mud
2	Water	11	Open Water
3	Low Int Dev Perv	20	Utility Swaths
3	Low Int Dev Perv	12	Developed, Open Space
3	Low Int Dev Perv	22	Developed, Low Intensity
4	Low Int Dev Imper	222	10+21+22 Impervious
5	Med Int Dev Perv	231	Developed, Medium Intensity
6	Med Int Dev Imperv	232	Developed, Medium Intensity
7	High Int Dev Perv	241	Developed, High Intensity
8	High Int Dev Imperv	242	Developed, High Intensity
9	Barren	31	Clearcut/Sparse
9	Barren	33	Quarries/Strip Mines
9	Barren	34	Rock Outcrop
10	Forest	41	Deciduous Forest
10	Forest	42	Evergreen Forest
10	Forest	43	Mixed Forest
11	Golf	73	Golf Courses
12	Pasture	80	Pasture
13	Crop	83	Row Crop

LSPC Land Use ID	LSPC Land Use Description	Geoprocessed Land Use Code	Geoprocessed Land Use Description
14	Wetland	91	Forested Wetland
14	Wetland	92	Non-forested Wetland (salt/brackish)
14	Wetland	93	Non-forested Wetland (freshwater)
15	All Other Impervious	332	Catch-all for Remaining Impervious

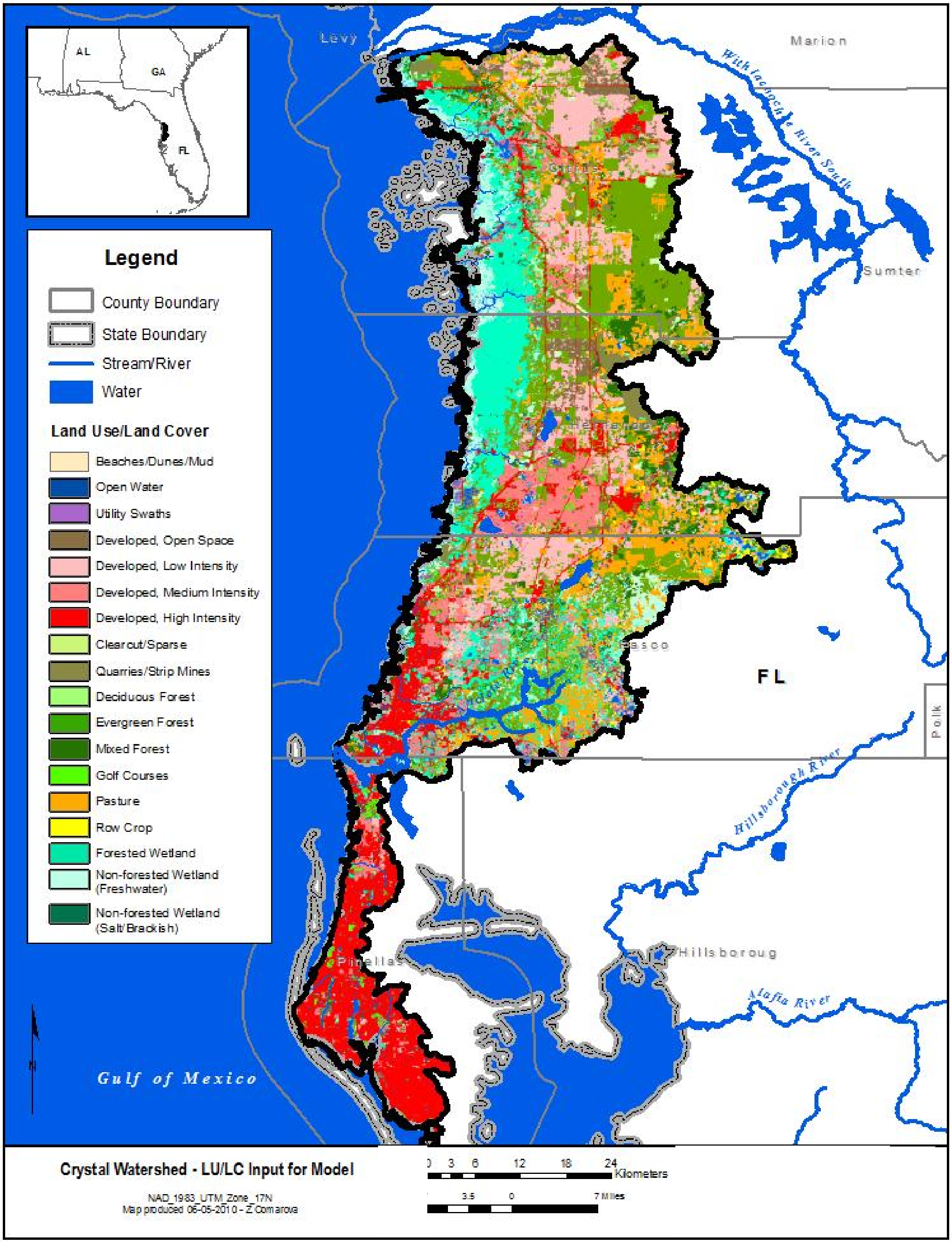

Figure 3.7-1 SWFWMD 2006 land use coverage of the Crystal watershed

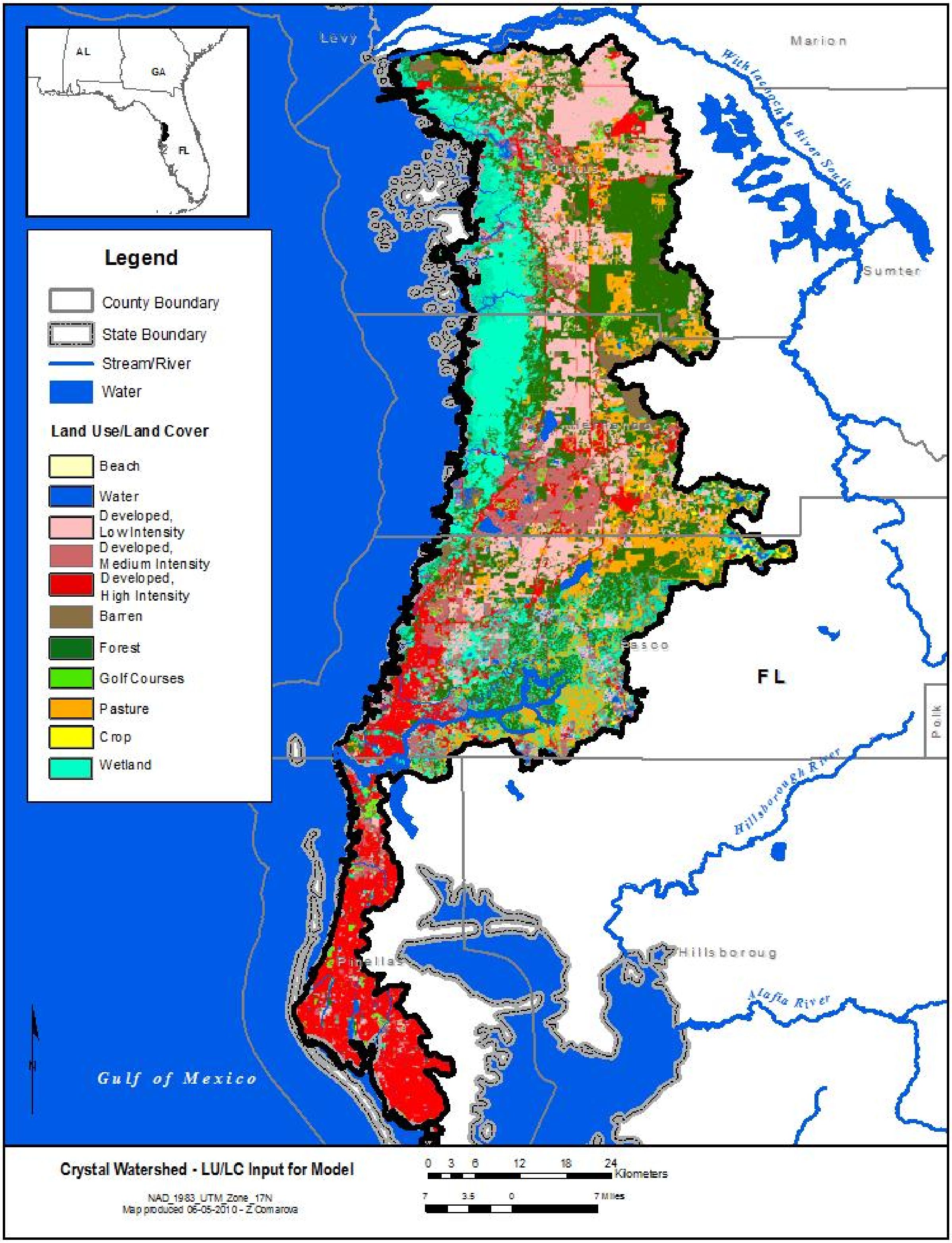

Figure 3.7-2 Re-classified SWFWMD 2006 land use coverage of the Crystal watershed

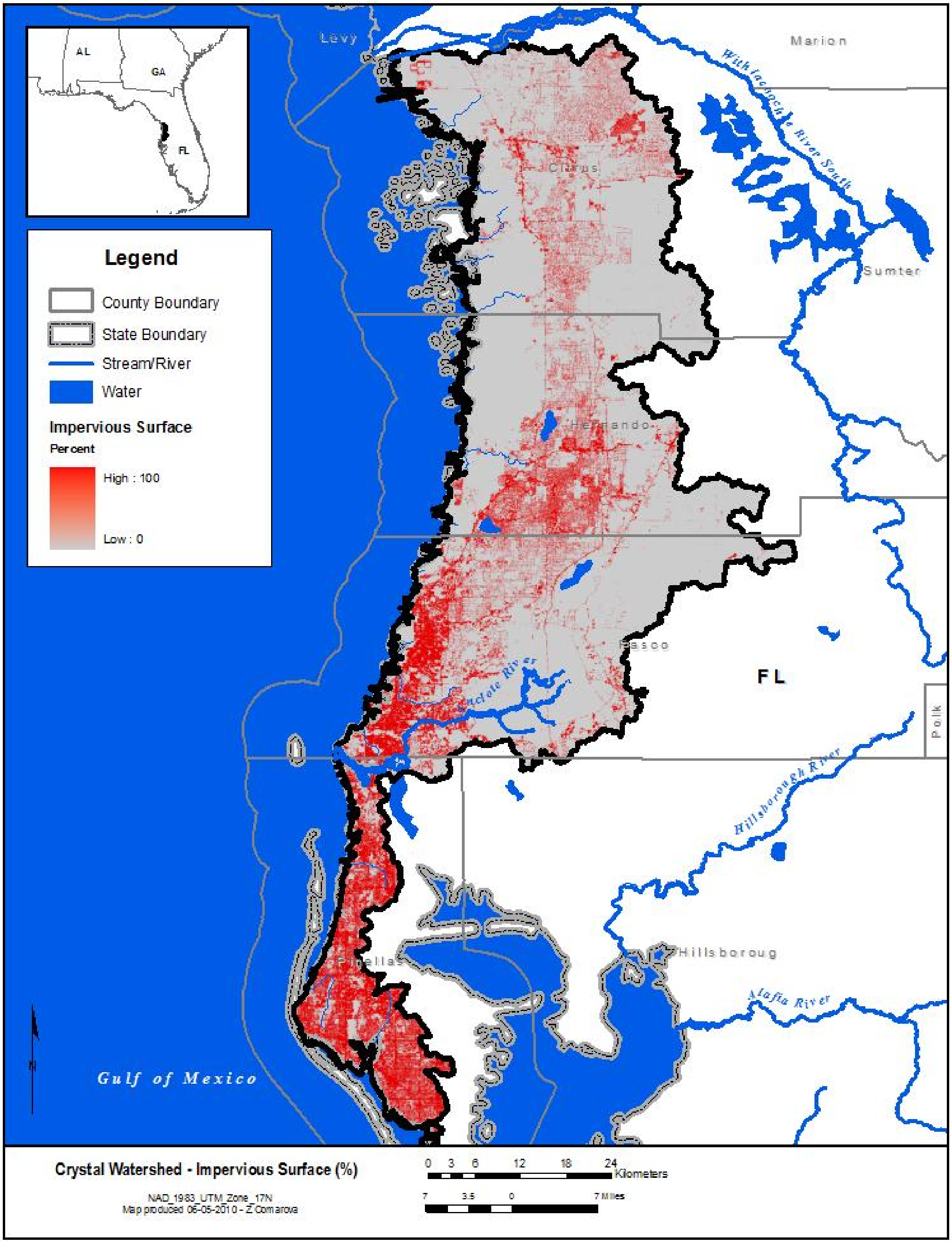

Figure 3.7-3 NLCD 2006 impervious coverage of the Crystal watershed

Table 3.7-3 SWFWMD 2006 and NLCD 2006 combined land use breakdown for the Crystal watershed

Land Use Code	Land Use Description	Area (acres)	Area (hectares)	Percent (%)
7	Beaches/Dunes/Mud	0	0	0.00
11	Open Water	25770	10429	3.60
21	Developed, Open Space	29597	11978	4.14
22	Developed, Low Intensity	82091	33221	11.47
31	Clearcut/Sparse	11377	4604	1.59
33	Quarries/Strip Mines	11225	4542	1.57
41	Deciduous Forest	554	224	0.08
42	Evergreen Forest	123782	50093	17.29
43	Mixed Forest	35019	14172	4.89
73	Golf Courses	7442	3012	1.04
80	Pasture	67596	27355	9.44
83	Row Crop	3280	1327	0.46
91	Forested Wetland	82343	33323	11.50
92	Non-forested Wetland (Salt/Brackish)	504	204	0.07
93	Non-forested Wetland (Freshwater)	52919	21416	7.39
222	20+21+22 Impervious	12272	4966	1.71
231	Developed, Medium Intensity Pervious	39252	15885	5.48
232	Developed, Medium Intensity Impervious	13791	5581	1.93
241	Developed, High Intensity Pervious	61940	25066	8.65
242	Developed, High Intensity Impervious	46510	18822	6.50
332	Catch-all for Remaining Impervious	8497	3438	1.19

3.8 Point Source Discharges

Facilities permitted under the National Pollutant Discharge Elimination System (NPDES) are, by definition, considered point sources. The NPDES geographic information system (GIS) coverage provided by FDEP, which reflected current 2009 dischargers, was adopted as the starting point for the evaluation of point sources for the Crystal watershed model. Stormwater discharges, such as MS4s, were not input directly into the model but were assumed to be included in the urban land use loading. Point sources that were designated as reuse facilities were not input directly into the model, but were accounted for in the adjustment of the hydrologic calibration parameters. Data for the possible permits was sought from the FDEP and the U.S. Environmental Protection Agency's Envirofacts Data Warehouse Permit Compliance System (EPA-PCS). Permits that discharged directly into the adjacent estuaries were excluded from the watershed models. The remaining permits with data were processed into a time series from 1996 through 2009.

The FDEP point source information was provided in an electronic format in the Water Resources Database (WRDB) that included discharge and associated water quality parameters with each point source. The files were reviewed to determine if there were any errors or potential problems with accuracy and to ensure the best possible continuous record was developed from the provided files. However, there were still large gaps and the EPA-PCS data was used as an alternative data source in those situations. Missing periods of data also occurred in the FDEP point source files. If the gaps in the data were three months or less, an average was calculated from before and after gap months. If the gaps in the data were larger than three months the long term average was supplied. Some of the dischargers did not report loads or concentrations for all constituents in the LSPC model. The default concentrations adopted for the missing constituents are found in Table 3.8-1 and Table 3.8-2, and the point sources included in the Crystal watershed model are listed in Table 3.8-3 and shown in Figure 3.8-1.

Table 3.8-1 Default water quality concentrations used for municipal point sources when data were not available

Constituent	Discharger Less than 1.0 MGD	Discharger Greater than 1.0 MGD
Flow	Maximum Value found from 1997 through 2009 or Permitted Flow	Maximum Value found from 1997 through 2009 or Permitted Flow
Total Phosphorus	5.0 mg/l	1.0 mg/l
Total Nitrogen	29.4 mg/l	17.0 mg/l
BOD5	30.0 mg/l	10.0 mg/l
Dissolved Oxygen	2.0 mg/l for Critical Conditions (low flow)	2.0 mg/l for Critical Conditions (low flow)
Dissolved Oxygen	5.0 mg/l for all other runs	5.0 mg/l for all other runs
Temperature	15.0 °C - October through March	15.0 °C - October through March
Temperature	25.0 °C - April through September	25.0 °C - April through September
TSS	30 mg/l	30 mg/l

Table 3.8-2 Default water quality concentrations of constituents used for industrial point sources when data were not available

Constituent	Discharger Less than 1.0 MGD	Discharger Greater than 1.0 MGD
Flow	Maximum Value found from 1997 through 2007 or Design Flow	Maximum Value found from 1997 through 2007 or Design Flow
Total Phosphorus	0.0 mg/l unless otherwise noted	0.0 mg/l unless otherwise noted
Total Nitrogen	0.0 mg/l unless otherwise noted	0.0 mg/l unless otherwise noted
BOD5	30.0 mg/l	10.0 mg/l
Dissolved Oxygen	2.0 mg/l for Critical Conditions (low flow)	2.0 mg/l for Critical Conditions (low flow)
Dissolved Oxygen	5.0 mg/l for all other runs	5.0 mg/l for all other runs
Temperature	15.0 °C – October through March	15.0 °C – October through March
Temperature	25.0 °C – April through September unless otherwise noted	25.0 °C – April through September unless otherwise noted
TSS	30 mg/l	30 mg/l

Table 3.8-3 Point sources that were incorporated into the Crystal watershed model

NPDES	Facility Name	Class	County	Data Source
FL0021857	Clearwater, City of - Marshall Street AWWTF	Muncipal	Pinellas	FDEP
FL0030406	Tarpon Springs, City of	Muncipal	Pinellas	FDEP
FL0034789	Mid County Services Inc	Muncipal	Pinellas	FDEP
FL0036366	Progress Energy Florida - Crystal River Units 4 & 5	Industrial	Citrus	FDEP
FL0040436	South Cross Bayou WRF	Muncipal	Pinellas	FDEP

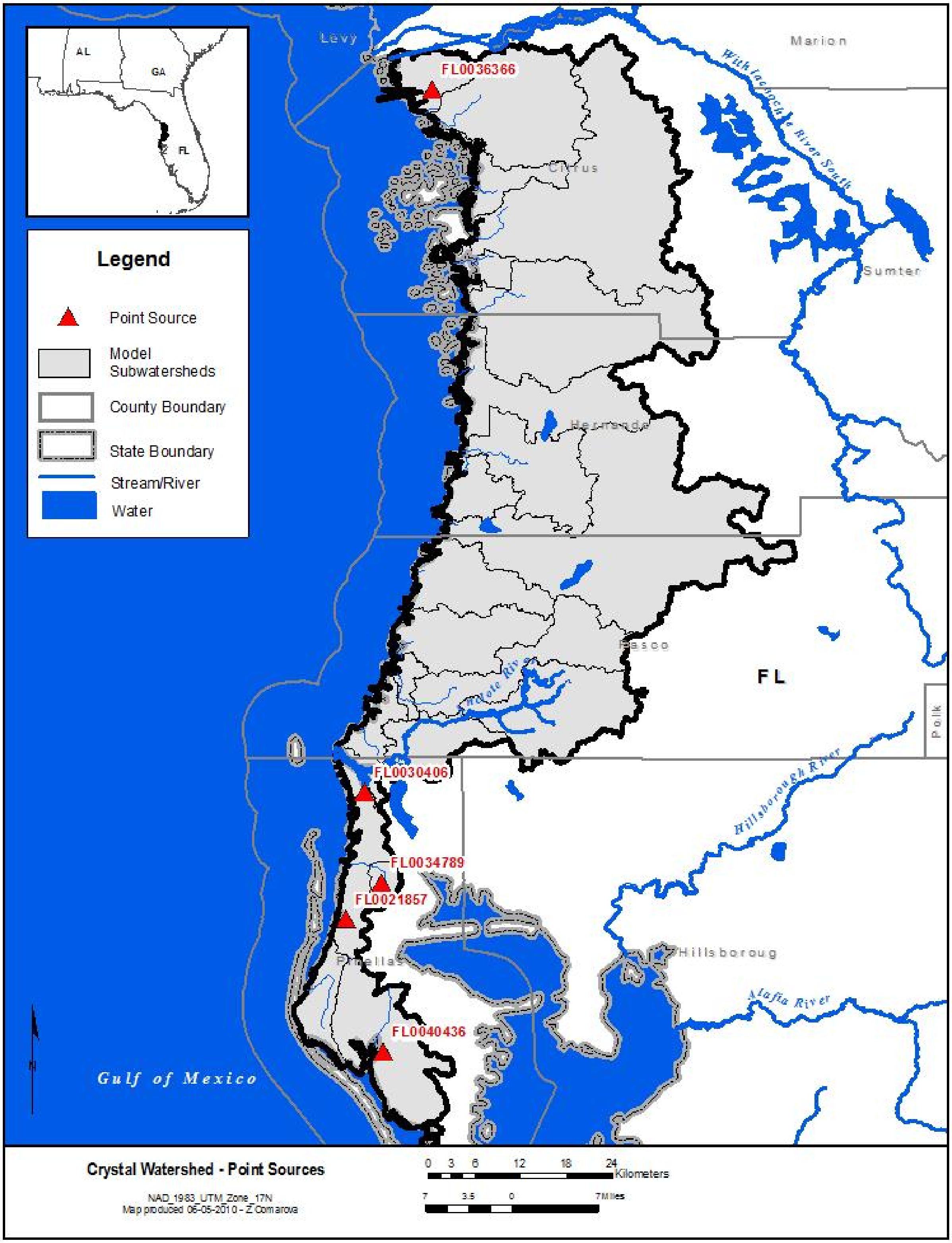

Figure 3.8-1 Calibration and validation stations used in the Crystak hydrology model

3.9 Municipal and Industrial Water Withdrawals

The majority of water withdrawals in Crystal watershed were from groundwater sources, and recharge occurs at temporal and spatial scales beyond the scope of simulation. Large water withdrawals were added to the model. Small municipal and industrial surface water withdrawals (withdrawals less than 0.1 MGD) were not input directly into the model, but were accounted for in the adjustment of the hydrologic calibration parameters. For security reasons, the locations of the water withdrawals are not identified.

3.10 Natural Springs

To correctly simulate baseflow for the watershed models, it was necessary to account for flow from natural springs. Data from the FDEP and the Florida Waters Management Districts was reviewed to determine the locations, discharges, and water quality concentrations of the springs. Monthly average spring discharges and water quality loads were added to the Crystal watershed model as point sources. If data were insufficient to provide monthly averages, yearly averages were used.

4.0 Watershed Hydrology Model

4.1 Hydrologic Representation

Watershed hydrology plays an important role in the determination of nonpoint source flow and ultimately nonpoint source loadings to a waterbody. The watershed model must appropriately represent the spatial and temporal variability of hydrological characteristics within a watershed. Key hydrological characteristics include interception storage capacities, infiltration properties, evaporation and transpiration rates, and watershed slope and roughness. LSPC's algorithms are identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF modules used to represent watershed hydrology include PWATER (water budget simulation for pervious land units) and IWATER (water budget simulation for impervious land units). A detailed description of relevant hydrological algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

During the calibration process, model parameters were chosen based on local knowledge of land use, soil types, and groundwater conditions. They were adjusted within reasonable constraints until an acceptable agreement was achieved between simulated and observed stream flow. Model parameters adjusted included: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, losses to the deep groundwater system, and Manning's n.

4.2 Observed Flow Data

Historical and short-term USGS flow stations located in the Crystal watershed were used to calibrate and validate the LSPC watershed hydrology model (Tables 4.2-1 and Figure 4.2-1). Available flow gages in each watershed were reviewed for the following factors: length of available flow data, tidal influence, anthropogenic influence, size of waterbody, and availability of associated water quality data. The best available gages were then selected based on the result of the assessment.

4.3 Hydrology Model Calibration and Validation

The calibration of the LSPC watershed hydrology model involved comparing simulated stream flows to the USGS flow stations. The calibration of the hydrologic parameters was performed from January 1, 1997 through December 31, 2009. The best available gages were used as hydrology calibration stations. The validation stations did not have the best hydrology data, and potential data problems included short period of records, tidally influenced stations, and upstream control structures. A rating system was applied to the calibration and validations stations to determine the overall calibration success. A weighted score was assigned to simulated verse observed errors, with total flow, storm flow, and low flow volumes having the greatest weight. The summation of the weighted scores was assigned a qualitative descriptor of Very Good (VG), Good (G), Fair (F), or Poor (P). The highest possible score was 80 and the lowest possible score was 20. Scores from 80-76 were rated as VG, 75-56 G, 55-36 F, and 35-20 P.

Model calibration utilized a top-down approach, i.e. upstream watershed gages were calibrated before downstream calibration gages. This methodology allowed for isolation of individual hydrologic soil groups and land uses. However, if gages had similar hydrologic soils groups and land uses, calibration priority was given to the most downstream gage on major rivers. Both visual and statistical metrics were utilized during calibration. Emphasis was on total flow, storm flow, and low flow volumes, and ensuring that storm peaks, recession curves, and baseflows visually represented the measured USGS flow data.

Initial parameter selection was based on modeling parameter recommendations in BASINS Technical Note 6 (USEPA 2006). Parameters were then adjusted within the BASINS Technical Note 6 typical minimum and maximum ranges for both hydrologic soil group and land use. Parameters were not adjusted outside the possible minimum and maximum ranges. To calibrate, information on the watersheds' topography, geology, climate, land use, and anthropogenic influences was researched. This data was used to assist in parameter adjustment. Results of the hydrologic model calibrations are presented in section 4.4 Hydrology Model Calibration and Validation.

Table 4.2-1 USGS flow gages used for calibration in the Crystal watershed.

Station ID	Station Name	Drainage Area (mi^2)	Begin Date	End Date
02310000	ANCLOTE RIVER NEAR ELFERS FL	72	1/1/1996	12/31/2009

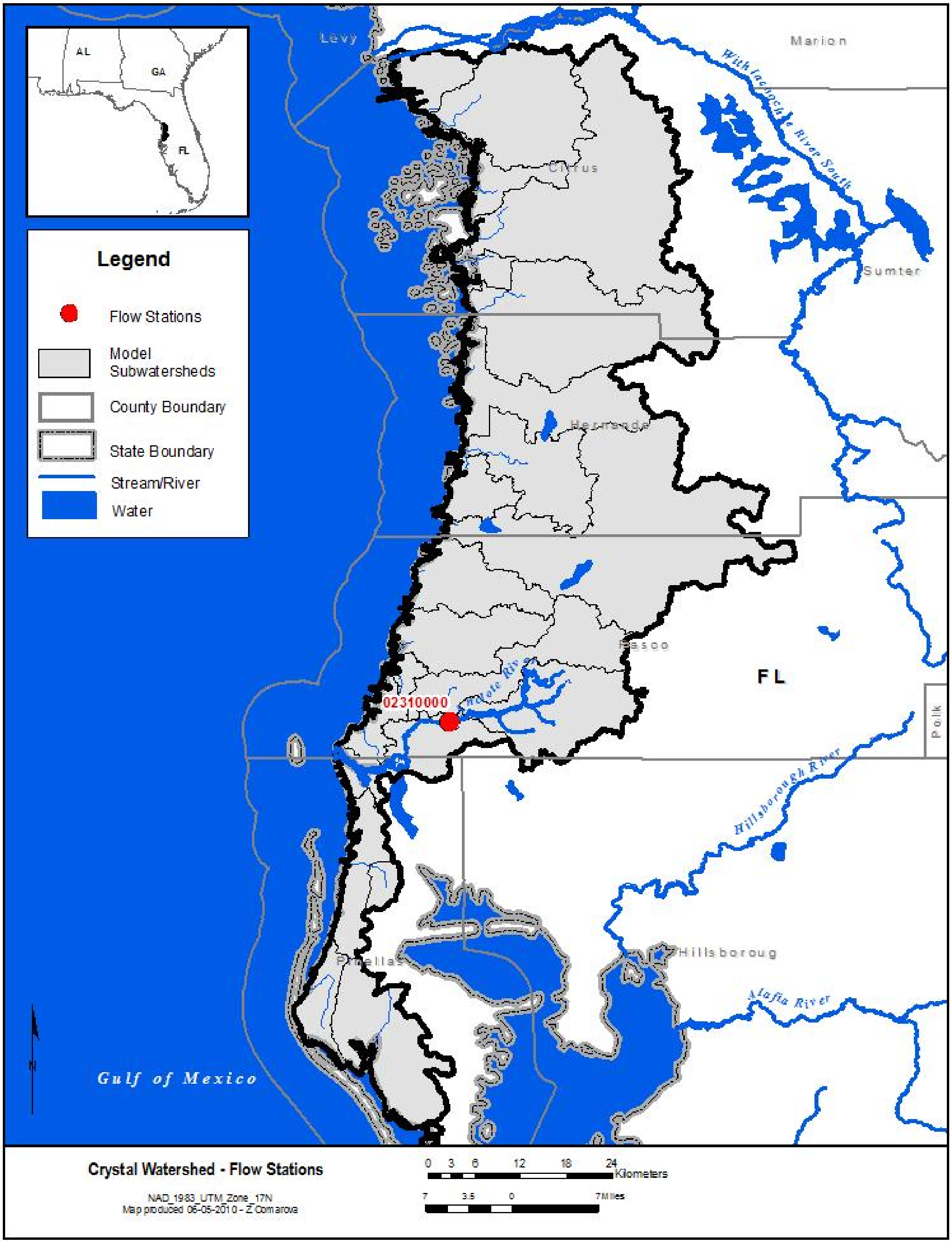

Figure 4.2-1 Calibration and validation stations used in the Crystal hydrology model

4.4 Hydrology Model Calibration and Validation Results

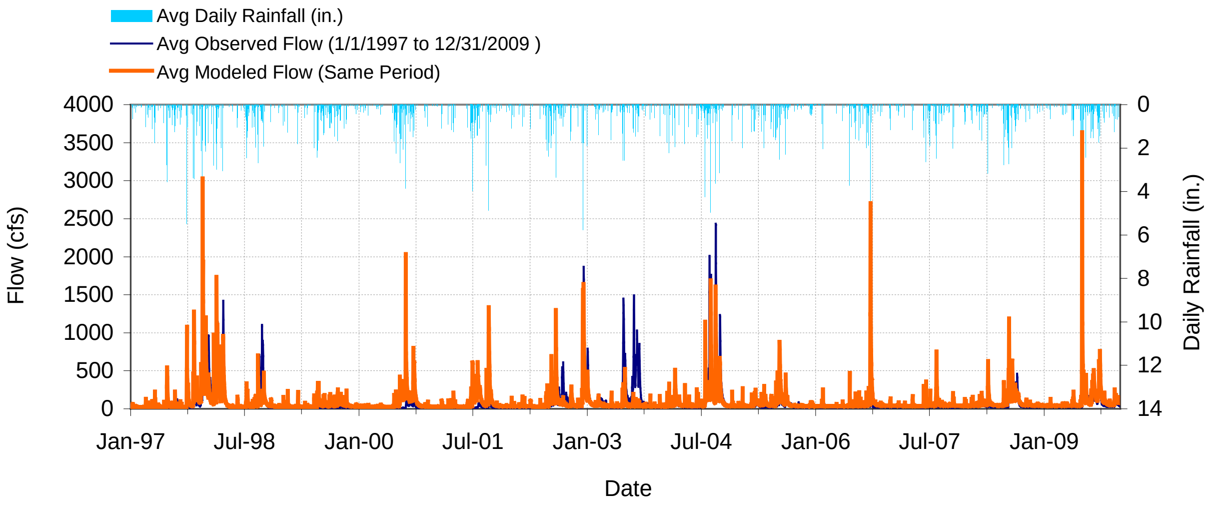

Figure 4.4-1 Mean daily flow: Model Outlet 140014 vs. USGS 02310000 Anclote River near Elfers, FL.

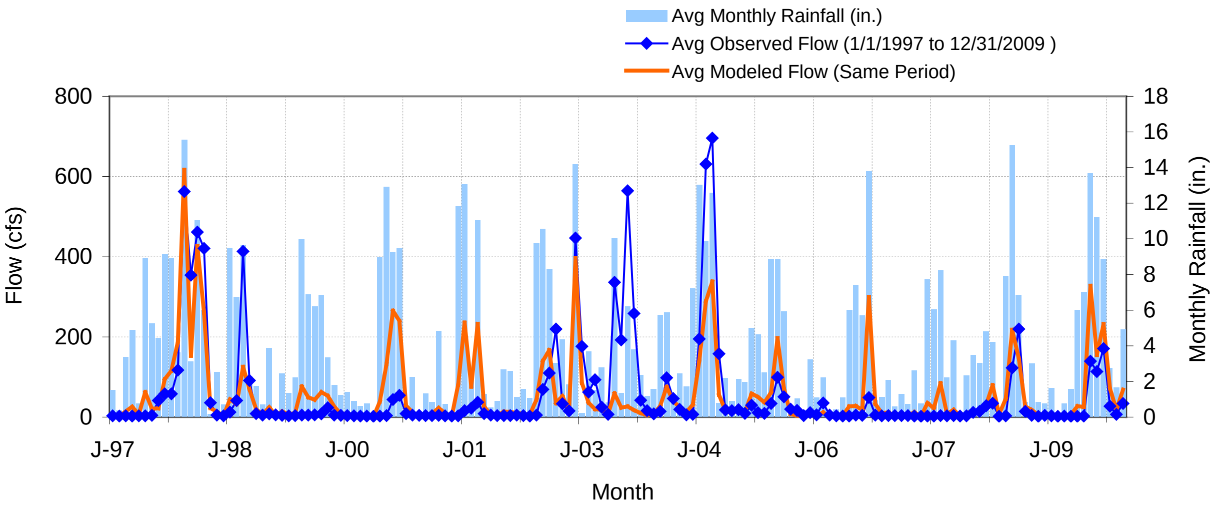

Figure 4.4-2 Mean monthly flow: Model Outlet 140014 vs. USGS 02310000 Anclote River near Elfers, FL.

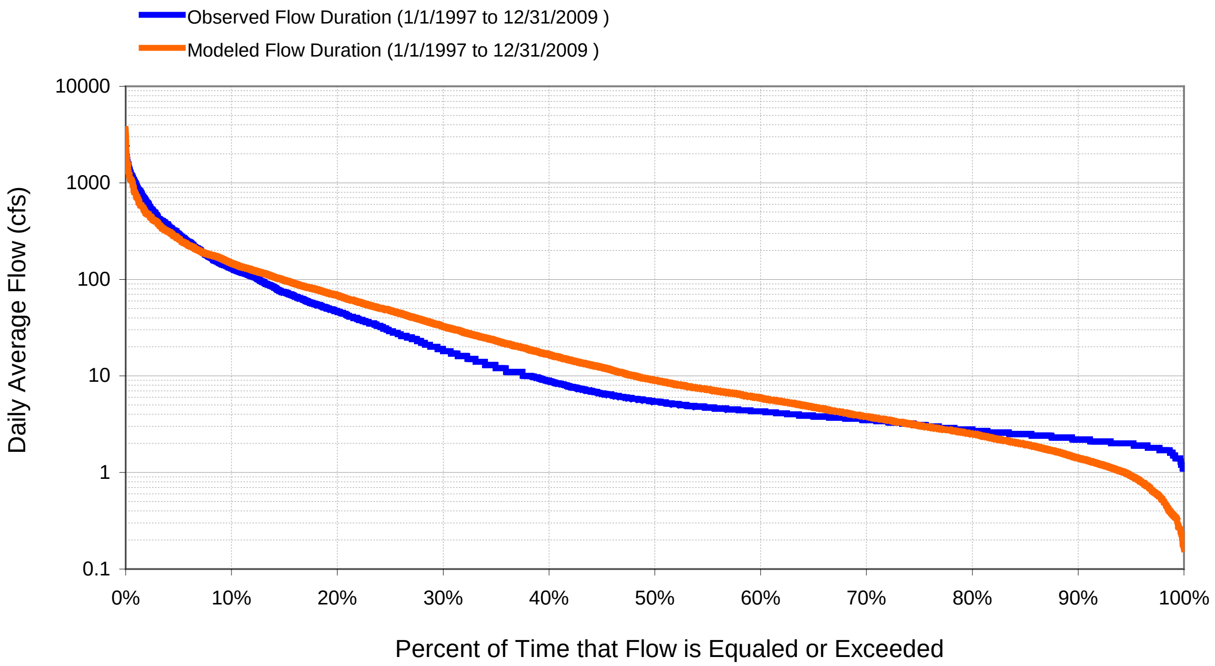

Figure 4.4-3 Flow exceedance: Model Outlet 140014 vs. USGS 02310000 Anclote River near Elfers, FL.

Table 4.4-1 Summary statistics: Model Outlet 140014 vs. USGS 02310000 Anclote River near Elfers, FL.

Category	LSPC Simulated Flow*	Observed Flow Gage**	Error Statistic (%)	Recommended Criteria	Score
Total Simulated In-stream Flow	11.05	10.92	1.22	10	16
Total of Simulated Highest 10% Flows	7.25	8.19	11.70	10	9
Total of Simulated Lowest 50% flows	0.34	0.30	-11.53	15	12
Simulated Summer Flow Volume	5.67	5.69	-0.46	30	8
Simulated Fall Flow Volume	2.48	2.19	13.21	30	8
Simulated Winter Flow Volume	1.73	2.32	-25.65	30	8
Simulated Spring Flow Volume	1.18	0.72	65.01	30	2
Total Simulated Storm Value	5.05	3.58	41.29	20	1
Simulated Summer Storm Value	2.55	1.97	29.34	50	4

*LSPC Simulated Reach Outflow from Subbasin 140014.
**Observed Flow Gage from USGS 02310000 ANCLOTE RIVER NEAR ELFERS FL
13-Year Analysis Period: 01/01/1997 – 12/31/2009

Nash-Sutcliffe Coefficient of Efficiency – 0.037
Baseline adjusted coefficient (Garrick) – 0.281
Total Score – 68 Rating – “G”

5.0 Watershed Water Quality Model

5.1 Water Quality Model Overview

Once the LSPC watershed hydrology model was calibrated, the LSPC model was used to simulate water quality in the Crystal watershed. Many components needed for the setup of the water quality model were established during the setup of the hydrology model. These components include watershed segmentation, meteorological data, land use representation, soils, reach characteristics, and point source discharges.

5.2 Modeled Parameters

The LSPC water quality model was set up to model water temperature (TEMP), dissolved oxygen (DO), biochemical oxygen demand (BOD), total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS).

5.3 Observed Water Quality Data

Water quality data provided by FDEP was used to calibrate water quality at the selected hydrology calibration USGS flow gages. The FDEP provided their Impaired Waters Rule (IWR version 40) Database which consists of data provided by several organizations at 66,683 water quality stations in Florida. From the database, the water quality stations situated at the same locations as the USGS flow gages with the best overall dataset were selected for water quality calibration. In some instances, no one water quality station associated with a USGS flow gage provided an adequate water quality data set. In these situations, more than one water quality station associated with the gage was selected to provide a more comprehensive data set for the water quality calibration. Selected water quality calibration and validation stations are presented in Tables 5.3-1 and Figure 5.3-1

5.4 Water Temperature

In-stream temperature is an important parameter for simulating biochemical transformations. LSPC models in-stream temperatures by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF modules used to represent water temperature include PSTEMP (soil temperature) and HTRCH (heat exchange and water temperature). A detailed description of relevant temperature algorithms is presented in the HSPF (v12) User’s Manual (Bicknell et al. 2004).

Simulation of soil temperatures is accomplished by simulating water temperatures from the surface layer, upper subsurface layer, and groundwater subsurface layer. The surface determines the overland flow water temperature, the upper subsurface layer determines interflow temperature, and the groundwater subsurface layer determines groundwater temperature. Surface and upper subsurface layer temperatures were estimated by applying a regression equation as a function of measured air temperature and the groundwater subsurface temperature was given a temperature which reflected the mean average earth temperature for South Georgia.

Data for determining surface and upper subsurface regression equations was obtained from the Georgia Automated Environmental Monitoring Network at Attapulgus, GA. Data obtained included the measured daily average surface layer soil temperature and measured air temperature. The average surface layer soil temperature was manipulated by a multiplier and an offset to estimate a theoretical upper subsurface layer temperature. Monthly regression equations for surface and upper subsurface layers were set up using air temperature as the independent variable and layer temperature as the dependent variable. This allowed the use of air temperature as the input to the regression equation and the corresponding layer temperature was the output.

Soil temperature is only used to determine the water temperature of the three different flow paths (surface outflow, upper subsurface/interflow outflow, lower subsurface/groundwater outflow) contributing to stream flow. Once the water is in the stream, the temperature mass is impacted by mechanisms that can increase or decrease the heat content of the water. Mechanisms which can increase the heat content of the water are absorption of solar radiation, absorption of longwave radiation, and conduction-convection. Mechanisms which decrease the heat content are emission of longwave radiation, conduction-convection and evaporation (Bicknell et al. 2004).

5.5 Dissolved Oxygen and Biological Oxygen Demand

LSPC models in-stream dissolved oxygen by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF modules used to represent dissolved oxygen include PWTGAS (pervious water temperature and dissolved gas concentrations), IWTGAS (impervious water temperature and dissolved gas concentrations), and OXRX (primary DO and BOD balances). A detailed description of relevant temperature algorithms is presented in the HSPF (v12) User’s Manual (Bicknell et al. 2004). In order to accurately represent biochemical processing, temperature must be modeled because all transformation rates are temperature dependent. To calibrate dissolved oxygen, BOD was first adjusted through manipulation of BOD decay rates and sinking and benthic release of BOD material.

In addition to the BOD in-stream transformations that either consume or produce dissolved oxygen, several other factors can influence the dissolved oxygen concentrations. The water temperature greatly influences the dissolved oxygen concentrations because colder water can dissolve more gas than warmer water. In addition, the atmospheric reaeration influences dissolved concentrations through water temperature, water depth, water velocity, circulation, reaeration rate, and a temperature correction coefficient for surface gas invasion. LSPC allows for user defined dissolved oxygen concentrations in inter-flow and groundwater by land use and month.

5.6 Sediment

LSPC models sediment by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF modules used to represent sediment include SEDMNT (pervious production and removal of sediment), SOLIDS (accumulation and removal of solids), and SEDTRN (behavior of inorganic sediment). A detailed description of relevant sediment algorithms is presented in the HSPF (v12) User’s Manual (Bicknell et al. 2004). The sediment calibration was achieved by adjusting parameters of the soil detachment equation and the rate at which the detached soil is washed off of the land surface. In addition, land use cover can prevent soil detachment by limiting rain drop impact, and land use cover was adjusted as necessary.

5.7 Nutrients

LSPC models nutrients by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF module used to represent nutrients was GQUAL. A detailed description of relevant nutrient algorithms is presented in the HSPF (v12) User’s Manual (Bicknell et al. 2004).

The determination of nonpoint source loadings to a waterbody is determined through accumulation and wash-off rates. The watershed model must appropriately represent the spatial and temporal variability of hydrological characteristics within a watershed. It must also appropriately represent the rate at which nutrient components build-up between rain events and wash off during rain events. Key general water quality characteristics include initial storage, wash-off and scour potency, accumulation rates, and maximum storage amounts. In addition, nutrients are influenced by the water supplied to a stream from groundwater and interflow. LSPC allows the user to supply groundwater and interflow concentrations, by hydrologic soil group and land use, by month. The accumulation and wash-off and interflow strongly influence peak flow water quality while groundwater reflects baseflow water quality.

5.8 Water Quality Model Calibration and Validation

The calibration of the LSPC water quality model involved comparing simulated water quality concentration and loads to the measured water quality concentrations and loads. The calibration of the water quality parameters was performed from January 1, 1997 through December 31, 2009. Water quality stations used for model calibration were co-located with hydrology stations used for model calibration and validation.

Similar to the watershed hydrology calibration, the water quality calibration utilized a top-down approach, i.e. upstream water quality stations were calibrated before downstream water quality stations. This methodology allowed for isolation of individual hydrologic soil groups, land uses, and reach groups. However, if stations had similar hydrologic soils groups, land uses, and/or reach groups, calibration priority was given to the most downstream station on major rivers.

Measured water quality data is dependent on several variables, such as the sampling time of day, in-stream sampling location, sample contamination, and type of laboratory analysis. Additionally, unknown events could have occurred spatially and temporally near the sampling event, such as a sanitary sewer overflow or illegal dumping. Because of these unknown variables in water quality data, it is difficult to calibrate the water quality models to every measured data point. Modeled water quality concentrations are considered to represent the measured water quality data when the modeled water quality is able to predict seasonal, baseflow, and stormflow trends in the data. Nutrient loading plots and tables were also reviewed when calibrating the water quality model to ensure the best calibration fit to the measured data.

Both visual and statistical metrics were utilized during calibration. Visual calibration was accomplished by matching the trends in the measured water quality concentration data. Loading metrics, including annual loading percent error, were utilized for statistical calibration. Annual loading was only analyzed when two or more water quality samples were taken in a given year, and measured flow data was collected that year. If no measured flow data was collected but the contributing area of the water quality station had similar land uses and soil types as the contributing area of a neighboring hydrology station, weighted measured flow was used to calculate the loadings. A rating system was applied to the percent error of the average annual loadings at the calibration and validations stations to determine the overall calibration success. The average annual loading percent error was assigned a qualitative descriptor of Very Good (VG), Good (G), Fair (F), or Poor (P). Scores from ±0-40% were rated as VG, ±40-90% G, ±90-150% F, and ±150-500% P.

Initial water quality parameters were based on previous modeling efforts in Florida along with information in BASINS Technical Notes 8 and Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (USEPA 2006 and USEPA 1985). Information on TN and TP loading and application rates for specific land uses was used to determine initial TN and TP accumulation rates and interflow and groundwater concentrations. Water quality parameters were adjusted within accepted minimum and maximum ranges for each hydrologic soil group, land use, and reach group.

Temperature, DO, and BOD were calibrated simultaneously because the DO algorithms require water temperature, and the DO and BOD algorithms are interrelated. Temperature was calibrated by adjusting surface and interflow temperature slopes and intercepts, groundwater temperature, and radiation coefficients until the simulated data closely matched observed. Following temperature calibration, dissolved oxygen and biological oxygen demand were calibrated by adjusting reaeration, DO interflow and groundwater concentration, BOD decay rate, BOD settling rate, and benthic oxygen demand. Sediment was calibrated by adjusting detachment, scour, and build-up/wash-off coefficients. The nutrient constituents were modeled by build-up/wash-off and assigning land use associated concentrations in groundwater and interflow. Adjustments were made to monthly accumulation rate, monthly storage limit, interflow concentration, and groundwater concentration for TN and TP until the simulated data was in range with the observed field data.

Results of the water quality model calibrations are presented in Sections 5.9 through 5.12. Nutrient loading analyses are presented for selected stations in section 5.13.

Table 5.3-1 Water quality stations used for calibration in the Crystal watershed.

Station ID	Data Source	Station Name	Drainage Area (mi^2)	Data Range	Data Collected
21FLGW 3509	FDEP IWR 40	ANCLOTE RIVER NEAR ELFERS FL	72	1999-2009	Temp, DO, TSS, TN, TP
21FLPCSWFL0055 000263100	FDEP IWR 40	CRYSTAL RIVER NEAR CRYSTAL RIVER FL	78	1999-2006	Temp, DO, TN, TP
112WRD 02310700	FDEP IWR 40	HOMOSASSA RIVER NEAR HOMOSASSA FL	162	1999-2006	Temp, DO, TN, TP

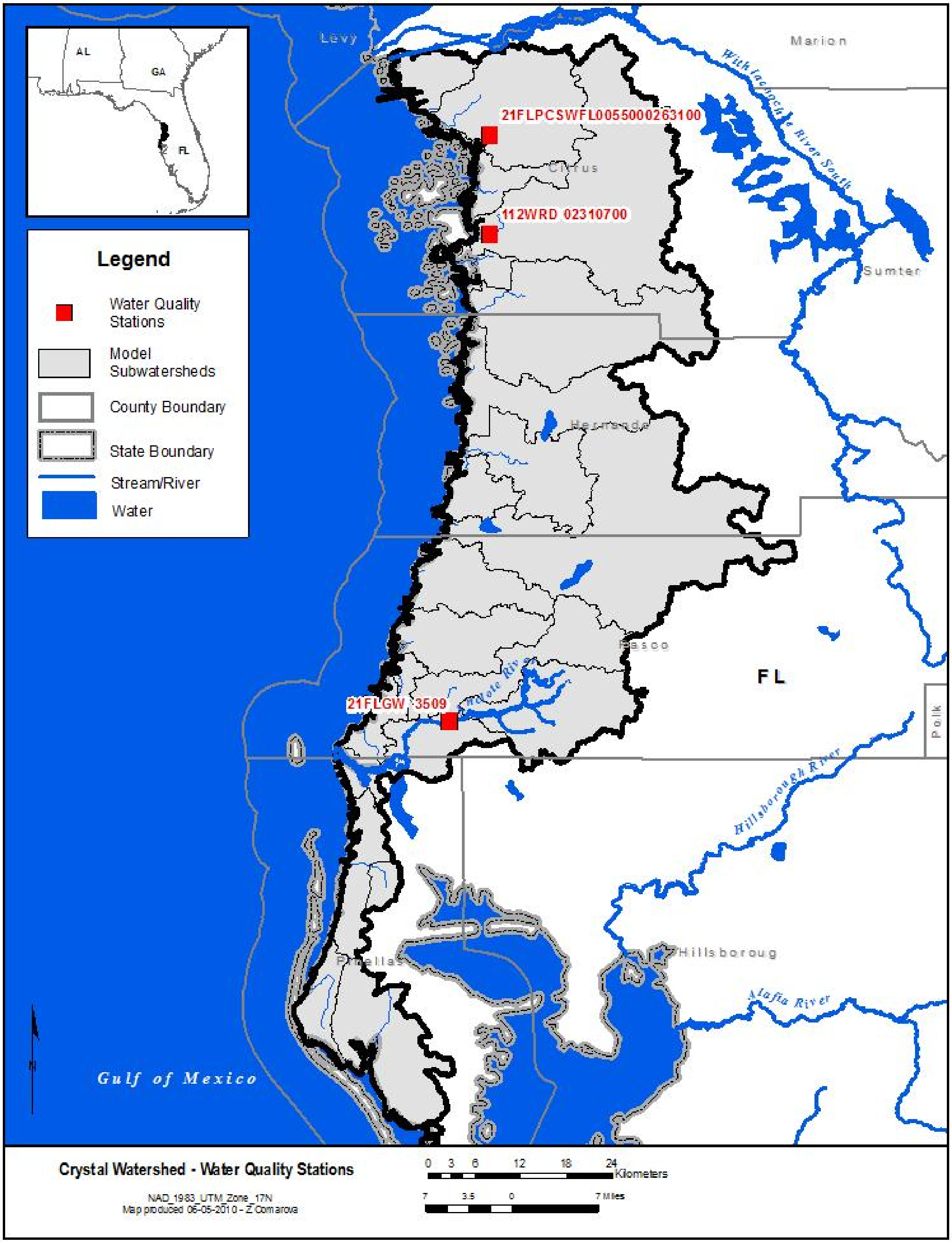

Figure 5.3-1 Calibration and validation stations used in the Crystal water quality model

5.9 Water Temperature Model Calibration and Validation Results

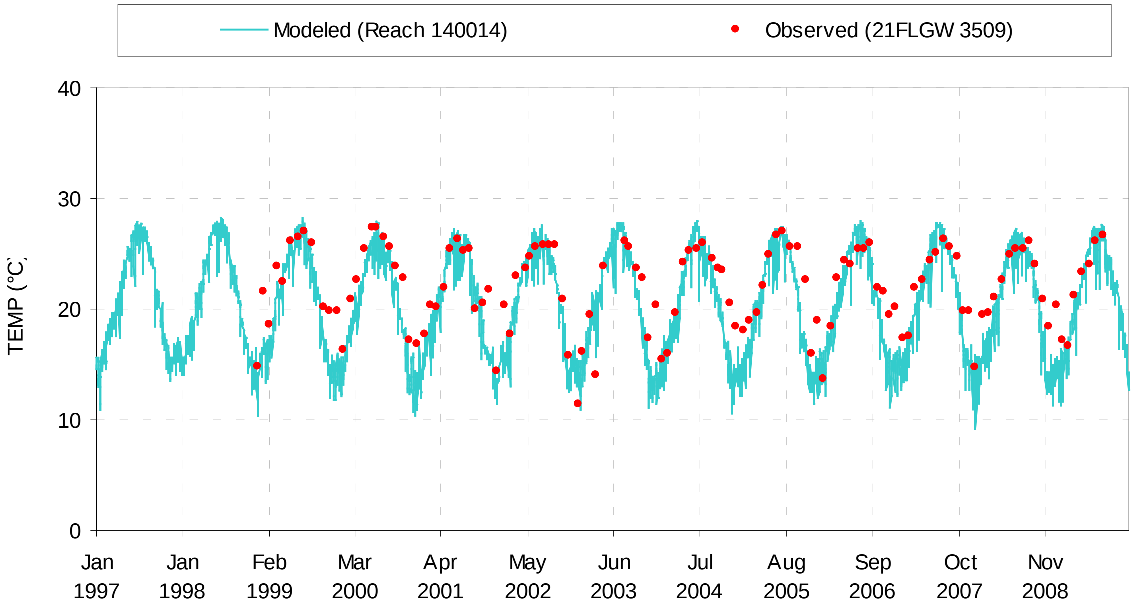

Figure 5.9-1 Modeled vs. observed temperature (°C) at 21FLGW 3509.

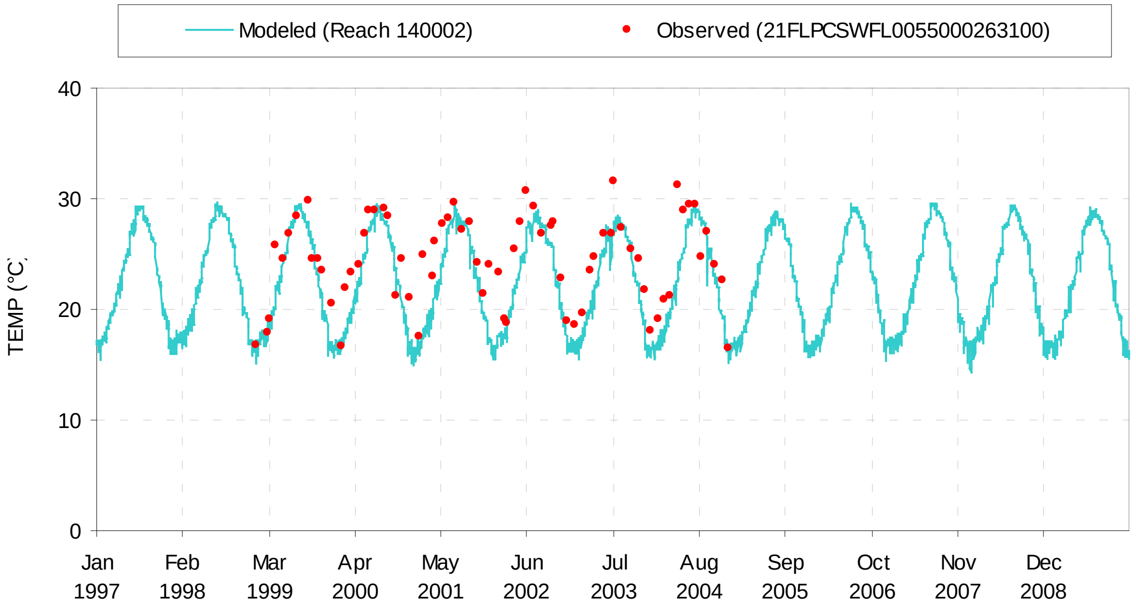

Figure 5.9-2 Modeled vs. observed temperature (°C) at 21FLPCSWFL0055000263100.

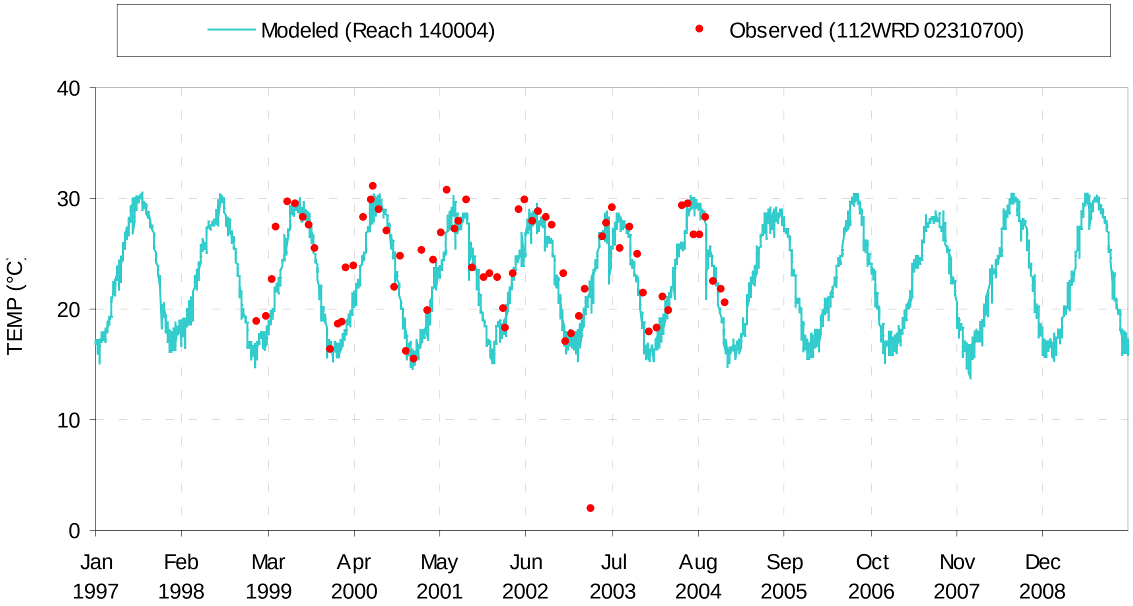

Figure 5.9-3 Modeled vs. observed temperature (°C) at 112WRD 02310700.

5.10 Dissolved Oxygen and Biological Oxygen Demand Model Calibration and Validation Results

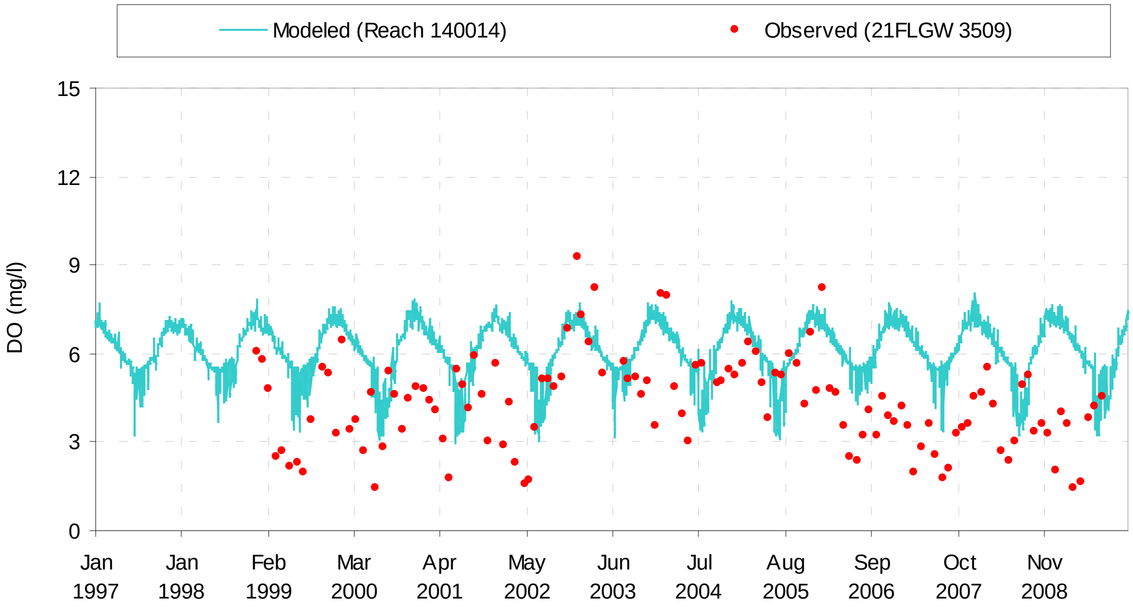

Figure 5.10-1 Modeled vs. observed DO (mg/l) at 21FLGW 3509.

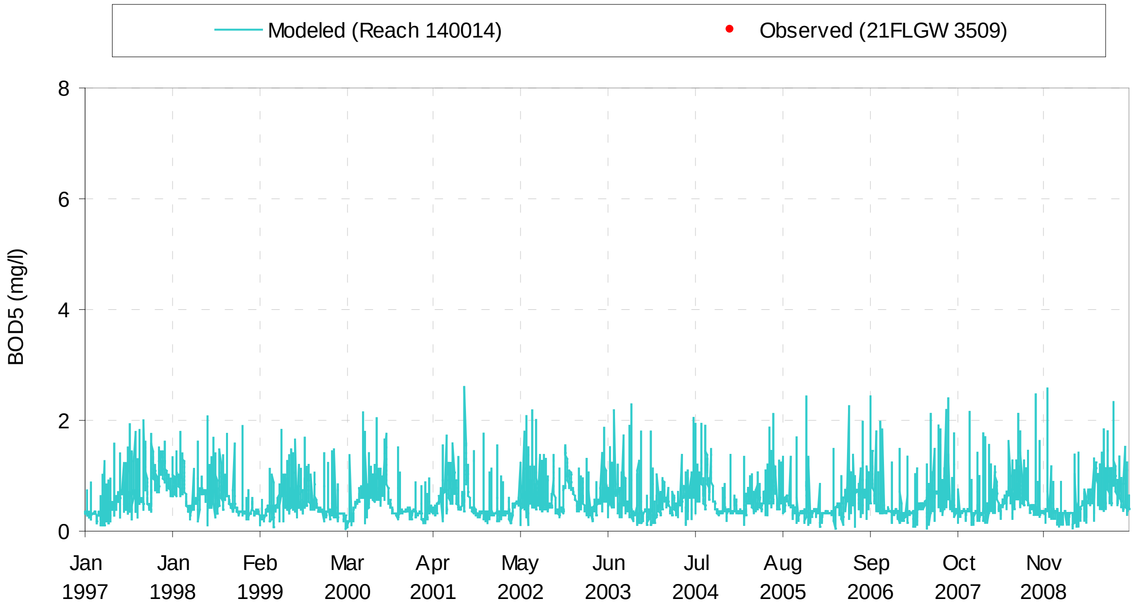

Figure 5.10-2 Modeled vs. observed BOD5 (mg/l) at 21FLGW 3509.

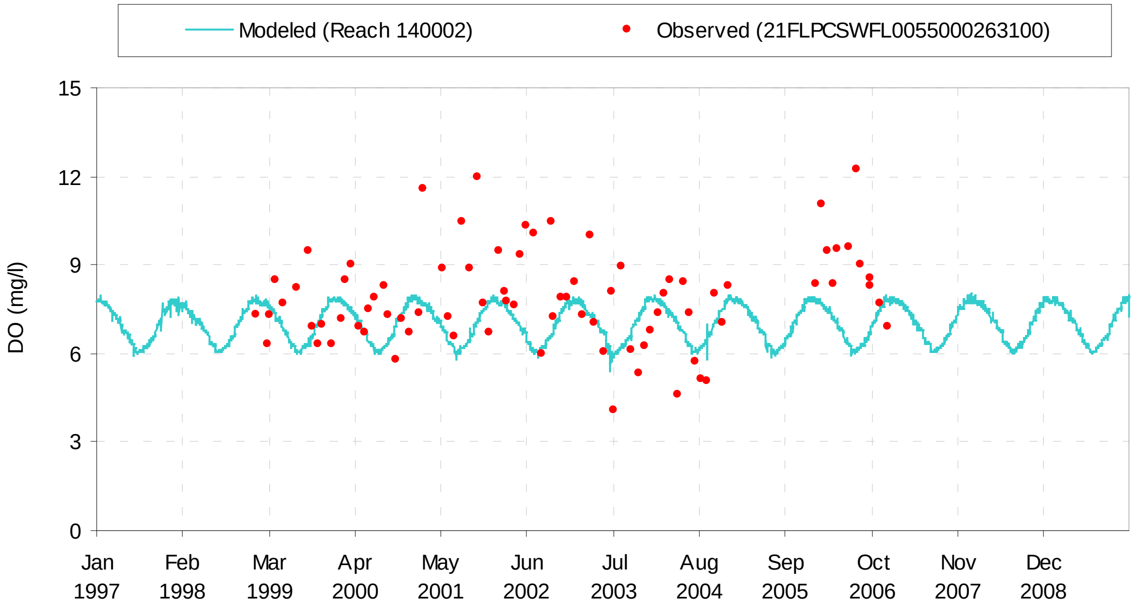

Figure 5.10-3 Modeled vs. observed DO (mg/l) at 21FLPCSWFL0055000263100.

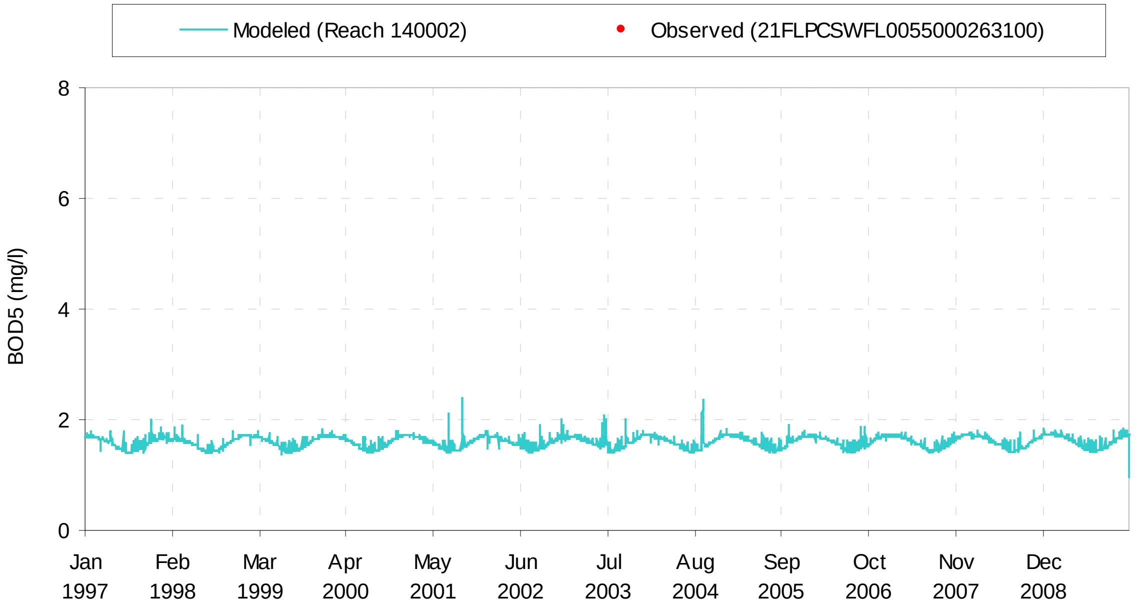

Figure 5.10-4 Modeled vs. observed BOD5 (mg/l) at 21FLPCSWFL0055000263100.

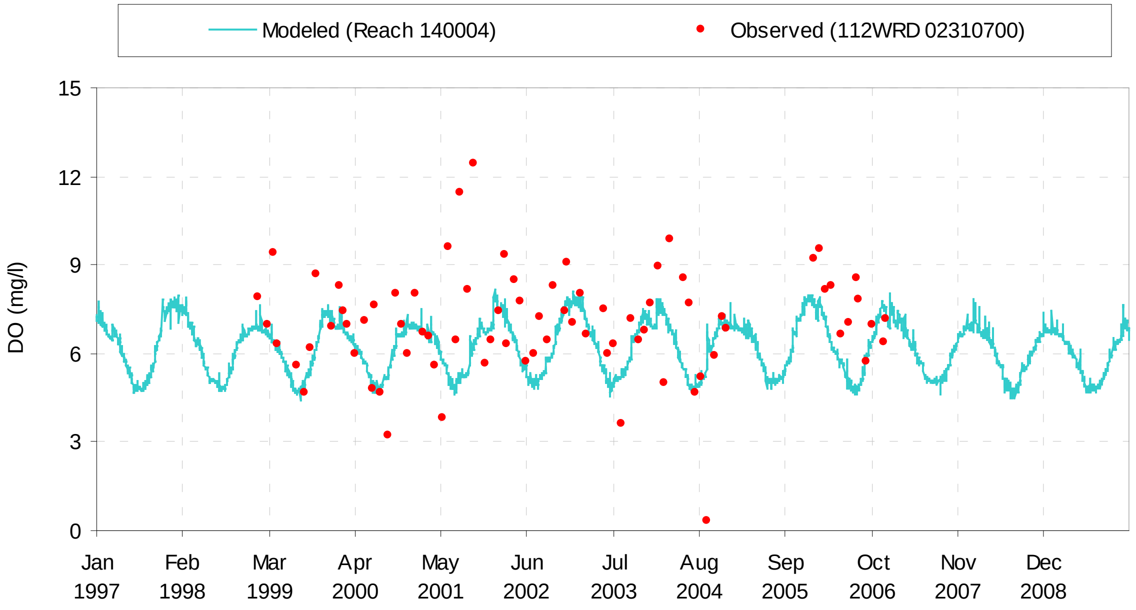

Figure 5.10-5 Modeled vs. observed DO (mg/l) at 112WRD 02310700.

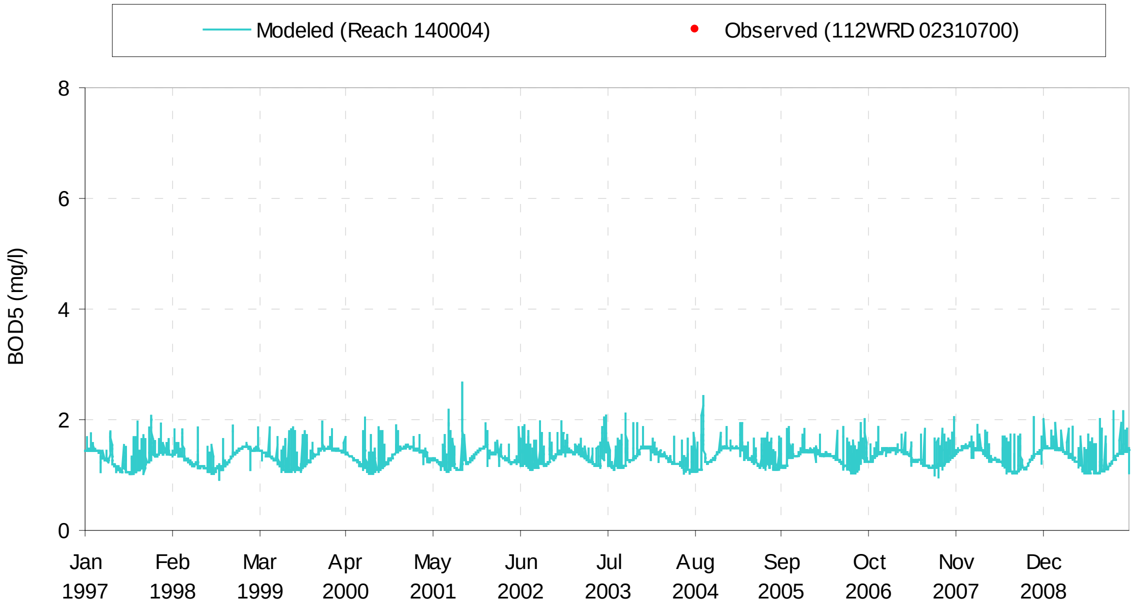

Figure 5.10-6 Modeled vs. observed BOD5 (mg/l) at 112WRD 02310700.

5.11 Sediment Model Calibration and Validation Results

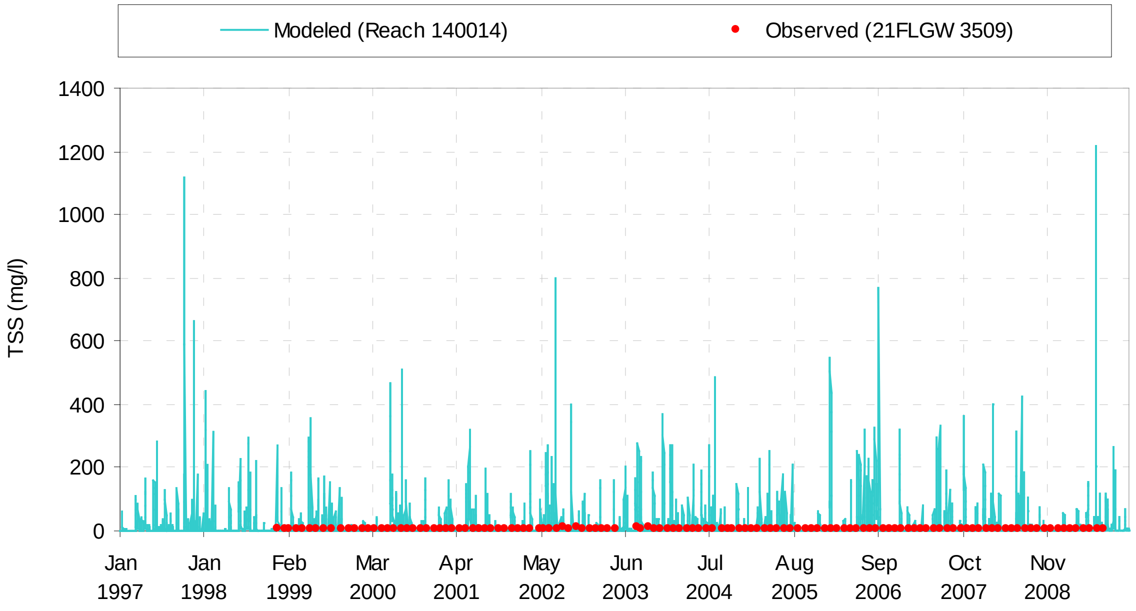

Figure 5.11-1 Modeled vs. observed TSS (mg/l) at 21FLGW 3509.

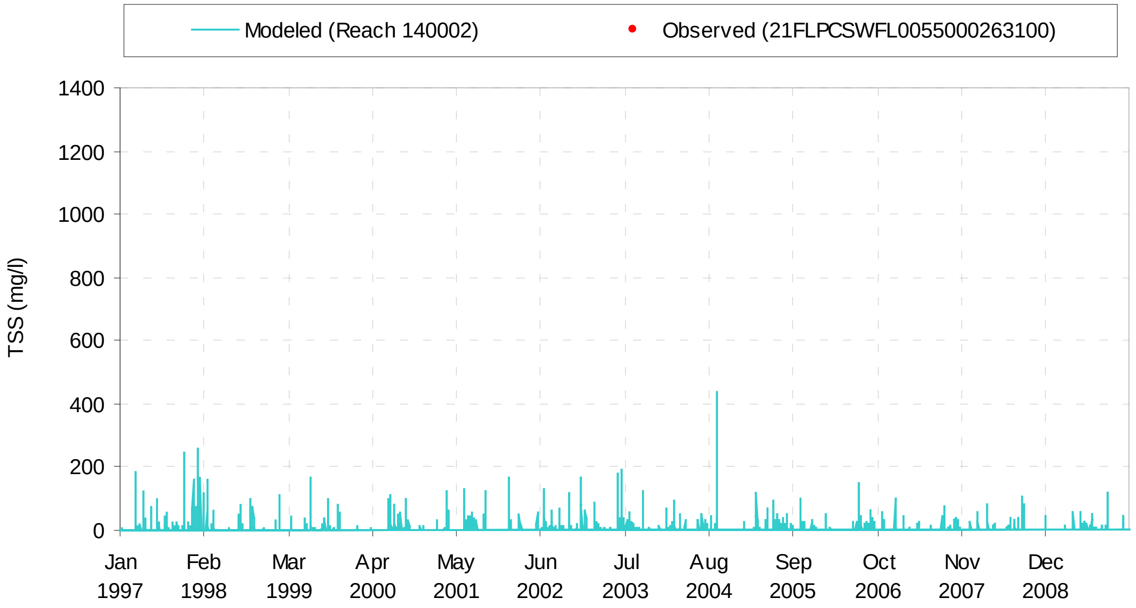

Figure 5.11-2 Modeled vs. observed TSS (mg/l) at 21FLPCSWFL0055000263100.

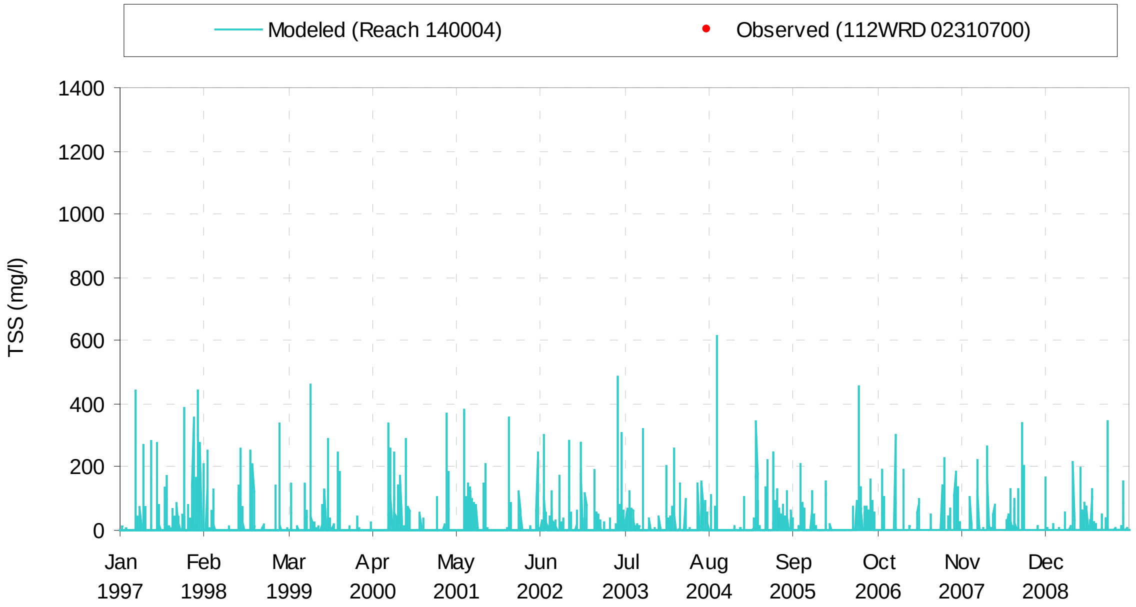

Figure 5.11-3 Modeled vs. observed TSS (mg/l) at 112WRD 02310700.

5.12 Nutrients Model Calibration and Validation Results

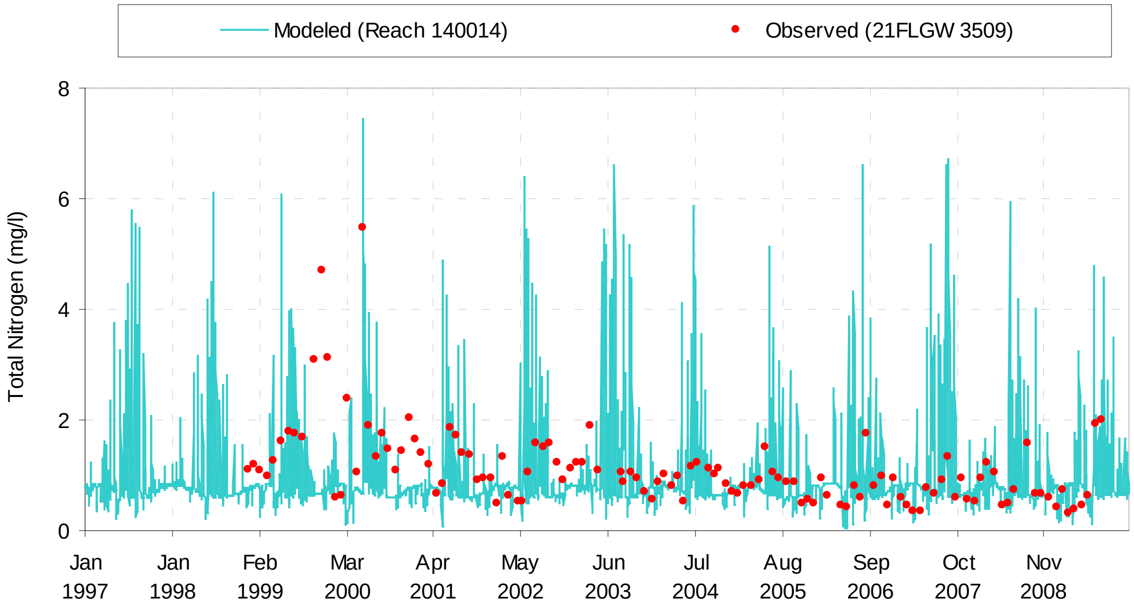

Figure 5.12-1 Modeled vs. observed total nitrogen (mg/l) at 21FLGW 3509.

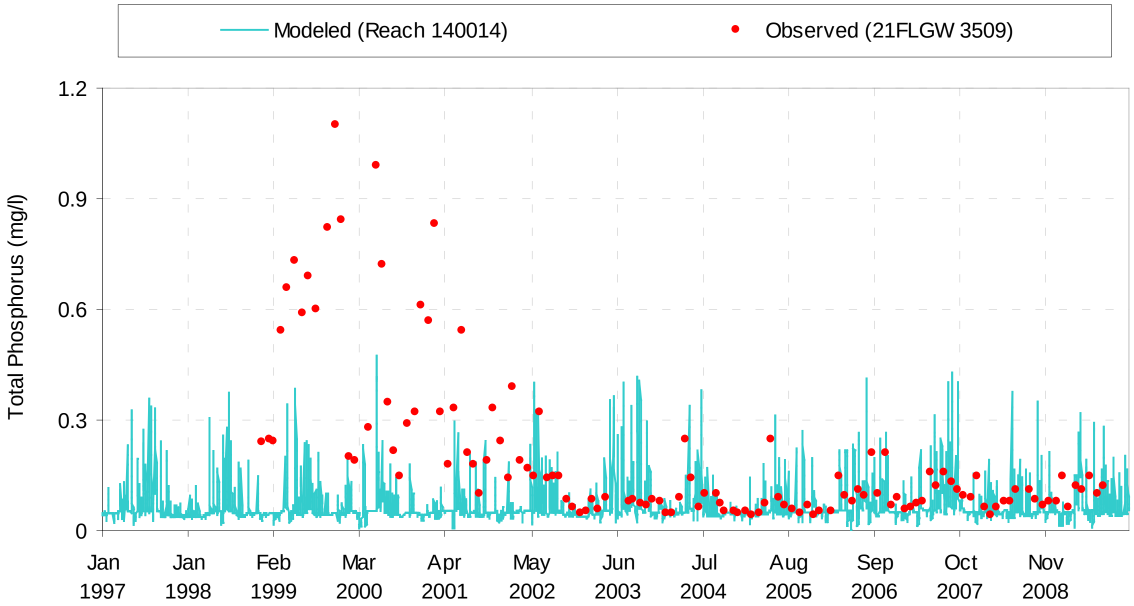

Figure 5.12-2 Modeled vs. observed total phosphorus (mg/l) at 21FLGW 3509.

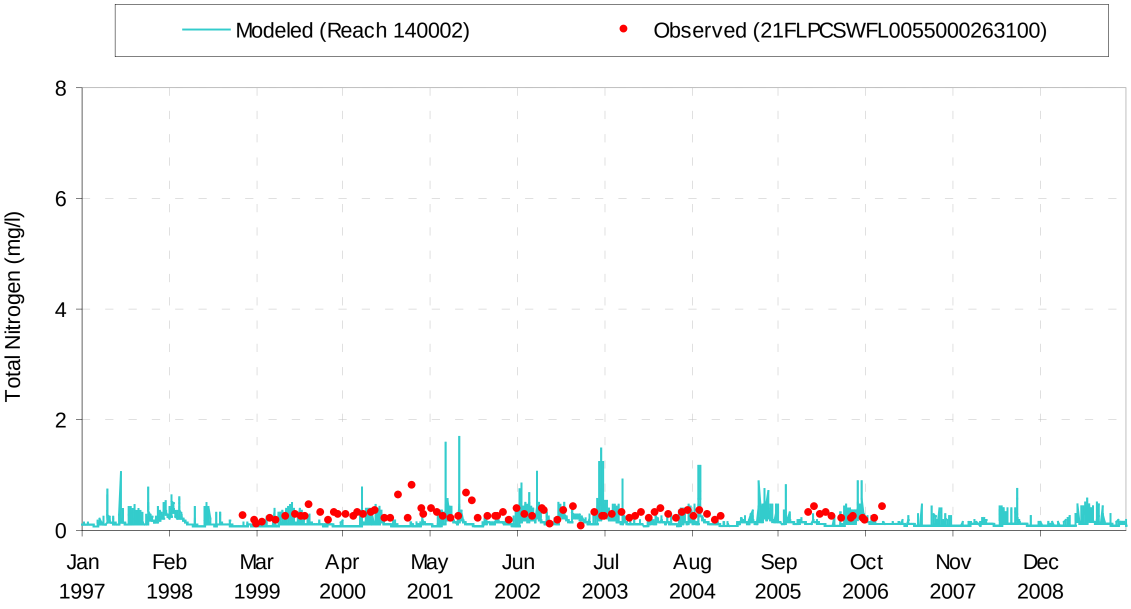

Figure 5.12-3 Modeled vs. observed total nitrogen (mg/l) at 21FLPCSWFL0055000263100.

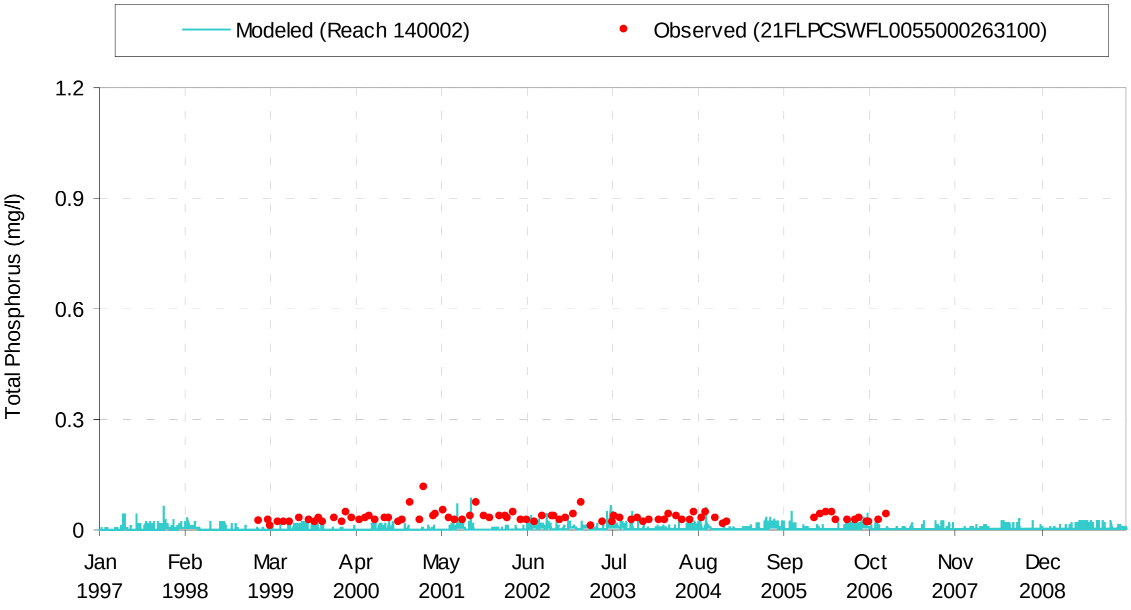

Figure 5.12-4 Modeled vs. observed total phosphorus (mg/l) at 21FLPCSWFL0055000263100.

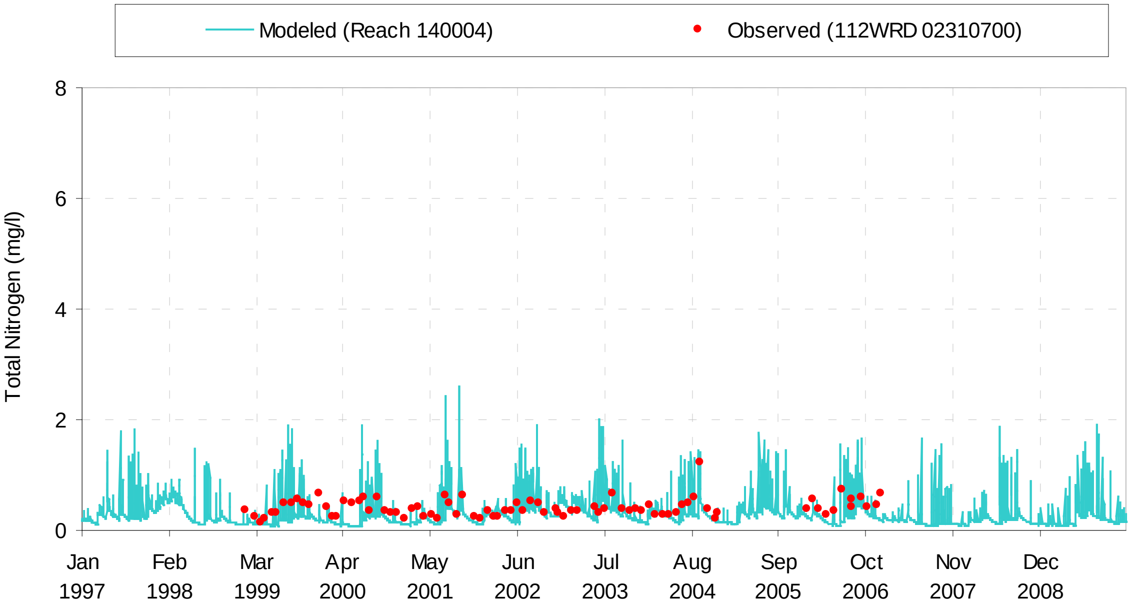

Figure 5.12-5 Modeled vs. observed total nitrogen (mg/l) at 112WRD 02310700.

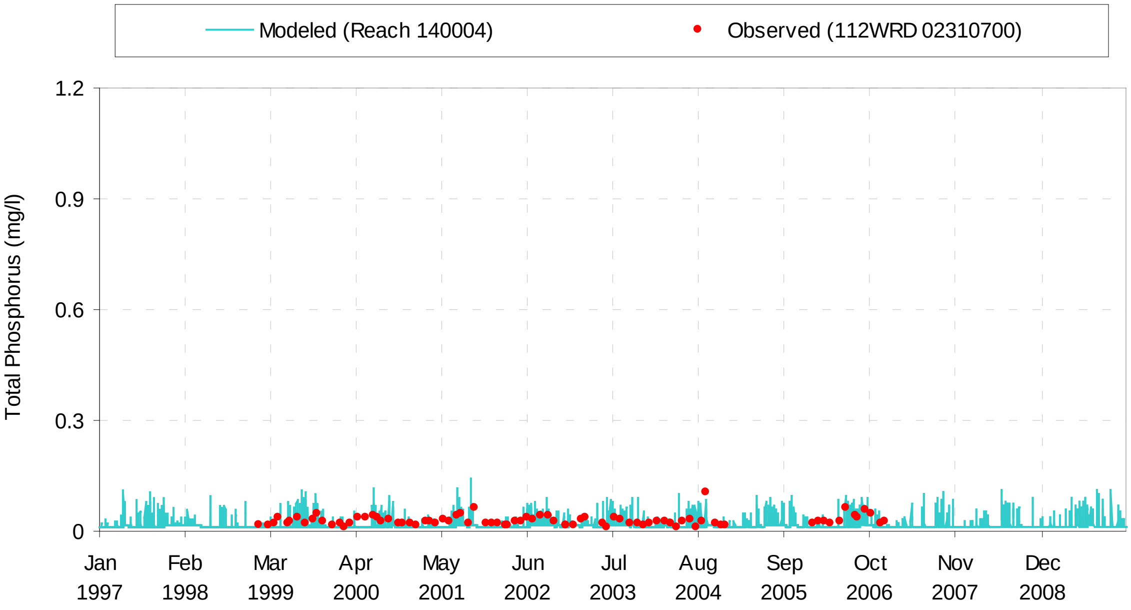

Figure 5.12-6 Modeled vs. observed total phosphorus (mg/l) at 112WRD 02310700.

5.13 Nutrients Model Loading Analysis Results

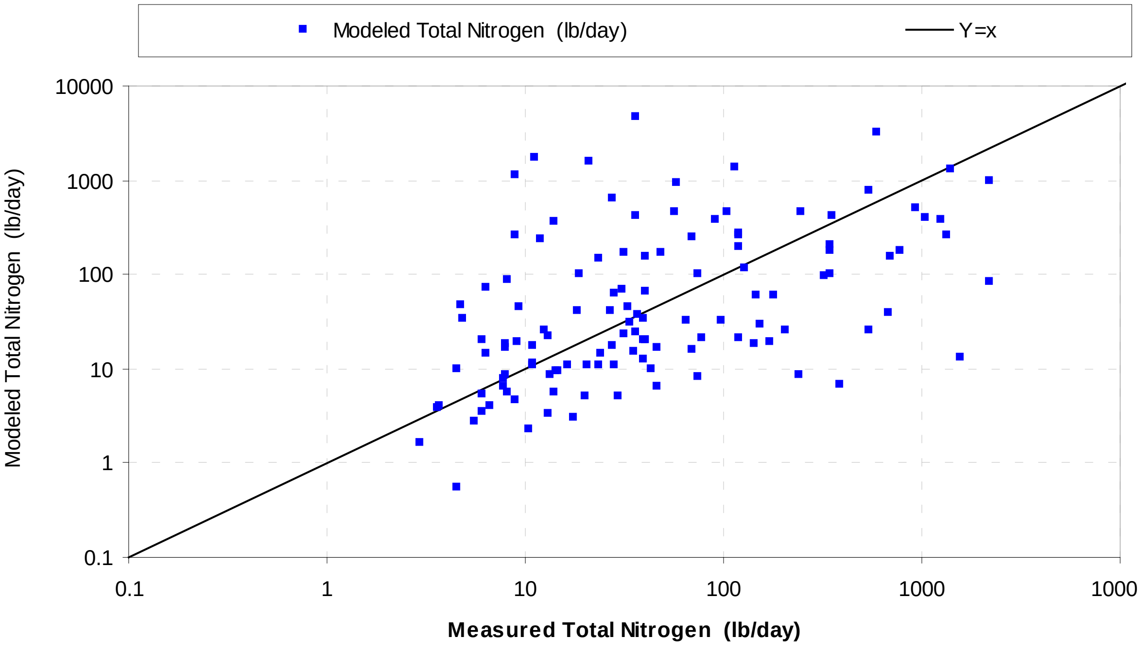

Figure 5.13-1 Total nitrogen (mg/l) load scatter plot at 21FLGW 3509.

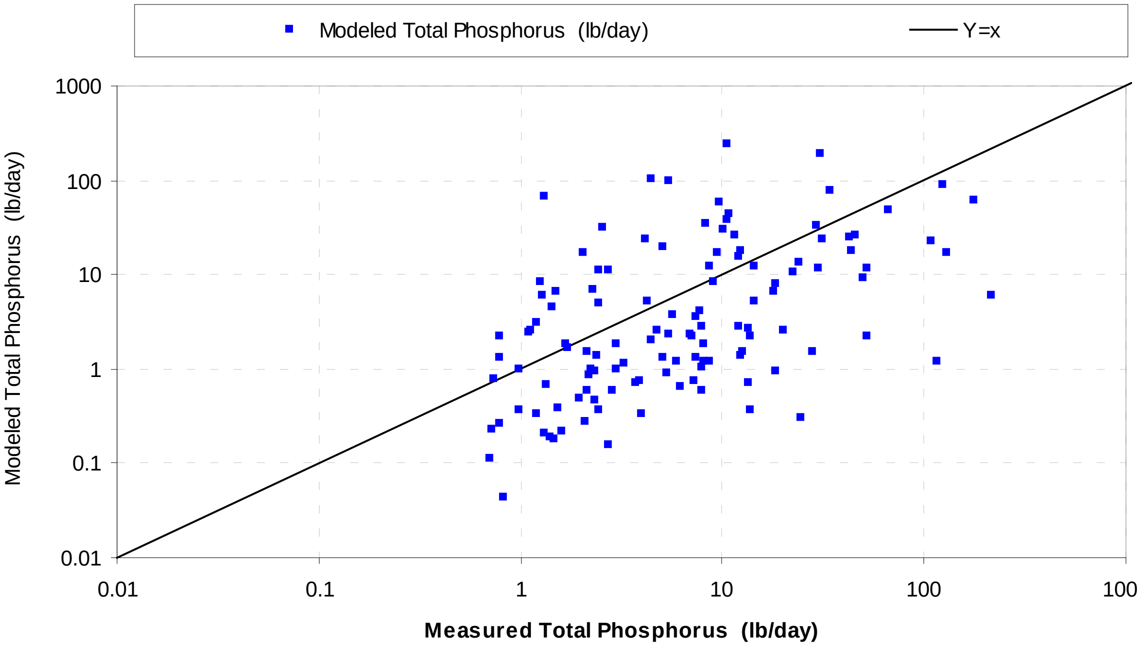

Figure 5.13-2 Total phosphorus (mg/l) load scatter plot at 21FLGW 3509.

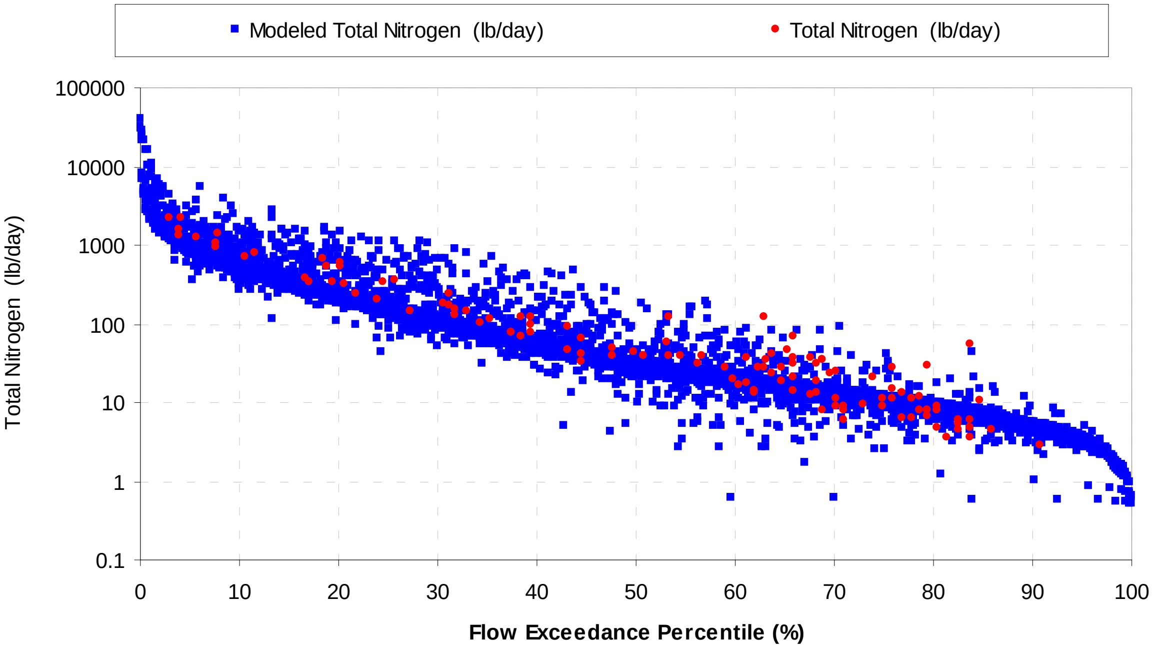

Figure 5.13-3 Total nitrogen (mg/l) load duration curve at 21FLGW 3509.

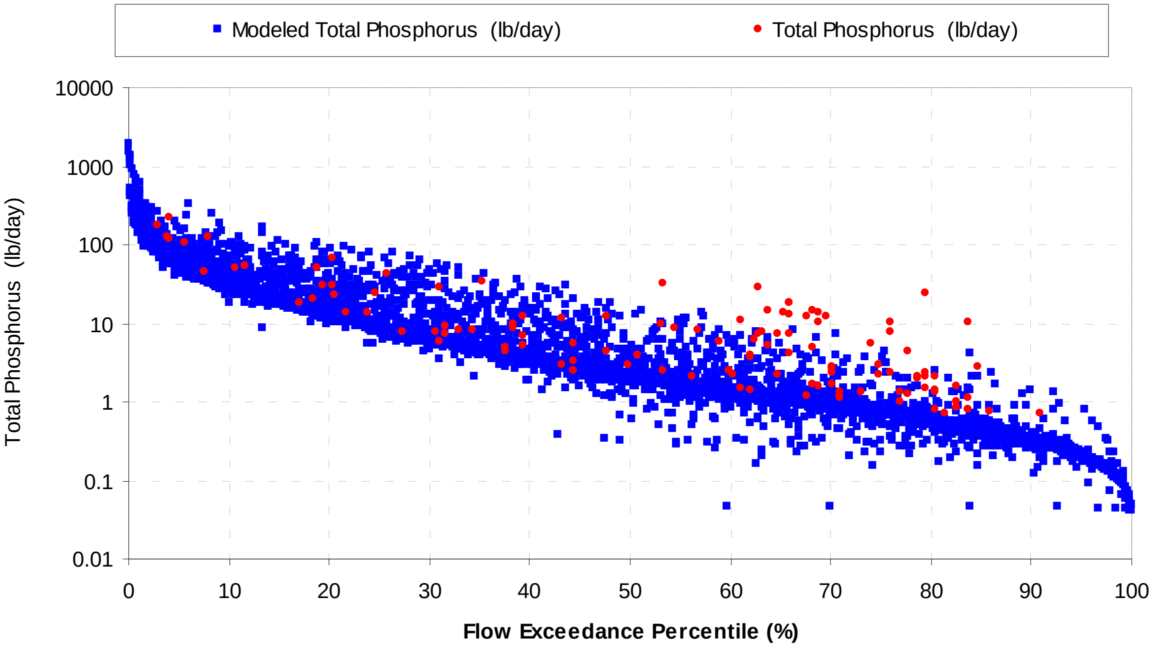

Figure 5.13-4 Total phosphorus (mg/l) load duration curve at 21FLGW 3509.

Table 5.13-1 Total nitrogen (lb/year) percent error for measured and modeled loading by year at 21FLGW 3509.

Year	Measured TN (lb/yr)	Modeled TN (lb/yr)	% Error
1997			
1998			
1999	26,835	68,481	155.2
2000	35,709	164,418	360.4
2001	26,953	138,283	413.1
2002	185,218	184,373	-0.5
2003	312,423	59,671	-80.9
2004	355,272	209,589	-41.0
2005	48,735	104,334	114.1
2006	20,349	112,065	450.7
2007	4,205	53,796	1179.2
2008	88,183	132,658	50.4
2009			
Average	110,388	122,767	11.2

Rating – VG

Table 5.13-2 Total phosphorus (lb/year) percent error for measured and modeled loading by year at 21FLGW 3509.

Year	Measured TP (lb/yr)	Modeled TP (lb/yr)	% Error
1997			
1998			
1999	8,260	4,715	-42.9
2000	6,876	9,660	40.5
2001	4,833	8,414	74.1
2002	16,747	10,823	-35.4
2003	22,739	3,955	-82.6
2004	28,654	12,122	-57.7
2005	4,092	6,307	54.1
2006	2,258	7,004	210.2
2007	618	3,535	472.0
2008	7,678	7,863	2.4
2009			
Average	10,275	7,440	-27.6

Rating – VG

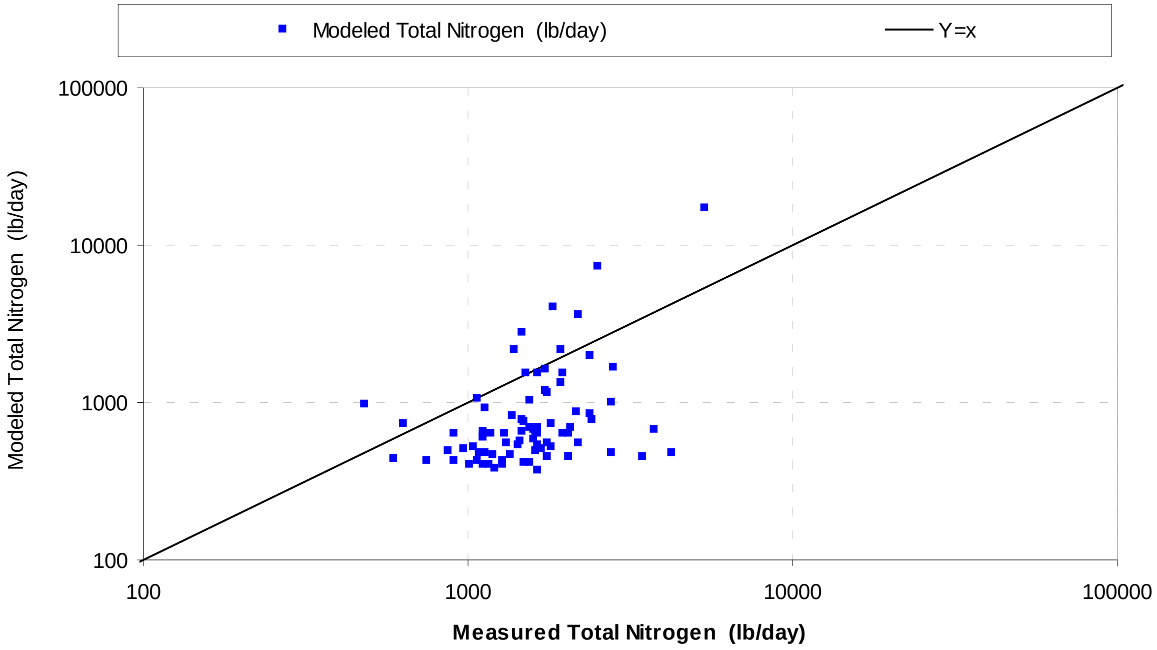

Figure 5.13-5 Total nitrogen (mg/l) load scatter plot at 21FLPCSWFL0055000263100.

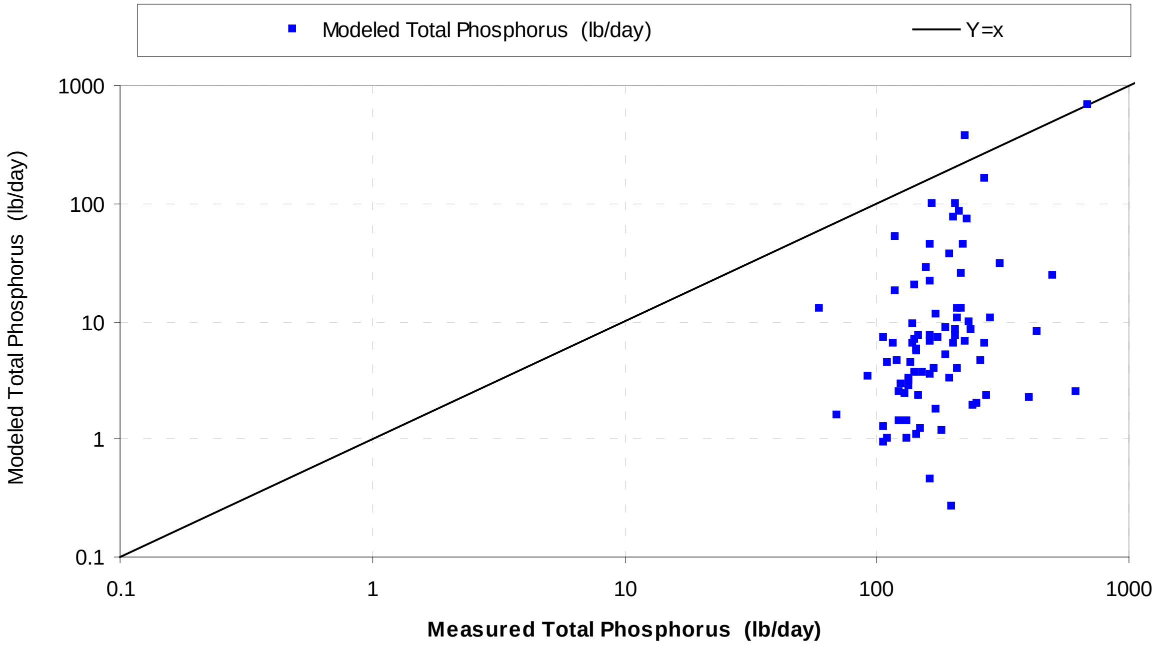

Figure 5.13-6 Total phosphorus (mg/l) load scatter plot at 21FLPCSWFL0055000263100.

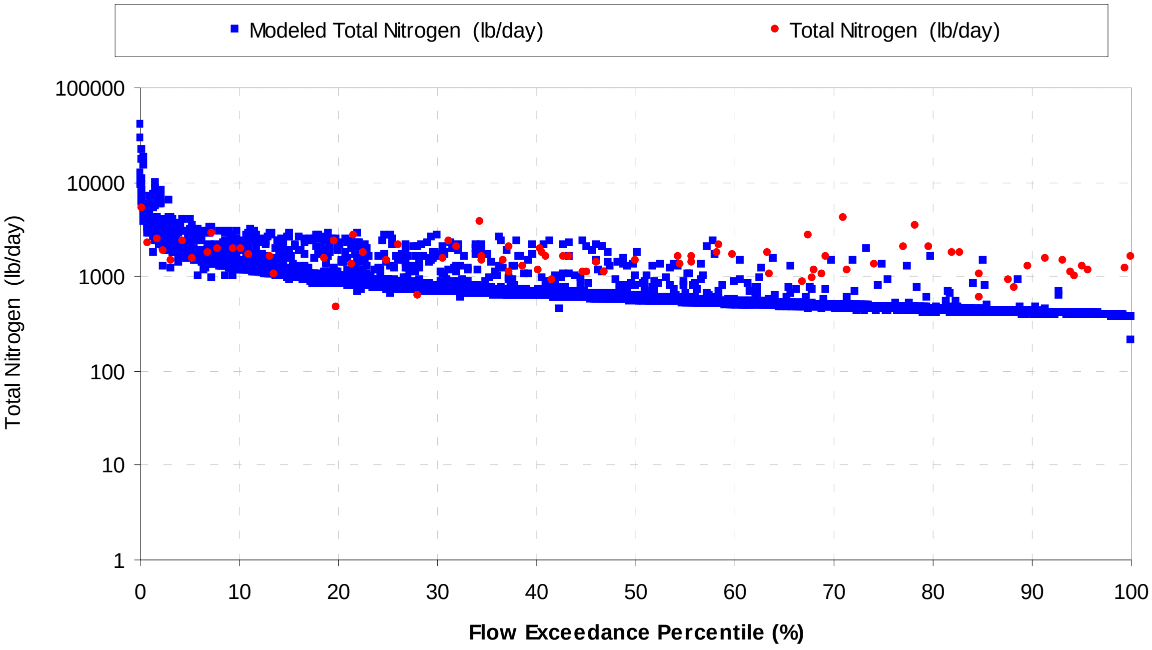

Figure 5.13-7 Total nitrogen (mg/l) load duration curve at 21FLPCSWFL0055000263100.

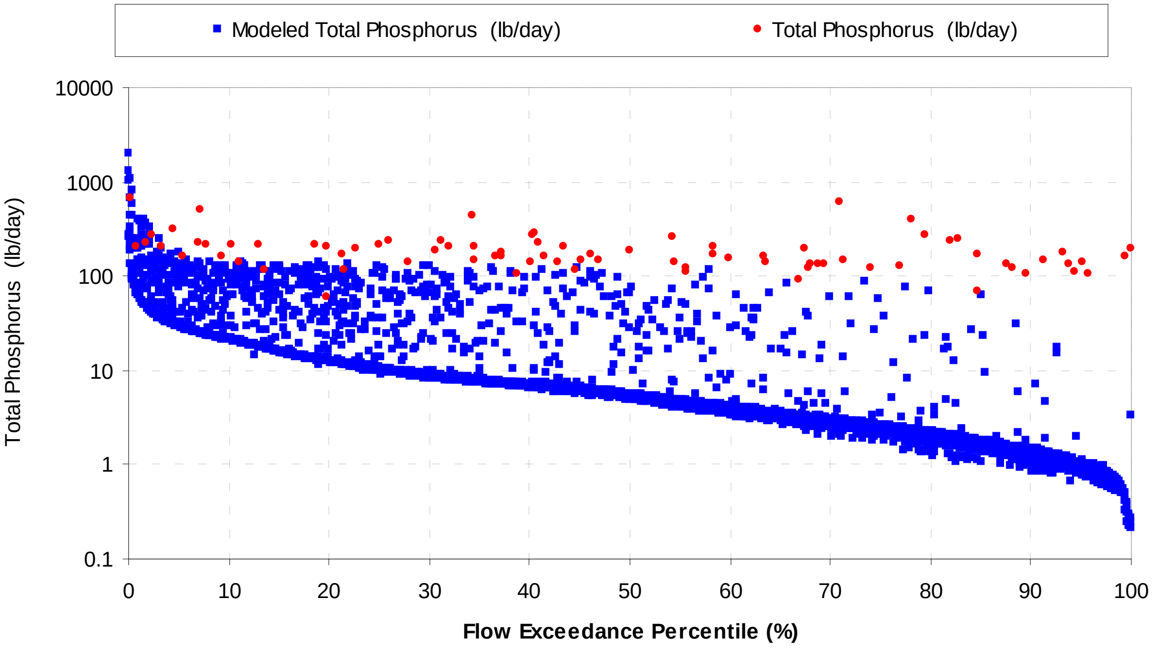

Figure 5.13-8 Total phosphorus (mg/l) load duration curve at 21FLPCSWFL0055000263100.

Table 5.13-3 Total nitrogen (lb/year) percent error for measured and modeled loading by year at 21FLPCSWFL0055000263100.

Year	Measured TN (lb/yr)	Modeled TN (lb/yr)	% Error
1997			
1998			
1999	501,804	241,456	-51.9
2000	609,679	234,961	-61.5
2001	775,606	320,902	-58.6
2002	597,557	422,171	-29.4
2003	615,608	522,621	-15.1
2004	606,496	375,324	-38.1
2005			
2006	567,142	317,096	-44.1
2007			
2008			
2009			
Average	610,556	347,790	-43.0

Rating – G

Table 5.13-4 Total phosphorus (lb/year) percent error for measured and modeled loading by year at 21FLPCSWFL0055000263100.

Year	Measured TP (lb/yr)	Modeled TP (lb/yr)	% Error
1997			
1998			
1999	47,414	4,793	-89.9
2000	67,595	4,101	-93.9
2001	94,091	7,009	-92.6
2002	71,625	10,092	-85.9
2003	71,127	12,641	-82.2
2004	69,430	8,477	-87.8
2005			
2006	66,103	6,796	-89.7
2007			
2008			
2009			
Average	69,627	7,701	-88.9

Rating – G

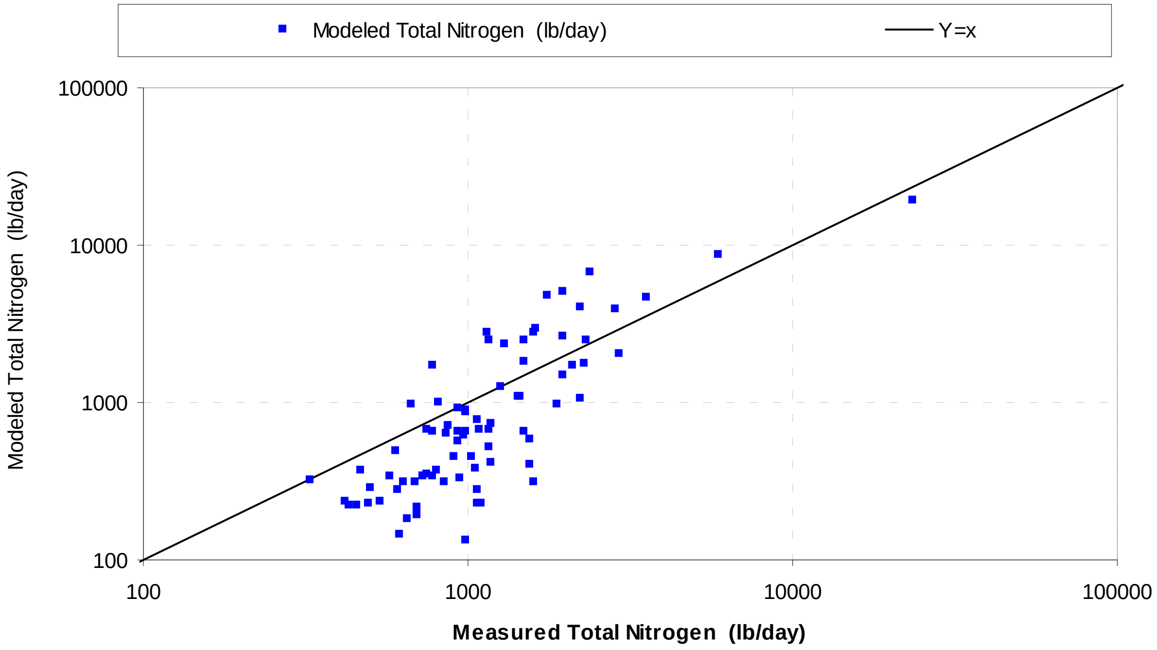

Figure 5.13-9 Total nitrogen (mg/l) load scatter plot at 112WRD 02310700.

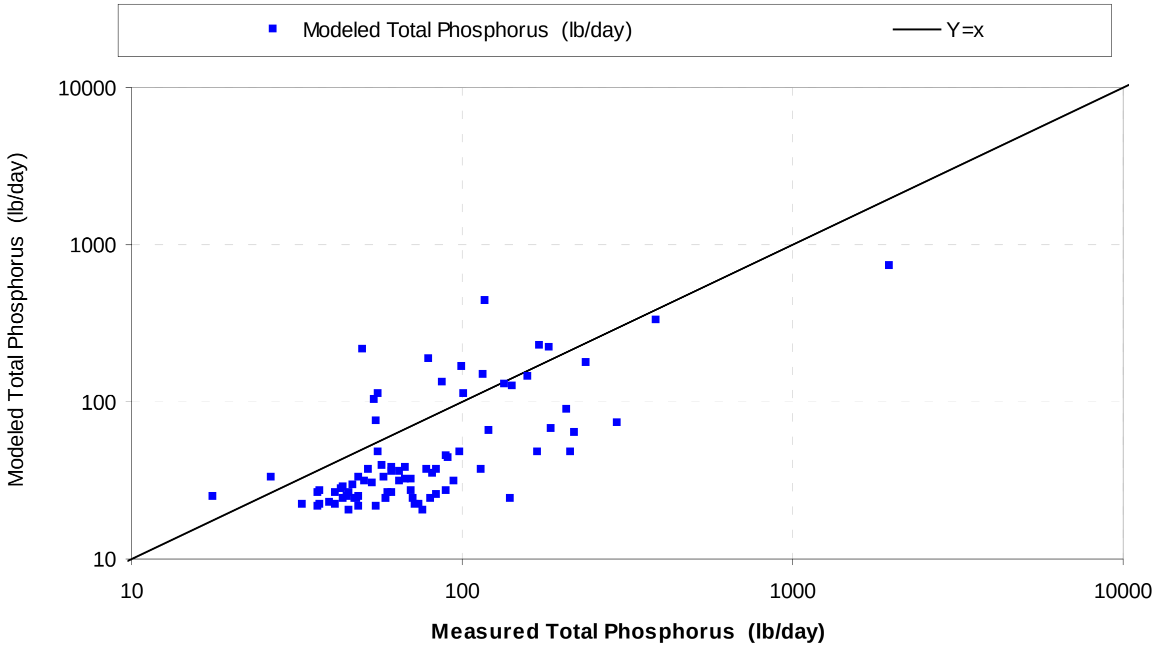

Figure 5.13-10Total phosphorus (mg/l) load scatter plot at 112WRD 02310700.

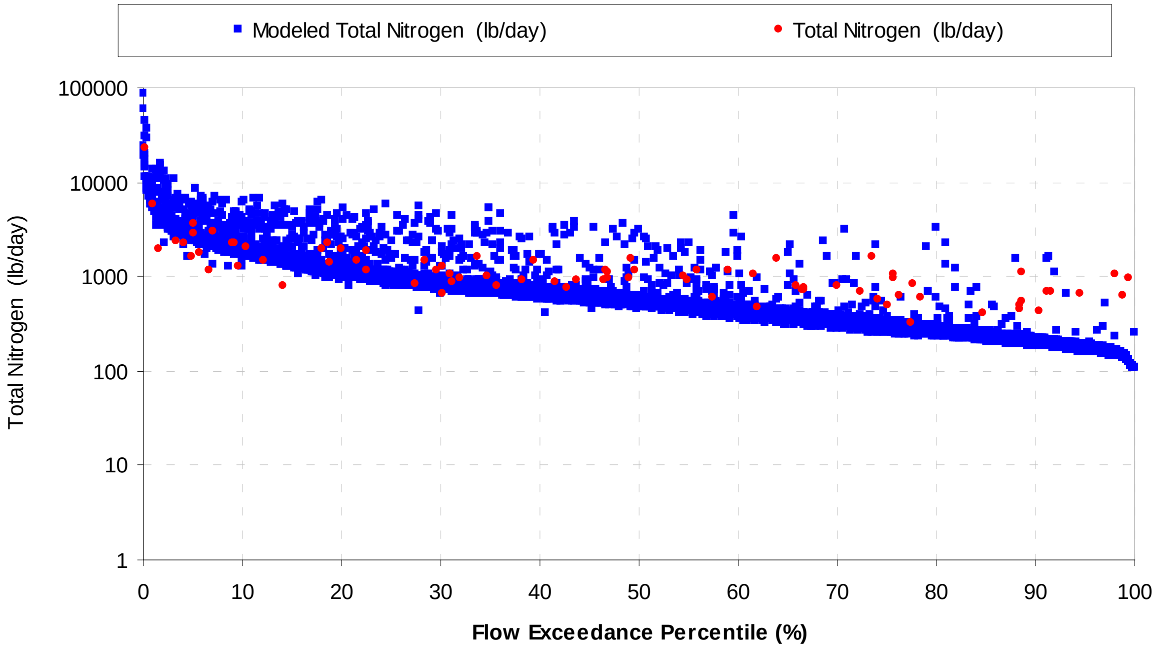

Figure 5.13-11Total nitrogen (mg/l) load duration curve at 112WRD 02310700.

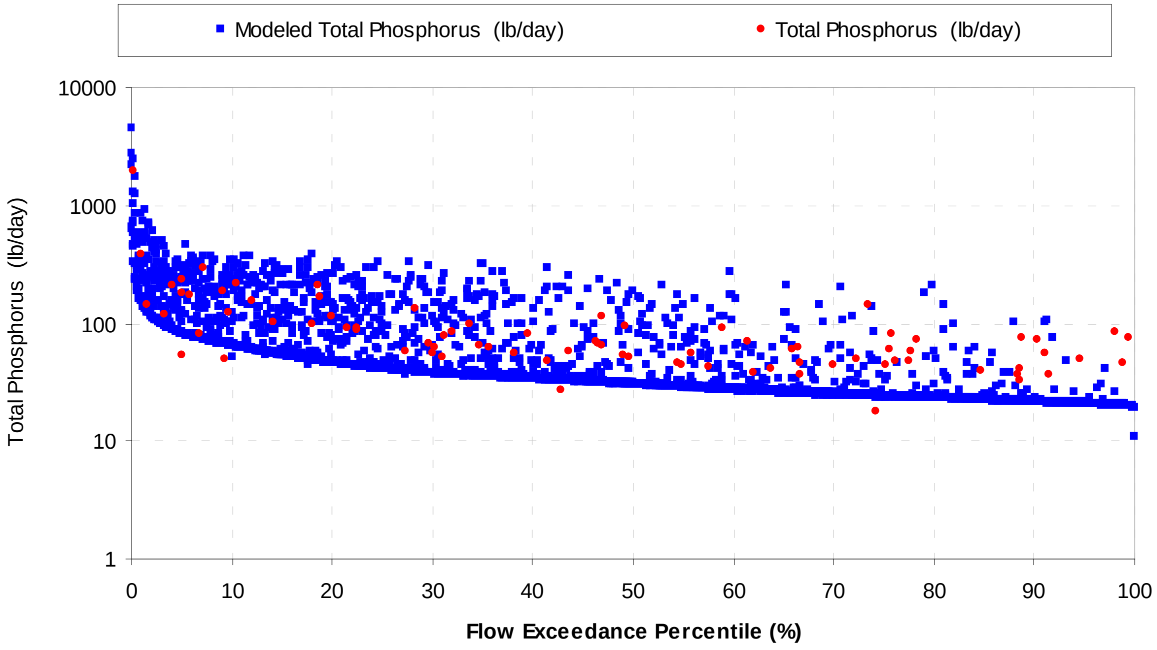

Figure 5.13-12Total phosphorus (mg/l) load duration curve at 112WRD 02310700.

Table 5.13-5 Total nitrogen (lb/year) percent error for measured and modeled loading by year at 112WRD 02310700.

Year	Measured TN (lb/yr)	Modeled TN (lb/yr)	% Error
1997			
1998			
1999	370,252	263,389	-28.9
2000	382,344	246,586	-35.5
2001	406,224	420,016	3.4
2002	490,879	610,037	24.3
2003	588,026	802,326	36.4
2004	687,729	525,583	-23.6
2005			
2006	521,510	410,325	-21.3
2007			
2008			
2009			
Average	492,423	468,323	-4.9

Rating – VG

Table 5.13-6 Total phosphorus (lb/year) percent error for measured and modeled loading by year at 112WRD 02310700.

Year	Measured TP (lb/yr)	Modeled TP (lb/yr)	% Error
1997			
1998			
1999	23,866	17,640	-26.1
2000	24,687	16,041	-35.0
2001	35,374	22,507	-36.4
2002	37,769	28,974	-23.3
2003	38,503	34,214	-11.1
2004	48,150	25,713	-46.6
2005			
2006	40,617	22,013	-45.8
2007			
2008			
2009			
Average	35,566	23,872	-32.9

Rating – VG

6.0 References

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