Watershed Hydrology and Water Quality Modeling Report

for

Charlotte Harbor, Florida

September, 2009

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Region4 serving the southeast

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1.0 INTRODUCTION

Charlotte Harbor, Florida is on the west side of the peninsula, between Tampa Bay and The Keys. Charlotte Harbor is home the second largest estuary in the state of Florida and the 17th largest in the country. Charlotte Harbor is fed by the Peace and Myakka Rivers. These two watersheds include portions of Desoto, Hardee, Charlotte, Manatee, Sarasota, Polk, and Highlands's counties. Figure 1-1 shows Charlotte Harbor, surrounding counties and other features of the watershed. This report documents the development and calibration of a watershed model that will be used to approximate watershed flows, and nutrient loadings entering Charlotte Harbor.

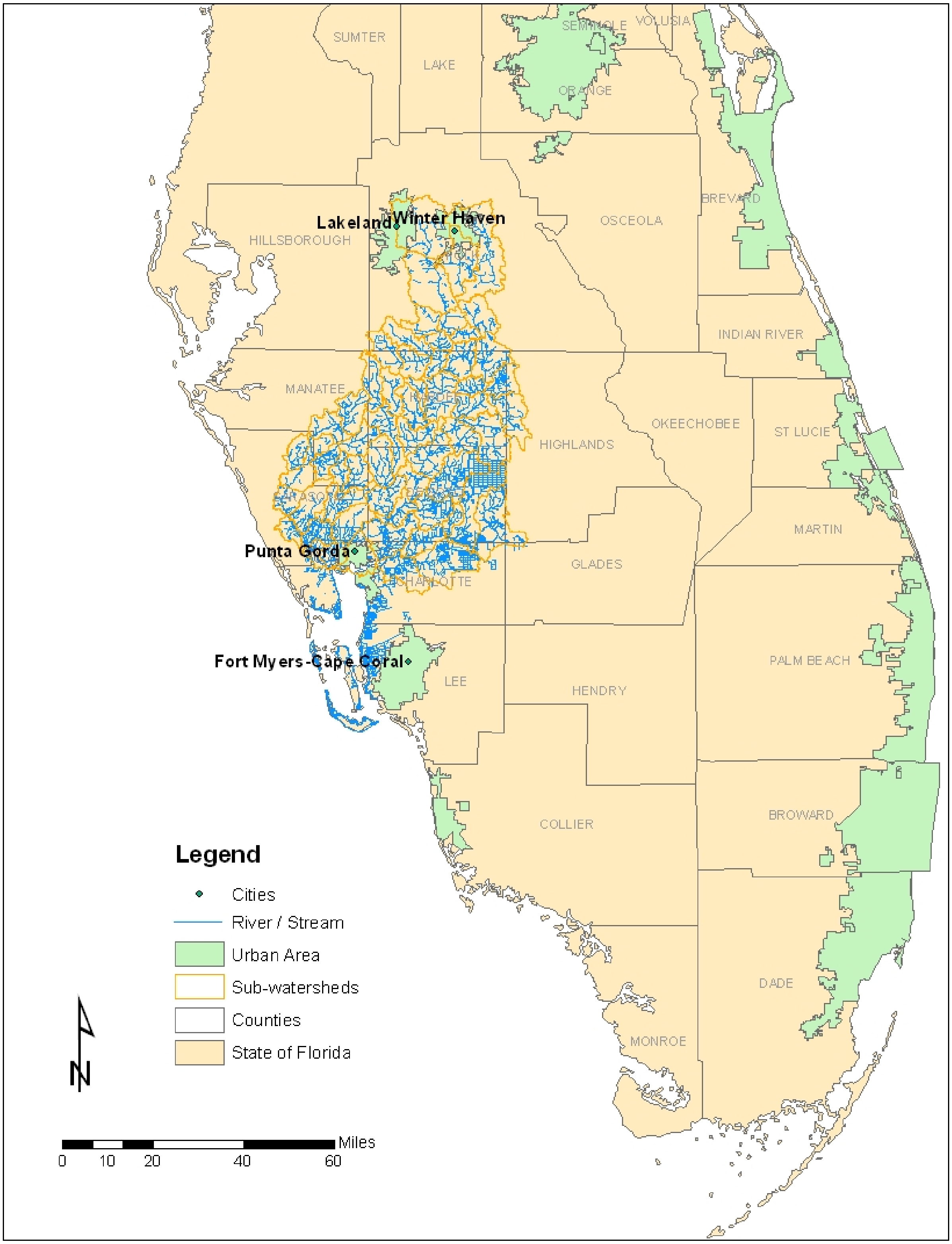

Figure 1-1 Location of Charlotte Harbor

2.0 MODEL SELECTION

2.1 LSPC Watershed Model

The Loading Simulation Program C++ (LSPC) was used to represent the hydrological and water quality conditions in the Lake Lanier Watershed. LSPC is a comprehensive data management and modeling system that is capable of representing loading, both flow and water quality, from non-point 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 pervious and impervious lands and water bodies. LSPC was configured to simulate the watershed as a series of hydrologically connected sub-watersheds. LSPC is based on the Mining Data Analysis System (MDAS), with modifications for non-mining applications such as nutrient and fecal coliform modeling. MDAS was developed by EPA Region 3 through mining TMDL applications.

3.0 WATERSHED MODEL DEVELOPMENT

3.1 Overview

The watershed model represented the variability of nonpoint source contributions through dynamic representation of hydrology and land practices. The watershed model included all point and nonpoint 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)
- Hydrologic representation (section 4.1)
- Hydrology Calibration and Validation (sections 4.3 and 4.4)
- Water Quality Overview (section 5.3)
- Reach Group Representation (section 5.4)
- Observed Water Quality Data Calibration and Validation (section 5.5)
- Nutrients Representation (section 5.9)

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

3.2 Watershed Segmentation

In order to evaluate the sources contributing to an impaired water body 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. These sub-watersheds were selected with the goal of maximizing efficiency while maintaining accuracy.

The entire Charlotte Harbor, Peace River and Myakka River, Watershed area was delineated into 60 sub-watersheds to provide appropriate hydrological connectivity (Figure 3-2). The sub-watersheds were delineated using the Digital Elevation Map (DEM) in 1/3-arc-second resolution (10m), the National Hydrography Dataset (NHD).

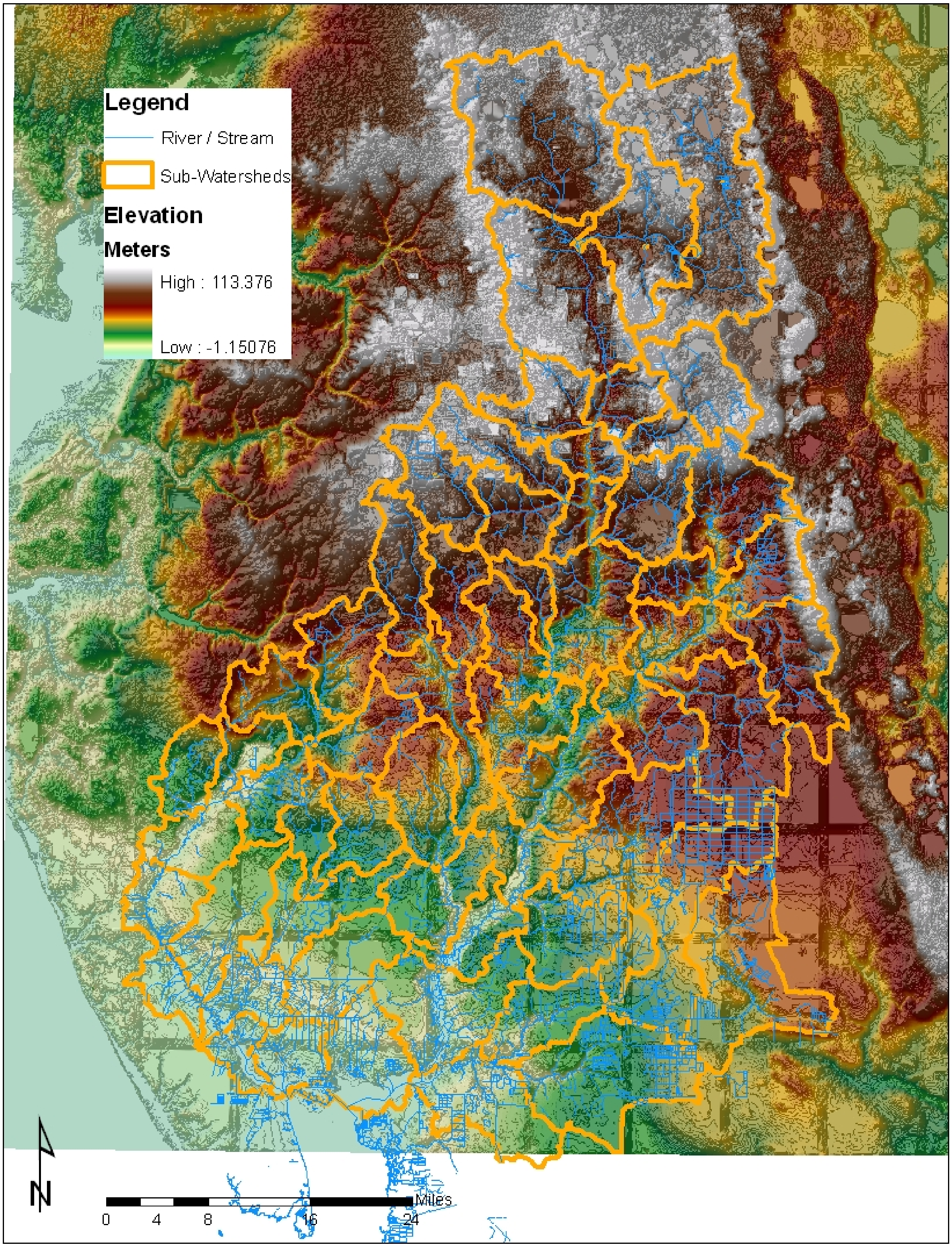

Figure 3-3 Digital Elevation Map (DEM) Coverage of the Charlotte Harbor and the Peace River Watershed with the LSPC subwatersheds shown.

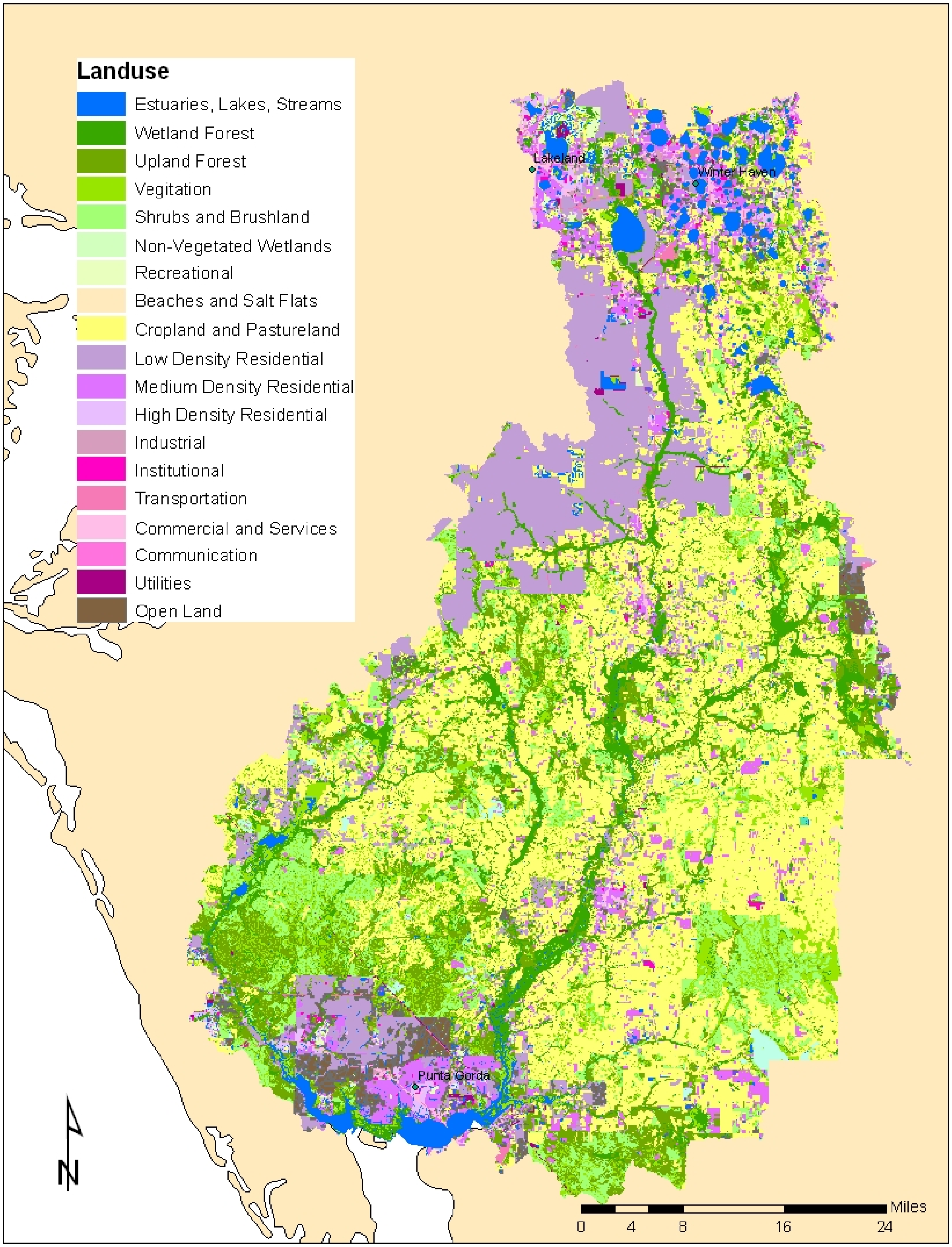

Figure 3-4 LULC Coverage of the St. Andrews Bay

3.3 Simulation Period

The US Geological Survey (USGS) recommends looking at 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. In this case, the model was simulated over a 9-year period. The LSPC model was simulated from January 1, 1999 through December 31, 2008. To allow the model plenty of "spin-up" time, the model was run for a full year (January 1998 to December 1998) before the simulation period.

The LPSC watershed hydrology and water quality model was calibrated from January 1, 1999 through December 31, 2008.

3.4 Soils

Soil data for the Charlotte Harbor watershed was obtained from the State Soil Geographic Data Base (STATSGO). There are two main Hydrologic Soil Group (Group A, and Group C) in the watersheds. These soil groups are described below:

Group A Soils	Have high infiltration rates, and are deep well to excessively drained sands and gravels.
Group C Soils	Have low infiltration rates when wet and consist chiefly of soils having a layer that impedes downward movement of water with moderately fine-to-fine texture.
Group D Soils	Have poor infiltration rates and consists of clayey poorly drained soils.

The total area that each hydrologic soil group covered within each sub-watershed was determined. The sub-watersheds were represented by the hydrologic soil group that had the highest percent of coverage. Figure 3-5 shows the different soil types that are within the Charlotte Harbor Watershed. Appendix A presents the dominant soil type for each sub-watershed.

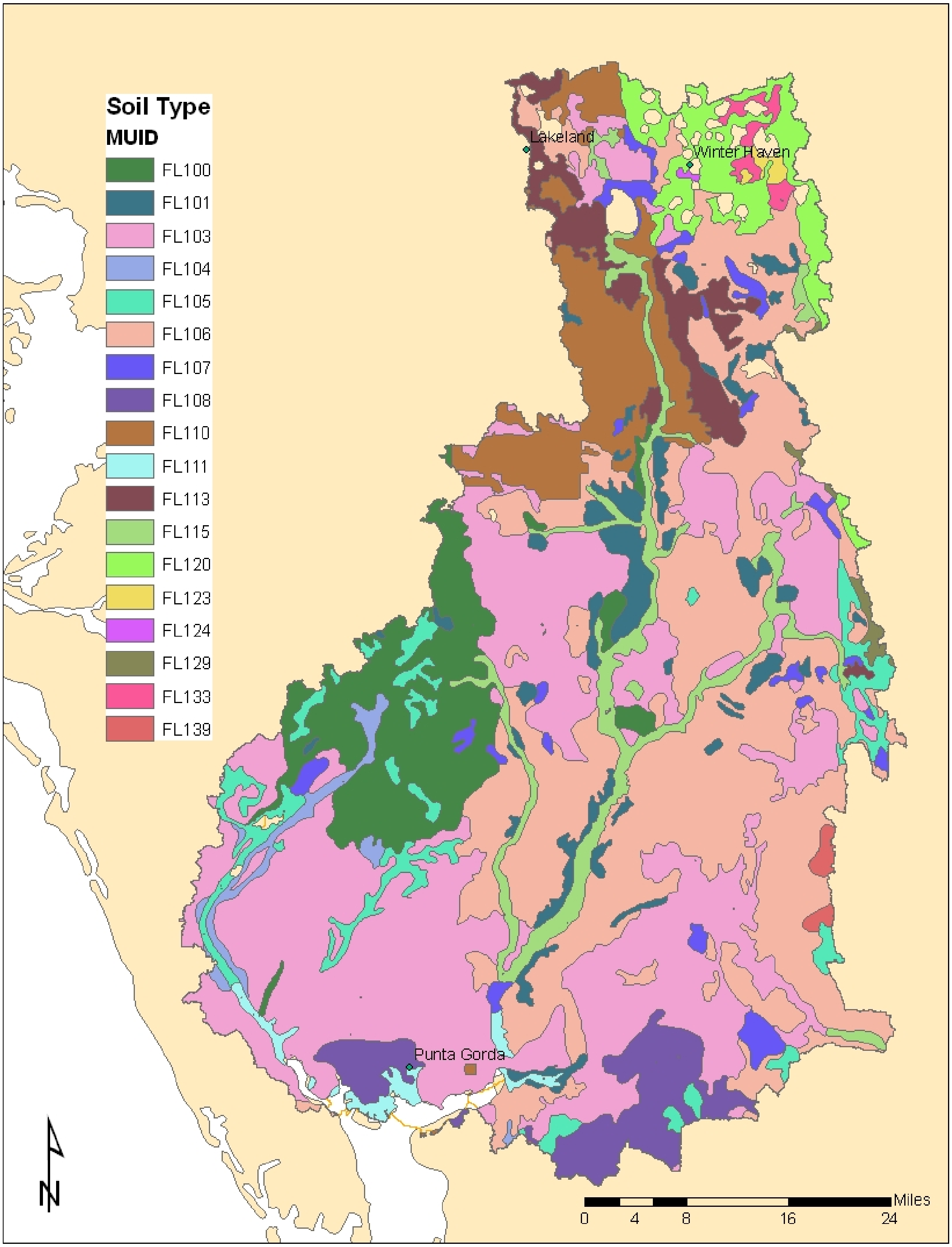

Figure 3-5 Soils Coverage for the Charlotte Harbor Watershed

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. An ASCII file (*.air) was generated for each meteorological station used in the hydrological evaluations in LSPC. Each meteorological station file contains atmospheric data used in modeling the hydrological processes. These data include 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.

Seven weather stations were available for modeling the Charlotte Harbor. These stations include: Sarasota International Airport, Myakka River State Park, and cities of Arcadia, Desoto, Punta Gorda, Wauchula, and Winterhaven.

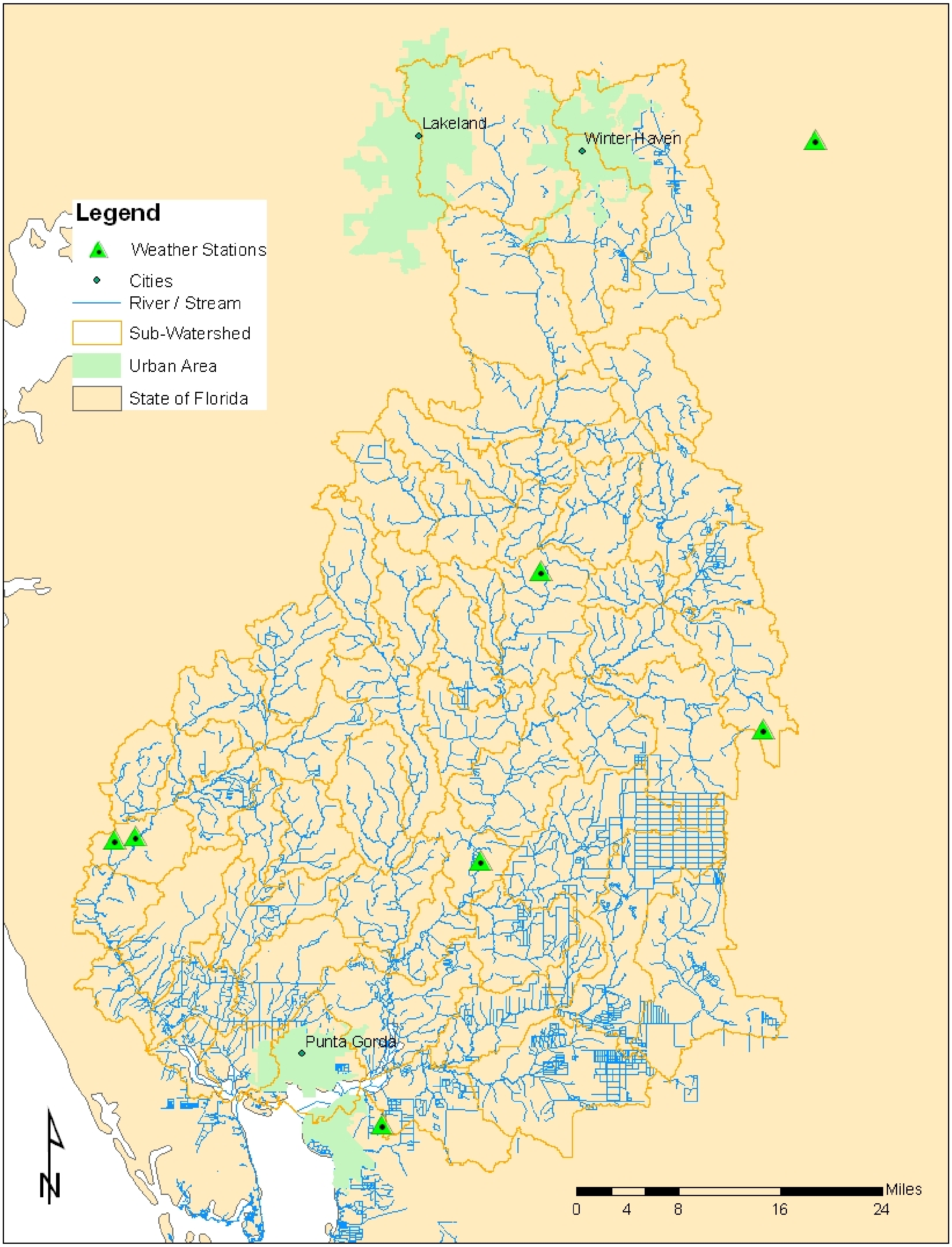

Figure 3-6 Location of Meteorological Station used in the LSPC Watershed Model

3.6 Reach Characteristics

The LSPC model must have a representative reach defined for each sub-watershed. 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 Digital Elevation Maps (DEM) and the National Hydrography Dataset (NHD). The channel geometry is described by a bank full width and depth (the main channel), a bottom width factor, a flood plain width factor and slope of the flood plain. Details about each reach can be found in Appendix C.

3.7 Land Use Representation

The watershed model uses land use data as the basis for representing hydrology and nonpoint source loading. Land Use and Land Cover data was used from the EPA and USGS. Land use classifications are presented in Table 3-2. Appendix D presents the breakdown of each land use by sub-watershed.

The LSPC model requires division of land uses in each sub-watershed into separate pervious and impervious land units. For applicable land use classifications a percent impervious cover was created. LSPC requires that these land uses be split into pervious and impervious and reclassified as two separate land cover classes (percentages shown in table 3-2). The reclassification is necessary so that appropriate infiltration rates and etc. can be assigned for each classification.

Table 3-2 Land Use Representation

Land Use Code	Description	% Pervious
11	Developed Low Intensity	0.55
12, 14	Developed Medium Intensity	0.45
13, 15, 17	Developed High Intensity	0.15
16	Disturbed	1
18, 19	Developed Open	0.85
21 -26	Agriculture	1
31 - 33, 41 - 44	Forest	1
51 - 54	Open Water	1
61 - 65	Wetlands	1
66, 72	Barren	1
74	Disturbed	1
81, 82	Developed Low Intensity	0.55
83	Developed High Intensity	0.15

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 water body. 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 adjusted, based on local knowledge of soil types and groundwater conditions, within reasonable constraints until an acceptable agreement was achieved between simulated and observed stream flow. Model parameters adjusted included: evapo-transpiration, infiltration, upper and lower zone storage, groundwater storage, and losses to the deep groundwater system. The final calibrated hydrological parameters are presented in Appendix J.

4.2 Observed Flow Data

Historical and short-term USGS flow stations located in the Charlotte Harbor watershed were used to calibrate and validate the LSPC watershed hydrology model (Figure 4-1). There are two USGS flow stations in the Charlotte Harbor watershed that were used for calibration. Both of the USGS flow stations contained a complete flow record for the simulation period from January 1, 1999 through December 31, 2008. The following two stations were used: Prairie Creek gage station near Fort Ogden (02298123), and Horse Creek gage station near Arcadia, Fl (02297310).

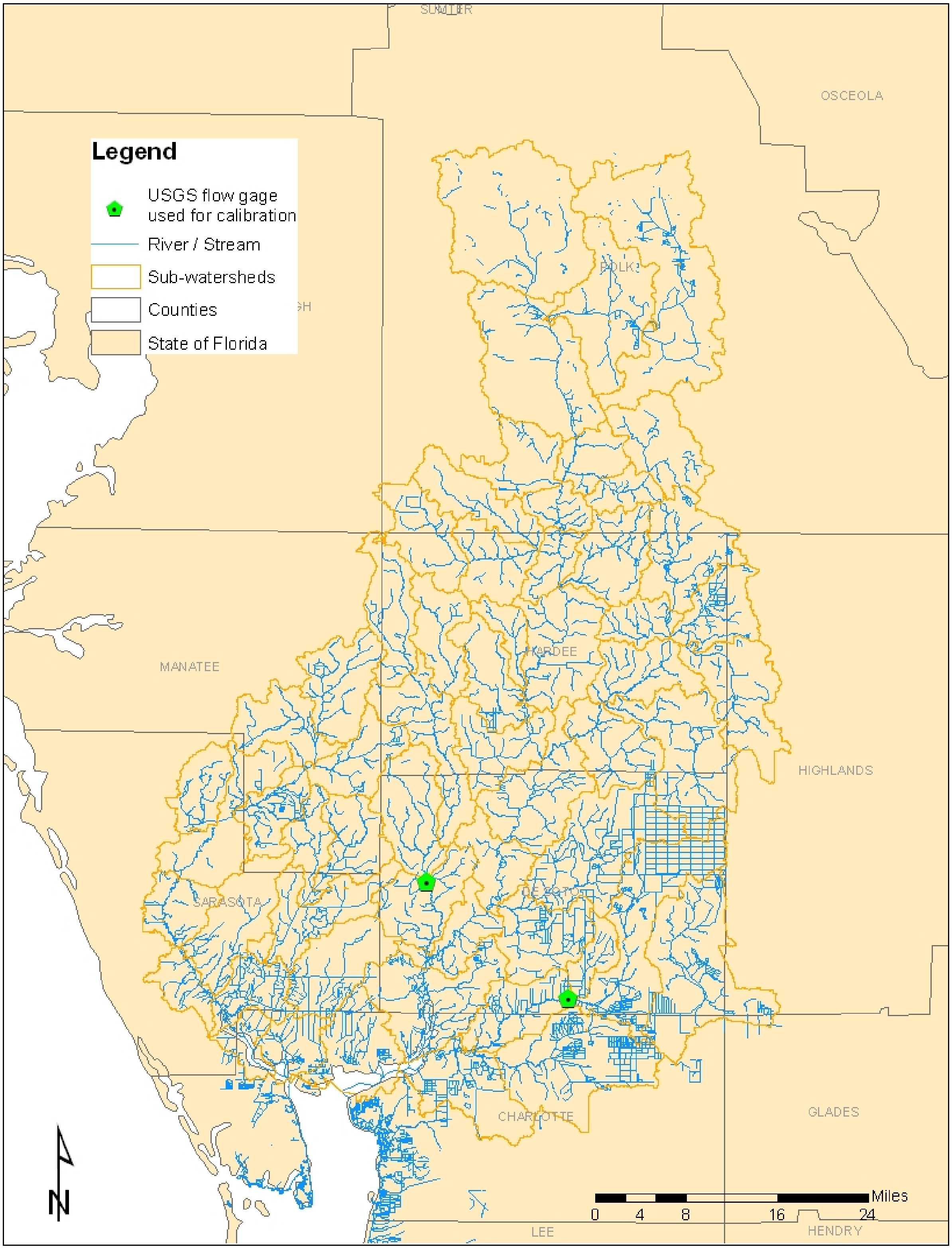

Figure 4-1 Calibration Stations used in the Hydrology Model

4.3 Hydrology Model Calibration

The calibration of the LPSC watershed hydrology model involved comparing simulated stream flows to two USGS flow stations. The calibration of the hydrologic parameters was performed from January 1, 1999 through December 31, 2008. Results of the model calibrations are presented in Appendix K.

4.4 Hydrology Model Validation

An important step of the modeling process is model validation. Model validation is the process of taking the hydrological parameters that have been calibrated, applying those parameters to other watersheds, and comparing the simulated flow to measured flow from a USGS stream gauging station for the same period of time. Model validation is sometimes called model verification, as essentially you are validating or verifying that hydrological parameters calibrated in one watershed will produce acceptable results in another watershed. It is important that when selecting watersheds to perform validations, those watersheds represent a wide variety of land uses as well as drainage areas. This will help to ensure that the hydrological parameters that were calibrated apply to a wide range of conditions. Validation of the hydrologic parameters was performed by comparing simulated flow data to measured data collected at two separate USGS flow gages. The validation of the hydrological parameters was performed from January 1, 1999 through December 31, 2008. Results of the model validation are presented in Appendix K.

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 create a water quality model of the watersheds. The watershed water quality model included all point and nonpoint source contributions. Many components of the water quality model were established during hydrology modeling. 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 setup to model Biochemical Oxygen Demand (BOD), Total Nitrogen (TN), Ammonia (NH3), Nitrate + Nitrite (NOx), Organic Nitrogen (Org-N), Total Phosphorus (TP), Orthophosphate (PO4), Organic Phosphorus (Org-P), and Total Suspended Solids (TSS).

5.3 Water Quality Representation

Accumulation and wash-off rates play an important role in the determination of nonpoint source loadings to a water body. 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. Generally, important water quality characteristics include initial storage, wash off and scour potency, accumulation rates, maximum storage amounts, and groundwater and interflow concentrations.

In order to calibrate the nutrient loadings for the water shed event mean concentrations (table 3-4) for each land use, as established in the literature, were used. The value for each nutrient load was weighted according to the percent of each land use for the land upstream of the chosen calibration basin. The total weighted value for each nutrient was used as the basis for calibration.

The .AIR weather file was modified so that there was a dry period of a month and a half preceded each rainfall event. The rainfall event data was determined by 24 hour storm event averages, ranging in intensity. The intensity range included a one year event, two year event, five year event, ten year event, 25 year event, 50 year event and a 100 year event. The nutrient out flux expected from each event was calibrated to the weighted nutrient loadings described previously

LSPC's water quality algorithms are identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). A detailed description of relevant water quality algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

Table 3-4 Event Mean Concentrations by landuse class.

Table 3-5 Weighted concentration, calibrated concentration and percent difference.

Total Weighted Conc.		7.308373	152.4798	2.204189	1.198892	0.378867	0.496299	0.515738	0.315054	0.217658
Storm Event		**Calibration results**								
Duration	**Magnitude**	**BOD**	**TSS**	**N**	**ORG-N**	**NH3**	**NO2+NO3**	**TP**	**ORG-P**	**DP (ortho)**
24 hour	1 year	7.45498	152.643	2.1637	1.1947	0.377594	0.508639	0.511046	0.319064	0.214984
24 hour	2 year	7.53367	151.211	2.15862	1.20053	0.377322	0.484054	0.540006	0.319341	0.224578
24 hour	5 year	7.47688	139.692	2.22306	1.2129	0.344493	0.494456	0.497887	0.303299	0.222728
24 hour	10 year	7.51904	161.92	2.25704	1.24866	0.409782	0.504668	0.539054	0.335698	0.222803
24 hour	25 year	7.51396	147.006	2.18847	1.18645	0.380499	0.486727	0.513936	0.326888	0.224967
24 hour	50 year	7.45058	148.919	2.1245	1.28291	0.400914	0.501506	0.522144	0.341552	0.228115
24 hour	100 year	6.87249	141.559	2.21691	1.22959	0.394751	0.508839	0.529236	0.317761	0.218572
Storm Event		**Percent difference**								
Duration	**Magnitude**	**BOD**	**TSS**	**N**	**ORG-N**	**NH3**	**NO2+NO3**	**TP**	**ORG-P**	**DP (ortho)**
24 hour	1 year	2.006009	0.107001	-1.8369	-0.3497	-0.33594	2.486336	-0.90971	1.272907	-1.22833
24 hour	2 year	3.082719	-0.83214	-2.06737	0.136585	-0.40774	-2.46733	4.705546	1.360829	3.179514
24 hour	5 year	2.305665	-8.38658	0.856159	1.16837	-9.07279	-0.37141	-3.4612	-3.731	2.329555
24 hour	10 year	2.882538	6.191084	2.397769	4.151123	8.159919	1.686214	4.520956	6.552643	2.364013
24 hour	25 year	2.813029	-3.58988	-0.71313	-1.03783	0.430817	-1.92874	-0.34935	3.756294	3.358235
24 hour	50 year	1.945804	-2.33529	-3.61533	7.007926	5.819255	1.049099	1.242158	8.410739	4.804544
24 hour	100 year	-5.96416	-7.16216	0.577145	2.560489	4.192562	2.526634	2.617275	0.859327	0.420133

5.4 *Water Quality Data Calibration*

The process of calibration involved adjusting monthly accumulation rates, storage limit; and interflow and groundwater concentration. The storage limit and accumulation rates were adjusted keeping in mind that the ratio of the storage limit to accumulation rate dictates how many days it takes for the storage limit to be reached. As the parameters were adjusted the values concentration values for each storm event were compared to the nutrient concentrations weighted by land cover. Table 3-5 shows the concentration values from the calibrated model and the percent difference from the weighted concentration.

6.0 References

Bicknell, Brian R., J.C. Imhoff, J.L. Kittle, Jr., T.H. Jobes, A.S. Donigian, Jr., 2004. HSPF Version 12 User's Manual. Aqua Terra Consultants, Mountain View, California.

Donigian, A.S., and J.T. Love, 2003. Sediment Calibration Procedures and Guidelines for Watershed Modeling. Aqua Terra Consultants, Mountain View, California.

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APPENDIX A: HYDROLOGY CALIBRATION

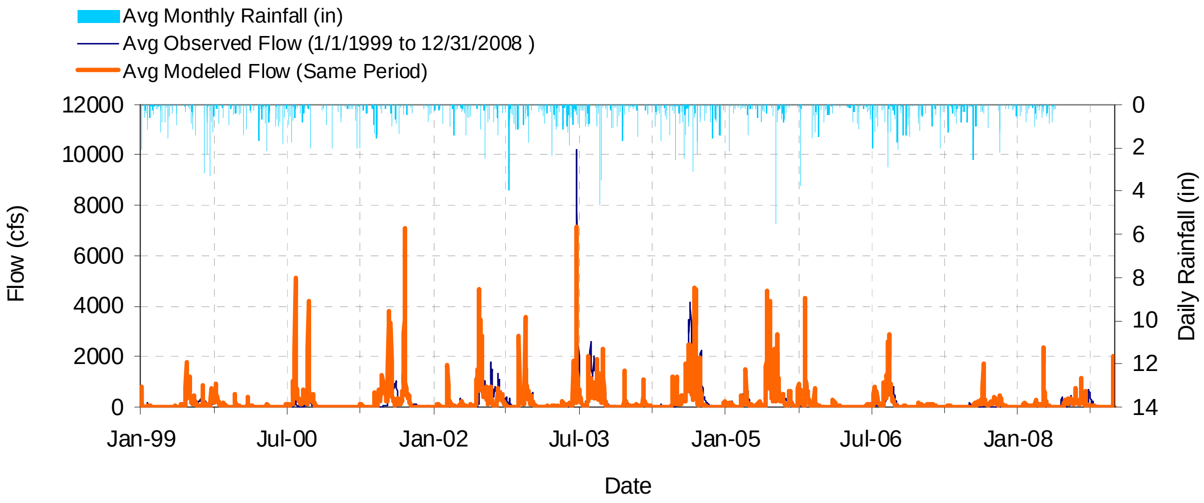


Figure A-1. Mean daily flow: Model Outlet 5 vs. USGS 02297310 Horse Creek Near Arcadia FL

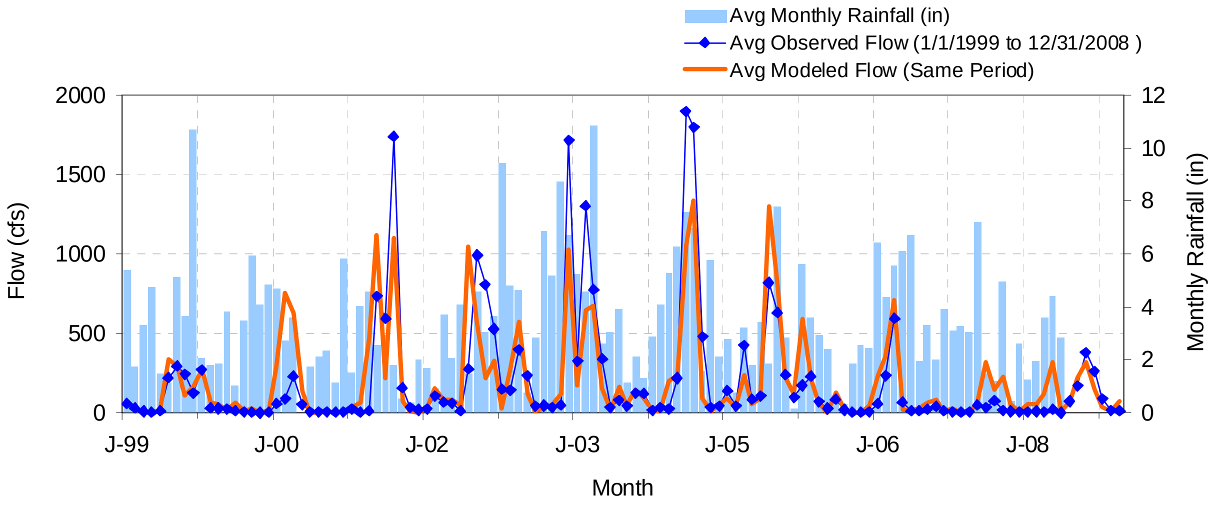


Figure A-2. Mean monthly flow: Model Outlet 5 vs. USGS 02297310 Horse Creek Near Arcadia FL

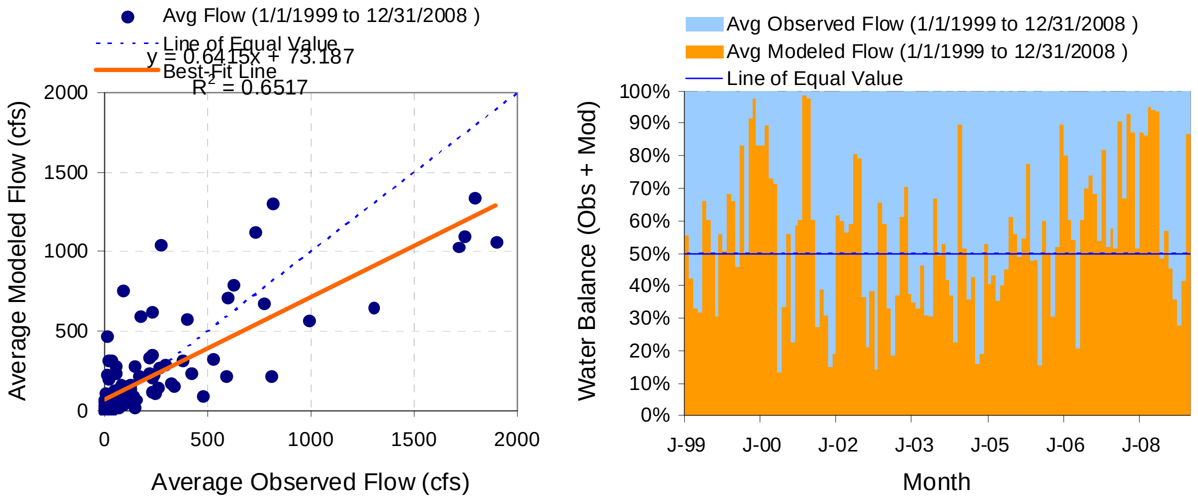


Figure A-3. **Monthly flow regression and temporal variation: Model Outlet 5 vs. USGS 02297310 Horse Creek Near Arcadia FL**

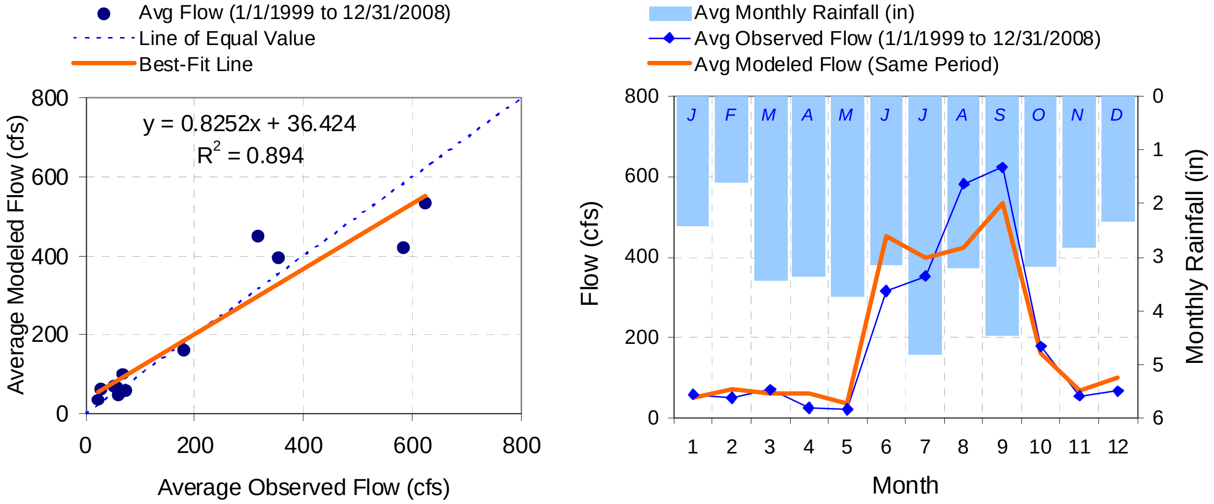


Figure A-4. **Seasonal regression and temporal aggregate: Model Outlet 5 vs. USGS 02297310 Horse Creek Near Arcadia FL**

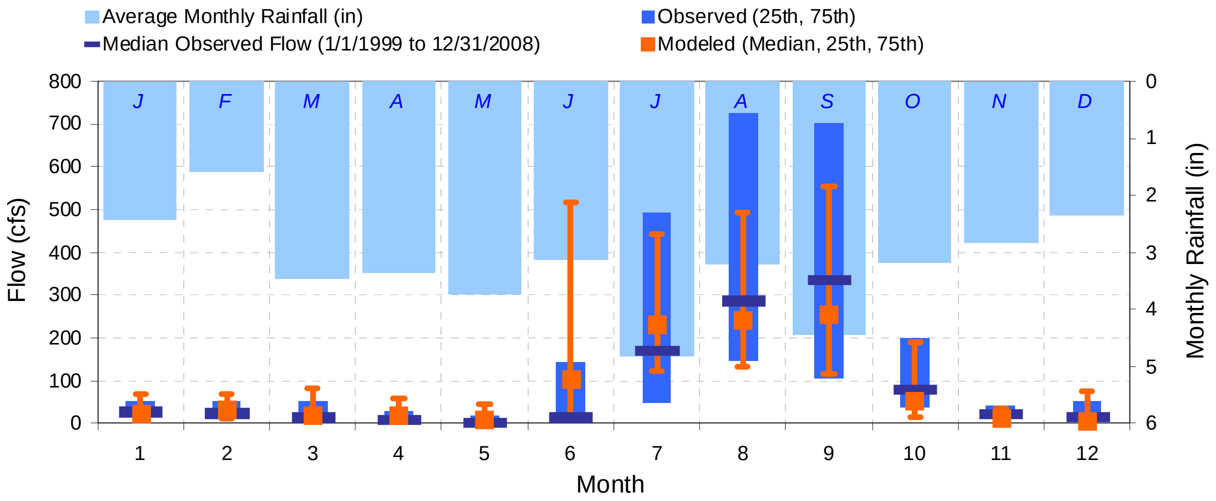
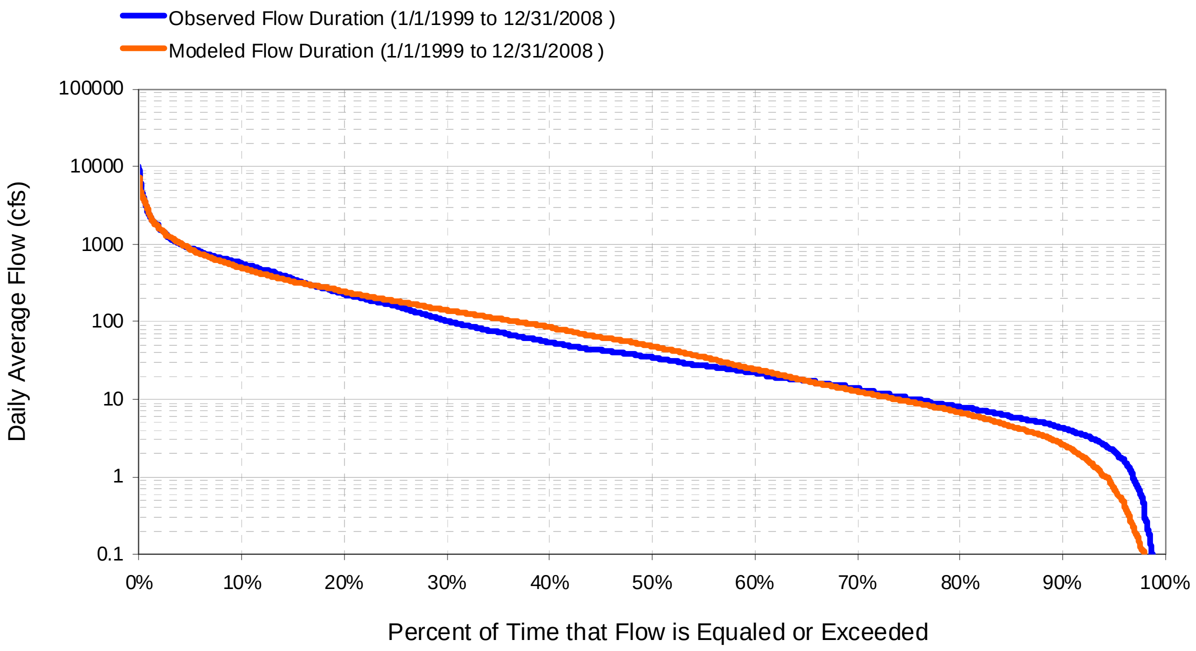


Figure A-5. Seasonal medians and ranges: Model Outlet 5 vs. USGS 02297310 Horse Creek Near Arcadia FL

Table A-1. Seasonal summary: Model Outlet 5 vs. USGS 02297310 Horse Creek Near Arcadia FL

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	58.40	28.00	14.00	53.50	50.77	24.10	9.48	67.31
Feb	50.13	25.00	12.50	51.00	70.68	34.72	11.91	68.96
Mar	71.71	15.00	6.35	52.00	60.30	19.85	7.07	80.97
Apr	25.59	11.00	4.00	27.50	62.37	21.38	4.17	57.49
May	22.15	3.45	0.85	19.75	36.86	10.90	1.80	43.74
Jun	315.64	15.00	5.70	143.25	453.06	102.91	9.49	518.48
Jul	352.15	172.00	47.25	492.75	397.28	232.06	123.13	441.76
Aug	581.93	288.00	146.00	726.25	422.18	242.48	132.79	493.37
Sep	622.69	337.50	104.25	703.50	534.56	256.27	116.87	554.60
Oct	179.02	80.50	39.00	201.00	161.96	54.92	15.51	191.24
Nov	55.15	22.00	11.00	41.25	67.13	12.40	5.39	34.68
Dec	67.56	16.00	8.70	53.00	102.27	7.63	3.02	76.95



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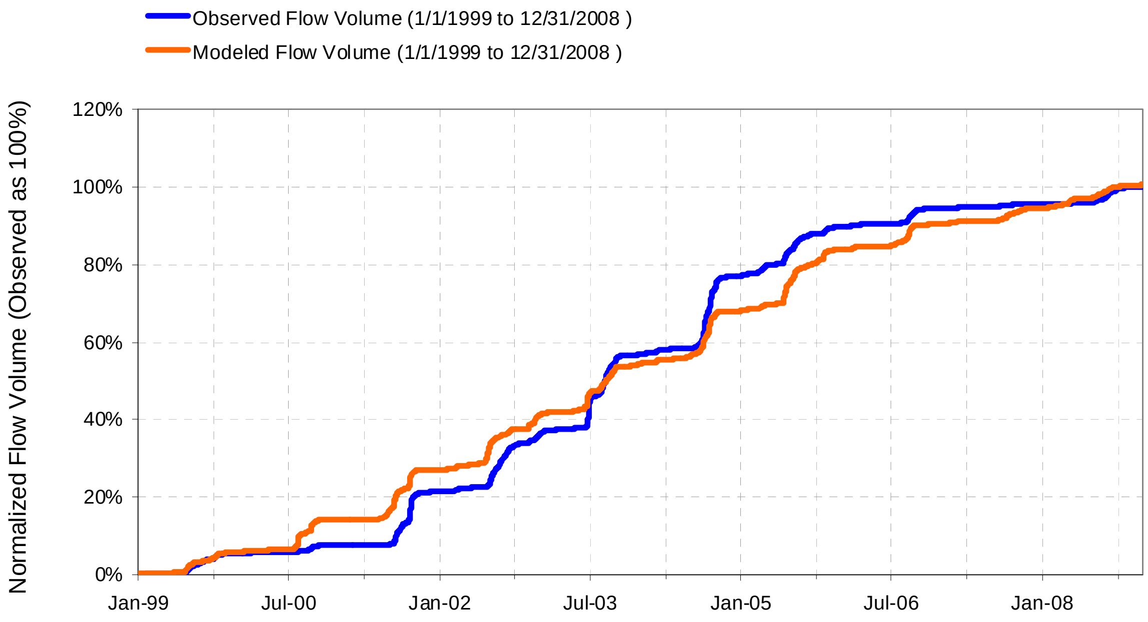
igure A-6. Flow exceedence: Model Outlet 5 vs. USGS 02297310 Horse Creek Near Arcadia FL



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igure A-7. Flow accumulation: Model Outlet 5 vs. USGS 02297310 Horse Creek Near Arcadia FL

Table A-2. Summary statistics: Model Outlet 5 vs. USGS 02297310 Horse Creek Near Arcadia FL

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 5 10-Year Analysis Period: 1/1/1999 - 12/31/2008 Flow volumes are (inches/year) for upstream drainage area		**USGS 02297310 HORSE CREEK NEAR ARCADIA FL** Hydrologic Unit Code: 3100101 Latitude: 27.19949477 Longitude: -81.9884193 Drainage Area (sq-mi): 218	
Total Simulated In-stream Flow:	**12.57**	Total Observed In-stream Flow:	**12.50**
Total of simulated highest 10% flows:	**7.76**	Total of Observed highest 10% flows:	**8.09**
Total of Simulated lowest 50% flows:	**0.42**	Total of Observed Lowest 50% flows:	**0.39**
Simulated Summer Flow Volume (months 7-9):	**7.07**	Observed Summer Flow Volume (7-9):	**8.13**
Simulated Fall Flow Volume (months 10-12):	**1.74**	Observed Fall Flow Volume (10-12):	**1.59**
Simulated Winter Flow Volume (months 1-3):	**0.93**	Observed Winter Flow Volume (1-3):	**0.93**
Simulated Spring Flow Volume (months 4-6):	**2.83**	Observed Spring Flow Volume (4-6):	**1.86**
Total Simulated Storm Volume:	**4.80**	Total Observed Storm Volume:	**3.00**
Simulated Summer Storm Volume (7-9):	**2.64**	Observed Summer Storm Volume (7-9):	**1.86**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	*1995-1999*	*2000-2004*
Error in total volume:	0.52	10	-1.43	7.35
Error in 50% lowest flows:	7.31	10	-1.60	-3.91
Error in 10% highest flows:	-4.08	15	2.26	1.75
Seasonal volume error - Summer:	-13.01	30	13.27	-2.52
Seasonal volume error - Fall:	9.75	30	4.49	12.42
Seasonal volume error - Winter:	-0.16	30	-18.21	13.31
Seasonal volume error - Spring:	**52.02**	**30**	**1.90**	**6.11**
Error in storm volumes:	**60.18**	**20**	**1.13**	**12.07**
Error in summer storm volumes:	41.92	50	3.16	15.42
Nash-Sutcliffe Coefficient of Efficiency, E:	0.307	Model accuracy increases	0.688	0.814
Baseline adjusted coefficient (Garrick), E':	0.377	as E or E' approaches 1.0	0.517	0.549

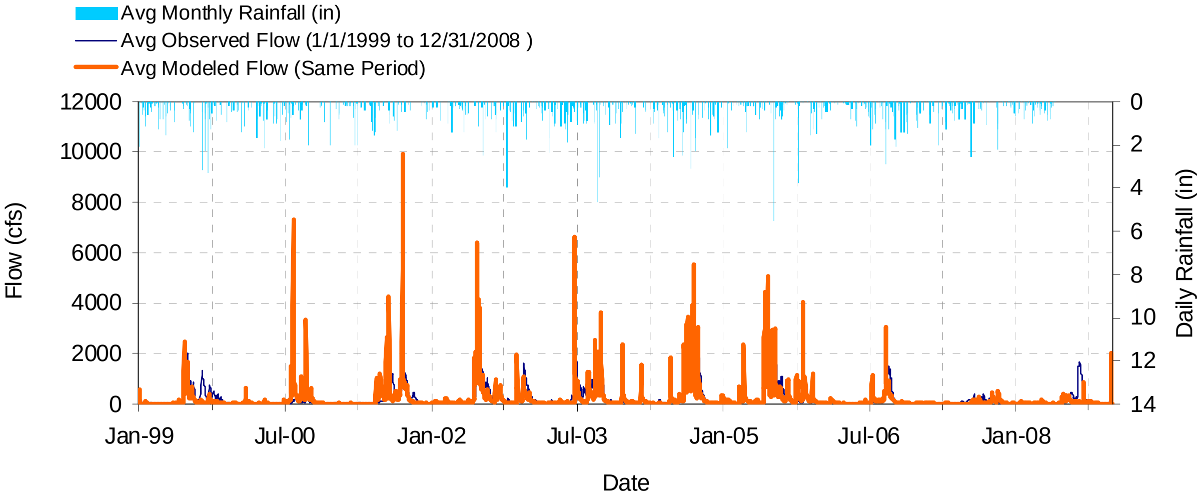


Figure A-8. **Mean daily flow: Model Outlet 10 vs. USGS 02298123 Prairie Creek Near Fort Ogden FL**

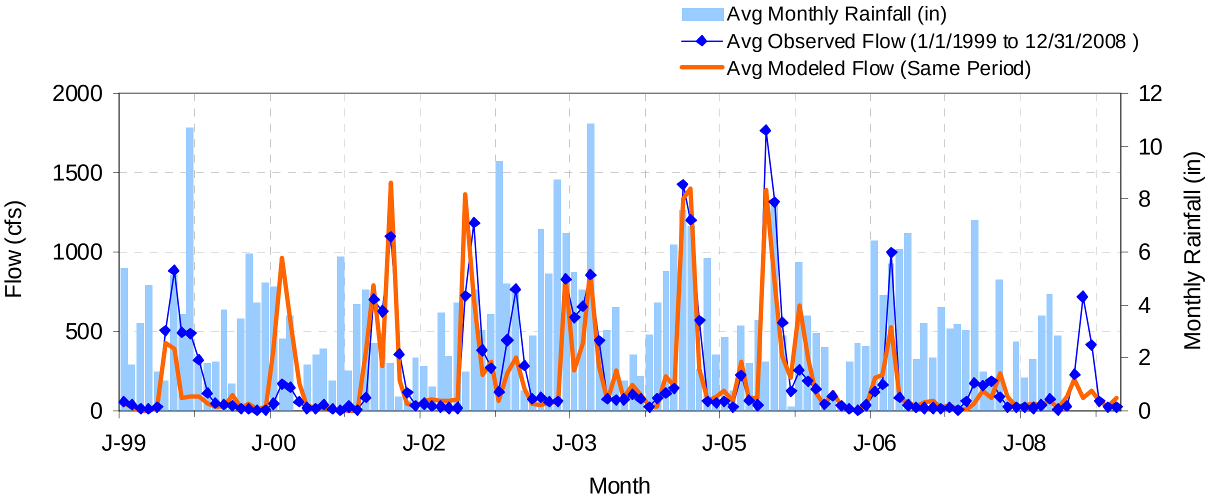


Figure A-9. **Mean monthly flow: Model Outlet 10 vs. USGS 02298123 Prairie Creek Near Fort Ogden FL**

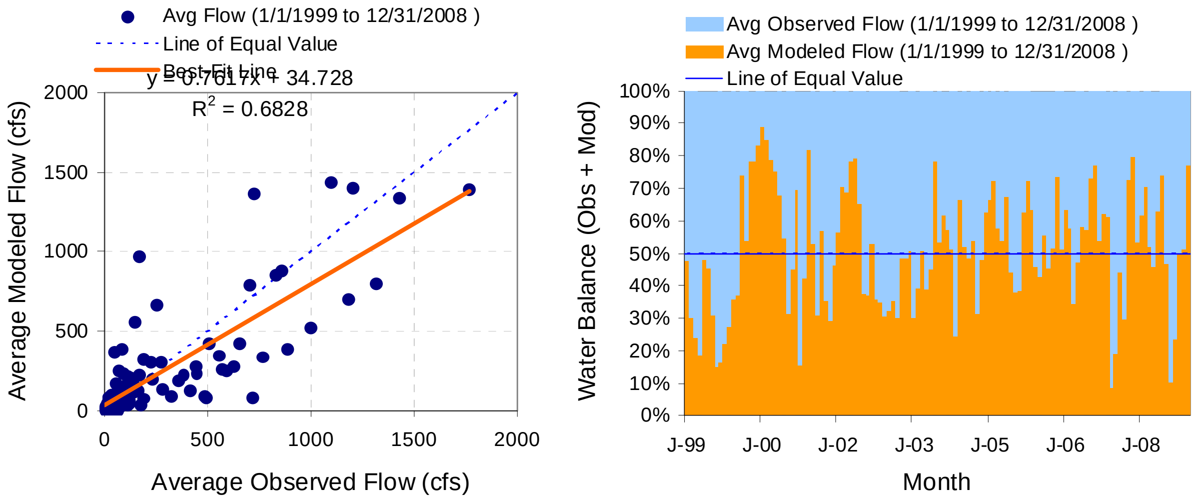


Figure A-10. Monthly flow regression and temporal variation: Model Outlet 10 vs. USGS 02298123 Prairie Creek Near Fort Ogden FL

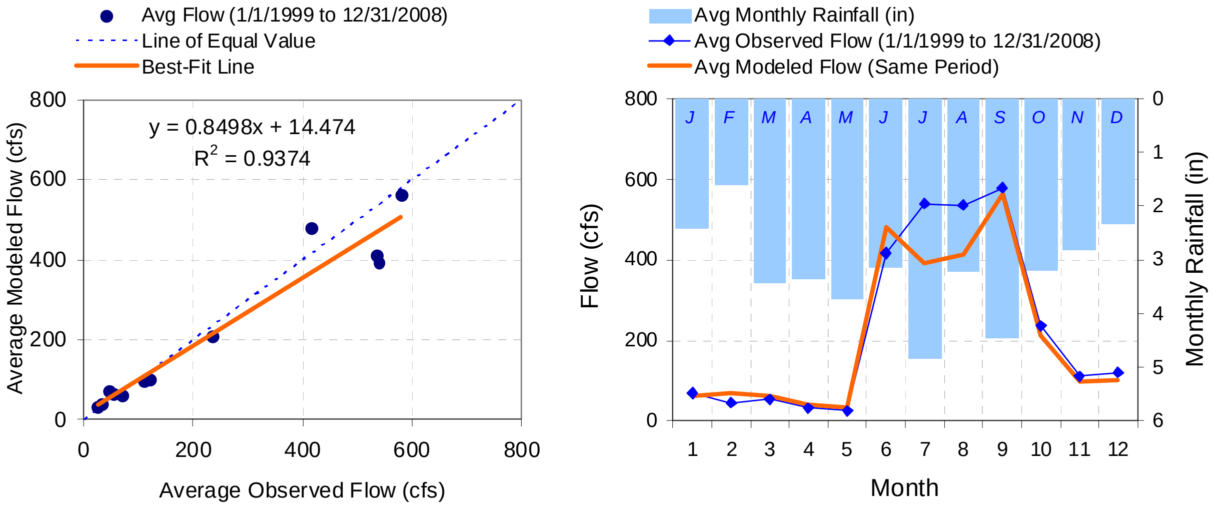


Figure A-11. Seasonal regression and temporal aggregate: Model Outlet 10 vs. USGS 02298123 Prairie Creek Near Fort Ogden FL

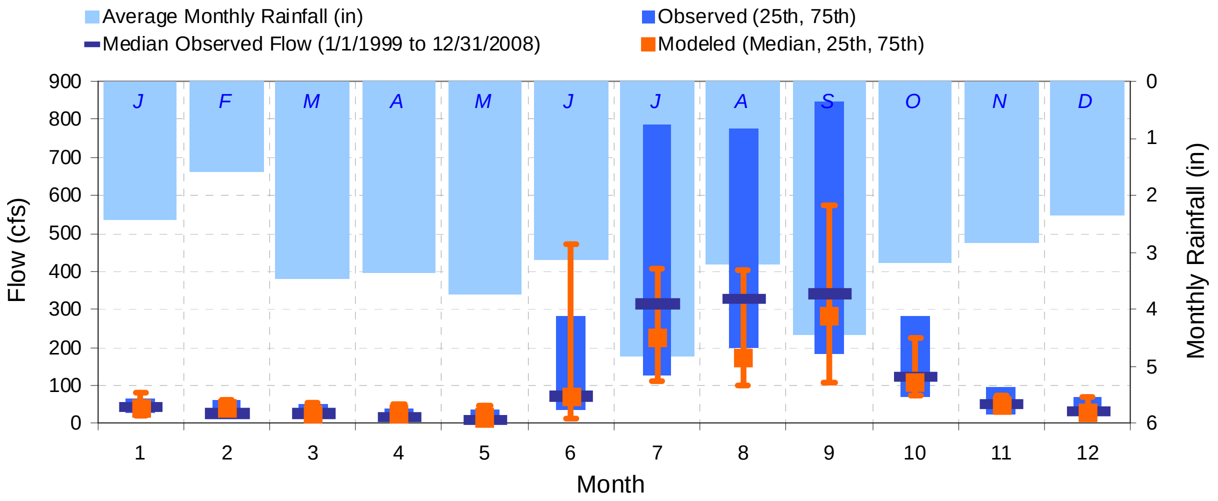
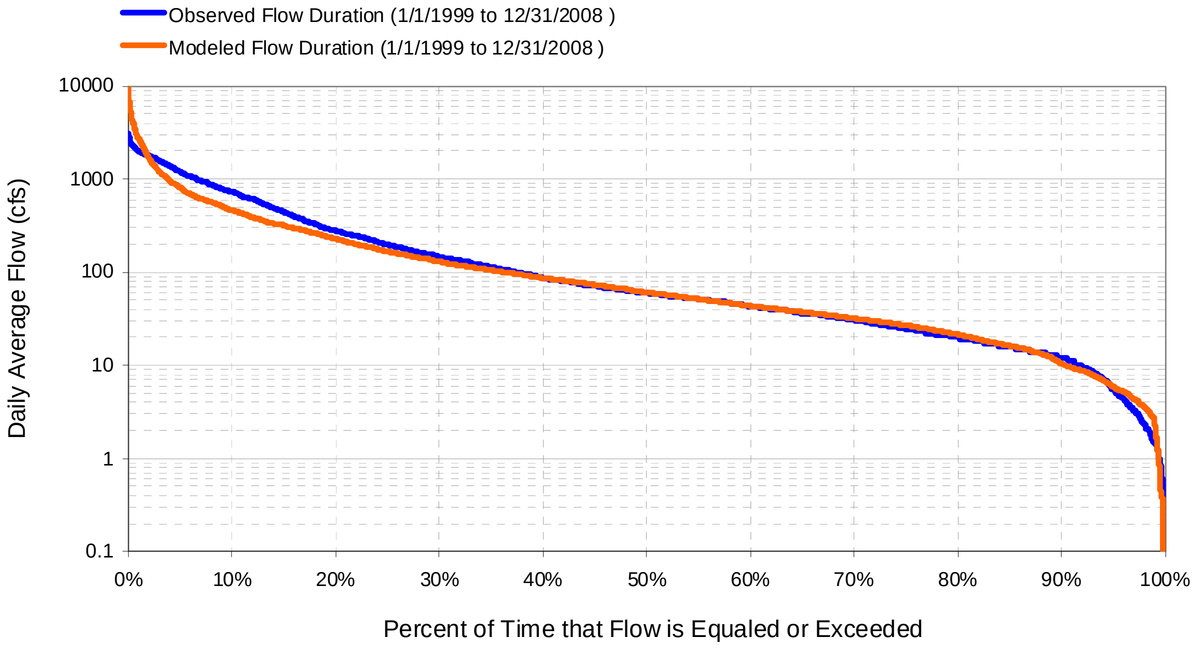


Figure A-12. Seasonal medians and ranges: Model Outlet 10 vs. USGS 02298123 Prairie Creek Near Fort Ogden FL

Table A-3. Seasonal summary: Model Outlet 10 vs. USGS 02298123 Prairie Creek Near Fort Ogden FL

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	69.26	45.00	30.00	66.50	62.11	42.59	22.62	81.58
Feb	45.47	28.00	20.00	64.50	70.50	42.44	29.79	62.96
Mar	54.00	27.50	15.00	52.75	62.85	27.63	15.33	55.18
Apr	32.46	20.00	11.00	39.00	38.72	27.29	10.03	50.97
May	25.11	10.00	4.33	37.00	31.37	16.64	7.77	46.36
Jun	416.27	74.00	35.75	281.50	480.43	70.79	15.03	470.64
Jul	539.12	316.00	125.00	787.00	392.64	226.26	111.34	406.71
Aug	535.74	328.00	198.00	773.25	411.22	174.07	101.31	402.04
Sep	579.33	342.50	184.50	844.75	561.60	282.99	106.51	573.14
Oct	235.95	125.00	69.25	280.50	210.56	107.88	75.03	225.26
Nov	110.24	54.00	23.00	97.00	98.00	48.98	34.20	72.82
Dec	119.42	35.00	21.00	70.75	101.10	30.60	20.88	71.38



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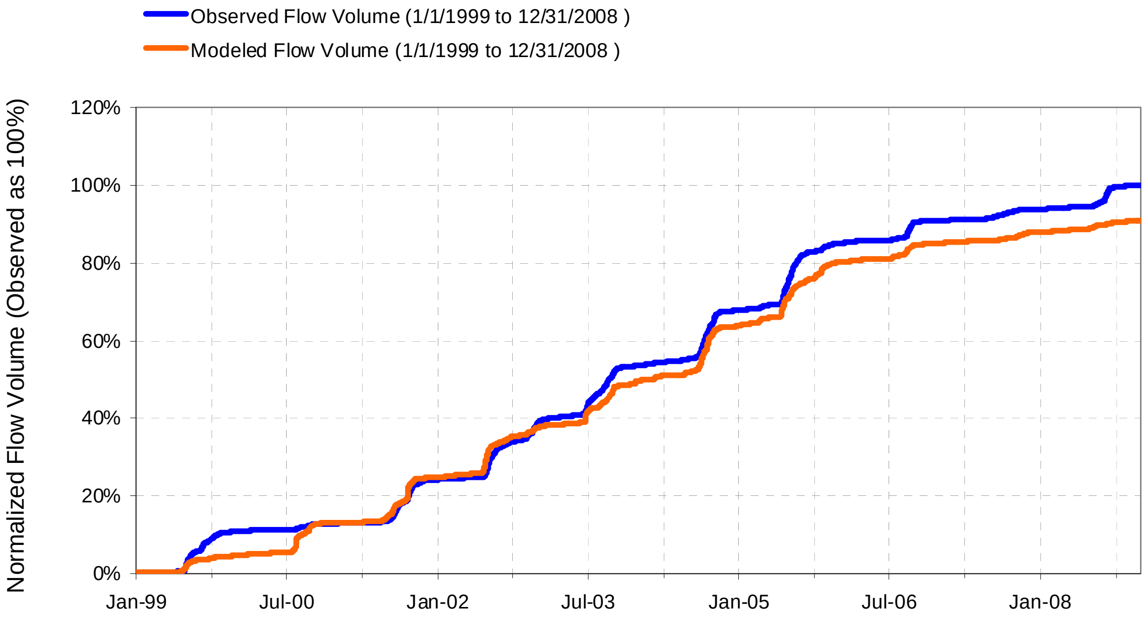
igure A-13. Flow exceedence: Model Outlet 10 vs. USGS 02298123 Prairie Creek Near Fort Ogden FL



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igure A-14. Flow accumulation: Model Outlet 10 vs. USGS 02298123 Prairie Creek Near Fort Ogden FL

Table A-4. Summary statistics: Model Outlet 10 vs. USGS 02298123 Prairie Creek Near Fort Ogden FL

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 10 10-Year Analysis Period: 1/1/1999 - 12/31/2008 Flow volumes are (inches/year) for upstream drainage area		**USGS 02298123 PRAIRIE CREEK NEAR FORT OGDEN FL** Hydrologic Unit Code: 3100101 Latitude: 27.05199986 Longitude: -81.7845267 Drainage Area (sq-mi): 233	
Total Simulated In-stream Flow:	**12.25**	Total Observed In-stream Flow:	**13.47**
Total of simulated highest 10% flows:	**7.53**	Total of Observed highest 10% flows:	**7.72**
Total of Simulated lowest 50% flows:	**0.80**	Total of Observed Lowest 50% flows:	**0.78**
Simulated Summer Flow Volume (months 7-9):	**6.67**	Observed Summer Flow Volume (7-9):	**8.09**
Simulated Fall Flow Volume (months 10-12):	**2.01**	Observed Fall Flow Volume (10-12):	**2.29**
Simulated Winter Flow Volume (months 1-3):	**0.94**	Observed Winter Flow Volume (1-3):	**0.82**
Simulated Spring Flow Volume (months 4-6):	**2.64**	Observed Spring Flow Volume (4-6):	**2.27**
Total Simulated Storm Volume:	**4.59**	Total Observed Storm Volume:	**2.29**
Simulated Summer Storm Volume (7-9):	**2.60**	Observed Summer Storm Volume (7-9):	**1.33**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	*1995-1999*	*2000-2004*
Error in total volume:	-8.99	10	-1.43	7.35
Error in 50% lowest flows:	2.31	10	-1.60	-3.91
Error in 10% highest flows:	-2.52	15	2.26	1.75
Seasonal volume error - Summer:	-17.62	30	13.27	-2.52
Seasonal volume error - Fall:	-12.02	30	4.49	12.42
Seasonal volume error - Winter:	14.91	30	-18.21	13.31
Seasonal volume error - Spring:	16.20	30	1.90	6.11
Error in storm volumes:	**100.73**	**20**	**1.13**	**12.07**
Error in summer storm volumes:	**95.21**	**50**	**3.16**	**15.42**
Nash-Sutcliffe Coefficient of Efficiency, E:	-0.138	Model accuracy increases	0.688	0.814
Baseline adjusted coefficient (Garrick), E':	0.368	as E or E' approaches 1.0	0.517	0.549