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5. SITE SPECIFIC MODEL SELECTION, PREPARATION, VERIFICATION, CALIBRATION, AND VALIDATION

5.1 Model Selection and Description

Previously submitted

5.2 HSPF Model

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This section describes the Hydrologic Simulation Program – FORTRAN (HSPF) model setup for the Caloosahatchee River watershed (HUC 03090205), model output and verification. The model is used to simulate flow, total suspended solids (TSS), total phosphorus (TP), total nitrogen (TN), carbonaceous biochemical oxygen demand (CBOD) and dissolved oxygen (DO), and provide pollutant load time-series that are used as input to the EFDC hydrodynamic and water quality model.

terminology hydrologic units? Global

The Caloosahatchee River watershed was divided into 102 subwatersheds that included major tributaries and point source discharges. The model was progressively calibrated for flow, temperature, TSS, BOD, nutrients and DO. HSPF generates non-point source runoff and loads from land sources and drains them to adjacent stream segments. Flow in the stream segments is routed downstream along with water quality constituents. Appropriate land based and in-stream processes ~~are~~ were selected and parameterized through model calibration and sensitivity analyses. Modeled streamflow and pollutant concentrations are compared with observed data from flow gages and water quality monitoring stations for model calibration and validation. Finally, time series of flow, temperature, and water quality constituent concentrations computed at different locations of tidal lower part of the Caloosahatchee River serve as input to the EFDC model.

5.2.1 HSPF MODEL DEVELOPMENT

The Caloosahatchee HSPF model simulates flow and water quality constituent loads from various land uses in each subwatershed and transports water and water quality constituents through stream/lake segments. The upstream boundary of the Caloosahatchee River is defined by the Moorehaven Lock (S-77), which generally controls the flow from Lake Okeechobee to the river. There are many wastewater treatment plants, most of which are small facilities in the watershed. The discharge and pollutant loads from these wastewater treatment plants were incorporated in the model. The watershed also includes a large number of pumps that withdraw water from surface and ground water sources. Pumping of ground water and releasing the return flow to surface water affect the flow and water quality in stream reaches.

more show

? # Modeled ?

The model consists of physical data describing the distribution and characteristics of various land uses, physical attributes of stream and lake reaches, time series input data and model parameters.

Many input data are derived from spatial data using standard geographic information system (GIS) software. Time series input data, such as rainfall, temperature, upstream boundary condition, point source discharge and groundwater pumpage data were analyzed in Microsoft Excel to perform data quality checks and to estimate data for missing values. Processed time series data were stored in the WDM format for efficient use by the model. Initial model parameters were selected based on literature values. The final and site specific parameter values were obtained through model calibration.

5.2.1.1 Model Simulation Period

The HSPF hydrologic model was calibrated using data from January 1, 2001 through December 31, 2005 and validated used using data from January 1, 1997 through December 31, 1999. The intended simulation period through December 31, 2006 was shortened due to unavailability of flow data at the upstream boundary (i.e. inflow from Lake Okeechobee at the S-77 lock). The HSPF water quality model calibrated using the ambient water quality data from January 1, 2004 through December 31, 2005 and validated using the ambient water quality data from January 1, 2002 through December 31, 2003.

really? This is usually available

5.2.1.2 Model Constituents

Flow and the following water quality constituents were modeled using HSPF:

- Water temperature
- Total suspended solids
- Carbonaceous Biochemical oxygen demand (BOD) BOD5 ? how does it relate to BOD5?
- Nitrogen (~~various species~~) TN, TKN, NO2+NO3, NH3/NH4*
- TP and Ortho-Phosphate
- Phytoplankton (chlorophyll a)
- Dissolved oxygen (DO)

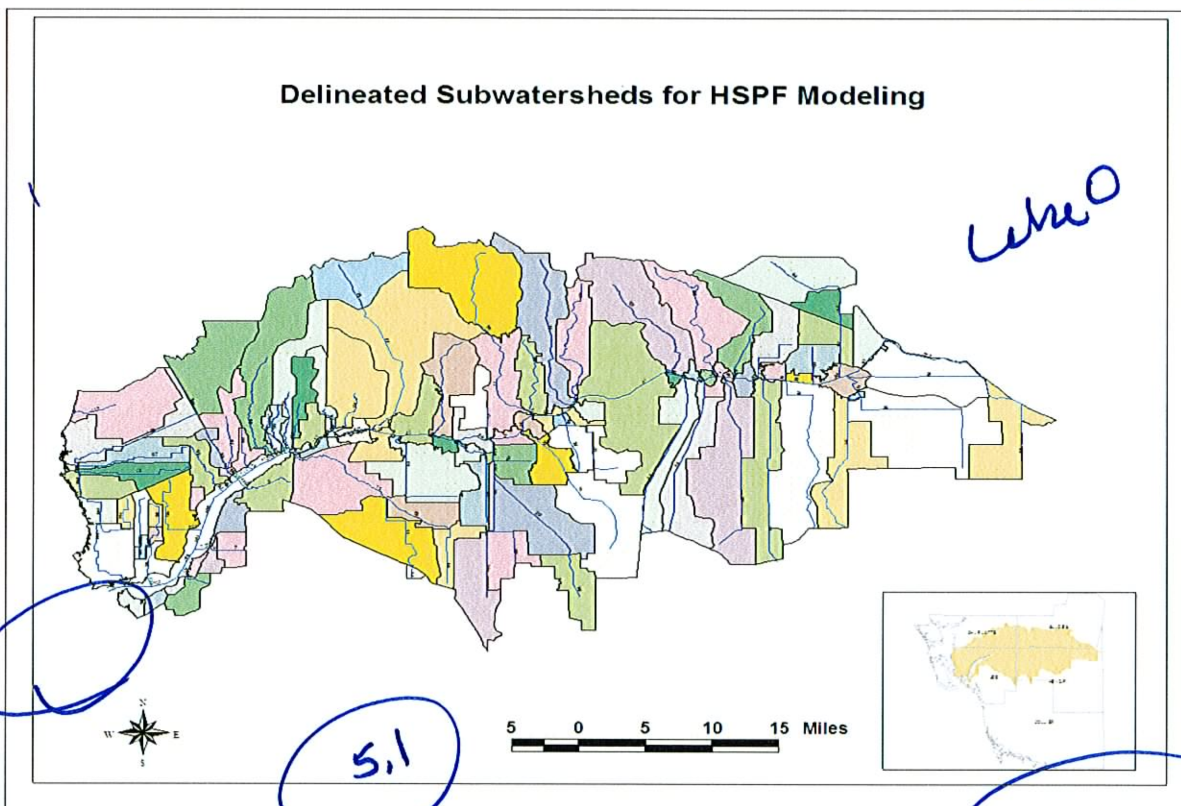
With the exception of phytoplankton, all of these constituents were modeled for the tributary land area, and loaded to the HSPF reaches in the watershed.

5.2.1.3 Model Discretization

The smallest discrete hydrologic unit in a HSPF model application is a subwatershed and associated receiving water reach. The model requires the acreage of various land uses in each subwatershed and ~~the stream~~ reach that the land segments discharge to. The Caloosahatchee River watershed was divided into 102 subwatersheds and the stream network was divided into 97 reaches, see Figure 5.1 ~~1 below~~. The subwatershed boundaries were delineated using existing WBID boundaries, topographic data (Composite Topography for SW Florida, 100-ft), and the drainage network (High Resolution National Hydrography Dataset, USGS) in GIS. Tributary confluences, hydraulic structures and flow gages were used to define the segmentation locations. Also major changes in slope, channel cross-section, depth and other physical characteristics were considered in model segmentation. One F-Table (a depth-discharge relationship or rating curve) was developed for each reach ~~assuming a~~ using an equivalent trapezoidal cross-section and obtaining reach characteristics data from? (ref)

A previous modeling effort of the Caloosahatchee River watershed compiled the stream cross-section data from various sources and estimated reach characteristics ~~assuming~~ using an equivalent trapezoidal cross-sections. According to the report, the District provided the cross sections for parts of C-43, Jack's Branch, County Line Ditch, Canal 1, Canal 2, C-19, 42-foot canal and Hilliard Canal. The cross-sections for other stream segments were estimated from the topographic data. Table 1 lists the reach characteristics used to develop the F-Tables for the HSPF model. 5.1

who?



5.1

Figure 1 Delineated subwatersheds for HSPF Modeling

11 x 17

Label: IDs, Major Roads, watercourse, structures

Table 1. Reach characteristics used to develop F-Tables (rating curves) for the HSPF model

5.1

Reach ID (HSPF)	Reach Name	Length (mile)	Bottom Width (ft)	Side Slope (ft/ft)	Manning's Roughness
4	Hendry Creek	1.94	75	4.0	0.034
6	WC L-Canal	0.62	30	5.0	0.034
7	WC L-Canal	2.22	30	5.0	0.034
9	Billy Creek	4.13	15	3.5	0.034
10	Able Canal	9.73	250	2.0	0.034
11	Sailfish	8.41	45	2.0	0.034
12	57-19-1	1.18	20	3.0	0.034
13	Able Canal	5.68	50	2.0	0.034
14	Bellwest	4.91	50	3.2	0.034
18	C-43	2.36	164	6.2	0.030
19	Hickey Creek	10.19	46	1.4	0.022
20	C-43	2.13	118	7.1	0.030
21	C-43	2.01	72	5.3	0.030
22	Bedman Creek	2.98	33	1.2	0.022
23	Dog Canal	5.85	26	1.0	0.022
24	C-43	2.50	52	4.9	0.030
25	LPDD Header Canal1	2.83	27	0.7	0.022
26	Duda Canal	4.78	50	3.0	0.022
27	Hendry Canal Ext	6.08	53	0.8	0.022
28	Duda Canal	4.00	50	3.0	0.022
29	Townsend Canal	8.61	66	0.5	0.022
30	Townsend Canal	4.18	66	0.5	0.022
31	C-43	2.81	223	1.0	0.030
32	Roberts Canal	5.24	32	0.5	0.022
33	Roberts Canal	8.45	13	1.0	0.022
34	C-43	1.48	223	1.0	0.030
35	C-43	2.32	219	1.1	0.030
36	Crawford	1.10	30	0.8	0.022
37	Crawford	4.16	15	1.0	0.022
38	SR-29 Ditch	7.41	30	0.7	0.022
39	C-43	1.06	94	4.5	0.030
40	C-43	0.48	85	4.7	0.030
41	C-43	7.53	111	4.0	0.030
42	C-43	1.49	190	1.9	0.030
43	Canal 1	14.33	50	1.0	0.022
44	C-43	1.45	298	3.9	0.030
45	Canal 2	13.32	65	0.6	0.022
46	C-43	1.07	298	3.9	0.030
47	C-43	0.57	298	3.9	0.030
48	Canal 3	15.59	56	3.6	0.022
49	C-43	0.81	298	3.9	0.030
50	C-43	1.91	298	3.9	0.030

1 2 3 ?

?

these seem low

Reach ID (HSPF)	Reach Name	Length (mile)	Bottom Width (ft)	Side Slope (ft/ft)	Manning's Roughness
51	42-Foot Canal	16.07	14	0.5	0.022
52	C-43	1.78	227	4.5	0.030
53	C-43	1.97	44	6.1	0.030
54	Hilliard Canal	15.59	52	0.6	0.022
55	C-43	3.87	659	6.2	0.030
56	Left HH Canal	13.29	36	0.8	0.022
57	Flaghole Canal	2.56	52	2.8	0.022
58	FlagHole5	13.72	37	1.0	0.022
59	Disston Main Canal	10.05	72	0.8	0.022
60	Industrial Canal	8.80	52	1.0	0.022
61	C-43	3.20	72	3.3	0.030
62	C-19	4.47	20	3.0	0.022
63	C-19	3.16	10	3.0	0.022
64	C-19	6.28	2	3.0	0.022
65	(No name)	3.17	30[1]	1.0[1]	0.034[1]
66	Meanderline Ditch	5.35	9	0.2	0.022
67	Citrus Center Canal	6.77	30	0.7	0.022
68	Lindens Pen Marsh	14.91	20	1.0	0.022
69	Cypress Branch	11.34	20	1.7	0.074
70	Polywog Branch	13.52	10	1.0	0.022
71	Bee Branch	14.22	10	0.6	0.022
72	Ft. Denaud	7.25	3	1.0	0.022
73	Jacks Branch	8.68	20	0.9	0.022
74	Jacks Branch	8.45	20	0.9	0.022
75	County Line	3.23	13	0.9	0.022
76	Cypress Creek	9.72	10	0.6	0.022
77	Big Island Canal	13.09	35	0.5	0.022
79	Big Island Canal	4.23	35	0.5	0.022
80	Owl Creek	0.50	13	1.5	0.034
81	Trout Creek	4.51	50	5.0	0.034
82	Owl Creek	1.99	13	0.9	0.034
84	Stroud Creek	4.40	20	3.3	0.034
85	Popash Creek	5.98	20	3.0	0.034
86	Bayshore Creek	4.81	20	5.0	0.034
87	Chapel Creek	3.88	20	2.5	0.034
88	Daughtrey Branch1	10.51	13	2.0	0.034
89	Marshpoint	3.62	13	3.0	0.034
90	Powell Creek	0.91	100	4.0	0.034
91	Powell Creek	4.68	30	4.0	0.034
92	(No name)	3.81	30[1]	4.0[1]	0.034[1]
93	Yellow Fever Creek	4.66	50	4.0	0.034
95	Mackinac	7.09	162	2.0	0.034

Reach ID (HSPF)	Reach Name	Length (mile)	Bottom Width (ft)	Side Slope (ft/ft)	Manning's Roughness
96	San Carlos	2.94	133	2.0	0.034
97	San Carlos	2.23	90	2.0	0.034
98	San Carlos	2.60	90	2.0	0.034
99	Courtney	2.92	70	2.1	0.034
100	Courtney	4.73	70	2.1	0.034
101	Aries	10.18	130	2.0	0.034
102	Aries	3.62	130	2.0	0.034
124	Bedman Creek	1.96	33	1.4	0.022
126	Townsend Canal	1.28	66	0.5	0.037
131	C-43	0.26	223	1.0	0.030
150	C-43	0.47	284	4.0	0.030
172	Jacks Branch	0.32	20	0.9	0.022
501	C-43	3.28	262	4.5	0.030
559	Disston Main Canal	8.75	77	0.7	0.022

[1] Estimated using topographic data and aerial photo

5.2.1.4 Land Use

The seamless GIS coverage of a 2004 land use data provided by the ~~South Florida Water Management District (~~SFWMD~~)~~ was considered appropriate for the development of the existing condition model. Since the year of the land use data coincided with the model calibration period, the data was considered representative of the watershed condition. The land uses were grouped into ten different classes to capture the variation of watershed characteristics affecting the flow and pollutant loads. Distribution of these land uses are shown in Figure 2. The figure shows that urban areas (e.g. commercial, and high, medium and low density residential areas) were more concentrated in lower Caloosahatchee River watershed along shores and a larger percentage of croplands are located in the upper part of the watershed. areas ~~Acreage~~ of different land uses in each subwatershed was computed in GIS overlaying and intersecting the land use GIS data with the delineated subwatershed boundary. Percent of directly connected impervious area (DCIA) for each land use was initially estimated based on previous modeling efforts and similar studies and the pervious and impervious area of various land uses in each subwatershed was incorporated in the model. The DCIA values were refined and finalized through model calibration. A summary of land use distribution in the areas upstream and downstream of Franklin Lock (S-79) is provided in Table 2 and graphically shown in Figure 3. The table also includes the distribution of land uses for the entire watershed as well as the DCIA values.

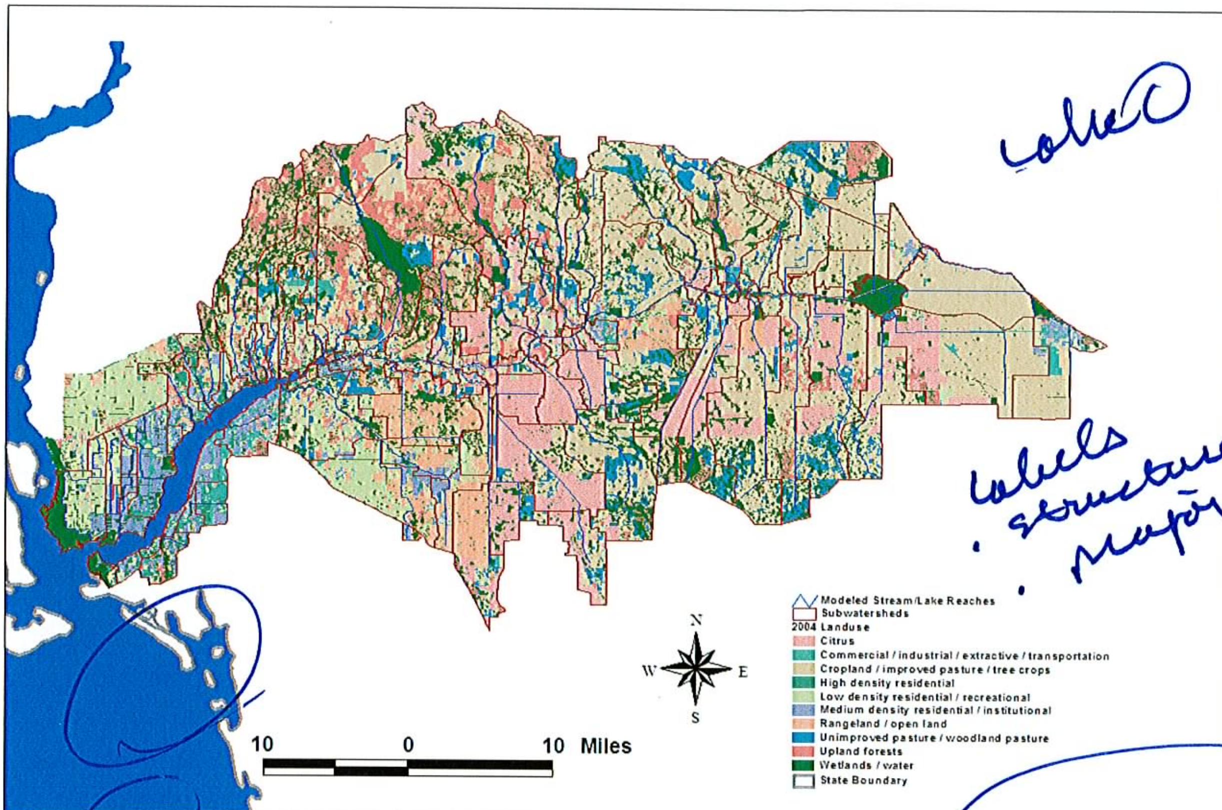


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Figure 2. Distribution of land uses in the Caloosahatchee River watershed. 8.5 x 11

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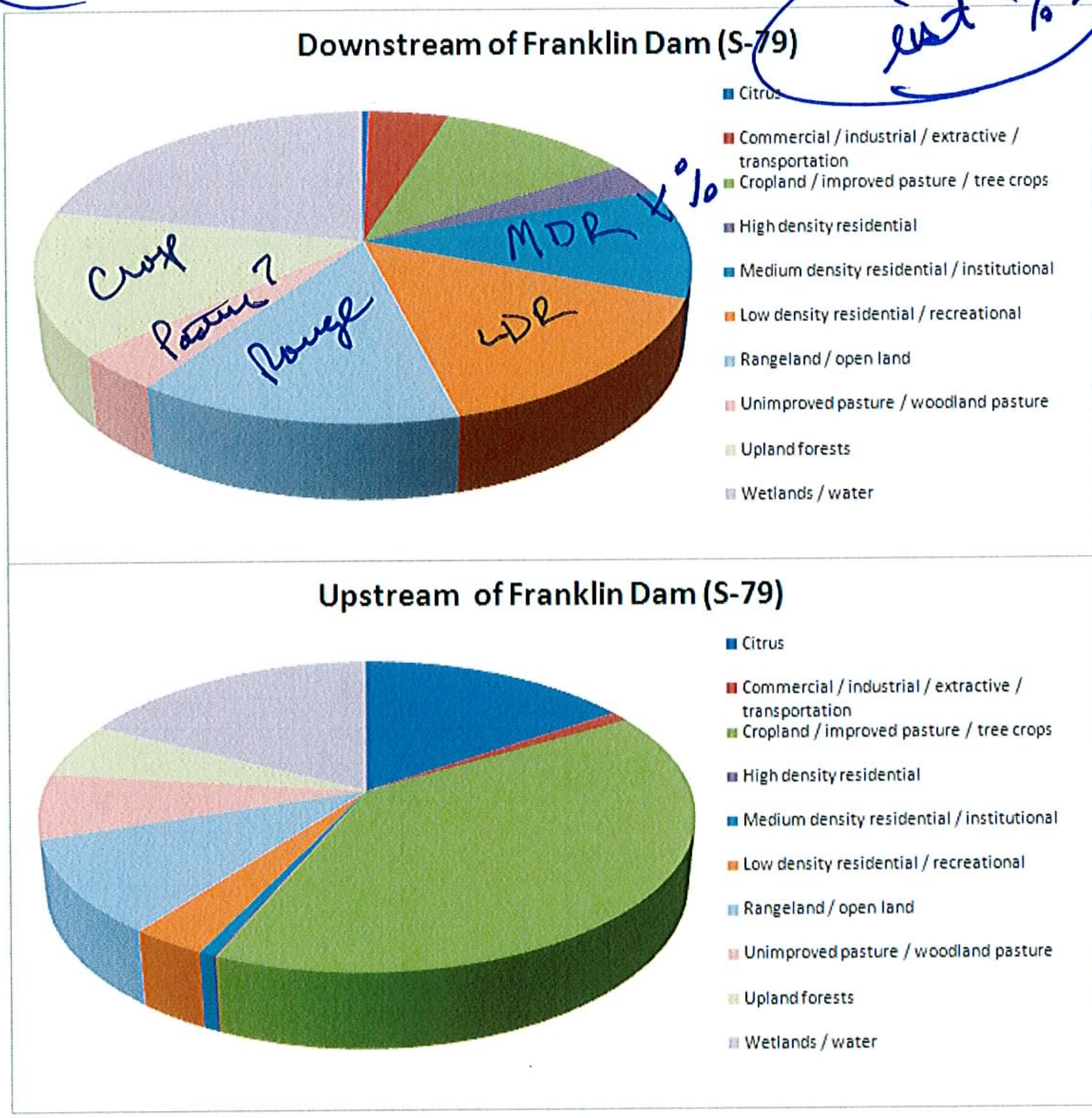
Table 2. Distribution of areas and estimated DCIA by land use in the upper, the lower and the entire Caloosahatchee River watershed.

Location	Land Use	Area (acres)	Percent of Total Area (%)	DCIA (%)
	Citrus	976	0.38	1
	Commercial / industrial / extractive / transportation	11944	4.60	66
	Cropland / improved pasture / tree crops	29269	11.28	1
	High density residential	8727	3.36	49
Downstream of Franklin Dam (S-79)	Medium density residential / institutional	29500	11.37	26
	Low density residential / recreational	39092	15.07	10
	Rangeland / open land	35516	13.69	1
	Unimproved pasture / woodland pasture	9908	3.82	1
	Upland forests	38295	14.76	1
	Wetlands / water	56257	21.68	0
	Total Area/Average DCIA	*259484*		*10*

nearest 0.1%

Upstream of Franklin Dam (S-79)	Citrus	97645	15.74	1
	Commercial / industrial / extractive / transportation	6384	1.03	66
	Cropland / improved pasture / tree crops	246376	39.70	1
	High density residential	558	0.09	49
	Medium density residential / institutional	4302	0.69	26
	Low density residential / recreational	19824	3.19	10
	Rangeland / open land	61069	9.84	1
	Unimproved pasture / woodland pasture	41636	6.71	1
	Upland forests	34909	5.63	1
	Wetlands / water	107820	17.38	0
	Total Area/Average DCIA	***620524***		***2***
Entire Caloosahatchee River Watershed	Citrus	98621	11.21	1
	Commercial / industrial / extractive / transportation	18329	2.08	66
	Cropland / improved pasture / tree crops	275645	31.32	1
	High density residential	9285	1.06	49
	Medium density residential / institutional	58916	3.84	26
	Low density residential / recreational	33803	6.69	10
	Rangeland / open land	96585	10.98	1
	Unimproved pasture / woodland pasture	51544	5.86	1
	Upland forests	73205	8.32	1
	Wetlands / water	164077	18.64	0
	Total Area/Average DCIA	***880009***		***5***

Figure 3. Distribution of land uses in the lower and the upper Caloosahatchee River watershed.



5.2.1.5 Meteorological Data

HSPF uses meteorological data to generate runoff and pollutant loads. Modeled runoff and pollutant loads from point and nonpoint sources were routed through stream reaches. Representative hourly rainfall and potential evapotranspiration (PET) are the key meteorological inputs to HSPF. Hourly precipitation data for the desired simulation period (January 1996 through December 2006) is available from many Lee County, the ~~South Florida Water~~

SFWMD

~~Management District~~ and the ~~National Oceanic and Atmospheric Administration (NOAA)~~ rain gages in the Caloosahatchee River watershed. But none of the gages has a complete data set covering the entire simulation period. Because of missing data at the precipitation gages, large watershed area and significant spatial variation in storm intensity, it was necessary to use precipitation data derived from the Next Generation ~~Doppler~~ Radar (NEXRAD) data. NOAA's National Weather Service maintains 159 Weather Surveillance Radar-1988 Doppler (WSR-88D) sites throughout the United States and some overseas locations that comprise the NEXRAD network. From three meteorological base data quantities – reflectivity, mean radial velocity, and spectrum width, hourly precipitation data are computed on a seamless 1.1x1.1 nautical mile grid. The time series data for all the grid cells located in the Caloosahatchee River watershed were obtained and aggregated into fifteen area-weighted precipitation time series representing different parts of the watershed. Fifteen time series were selected to attain the maximum spatial resolution in precipitation data without exceeding the model limits ~~. These areas were defined by~~ grouping multiple subwatersheds as shown in Figure 5. 4. The total ~~annual~~ precipitation for each NEXRAD precipitation zone and their variability are provided in Table 5. 3. ~~The table clearly shows that~~ precipitation is ~~the maximum~~ higher near coast and gradually reduces towards Lake Okeechobee.

by total number of operations in our model

Observed daily temperature and evapotranspiration data were available from the SFWMD meteorological station -- S78W. However, the observed evapotranspiration data was not available for the entire simulation period. Therefore, daily potential evapotranspiration (PET) data was computed in WDMUtil using Hamon's method (Hamon, 1961). Hamon's method was selected because it required only the daily maximum and the minimum temperatures, and latitude of the location as input. Total annual PET was then compared with available evapotranspiration at S78W and adjusted to ensure that the computed PET time series was representative of the Caloosahatchee River watershed. The average annual PET for the Caloosahatchee River watershed was 54.3 inches. Daily PET was then desegregated to hourly values using WDMUtil.

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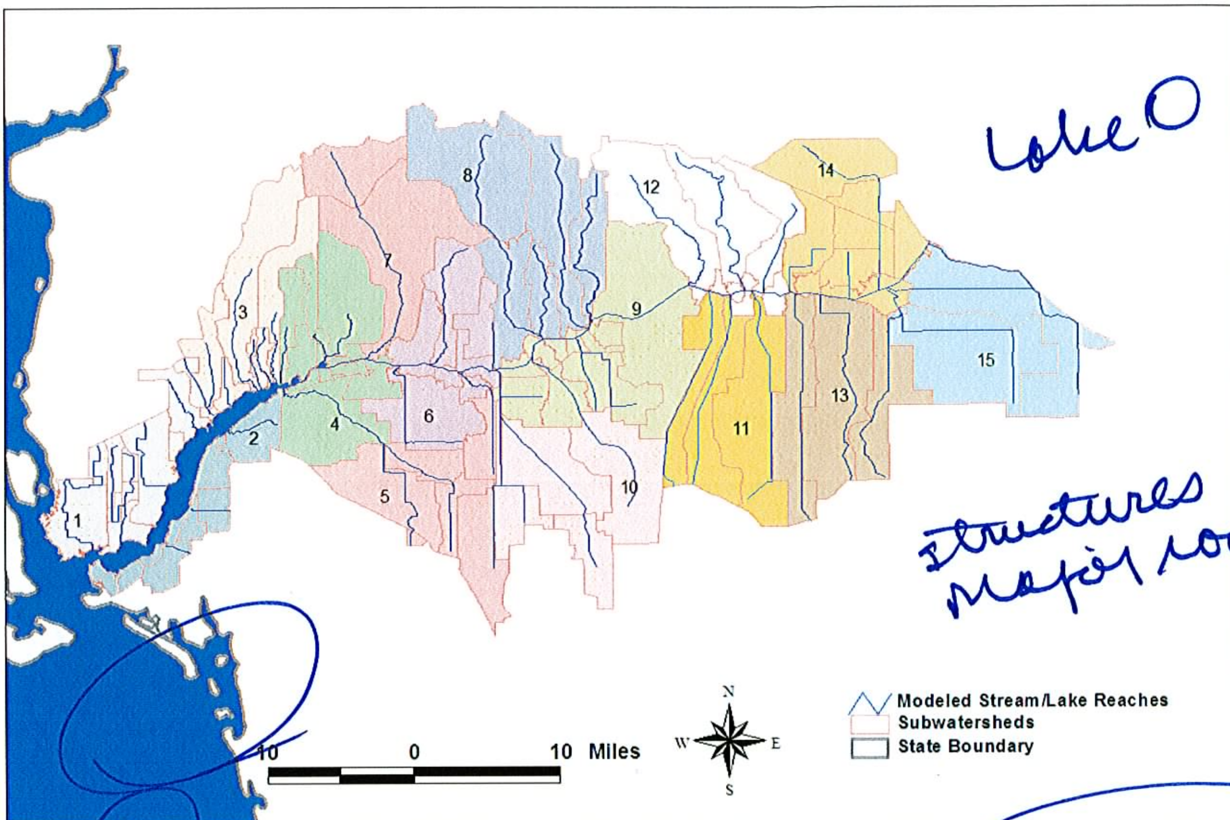

Lake O

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major roads

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Figure 4. Zones defining the areas of equal precipitation time series as developed from hourly NEXRAD data.

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Table 3. Total annual precipitation by NEXRAD zone and their statistics

Location	Total Precipitation (in) by Year								
	1997	1998	1999	2000	2001	2002	2003	2004	2005
NEXRAD Zone 01	69.0	67.6	69.1	58.9	64.1	83.8	80.4	61.9	75.6
NEXRAD Zone 02	68.1	65.0	69.0	54.8	62.7	76.5	79.1	63.9	80.6
NEXRAD Zone 03	59.8	63.4	66.0	41.5	50.2	66.1	70.0	54.4	67.8
NEXRAD Zone 04	61.6	64.9	61.5	42.2	53.3	70.7	69.5	55.1	70.3
NEXRAD Zone 05	59.0	59.4	63.1	58.3	66.2	64.9	72.7	55.0	68.8
NEXRAD Zone 06	63.8	65.1	63.0	44.6	59.3	69.7	69.3	57.2	73.4
NEXRAD Zone 07	64.7	64.1	60.4	42.9	54.1	71.6	64.7	53.6	67.1
NEXRAD Zone 08	62.6	58.9	58.3	40.8	55.6	67.2	60.3	50.8	65.8
NEXRAD Zone 09	56.4	61.8	60.2	41.7	57.2	69.6	65.8	47.4	69.8
NEXRAD Zone 10	51.0	54.8	65.5	58.1	69.1	62.5	60.2	48.0	68.1
NEXRAD Zone 11	45.6	54.4	59.6	40.7	57.9	59.9	61.1	43.1	71.5
NEXRAD Zone 12	53.8	52.6	57.9	37.1	49.2	65.9	65.3	45.4	65.3
NEXRAD Zone 13	45.4	54.0	57.3	39.6	51.5	56.5	56.2	43.6	67.6
NEXRAD Zone 14	49.8	56.9	58.2	33.8	44.9	53.0	56.4	39.3	59.2
NEXRAD Zone 15	47.1	56.5	59.0	36.6	47.8	50.0	53.0	49.5	62.6

Average	*57.2*	*60.0*	*61.9*	*44.8*	*56.2*	*65.9*	*65.6*	*51.2*	*68.9*
Minimum	*45.4*	*52.6*	*57.3*	*33.8*	*44.9*	*50.0*	*53.0*	*39.3*	*59.2*
Maximum	*69.0*	*67.6*	*69.1*	*58.9*	*69.1*	*83.8*	*80.4*	*63.9*	*80.6*
Standard Deviation	*8.0*	*4.9*	*3.9*	*8.4*	*7.1*	*8.8*	*8.0*	*7.0*	*5.2*

whole tables

5.2.1.6 Boundary Conditions

The Caloosahatchee River originates from Lake Okeechobee and flows southwestwardly to the estuary. There are three major structures – Moorehaven Lock (S-77), Ortona Lock (S-78) and Franklin Lock (S-79) along the Caloosahatchee River. These three locks are operated to maintain the water level in the Caloosahatchee River and used for navigational purpose. The Moorehaven Lock (S-77) is located at the upstream end of the Caloosahatchee River and, therefore, defines the upstream boundary of the HSPF model. Flow and ambient water quality measurements at S-77 were used to develop time series input data for the boundary condition. The Franklin Lock (S-79), located 43 miles downstream of the Lake Okeechobee, separates the freshwater upper part of the river from the tidal lower part of the river. The Ortona Lock (S-78) is located between the other two locks at 16 miles downstream of Lake Okeechobee. The Caloosahatchee River HSPF model includes the reaches between the Moorehaven Lock (S-77) and the Franklin Lock (S-79), and tributaries draining to these reaches. The model also includes reaches contributing to the tidal part of the Caloosahatchee River, but excludes the lower tidal part of the Caloosahatchee River (i.e. downstream of S-79). The tidal lower part of the Caloosahatchee River is included in the EFDC modeling domain. Flow through the Ortona Lock and the Franklin Lock are computed by the model using specific rating curves (i.e. F-Tables) and modeled flows at the reaches upstream of the locks. In order to have continuous flow data at S-77 to define the boundary condition for the entire simulation period and at S-78 and S-79 for model calibration and validation, the data from the gages at these locks were analyzed and the data gaps were filled as discussed below.

Daily mean flow data are available from two SFWMD gages – S77-S and S78-T at Moorehaven and Ortona Locks, respectively. These flow data span from 5/1/1996 to 5/6/2006 at the S77-S gage and from 1/1/1995 to 9/30/2003 at the S78-T gage. Additionally, three USGS flow gages (02292000, 02292480 and 02292900) are located at or near the S-77, S-78 and S-79 locks. An analysis of flow data from all the gages reveals that the flow data from the S78-T and 02292480 gages are essentially the same except that the S78-T flow data reports six missing values, and strong correlations exist between different datasets as presented in Table 1. The simple linear regression equations presented in Table 4 were used to populate the missing values and obtain complete flow time series data between Jan 1, 1995 and May 5, 2006. No data was available at any station after May 5, 2006. All negative values in the final flow time series were replaced by 0.0 since the HSPF model can ~~handle~~ directly simulate flows in only one direction. special action?

Table 5. 4 Correlation of Datasets

Average Daily Flow (cfs)			
Independent Variable (X)	Dependent Variable (Y)	Regression Equation	Coefficient of Determination (r^2)
USGS 02292000	S77-S	Y = 1.0563(X)-24.789	0.9852
S77-S	S78-T	Y = 1.0329(X) - 41.889	0.9076
S78-T	022929000	Y = 1.3225(X) + 340.15	0.8406

Observed water quality concentrations at S-77 were obtained from the District's DBHydro database. Concentrations of water quality constituents were linearly interpolated and multiplied by daily flow to develop daily load (flux) time series of heat, total suspended solids, ammonia, nitrate + nitrite, organic nitrogen, phosphate and dissolved oxygen. TKN TP These data were used to define the loads at the upstream boundary of the Caloosahatchee River. Time varying flow and fluxes of heat, total sauspended solids, ammonia, nitrate, nitrite, organic ~~nitrogen~~, phosphate and dissolved oxygen are shown in Figures 5. 5 through 5. 14, respectively. No CBOD measurement was available at S77.

group

revise list TKN TP

confirm BOD5

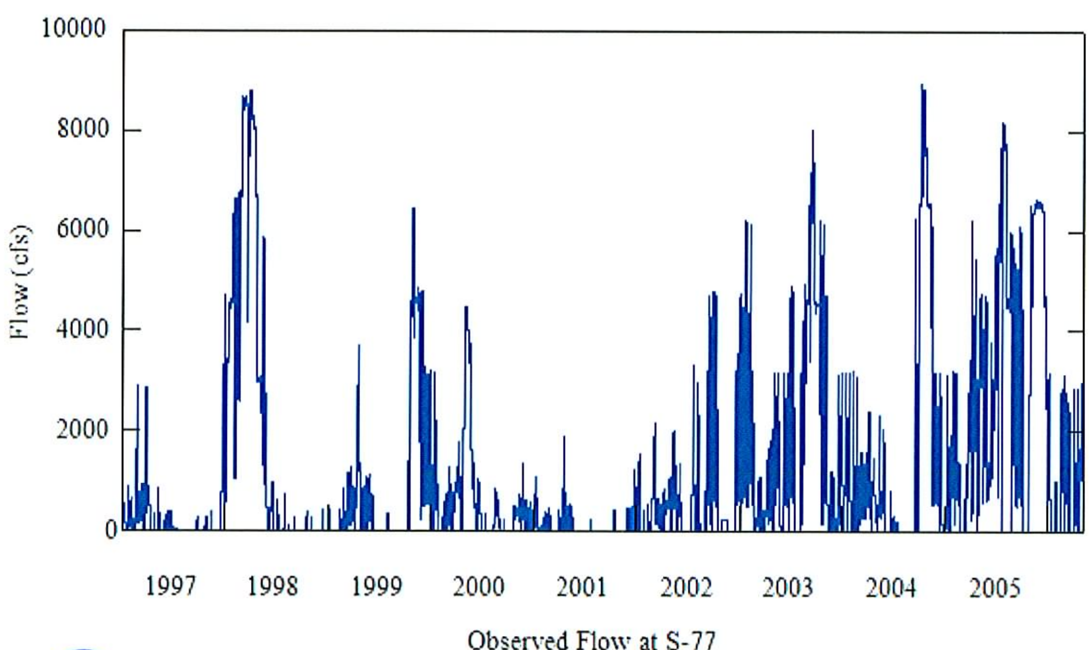

Figure 5. 5. Daily average flow at S77.

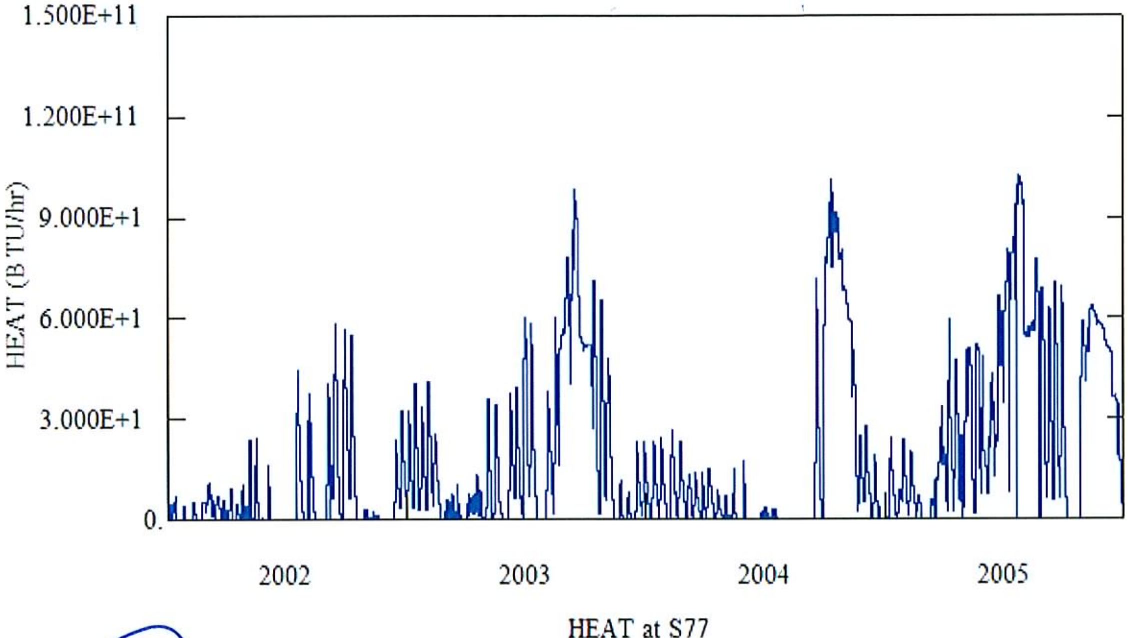

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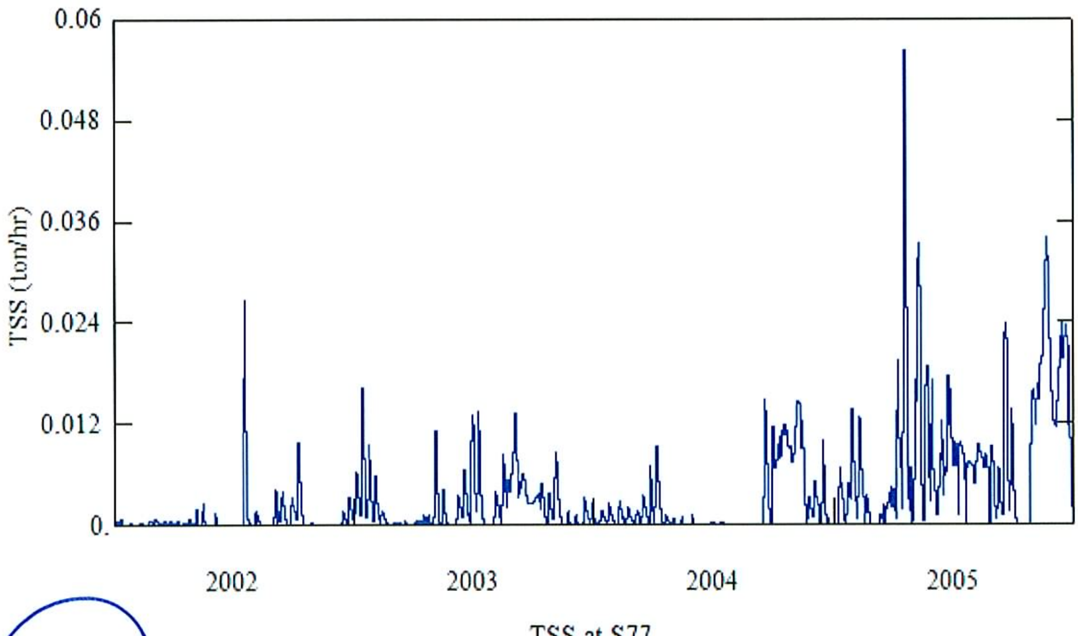
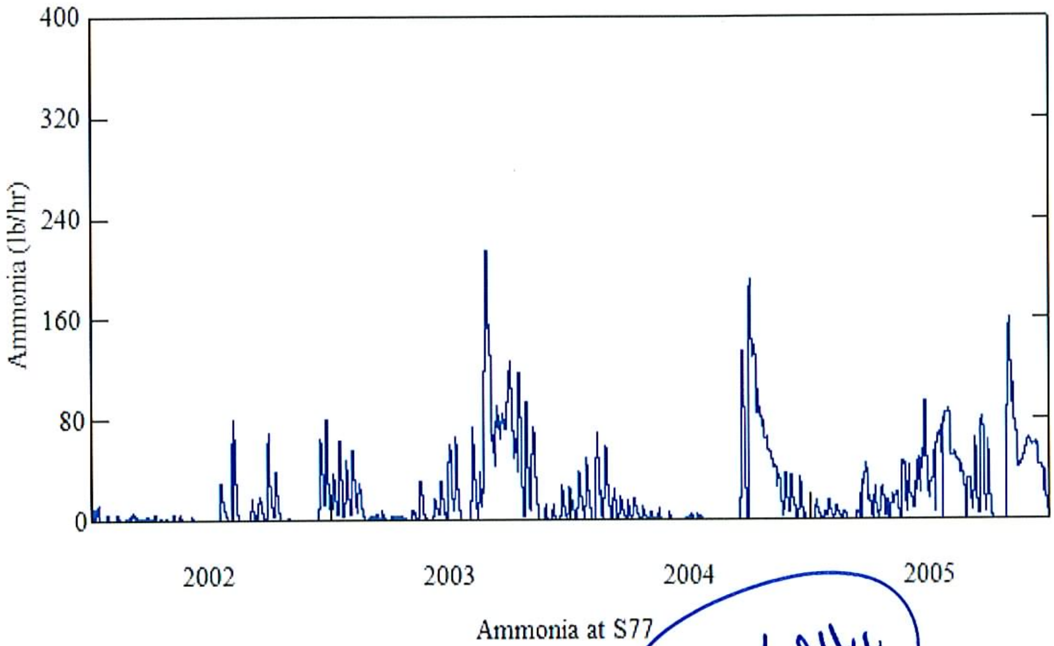
Figure 6. Hourly heat flux at S77.



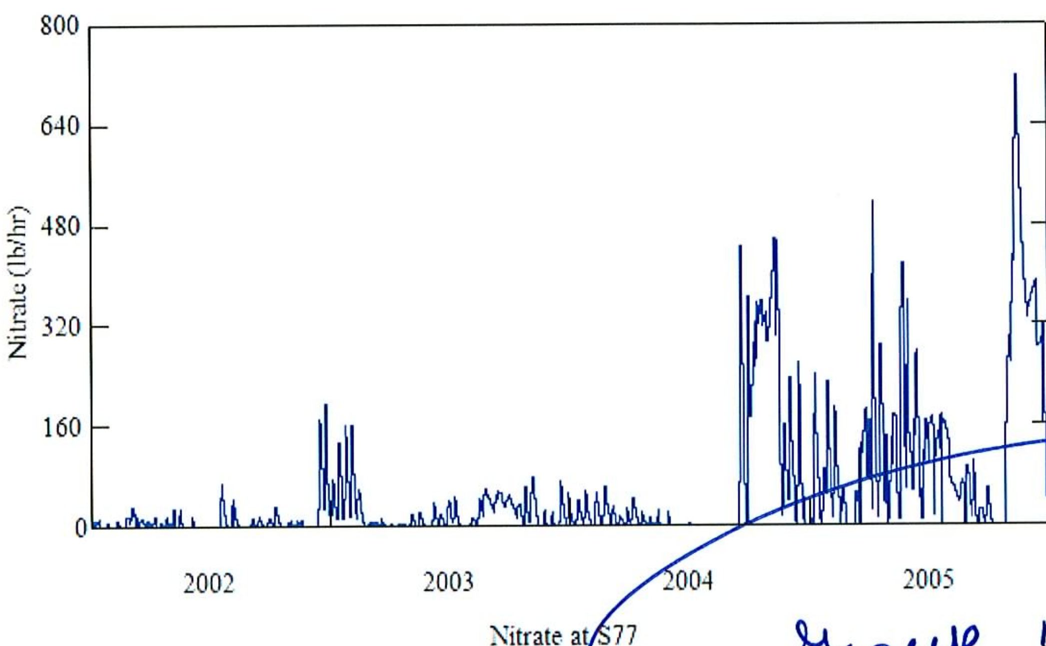
5.

Figure 7. Hourly total suspended solids flux at S77



NH_3/NH_4

Figure 8. Hourly ammonia flux at S77.



Group NO_2+NO

Figure 9. Hourly nitrate flux at S77.