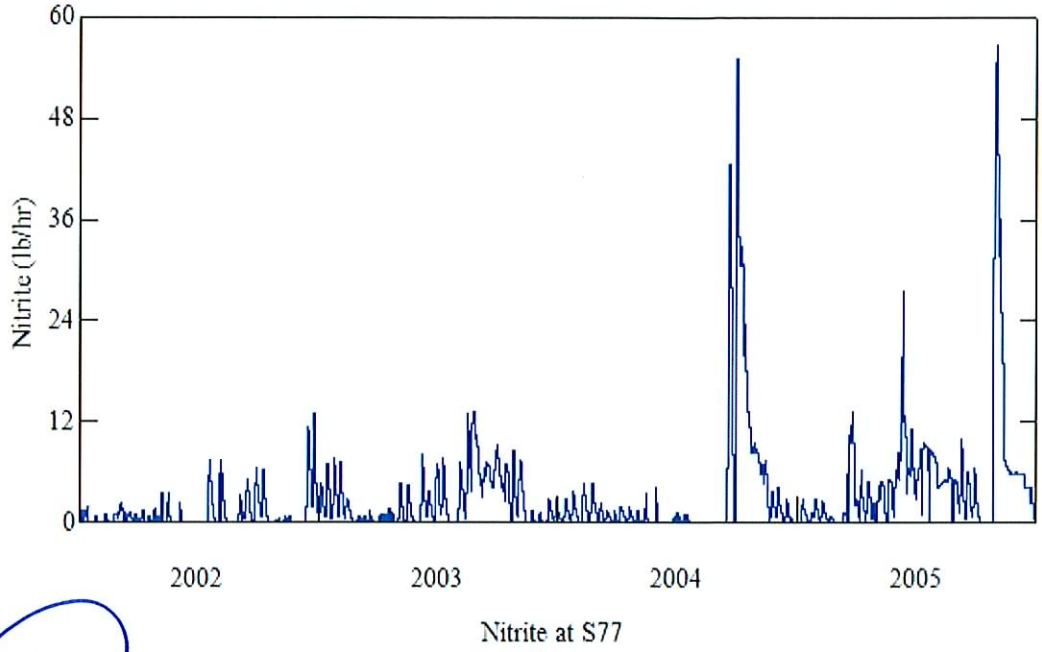


Figure 10. Hourly nitrite flux at S77.

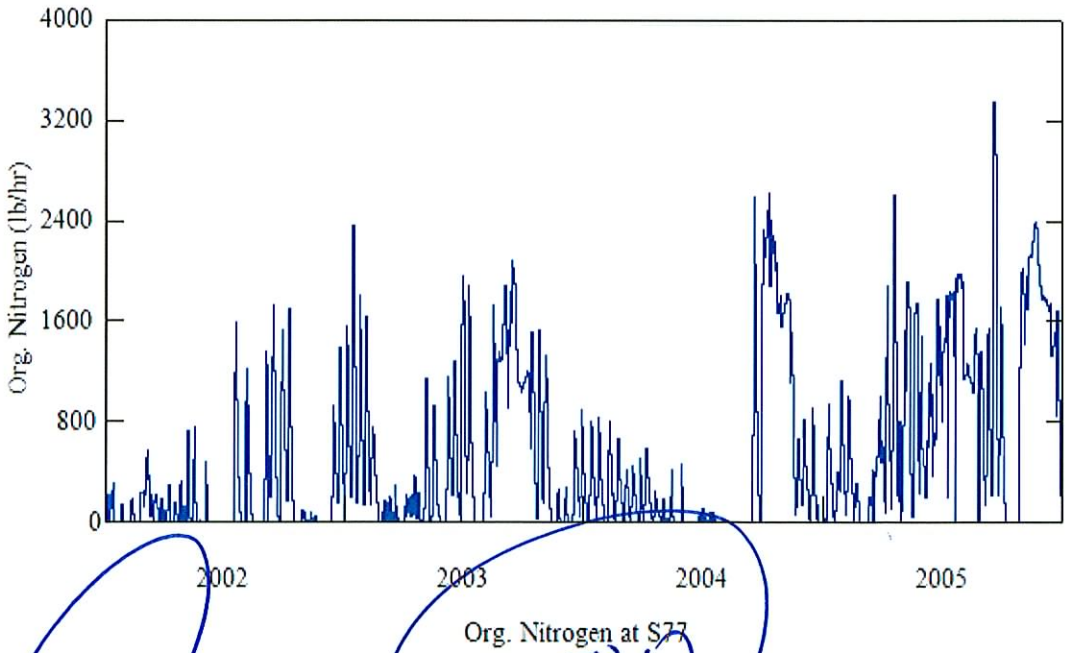


Figure 11. Hourly organic nitrogen flux at S77.

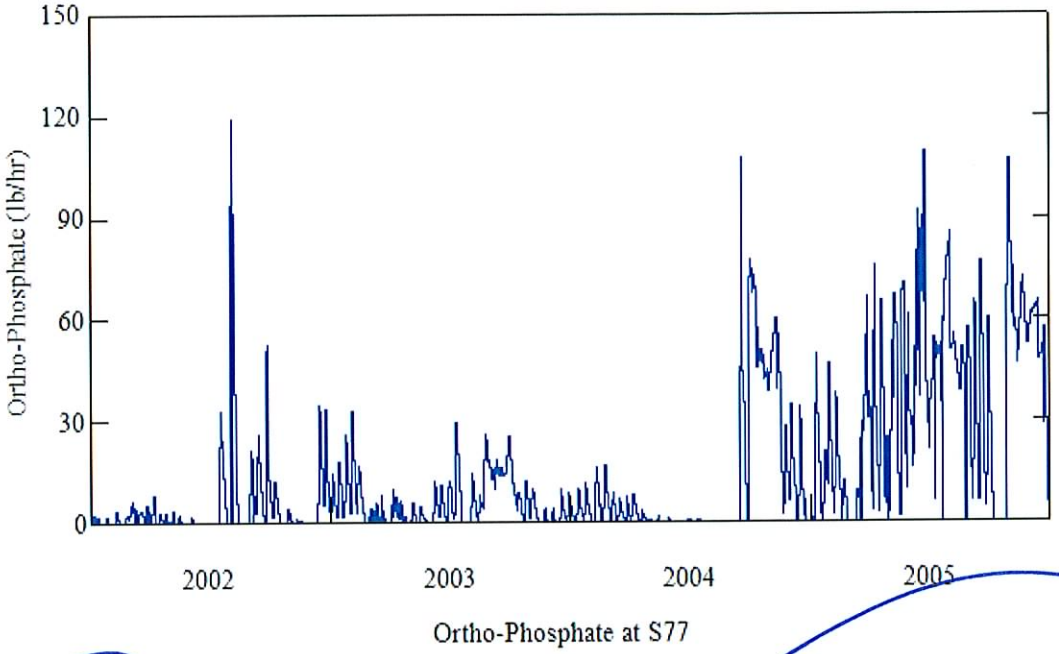


Figure 12. Hourly ortho-phosphate flux at S77.

add TP

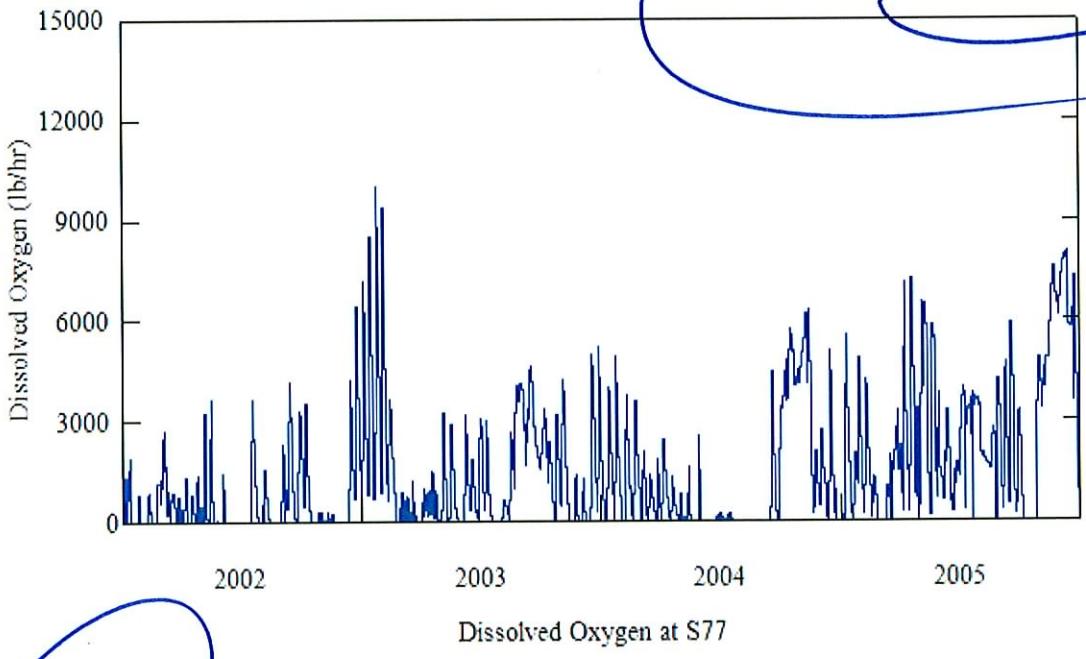


Figure 13. Hourly dissolved oxygen flux at S77.

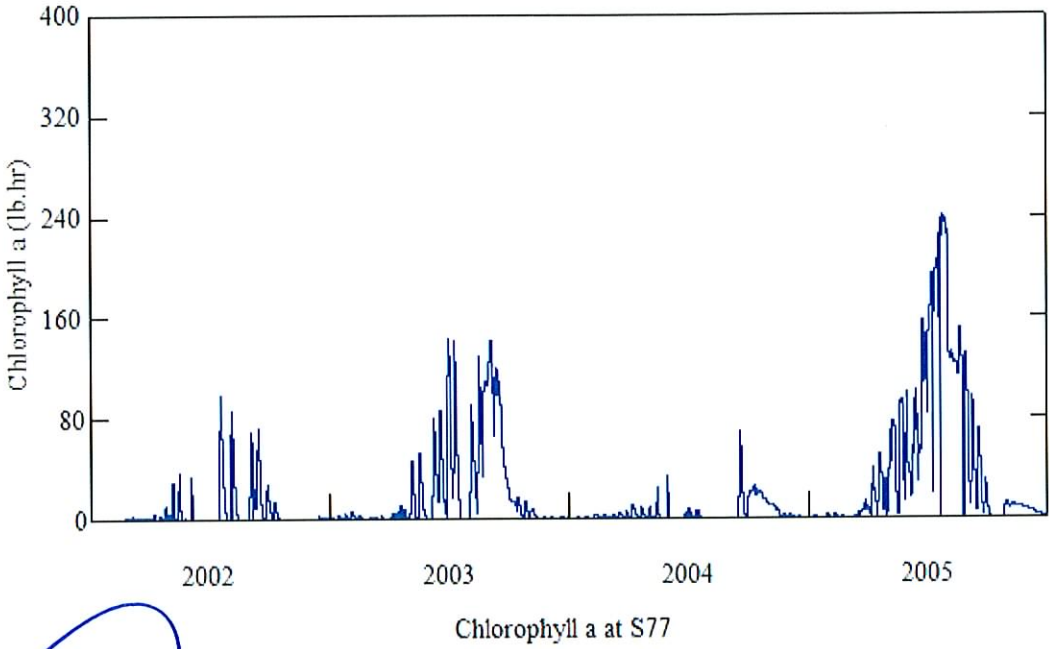


Figure 14. Hourly chlorophyll a flux at S77.

5.2.1.7 Point Source Discharges

Point source discharge data are needed to develop a comprehensive water quality model and compute waste load allocation (WLA) portion of the TMDL. Data obtained from FDEP indicate that there are 93 NPDES permitted facilities in the watershed. Geographic locations of these point sources are shown in Figure 14. Forty four of these facilities were identified as domestic or industrial wastewater treatment facilities having effluent measurements in Discharge Monitoring Report (DMR) data. DMR data for these point sources were obtained from the FDEP and average flow and pollutant loads were computed. The waterbody (HSPF reach ID) receiving the effluent from each point source was identified using either the EPA's Permit Compliance System (PCS) data or their geographic location in GIS. Information about the facility, flow, receiving waterbody and the type of wastewater source are provided in Table 5. Average concentrations of water quality constituents in the point source effluents as determined from the DMR data are listed in Table 6. Average flow and concentrations were used to determine the pollutant loads from individual point sources and entered in the model.

Five of other wastewater treatment facilities (NPDES permit numbers: FL0021270, FL0021261, FL0030325, FL0039829 and FL0030007) discharge to the tidal Caloosahatchee River downstream of S79. Discharges from these five facilities are considered in the EFDC model.

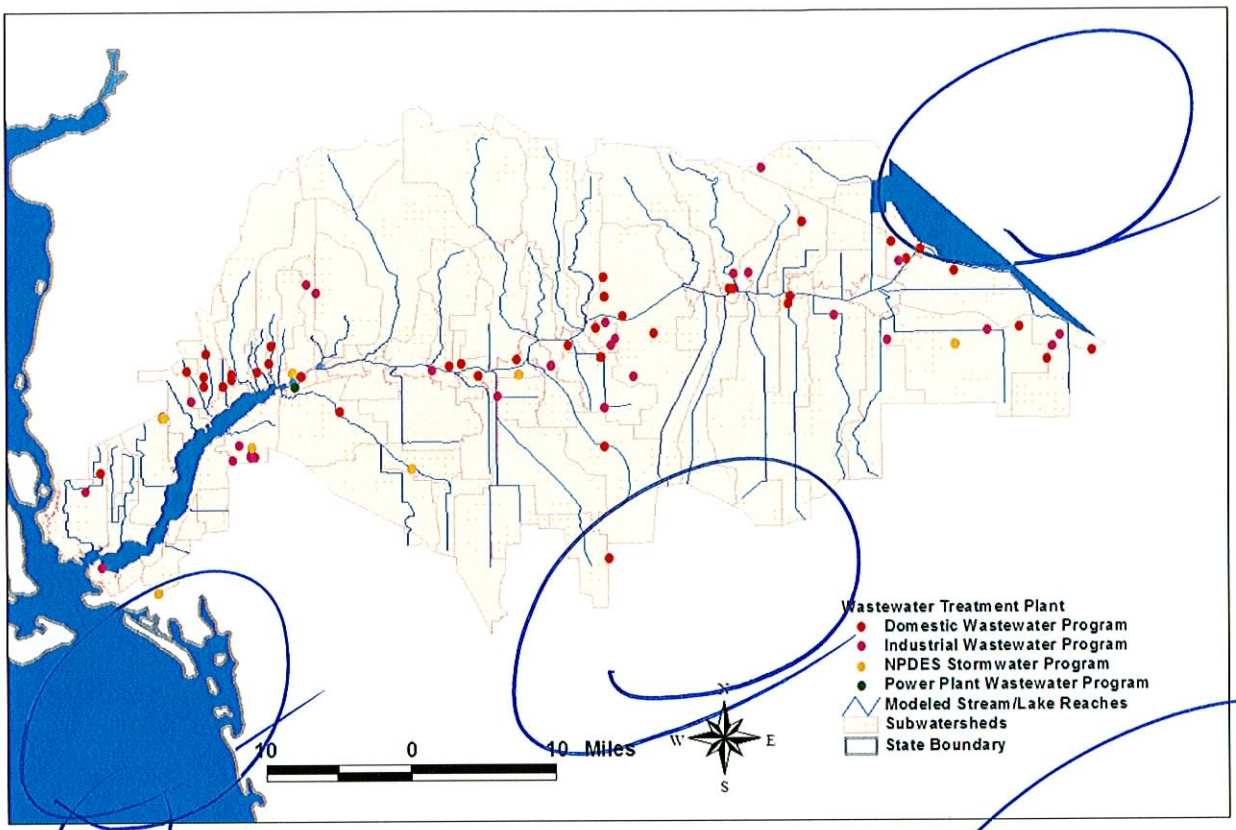


Figure 14. Location of permitted wastewater treatment facilities in the Caloosahatchee River watershed.

8.5 X 11

Table 5. Wastewater treatment facilities and their discharge information

Facility ID	Facility Name	Receiving HSPF Reach	Design Flow (MGD)	Avg Flow (MGD)	Type
FLA014565	Lehigh Acres WWTP	13	2.48	1.7746	Domestic
FL0040665	Clewiston, City of - WWTF	58	1.5	1.6875	Domestic
FLA014548	North Fort Myers Utility	90	3.5	1.3385	Domestic
FLA014290	Port Labelle	41	0.25	0.1995	Domestic
FLA014283	Labelle, City of	40		0.1944	Domestic
FLA016891	Glades County WWTP	61		0.1020	Domestic
FLA014676	River Trails Mobile Home Park	87	0.097	0.0598	Domestic
FLA014661	Pioneer Village WWTP	86	0.045	0.0483	Domestic
FLA014263	Benbow WWTP	59		0.0449	Domestic
FLA014651	Crews Sanitation Co - Regional Residual Management Facility	9	0.045	0.0284	Domestic
FLA014248	Whisper Creek RV Resort	41	0.044	0.0216	Domestic
FLA014487	Bay Pointe Condominium	82	0.04	0.0211	Domestic
FLA014552	Spring Woods Home Owners Assn	88	0.02	0.0196	Domestic
FLA014304	Labelle Labor Village	33	0.055	0.0183	Domestic

FLA014419	Charleston Park STP	24	0.015	0.0159	Domestic
FLA014451	Julia Park	87	0.015	0.0149	Domestic
FLA014260	Sportsmans Village RV Condo WWTP	59	0.025	0.0144	Domestic
FLA014446	Oak Park Mobile Home Village	24	0.02	0.0144	Domestic
FLA014607	Upriver Campgrounds	82	0.03	0.0127	Domestic
FLA269913	River Bend Motorcoach Resort	31		0.0127	Domestic
FLA014278	River Oaks Subdivision	46	0.015	0.0119	Domestic
FLA014308	Greentree South	38	0.02	0.0118	Domestic
FLA184756	Airglades Industrial Park	58	0.025	0.0113	Domestic
FLA014287	Grandma's Grove RV Park	36	0.025	0.0108	Domestic
FLA014288	Riverbend Estates	41		0.0102	Domestic
FLA014267	Meadowlark Campground	46	0.015	0.0102	Domestic
FLA014491	High Point WWTP	84	0.025	0.0097	Domestic
FLA014417	Alva Schools - Elementry and Middle	76	0.02	0.0083	Domestic
FLA014566	Seminole Campground	84	0.01	0.0080	Domestic
FLA014250	Robin's Nest RV Resort	66	0.03	0.0071	Domestic
FLA185281	Maple Corner WWTP	41		0.0063	Domestic
FLA014277	Hendry Isles Resort	51	0.0075	0.0062	Domestic
FLA014300	Holiday Trav - L - Park KOA	58	0.015	0.0057	Domestic
FLA014596	Swan Lake Mobile Home Park	90	0.025	0.0055	Domestic
FLA014272	Golfer's Heaven At Hendry Isles	51	0.025	0.0048	Domestic
FLA014294	South Florida United Methodist Camp	31	0.012	0.0046	Domestic
FLA014450	Whispering Pines Condo Association	101	0.01	0.0040	Domestic
FLA014664	Garden RV Park WWTP	90	0.005	0.0038	Domestic
FLA014455	Hut Restaurant	10	0.005	0.0020	Domestic
FLA014262	River Gardens	61	0.035	0.0015	Domestic
FLA324418	Muse School - West Glades Elementary	41		0.0014	Domestic
FLA014302	US Sugar Corp - Clewiston Mill	60	37.6	2.4478	Industrial
FLA014292	Citrus Belle Packing Plant	33	0.5	0.3003	Industrial
FLA014291	Jack M Berry Inc	32	0.49	0.0799	Industrial

Table 6. Average concentrations of water quality constituents in point source effluents based on DMR data.

Facility ID	TSS (mg/L)	CBOD5 (mg/L)	TKN (mg/L N)	NO_3 (mg/L N)	NO_2 (mg/L N)	TON (mg/L N)	TN (mg/L)	TP (mg/L)	DO (mg/L)	Fecal Coli. (#/100 mL)
FLA014302	1620	1974	14.7	0.7	0.0	15.8				
FLA014565	43	68					4.8			1
FL0040665	68	58					15.7	1.4	4.9	30
FLA014548	89	80								3
FLA014292				0.4				14.5		
FLA014290	74	78		2.8						9
FLA014283	213	223		1.9						10
FLA016891	85	77		5.3			22.9			49
FLA014291		60					5.8			
FLA014676	80	83		5.6						1
FLA014661	87	85		2.9			10.4			7
FLA014263	38	33		5.3						21
FLA014651										
FLA014248	100	145								1
FLA014487	84	107		3.7						1
FLA014552	64	126		0.8						5
FLA014304	104	102		2.6			3.0			1
FLA014419	90	87		2.4			3.8			1
FLA014451	76	79		4.3			3.9			2
FLA014260	60	56		6.3						14
FLA014446	82	78		2.5			5.0			2
FLA014607	124	115		2.4						1
FLA269913	73	32		8.4						2
FLA014278	88	89		14.1						29
FLA014308	74	80		2.5						1
FLA184756	84	265		6.4			11.3			71
FLA014287	108	80		0.1			19.5			2
FLA014288	102	82		2.0						45
FLA014267	136	363								4
FLA014491	75	61		3.1						1
FLA014417	74	49		2.8			15.6			1
FLA014566	104	97		5.6			2.9			2
FLA014250	103	116		10.3						41
FLA185281	72	375		2.6						1
FLA014277	172	125					1.8			7
FLA014300	62	62		2.6						63
FLA014596	103	79		3.4						1
FLA014272	67	73					0.4			4

Facility ID	TSS (mg/L)	CBOD5 (mg/L)	TKN (mg/L N)	NO_3 (mg/L N)	NO_2 (mg/L N)	TON (mg/L N)	TN (mg/L)	TP (mg/L)	DO (mg/L)	Fecal Coli. (#/100 mL)
FLA014294	69	85		2.4			7.9			2
FLA014450	134	68		3.9						1
FLA014664	116	104					4.8			1
FLA014455	201	120		3.4						1
FLA014262	100	109		8.4			6.2			111
FLA324418	48	50		6.0						18

5.2.1.8 Groundwater Withdrawals

The South Florida Water Management District (SFWMD) issues water withdrawal permits and maintains a database of pumpage information. Data obtained from the District included a GIS data showing the locations of surface and groundwater withdrawal permits. Only the groundwater withdrawals information were processed and incorporated in the model to account for additional flow and pollutant loads to the surface water system. Historic flow data were analyzed to determine the monthly average pumpage in each subwatershed. Pollutant loads were estimated based on observed groundwater concentrations in the area wells and average pumpage. Locations of these groundwater withdrawal pumps are shown in Figure 15. Average pumpage and groundwater water quality concentrations used in the model are provided in Figure 16 and Table 7, respectively.

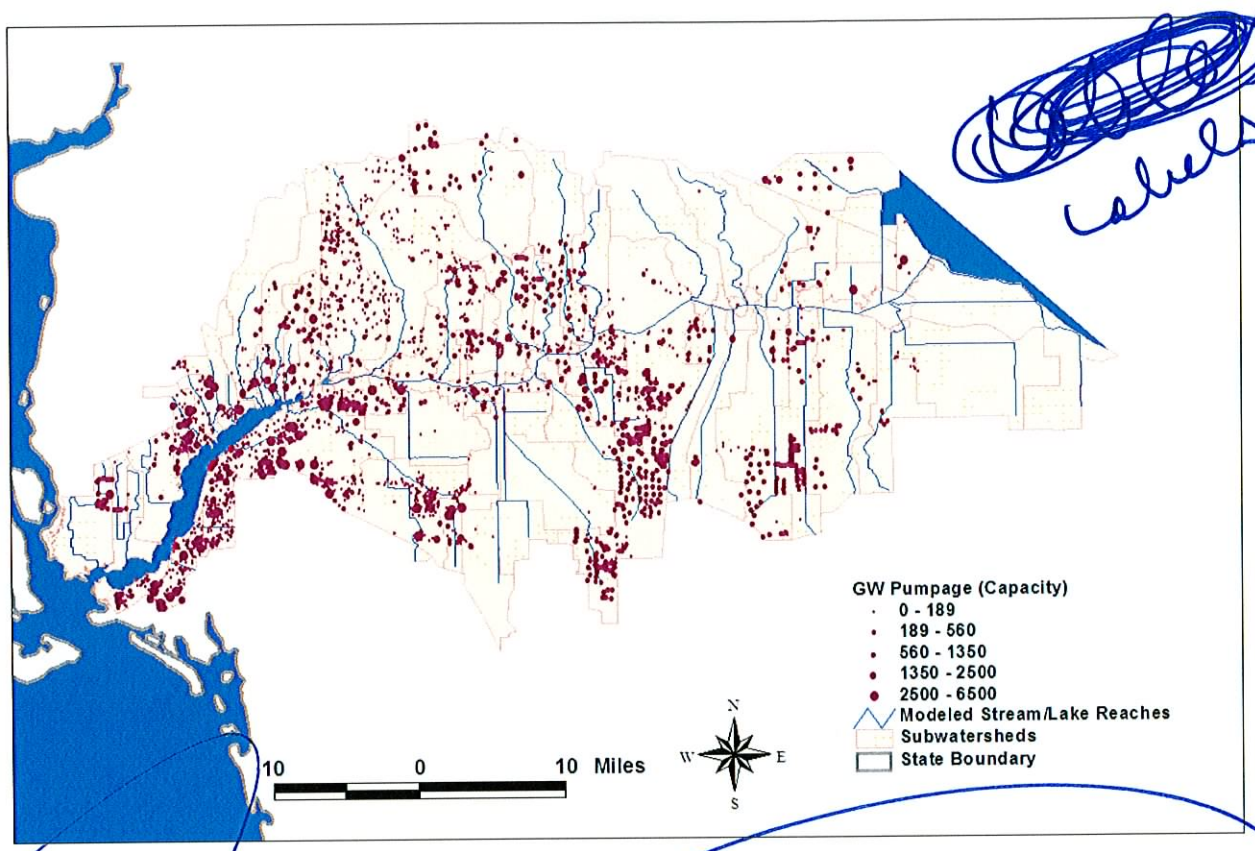


Figure 15. Location of groundwater withdrawals in the Caloosahatchee River watershed.

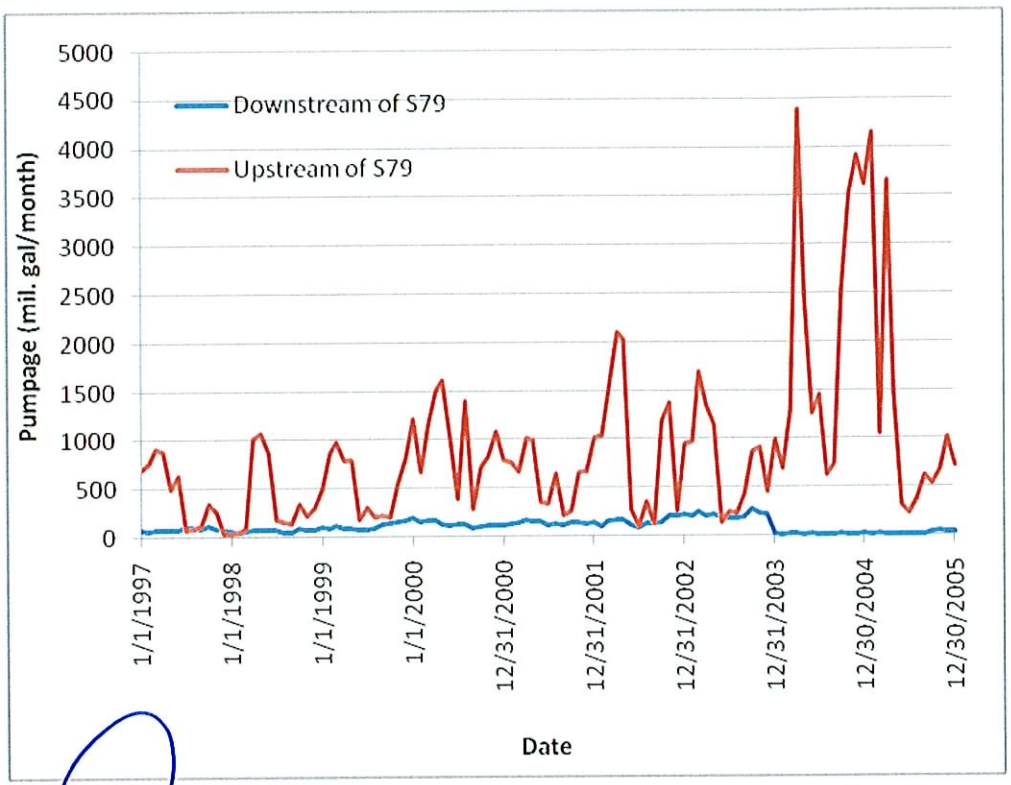


Figure 16. Historic groundwater pumpage in areas upstream and downstream of S79.

Table 7. Average water quality concentrations in groundwater

Constituent	Concentration (mg/L)
Ammonia Nitrogen	0.83
Dissolved Oxygen	0.74
Total Kjeldahl Nitrogen	1.64
Nitrate plus nitrite	0.07
Organic Nitrogen	0.81
Phosphate	0.27
Total Phosphorus	0.39

5.2.1.9 Atmospheric Deposition

HSPF accepts both dry and wet deposition of atmospheric pollutants. The dry deposition can be specified as mass flux where as the wet deposition can be specified as concentration in rain water. In Florida there are 7 National Atmospheric Deposition Program/National Trends

Network (NADP/NTN) stations that monitor wet atmospheric deposition of nutrients. However, none of these stations are located in the study area. The nearest station, F41, is approximately 60 miles north of the Caloosahatchee River watershed. Lee County maintains an atmospheric deposition monitoring site at Lover's Key (site ID LKATMDEP) that recorded data from March 2005 through June 2007. The wet atmospheric deposition of nitrogen and phosphorus were obtained from this Lee County site to calculate monthly average concentrations. Computed average monthly concentrations are presented in Table 8. The wet atmospheric deposition data for organic nitrogen (ON) were not available and, therefore, calculated by subtracting ammonia from TKN. The dry atmospheric deposition data are not available at the Lee County and the NADP/NTN sites. Hence, the nutrient loads from dry atmospheric deposition were assumed to be negligible.

Table 8. Monthly average nutrient concentrations in wet atmospheric deposition monitored at Lover's Key, Lee County.

Month	Wet Deposition Concentration (mg/L)						
	Ammonia	Nitrite	Nitrate	TKN	Org. Nitrogen	Phosphate	Total P
Jan	0.175	0.010	0.217	1.000	0.825	0.003	0.008
Feb	0.188	0.007	0.350	0.530	0.342	0.002	0.005
Mar	0.204	0.002	0.155	0.563	0.359	0.063	0.011
Apr	0.244	0.002	0.180	0.278	0.034	0.007	0.033
May	0.451	0.003	0.277	0.716	0.265	0.062	0.080
Jun	0.168	0.007	0.174	0.420	0.252	0.013	0.017
Jul	0.108	0.004	0.165	0.184	0.076	0.003	0.008
Aug	0.139	0.004	0.291	0.283	0.144	0.005	0.011
Sep	0.097	0.005	0.164	0.212	0.115	0.002	0.006
Oct	0.082	0.003	0.107	0.327	0.244	0.012	0.023
Nov	0.107	0.011	0.145	1.335	1.229	0.005	0.020
Dec	0.103	0.005	0.085	0.285	0.183	0.002	0.008

5.2.1.10 Best Management Practices

[SHC: Obtained urban and agricultural BMP data and their pollutant removal efficiencies from CDM. DSLLC will appreciate if Gabriel can write this section describing the data]

5.2.1.11 Model Coefficients

Model coefficients are required to fully represent the components of hydrologic cycle (e.g., surface and subsurface flows and storages, infiltration, evapotranspiration, etc), pollutant loads from land segments, routing of flow and pollutants in receiving water bodies, and in-stream processes involving water quality constituents. Model coefficients were initially selected from literature sources (USEPA, 2000; USEPA 1978; Tellis, 2001; Bowie, 1985) and further refined through model calibration.

5.2.1.12 Initial Conditions

In a continuous simulation model it is necessary to specify the state of the system at the start of the simulation. In HSPF initial conditions are specified by assigning values to a number of state variables. HSPF input for initial hydrologic condition are not directly measurable quantities. Therefore, the variables that determine the initial hydrologic condition of the watershed were estimated by adjusting their values to match modeled flow with observed data. Initial condition for the water quality variables were assigned based on the observed water quality data.

5.2.2 VERIFICATION of HSPF MODEL

The Caloosahatchee River HSPF model consists of a network of stream reaches and associated land segments. Reach connectivity, distribution of land uses, and connectivity of land segments and reaches were manually checked using a custom spreadsheet as well as the ArcView GIS software. Also the error/warning log file generated by HSPF during the model execution was checked to ensure that no error or significant warnings were reported in the log file.

5.2.3 SENSITIVITY ANALYSIS

In order to evaluate the impact of changes in input data on streamflows four scenarios were modeled and compared with calibrated hydrologic model results. These scenarios include

- A 20 percent increase in precipitation
- A 50 percent increase in evapotranspiration
- Infiltration rates reduced by a factor of 10
- A five times increase in hydrologically connected imperviousness of urban land uses

Because of the non-linear relationship between input data and streamflow, the HSPF input data that have the greatest impact on streamflow could not be determined for certain. However, the changes in input data resulted in changes in streamflow as shown in Figures 17 through 20. An increase in precipitation, a reduction in infiltration and an increase in hydrologically connected imperviousness increased peak flow where as an increase in evapotranspiration reduced streamflow. The impacts caused by the changes in input data are reasonable and, therefore, the model is considered responsive. It is important to note that the impact of changes in input data are less pronounced at the USGS gage (02292900) as the inflow from Lake Okeechobee to Caloosahatchee River and subsequent discharge at gage S-78 constitute a significant part of the flow in the Caloosahatchee River.

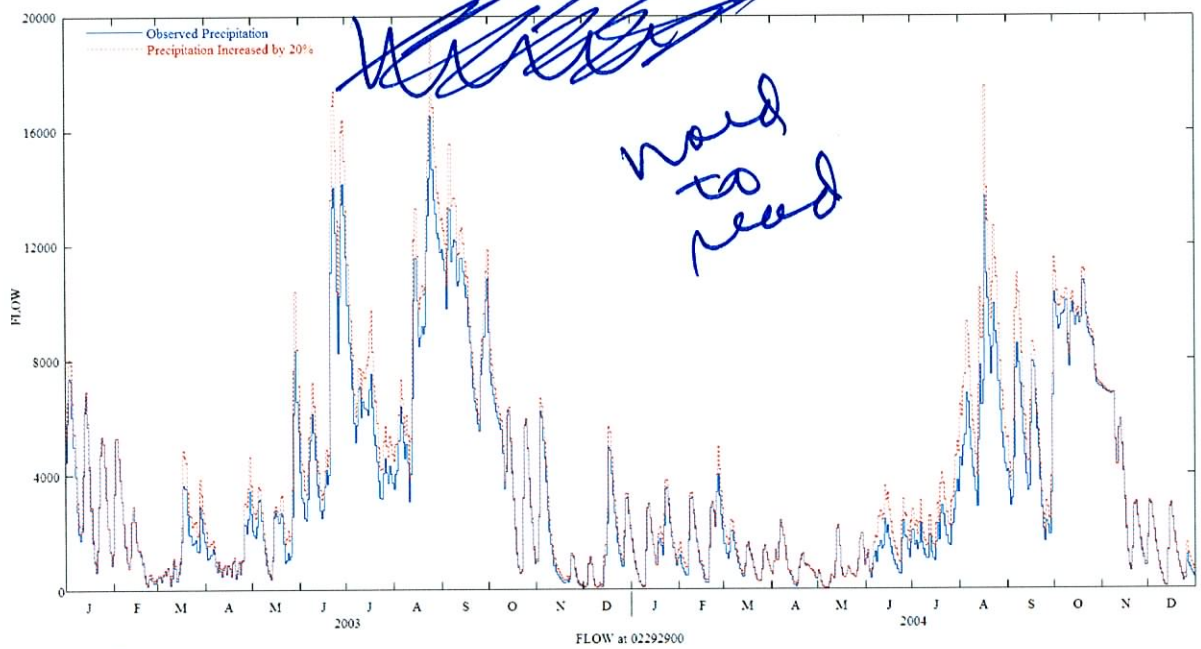


Figure 3 Impact of 20% increase in rainfall intensity on streamflow at the USGS gage 02292900

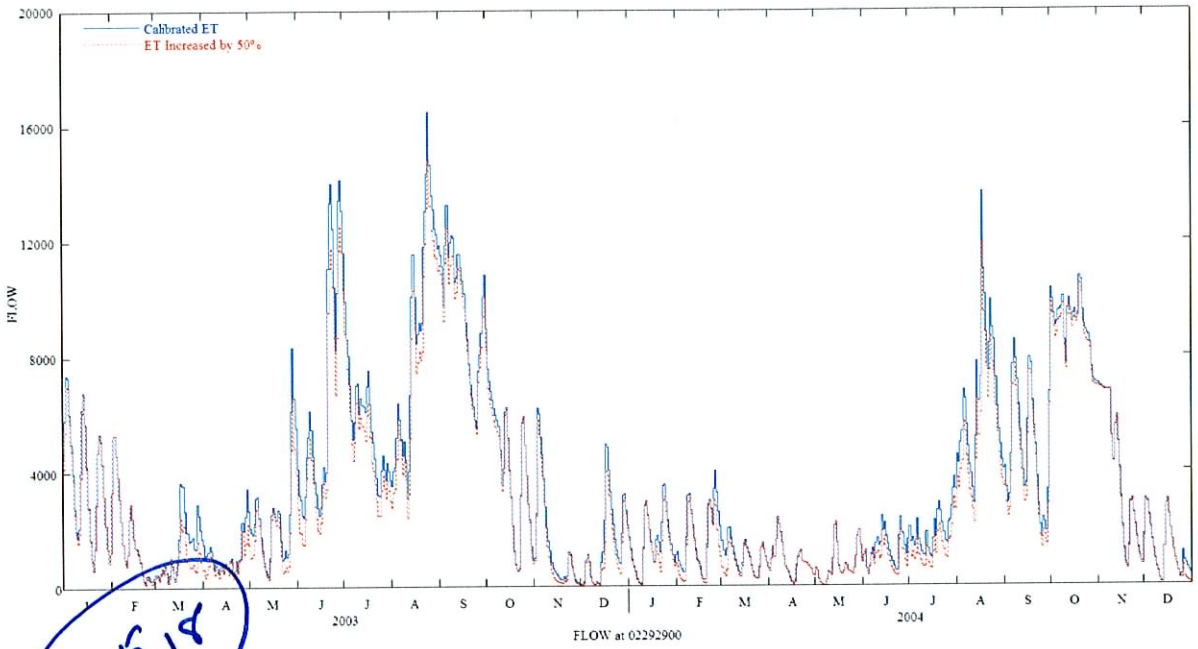


Figure 4 Impact of 50% increase in evapotranspiration rate on streamflow at the USGS gage 02292900

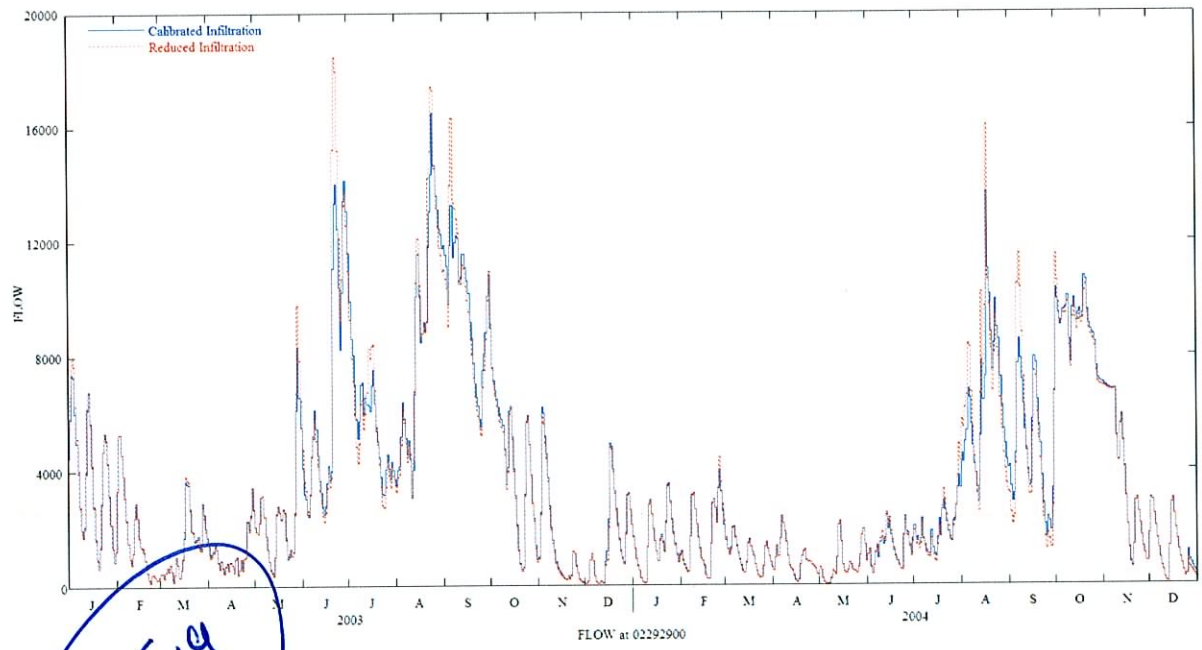


Figure 5 Impact of reduction of infiltration rate on streamflow at the USGS gage 02292900

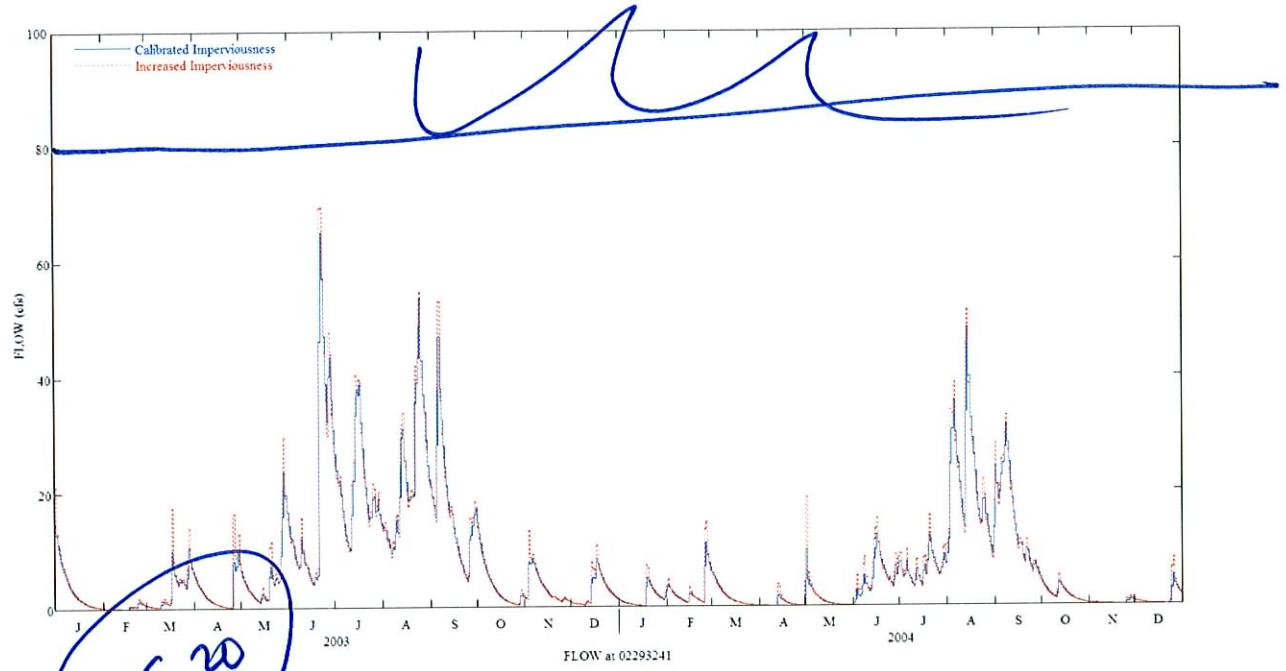


Figure 6. Impact of increased imperviousness on streamflow at the USGS gage 02293241

5.6 HSPF Model Calibration and Validation

5.6.1 Hydrologic Calibration

Two USGS gages on the main stem of the Caloosahatchee River and three gages on small tributaries in Ft. Myers and the City of Cape Coral have long-term flow data available. These gages are:

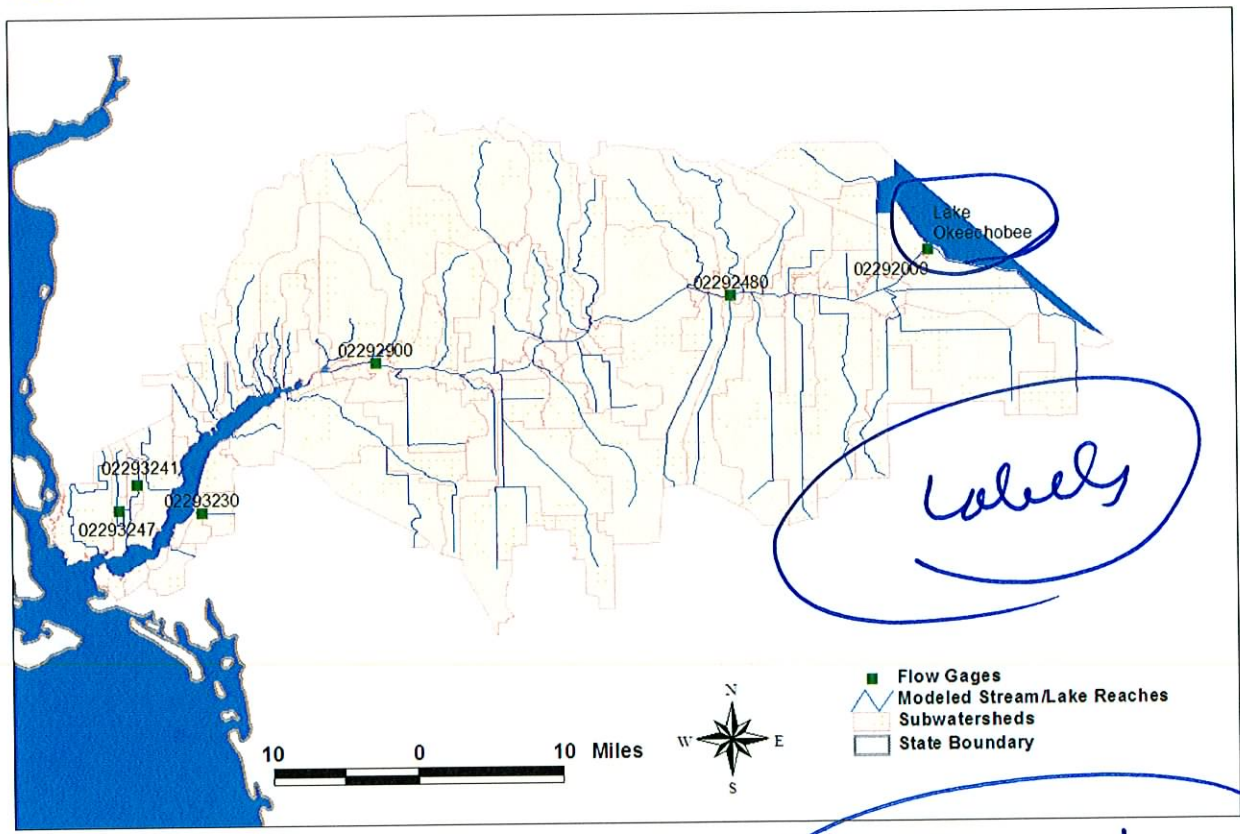
- Caloosahatchee River at S-79, near Olga (02292900)
- Caloosahatchee Canal at Ortona Lock, near La Belle (02292480)
- Whiskey Creek at Ft. Myers (02293230)
- San Carlos Canal at Cape Coral (02293241)
- Courtney Canal at Cape Coral (02293243)

The locations of these gages are shown in Figure 21. The daily average flow from the gages at S-79, S-78 (Ortona Lock), and San Carlos Canal were used to calibrate and validate the model. The quality of daily flow data recorded at the San Carlos Canal and the Courtney Canal gages is considered poor by USGS (http://pubs.usgs.gov/wdr/2004/wdr-fl-04-2a/pdf/p344-345.pdf and http://pubs.usgs.gov/wdr/2004/wdr-fl-04-2a/pdf/p342-343.pdf). According to USGS measured flows at these gages are impacted by heavy debris buildup on the carp grates installed on top of the weir. Estimated daily flows at the Whiskey Creek at Ft. Myers are also considered poor by USGS. Therefore, the daily flows at the San Carlos Canal gage were used with caution for

model calibration and validation. During the model calibration flows were computed at the same locations as the gages and compared with observed flows to estimate appropriate model parameters providing a good match.

Hydrologic calibration of the model was performed using January 2001 through December 2005 flow data. Daily average modeled and observed flows at S-79, S-78 and the San Carlos Canal gages are plotted in Figures 22 through 24. Scatter plots of monthly mean modeled versus observed flows (Figures 25 and 26) show that the model output are in good agreement at S-79 while at the San Carlos Canal gage the match is not as good. The relatively poor match at the San Carlos Canal gage is attributed to the errors in observed data (frequent 0.0 flows) as discussed earlier. A comparison of average annual flows at S-79 (Table 9) shows only a 3% error in hydrologic calibration over the entire simulation period.

Figure 21. Flow gages in the Caloosahatchee River watershed that have long-term daily flow records.



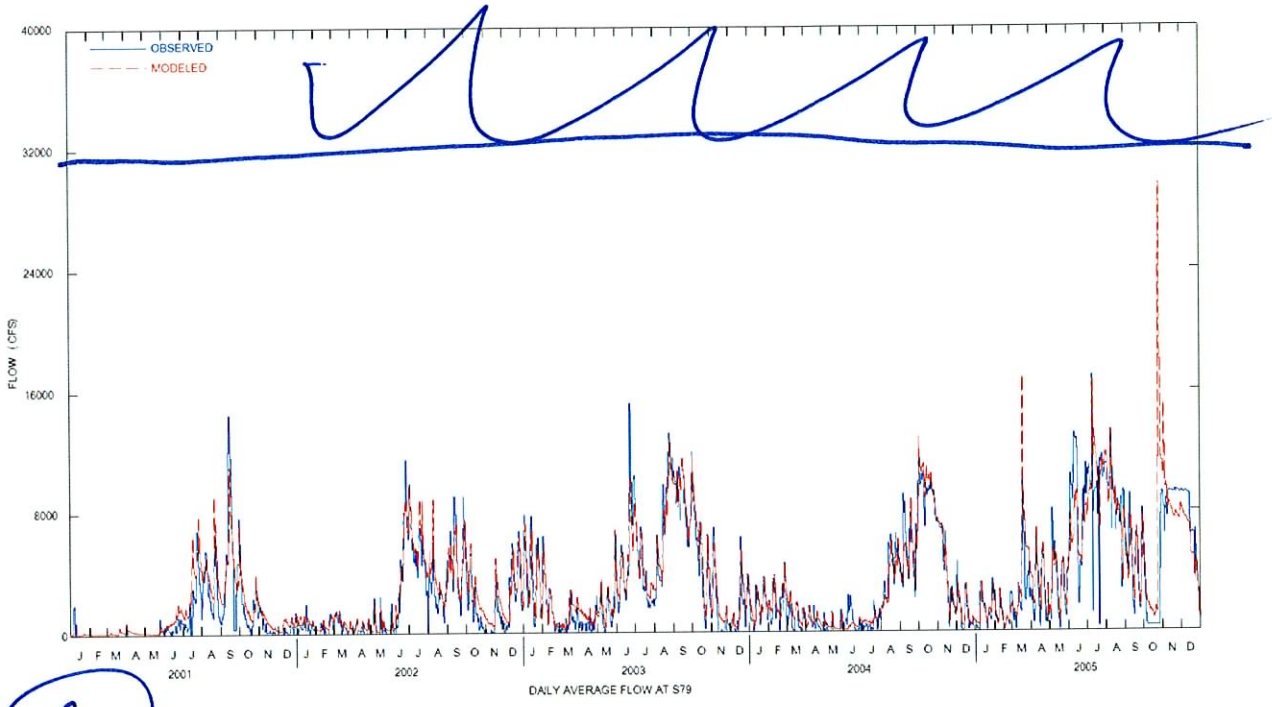


Figure 22. Modeled and observed flows at S-79 for the calibration period.

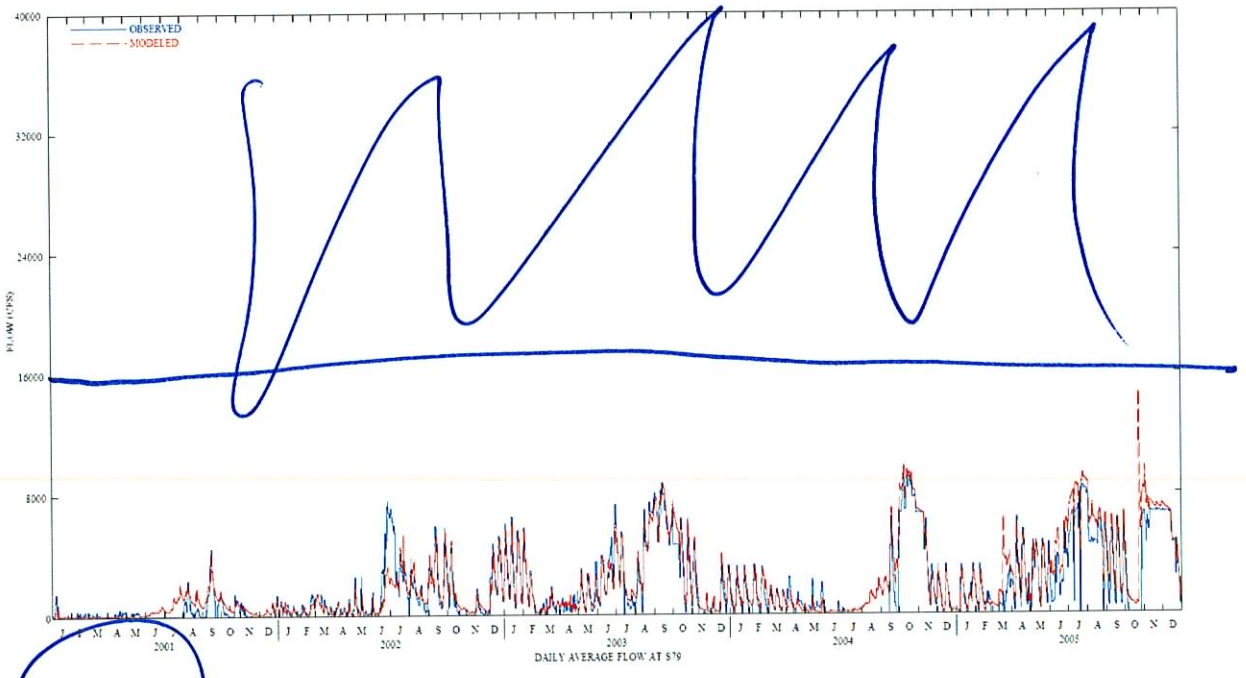


Figure 23. Modeled and observed flows at S-78 for the calibration period.

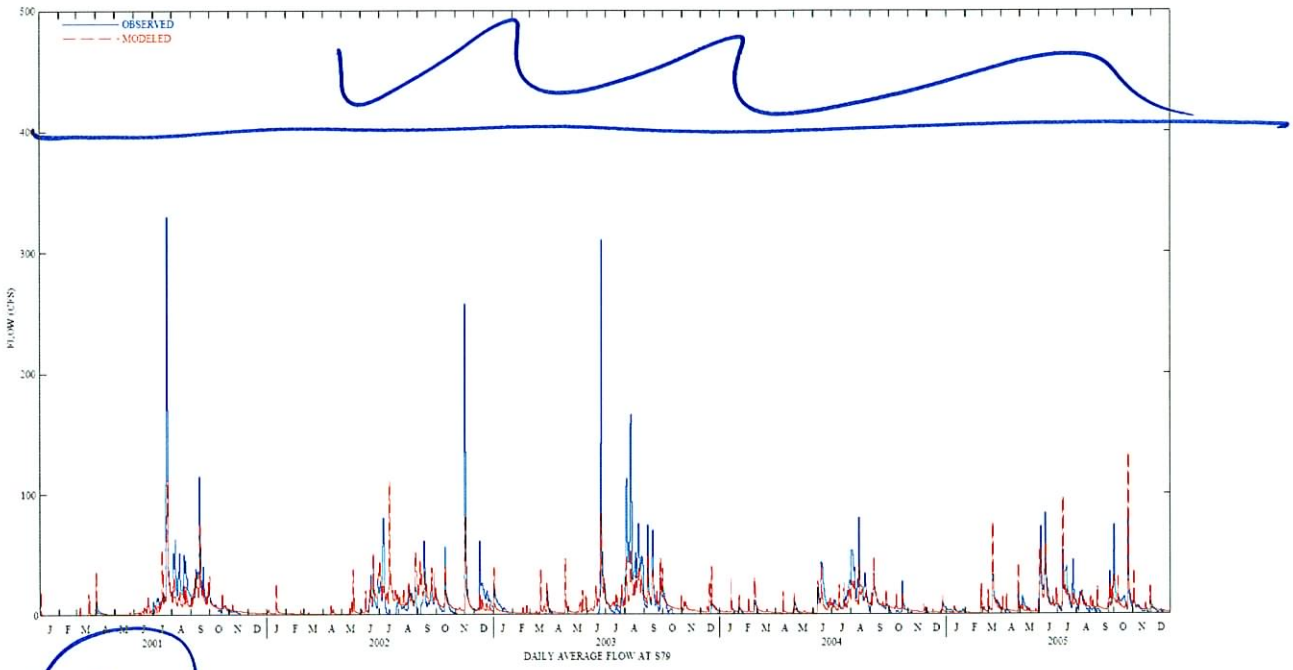


Figure 24. Modeled and observed flows at the San Carlos Canal gage for the calibration period.

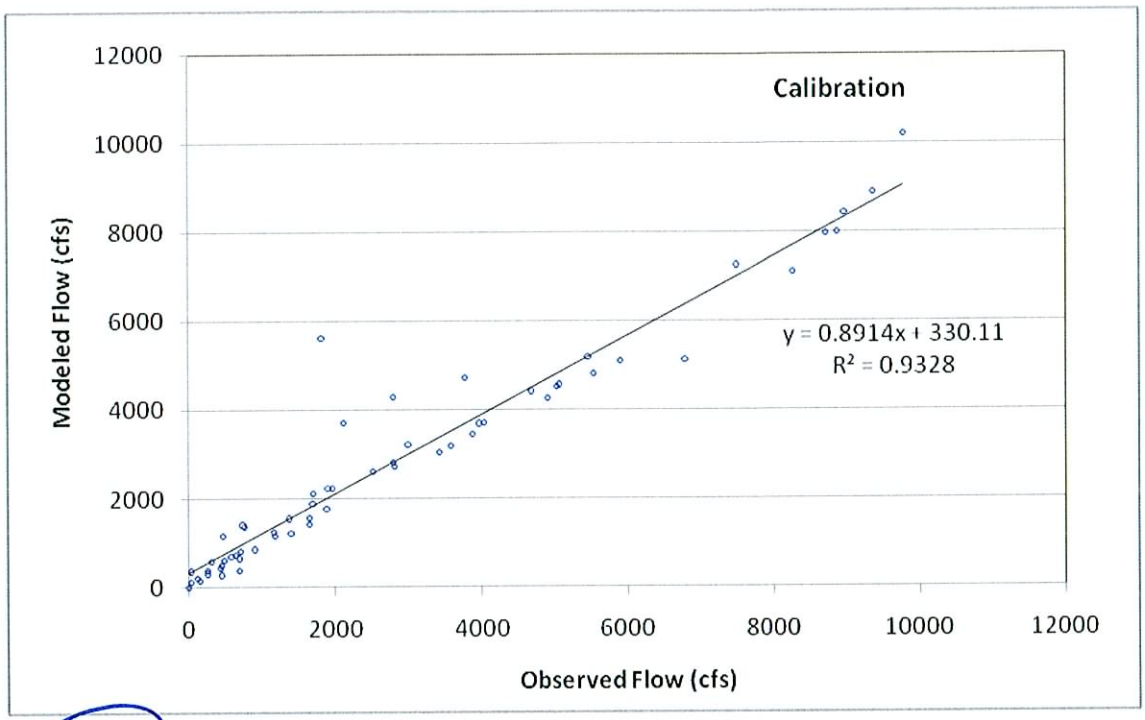


Figure 25. Comparison of monthly average modeled and observed flows at S-79 for the calibration period.

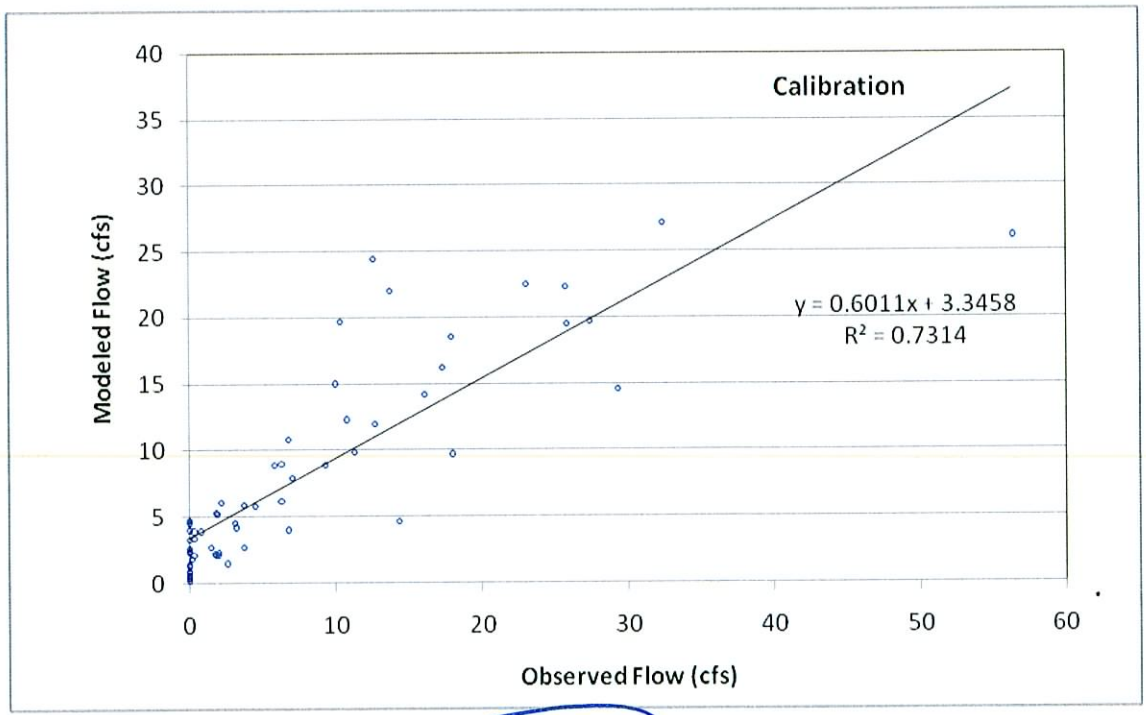


Figure 26. Comparison of monthly average modeled and observed flows at the San Carlos Canal gage for the calibration period.

Table 9. Observed and modeled annual average flows and associated errors at S-79 during model calibration.

Year	Annual Average Flow (cfs)		
	Observed	Modeled	Percent Difference
2001	1123	1326	15%
2002	2056	2179	6%
2003	3593	3483	-3%
2004	2556	2431	-5%
2005	5059	5059	0%
Average	2878	2896	3%

5.6.2 Hydrologic Validation

Model validation using an independent dataset confirms that a calibrated model can reliably simulate the conditions outside the calibration domain without further adjustment of the parameter values. Hydrologic validation of the Caloosahatchee River watershed model was performed using the observed flows from January 1997 through December 1999. Daily average modeled and observed flows at S-79, S-78 and the San Carlos Canal gages for the validation period are plotted in Figures 27 through 29. Scatter plots of monthly mean modeled versus observed flows (Figures 30 and 31) show that the model output are in good agreement at S-79 while at the San Carlos Canal gage the match is not as good. As discussed earlier the relatively poor match at the San Carlos Canal gage may be attributed to the errors in observed data (frequent 0.0 flows). A comparison of average annual flows at S-79 (Table 9) shows only a 3% error in hydrologic validation over the entire simulation period.

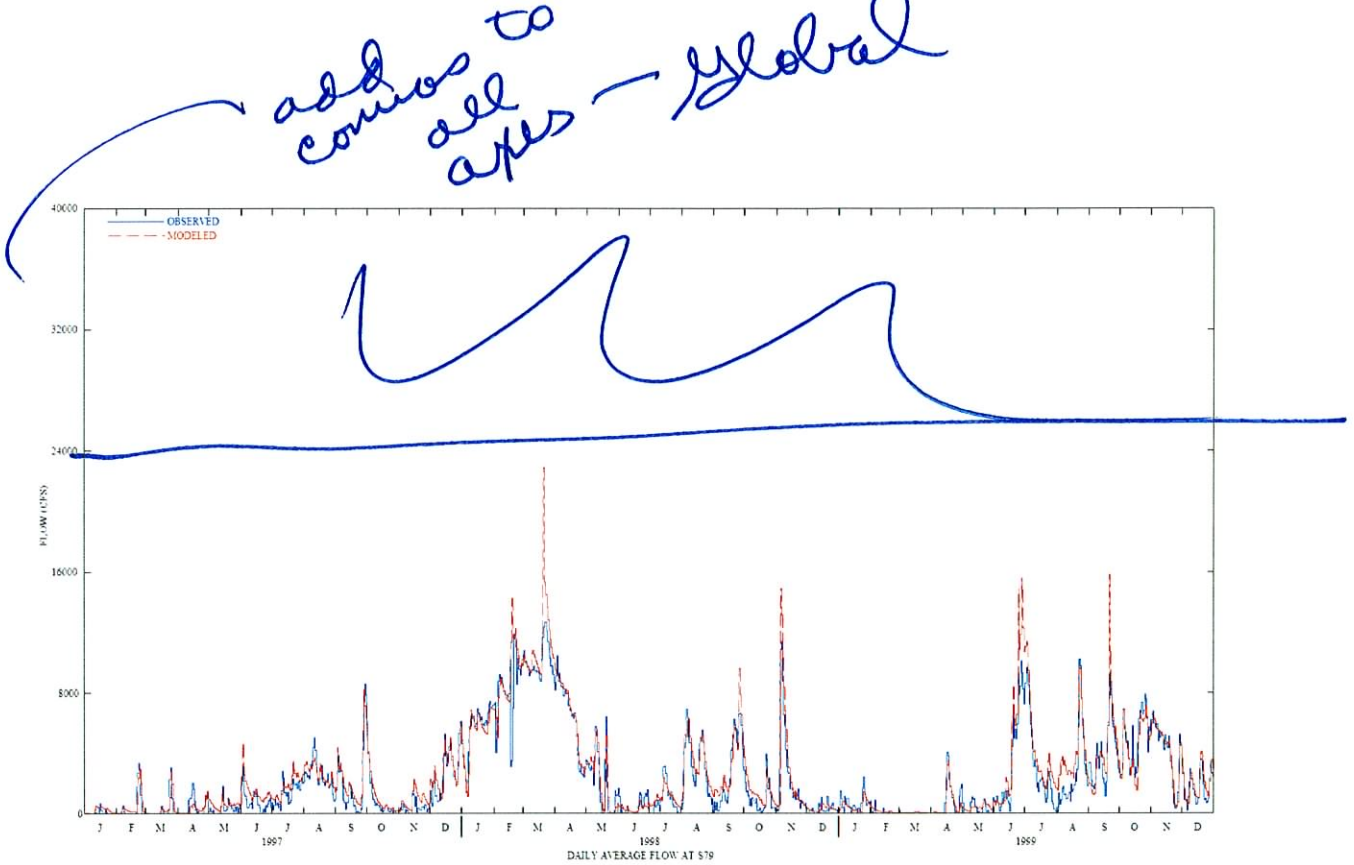


Figure 27. Modeled and observed flows at S-79 for the validation period.

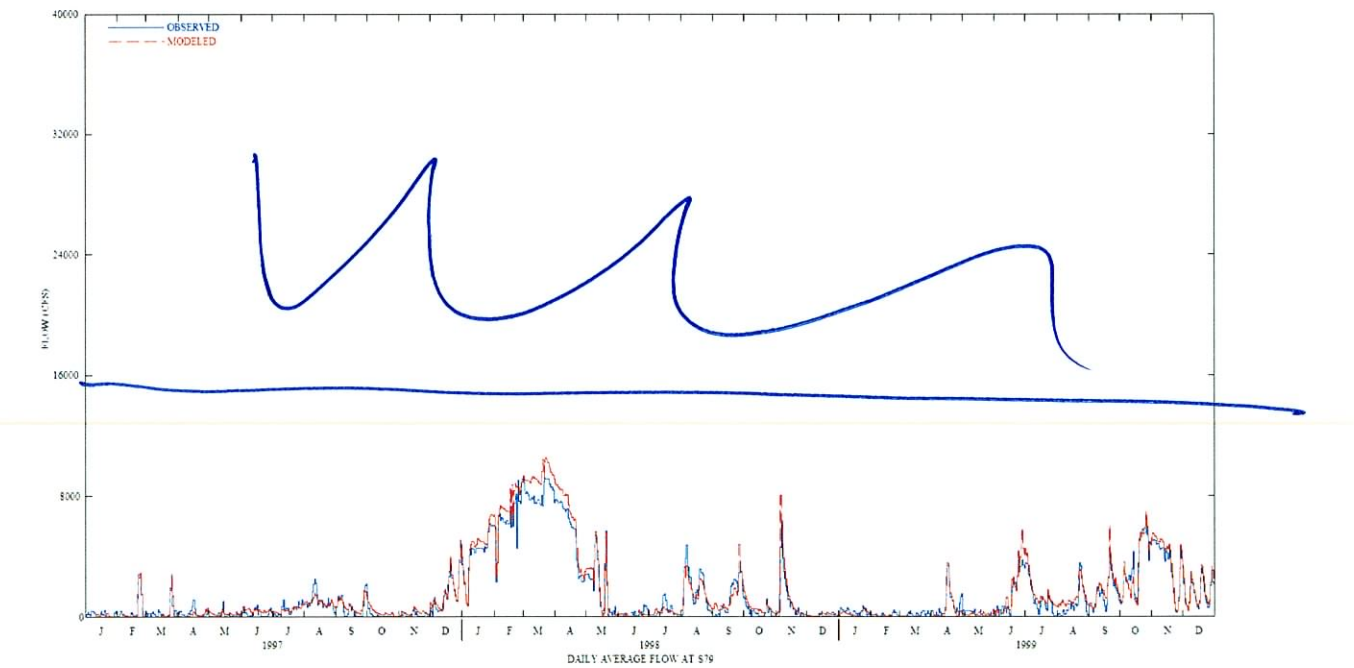


Figure 28. Modeled and observed flows at S-78 for the validation period.

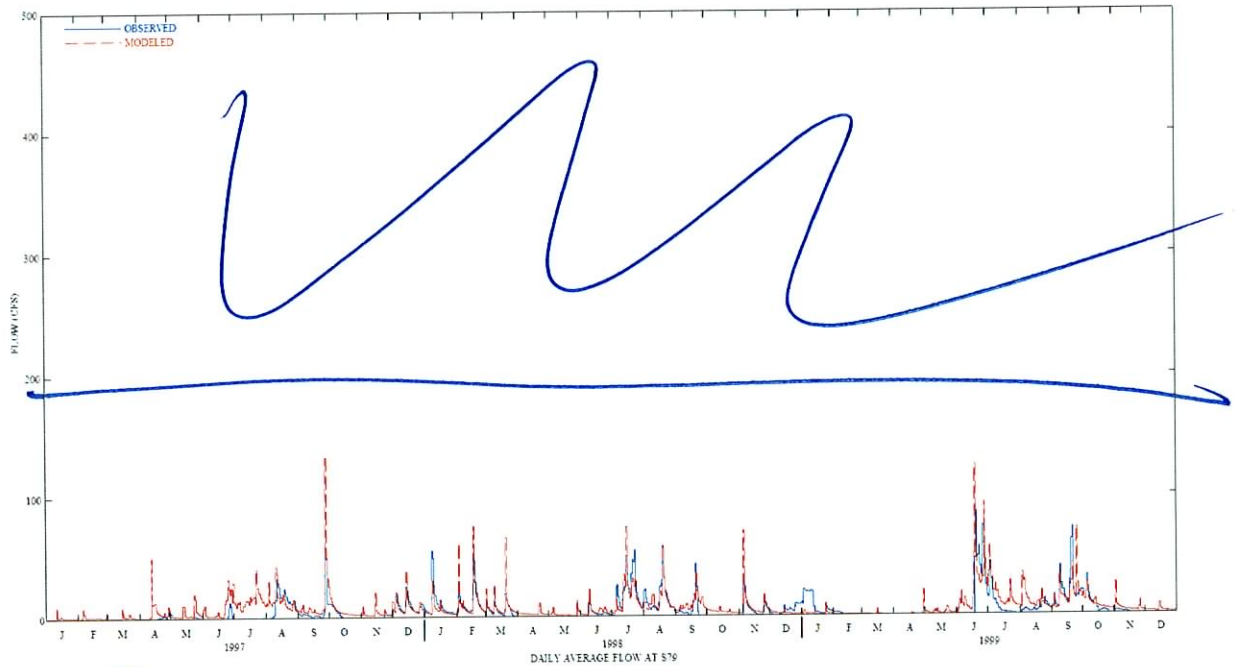


Figure 29. Modeled and observed flows at the San Carlos Canal gage for the validation period.

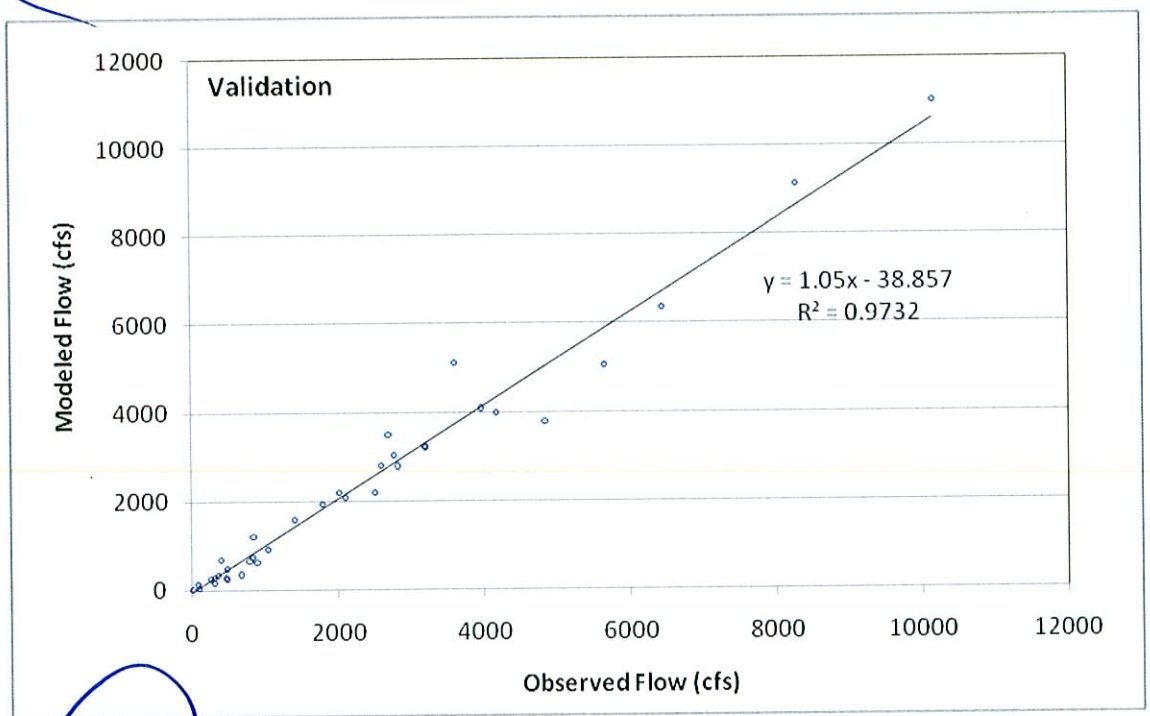


Figure 30. Comparison of monthly average modeled and observed flows at S-79 for the validation period.

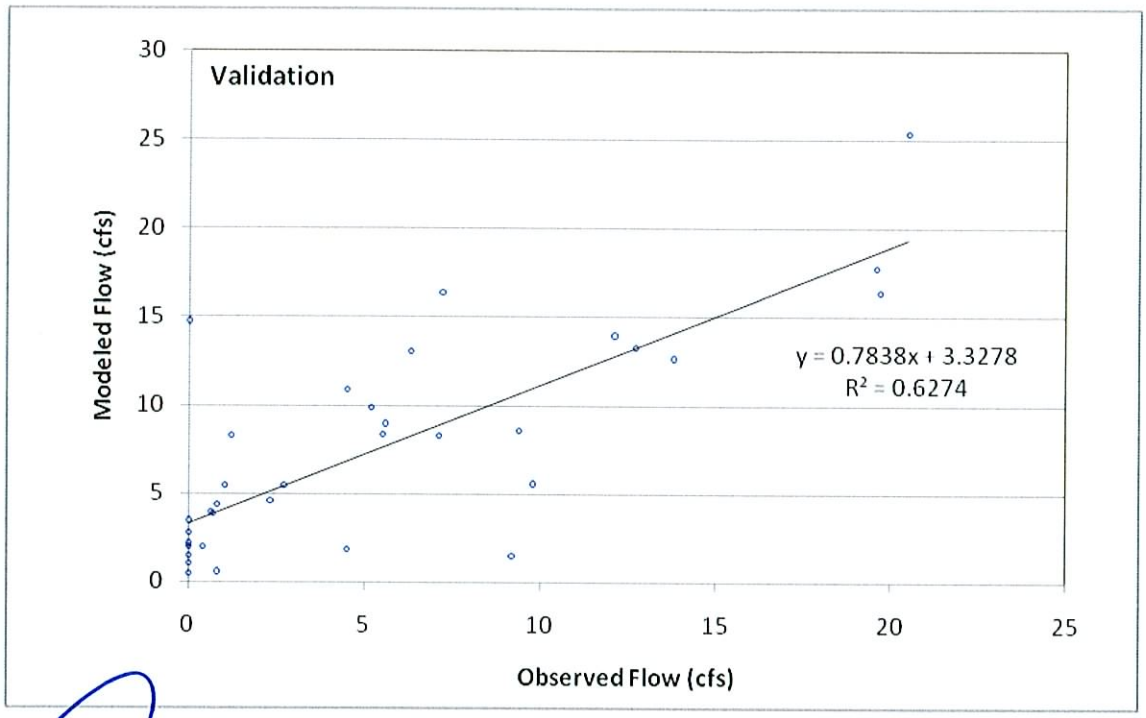


Figure 31. Comparison of monthly average modeled and observed flows at the San Carlos Canal gage for the validation period.

Table 9. Observed and modeled annual average flows and associated errors at S-79 during model validation.

Year	Annual Average Flow (cfs)		
	Observed	Modeled	Percent Difference
1997	1041	1085	4%
1998	3616	3699	2%
1999	2181	2266	4%
Average	2279	2350	3%

5.6.3 Water Quality Calibration

The Caloosahatchee River HSPF model simulates water quality constituents in the main stem of the river and also in the tributaries. Surface and sub-surface flows from the watershed transport pollutants from the land segments into the stream reaches. The instream advective process transports pollutants from upstream to downstream reaches and the kinetic processes act as