Technical Memorandum 50

Watershed Model Development for the Indian River Lagoon Basin: Providing Simulated Runoff and Pollution Load to the Indian River Lagoon Pollution Load Reduction Model

by

Marc Adkins
Maria Mao
Marsha Taylor
Whit Green
Chris Basci
Martien Bergman
Dale Smith

St. Johns River Water Management District
Department of Water Resources
Division of Engineering
Palatka, Florida
June 2004

EXECUTIVE SUMMARY

Background

The Indian River Lagoon (IRL) lies on the east coast of Florida, extending 140 miles from Ponce de Leon Inlet to St. Lucie Inlet. Three-fourths of the IRL is within the St. Johns River Water Management District (SJRWMD) boundary. In 1996, SJRWMD contracted with the University of Florida to develop the Indian River Lagoon Pollution Load Reduction (PLR) Model, a three-dimensional hydrodynamic/salinity and water quality and light attenuation model.

During development of the IRL PLR model, runoff and pollution loading input were estimated from 1998 gaged discharge and observed water quality data. However, to evaluate existing and anticipated impacts to the IRL, input representing past, current, and future conditions is needed for the IRL PLR model.

Objective

The purpose of this work is to estimate runoff and pollution loading from past, current, and future conditions for use as input into the IRL PLR model.

Methods

Implied in the stated objective is the accounting of runoff and pollution load from all area that drains to the IRL within the SJRWMD boundaries. To achieve this goal, the entire IRL watershed within SJRWMD must be represented using a watershed model. Watershed models that have been developed for portions of the IRL watershed (Bergman and Donnangelo 1995, 1996a, 1996b, 1998) were expanded and applied to the entire IRL drainage area within SJRWMD. Expansion of existing models included incorporating the simulation of nonpoint source pollution from different land uses. Seven land use groups are identified: urban, high-intensity use; urban, medium-intensity use; urban, low-intensity use; Agriculture; Open Land; Forest; and Wetland.

Representing runoff and pollution generation differences between each land use provides a method to estimate past, current, and future conditions. Each condition consists of a unique acreage of each land use. Each land use produces a representative amount of runoff and pollution load; urban area produces more pollution than forest or open land. Increased urban area and reduced undeveloped area result in increased pollution load.

The land use areas for each condition are summarized in Table ES1. The greatest increase of high-intensity use urban, 33%, occurs in the Banana River Basin. The greatest increase of medium-intensity use urban, 40%, occurs in the south IRL. Correspondingly, open land, forest, and wetland areas decrease over time.

Nine discharge gaging stations were used to calibrate the watershed models. January 1, 1994, to December 31, 2000, is the calibration period. This time period provides a variety of hydrological conditions for the models to simulate. Model runoff results are calibrated to gaged data by comparing simulated to observed discharge hydrographs, discharge duration curves, and annual runoff volumes. Water quality results are adjusted by comparing the average annual pollution loading rate of each land use to reported pollution loading rates (Harper 1994).

Results and Conclusions

Results have been given to the hydrodynamic modelers to input into the IRL PLR model. The results consist of daily time-series of discharge and pollution load representing the past, current, and future conditions.

The average annual volume and pollution load results are compared between past, current, and future conditions. Table ES2 shows that the pollution load increases as the watershed becomes more developed. The greatest percent change between current and past conditions occurs in the Banana River. The greatest percent change between current and future conditions occurs in the Mosquito Lagoon. The 21% runoff volume reduction in the central Indian River is due to implementation of the C-1 Rediversion Plan, which diverts approximately 50% of the runoff from the Melbourne-Tillman Water Control District westward toward the upper St. Johns River.

Future work will use the IRL watershed models to evaluate the potential runoff and pollution reductions that may be achieved with the construction and operation of various regional stormwater treatment areas around the Sebastian River.

Additional work may be considered to represent local stormwater treatment facilities that accompany development occurring after 1984. Also, work may be considered to take account of the drainage detail in the nearshore areas, barrier islands, and Merritt Island area. Finally, work may be considered to take into account the many mosquito impoundments primarily in the Mosquito Lagoon, north Indian River, and Banana River areas. Consideration of possible watershed model improvements should be made after the IRL PLR model has been run and evaluation of the results indicate the need to revise runoff and pollution loads from the surrounding watershed.

Table ES1. Land use in the Indian River Lagoon major basin (in acres)

		Urban HI	Urban MI	Urban LI	Agriculture	Open Land	Forest	Wetland	Total
Mosquito Lagoon	Past	1,475	253	1,063	941	3,530	15,921	19,812	42,993
	Present	2,856	5,444	1,959	436	7,603	8,205	17,158	43,662
	Future	7,642	6,195	2,061	722	5,622	5,523	15,054	42,819
	% past	3	1	2	2	8	37	46	100
	% present	7	12	4	1	17	19	39	100
	% future	18	14	5	2	13	13	35	100
North Indian River	Past	2,924	382	1,133	12,092	11,998	33,814	51,716	114,059
	Present	8,634	3,898	5,489	10,787	15,858	19,405	51,844	115,916
	Future	13,809	7,968	9,306	10,120	12,601	12,793	50,052	116,648
	% past	3	0	1	11	11	30	45	100
	% present	7	3	5	9	14	17	45	100
	% future	12	7	8	9	11	11	43	100
Banana River	Past	1,600	40	519	1,033	7,243	23,755	13,402	47,592
	Present	11,010	4,217	1,601	285	7,733	15,049	10,299	50,195
	Future	18,359	4,733	1,618	103	6,144	11,897	8,110	50,965
	% past	3	0	1	2	15	50	28	100
	% present	22	8	3	1	15	30	21	100
	% future	36	9	3	0	12	23	16	100
Central Indian River	Past	2,603	765	1,839	9,281	35,925	49,217	24,649	124,279
	Present	13,855	29,573	17,455	10,656	17,511	18,121	19,991	127,162
	Future	28,998	43,994	20,363	7,730	2,219	1,978	8,805	114,085
	% past	2	1	1	7	29	40	20	100
	% present	11	23	14	8	14	14	16	100
	% future	25	39	18	7	2	2	8	100
Sebastian River	Past	1,518	57	694	21,351	41,525	31,277	46,523	142,945
	Present	3,566	6,131	8,994	36,328	22,958	23,872	18,095	119,944
	Future	5,737	16,658	11,178	60,880	5,688	5,648	16,608	122,397
	% past	1	0	0	15	29	22	33	100
	% present	3	5	7	30	19	20	15	100
	% future	5	14	9	50	5	5	14	100
South Indian River	Past	2,422	284	1,600	17,294	5,410	27,685	13,383	68,079
	Present	7,182	11,749	6,362	24,006	5,338	8,639	5,202	68,478
	Future	16,444	27,038	356	18,500	1,058	1,566	3,485	68,446
	% past	4	0	2	25	8	41	20	100
	% present	10	17	9	35	8	13	8	100
	% future	24	40	1	27	2	2	5	100
Total	Past	12,542	1,781	6,848	61,991	105,630	181,669	169,485	539,946
	Present	47,104	61,012	41,861	82,499	77,001	93,291	122,589	525,357
	Future	90,988	106,586	44,881	98,054	33,332	39,406	102,114	515,360
	% past	2	0	1	11	20	34	31	100
	% present	9	12	8	16	15	18	23	100
	% future	18	21	9	19	6	8	20	100

Table ES2. Comparison of results between past, current, and future conditions

Past condition results
(average annual results using 1994–2000 rainfall data)

Region	Volume (ac-ft)	TSS (lbs)	TP (lbs)	TN (lbs)
Mosquito Lagoon	66,400	1,718,571	16,101	139,414
North Indian River	159,143	3,902,857	38,214	446,857
Banana River	92,329	2,021,857	15,749	91,314
Central Indian River	221,714	5,591,429	48,971	577,429
Sebastian River	279,571	5,542,857	63,314	384,714
Indian River Farms	115,171	3,644,286	43,814	316,286
Total	934,329	22,421,857	226,164	1,956,014

Percent change
from current to past condition

Region	Vol	TSS	TP	TN
Mosquito Lagoon	-9	-49	-33	-26
North Indian River	-8	-59	-41	-23
Banana River	-22	-78	-65	-69
Central Indian River	-14	-68	-60	-41
Sebastian River	14	-40	-30	-35
Indian River Farms	-20	-65	-46	-44
Total	-7	-62	-47	-39

Current condition results
(average annual results, 1994–2000 rainfall data)

Region	Volume (ac-ft)	TSS (lbs)	TP (lbs)	TN (lbs)
Mosquito Lagoon	73,200	3,381,429	23,971	188,286
North Indian River	172,114	9,465,714	64,743	577,429
Banana River	117,886	9,234,286	44,686	293,571
Central Indian River	258,143	17,420,000	121,629	985,000
Sebastian River	244,429	9,187,143	90,871	588,143
Indian River Farms	143,429	10,358,571	81,571	569,714
Total	1,009,200	59,047,143	427,471	3,202,143

Future condition results
(average annual results 1994–2000 rainfall data)

Region	Volume (ac-ft)	TSS (lbs)	TP (lbs)	TN (lbs)
Mosquito Lagoon	76,814	6,844,286	39,029	266,429
North Indian River	179,643	14,342,857	88,129	686,429
Banana River	124,971	15,024,286	67,657	407,429
Central Indian River	204,286	22,000,000	146,714	1,000,286
Sebastian River	257,429	14,825,714	122,371	754,429
Indian River Farms	157,857	17,171,429	112,800	752,429
Total	1,001,000	90,208,571	576,700	3,867,429

Percent change
from current to future condition

Region	Vol	TSS	TP	TN
Mosquito Lagoon	5	102	63	42
North Indian River	4	52	36	19
Banana River	6	63	51	39
Central Indian River	-21	26	21	2
Sebastian River	5	61	35	28
Indian River Farms	10	66	38	32
Total	-1	53	35	21

Percent change from past to future condition

Region	Volume	TSS	TP	TN
Mosquito Lagoon	15	120	83	63
North Indian River	12	114	79	42
Banana River	30	153	124	127
Central Indian River	-8	119	100	54
Sebastian River	-8	91	64	65
Indian River Farms	31	130	88	82
Total	7	120	87	66

CONTENTS

FIGURES

TABLES

INTRODUCTION

The Indian River Lagoon (IRL) lies on the east coast of Florida, extending 140 miles from Ponce de Leon Inlet near New Smyrna Beach to St. Lucie Inlet. The northern three-fourths of the IRL is within the St. Johns River Water Management District (SJRWMD) (Figure 1).

SJRWMD is in the process of developing pollutant load reduction goals (PLRGs) to protect and preserve the natural functions of the IRL within its jurisdiction. Past drainage practices and recent population increases on Florida's east coast have increased freshwater runoff and pollution to the IRL, which has decreased water quality and reduced seagrass habitat. The PLRGs will impose environmental requirements that will promote seagrass growth and expansion.

PLRG development requires constructing and using a defensible pollution load reduction model that is capable of predicting the IRL's water quality response to freshwater runoff and pollution loading. In 1996, SJRWMD contracted with the University of Florida to develop the Indian River Lagoon Pollution Load Reduction (IRL PLR) Model, a three-dimensional hydrodynamic/salinity and water quality and light attenuation model.

During development of the IRL PLR model, runoff and pollution loading input were estimated from gaged discharge and observed water quality data during 1998. However, in order to evaluate impacts to the IRL for past, current, and future conditions, SJRWMD needed to develop a watershed model of the entire drainage area capable of estimating runoff and pollution loading due to past and future, as well as present, conditions.

Purpose and Scope

The purpose of this work is to estimate runoff and pollution loading into the IRL for use as input into the IRL PLR model. The runoff and pollution loading for past, current, and future conditions will be estimated. These conditions are of interest to evaluate the impact of existing and anticipated development to the IRL. This document presents the data used and methods applied to estimate the runoff and pollution loading. Also, within this document are evaluations of the results.

Implied in the stated purpose is the accounting of the runoff and pollution load from all area that drains to the IRL within the SJRWMD boundaries. To achieve this goal, the entire IRL watershed within SJRWMD must be represented with a watershed model. Watershed models that have been developed for portions of the IRL watershed (Bergman and Donnangelo 1995, 1996a, 1996b, 1998) will be expanded to areas that are currently not represented by watershed models (primarily barrier islands and nearshore drainage) and will be updated to incorporate land use differences and nonpoint source pollution simulation.

The representation of land use differences within the watershed model provides a method to estimate past, current, and future conditions. Each condition consists of a unique acreage of each land use. Each land use produces a representative amount pollution load (the urban areas produce more pollution than forest or open land). Over time, undeveloped area such as forest and open land decrease and urban area increases. Increased urban area and reduced undeveloped area result in increased pollution load.

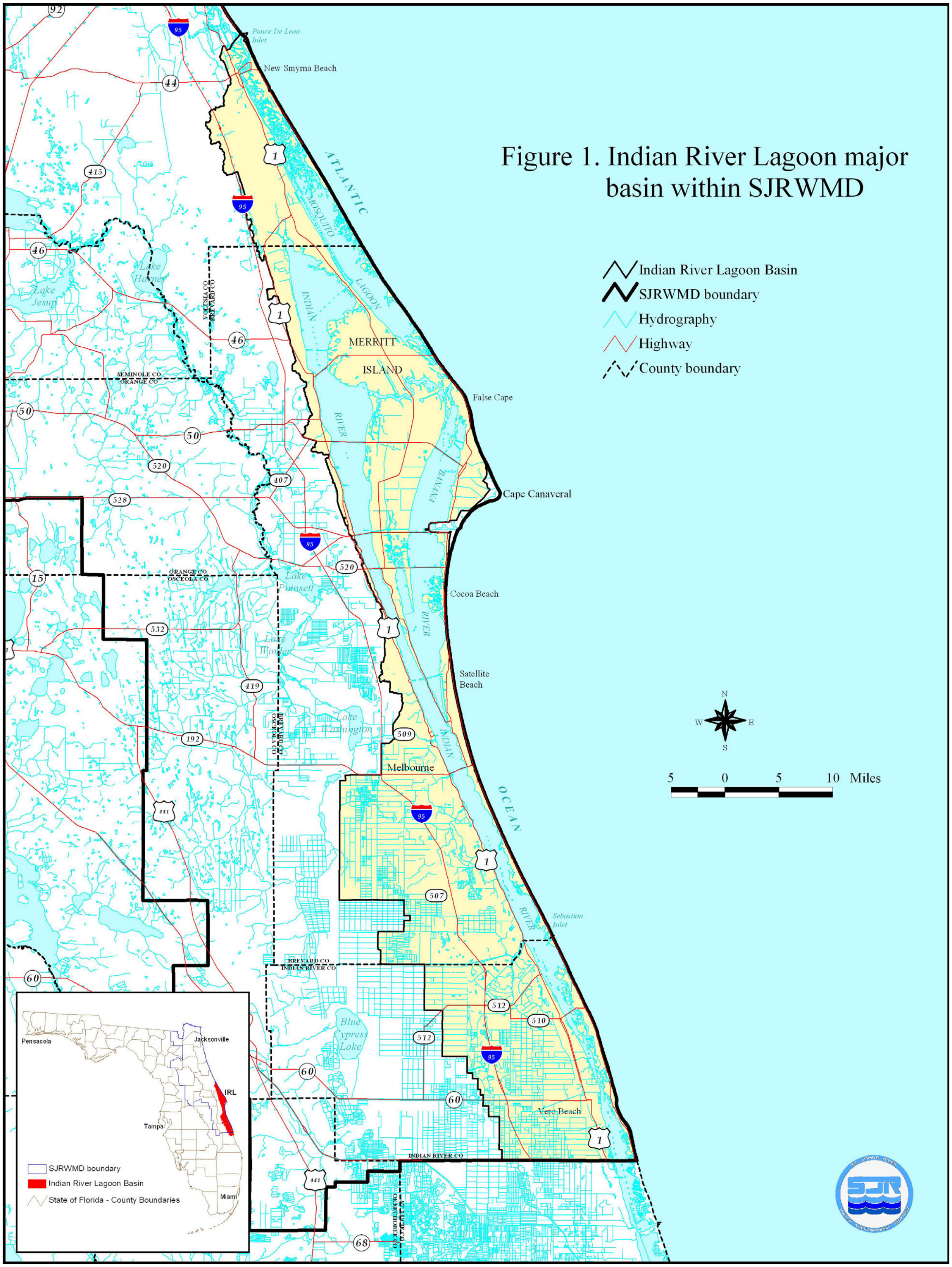

Figure 1. Indian River Lagoon major basin within SJRWMD
Indian River Lagoon Basin
SJRWMD boundary
Hydrography
Highway
County boundary
5 0 5 10 Miles
N
S
E
W
New Smyrna Beach
Ponce De Leon Inlet
ATLANTIC
OCEAN
MOSQUITO LAGOON
INDIAN RIVER
BANANA RIVER
MERRITT ISLAND
False Cape
Cape Canaveral
Cocoa Beach
Satellite Beach
Melbourne
Sebastian Inlet
Vero Beach
Lake Jesup
Lake Harney
Lake Poinsett
Lake Winder
Lake Washington
Blue Cypress Lake
SEMINOLE CO
ORANGE CO
OSCEOLA CO
BREVARD CO
INDIAN RIVER CO
Pensacola
Jacksonville
Tampa
Miami
IRL
SJRWMD boundary
Indian River Lagoon Basin
State of Florida - County Boundaries

Previous Watershed Models

Several hydrologic models and water quality models have been developed to investigate the runoff and the pollution loading into the IRL. Previous models of the IRL watershed can be separated into two efforts. One effort consisted of modifying the SJRWMD Pollution Load Screening Model (PLSM) (Mundy and Bergman 1998) and applying it specifically to the IRL watershed. The PLSM estimates annual pollution load as a function of runoff volume and pollution concentrations generated by various land use groups. The model was developed to compare the relative contribution from different land uses. The results are annual values, best used as a screening tool for planning purposes. However, the model is useful for large areas such as the IRL watershed and provides good spatial detail of runoff and pollution loading. Green and Steward (2003) modified the PLSM to improve the representation of conditions in the IRL.

The second effort has consisted of developing hydrologic and water quality models to simulate the runoff and pollution loading from significant tributaries to the IRL. These models contained comprehensive hydrologic and water quality simulation capabilities representing the temporal dynamics of the rainfall-infiltration-runoff-washoff processes. However, they were applied primarily to basins drained by significant tributaries, where gaged data could be used to calibrate the models. Bergman and Donnangelo (1995, 1996a, 1996b, 1998) performed the majority of this work. Also, Bergman et al. (2001) calibrated the simulation of water quality to collected data in the South Prong of the Sebastian River.

Model Selection

The Hydrologic Simulation Program — FORTRAN (HSPF) (Bicknell et al. 2001) was selected because of its comprehensive hydrologic and water quality simulation capabilities. HSPF can be described as a computer program capable of simulating the hydrologic and associated water quality processes on pervious and impervious land surfaces, in streams, and in well-mixed impoundments. It performs a detailed accounting of mass for all subsets of the hydrologic cycle, such as rainfall, evapotranspiration, surface runoff, interflow, and groundwater flow.

The hydrology of HSPF is based upon the principles of the Stanford Watershed Model (Crawford and Linsley 1966) and has continued to develop under the direction of the U.S. Environmental Protection Agency. HSPF simulates the hydrology of a watershed using a network of nonlinear storages that represent the components of the natural system. Inflows to and outflows from storages are controlled by parameters that describe the physical characteristics of each component. The user links parameter values to characteristics of the physical system or obtains parameter values through calibration.

HSPF was the program used for previous IRL watershed modeling efforts. The selection of HSPF to represent the remaining area builds on the work invested in the existing watershed models.

PROJECT DEVELOPMENT

Data Development

Data collected around the Indian River Lagoon are used to characterize the watershed, meteorologic, hydrologic, and water quality conditions. Various agencies are involved in the data collection effort. All of the necessary watershed data, such as drainage basin delineation, soil type, and land use are available in the SJRWMD geographic information system (GIS) database. Both the National Oceanic and Atmospheric Administration (NOAA) and SJRWMD collect the meteorological data. Stream discharges and stages are measured by the U.S. Geological Survey (USGS). In-stream water quality data are collected by SJRWMD.

Drainage Basin

The Indian River Lagoon major basin and the Interbasin Diversion Planning Unit as defined by Adamus and others (1997) is the area of interest in this investigation.

The Indian River Lagoon major basin can be divided into six significant basins (Figure 2). This separates the IRL watershed into six smaller manageable portions. From north to south, the basins are the Mosquito Lagoon, the north Indian River, the Banana River, the central Indian River, the Sebastian River, and the south Indian River regions.

The six Indian River basins are further separated into drainage areas (Figures 3 and 4 and Table 1). Drainage areas consist of drainage basins, nearshore drainage, and barrier island drainage. Primarily, a drainage area defines the area that contributes runoff to a reach of the IRL. Definition of IRL reaches begins with the segments originally used to evaluate seagrass (Carter et al. 2001). Additional breaks between segments have been made at natural and man-made features, such as causeways. In some cases, the drainage area defines the area contributing runoff to a tributary, such as the Sebastian River North Prong (6100), the Fellsmere Farms Canal (6200), and the Sebastian River South Prong (6300). In other cases, drainage areas define only a nearshore and barrier island area that contributes runoff to an IRL segment such as drainage areas 1300, 1400, 2300, 2800, 4800, and 6534. The individual drainage areas define all area contributing runoff to the IRL.

Soils

Soils in the Indian River Lagoon watershed have been categorized into hydrologic soil groups, which classify the soil based on infiltration characteristics. Table 2 shows the area and Figure 5 shows the distribution of the hydrologic soil groups in the watershed. The soil maps are obtained from the Natural Resources Conservation Service (previously the Soil Conservation Service) Soils Survey data compiled by counties. The majority of the area consists of B/D soils, particularly in the central Indian River, Sebastian River, and south Indian River areas.

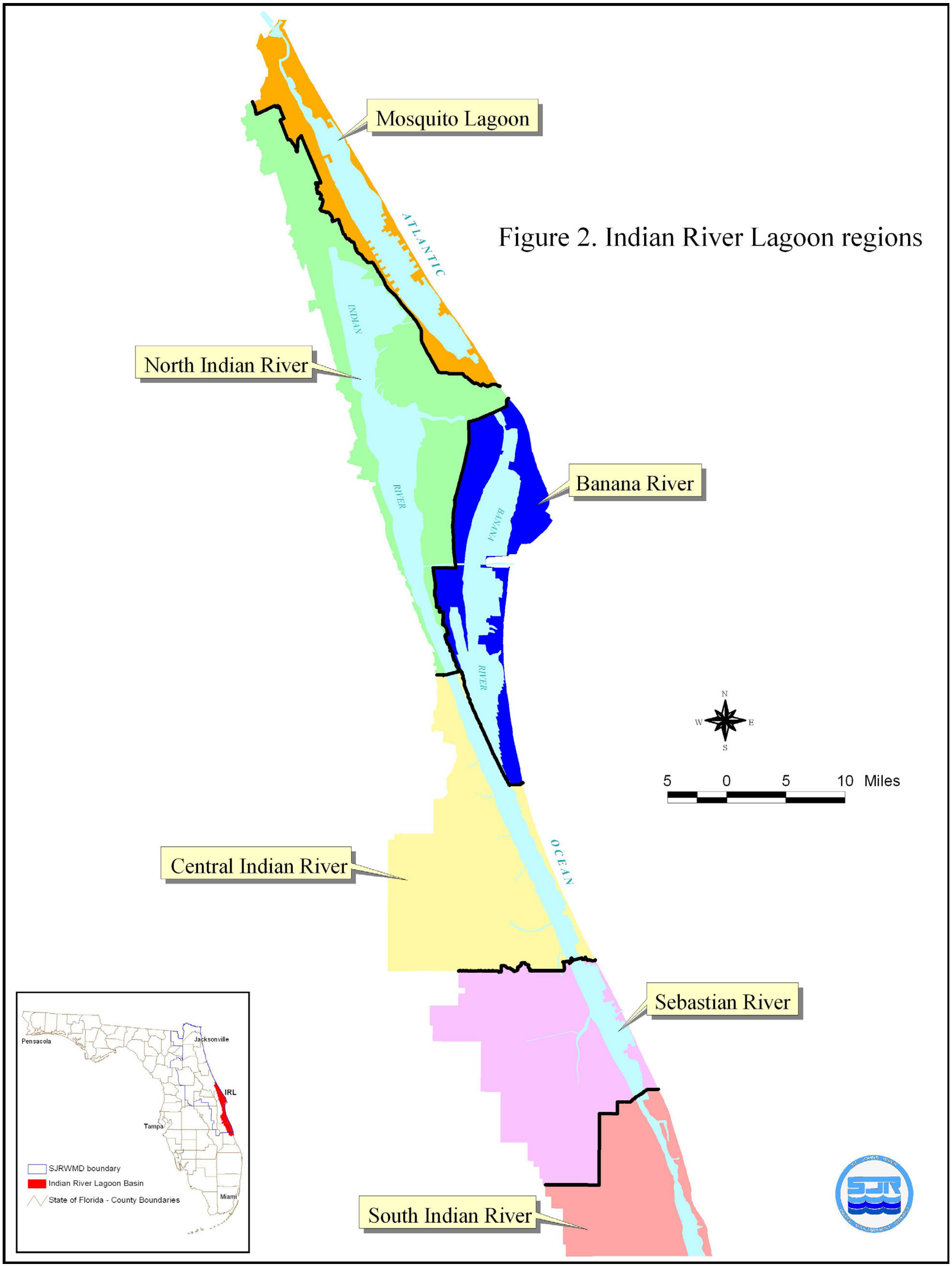
Figure 2. Indian River Lagoon regions
Mosquito Lagoon
North Indian River
Banana River
Central Indian River
Sebastian River
South Indian River
ATLANTIC
OCEAN
INDIAN
RIVER
BANANA
RIVER
N
W
E
S
5
0
5
10
Miles
Pensacola
Jacksonville
IRL
Tampa
Miami
SJRWMD boundary
Indian River Lagoon Basin
State of Florida - County Boundaries

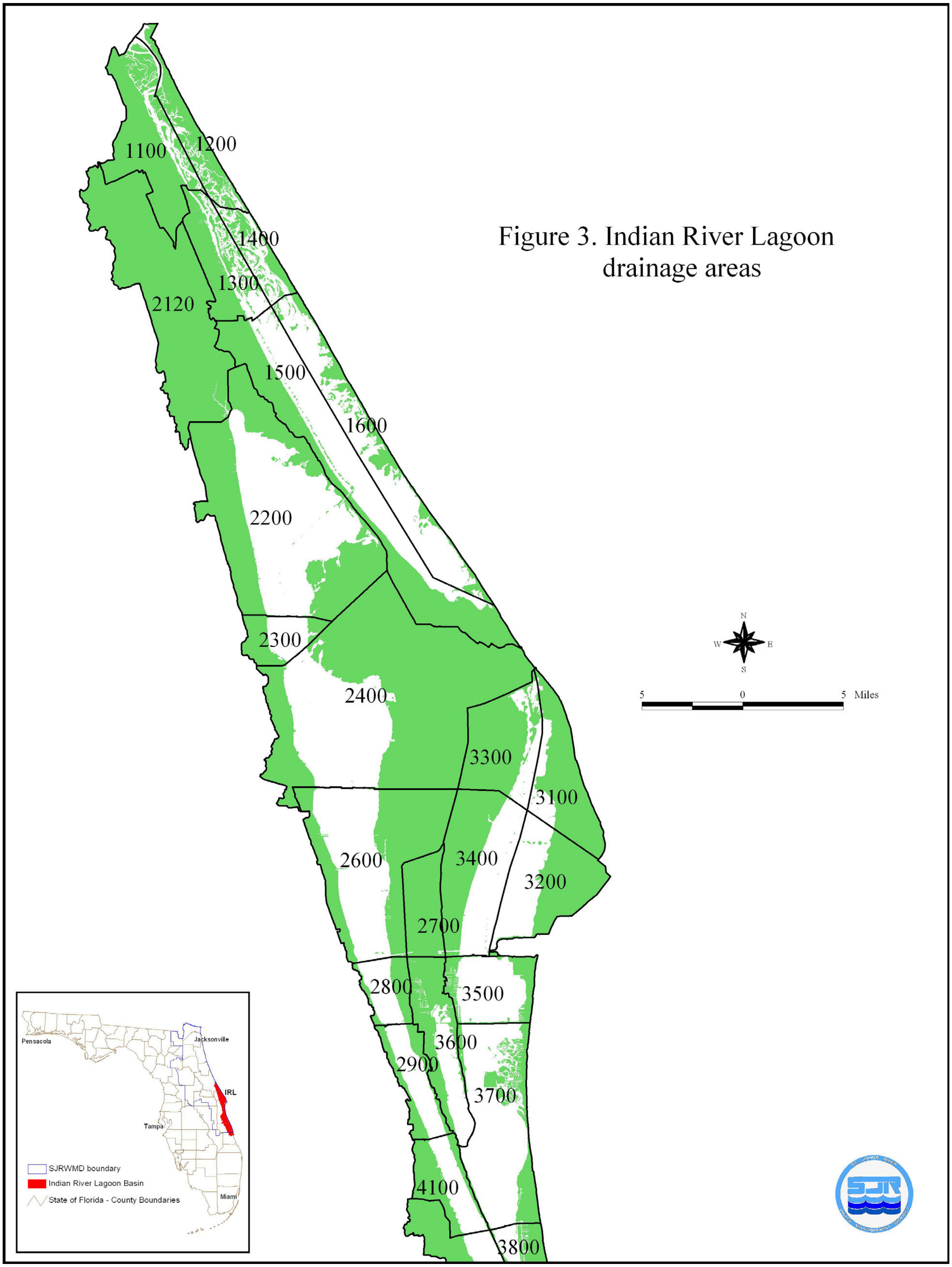

Figure 3. Indian River Lagoon drainage areas

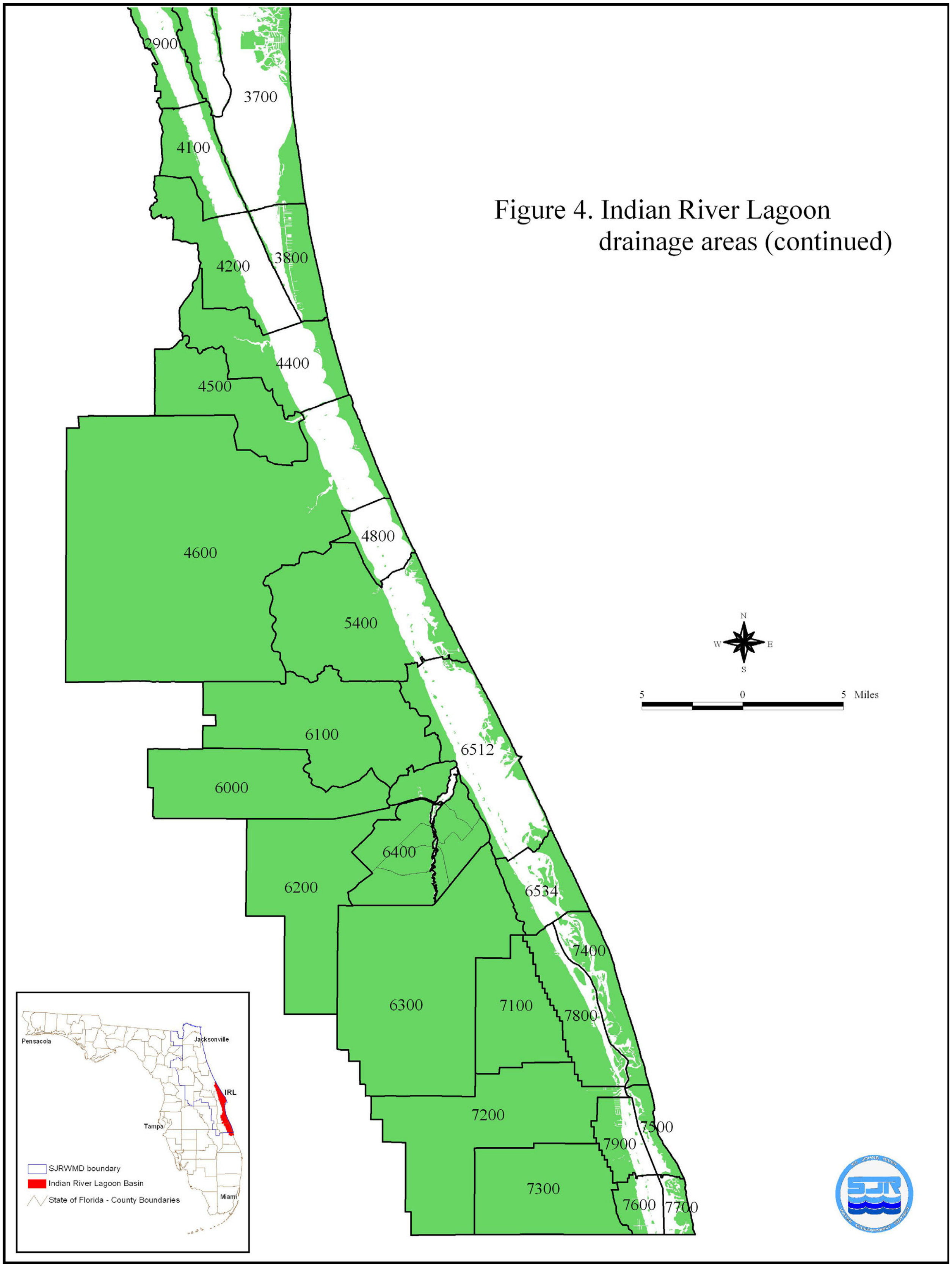
Figure 4. Indian River Lagoon
drainage areas (continued)
2900
3700
4100
3800
4200
4400
4500
4600
4800
5400
6100
6512
6000
6400
6200
6534
7400
6300
7100
7800
7200
7500
7900
7300
7600
7700
N
W
E
S
5
0
5 Miles
Pensacola
Jacksonville
IRL
Tampa
Miami
SJRWMD boundary
Indian River Lagoon Basin
State of Florida - County Boundaries

Table 1. Drainage areas within the Indian River Lagoon major basin

Basin Name	DA ID	Acres	Percent DA/Region	Percent Basin/Total	Basin Name	DA ID	Acres	Percent DA/Basin	Percent Basin/Total
						4100	3,791	3	
	1100	12,438	28			4200	7,283	6	
	1200	4,594	11			4400	8,825	7	
	1300	6,002	14			4500	11,695	9	
	1400	2,189	5			4600	74,783	59	
	1500	14,349	33			4800	980	1	
	1600	4,090	9			5400	19,805	16	
Mosquito Lagoon	**Total**	43,662	100	8	**Central IRL**	**Total**	127,162	100	24
	2120	27,526	24						
	2200	22,595	19			6000	16,587	14	
	2300	2,633	2			6100	22,847	19	
	2400	40,837	35			6200	20,827	17	
	2600	13,981	12			6300	36,609	30	
	2700	3,577	3			6400	15,174	13	
	2800	2,022	2			6512	4,859	4	
	2900	2,743	2			6534	3,903	3	
North Indian River	**Total**	115,916	100	22	**Sebastian**	**Total**	120,807	100	23
						7100	10,820	16	
	3100	8,417	16			7200	24,480	36	
	3200	7,146	14			7300	15,324	22	
	3300	8,741	17			7400	4,535	7	
	3400	8,764	17			7500	1,453	2	
	3500	2,581	5			7600	1,525	2	
	3600	6,320	12			7700	899	1	
	3700	5,033	10			7800	6,831	10	
	3800	4,419	9			7900	2,611	4	
Banana River	**Total**	51,422	100	10	**South IRL**	**Total**	68,478	100	13
					IRL Basin	**Total**	527,447		100

Table 2. Hydrologic soil groups in the Indian River Lagoon major basin

Hydrologic Soil Group	Acres	Percent	Comments
A	43,804	8	High infiltration rate
B	4,118	1	Moderate infiltration rate
B/D	292,160	55	*
C	51,688	10	Slow infiltration rate
C/D	30,013	6	*
D	89,174	17	Very slow infiltration rate
U	7,311	1	Urban land
W	9,043	2	Water
X	110	0	Pits
Total	527,422	100	

*Drainage improvements will increase the natural infiltration rate of D to C or B

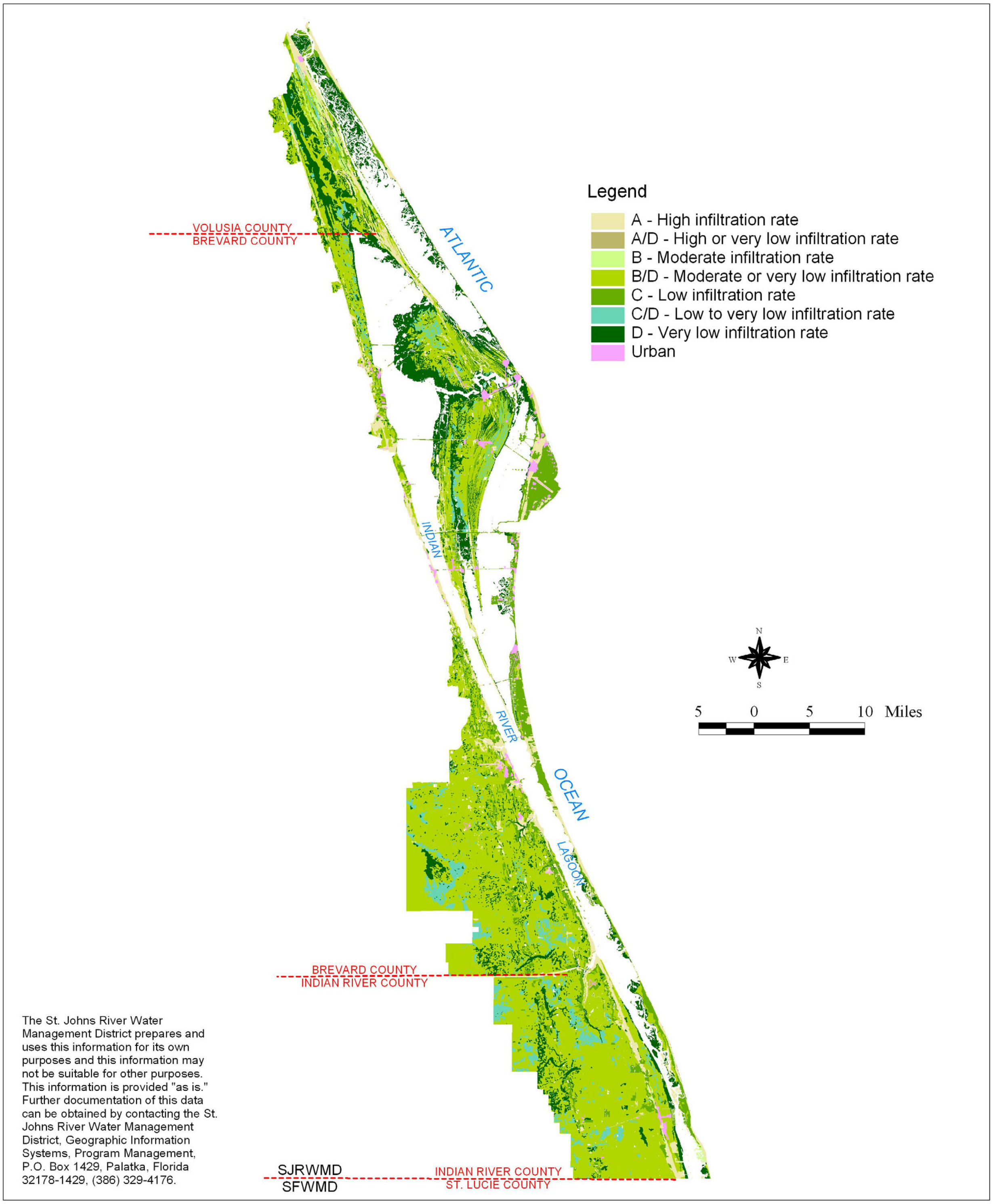

Figure 5. Hydrologic soil groups in the Indian River Lagoon major basin

Land Use

There are three conditions of interest — past, current, and future. These conditions will be characterized by land use. Due to the limitations of watershed modeling, a large number of detailed land use categories will not increase the accuracy of the model. For this reason, the land use is grouped into seven land use categories:

- High-intensity use urban
- Medium-intensity use urban
- Low-intensity use urban
- Agriculture
- Open land
- Forest
- Wetlands

The land use information for each condition is obtained from various sources. Each source uses different descriptions to identify the land use. Using these seven land use definitions to describe each condition also provides some measure of consistency in comparing the changes.

Land use data used to characterize the present condition are obtained from SJRWMD's GIS map "Land Use/Land Cover, 1995, SJRWMD." SJRWMD has classified the land within its boundaries using a modified Florida Land Use and Cover Classification System (FLUCCS) (Florida Department of Transportation 1999). In the appendix, Table A1 shows the mapped land use grouped into the seven modeled land uses. Each mapped land use was placed in a particular modeled land use group with similar pollution producers. For example, electrical power transmission lines are included in the open land category with other land uses that have similar nonpoint source pollution production.

Some land use areas were not considered part of the watershed. For example, water areas are identified in the FLUCCS. However, areas such as Bays and Estuaries (FLUCCS 5400) and Streams and Waterways (FLUCCS 5100) were not considered to contribute runoff. The FLUCCS category of Bays and Estuaries identifies the IRL estuary simulated with the IRL PLR model. Streams and waterways are considered conveyances and are included in the routing portion of the watershed models.

Land use data used to characterize the past condition were obtained from a series of 1943 Soil Conservation Service aerial photographs. Dynamac Corporation interpreted the aerials and identified the land use for SJRWMD using the 1985 FLUCCS. Further modification of the land use identification was performed subsequently by SJRWMD. Therefore, definitions describing the 1943 mapped land use do not exactly match the land use definitions used to describe the 1995 land uses. Table A2 shows the past mapped land uses grouped into the seven modeled land use categories.

The land use map provided to SJRWMD from the East Central Florida Regional Planning Council (ECFRPC) (source: metadata for 1996 SJRWMD Future Land Use Map) was used to characterize the future condition. This future "land use" map represents local governments' planned built-out condition and does not attempt to accurately represent natural features, such as wetland, forest, or open land. Also, the entire Kennedy Space Center was labeled Public Facilities/Institutional, which would be grouped into the modeled category of high-intensity urban. For these reasons, more work was required to arrange the mapped land use into the modeled land groups. An intermediate land use definition of “undeveloped” was created, and additional treatment of the Kennedy Space Center was required. Table A3 shows how the mapped land use definitions were grouped into the intermediate land use categories.

Future wetland area needed to be estimated. *Florida Statutes* protects wetlands. However, wetland loss due to development has been documented. Future wetland acreage was estimated by reducing the 1995 wetland area within each subbasin when overlapped by future urban or agricultural areas. The reduction factors were derived from the SJRWMD annual wetland loss reports in Volusia, Indian River, and Brevard counties between 1987 and 1996. During those years, urban development resulted in removal of 16% of onsite wetlands. Agricultural development was responsible for removal of 6% of onsite wetlands. With this information, the 1995 wetlands map was superimposed onto the future land use map. All 1995 wetlands overlaid by urban were reduced 16%. All 1995 wetlands overlaid by agriculture were reduced 6%. No 1995 wetlands overlaid by undeveloped land were reduced. The total wetland area remaining was the area of future wetlands. These wetland areas were subtracted from the respective overlaid future areas.

To represent future open land and forest, the remaining undeveloped area was divided into the two categories by assuming that the open land and forest proportions remained the same from present to future. For example, if the present condition open land and forest areas within a subbasin were 4,000 acres and 6,000 acres, respectively, the total undeveloped land for present condition is 10,000 acres. If the undeveloped area in the future condition is determined to be 5,000 acres, then 40% (2,000 acres) will be open land and 60% (3,000 acres) will be forest.

Attention was given to improving estimates of the land use at the Kennedy Space Center. To better understand the changes that may occur at the Kennedy Space Center, a comparison between the 1990 and 2000 land use maps was made. These two maps were chosen because they provided the longest period for comparing land use changes. This comparison revealed that the developed area has not significantly increased over the past 10 years. However, it was acknowledged that development could occur with the beginning of another space program, such as a mission to Mars. Three alternative treatments of the Kennedy Space Center were discussed: (1) leave the entire area grouped into high-impact urban, (2) use the present land use, indicating no increased development, (3) assume that increased development occurs at a rate similar to the rest of the IRL watershed.

The third alternative was chosen. A growth factor of 1.9 for urban areas was determined by comparing the current to future IRL land use (excluding the Kennedy Space Center). This factor was applied to the Kennedy Space Center current condition urban land to determine the area of urban land in the future condition.

In addition to land use changes, watershed boundary modifications increased or decreased the runoff and associated pollution into the IRL. Boundary modifications have occurred or will occur in the Banana River (DA 3100–3800), Turkey Creek (DA 4600), and the Sebastian River (DA 6000–6200). From the 1950s through the 1960s, there was much construction on Cape Canaveral as the space program was developed. Some of the construction included creating islands and expanding shoreline. As a result, the drainage area around the Banana River has increased about 4 square miles.

In the Sebastian River, several drainage modifications have changed the area that drains to the IRL (Clapp and Wilkening 1984). In the 1950s, drainage modifications increased the drainage area to the North Prong of the Sebastian River (DA 6100) about 8 square miles. In the late 1960s, the C-54 canal was constructed. The adjacent drainage (DA 6000) of approximately 20 square miles was added to the Sebastian River. In the 1970s, as part of the Upper St. Johns River Basin (USJRB) project, about 64 square miles of the Fellsmere Farms area (DA 6200) was rediverted to the USJRB.

In Turkey Creek (DA 4600), drainage modifications are planned as part of the C-1 Rediversion project. This project will remove about 20 square miles of contributing runoff area to the Indian River and redirect the runoff towards the USJRB.

Delineation and removal of the estuary area, particularly where land and water are interlaced, may have created area discrepancies. The areas in regions such as the Mosquito Lagoon, the north Indian River, and the south Indian River (where there have been no significant boundary modifications) vary less than 2% from past to present and future.

The land use areas for each condition are summarized in Table 3. The past, present, and future land use distribution can be seen in Figures 6–8, respectively. Comparison of the three figures provides a visual accounting of the increased development that has occurred and will occur in the IRL watershed. The greatest increase of high-intensity use urban area occurs in the Banana River basin. The percent increase from past to future is 3% to 36%. The greatest increase of medium intensity use urban area occurs in the south IRL where the percent increase from past to future is 0% to 40%. Correspondingly, open land, forest, and wetland decrease over time.

Rainfall

Rainfall collection stations that report rainfall at 1-hour time-steps were selected to represent rainfall over the IRL major basin (Figure 9 and Table 4). The period of interest is from January 1994 to December 2000. Notice that four rainfall collection stations do not begin collecting data until 1996. Missing rainfall data at a particular station were filled with the nearby rainfall data.

The rainfall stations used to represent rainfall over the IRL major basin are operated by SJRWMD. Three NOAA stations (that collect hourly rainfall) are used to fill missing data. Also, the NOAA stations have collected rainfall at least since 1942 and are used to characterize the rainfall over the IRL major basin during "past conditions," January 1942 to December 1948.

<u>Evaporation</u>. Pan evaporation data, collected at the NOAA Vero Beach 4W station (ID 9219), were used to estimate potential evapotranspiration over the basin.

<u>Hydrology</u>. Discharge data were collected at significant tributaries to the IRL (Figure 10 and Table 5). The gaging stations collecting data through December 2000 were used to calibrate the hydrological portion of the watershed models.

Table 3. Land use in the Indian River Lagoon major basin (in acres)

		Urban HI	Urban MI	Urban LI	Agriculture	Open Land	Forest	Wetland	Total
Mosquito Lagoon	Past	1,475	253	1,063	941	3,530	15,921	19,812	42,993
	Present	2,856	5,444	1,959	436	7,603	8,205	17,158	43,662
	Future	7,642	6,195	2,061	722	5,622	5,523	15,054	42,819
	%Past	3	1	2	2	8	37	46	100
	%Present	7	12	4	1	17	19	39	100
	%Future	18	14	5	2	13	13	35	100
North Indian River	Past	2,924	382	1,133	12,092	11,998	33,814	51,716	114,059
	Present	8,634	3,898	5,489	10,787	15,858	19,405	51,844	115,916
	Future	13,809	7,968	9,306	10,120	12,601	12,793	50,052	116,648
	%Past	3	0	1	11	11	30	45	100
	%Present	7	3	5	9	14	17	45	100
	%Future	12	7	8	9	11	11	43	100
Banana River	Past	1,600	40	519	1,033	7,243	23,755	13,402	47,592
	Present	11,010	4,217	1,601	285	7,733	15,049	10,299	50,195
	Future	18,359	4,733	1,618	103	6,144	11,897	8,110	50,965
	%Past	3	0	1	2	15	50	28	100
	%Present	22	8	3	1	15	30	21	100
	%Future	36	9	3	0	12	23	16	100
Central Indian River	Past	2,603	765	1,839	9,281	35,925	49,217	24,649	124,279
	Present	13,855	29,573	17,455	10,656	17,511	18,121	19,991	127,162
	Future	28,998	43,994	20,363	7,730	2,219	1,978	8,805	114,085
	%Past	2	1	1	7	29	40	20	100
	%Present	11	23	14	8	14	14	16	100
	%Future	25	39	18	7	2	2	8	100
Sebastian River	Past	1,518	57	694	21,351	41,525	31,277	46,523	142,945
	Present	3,566	6,131	8,994	36,328	22,958	23,872	18,095	119,944
	Future	5,737	16,658	11,178	60,880	5,688	5,648	16,608	122,397
	%Past	1	0	0	15	29	22	33	100
	%Present	3	5	7	30	19	20	15	100
	%Future	5	14	9	50	5	5	14	100
South Indian River	Past	2,422	284	1,600	17,294	5,410	27,685	13,383	68,079
	Present	7,182	11,749	6,362	24,006	5,338	8,639	5,202	68,478
	Future	16,444	27,038	356	18,500	1,058	1,566	3,485	68,446
	%Past	4	0	2	25	8	41	20	100
	%Present	10	17	9	35	8	13	8	100
	%Future	24	40	1	27	2	2	5	100
Total	Past	12,542	1,781	6,848	61,991	105,630	181,669	169,485	539,946
	Present	47,104	61,012	41,861	82,499	77,001	93,291	122,589	525,357
	Future	90,988	106,586	44,881	98,054	33,332	39,406	102,114	515,360
	%Past	2	0	1	11	20	34	31	100
	%Present	9	12	8	16	15	18	23	100
	%Future	18	21	9	19	6	8	20	100

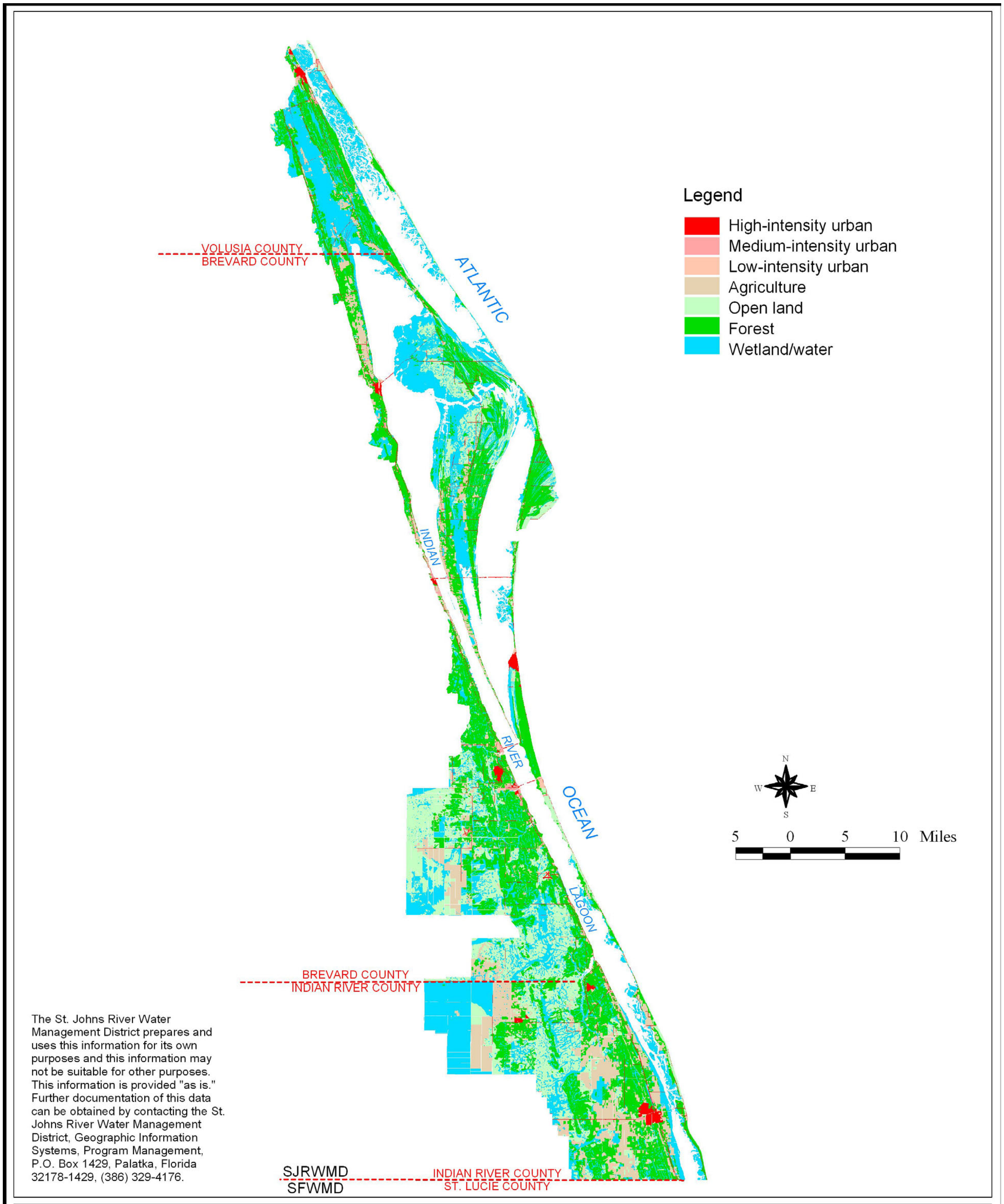

Figure 6. 1943 land use in the Indian River Lagoon major basin

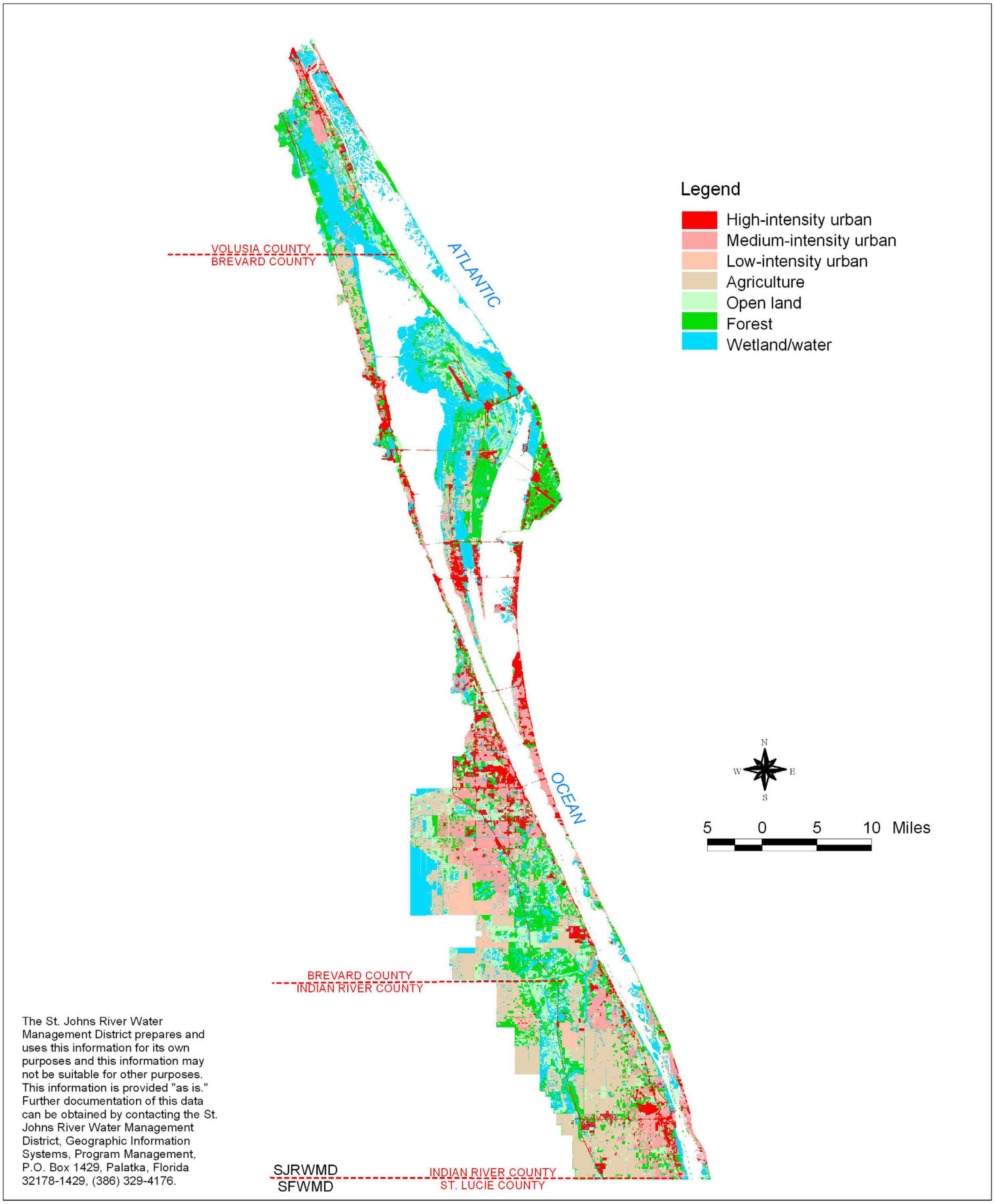

Figure 7. 1995 land use in the Indian River Lagoon major basin

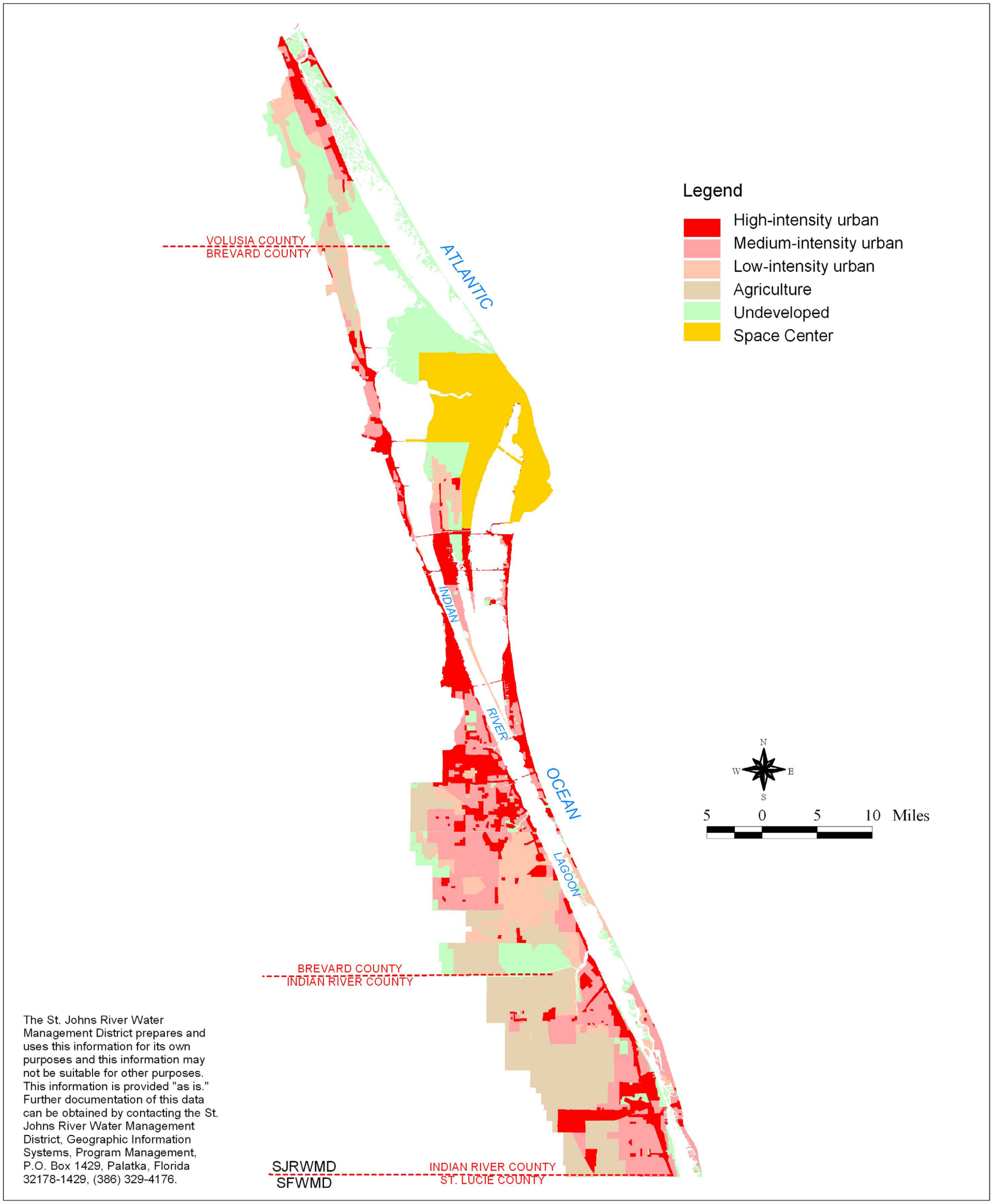

Figure 8. Future land cover in the Indian River Lagoon major basin

Water Quality. Water quality data are collected at about monthly intervals throughout the IRL. The collection locations at the outlet of significant tributaries were selected for comparison to model results (Figure 10 and Table 6). The water quality constituents of interest are total suspended solids, total phosphorus, orthophosphorus, and total nitrogen.

Model Development

As discussed in the introduction, most of the significant tributaries have been represented with a watershed model. These significant tributaries include Turnbull Creek, the Eau Gallie River, Crane Creek, Turkey Creek, Goat Creek, Trout Creek, the North Prong of the Sebastian River, Fellsmere Farms, and the South Prong of the Sebastian River. The only significant tributaries that were not previously modeled are the North, Main, and South canals (DA 7100, 7200, and 7300). The remaining areas that drain into the IRL can be defined as barrier islands, Merritt Island, and nearshore drainage.

The existing models were updated to simulate the period of interest and to appropriately represent land use. Watershed models were created for the North, Main, and South canals and were calibrated to match gaged data. Water quality parameters were adjusted to produce average annual loads equal to literature values. The barrier islands and the nearshore areas were modeled using runoff parameters developed at the gaged tributaries.

Hydrologic Model

HSPF is a continuous simulation model. The three principal modules used to represent the hydrology are PERLND, IMPLND, and RCHRES.

PERLND simulates the hydrology of a pervious land segment. Moisture is supplied by rainfall. A fraction is stored as interception. Moisture exceeding interception storage becomes available for infiltration and runoff. Moisture that directly infiltrates moves to the lower zone and groundwater storages. Other water may go to the upper zone storage, may be routed as runoff from surface detention or interflow storage, or may stay on the overland flow plane, from which it runs off or infiltrates at a later time. A portion of the water stored in the upper zone percolates downward and joins the direct infiltration. This direct infiltration and percolation is divided over lower zone storage, active groundwater storage, and deep percolation. The outflow from the groundwater storage represents base flow. Losses occur in the form of deep percolation and evapotranspiration from water stored as interception, upper zone moisture, and lower zone moisture.

Parameters in PERLND are linked with simulation of hydrologic processes. Many of these parameters can be associated with physical characteristics such as land use, soil type, and topography. In this study, watershed parameters are primarily associated with land use. The seven land categories previously defined will make up the seven PERLND land segments within each subbasin.

Table 4. Rainfall collection stations in the Indian River Lagoon major basin

Lat	Long	Station ID	Owner	Begins	Ends	Site_name	Full Name
273919	802416	1510686	SJRWMD	2/9/1996	6/30/2003	Vero Beach	Vero Beach Airport at Vero Beach Rain
273943	803609	1250526	SJRWMD	6/18/1993	5/15/2002	BCWMA East 1	BCWMA East Site 1 near Fellsmere Rain
274523	803040	870172	SJRWMD	8/17/1990	5/16/2002	West Canal	West Canal at CR 510 near Sebastian Rain[1]
274622	803531	720120	SJRWMD	6/26/1990	7/10/2002	Snyder Fish Farm	Snyder Fish Farm at Fellsmere Rain
274900	804212	510206	SJRWMD	2/7/1990	4/15/2003	S-96	S-96 near Fellsmere Rain
274950	803223	520215	SJRWMD	2/13/1990	6/17/2003	S-157	S-157 near Roseland Rain
275317	803957	740124	SJRWMD	6/28/1990	7/9/2002	Willowbrook TP	Willowbrook near Vero Beach Rain
275323	803209	730122	SJRWMD	6/27/1990	7/10/2002	Barefoot Bay	Barefoot Bay near Vero Beach Rain
275647	803637	760128	SJRWMD	8/17/1990	5/19/2002	I-95 rest stop	I-95 rest stop near Palm Bay Rain
275751	803338	750126	SJRWMD	6/27/1990	8/14/2002	Valkaria Airport	Valkaria Airport near Valkaria Rain
275917	804334	840158	USGS/SJRWMD	8/1/1989	7/10/2002	Malabar Rptr	Malabar Repeater at Palm Bay Rain
280134	803551	1000410	SJRWMD	7/20/1993	4/2/2003	Palm Bay STP	Palm Bay STP near Palm Bay Rain
280257	803940	770130	USGS/SJRWMD	8/1/1989	7/9/2002	C-69 Canal	C-69 Canal at Eber Road at West Melbourne Rain
280438	803608	790135	USGS/SJRWMD	8/1/1989	5/21/2002	Crane Creek	Crane Creek at City Hall at West Melbourne Rain
280742	803832	900147	USGS/SJRWMD	1/20/1987	4/9/1997	Eau Gallie River	Eau Gallie River at Mosswood Dr. at Melbourne Rain
280831	804004	100109	SJRWMD	8/3/1990	6/12/2003	Melbourne FS	Melbourne Field Station at Melbourne Rain
282138	804035	1500682	SJRWMD	2/9/1996	6/12/2003	Kiwanis Park	Kiwanis Park at Merritt Island Rain
283159	804848	1470670	USGS/SJRWMD	8/1/1989	5/6/2002	Addison Creek	Addison Creek Grissom Pky near Port St John Rain
283514	805218	690313	SJRWMD	11/15/1990	10/31/2001	Fox Lake	Fox Lake near Titusville Rain
284520	805118	1390643	USGS/SJRWMD	8/1/1989	5/6/2002	Big Flounder	Big Flounder near Scottsmoor Rain
284639	805308	1480674	SJRWMD	2/9/1996	7/21/2003	Oak Hill	Oak Hill near Oak Hill Rain
285425	804915	1490678	SJRWMD	3/28/1996	7/21/2003	Playalinda	Playalinda near Turtle Mound Rain
280600	803900	5612	NOAA	1/1/1942	continues	NOAA Melbourne	Melbourne WFO
274100	802600	9219	NOAA	1/1/1942	continues	NOAA Vero 4W	Vero Beach 4 W
291058	810254	2158	NOAA	1/1/1942	continues	NOAA Daytona	Daytona Beach International Airport

[1]The west canal gage replaced the “radial gate 1” gage (ID 890185) on 10/3/1996. The two gages are used to represent one rainfall time-series.

Table 5. Discharge data collection locations within the Indian River Lagoon watershed

Lat	Long	Station	Owner	Begins	Status	Quality	Station Description
280735	803849	2249007	USGS	Jan-91	Active	Poor	Eau Gallie River at Heather Glen CR at Melbourne
280437	803609	2249518	USGS	Mar-87	Active	Poor	Crane Creek at U.S. 1 at Melbourne
280100	803546	2250030	USGS	Mar-81	Active	Fair	Turkey Creek at Palm Bay
275801	803357	2250500	USGS	May-89	Inactive*	Good	Goat Creek near Valkaria
275613	803207	2250700	USGS	May-89	Inactive*	Poor	Trout Creek at Grant
275121	803128	2251500	USGS	Feb-87	Active	Good	North Prong St. Sebastian Creek near Micco
274949	803204	2251767	USGS/ SJRWMD	Feb-55	Active	Fair	Fellsmere Canal near Micco
274948	803225	520210	SJRWMD	Jan-70	Active	Poor	S-157 structure in C-54 canal†
274610	803021	2251000	USGS	Oct-93	Active	Fair‡	South Prong St. Sebastian River near Sebastian
274132	802500	2252500	USGS	Dec-50	Active	Fair	North Canal near Vero Beach
273854	802410	2253000	USGS	Jan-48	Active	Good	Main Canal at Vero Beach
273611	802324	2253500	USGS	Oct-50	Active	Fair	South Canal near Vero Beach

*As of September 1996
†Discharge is computed from upstream stage and gate position
‡Except for discharge below 100 cfs, which is poor

Table 6. Water quality grab locations near the Indian River Lagoon tributaries

Lat	Long	Station ID	Begins	Status	Station Description
274950	803223	C54US	Jan-91	Inactive as of Oct-03	C-54 canal immediately upstream of SR 157
280439	803608	IRLCCU	Mar-90	Active	Crane Creek at U.S. 1
280725	803750	IRLEGU	Mar-90	Active	Eau Gallie River at U.S. 1
275122	803128	IRLSEBNP	Aug-95	Inactive as of Oct-96	North Prong of Sebastian River at Wilden Road
274610	803021	IRLSIR003	Jun-92	Inactive as of May-02	South Prong of Sebastian River at SR 512
284914	803141	IRLTBC	Jan-89	Active	Turnbull Creek at U.S. 1
280158	803448	IRLTUS	Jul-79	Active	Turkey Creek at U.S. 1
274946	803215	IRLUPSFW	Aug-95	Inactive as of Oct-96	Fellsmere Canal upstream of weir
273857	802408	IRLVMC	Feb-89	Active	Main Canal at U.S. 1
274134	802449	IRLVNC	Feb-89	Active	North Canal at U.S. 1
273617	802258	IRLVSC	Feb-89	Active	South Canal at U.S. 1

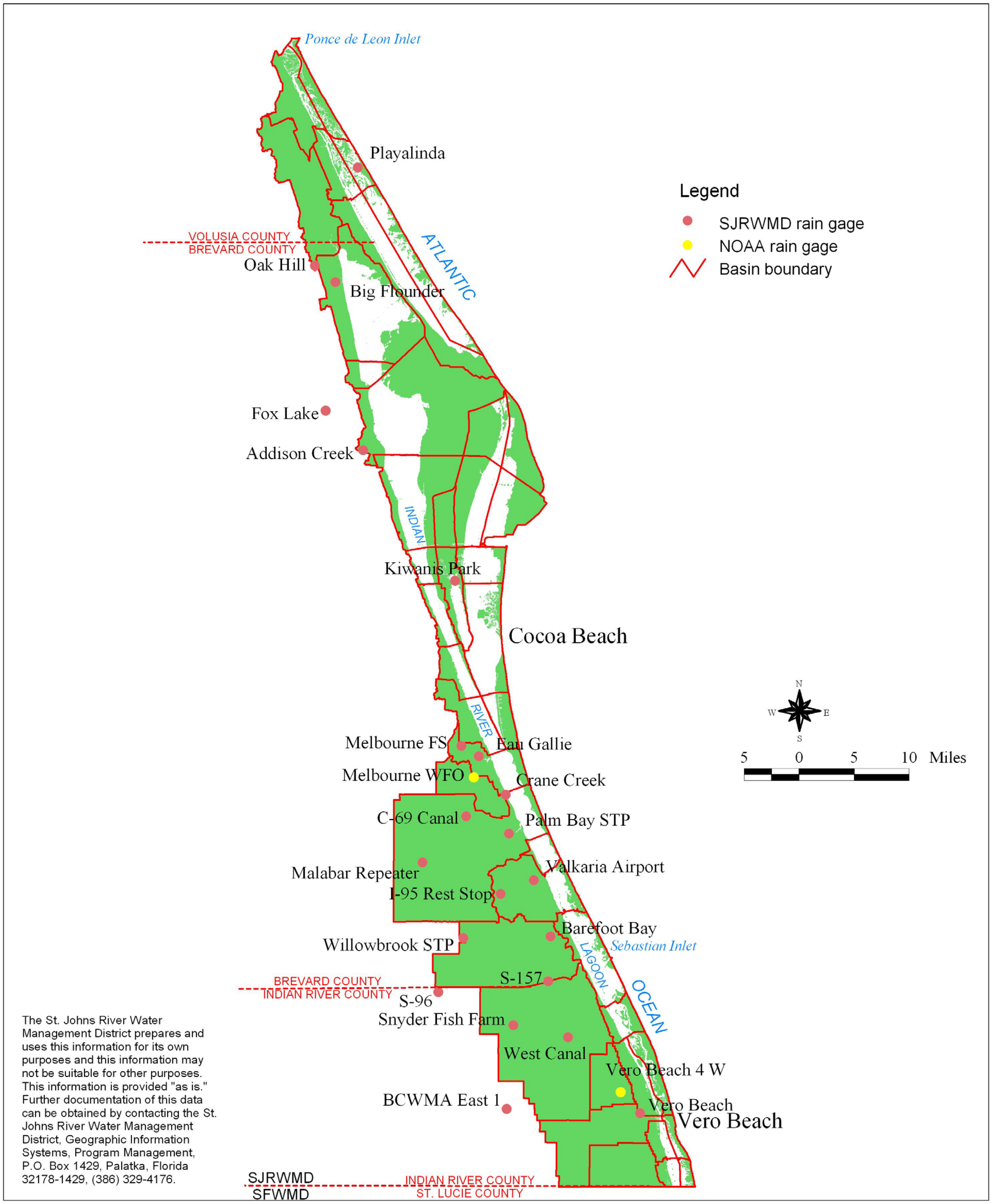

Figure 9. Rainfall collection stations in the Indian River Lagoon major basin

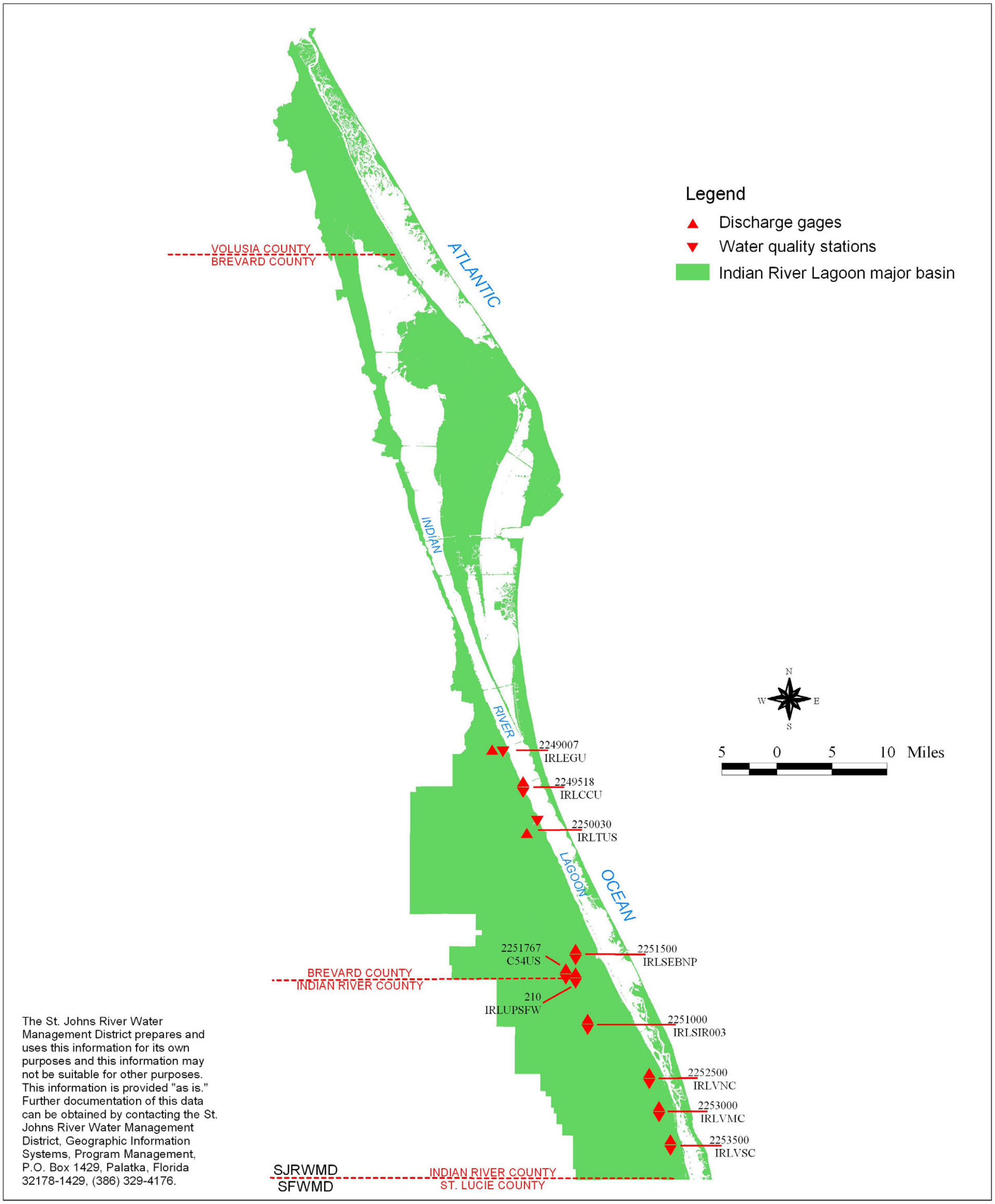

Figure 10. Discharge gaging and water quality monitoring stations in the Indian River Lagoon major basin

The concept that urban and agricultural areas have improved drainage and produce greater surface runoff than undeveloped areas, such as open land and forest, is used when assigning PERLND parameter values. As the model is calibrated, the relative value of the parameters between each land use is maintained.

IMPLND is used to represent impervious land segments directly connected to the drainage system. IMPLND is applied to represent areas such as parking lots and streets with curb and gutter drainage. The application of this model component is primarily for urban areas. More intensively developed urban land segments have larger IMPLND fractions. Table 7 shows the range of percent impervious applied to each land use group.

Table 7. Range of percent directly connected impervious

Land Use Group	**Minimum Percent Impervious**	**Maximum Percent Impervious**
High-density urban	65	95
Medium-density urban	25	40
Low-density urban	5	25
Agriculture	0	5
Open land	0	5
Forest	0	5
Wetland		0

RCHRES routes runoff from PERLND and IMPLND through the channel system; the runoff is routed using stage-storage-discharge relationships. The stage-storage-discharge relationships are developed by first estimating the stream channel geometry from channel surveys, topographic maps, and field inspections, then computing backwater profiles or computing normal depth and discharge along the various channel reaches.

Hydrologic Calibration

Hydrologic calibration consists of initializing model parameters, performing a simulation, comparing the simulated results to gaged discharges and, finally, adjusting the parameters. Simulation of hydrology, comparison of results, then adjustment of parameters is performed iteratively until a satisfactory match is achieved. Model parameters are adjusted for each land use to maintain the concept that developed areas produce more runoff than undeveloped areas. Criteria used to evaluate the match are outlined in Bergman (2003). The criteria are a comparison of simulated and observed annual volumes and volumes over the entire simulation period, a visual match of simulated and observed flows, and a comparison of discharge duration.

Nine discharge gaging stations are used to compare simulated to gaged discharge. The period of the calibration was from January 1, 1994, to December 31, 2000. This time period provides a variety of hydrological conditions for simulation. Hurricane Gordon passed over the Indian River Lagoon major basin in November 1994, and Hurricane Erin passed over the basin in August 1995. The 1997–98 winter was an El Nino winter, followed by a dry summer.

The Eau Gallie River (DA 4400) simulated discharge at Heather Glen is compared to gaged data (Figure 11). On average, the model underestimates the annual runoff 13%. The largest percent difference is 29% in 1997 and 1998. The smallest percent difference is zero in 1994. Comparison of the daily discharge shows that the general trend is matched. However, all peak discharge events are overestimated. Comparison of the discharge duration shows that the simulated curve lies below the gaged curve for discharges less than 50 cubic feet per second (cfs).

The Crane Creek (DA 4500) simulated discharge at U.S. 1 is compared to gaged data (Figure 12). On average, the model underestimates the annual runoff 17%. The largest percent difference is 26% in 1994. The smallest percent difference is 5% in 1996. Comparison of the daily discharge shows that the general trend of low flow with episodic extreme peaks is matched. The three largest peak discharges (all above 1,000 cfs) are underestimated. Comparison of the discharge duration shows that the simulated curve lies below the gaged curve in the range from 100 cfs to 10 cfs, but lies above the gaged curve for discharges less than 10 cfs.

The Turkey Creek (DA 4600) simulated discharge at Point Malabar Bridge is compared to gaged discharge (Figure 13). On average, the model underestimates annual runoff by 9%. The largest percent difference is 20% in 1994. The smallest percent differences are 1% and zero in 1999 and 2000. Comparison of the daily discharge shows the general trend is matched. The largest peak discharge (3,500 cfs gaged) is underestimated (2,500 cfs simulated), but the next largest peak discharge (2,900 cfs gaged) is closely matched (2,800 cfs simulated). Comparison of the discharge duration shows that the simulated curve closely matches the gaged curve for discharges greater than 20 cfs.

The Sebastian River North Prong (DA 6100) simulated discharge is compared to gaged data (Figure 14). On average, the model overestimates the annual runoff at 2%. The largest percent difference is 23% in 1997. The smallest percent difference is the 3% overestimation in 1998. Comparison of the daily discharge shows that the general trend is matched. There are three peak discharge events near 1,000 cfs or greater. The event in 1994 is underestimated. The event in 1997 is overestimated. The event in 1999 is closely matched. Comparison of the discharge duration shows that the simulated curve is close to the gaged duration curve.

The Fellsmere Farm (DA 6200) simulated discharge is compared to the gaged data (Figure 15). On average, the model underestimates the annual runoff by 3%. The largest percent difference is 18% in 1999. The smallest percent difference is 2% in 2000. Comparison of the daily discharge shows the hydrograph trend is matched. The three largest peak discharge events greater than 1,000 cfs are slightly underestimated. Comparison of the discharge duration shows that the simulated curve lies below the gaged discharge curve for discharge greater than 50 cfs, but lies above the gaged discharge curve for discharges less than 50 cfs.

The Sebastian River South Prong (DA 6300) simulated discharge at SR 512 is compared to gaged data (Figure 16). On average, the model underestimates the annual runoff by 4%. The largest percent difference is 21% in 2000. The smallest percent difference is 2% underestimation in 1996. Comparison of the daily discharge shows that the general trend is matched. However, the largest peak discharge is overestimated. Comparison of the discharge duration shows that the simulated curve is close to the gaged duration.

The Indian River Farms North Canal (DA 7100) model discharge is compared to the gaged data (Figure 17). Overall, the model underestimates the annual runoff volume by 10%. The largest percent difference is 29% in 2000. The smallest percent difference is 9% in 1994. Comparison of the daily discharge shows that the hydrograph trend is matched. The largest peak discharge event is significantly underestimated; the second largest peak discharge event is matched. Comparison of the discharge duration shows that the simulated curve lies close to the gaged duration curve above 20 cfs and then falls below the gaged duration curve for smaller discharges.

The Indian River Farms Main Canal (DA 7200) model discharge is compared to the gaged data (Figure 18). On average, the model matches the annual runoff volume. The largest percent difference is 12% in 1996. The smallest percent difference is 1% in 1997. Comparison of the daily discharge shows that the hydrograph trend is matched. The two peak discharge events, both greater than 1,000 cfs, are overestimated. Comparison of the discharge duration shows that the simulated curve lies close to the gaged duration curve for discharges above 20 cfs and then falls below the gaged duration curve for smaller discharges.

The Indian River Farms South Canal (DA 7300) model discharge is compared to the gaged data (Figure 19). On average, the model overestimates the annual runoff volume by 2%. The largest percent difference is 27% underestimated in 1996. The annual runoff is matched in 1997. Comparison of the daily discharge shows that the hydrograph trend is matched. Two of the three peak discharge events, both greater than 1,000 cfs, are matched. Comparison of the discharge duration shows that the simulated curve lies close to the gaged duration curve above 17 cfs, then falls below the gaged duration curve for smaller discharges.

Finally, evaluation of the calibration is performed by computation and examination of the Nash-Sutcliffe (NS) coefficient (Table 8). The NS coefficient measures the improved prediction of the discharge when a model is used (Bergman 2003). NS equal to zero can be interpreted that the model does not predict any better than the mean of the observed data. NS equal to one can be interpreted that the model exactly predicts the observed data. The highest NS is at the Sebastian River North Prong with a value of 0.82. The lowest NS values are from the Indian River Farms North and Main canals, with a value of 0.60. Overall, the models produce a good to very good representation of the discharge into the IRL when compared to gaged discharge.

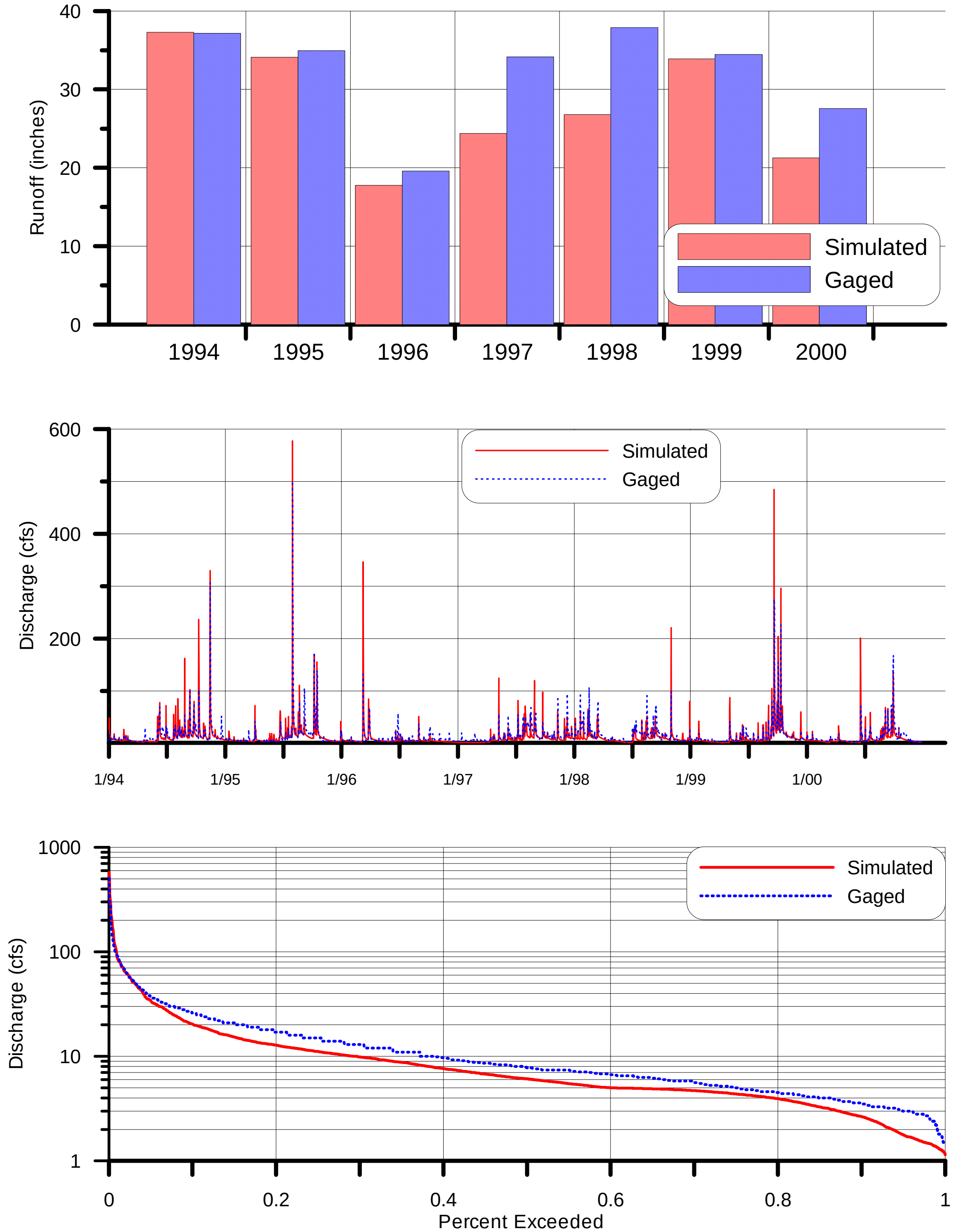

Figure 11. Comparison of simulated to gaged streamflow in the Eau Gallie River at USGS gage 2249007

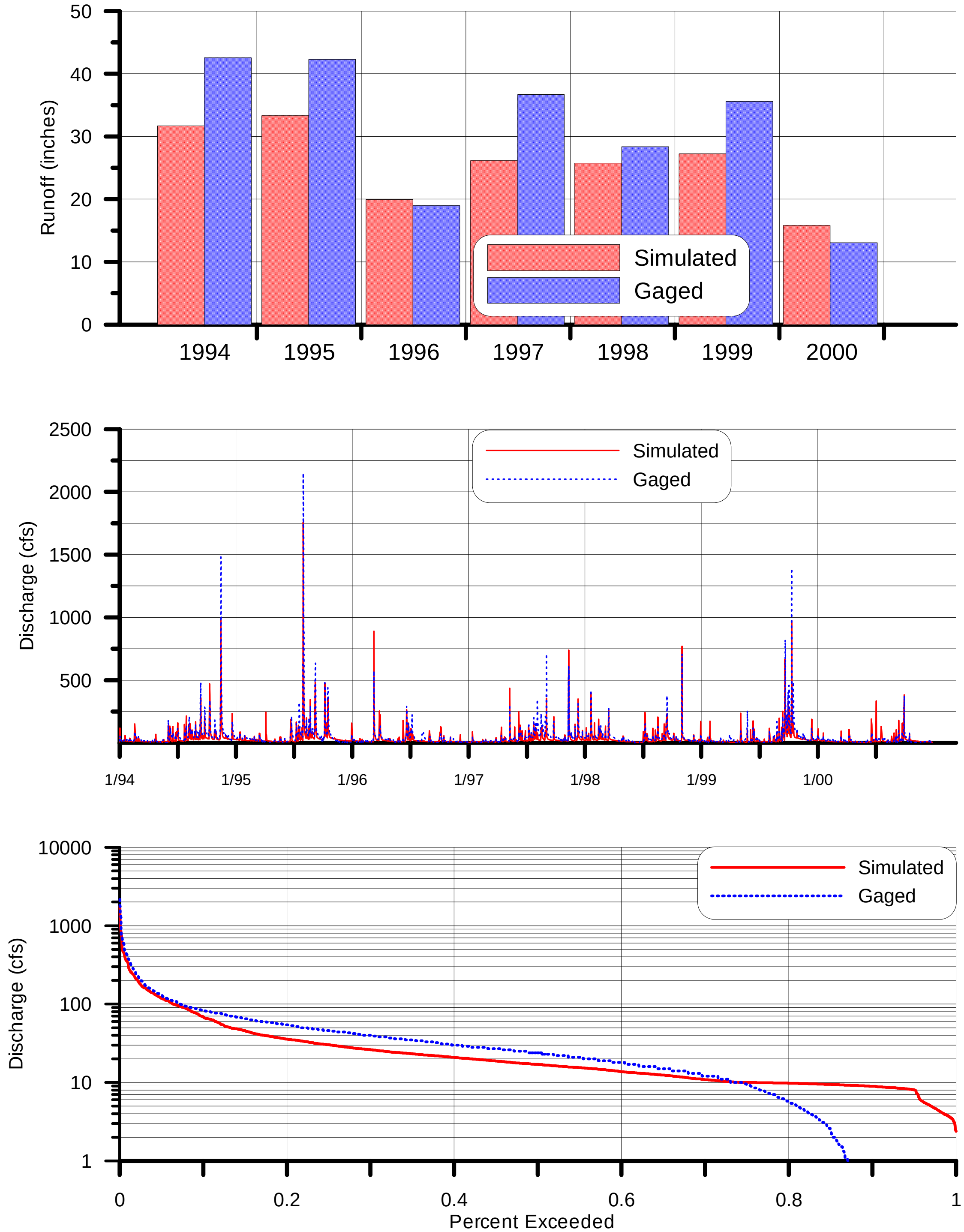

Figure 12. Comparison of simulated to gaged streamflow in Crane Creek at USGS gage 2249518

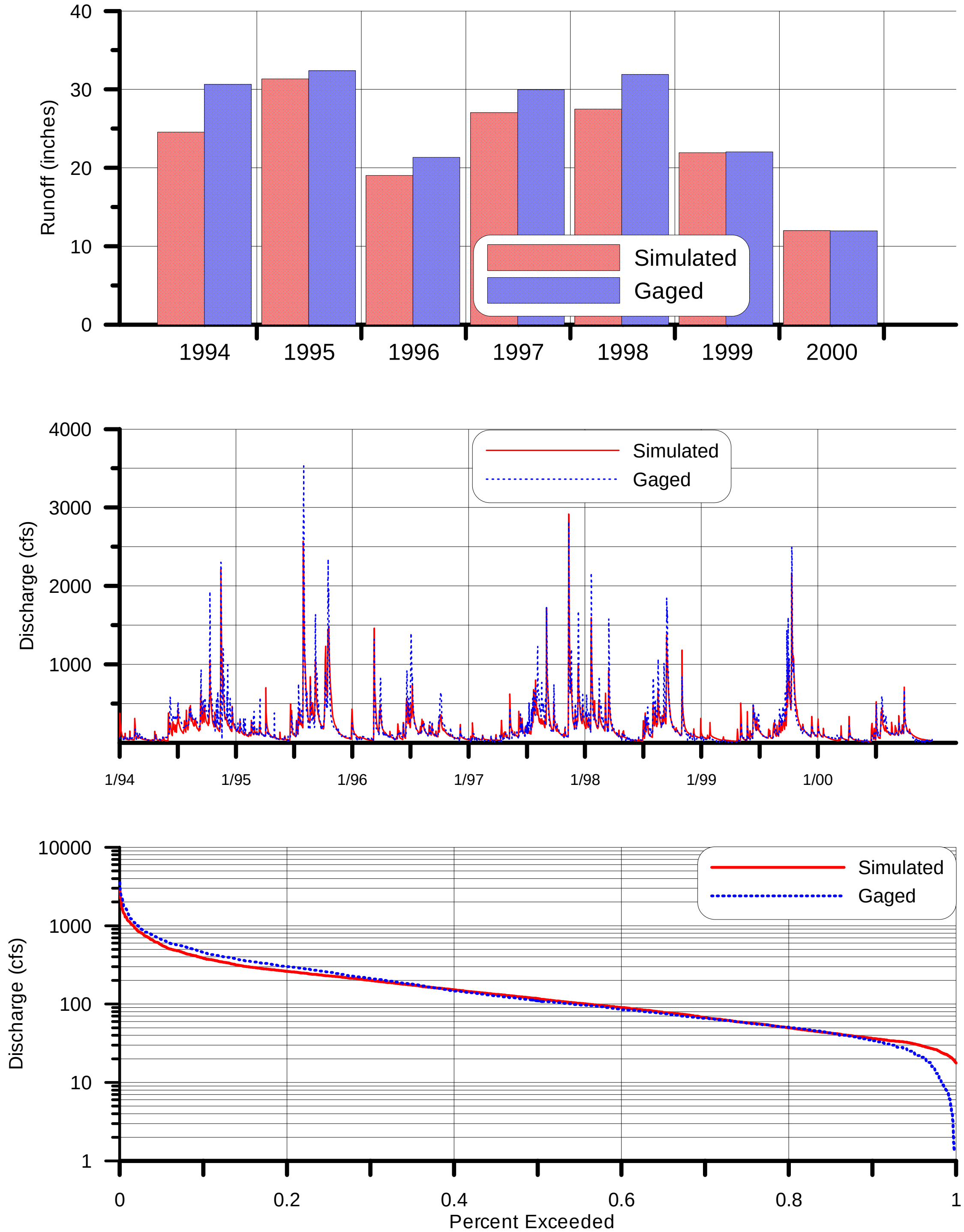

Figure 13. Comparison of simulated to gaged streamflow in Turkey Creek at USGS gage 2250030

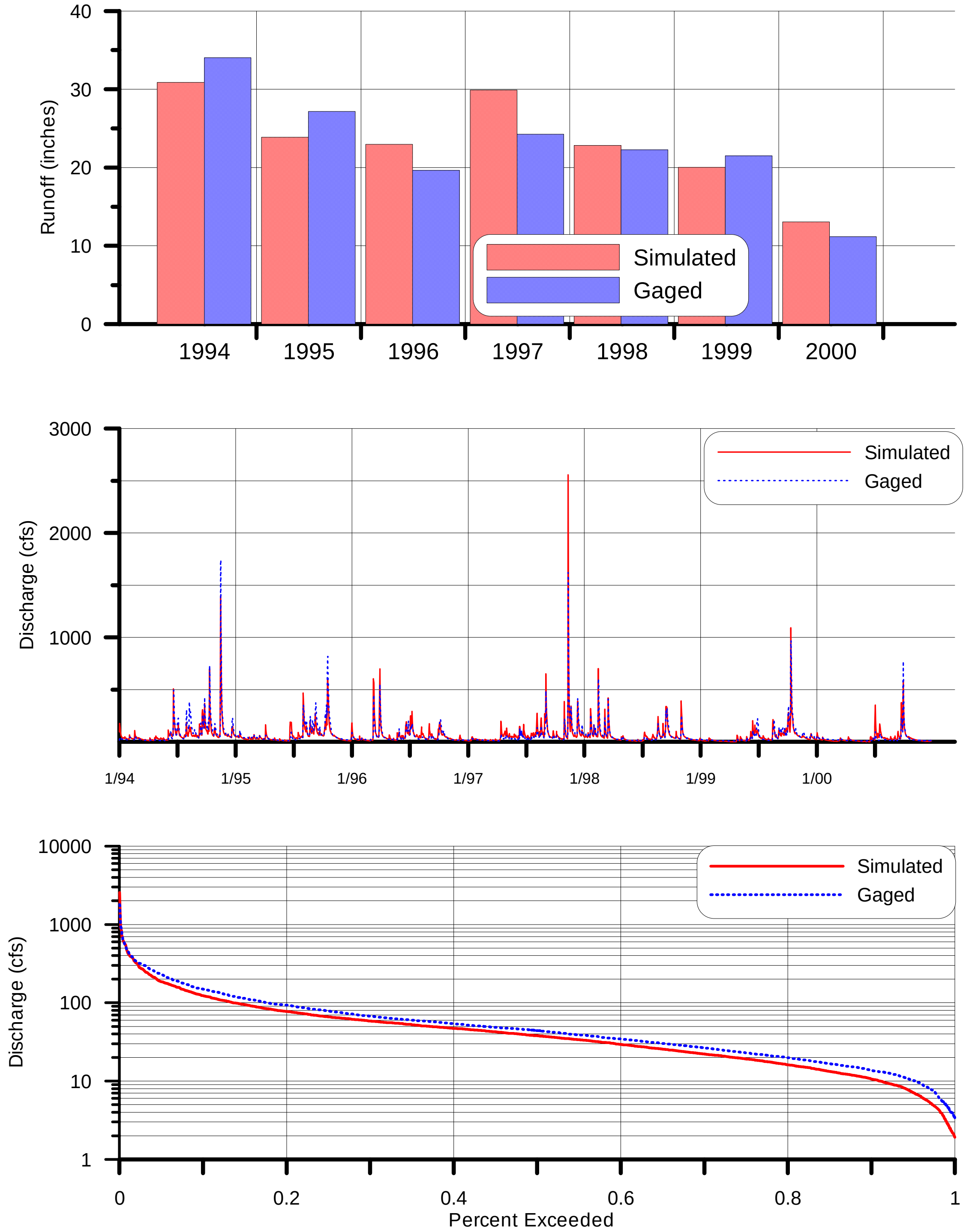

Figure 14. Comparison of simulated to gaged streamflow in the Sebastian River North Prong at USGS gage 2251500

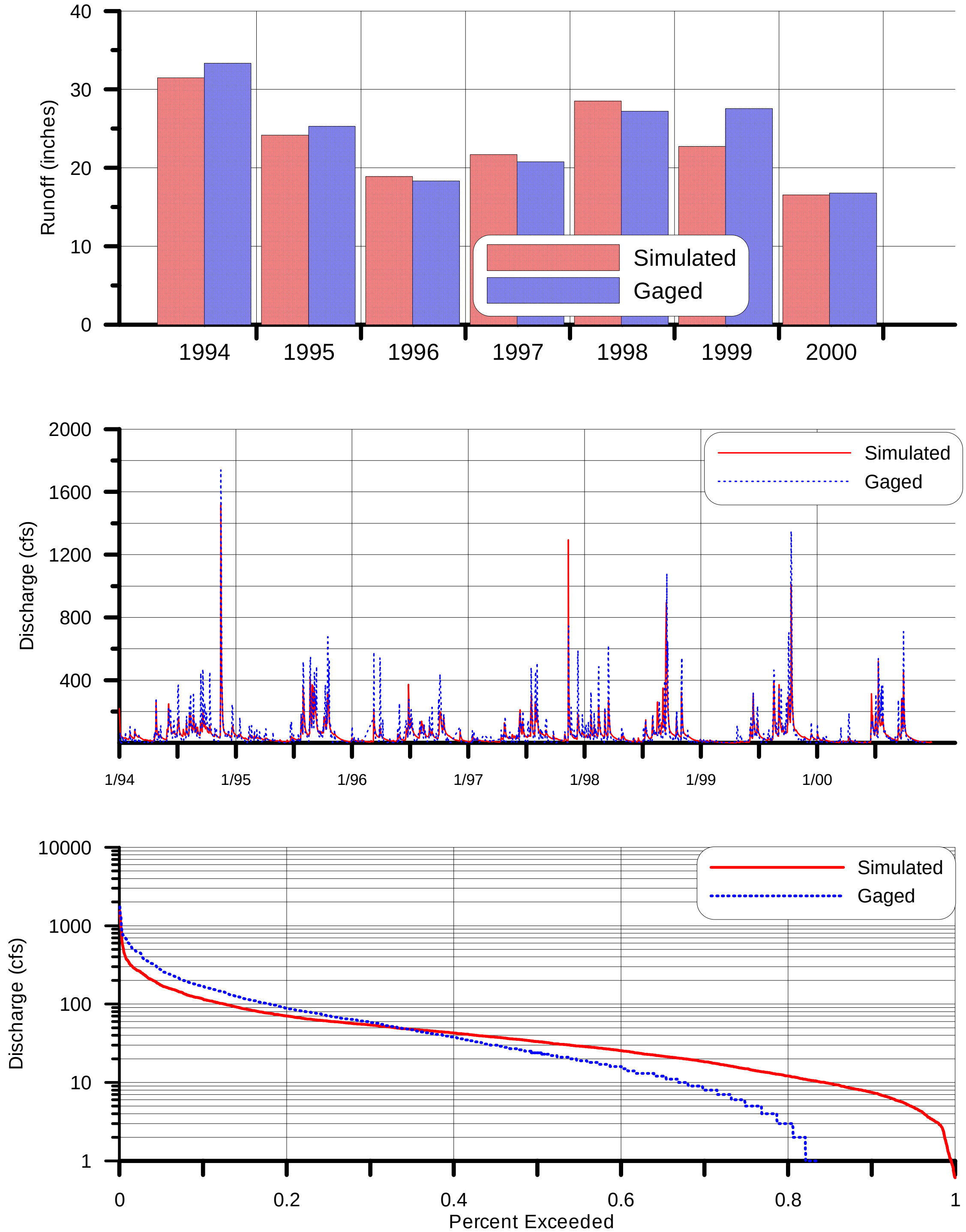

Figure 15. Comparison of simulated to gaged streamflow in Fellsmere Canal at USGS gage 2251767

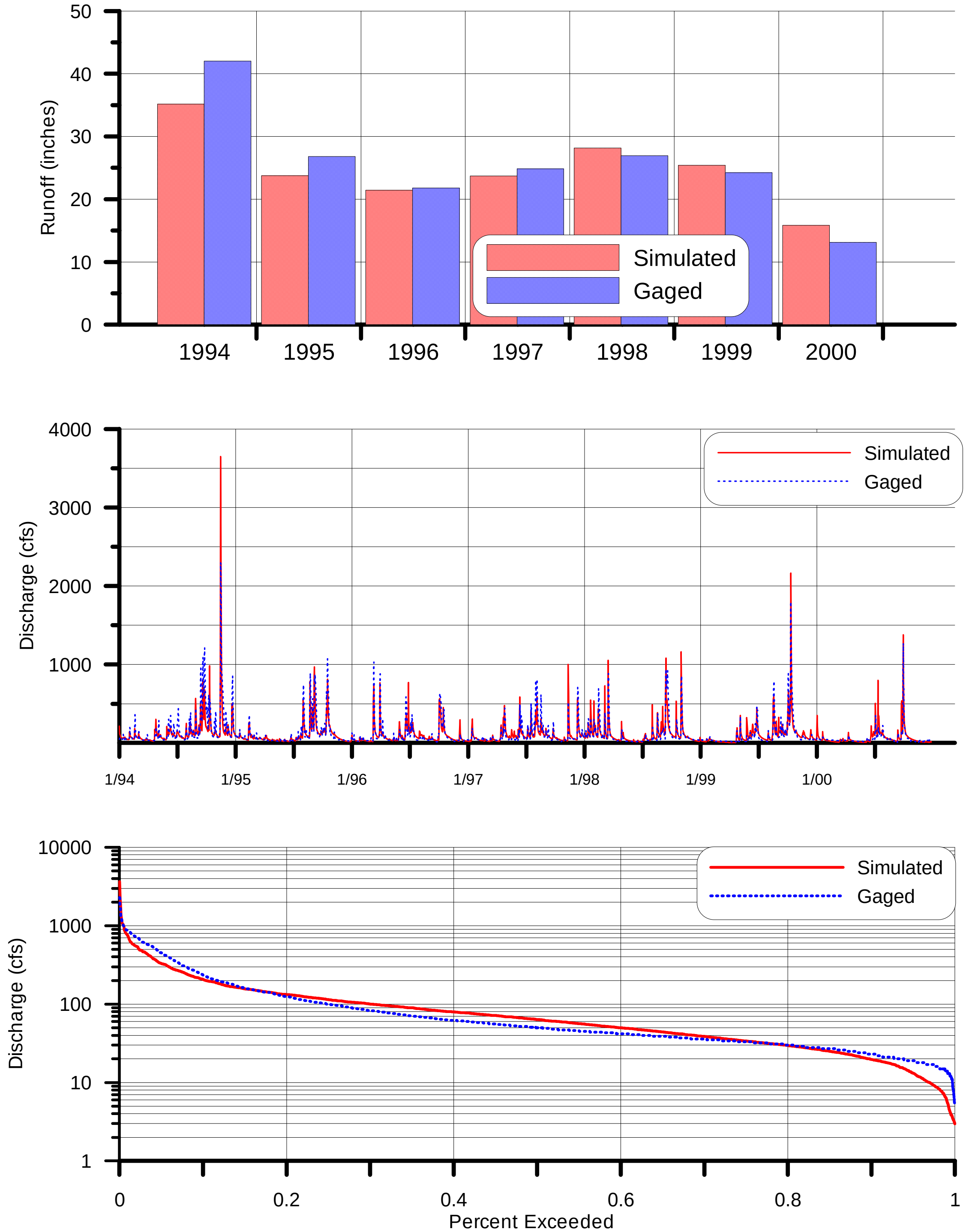

Figure 16. Comparison of simulated to gaged streamflow in the Sebastian River South Prong at USGS gage 2251000

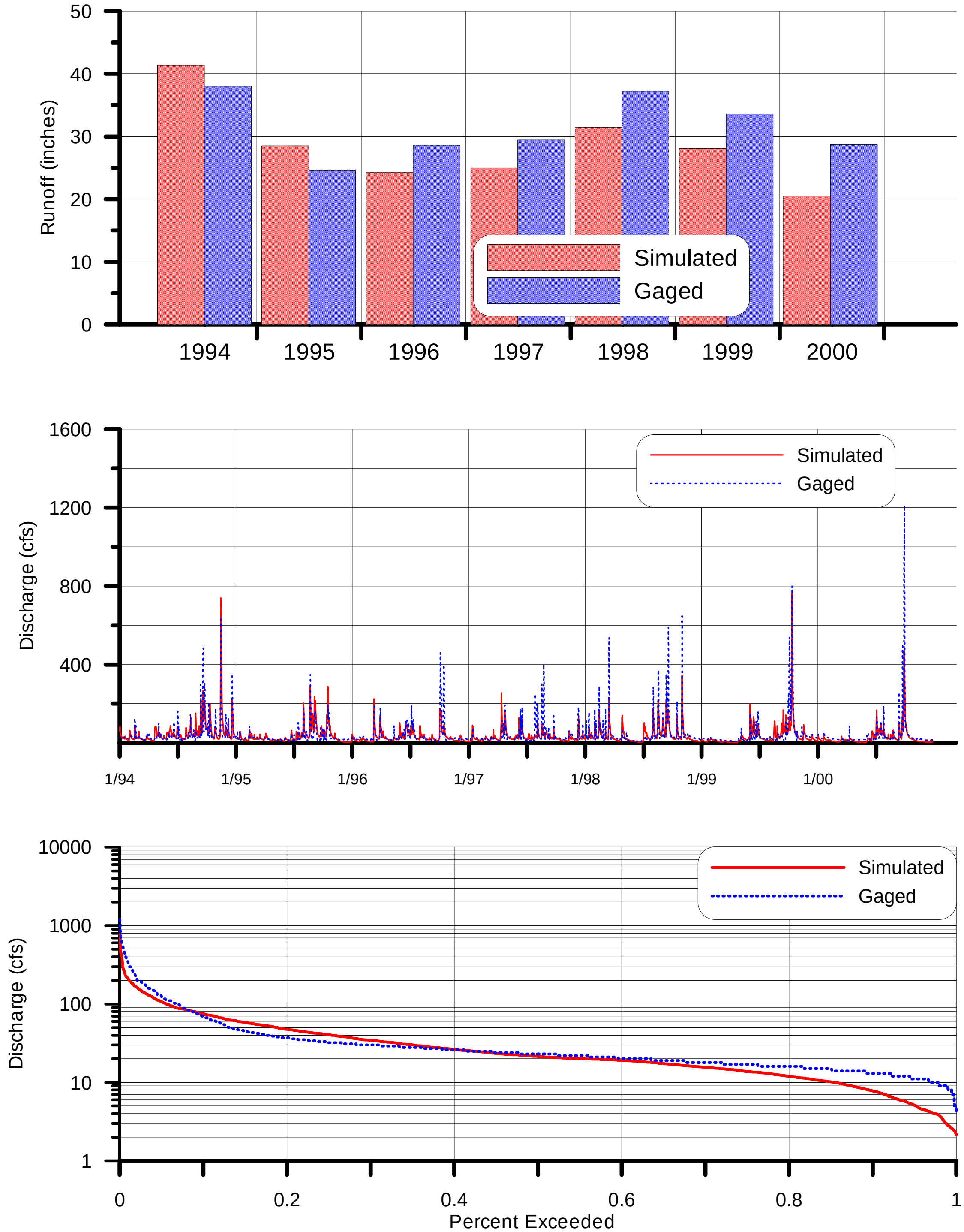

Figure 17. Comparison of simulated to gaged streamflow in Indian River Farms North Canal at USGS gage 2252500

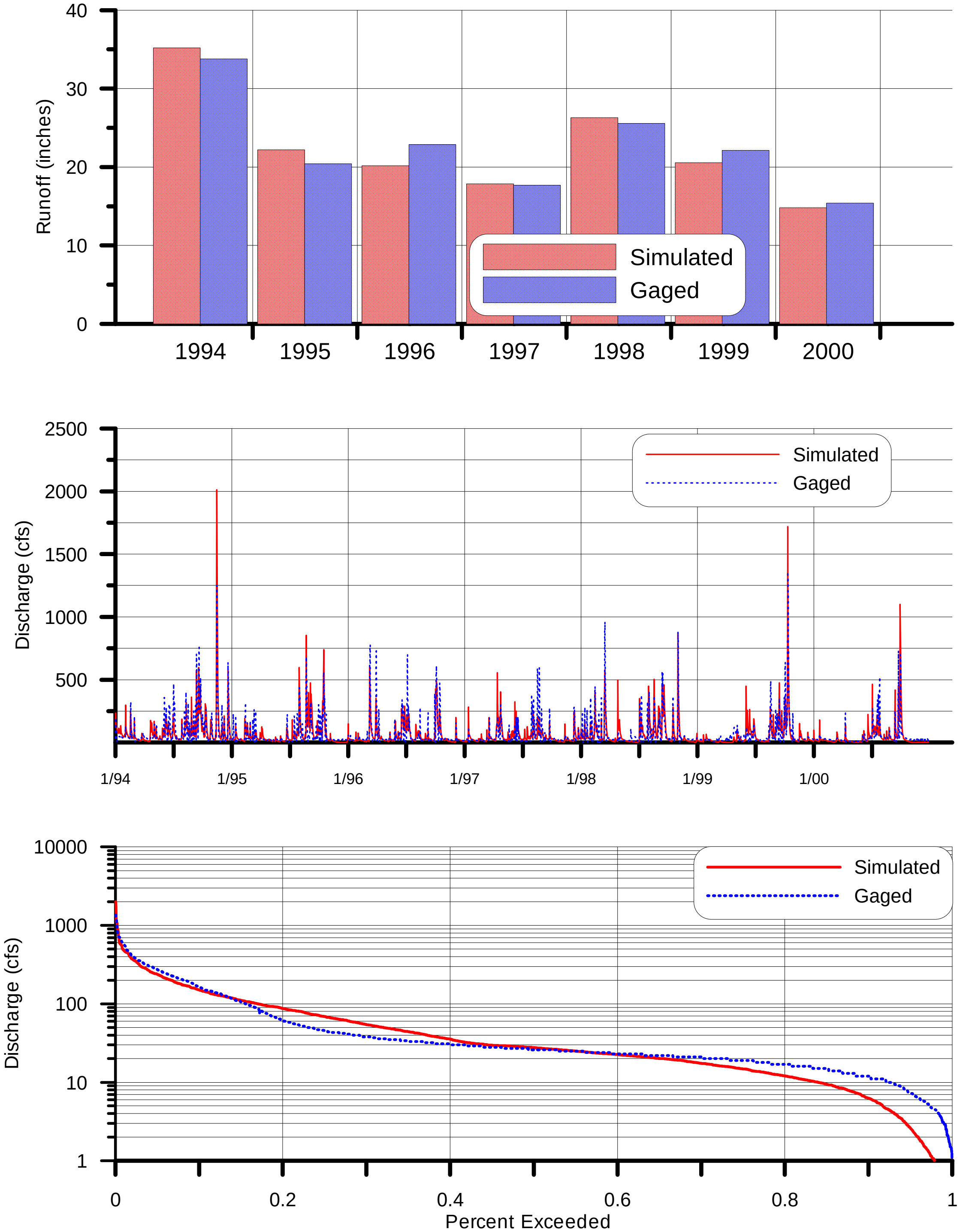

Figure 18. Comparison of simulated to gaged streamflow in Indian River Farms Main Canal at USGS gage 2253000

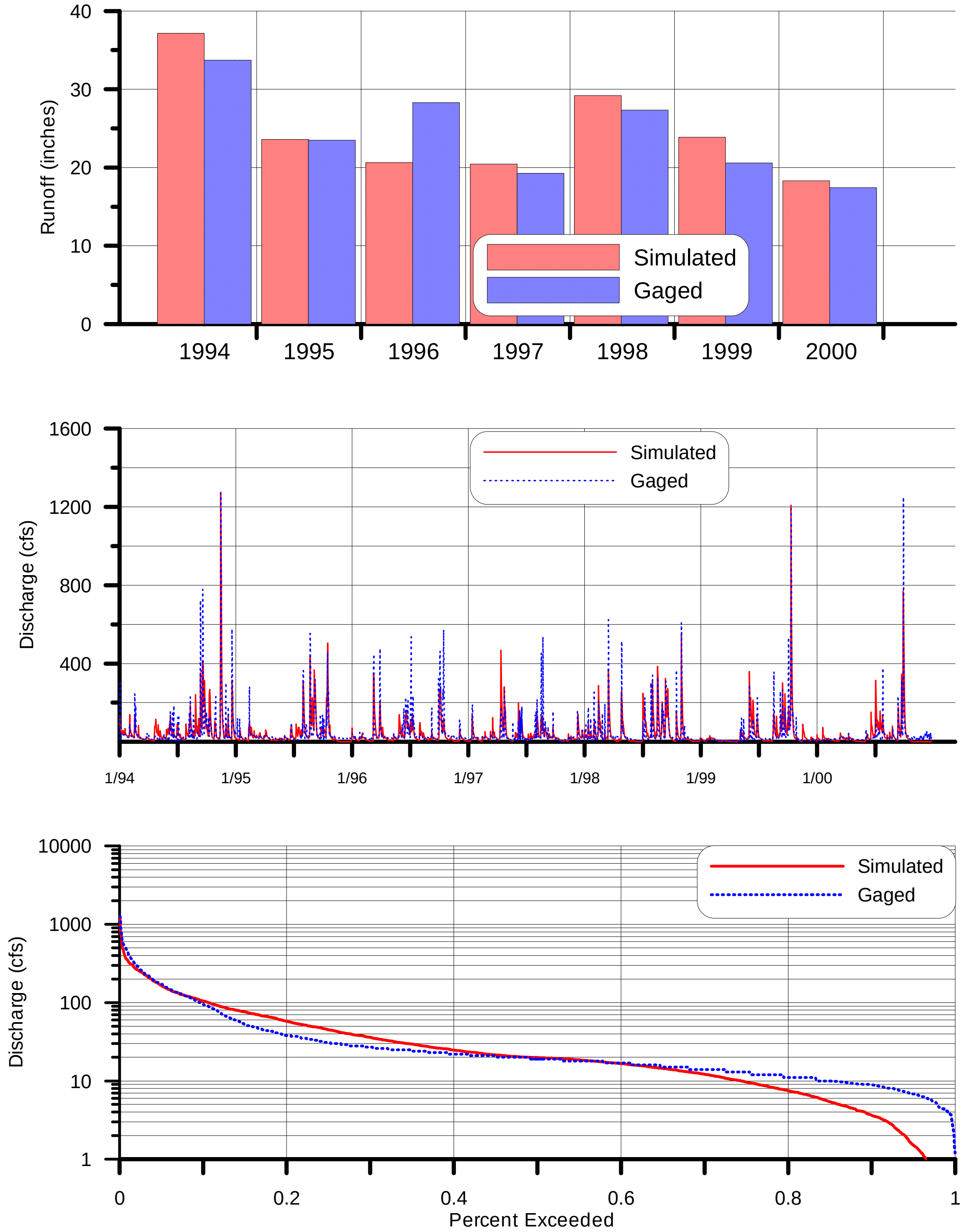

Figure 19. Comparison of simulated to gaged streamflow in Indian River Farms South Canal at USGS gage 2253500

Table 8. Nash-Sutcliffe (NS) statistical indication of goodness of match

Basin	Subbasin Name	DA ID	NS	General Evaluation
Central Indian River	Eau Gallie River	4400	0.62	Good
	Crane Creek	4500	0.78	Good
	Turkey Creek	4600	0.81	Very good
Sebastian River	Sebastian River North Prong	6100	0.82	Very good
	Fellsmere Farms	6200	0.72	Good
	Sebastian River South Prong	6300	0.73	Good
South Indian River	Indian River Farms North Canal	7100	0.60	Good
	Indian River Farms Main Canal	7200	0.60	Good
	Indian River Farms South Canal	7300	0.75	Good

Water Quality Model

The nonpoint source pollutants simulated for this project are total suspended solids (TSS), total phosphorus (TP), orthophosphorus (PO4), and total nitrogen (TN). Simulation of nonpoint source pollution includes the production of pollution from the land surface followed by the simulation of in-stream processes as the pollutant is transported through the stream system to the basin outlet. HSPF is equipped to handle both aspects. SEDMNT and SOLIDS handle simulation of sediment production for pervious and impervious land segments, respectively. Nutrients, TP, PO4, and TN are simulated by PQUAL and IQUAL for pervious and impervious land segments. Both SEDMNT and PQUAL are submodules of PERLND, and both SOLIDS and IQUAL are submodules of IMPLND. Transport of sediment is performed by SEDTRN, and transport of nutrients is performed by GQUAL, or CONS is used if conservative routing is selected for the constituent. SEDTRN, GQUAL, and CONS are all submodules of RCHRES.

SEDMNT simulates land surface erosion. Sediment is detached from the soil matrix and then carried into the streams with runoff in proportion to the sediment transport capacity of the overland flow. SOLIDS simulates the production of sediment with buildup and washoff routines.

PQUAL simulates the production of nonpoint source pollution loads by a combination of buildup and washoff routines, attachment to sediment washoff, interflow contributions, and base flow contributions. The buildup and washoff routines are simple routines that mimic accumulation of pollution on land during dry periods. Washoff of pollution occurs during periods of rain. Both buildup and washoff are handled by exponential functions with coefficients obtained through calibration. The portion that leaves the land by attachment to sediment particles removed by surface runoff is quantified by the potency factor, expressed in pounds of nutrient per ton of sediment. IQUAL simulates the production of nonpoint source pollution loads with only buildup and washoff routines.

SEDTRN simulates processes that address sediment transport, including scour and deposition within a RCHRES. GQUAL simulates processes of pollution transport, including transformation and first order decay in the water column. GQUAL also simulates mechanisms that describe equilibria between pollution adsorbed to bottom and suspended sediments and concentrations in the water column. For this study, in-stream processes are not simulated in such detail because of the extra data needed and complexities involved. Instead, pollution is routed as conservative constituents or with little deposition and scour, no transformation, and very little decay.

Few data useful for calibrating the simulation of nonpoint source pollution production and transportation have been collected in the Indian River. Storms and subsequent stormwater runoff force the movement of nonpoint source pollution to the receiving water body; however, the majority of water quality data from the Indian River are collected on a monthly interval without regard to rainstorm occurrence. As a result, the data are not particularly representative of nonpoint source pollution.

Pollution data were collected during and subsequent to storms for calibration of the Sebastian River South Prong model (Bergman et al. 2001). The South Prong model parameters resulting from this calibration were used as a guide for assigning initial parameters values to the other models. Also, during this project, pollution data were collected in Crane Creek during and subsequent to storms. Although the data collection was conducted too late to use in this report, the collected pollution concentrations were used to support the fact that the watershed models produced reasonable stormwater pollution concentrations.

The primary source for evaluating the model's water quality results and making subsequent adjustments to parameters was the annual loads reported in Harper (1994). Table 9 is a summary of the annual pollution loading rates presented in that report. Because the pollution loading rates were identified with various land uses, the reported data were useful for establishing the expected pollution load from each modeled land use. However, no annual pollution loading rate is reported for forest. Forest pollution loading rates were obtained from the IRL PLSM model (Green and Steward 2003), which obtained and adjusted values reported by Riekerk (1985).

The land use descriptions in Table 9 differ from the modeled land use descriptions. The differences were addressed by computing a weighted average of the literature values within the modeled land use. First, Harper's land use categories were assigned to the FLUCCS descriptions. Next, the area of each FLUCCS was multiplied by the assigned pollution loading rate and summed by the modeled land use. The sum for each group was then divided by the area of the modeled land use. Table 10 shows the annual pollution loading rates expected from each modeled land use.

Table A4 gives a closer look at the averaging process. Notice that the modeled high-intensity urban consists of 35% high-intensity commercial, 31% multi-family residential, and 15% low-intensity commercial. The modeled medium-intensity urban is 93% single-family residential. The modeled low-intensity urban is 90% low-density residential. Agriculture is 65% citrus and 26% pasture.

Wetlands were not considered to contribute pollution loading and were assigned no pollution loading rate. This differs from the results presented in Harper's report. The reason no loading rate is assigned to wetland is that the wetlands are viewed as receiving pollution from surrounding surface runoff (perhaps providing some treatment), then conveying the pollution downstream.

Table 9. Summary of central and south Florida stormwater loading rates (in pounds per acre-year)

	Loading Rate			
Land Use Category	**TSS**	**TP**	**PO4**	**TN**
Low-density residential	70.3	0.71	0.37	6.35
Single-family	123.7	1.31	0.74	10.32
Multi-family	564.5	3.79	2.04	18.76
Low-intensity commercial	756.3	1.43	0.35	11.42
High-intensity commercial	959.2	4.32	3.35	28.67
Industrial	844.5	2.73	1.14	16.10
Highway	401.3	2.91	0.80	14.75
Pasture	277.8	1.93	1.61	10.01
Citrus	48.3	0.43	0.27	6.42
Row crops	—	1.31	0.93	6.26
General agriculture	163.2	1.21	0.84	7.98
Recreational/open space	16.8	0.10	0.01	2.36
Mining	388.1	0.62	0.29	4.87
Wetland	24.7	0.49	0.45	3.99
Open water/lake	17.9	0.60	0.29	7.12

Source: Adapted from Harper 1994, Table 30

Table 10. Expected annual pollution loading rate (in pounds per acre-year) for each land use group

Land Use Group	**TSS**	**TP**	**PO4**	**TN**
Urban high-intensity	734.6	3.45	2.04	20.51
Urban med-intensity	115.7	1.22	0.68	9.73
Urban low-intensity	114.2	0.83	0.44	6.99
Agriculture	128.3	0.91	0.68	7.37
Forests	15.2	0.44	0.11	3.55
Open land	16.7	0.10	0.01	2.36
Wetland	—	—	—	—

One final issue: Harper broadly states that no treatment is included in the pollution loading rates presented in his report. His discussion of the specific study areas reveals that there is some treatment in the form of swales with single-family residential and low-density residential areas. Beginning in 1984, surface water management systems were required for new development. As a result, to the degree that treatment is not included to compute the annual pollution loading rates, the pollution load may be overestimated, particularly for high-intensity use urban areas in the future condition.

Water Quality "Calibration"

Adjustment of the water quality model results consisted of initializing water quality parameters, performing a simulation, computing the average annual pollution loading per acre over the period 1994 through 2000, comparing the average result to the expected annual pollution loading rates, then adjusting the water quality parameters. Simulation of the nonpoint source pollution, computation of the average annual pollution loading rate, comparison to expected values, and parameter adjustment are performed iteratively until a satisfactory match is achieved.

Table 11 shows the average annual pollution load per acre of each land use within the calibrated drainage areas compared to the expected annual pollution loading rate. The pollution loading from Indian River Farms North, Main, and South canals were lumped together for evaluation. The expected annual pollution loading rates are reasonably matched for each land use group.

Tables A5–A11 provide a more detailed examination of the pollution loading rate by presenting the pollution loading rate for each year and computing the percent difference between computed and expected results. The land use groups can be separated into developed and undeveloped subsets. High-intensity urban, medium-intensity urban, low-intensity urban, and agriculture are developed areas. The developed areas are associated with higher rates of loading. Open land, forest, and wetland are undeveloped areas and produce the lowest levels of pollution loading. Notice that the low-level pollution loading rates have greater percent differences than the mid- and high-level pollution loadings. When the expected loading rate is small, the difficulty of matching modeled and expected loading rates increases, and frequently produces a comparatively large error. The expected PO4 loading for open land of 0.001 lbs/acre/year is very low and is very hard to match. Even so, the pollution loading rates generated by undeveloped lands are small compared to the developed lands.

Wetland areas are considered to be water quality sinks rather than pollution producers. However, due to groundwater pollution concentrations (a regional phenomenon) included in the model simulation of wetland land use, it may not be possible to obtain zero pollution loading for wetlands. However, the wetland pollution loading rates are the lowest of all land uses.

Figures A1–A9 show the daily concentrations of the four constituents and the monthly grab samples. The grab samples result from scheduled data collection field trips, which are planned without regard to storm conditions (unless it is to avoid hazardous weather). For this reason, the grab samples are not representative of stormwater pollution concentrations, but may be considered more representative of the lower range of pollution concentrations. Evaluation of the simulated pollution concentrations is a qualitative exercise to ensure that the concentrations do not exceed the expected ranges. The expected range for TSS storm event concentrations is hundreds of milligrams per liter. The expected range for TN storm event concentrations is tens of milligrams per liter. The expected range for TP and PO4 storm event concentrations is in the single digits.

Finally, the model results were compared to the original input to the IRL PLR model. Data collected from January to December 1998 were originally used for this input (Sheng et al. 2002), and it is not clear how the input data are estimated. However, one criticism of the input was that in IRL segments where little or no discharge data existed, there was little input into the model. This is particularly true for the Mosquito Lagoon, North IRL, and Banana River.

A comparison to previously estimated pollution loadings is shown in Table 12. The segments in the table are reaches of the IRL used by Sheng. The simulated TSS loads for three segments with little data collection, such as the Mosquito Lagoon (1), segment 2 (the north part of the North IRL), and the Banana River (3) are as much as 405 times the original IRL PLR model input. In contrast, the simulated TSS loads for segments with data collection, such as segment 5 (part of the Central IRL), the Sebastian River, and Indian River Farms, are five times and less than the previously estimated load.

A similar comparison can be made for TP and TN. In segments with little gaged discharge, the simulated TP and TN are as much as 39 and 22 times the original IRL PLR model input; in contrast with segments with increased data collection, the simulated TP and TN are two and one times the previously estimated load.

Another perspective is gained in comparing the percent of total load with the percent of runoff area. Two convenient areas to compare are the Mosquito Lagoon and the Banana River. Their respective areas are 8% and 10% of the entire IRL watershed (Table 1). If the land use over the entire IRL watershed was homogenous, pollution contributions from the comparison areas would be 8% and 10%. The Mosquito Lagoon is less developed than the IRL watershed as a whole (Table 3). The Banana River has significantly greater high-intensity use urban, but less of other types of developed land use than is found in the IRL watershed as a whole. The watershed model produces pollution loads for the Mosquito Lagoon that are less than 8% and produces pollution loads for the Banana River that are near 10%. In contrast, the original pollution load input into the Mosquito Lagoon is 3% and less. The original pollution load input into the Banana River is zero, 9%, and 4% of the IRL total input of TSS, TP, and TN, respectively.

Table 11. Average annual pollution loading results from calibrated drainage basins

Indian River		Average Annual Pollution Loading Rate (pounds/acre)							
Land Use	Pollutant	EG	CC	TC	NP	FF	SP	IRF	Avg Goal
High-intensity urban	TSS	786.3	714.8	721.6	733.0	733.0	743.7	715.8	734.0
	TP	3.58	3.41	3.47	3.60	3.60	2.65	3.29	3.45
	PO4	2.17	2.01	2.00	1.96	1.96	1.71	1.93	2.04
	TN	20.02	19.86	19.87	20.19	20.19	18.35	19.95	20.51
Medium-intensity urban	TSS	147.6	120.6	125.4	116.4	116.4	121.1	118.1	116.0
	TP	1.20	1.15	1.18	1.22	1.22	1.25	1.30	1.22
	PO4	0.73	0.66	0.71	0.65	0.65	0.71	0.72	0.68
	TN	11.20	9.73	10.28	9.79	9.79	7.56	9.45	9.73
Low-intensity urban	TSS	126.7	121.7	125.7	108.5	108.5	97.5	102.9	114.0
	TP	0.86	0.87	0.82	0.99	0.99	1.01	1.04	0.83
	PO4	0.46	0.47	0.45	0.46	0.46	0.66	0.47	0.44
	TN	8.49	7.24	7.74	6.88	6.88	6.41	7.34	6.99
Agriculture	TSS	177.7	130.9	125.2	122.2	122.2	128.3	125.5	128.0
	TP	0.96	0.92	0.91	0.92	0.92	1.06	1.13	0.91
	PO4	0.73	0.64	0.68	0.35	0.35	0.45	0.73	0.68
	TN	8.59	7.64	8.34	5.28	5.28	5.37	8.47	7.37
Open land	TSS	22.2	17.5	16.1	17.3	17.3	20.6	16.4	17.0
	TP	0.39	0.58	0.30	0.24	0.24	0.58	0.33	0.10
	PO4	0.11	0.21	0.09	0.09	0.09	0.36	0.03	0.001
	TN	5.41	4.68	4.89	1.39	1.39	6.00	3.40	2.36
Forest	TSS	15.8	12.6	11.2	16.9	16.9	14.1	14.3	15.0
	TP	0.37	0.55	0.27	0.22	0.22	0.45	0.59	0.44
	PO4	0.12	0.21	0.09	0.07	0.07	0.25	0.12	0.11
	TN	4.98	4.52	4.69	3.01	3.01	4.28	4.53	3.55
Wetland	TSS	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0
	TP	0.12	0.25	0.13	0.03	0.03	0.29	0.02	0
	PO4	0.02	0.10	0.04	0.00	0.00	0.15	0.00	0
	TN	2.11	2.12	2.32	0.03	0.03	2.37	0.21	0

Note: EG = Eau Gallie River
CC = Crane Creek
TC = Turkey Creek
NP = North Prong Sebastian River
FF = Fellesmere Farms canal
SP = South Prong Sebastian River
IRF = Indian River Farms North, Main, and South canals

PO4 = orthophosphorus
TN = total nitrogen
TP = total phosphorus
TSS = total suspended solids

Table 12. Comparison of 1998 Indian River Lagoon watershed model development (IRLWMD) results to IRL pollution load reduction (PLR) model reported 1998 input

IRLWMD results

Segment	Annual Load (pounds/year) TSS	TP	TN
Mosquito Lagoon	3,430,000	22,400	171,000
Segment 2	3,890,000	35,300	356,000
Segment 4	7,060,000	44,900	361,000
Banana River	7,710,000	41,900	276,000
Segment 5	14,800,000	103,000	819,000
Sebastian River	10,200,000	87,600	524,000
Indian River Farms	10,200,000	82,000	577,000
Total	54,800,000	405,100	3,037,000
	Percent of Total		
Mosquito Lagoon	6	6	6
Segment 2	7	9	12
Segment 4	13	11	12
Banana River	10	7	8
Segment 5	27	25	27
Sebastian River	19	22	17
Indian River Farms	19	20	19

Input to IRL PLR used by UF*

Segment	Annual Load (pounds/year) TSS	TP	TN
Mosquito Lagoon (1)	16,449	7,283	64,276
Segment 2	39,172	902	15,953
Segment 4	370,429	4,489	46,843
Banana River (3)	12,901	22,151	76,994
Segment 5	5,132,958	53,555	688,306
Sebastian River (6)	6,785,054	73,325	644,008
Indian River Farms (7)	2,068,718	73,279	459,315
Total	14,425,681	234,985	1,995,695
	Percent of Total		
Mosquito Lagoon	0	3	3
Segment 2	0	0	1
Segment 4	3	2	2
Banana River	0	9	4
Segment 5	36	23	34
Sebastian River	47	31	32
Indian River Farms	14	31	23

Ratio of IRLWMD:UF

Segment	TSS	TP	TN
Mosquito Lagoon	209	3	3
Segment 2	99	39	22
Segment 4	19	10	8
Banana River	405	1	3
Segment 5	3	2	1
Sebastian River	2	1	1
Indian River Farms	5	1	1
Total	**4**	**2**	**2**

**IRLPLR Model Development Project Final Report Vol. 3, Table 2.7*

Numbers in parentheses identify IRLPLR segments

Segment 2 is the upper part of the north IRL, DA 2120-2400

Segment 4 is the lower part of the north IRL and the upper Central IRL, DA 2600-4200

Segment 5 is the remainder of the central IRL, DA 4400-5400

Note: TN = total nitrogen
TP = total phosphorus
TSS = total suspended solids

RESULTS AND CONCLUSIONS

Four sets of results have been given to the hydrodynamic modelers to input into the IRL PLR model. The results consist of daily time-series of discharge and pollution load for each drainage area (as identified in Table 1 and Figures 3 and 4) representing the past, current, and future conditions. Three sets use rainfall input from January 1994 to December 2000, the calibration period. The fourth set represents the past condition and uses rainfall collected from January 1942 to December 1948 at the three NOAA gages.

The average annual volume and pollution load results are compared between past, current, and future conditions. Table 13 shows that the pollution load increases as the watershed becomes more developed. The greatest percent change between current and past conditions occurs in Banana River. The greatest percent change between current and future conditions occurs in the Mosquito Lagoon. The runoff volume reduction in the central Indian River of 21% is due to implementation of the C-1 Rediversion Plan, which rediverts approximately 50% of the runoff from the Melbourne-Tillman Water Control District back to the upper St. Johns River to the west.

Future work will use the IRL watershed models to evaluate the potential runoff and pollution reductions that may be achieved with the construction and operation of various regional stormwater treatment areas around the Sebastian River.

Additional work may be considered to represent local stormwater treatment facilities that accompany development occurring after 1984. Also, work may be considered to take account of the drainage detail in the nearshore areas, the barrier islands, and the Merritt Island area. Finally, work may be considered to take into account the many mosquito impoundments, primarily in the Mosquito Lagoon, North Indian River, and Banana River areas. Consideration of possible watershed model improvements should be made after the IRL PLR model has been run and evaluation of the results indicate the need to revise runoff and pollution loads from the surrounding watershed.

Table 13. Comparison of results between past, current, and future conditions

Past condition results
(average annual results using 1994–2000 rainfall data)

Region	Volume (ac-ft)	TSS (lbs)	TP (lbs)	TN (lbs)
Mosquito Lagoon	66,400	1,718,571	16,101	139,414
North Indian River	159,143	3,902,857	38,214	446,857
Banana River	92,329	2,021,857	15,749	91,314
Central Indian River	221,714	5,591,429	48,971	577,429
Sebastian River	279,571	5,542,857	63,314	384,714
Indian River Farms	115,171	3,644,286	43,814	316,286
Total	934,329	22,421,857	226,164	1,956,014

Percent change
from current to past condition

Region	Vol	TSS	TP	TN
Mosquito Lagoon	-9	-49	-33	-26
North Indian River	-8	-59	-41	-23
Banana River	-22	-78	-65	-69
Central Indian River	-14	-68	-60	-41
Sebastian River	14	-40	-30	-35
Indian River Farms	-20	-65	-46	-44
Total	-7	-62	-47	-39

Current condition results
(average annual results, 1994–2000 rainfall data)

Region	Volume (ac-ft)	TSS (lbs)	TP (lbs)	TN (lbs)
Mosquito Lagoon	73,200	3,381,429	23,971	188,286
North Indian River	172,114	9,465,714	64,743	577,429
Banana River	117,886	9,234,286	44,686	293,571
Central Indian River	258,143	17,420,000	121,629	985,000
Sebastian River	244,429	9,187,143	90,871	588,143
Indian River Farms	143,429	10,358,571	81,571	569,714
Total	1,009,200	59,047,143	427,471	3,202,143

Future condition results
(average annual results 1994–2000 rainfall data)

Region	Volume (ac-ft)	TSS (lbs)	TP (lbs)	TN (lbs)
Mosquito Lagoon	76,814	6,844,286	39,029	266,429
North Indian River	179,643	14,342,857	88,129	686,429
Banana River	124,971	15,024,286	67,657	407,429
Central Indian River	204,286	22,000,000	146,714	1,000,286
Sebastian River	257,429	14,825,714	122,371	754,429
Indian River Farms	157,857	17,171,429	112,800	752,429
Total	1,001,000	90,208,571	576,700	3,867,429

Percent change
from current to future condition

Region	Vol	TSS	TP	TN
Mosquito Lagoon	5	102	63	42
North Indian River	4	52	36	19
Banana River	6	63	51	39
Central Indian River	-21	26	21	2
Sebastian River	5	61	35	28
Indian River Farms	10	66	38	32
Total	-1	53	35	21

Percent change from past to future condition

Region	Volume	TSS	TP	TN
Mosquito Lagoon	15	120	83	63
North Indian River	12	114	79	42
Banana River	30	153	124	127
Central Indian River	-8	119	100	54
Sebastian River	-8	91	64	65
Indian River Farms	31	130	88	82
Total	7	120	87	66

REFERENCES

Adamus, C., D. Clapp, S. Brown. 1997. *Surface water drainage basin boundaries: St. Johns River Water Management District: A reference guide.* Technical Publication SJ97-1. Palatka, Fla.: St. Johns River Water Management District.

Bergman, M. 2003. Guidelines for evaluation of the calibration of watershed models. Technical Memorandum 47, St. Johns River Water Management District, Palatka, Fla.

Bergman, M., and L. Donnangelo. 1995. Development of HSPF hydrologic simulation models for the Fellsmere Water Control District-East. Technical Memorandum 10, St. Johns River Water Management District, Palatka, Fla.

———. 1996a. Development of HSPF hydrologic simulation models for the South Prong drainage basin of the Sebastian River. Technical Memorandum 15, St. Johns River Water Management District, Palatka, Fla.

———. 1996b. Development of HSPF hydrologic simulation models for the North Prong drainage basin of the Sebastian River. Technical Memorandum 18, St. Johns River Water Management District, Palatka, Fla.

———. 1998. Simulation of freshwater discharges to the Sebastian River using regional parameters. Technical Memorandum 25, St. Johns River Water Management District, Palatka, Fla.

Bergman, M., L. Donnangelo, and W. Green. 2001. Simulation of sediment, phosphorus, and nitrogen storm loads in the South Prong watershed of the Sebastian River, Florida, using HSPF/BASINS. Technical Memorandum 43, St. Johns River Water Management District, Palatka, Fla.

Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr., T.H. Jobes, and A.S. Donigian Jr. 2001. *Hydrological simulation program—FORTRAN, HSPF, Version 12, user's manual*. Athens, Ga.: U.S. Environmental Protection Agency.

Carter, E., D.S. Rajasekhar, and R.W. Virnstein. 2001. Indian River Lagoon Restoration Program. Page 43 in *ESRI map book, Vol. 16, Geography—Creating Communities*. Redlands, Calif.: ESRI Press.

Clapp, D.A., and H.A. Wilkening III. 1984. *Interbasin diversion in the Upper St. Johns River Basin.* Technical Publication SJ 84-18. Palatka, Fla.: St. Johns River Water Management District.

Crawford, N.H., and R.K. Linsley. 1966. *Digital simulation in hydrology: Stanford watershed model IV*. Technical Report 39. Department of Civil Engineering. Stanford, Calif.: Stanford University.

Florida Department of Transportation. 1999. *Florida land use, cover and forms classification system.* Tallahassee.

Green, W.C., and J.S. Steward. 2003. The utility of a pollutant load screening model in determining provisional pollutant load reduction goals. Conference Proceedings of Emerging Technologies, Tools, and Techniques to Manage our Coasts in the 21st Century. U.S. Environmental Protection Agency. Cocoa Beach, Fla.

Harper, H. 1994. Stormwater loading rate parameters for central and south Florida. Environmental Research & Design, Inc., Orlando, Fla.

Mundy, C., and M. Bergman. 1998. The pollution load screening model: A tool for the 1995 District Water Management Plan and the 1996 Local Government Water Resource Atlases. Technical Memorandum 29, St. Johns River Water Management District, Palatka, Fla.

Riekerk, H. 1985. Water quality effects of pine flatwoods silviculture. *Journal of Soil and Water Conservation* 40(3):306–309.

Sheng, Y.P., C.Qiu, K. Park, and T. Kim. 2002. *Indian River Lagoon pollutant load reduction (IRLPLR) model development project, final report.* Vol. III. Gainesville: University of Florida.

APPENDIX

Table A1. Current land use, grouped into seven categories

Land Use Group	FLUCCS Code	FLUCCS Description
Urban, high-intensity use	1300	High Density Residential
Urban, high-intensity use	1400	Commercial and Services
Urban, high-intensity use	1420	Wholesale Sales and Services
Urban, high-intensity use	1430	Professional Services
Urban, high-intensity use	1460	Oil and Gas Storage – not associated with industry or manufacturing
Urban, high-intensity use	1470	Mixed Commercial and Services
Urban, high-intensity use	1490	Commercial and Services under Construction, as per Zoning
Urban, high-intensity use	1500	Industrial
Urban, high-intensity use	1510	Food Processing
Urban, high-intensity use	1520	Timber Processing
Urban, high-intensity use	1530	Mineral Processing
Urban, high-intensity use	1540	Oil and Gas Processing
Urban, high-intensity use	1550	Other Light Industry
Urban, high-intensity use	1560	Other Heavy Industrial
Urban, high-intensity use	1562	Prestressed Concrete Plants
Urban, high-intensity use	1700	Institutional
Urban, high-intensity use	1730	Military
Urban, high-intensity use	1750	Governmental
Urban, high-intensity use	1830	Race Tracks
Urban, high-intensity use	1840	Marinas and Fish Camps
Urban, high-intensity use	1870	Stadiums Not Associated with High Schools, Colleges, or Universities
Urban, high-intensity use	8110	Airports
Urban, high-intensity use	8130	Bus and Truck Terminals
Urban, high-intensity use	8140	Roads and Highways
Urban, high-intensity use	8150	Port Facilities
Urban, high-intensity use	8180	Auto Parking Facilities – Not Related to Other Land Use
Urban, high-intensity use	8191	Highways
Urban, high-intensity use	8310	Electrical Power Facilities
Urban, high-intensity use	8330	Water Supply Plants
Urban, high-intensity use	8340	Sewage Treatment Plants
Urban, high-intensity use	8350	Solid Waste Disposal
Urban, medium-intensity use	1200	Medium Density Residential
Urban, medium-intensity use	1820	Golf Courses
Urban, low-intensity use	1100	Low Density Residential
Urban, low-intensity use	1480	Cemeteries
Urban, low-intensity use	1600	Extractive
Urban, low-intensity use	1620	Sand and Gravel Pits
Urban, low-intensity use	1650	Abandoned Land
Urban, low-intensity use	1800	Recreational
Urban, low-intensity use	1850	Parks and Zoos
Urban, low-intensity use	1920	Inactive Land with Streets But Not Structures
Urban, low-intensity use	7400	Disturbed Land

Table A1—*continued*

Land Use Group	FLUCCS Code	FLUCCS Description
Urban, low-intensity use	7410	Rural Land in Transition, Future Use Unknown
Urban, low-intensity use	7420	Borrow Areas
Urban, low-intensity use	8120	Railroads
Urban, low-intensity use	8200	Communications
Agriculture	2110	Improved Pastures
Agriculture	2140	Row Crops
Agriculture	2150	Field Crops
Agriculture	2160	Mixed Crops
Agriculture	2200	Tree Crops
Agriculture	2210	Citrus Groves
Agriculture	2310	Cattle Feeding Operations
Agriculture	2320	Poultry Feeding Operations
Agriculture	2410	Tree Nurseries
Agriculture	2430	Ornamentals (under 2400, Nurseries and Vineyards)
Agriculture	2500	Specialty Farms
Agriculture	2510	Horse Farms
Agriculture	2520	Dairies
Agriculture	2540	Aquaculture
Open Land	1900	Open Land
Open Land	2120	Unimproved Pastures
Open Land	2130	Woodland Pastures
Open Land	2610	Fallow Cropland
Open Land	3100	Herbaceous
Open Land	3200	Shrub and brush land
Open Land	3300	Mixed Rangeland
Open Land	7430	Spoil Areas
Open Land	8320	Electrical Power Transmission Lines
Forest	2240	Abandoned Tree Crops
Forest	4100	Upland Coniferous Forest
Forest	4110	Pine Flatwoods
Forest	4120	Longleaf Pine - Xeric Oak
Forest	4130	Sand Pine
Forest	4200	Upland Hardwood Forest
Forest	4210	Xeric Oak
Forest	4300	Upland Mixed Forest
Forest	4340	Upland Mixed Coniferous/Hardwood
Forest	4370	Australian Pine
Forest	4410	Coniferous Pine
Forest	4430	Forest Regeneration

Table A1—*continued*

Land Use Group	FLUCCS Code	FLUCCS Description
Wetland/Water	1670	Holding Ponds
Wetland/Water	5200	Lakes
Wetland/Water	5300	Reservoirs
Wetland/Water	5340	Reservoirs Less Than 10 Acres (Dominant Feature)
Wetland/Water	6110	Bay Swamps
Wetland/Water	6120	Mangrove Swamp
Wetland/Water	6150	River/Lake Swamp (Bottomland)
Wetland/Water	6170	Mixed Wetland Hardwoods
Wetland/Water	6200	Wetland Coniferous Forest
Wetland/Water	6300	Wetland Forested Mixed
Wetland/Water	6410	Freshwater Marshes
Wetland/Water	6420	Saltwater Marshes
Wetland/Water	6430	Wet Prairies
Wetland/Water	6440	Emergent Aquatic Vegetation
Wetland/Water	6460	Mixed Scrub-Shrub Wetland
Wetland/Water	6500	Non-Vegetated Wetland
Wetland/Water	6180	Cabbage Palm Savanna
Wetland/Water	6210	Cypress
Wetland/Water	6220	Forested Depressional Pine

Table A2. Past land use, grouped into seven categories

Land Use Group	FLUCCS Code	Past Land Use Description
Urban, high-intensity use	1401	High Density Urban
Urban, high-intensity use	1800	High Density Urban
Urban, high-intensity use	1410	High Density Urban
Urban, medium-intensity use	1120	Medium Density Residential
Urban, low-intensity use	1110	Low Density Residential
Urban, low-intensity use	7410	Rural Land in Transition, Future Use Unknown
Agriculture	2210	Citrus Groves
Agriculture	2110	Improved Pasture
Agriculture	2140	Row Crops
Agriculture	2150	Field Crops
Agriculture	2300	Feeding Operations
Agriculture	2500	Specialty Farms
Open Land	3200	Shrub and Brush land
Open Land	3100	Herbaceous Rangeland
Open Land	2120	Unimproved Pastures
Open Land	3300	Mixed Rangeland
Open Land	7440	Disturbed Land
Open Land	7420	Borrow Areas
Open Land	7430	Spoil Areas
Forest	4110	Pine Flatwoods
Forest	4210	Xeric Oak
Forest	4214	Xeric Oak
Forest	4200	Upland Hardwood Forest
Forest	4120	Longleaf Pine - Xeric Oak
Forest	6210	Cypress
Forest	6180	Cabbage Palm Savanna
Forest	4340	Upland Mixed Coniferous/Hardwood
Forest	4130	Sand Pine
Forest	2240	Abandoned Tree Crops
Forest	4300	Upland Mixed Forest
Forest	4370	Australian Pine
Wetland/Water	6430	Wet Prairies
Wetland/Water	6410	Freshwater Marshes
Wetland/Water	6150	River/Lake Swamp (Bottomland)
Wetland/Water	6120	Mangrove Swamp
Wetland/Water	6460	Mixed Shrub-Shrub Wetland
Wetland/Water	6470	Vegetated Non-Forested Wetlands
Wetland/Water	6300	Wetland Forested Mixed
Wetland/Water	6431	Wet Prairies
Wetland/Water	6510	Non-Vegetated Wetland
Wetland/Water	6200	Wetland Coniferous Forest
Wetland/Water	5200	Lakes

Table A2—*continued*

Land Use Group	FLUCCS Code	Past Land Use Description
Wetland/Water	5340	Reservoirs Less Than 10 Acres (Dominant Feature)
Wetland/Water	6300	Wetland Forested Mixed
Wetland/Water	6170	Mixed Wetland Hardwoods
Wetland/Water	64500	Mixed Wetland Hardwoods

Table A3. Future land use, grouped into seven categories

Land Use Group	LU Code	Future Land Use Description
Urban, high-intensity use	1	High Density Residential (>5 DU/acre)
Urban, high-intensity use	4	High Density Commercial
Urban, high-intensity use	6	Public Facilities/Institutional
Urban, high-intensity use	7	Industrial
Urban Medium WQ Impact	2	Medium Residential (>2 DU/acre and <=5 DU/acre)
Urban, low-intensity use	3	Low Residential (>=1 DU/10acres and <2 DU/acre)
Urban, low-intensity use	5	Low Density Commercial
Agriculture	8	General Agriculture
Undeveloped	10	Recreation/Open Space
Undeveloped	11	Conservation/Public Lands
Undeveloped	13	Rural Residential (<1 DU/10acres)
Undeveloped	14	Silviculture/Timber Production
Undeveloped	15	Water
Space Center	17	Space Center

Table A4. Determination of HSPF land use group annual pollution rate

HSPF LU	FLUCCS	Acres	Land Use Description	Harpers LU	Harpers area	% area	TSS (LBS/YR)	TP (LBS/YR)	PO4 (LBS/YR)	TN (LBS/YR)
Urban, high	1400	9,628	Commercial and Services	High-Intensity Commercial	16,721	35%	9,234,807	41,610	32,269	275,983
Urban, high	1460	13	Oil and Gas Storage - Not Assoc. with Industry or Manufacture	High-Intensity Commercial			12,724	57	44	380
Urban, high	1830	43	Race Tracks	High-Intensity Commercial			40,871	184	143	1,221
Urban, high	1840	286	Marinas and Fish Camps	High-Intensity Commercial			274,037	1,235	958	8,190
Urban, high	1870	11	Stadiums Not Assoc. with High Schools or Colleges	High-Intensity Commercial			10,594	48	37	317
Urban, high	8110	5,292	Airports	High-Intensity Commercial			5,075,873	22,871	17,736	151,693
Urban, high	8130	13	Bus and Truck Terminals	High-Intensity Commercial			12,741	57	45	381
Urban, high	8150	98	Port Facilities	High-Intensity Commercial			94,013	424	329	2,810
Urban, high	8180	30	Auto Parking Facilities - Not Related to Other Land Use	High-Intensity Commercial			28,321	128	99	846
Urban, high	8310	279	Electrical Power Facilities	High-Intensity Commercial			267,844	1,207	936	8,005
Urban, high	8330	91	Water Supply Plants	High-Intensity Commercial			86,821	391	303	2,595
Urban, high	8340	434	Sewage Treatment Plants	High-Intensity Commercial			415,804	1,874	1,453	12,426
Urban, high	8350	505	Solid Waste Disposal	High-Intensity Commercial			483,988	2,181	1,691	14,464
Urban, high	8140	5,228	Roads and Highways	Highway/Transportation	5,337	11%	2,097,885	15,215	4,161	77,115
Urban, high	8191	109	Highways	Highway/Transportation			43,797	318	87	1,610
Urban, high	1500	17	Industrial	Industrial	3,189	7%	14,206	46	19	271
Urban, high	1510	271	Food Processing	Industrial			228,877	741	310	4,362
Urban, high	1520	28	Timber Processing	Industrial			23,700	77	32	452
Urban, high	1530	5	Mineral Processing	Industrial			4,440	14	6	85
Urban, high	1540	3	Oil and Gas Processing	Industrial			2,911	9	4	55
Urban, high	1550	2,766	Other Light Industry	Industrial			2,335,921	7,563	3,165	44,523
Urban, high	1560	90	Other Heavy Industrial	Industrial			75,859	246	103	1,446
Urban, high	1562	9	Prestressed Concrete Plants	Industrial			7,281	24	10	139
Urban, high	1700	4,159	Institutional	Low-Intensity Commercial	7,259	15%	3,145,575	5,961	1,440	47,505
Urban, high	1730	1,747	Military	Low-Intensity Commercial			1,321,148	2,504	605	19,952
Urban, high	1750	1,353	Governmental	Low-Intensity Commercial			1,023,231	1,939	468	15,453
Urban, high	1300	14,598	High Density Residential	Multi-Family Residential	14,598	31%	8,240,309	55,365	29,742	273,926
Total		47,104	9%	(lbs/ac/yr)			734.63	3.45	2.04	20.51
Urban, medium	1820	4,523	Golf Courses	Recreation/Open Space	4,523	7%	75,804	459	30	10,672
Urban, medium	1200	56,488	Medium Density Residential	Single-Family Residential	56,488	93%	6,987,598	73,986	41,726	582,923
Total		61,012	12%	(lbs/ac/yr)			115.77	1.22	0.68	9.73

Table A4—*continued*

HSPF LU	FLUCCS	Acres	Land Use Description	Harpers LU	Harpers area	% area	TSS (LBS/YR)	TP (LBS/YR)	PO4 (LBS/YR)	TN (LBS/YR)
Urban, low	1810	119	Swimming Beach	High-Intensity Commercial	863	2%	114,533	516	400	3,423
Urban, low	1850	744	Parks and Zoos	High-Intensity Commercial			713,370	3,214	2,493	21,319
Urban, low	8120	390	Railroads	Highway/Transportation	390	1%	156,377	1,134	310	5,748
Urban, low	1600	803	Extractive	Industrial	997	2%	678,093	2,195	919	12,924
Urban, low	1620	193	Sand and Gravel Pits	Industrial			163,185	528	221	3,110
Urban, low	1670	1	Abandoned Land	Industrial			747	2	1	14
Urban, low	1100	23,033	Low Density Residential	Low-Density Residential	37,762	90%	1,620,135	16,252	8,583	146,269
Urban, low	1920	13,426	Inactive Land with Streets But Not Structures	Low-Density Residential			944,378	9,473	5,003	85,260
Urban, low	7410	1,302	Rural Land in Transition, Future Use Unknown	Low-Density Residential			91,616	919	485	8,271
Urban, low	8200	114	Communications	Low-Intensity Commercial	114	0%	85,919	163	39	1,298
Urban, low	7400	476	Disturbed Land	Mining/Extractive	531	1%	184,607	295	137	2,318
Urban, low	7420	56	Borrow Areas	Mining/Extractive			21,568	34	16	271
Urban, low	1480	240	Cemeteries	Recreation/Open Space	1,332	3%	4,014	24	2	565
Urban, low	1800	1,092	Recreational	Recreation/Open Space			18,306	111	7	2,577
Total		41,988	8%	(lbs/ac/yr)			114.24	0.83	0.44	6.99
Agriculture	2200	51	Tree Crops	Citrus	53,343	65%	2,472	22	14	329
Agriculture	2210	53,292	Citrus Groves	Citrus			2,573,444	23,149	14,454	341,951
Agriculture	2310	40	Cattle Feeding Operations	General Agriculture	774	1%	6,498	48	33	318
Agriculture	2320	16	Poultry Feeding Operations	General Agriculture			2,570	19	13	126
Agriculture	2410	42	Tree Nurseries	General Agriculture			6,824	51	35	334
Agriculture	2430	285	Ornamentals (under 2400, Nurseries and Vineyards)	General Agriculture			46,497	346	239	2,275
Agriculture	2500	67	Specialty Farms	General Agriculture			10,938	81	56	535
Agriculture	2510	179	Horse Farms	General Agriculture			29,267	218	150	1,432
Agriculture	2520	6	Dairies	General Agriculture			982	7	5	48
Agriculture	2540	139	Aquaculture	General Agriculture			22,650	169	116	1,108
Agriculture	2110	21,832	Improved Pastures	Pasture	21,832	26%	6,065,458	42,169	35,237	218,549
Agriculture	2140	463	Row Crops	Row Crops	6,528	8%	128,663	608	430	2,900
Agriculture	2150	5,164	Field Crops	Row Crops			1,434,643	6,775	4,794	32,336
Agriculture	2160	901	Mixed Crops	Row Crops			250,421	1,183	837	5,644
Total		82,477	16%	(lbs/ac/yr)			128.30	0.91	0.68	7.37

Table A4—*continued*

HSPF LU	FLUCCS	Acres	Land Use Description	Harpers LU	Harpers area	% area	TSS (LBS/YR)	TP (LBS/YR)	PO4 (LBS/YR)	TN (LBS/YR)
Forest	2240	3,786	Abandoned Tree Crops	Forest	91,258	100%	57,683	1,670	417	13,440
Forest	4100	8	Upland Coniferous Forest	Forest			119	3	1	28
Forest	4110	44,863	Pine Flatwoods	Forest			683,557	19,785	4,946	159,266
Forest	4120	317	Longleaf Pine - Xeric Oak	Forest			4,831	140	35	1,126
Forest	4130	2,095	Sand Pine	Forest			31,928	924	231	7,439
Forest	4200	4,145	Upland Hardwood Forest	Forest			63,162	1,828	457	14,717
Forest	4210	7,581	Xeric Oak	Forest			115,515	3,343	836	26,915
Forest	4300	11	Upland Mixed Forest	Forest			164	5	1	38
Forest	4340	25,754	Upland Mixed Coniferous/Hardwood	Forest			392,398	11,357	2,839	91,427
Forest	4370	460	Australian Pine	Forest			7,003	203	51	1,632
Forest	4410	1,187	Coniferous Pine	Forest			18,087	523	131	4,214
Forest	4430	1,051	Forest Regeneration	Forest			16,017	464	116	3,732
Total		91,258	17%	(lbs/ac/yr)			15.24	0.44	0.11	3.55
Open Land	1900	1,303	Open Land	Recreation/Open Space	77,199	100%	21,838	132	9	3,075
Open Land	2120	3,712	Unimproved Pastures	Recreation/Open Space			62,204	376	25	8,758
Open Land	2130	1,608	Woodland Pastures	Recreation/Open Space			26,952	163	11	3,795
Open Land	2610	1,914	Fallow Cropland	Recreation/Open Space			32,078	194	13	4,516
Open Land	3100	10,247	Herbaceous	Recreation/Open Space			171,713	1,039	68	24,175
Open Land	3200	45,325	Shrub and brush land	Recreation/Open Space			759,557	4,597	300	106,938
Open Land	3300	8,015	Mixed Rangeland	Recreation/Open Space			134,310	813	53	18,909
Open Land	7100	117	Beaches Other Than Swimming Beaches	Recreation/Open Space			1,965	12	1	277
Open Land	7200	81	Sand Other Than Beaches	Recreation/Open Space			1,359	8	1	191
Open Land	7430	3,716	Spoil Areas	Recreation/Open Space			62,275	377	25	8,768
Open Land	8320	1,161	Electrical Power Transmission Lines	Recreation/Open Space			19,451	118	8	2,738
Total		77,199	15%	(lbs/ac/yr)			16.76	0.10	0.01	2.36

Table A4—*continued*

HSPF LU	FLUCCS	Acres	Land Use Description	Harpers LU	Harpers area	% area	TSS (LBS/YR)	TP (LBS/YR)	PO4 (LBS/YR)	TN (LBS/YR)
Wetland/Water	1660	45	Holding Ponds	Open Water/Lake	10,491	9%	803	27	13	322
Wetland/Water	5200	3,742	Lakes	Open Water/Lake			66,424	2,253	1,073	26,652
Wetland/Water	5300	2,707	Reservoirs	Open Water/Lake			48,044	1,629	776	19,277
Wetland/Water	5340	3,997	Reservoirs Less Than 10 Acres (Dominant Feature)	Open Water/Lake			70,939	2,406	1,146	28,464
Wetland/Water	6110	139	Bay Swamps	Wetland	111,978	91%	3,429	68	62	554
Wetland/Water	6120	5,307	Mangrove Swamp	Wetland			131,069	2,598	2,387	21,182
Wetland/Water	6150	73	River/Lake Swamp (Bottomland)	Wetland			1,795	36	33	290
Wetland/Water	6170	12,377	Mixed Wetland Hardwoods	Wetland			305,671	6,059	5,568	49,399
Wetland/Water	6180	252	Cabbage Palm Savanna	Wetland			6,219	123	113	1,005
Wetland/Water	6200	918	Wetland Coniferous Forest	Wetland			22,659	449	413	3,662
Wetland/Water	6210	1,725	Cypress	Wetland			42,600	844	776	6,885
Wetland/Water	6220	61	Forested Depressional Pine	Wetland			1,499	30	27	242
Wetland/Water	6300	17,402	Wetland Forested Mixed	Wetland			429,757	8,518	7,828	69,452
Wetland/Water	6410	33,294	Freshwater Marshes	Wetland			822,223	16,298	14,976	132,877
Wetland/Water	6420	10,619	Saltwater Marshes	Wetland			262,240	5,198	4,777	42,380
Wetland/Water	6430	12,447	Wet Prairies	Wetland			307,393	6,093	5,599	49,677
Wetland/Water	6440	589	Emergent Aquatic Vegetation	Wetland			14,551	288	265	2,352
Wetland/Water	6460	16,367	Mixed Scrub-Shrub Wetland	Wetland			404,189	8,012	7,362	65,320
Wetland/Water	6500	410	Non-Vegetated Wetland	Wetland			10,116	201	184	1,635
Total		122,469	23%	(lbs/ac/yr)			24.1	0.50	0.44	4.26
Grand Total		523,506		lbs/yr			62,680,942	455,644	276,931	3,488,787
				(lbs/ac/yr)			119.73	0.870	0.529	6.664

Table A5. Annual pollution load from the Eau Gallie River basin

	Pollutant	1994	1995	1996	1997	1998	1999	2000	Avg	Goal	%Diff
Urban, high-intensity											
	TSS	1120.3	860.0	515.9	783.8	657.6	963.7	603.0	786.3	734.0	7
	TP	4.61	3.79	2.51	3.80	3.48	4.08	2.80	3.58	3.45	4
	PO4	2.85	2.31	1.44	2.29	2.12	2.50	1.67	2.17	2.04	6
	TN	19.90	19.30	20.12	22.26	20.59	20.72	17.23	20.02	20.51	-2
Urban, medium-intensity											
	TSS	263.1	283.6	50.2	30.7	22.1	313.8	69.6	147.6	116.0	27
	TP	1.96	1.64	0.70	0.78	0.67	1.85	0.76	1.20	1.22	-2
	PO4	1.29	0.99	0.40	0.45	0.32	1.22	0.42	0.73	0.68	7
	TN	13.79	12.91	7.73	10.55	9.65	14.42	9.33	11.20	9.73	15
Urban, low-intensity											
	TSS	246.9	193.8	72.2	39.0	22.5	239.3	73.5	126.7	114.0	11
	TP	1.40	1.06	0.55	0.63	0.54	1.25	0.58	0.86	0.83	3
	PO4	0.83	0.54	0.27	0.33	0.22	0.74	0.28	0.46	0.44	5
	TN	11.28	9.86	5.83	7.67	7.71	10.28	6.80	8.49	6.99	22
Agriculture											
	TSS	364.0	318.0	55.8	18.2	8.4	388.0	91.8	177.7	128.0	39
	TP	1.67	1.38	0.47	0.51	0.47	1.60	0.60	0.96	0.91	5
	PO4	1.40	0.99	0.35	0.39	0.24	1.31	0.42	0.73	0.68	7
	TN	12.00	10.40	5.50	7.30	7.40	10.70	6.80	8.59	7.37	16
Open Land											
	TSS	41.8	42.2	3.5	0.4	0.4	62.6	4.4	22.2	17.0	30
	TP	0.56	0.51	0.25	0.31	0.35	0.49	0.29	0.39	0.10	292
	PO4	0.17	0.15	0.06	0.08	0.08	0.17	0.07	0.11	0.001	—
	TN	6.58	6.62	3.51	5.08	5.96	5.62	4.52	5.41	2.36	129
Forest											
	TSS	29.0	21.4	1.5	0.2	0.2	57.4	1.3	15.8	15.0	6
	TP	0.53	0.48	0.22	0.29	0.34	0.49	0.27	0.37	0.44	-15
	PO4	0.19	0.16	0.05	0.08	0.08	0.19	0.07	0.12	0.11	6
	TN	6.12	6.04	3.07	4.64	5.60	5.16	4.21	4.98	3.55	40
Wetland											
	TSS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	—
	TP	0.17	0.14	0.05	0.10	0.14	0.12	0.09	0.12	0	—
	PO4	0.03	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0	—
	TN	3.18	2.63	0.90	1.87	2.50	2.13	1.59	2.11	0	—

Table A6. Annual pollution load from the Crane Creek basin

	Pollutant	1994	1995	1996	1997	1998	1999	2000	Avg	Goal	%Diff
Urban, high-intensity											
	TSS	831.3	1113.9	512.2	725.5	631.0	762.0	427.9	714.8	734.0	-3
	TP	4.26	3.73	2.76	4.00	3.35	3.37	2.43	3.41	3.45	-1
	PO4	2.56	2.22	1.58	2.37	1.98	2.00	1.40	2.01	2.04	-1
	TN	20.39	18.36	21.40	21.82	19.60	20.60	16.83	19.86	20.51	-3
Urban, medium-intensity											
	TSS	140.0	427.8	35.8	58.6	48.3	103.0	30.8	120.6	116.0	4
	TP	1.39	2.01	0.78	1.08	0.98	1.18	0.62	1.15	1.22	-6
	PO4	0.81	1.24	0.42	0.61	0.53	0.69	0.32	0.66	0.68	-3
	TN	10.81	11.80	7.93	11.18	9.16	11.17	6.03	9.73	9.73	0
Urban, low-intensity											
	TSS	142.2	486.2	23.1	46.4	34.8	100.8	18.4	121.7	114.0	7
	TP	1.04	1.63	0.59	0.77	0.75	0.87	0.47	0.87	0.83	5
	PO4	0.56	0.94	0.30	0.41	0.37	0.48	0.22	0.47	0.44	6
	TN	8.43	9.70	5.93	7.48	7.13	7.67	4.33	7.24	6.99	4
Agriculture											
	TSS	156.8	582.7	11.8	35.1	22.5	98.7	8.5	130.9	128.0	2
	TP	1.12	1.98	0.55	0.73	0.73	0.92	0.44	0.92	0.91	1
	PO4	0.78	1.44	0.36	0.52	0.46	0.66	0.23	0.64	0.68	-7
	TN	9.10	10.70	5.80	7.90	7.40	8.30	4.30	7.64	7.37	4
Open Land											
	TSS	16.3	94.0	0.5	1.8	1.2	8.0	0.5	17.5	17.0	3
	TP	0.68	0.82	0.46	0.54	0.61	0.54	0.39	0.58	0.10	476
	PO4	0.25	0.28	0.17	0.20	0.23	0.20	0.15	0.21	0.001	—
	TN	5.48	6.17	3.82	4.47	5.14	4.43	3.28	4.68	2.36	98
Forest											
	TSS	10.1	70.5	0.2	1.0	0.8	5.5	0.3	12.6	15.0	-16
	TP	0.67	0.75	0.43	0.50	0.60	0.52	0.38	0.55	0.44	25
	PO4	0.25	0.27	0.16	0.19	0.23	0.19	0.15	0.21	0.11	87
	TN	5.53	5.83	3.59	4.22	5.02	4.24	3.18	4.52	3.55	27
Wetland											
	TSS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	—
	TP	0.35	0.34	0.17	0.22	0.30	0.22	0.15	0.25	0	—
	PO4	0.14	0.13	0.07	0.09	0.11	0.09	0.06	0.10	0	—
	TN	3.00	2.88	1.47	1.90	2.50	1.87	1.24	2.12	0	—

Table A7. Annual pollution load from the Turkey Creek basin

	Pollutant	1994	1995	1996	1997	1998	1999	2000	Avg	Goal	%Diff
Urban, high-intensity											
	TSS	681.5	854.3	678.0	860.6	794.3	675.0	507.3	721.6	734	-2
	TP	3.73	3.65	3.36	4.28	3.53	3.34	2.39	3.47	3.45	1
	PO4	2.18	2.11	1.92	2.47	2.04	1.94	1.35	2.00	2.04	-2
	TN	20.15	17.88	22.28	21.80	19.32	21.04	16.59	19.87	20.51	-3
Urban, medium-intensity											
	TSS	47.0	204.0	144.2	181.7	202.8	72.0	26.3	125.4	116	8
	TP	0.95	1.67	1.12	1.60	1.50	0.93	0.45	1.18	1.22	-4
	PO4	0.56	1.05	0.69	0.99	0.92	0.55	0.24	0.71	0.68	5
	TN	9.89	12.61	9.34	13.15	11.18	10.33	5.46	10.28	9.73	6
Urban, low-intensity											
	TSS	43.6	208.0	145.7	183.0	206.0	70.7	23.2	125.7	114	10
	TP	0.65	1.19	0.80	1.11	1.06	0.65	0.32	0.82	0.83	-1
	PO4	0.34	0.67	0.44	0.63	0.59	0.34	0.15	0.45	0.44	3
	TN	7.62	9.87	7.16	9.31	8.81	7.31	4.12	7.74	6.99	11
Agriculture											
	TSS	21.0	220.0	158.8	179.0	238.0	57.2	2.4	125.2	128	-2
	TP	0.60	1.46	0.88	1.24	1.30	0.65	0.22	0.91	0.91	0
	PO4	0.42	1.12	0.67	0.98	0.97	0.46	0.12	0.68	0.68	0
	TN	8.10	11.60	7.20	10.40	9.90	7.70	3.50	8.34	7.37	13
Open Land											
	TSS	1.2	21.6	36.8	18.8	28.8	5.5	0.1	16.1	17	-5
	TP	0.30	0.39	0.27	0.33	0.36	0.27	0.16	0.30	0.1	198
	PO4	0.10	0.11	0.07	0.09	0.10	0.09	0.05	0.09	0.001	—
	TN	5.40	6.26	4.09	5.11	5.70	4.73	2.92	4.89	2.36	107
Forest											
	TSS	1.6	18.0	17.4	14.7	21.4	4.9	0.3	11.2	15	-26
	TP	0.29	0.36	0.23	0.29	0.33	0.26	0.16	0.27	0.44	-38
	PO4	0.10	0.11	0.07	0.09	0.10	0.08	0.05	0.09	0.11	-22
	TN	5.28	5.93	3.85	4.82	5.52	4.59	2.84	4.69	3.55	32
Wetland											
	TSS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	—
	TP	0.15	0.17	0.10	0.12	0.16	0.12	0.07	0.13	0	—
	PO4	0.05	0.06	0.03	0.04	0.05	0.04	0.02	0.04	0	—
	TN	2.66	3.08	1.91	2.25	2.95	2.12	1.26	2.32	0	—

Table A8. Annual pollution load from the Sebastian River North Prong basin

	Pollutant	1994	1995	1996	1997	1998	1999	2000	Avg	Goal	%Diff
Urban, high-intensity											
	TSS	748.9	753.5	590.5	928.3	845.2	656.4	607.8	733.0	734.0	0
	TP	4.0	3.8	3.1	4.3	4.0	3.2	2.8	3.6	3.45	4
	PO4	2.2	2.1	1.8	2.3	2.1	1.8	1.5	2.0	2.04	-4
	TN	25.7	22.1	18.9	21.1	20.3	19.2	14.0	20.2	20.51	-2
Urban, medium-intensity											
	TSS	74.7	69.5	40.4	223.7	215.2	109.2	81.8	116.4	116.0	0
	TP	1.3	1.1	0.8	1.5	1.6	1.2	1.0	1.2	1.22	0
	PO4	0.7	0.7	0.5	0.7	0.8	0.6	0.5	0.7	0.68	-4
	TN	12.1	10.2	8.0	9.5	11.0	10.2	7.6	9.8	9.73	1
Urban, low-intensity											
	TSS	56.7	50.7	24.2	224.6	229.5	103.3	70.8	108.5	114.0	-5
	TP	0.9	0.8	0.6	1.3	1.4	1.0	0.8	1.0	0.83	19
	PO4	0.5	0.5	0.3	0.5	0.6	0.5	0.4	0.5	0.44	4
	TN	8.6	7.1	5.6	6.8	7.9	7.0	5.3	6.9	6.99	-2
Agriculture											
	TSS	524.7	20.4	609.6	890.9	332.0	26.2	20.5	122.2	128.0	-5
	TP	2.36	0.73	2.31	3.25	1.50	0.71	0.46	0.92	0.91	1
	PO4	1.06	0.32	1.05	1.51	0.66	0.30	0.20	0.35	0.68	-49
	TN	7.04	5.03	4.98	6.67	4.40	4.59	2.90	5.28	7.37	-28
Open Land											
	TSS	58.7	9.6	50.6	125.8	38.4	9.3	10.1	17.3	17.0	2
	TP	0.77	0.59	0.60	0.80	0.55	0.53	0.33	0.24	0.10	143
	PO4	0.47	0.37	0.36	0.48	0.34	0.34	0.21	0.09	0.00	—
	TN	7.47	6.16	5.69	6.87	5.45	5.57	3.41	1.39	2.36	-41
Forest											
	TSS	75.6	4.6	51.4	307.1	38.9	4.4	6.1	16.9	15.0	12
	TP	0.65	0.51	0.41	0.72	0.44	0.40	0.28	0.22	0.44	-51
	PO4	0.35	0.28	0.20	0.37	0.24	0.23	0.16	0.07	0.11	-38
	TN	5.88	4.97	3.52	5.40	4.23	3.94	2.74	3.01	3.55	-15
Wetland											
	TSS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—
	TP	0.36	0.32	0.24	0.30	0.24	0.23	0.17	0.03	0.00	—
	PO4	0.18	0.16	0.12	0.15	0.12	0.11	0.08	0.00	0.00	—
	TN	2.88	2.52	1.93	2.43	2.15	1.76	1.29	0.03	0.00	—

Table A9. Annual pollution load from the Fellsmere Farms basin

	Pollutant	1994	1995	1996	1997	1998	1999	2000	Avg	Goal	%Diff
Urban, high-intensity											
	TSS	748.9	753.5	590.5	928.3	845.2	656.4	607.8	733.0	734.0	0
	TP	4.0	3.8	3.1	4.3	4.0	3.2	2.8	3.6	3.45	4
	PO4	2.2	2.1	1.8	2.3	2.1	1.8	1.5	2.0	2.04	-4
	TN	25.7	22.1	18.9	21.1	20.3	19.2	14.0	20.2	20.51	-2
Urban, medium-intensity											
	TSS	74.7	69.5	40.4	223.7	215.2	109.2	81.8	116.4	116.0	0
	TP	1.3	1.1	0.8	1.5	1.6	1.2	1.0	1.2	1.22	0
	PO4	0.7	0.7	0.5	0.7	0.8	0.6	0.5	0.7	0.68	-4
	TN	12.1	10.2	8.0	9.5	11.0	10.2	7.6	9.8	9.73	1
Urban, low-intensity											
	TSS	56.7	50.7	24.2	224.6	229.5	103.3	70.8	108.5	114.0	-5
	TP	0.9	0.8	0.6	1.3	1.4	1.0	0.8	1.0	0.83	19
	PO4	0.5	0.5	0.3	0.5	0.6	0.5	0.4	0.5	0.44	4
	TN	8.6	7.1	5.6	6.8	7.9	7.0	5.3	6.9	6.99	-2
Agriculture											
	TSS	57.16	25.85	52.68	144.06	395.57	87.14	92.8	122.2	128.0	-5
	TP	0.8	0.7	0.6	0.9	1.9	0.9	0.7	0.9	0.91	1
	PO4	0.4	0.3	0.3	0.3	0.6	0.4	0.3	0.3	0.68	-49
	TN	6.6	5.6	4.6	4.3	6.7	5.5	3.6	5.3	7.37	-28
Open Land											
	TSS	8.68	4.8	1.48	47.2	34.49	13.33	11.03	17.3	17.0	2
	TP	0.3	0.18	0.14	0.33	0.3	0.23	0.22	0.2	0.10	143
	PO4	0.1	0.07	0.07	0.1	0.11	0.09	0.08	0.1	0.001	—
	TN	1.83	1.28	1.09	1.52	1.61	1.34	1.04	1.4	2.36	-41
Forest											
	TSS	5.14	2.15	0.07	31.99	61.21	9.4	8.09	16.9	15.0	12
	TP	0.21	0.16	0.05	0.28	0.36	0.27	0.18	0.2	0.44	-51
	PO4	0.06	0.06	0.01	0.08	0.1	0.11	0.06	0.1	0.11	-38
	TN	3.67	3.18	1.72	2.81	3.78	3.47	2.41	3.0	3.55	-15
Wetland											
	TSS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—
	TP	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—
	PO4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—
	TN	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—

Table A10. Annual pollution load from the Sebastian River South Prong basin

	Pollutant	1994	1995	1996	1997	1998	1999	2000	Avg	Goal	%Diff
Urban, high-intensity											
	TSS	872.2	832.7	648.6	878.9	775.1	617.9	580.8	743.7	734.0	1
	TP	3.2	2.8	2.3	3.0	2.8	2.4	2.0	2.6	3.45	-23
	PO4	2.1	1.8	1.5	2.0	1.8	1.5	1.3	1.7	2.04	-16
	TN	24.0	19.2	17.1	19.9	18.0	18.0	12.3	18.4	20.51	-11
Urban, medium-intensity											
	TSS	192.8	237.7	47.3	83.5	81.4	109.1	95.6	121.1	116.0	4
	TP	1.8	1.4	0.9	1.2	1.2	1.4	0.9	1.3	1.22	3
	PO4	1.0	0.7	0.5	0.7	0.7	0.8	0.5	0.7	0.68	5
	TN	10.3	7.2	6.3	7.9	7.7	8.4	5.2	7.6	9.73	-22
Urban, low-intensity											
	TSS	118.5	136.2	52.3	97.1	119.2	67.6	91.8	97.5	114.0	-14
	TP	1.3	1.1	0.8	1.0	1.2	1.0	0.8	1.0	0.83	21
	PO4	0.8	0.6	0.5	0.7	0.8	0.7	0.5	0.7	0.44	49
	TN	8.4	6.2	5.8	6.1	7.1	6.8	4.4	6.4	6.99	-8
Agriculture											
	TSS	296.1	340.1	5.8	29.9	62.8	92.9	70.8	128.3	128.0	0
	TP	1.9	1.5	0.5	0.8	0.9	1.1	0.7	1.1	0.91	16
	PO4	0.8	0.7	0.2	0.3	0.4	0.5	0.3	0.4	0.68	-34
	TN	7.9	5.1	4.1	4.9	5.8	6.2	3.6	5.4	7.37	-27
Open Land											
	TSS	31.9	34.0	3.3	19.0	24.3	14.1	17.9	20.6	17.0	21
	TP	0.8	0.6	0.5	0.6	0.6	0.6	0.4	0.6	0.10	481
	PO4	0.5	0.4	0.3	0.3	0.4	0.4	0.3	0.4	0.001	—
	TN	8.0	5.8	5.4	5.5	6.8	6.4	4.1	6.0	2.36	154
Forest											
	TSS	29.14	33.45	2.03	2.59	18.04	5.07	8.37	14.1	15.0	-6
	TP	0.65	0.5	0.38	0.36	0.52	0.46	0.28	0.45	0.44	2
	PO4	0.36	0.27	0.22	0.19	0.29	0.26	0.16	0.25	0.11	127
	TN	6.25	4.5	3.7	3.25	5.19	4.5	2.57	4.28	3.55	21
Wetland											
	TSS	0	0	0	0	0	0	0	0	0	—
	TP	0.41	0.34	0.26	0.25	0.32	0.29	0.18	0.29	0	—
	PO4	0.2	0.17	0.13	0.13	0.16	0.15	0.09	0.15	0	—
	TN	3.36	2.75	2.09	2.07	2.73	2.21	1.4	2.37	0	—

Table A11. Annual pollution load from the Indian River Farms North, Main, and South canal basins

	Pollutant	1994	1995	1996	1997	1998	1999	2000	Avg	Goal	%Diff
Urban, high-intensity											
	TSS	751.6	682.8	785.3	841.7	721.1	619.1	608.9	715.8	734.0	-2
	TP	3.82	3.27	3.44	3.60	3.32	3.10	2.47	3.29	3.45	-5
	PO4	2.23	1.91	2.01	2.13	1.93	1.78	1.49	1.93	2.04	-6
	TN	21.77	19.15	21.39	22.61	20.16	17.83	16.71	19.95	20.51	-3
Urban, medium-intensity											
	TSS	111.7	114.2	123.7	136.8	127.1	107.2	105.9	118.1	116.0	2
	TP	1.32	1.35	1.32	1.39	1.43	1.31	1.01	1.30	1.22	7
	PO4	0.8	0.71	0.7	0.76	0.78	0.69	0.58	0.72	0.68	5
	TN	9.12	9.36	9.52	10.09	10.75	9.14	8.14	9.45	9.73	-3
Urban, low-intensity											
	TSS	100.5	107.3	48.9	81.3	168.8	115.5	98.1	102.9	114.0	-10
	TP	0.82	1.13	0.77	0.94	1.51	1.17	0.91	1.04	0.83	25
	PO4	0.45	0.49	0.29	0.39	0.72	0.52	0.43	0.47	0.44	7
	TN	7.79	7.48	5.58	6.43	10.03	7.78	6.26	7.34	6.99	5
Agriculture											
	TSS	162.2	111.9	126.9	116.4	105.1	147.0	109.1	125.5	128.0	-2
	TP	1.17	1.12	1.17	1.09	1.12	1.31	0.95	1.13	0.91	24
	PO4	0.78	0.69	0.74	0.69	0.67	0.89	0.65	0.73	0.68	7
	TN	10.09	8.16	8.43	7.86	8.33	9.44	6.98	8.47	7.37	15
Open Land											
	TSS	14.4	23.9	7.8	12.7	18.1	23.7	14.3	16.4	17.0	-4
	TP	0.15	0.4	0.37	0.37	0.4	0.37	0.26	0.331	0.10	231
	PO4	0.01	0.04	0.04	0	0.04	0.04	0.03	0.029	0.001	—
	TN	3.02	3.72	3.36	3.31	4.12	3.63	2.61	3.396	2.36	44
Forest											
	TSS	13.7	16.2	13.4	13.1	13.0	18.4	12.0	14.3	15.0	-5
	TP	0.46	0.79	0.48	0.51	0.66	0.8	0.45	0.59	0.44	35
	PO4	0.12	0.12	0.11	0.11	0.15	0.14	0.11	0.12	0.11	12
	TN	4.52	5.13	4.18	4.04	5.17	5.16	3.52	4.53	3.55	28
Wetland											
	TSS	2.5	1.9	1.6	1.6	1.8	1.7	1.1	1.7	0	—
	TP	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0	—
	PO4	0	0	0	0	0	0	0	0.00	0	—
	TN	0.3	0.23	0.19	0.19	0.22	0.21	0.13	0.21	0	—

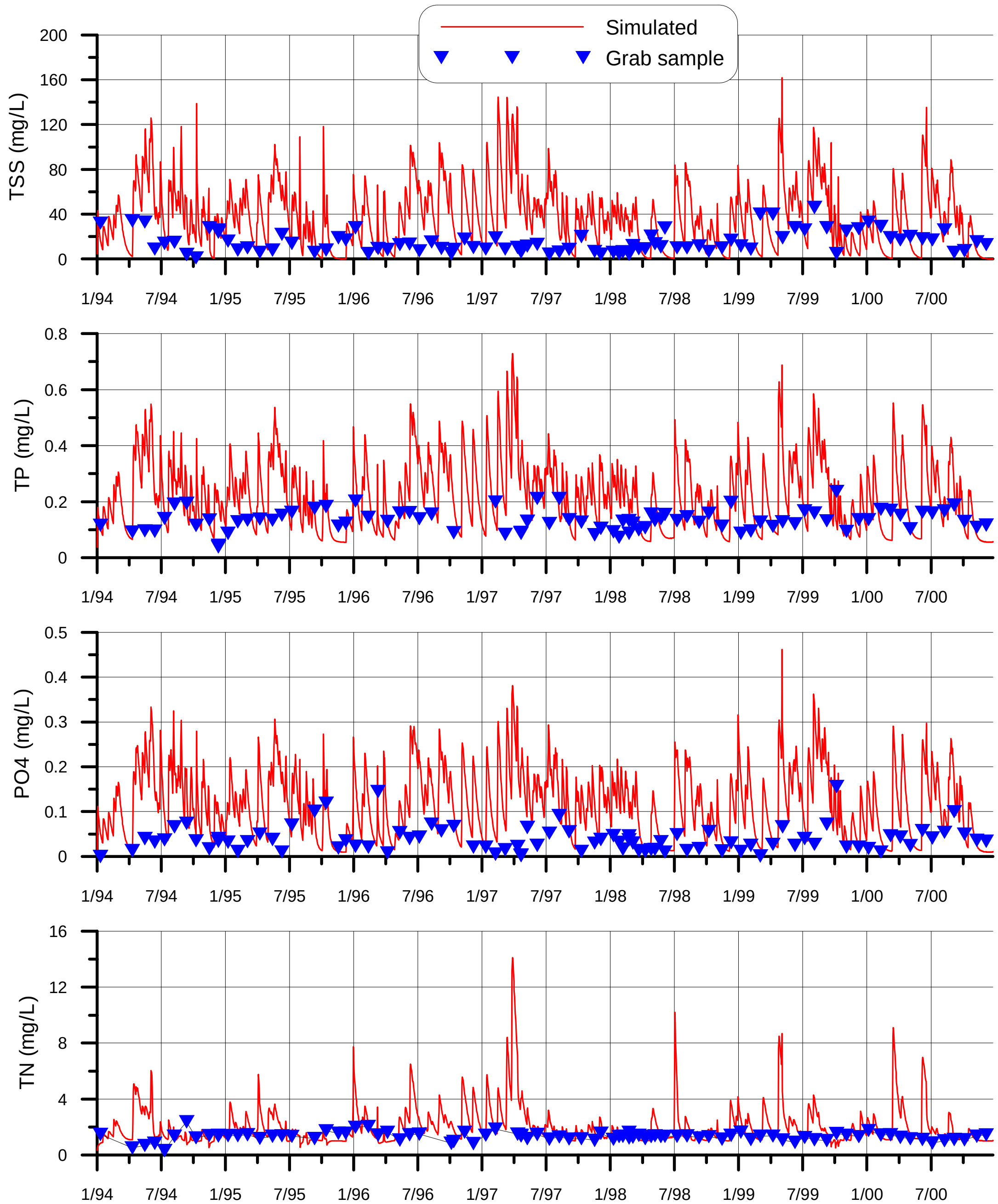

Figure A1. Comparison of simulated daily concentrations from the Eau Gallie River to grab samples collected at station IRLEGU

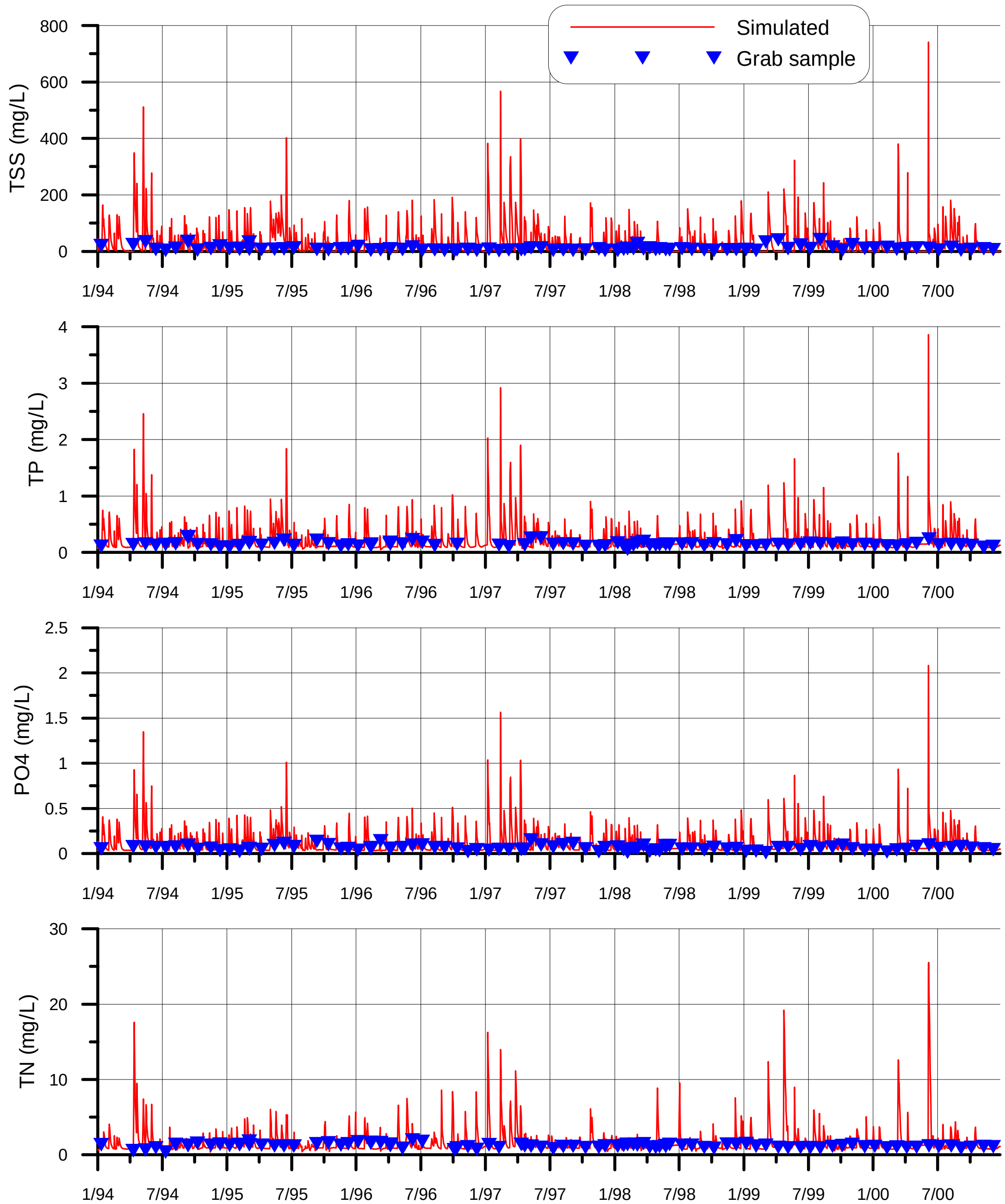

Figure A2. Comparison of simulated daily concentrations from Crane Creek to grab samples collected at station IRLCCU

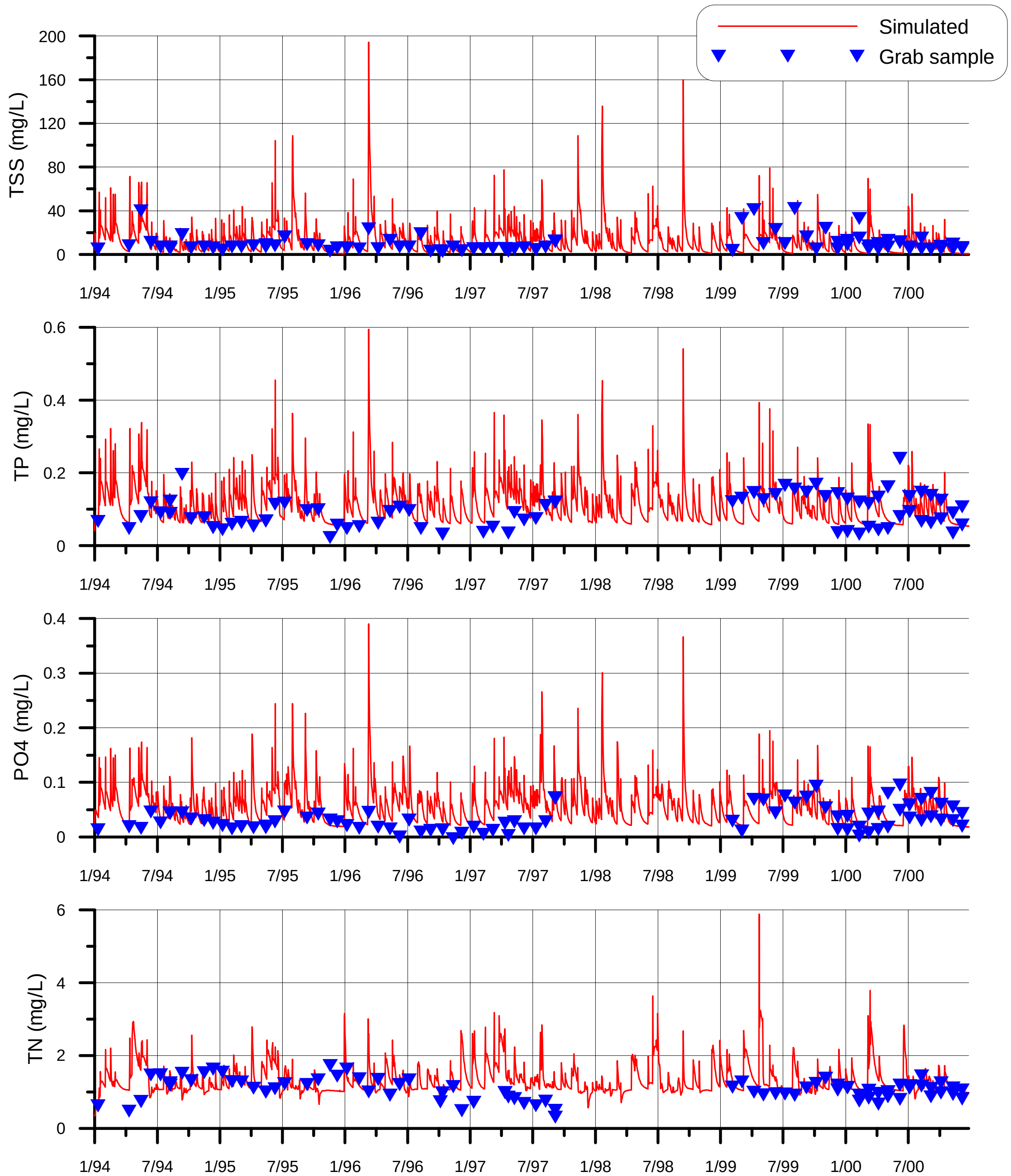

Figure A3. Comparison of simulated daily concentrations from Turkey Creek to grab samples collected at IRLTUS

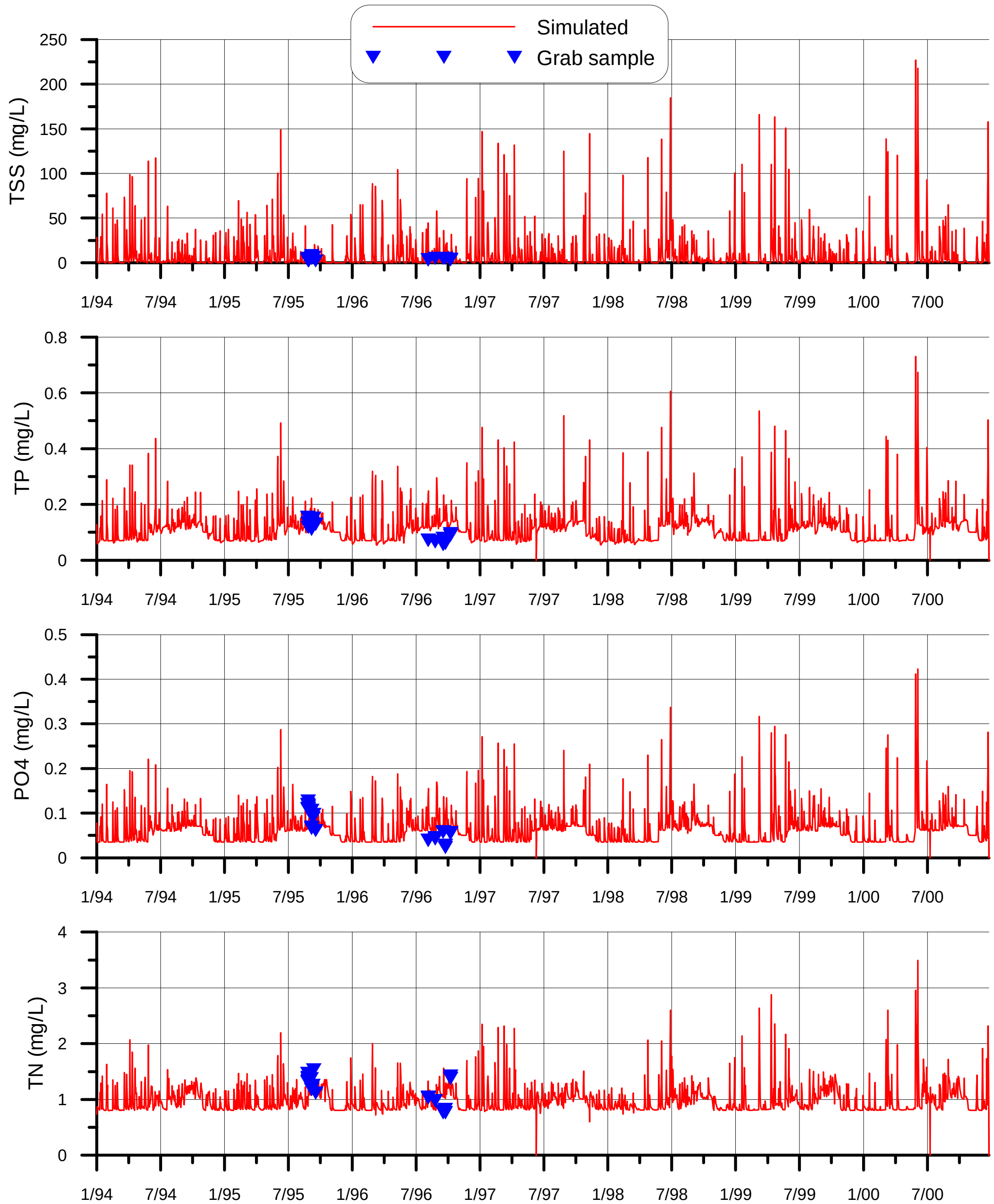

Figure A4. Comparison of simulated daily concentrations from the Sebastian River North Prong to grab samples collected at station IRLSEBNP

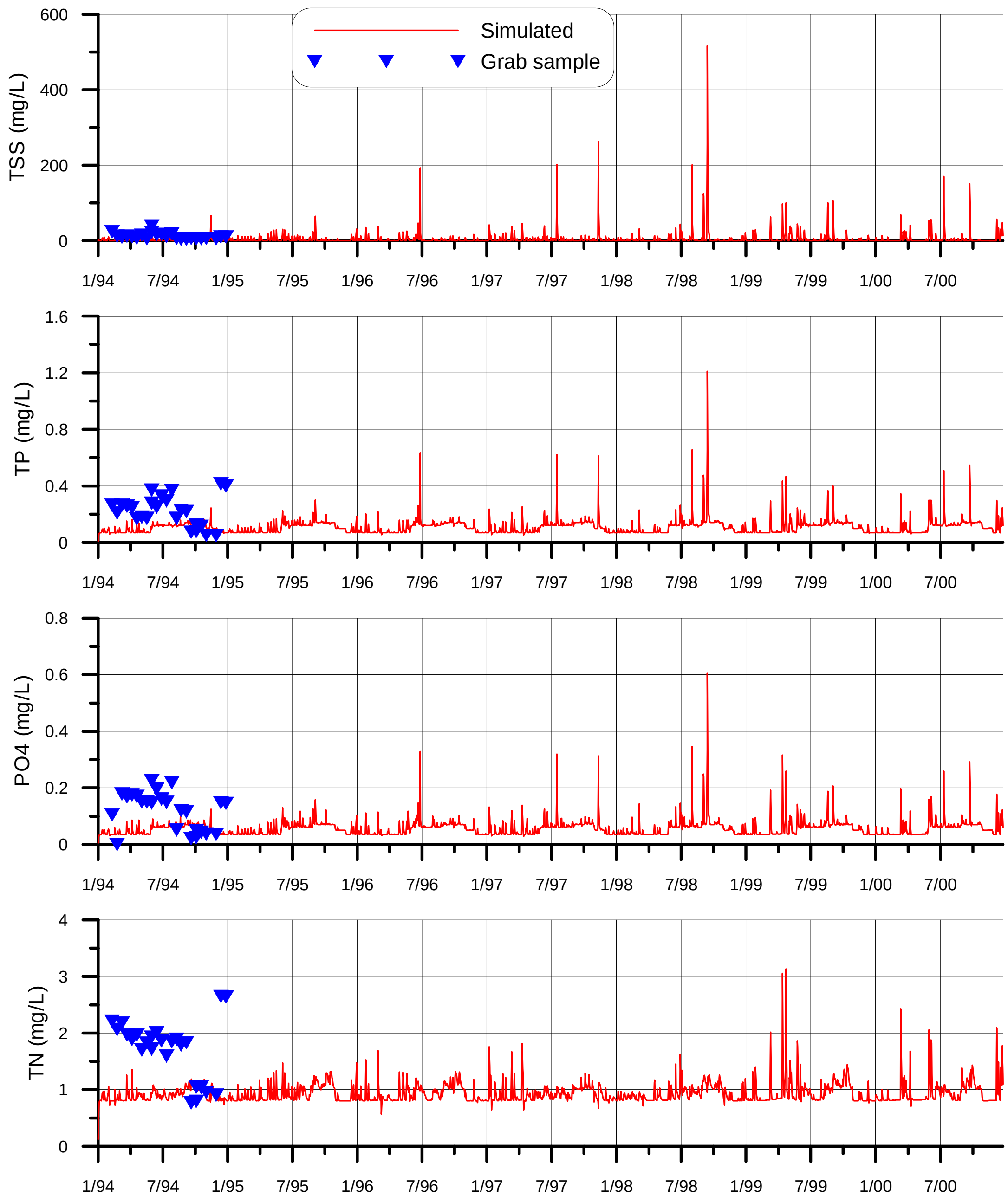

Figure A5. Comparison of simulated daily concentrations from Fellsmere Farms to grab samples collected at IRLUPSFW

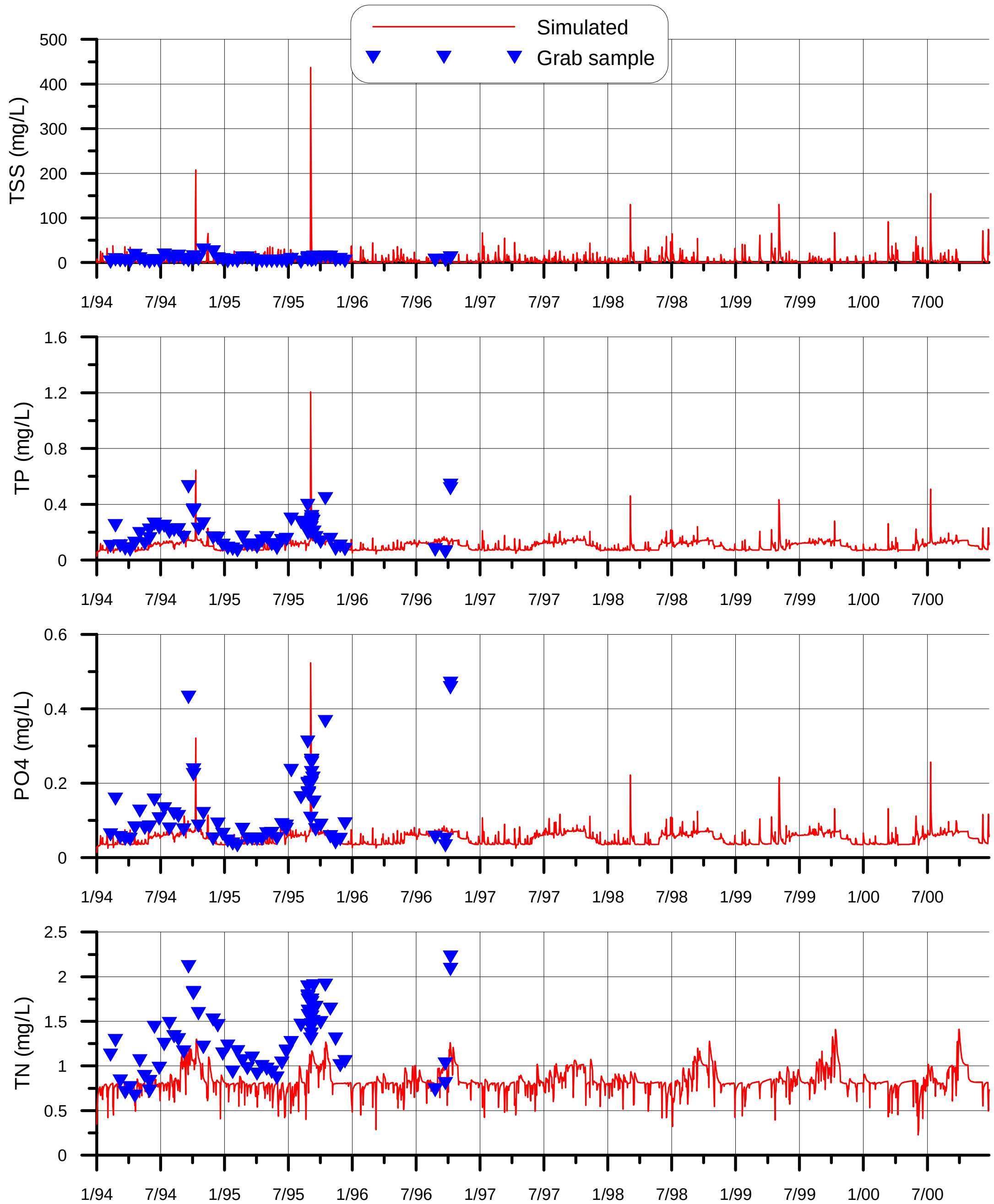

Figure A6. Comparison of simulated daily concentrations from the Sebastian River South Prong to grab samples collected at station IRLSIR003

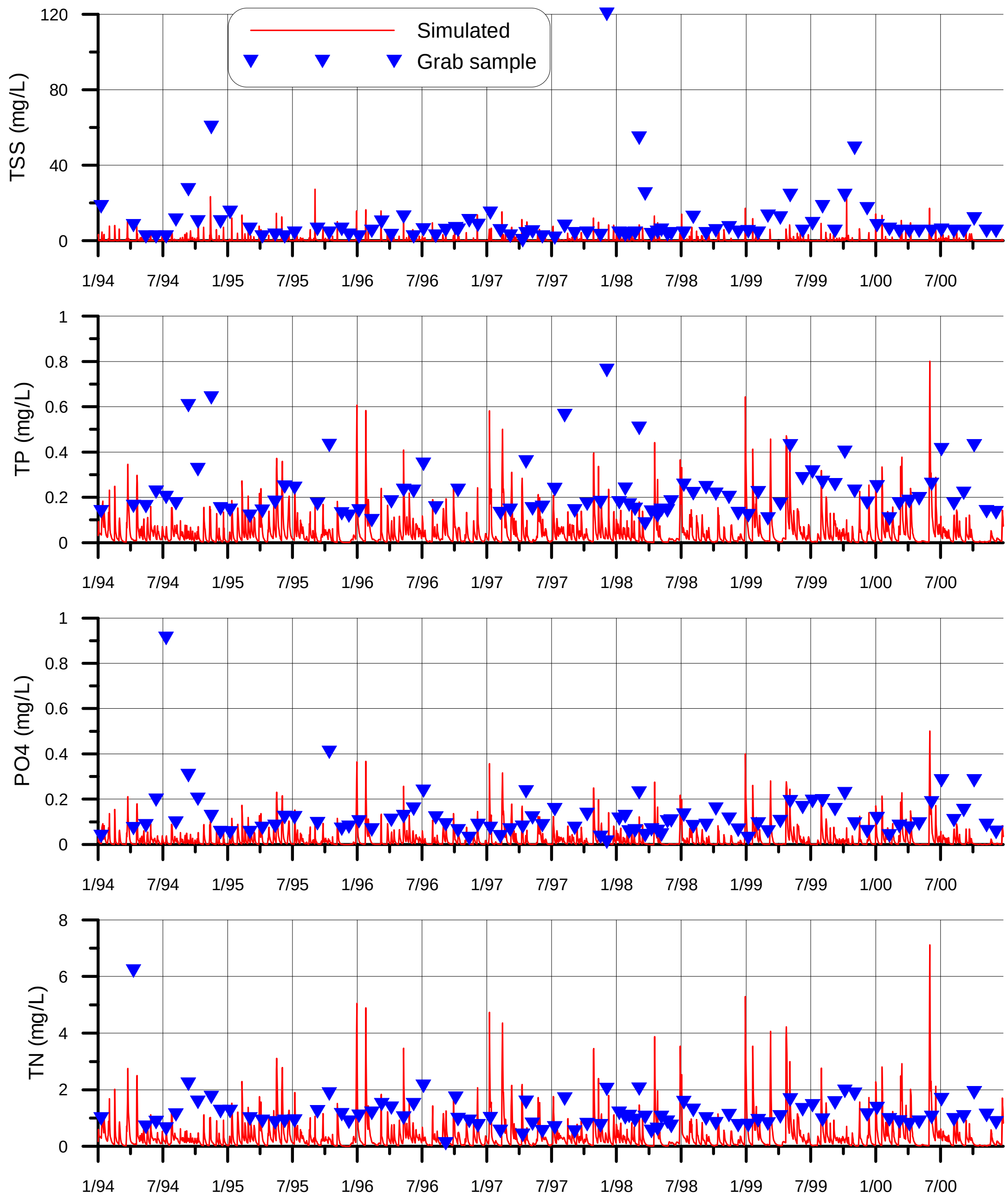

Figure A7. Comparison of simulated daily concentrations from North Canal to grab samples collected at station IRLVNC

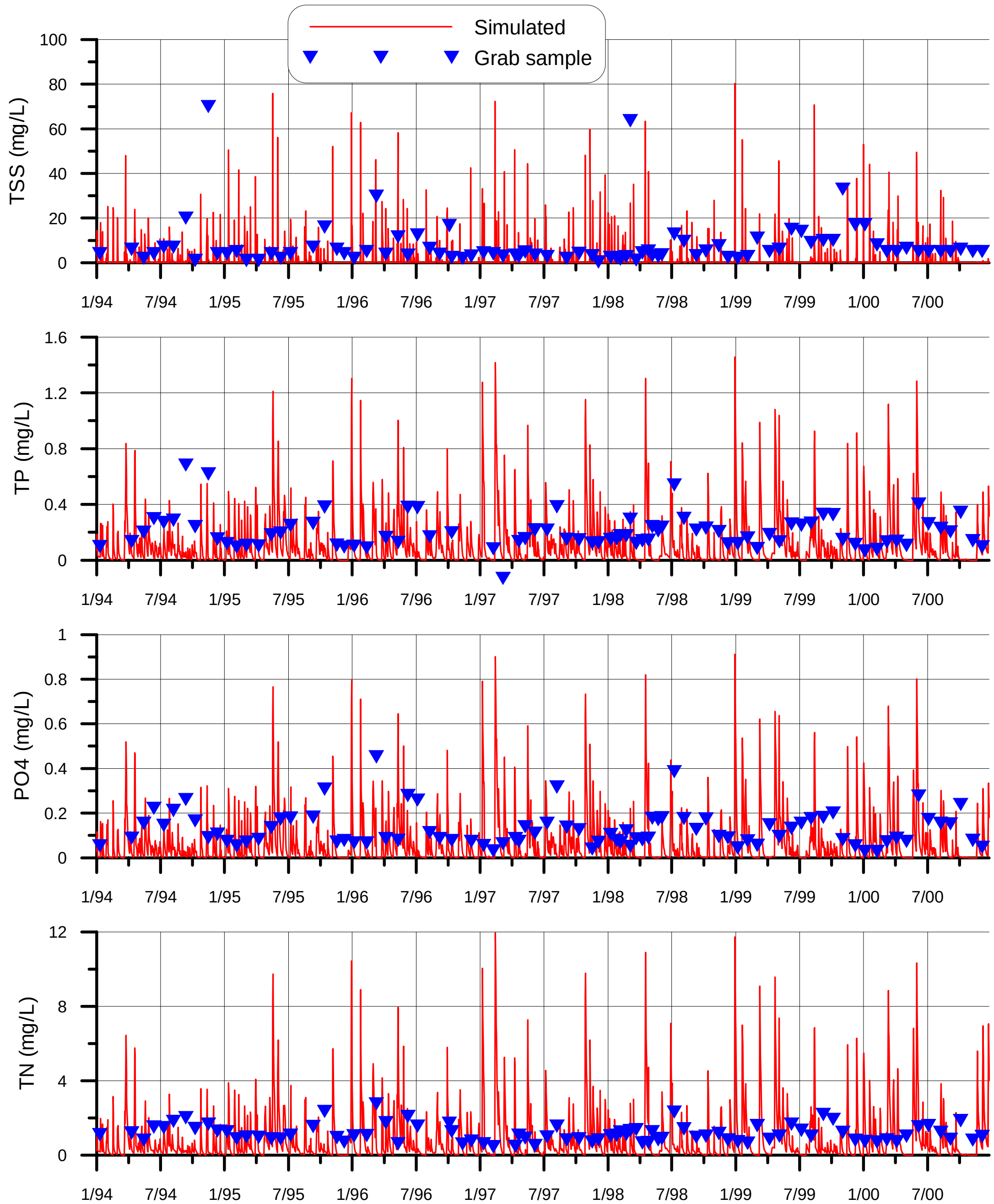

Figure A8. Comparison of simulated daily concentrations from Main Canal to grab samples collected at station IRLVMC

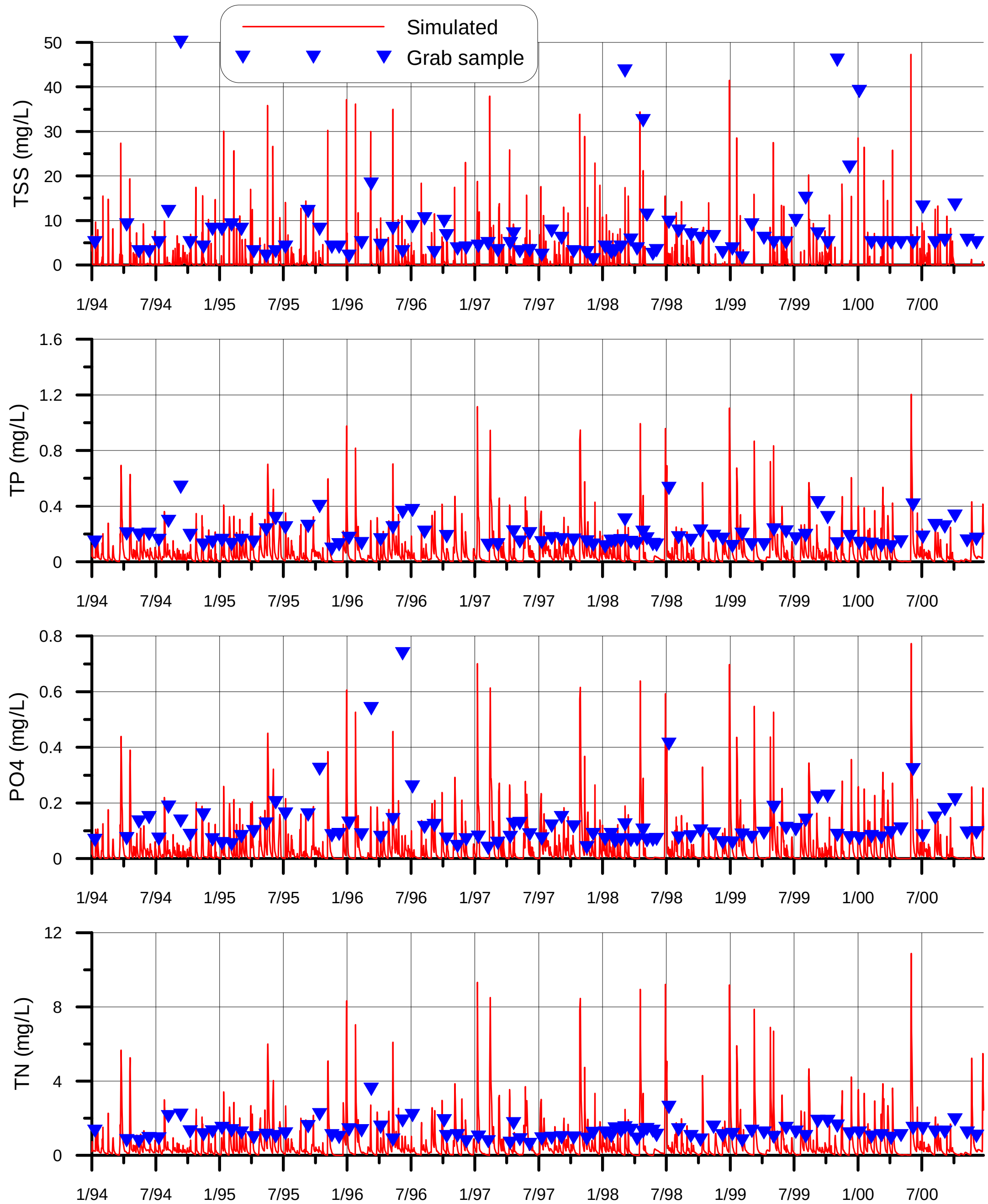

Figure A9. Comparison of simulated daily concentrations from South Canal to grab samples collected at station IRLVSC