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FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration

CENTRAL DISTRICT • INDIAN RIVER LAGOON BASIN

TMDL Report

Dissolved Oxygen and Nutrient TMDLs for Eight Tributary Segments of the Indian River Lagoon

Xueqing Gao, Ph.D.
Kyeongsik Rhew, Ph.D.



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Acknowledgments

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Editorial assistance provided by
Jan Mandrup-Poulsen, and Linda Lord

For additional information on the watershed management approach and impaired waters in the Indian River Lagoon Basin, contact
Mary Paulic
Florida Department of Environmental Protection
Bureau of Watershed Restoration
Watershed Planning and Coordination Section
2600 Blair Stone Road, Mail Station 3565
Tallahassee, FL 32399-2400
Email: Mary.Paulic@dep.state.fl.us
Phone: (850) 245–8560
Fax: (850) 245–8434

Access to all data used in the development of this report can be obtained by contacting
Xueqing Gao
Florida Department of Environmental Protection
Bureau of Watershed Management
Watershed Assessment Section
2600 Blair Stone Road, Mail Station 3555
Tallahassee, FL 32399-2400
Email: Xueqing.Gao@dep.state.fl.us
Phone: (850) 245-8464, Fax: (850) 245-8434

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Web sites

Florida Department of Environmental Protection, Bureau of Watershed Management

Total Maximum Daily Load Program

http://www.dep.state.fl.us/water/tmdl/index.htm

Identification of Impaired Surface Waters Rule

http://www.dep.state.fl.us/water/tmdl/docs/AmendedIWR.pdf

STORET Program

http://www.dep.state.fl.us/water/storet/index.htm

2012 305(b) Report

http://www.dep.state.fl.us/water/docs/2012_integrated_report.pdf

Criteria for Surface Water Quality Classifications

http://www.dep.state.fl.us/water/wqssp/classes.htm

Basin Status Reports and Water Quality Assessment Reports

http://www.dep.state.fl.us/water/tmdl/stat_rep.htm

U.S. Environmental Protection Agency

Region 4: Total Maximum Daily Loads in Florida

http://www.epa.gov/region4/water/tmdl/florida/

National STORET Program

http://www.epa.gov/storet/

Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the Total Maximum Daily Loads (TMDLs) for nutrients and Biochemical Oxygen Demand (BOD) for eight tributary segments within the Indian River Lagoon (IRL) Basin. These waterbodies were verified as impaired for nutrients and/or dissolved oxygen (DO), and were included on Verified Lists of impaired waters for the IRL Basin that were adopted by Secretarial Order on December 12, 2007 for the Cycle 1 water quality assessment conducted by the Florida Department of Environmental Protection (Department) or on February 7, 2012 for the Cycle 2 water quality assessment. The purpose of these TMDLs is to establish the allowable pollutant loadings to these waterbodies that would restore their water quality condition so that they meet their applicable water quality criteria for nutrients and DO.

1.2 Identification of Waterbody

The entire IRL is a 156-mile long estuary located on Florida's East Coast. Six coastal Florida Counties occur within the natural IRL watershed, which include, from north to south, Volusia, Brevard, Indian River, St. Lucie, Martin, and Palm Beach counties. The majority of the basin area is located in between Interstate Highway I-95 and the central portion of the Atlantic coastline of Florida. The basin is well developed, with close to 30 percent of the non-water areas being occupied by urban and built-up lands. About 20 municipalities and townships are located in the basin, among which are New Smyrna Beach, Titusville, Cocoa Beach, Melbourne, Palm Bay, and Vero Beach.

There are three inter-connected lagoons in the basin, which are commonly referred to as Mosquito Lagoon (ML), IRL, and Banana River Lagoon (BRL). Among these lagoons, the IRL is the largest one. It connects to the Atlantic Ocean directly through four major inlets including the Sebastian Inlet, Fort Pierce Inlet, St. Lucie Inlet, and Jupiter Inlet. The major source of freshwater input into IRL include the drainage basin runoff, tributary discharge, ground water input, and rainfall directly onto the surface of the lagoon . Several major tributaries discharge freshwater into IRL, which include Addison Creek, Eau Gallie River, Crane Creek, Turkey Creek, and Sebastian River. In addition, in the portion of the IRL basin from Melbourne south, several large drainage systems associated with water control districts or federal flood control projects were constructed which extended the drainage basin of the lagoon westward to include extensive areas that historically drained to the St. Johns River or Lake Okeechobee. Examples of these drainage systems include C-54 Canal, which drains into Sebastian River, and Vero Beach North, Main, and South Canals. Human activities and landuse patterns in the drainage basins of these tributaries pose not only significant impacts on the water quality of these tributaries, but also influence the water quality and habitats of the Indian River Lagoon.

Climate for IRL basin is predominantly humid subtropical, showing a dry season (November to May) and a wet season (June to October). Based on data over a 30-year period (1982–2011), the average summer temperature is 81.5°F, and the average winter temperature is 61.1°F In Titusville (http://climod.meas.ncsu.edu/). Average rainfall in the IRL Basin ranges from 55 to 60 inches per year with about 62 percent of the total rainfall from June through October. The spatial distribution of rainfall across the basin can be variable; historically, more rainfalls in the

Titusville area and the least rainfalls occur between Palm Bay and Sebastian Inlet.

The IRL is a nationally renowned aquatic ecosystem that supports tremendous biodiversity and provides recreational and commercial fishing resources, as well. It was designated in the 1987 Surface Water Improvement and Management (SWIM) Act as a priority waterbody in need of restoration and special protection. Major problems leading to this designation included the loss of or alteration of 75 percent of the lagoon's salt marsh and mangrove wetlands, excessive freshwater discharges into the central lagoon due to drainage improvements in coastal watersheds and diversion of floodwaters from the St. Johns River floodplain, and discharges of pollutant-laden wastewater and stormwater into the lagoon. Excessive freshwater input degraded hard clam habitat and seagrass coverage densities. Pollutants in discharges exacerbated the turbidity levels and promoted algae growth, contributing to the destruction of seagrass beds. In 1991, the IRL became a part of the National Estuary Program (NEP). Efforts under the IRL program at the St. Johns River Water Management District (SJRWMD) focus on improving water and sediment quality to restore or enhance seagrass and on rehabilitating impacted wetlands to recover as many of their natural functions as possible (http://www.sjrwmd.com/programs/outreach/irlnep/index.html). In 2009, the Department developed and adopted into rule nutrient and DO TMDLs for the main stem of IRL and BRL based on a nutrient pollutant reduction goal (PLRG) developed by the SJRWMD (Steward and Green, 2006 and 2007) to address the seagrass restoration issues. These TMDLs established the nutrient loading targets for the IRL and BRL that are required to restore the seagrass communities in these estuary segments.

Other than the seagrass problem associated with the main stem of IRL, water quality issues were also identified with tributaries that discharge into the lagoon through the Department's water quality assessment and impaired water listing process. For assessment purposes, the Department has divided the IRL basin into water assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or stream reach. The WBID numbers for the waterbodies addressed in this report are presented in **Figure 1.1. Table 1.1** lists the impaired WBIDs and impairments verified for these WBIDs.

Table 1.1. Waterbodies and Their Verified Impairments Included in This Report

WBID*		Water Segment Name	Verified Impairments
Cycle 1	Cycle 2		
3028	3028	Addison Creek	DO
3082	3082	Eau Gallie River	DO and Nutrients
3085A	3085A	Crane Creek	DO and Nutrients
3128	3128A	North Prong Sebastian River	DO
3129B	3129B1	South Prong Sebastian River Estuary Segment (Cycle 1 name was Sebastian River)	DO and Nutrients
3129B	3129B2	South Prong Sebastian River Freshwater Segment (Cycle 1 name was Sebastian River)	DO
3129A	3129A	Sebastian River Above IRL	DO and Nutrients
3135	3135A	C-54 at Confluence with Sebastian River	DO and Nutrients

*: WBID number for a given waterbody can be changed between Cycle 1 and Cycle 2 assessments. This table lists WBID numbers for waterbodies in both Cycle 1 and Cycle 2 water quality assessment

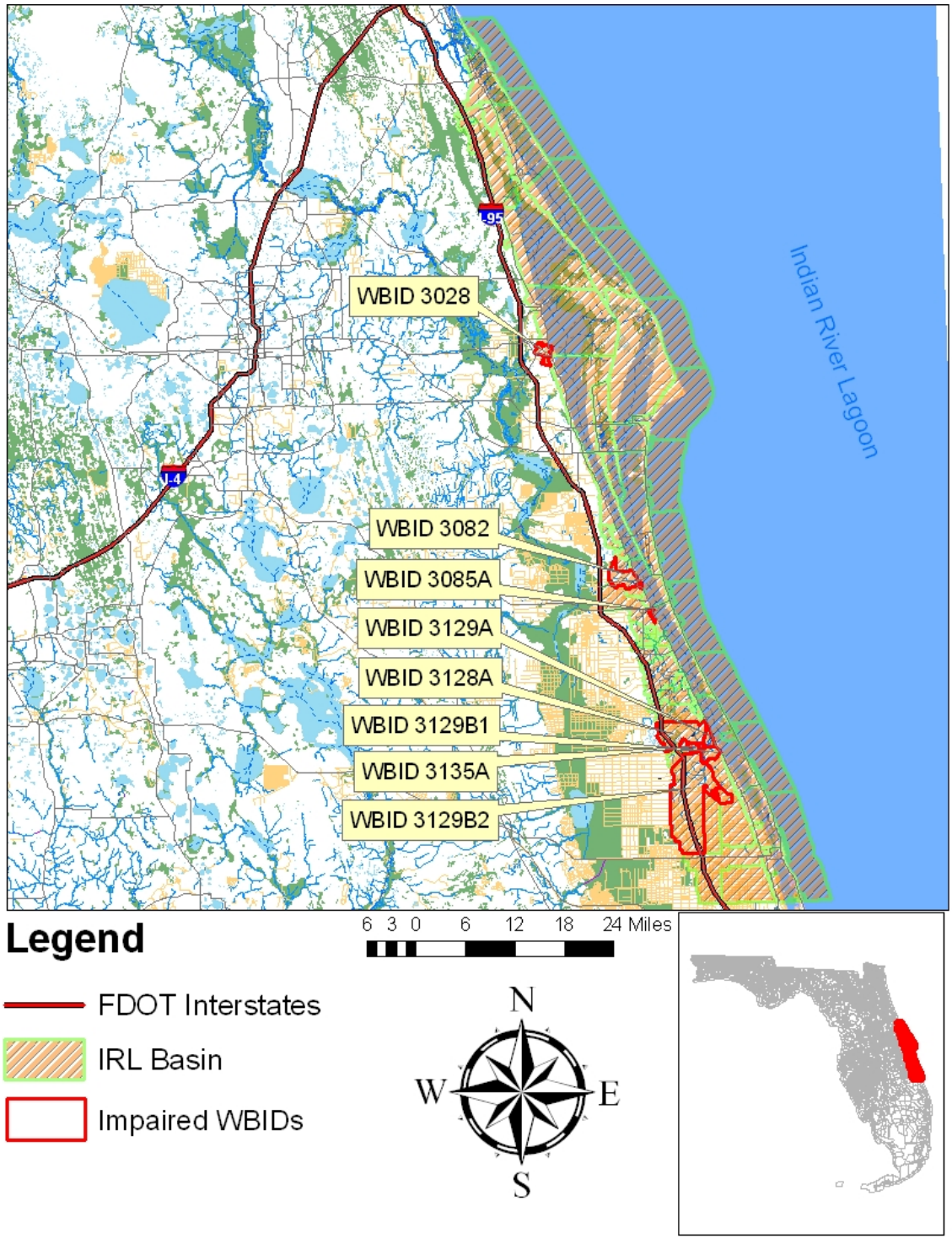


Figure 1.1. Location of Impaired Tributary Segments in the IRL Basin

Addison Creek is a waterbody located in the south of City of Titusville, Brevard County (**Figure 1.2**) and discharges to IRL in a northeast direction. The watershed of the creek is relatively natural, with about 25% of urban land uses. Most part of the watershed is occupied by forests and wetlands.

The Eau Gallie River is located in the northern part of City of Melbourne, Brevard County (**Figure 1.3**). It flows primarily in an easterly direction into the Indian River Lagoon. A spillway located about 1.6 miles from the river mouth separates the river into an upstream freshwater and a downstream saltwater segments. The river also receives flow coming from Elbow Creek, which discharges into the main stem of the river from the south. The Eau Gallie River watershed is highly developed with the majority of the watershed areas occupied by urban land uses.

Crane Creek is a waterbody located in the east central part of City of Melbourne, Brevard County (**Figure 1.4**). The creek discharges to the IRL main stem in a southwest to northeast direction. The part of the Crane Creek segment verified for DO impairment is the tidal portion of the creek, which is located in between the mouth of the creek in the east and about 0.05 miles upstream of the Grant Street Water Reclamation Facility. The tidal creek receives discharge from Hickory Ditch from the south and stormwater discharges from numerous urban drainage canals from the west. Some parts of the western drainage basin of the creek may discharge toward east to the IRL or toward west to the Upper St. Johns River basin, depending on the regional weather condition.

The Sebastian River has two major tributaries: North Prong and South Prong (**Figure 1.5**). The North Prong watershed is located immediately north of the Brevard County–Indian River County line. The South Prong watershed includes a network of canals managed by City of Sebastian and Indian River County. This watershed also received drainage from the Vero Lakes development. Both the North and South Prongs join the Sebastian River near Roseland. The Sebastian River watershed is relatively rural with large portion of the watershed areas occupied by agricultural lands. Its natural drainage area has been expanded through the Sottile, C-54, and Fellsmere Canals.

The C-54 Canal is located in the southern portion of Brevard County (**Figure 1.6**). The Canal was constructed by the U.S. Army Corps of Engineers (USACOE) in 1969 to provide flood control for the Upper St. Johns River Basin. The SJRWMD now owns and operates the C-54 Canal. Water may be released after, or in anticipation of, large storm events from the S-96 structure on the C-54 Canal into the Sebastian River.

1.3 Background

This report was developed as part of the Department's watershed management approach for restoring and protecting state waters and addressing TMDL Program requirements. The

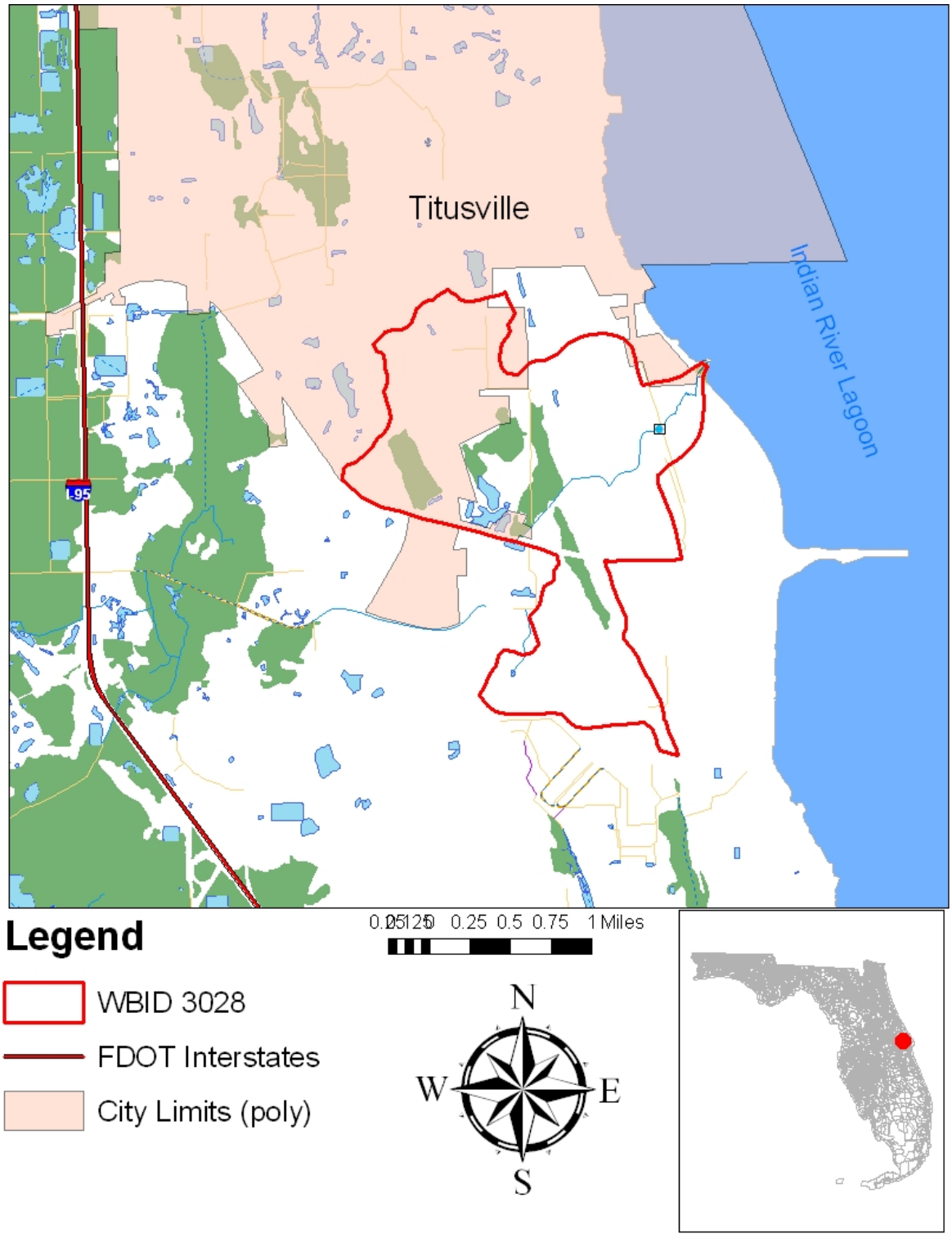


Figure 1.2. The Location of the Addison Creek WBID

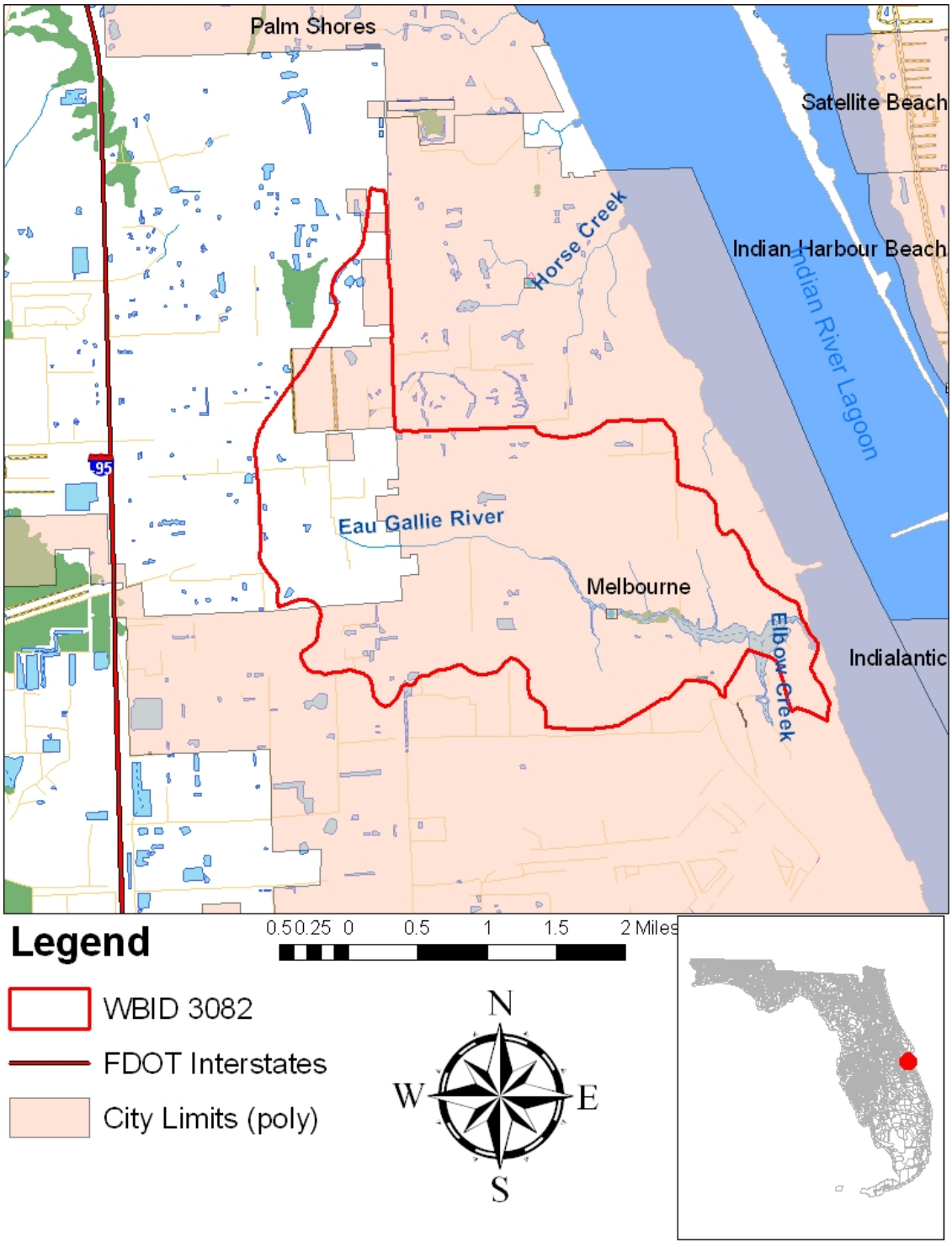


Figure 1.3. Location of the Eau Gallie River WBID

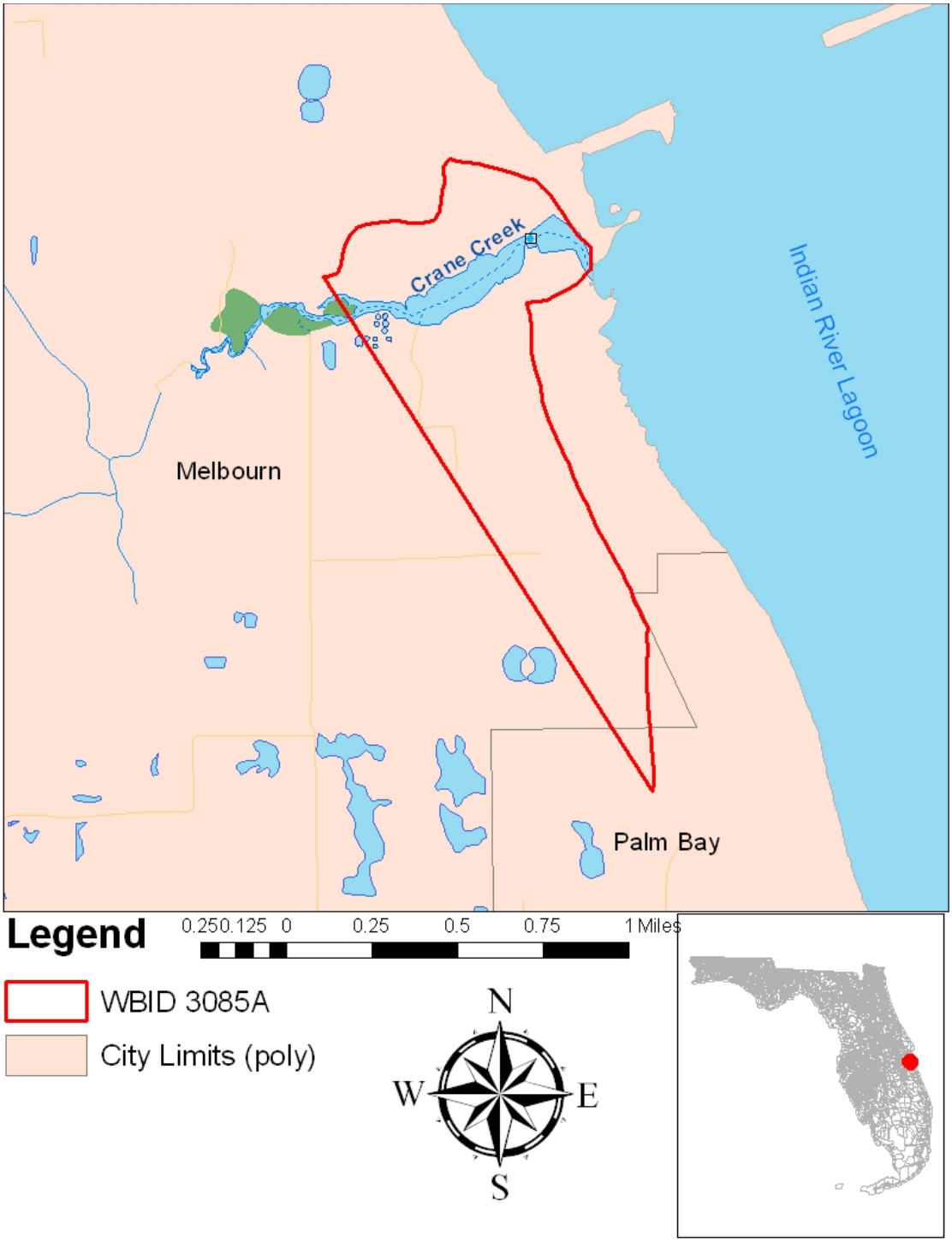


Figure 1.4. The Location of the Crane Creek WBID

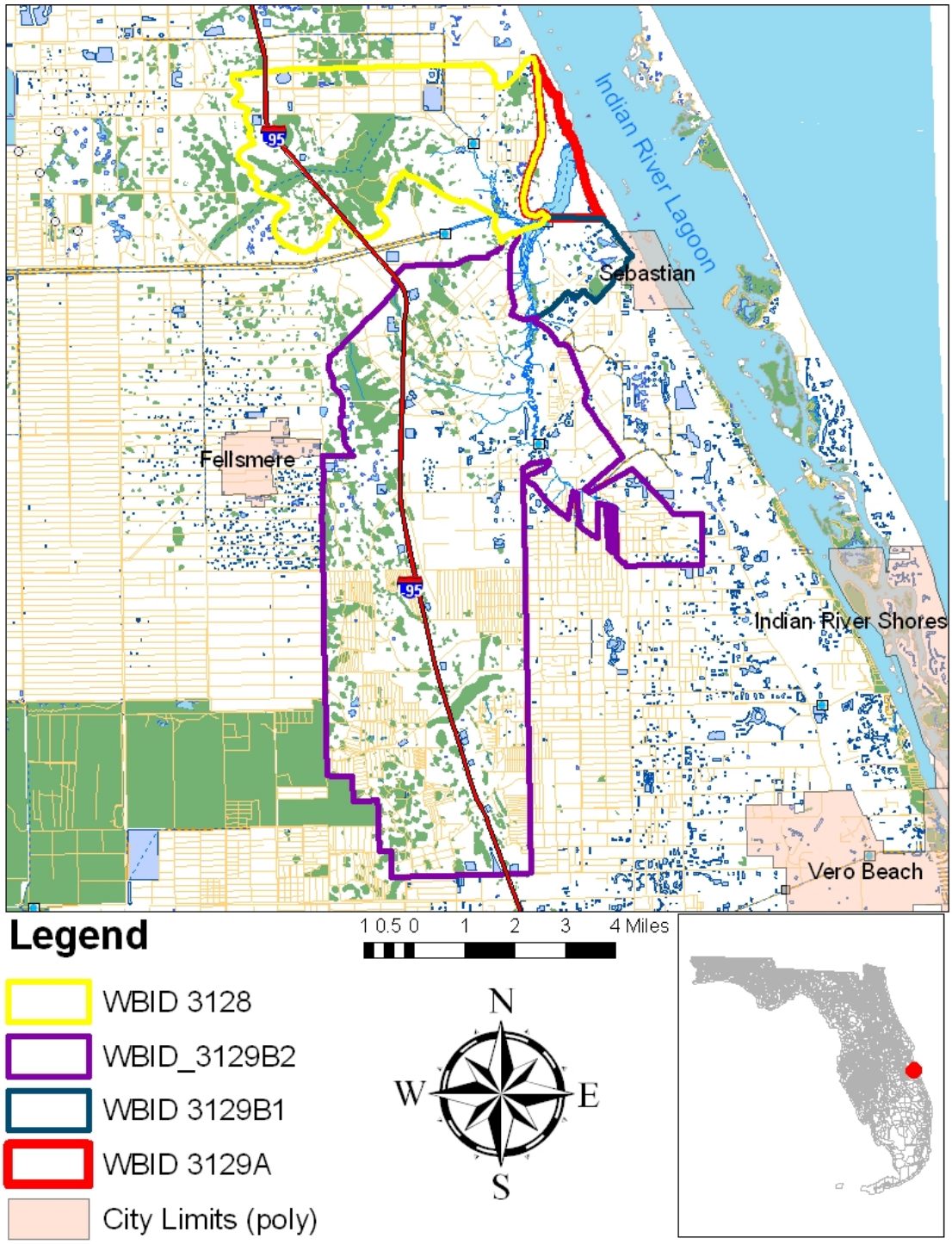


Figure 1.5. The Location of North Prong, South Prong, and Main Stem of the Sebastian River

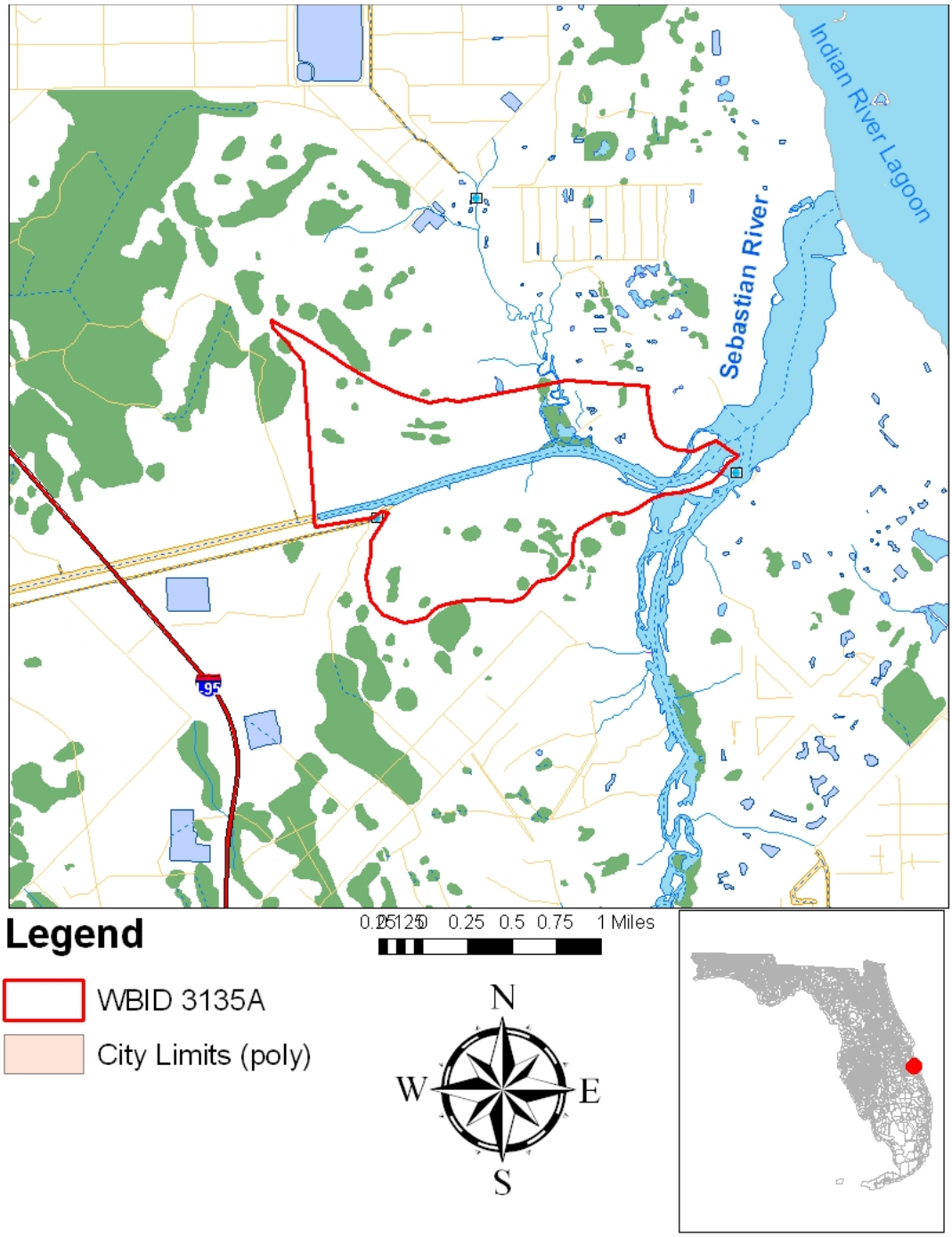


Figure 1.6. The Location of the C-54 Canal WBID

watershed approach, which is implemented using a cyclical management process that rotates through the state's 52 river basins over a 5-year cycle, provides a framework for implementing the TMDL Program–related requirements of the 1972 federal Clean Water Act and the Florida Watershed Restoration Act (FWRA).

A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality standards, including its applicable water quality criteria and its designated uses. TMDLs are developed for waterbodies that are verified as not meeting their water quality standards, and provide important water quality restoration goals that will guide restoration activities.

A nutrient and dissolved oxygen (DO) TMDL report for the Indian River Lagoon and Banana River Lagoon was established by the United States Environmental Protection Agency (EPA) in 2007 (EPA, 2007). TMDLs included in that report addressed the nutrient and DO conditions in the main stem Indian River Lagoon, as well as tributary water segments, using the water quality targets developed by the SJRWMD (Steward and Green, 2006 and 2007) with the intent to restore the seagrass distribution in the Indian River Lagoon and Banana River Lagoon. Several tributaries in this TMDL report were also in the EPA's TMDL report for nutrient and nutrient/DO impairments, which include the Eau Gallie River (on the Consent Decree List for nutrients), Crane Creek (on the Consent Decree List for DO and Nutrients), the North Prong of Sebastian River (on the Consent Decree List for DO and Nutrients), the Sebastian River above Indian River (on the Consent Decree for DO and Nutrients) and the C-54 Canal (on the Consent Decree List for DO and Nutrients). In 2009, the Department adopted nutrient and DO TMDLs only to address the nutrient and DO impairments for the main stems of Indian River Lagoon and Banana River Lagoon (FDEP, 2009). DO and nutrient impairments of these tributaries were not included in the Department's 2009 TMDL report because (1) except for the Eau Gallie River, the nutrient conditions of other tributary segments were not verified based on the available data (1/1/1999 through 6/30/2006) at the time the Department adopted the main stem seagrass TMDLs; and (2) for those tributaries verified for DO impairment, it was not clear whether nutrient levels had any impact on the observed low DO and, if nutrients indeed have some impacts, whether the nutrient loading targets for the main stem segments were sufficient to address the DO condition in these impaired tributaries. In addition, the BOD was considered the causative pollutant in several tributaries impaired for low DO. BOD was not addressed in the main stem seagrass TMDL/PLRG. Therefore, the Department decided to address the DO and nutrient impairments of these tributary segments in a separate set of TMDLs.

This TMDL report will be followed by the development and implementation of a restoration plan to reduce the pollutant loads that cause the verified DO impairment in these impaired tributary segments. These activities will depend heavily on the active participation of the SJRWMD, local governments, businesses, and other stakeholders. The Department will work with these organizations and individuals to undertake or continue reductions in the discharge of pollutants and achieve the established TMDLs for impaired waterbodies.

Chapter 2: DESCRIPTION OF WATER QUALITY PROBLEM

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the Clean Water Act requires states to submit to the EPA a list of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant source in each of these impaired waters on a schedule. The Department has developed these lists, commonly referred to as 303(d) lists, since 1992. The list of impaired waters in each basin is also required by the Florida Watershed Restoration Act (FWRA, Subsection 403.067[4)] Florida Statutes [F.S.]), and the list is amended annually to include updates for each basin statewide.

Florida's 1998 303(d) list included 16 waterbodies in the Indian River Lagoon Basin. However, the FWRA (Section 403.067, F.S.) stated that all previous Florida 303(d) lists were for planning purposes only and directed the Department to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After a long rulemaking process, the Environmental Regulation Commission adopted the new methodology as Chapter 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001, and modified in 2006 and 2007. The list of waters for which impairments have been verified using the methodology in the IWR is referred to as the Verified List.

2.2 Information on Verified Impairment

As defined in the IWR, the primary assessment index for assessing stream and estuarine nutrient condition is the annual average corrected chlorophyll *a* (Chlac) concentration. A stream or an estuary can be listed for nutrient impairment if, during the verified period of an assessment, its annual average ChlaC concentration exceeds the 20 µg/L threshold for streams and 11 µg/L threshold for estuary in any given year, or its annual average ChlaC concentration exceeds the 5-year rolling historical minimum annual average concentration by more than 50 percent in two consecutive years. In addition, the IWR also allows the use of information other than ChlaC concentration to verify nutrient-based impairment, including algal blooms, excessive macrophyte growth, a decrease in the distribution (either in density or areal coverage) of seagrasses or other submerged aquatic vegetation, changes in algal species richness, and excessive diel oxygen swings.

A waterbody can be verified for low DO impairment if more than 10 percent of DO samples show DO concentrations lower than the 5.0 mg/L criterion for streams or lower than the 5.0 mg/L criterion in a 24-hour period on average or the 4.0 mg/L any time for estuaries. In addition, the 10 percent exceedance rate needs to be met with 90 percent confidence level using the binomial distribution. The actual number of exceedance required for a given total number of collected samples to verify DO impairment is specified in the IWR. In order to verify the DO impairment for a given waterbody, besides the required number of DO exceedance, IWR also requires identification of the pollutant(s) that cause the observed lower DO condition. The following sections discussed the information used to verified DO and nutrient impairments

for eleven tributary segments in the IRL basin. Waterbodies are discussed in a north to south order

2.2.1 Addison Creek

Addison Creek (WBID 3028) was verified for the low DO impairment during the Department's Cycle 1 water quality assessment for Group 5 basins (based on data collected in the period from January 1, 1999 through June 30, 2006) because 48 of 72 DO measurements were lower than the 5.0 mg/L DO criterion. The median BOD concentration calculated based on 21 BOD measurements was 2.1 mg/L, which exceeded the assessment threshold of 2.0 mg/L for streams (**Table 2.1**). The median TN concentration calculated based on 48 TN measurements was 1.63 mg/L, which exceeded the assessment threshold of 1.6 mg/L for stream system (**Table 2.2**).Therefore, BOD and TN were considered causative pollutants for observed low DO concentration when the creek was verified for DO impairment. The impairment was confirmed based on the result of the Cycle 2 assessment (January 1, 2004, through June 30, 2011) which showed that 66 out of 111 DO measurements were lower than the 5.0 mg/L DO criterion (**Table 2.2**). The median BOD concentration calculated based on 39 BOD measurements was 2.0 mg/L, which met the assessment threshold of 2.0 mg/L for freshwater systems (**Table 2.1**). BOD was considered the causative pollutant for the low DO concentration during the Cycle 2 assessment. (**Table 2.2**).

Table 2.1. Threshold Values for Nutrient Parameters by Waterbody Type

	BOD	TN	TP
Lake	2.9	1.7	0.11
Coastal	2.1	1.0	0.19
Estuary	2.1	1.0	0.19
Spring	2.0	1.6	0.22
Stream	2.0	1.6	0.22
Blackwater	2.0	1.6	0.22

Note: Threshold values in this table were the 70th percentile of the concentration in all Florida waters of the same waterbody type.

Table 2.2. Data Used to Verify the DO Impairment in Addison Creek (Cycle 1 and Cycle 2 Water Quality Assessments)

Parameter	**Number**	
	Cycle 1	**Cycle 2**
Total number of samples	72	111
IWR required number of exceedances for the verified list	12	16
Number of observed exceedances	48	66
Number of seasons during which samples were collected	4	4
Highest DO observation (mg/L)	6.57	8.16
Lowest DO observation (mg/L)	1.18	0.12
Median DO observation (mg/L)	3.85	4.64
Mean DO observation (mg/L)	4.04	4.43
Median value for BOD observations (mg/L)	2.1	2.0

Median value for TN observations (mg/L)	1.63	1.406
Median value for TP observations (mg/L)	0.16	0.151
Possible causative pollutant by IWR	TN and BOD	BOD
FINAL ASSESSMENT	Impaired	Impaired

2.2.2 Eau Gallie River

Eau Gallie River (3082) was also verified for the low DO impairment during the Department's Cycle 1 water quality assessments for Group 5 basins because 49 of 207 DO measurements were lower than the 4.0 mg/L DO criterion (**Table 2.3**). The median BOD concentration calculated based on 9 BOD measurements was 4.0 mg/L, which exceeded the assessment threshold of 2.1 mg/L for estuary systems (**Table 2.1**). Therefore, BOD was considered the causative pollutant for observed low DO concentration. The impairment was confirmed based on the result of the Cycle 2 assessment (January 1, 2004, through June 30, 2011) which showed that 84 out of 417 DO measurements were lower than the 4.0 mg/L DO criterion (**Table 2.2**). The median TN concentration calculated based on 217 measurements was 1.001 mg/L, which exceeded the assessment threshold of 1.0 mg/L for estuarine systems (**Table 2.1**). TN was considered the causative pollutant for the low DO concentration during the Cycle 2 assessment. (**Table 2.3**).

Table 2.3. Data Used to Verify the DO Impairment in Eau Gallie River (Cycle 1 and Cycle 2 Assessments)

Parameter	Number	
	Cycle 1	**Cycle 2**
Total number of samples	207	417
IWR required number of exceedances for the verified list	27	51
Number of observed exceedances	49	84
Number of seasons during which samples were collected	4	4
Highest DO observation (mg/L)	19.3	15.91
Lowest DO observation (mg/L)	0.33	0.33
Median DO observation (mg/L)	5.89	5.99
Mean DO observation (mg/L)	6.07	6.07
Median value for BOD observations (mg/L)	4.0	No data
Median value for TN observations (mg/L)	1.11	1.001
Median value for TP observations (mg/L)	0.14	0.156
Possible causative pollutant by IWR	BOD	TN
FINAL ASSESSMENT	Impaired	Impaired

The Eau Gallie River was also verified for nutrient impairment during the Department's Cycle 1 water quality assessments based on the observation that the annual average corrected chlorophyll *a* (ChlaC) concentration exceeded the 11 µg/L assessment threshold in 1999, 2000, 2001, 2002, and 2005. The IWR requires the Department to identify the limiting nutrient in order to verify nutrient impairment. The parameter to be examined to determine the limiting nutrient is the long-term median value of the total nitrogen (TN) to total phosphorus (TP) ratio based on the

TN and TP weight concentration (mg/L). If the TN and TP ratio is larger than 30, phosphorus will be considered the limiting nutrient. If the TN and TP ratio is small than 10, nitrogen will be considered the limiting nutrients. If the ratio falls in between 10 and 30, the phytoplankton communities will be considered co-limited by both nitrogen and phosphorus. It has been commonly accepted that limiting nutrient is the nutrients that controls the growth of phytoplankton. Therefore, when developing nutrient TMDLs, the effort of controlling watershed nutrient loadings entering an impaired water segment should be focusing on controlling the loading of the limiting nutrients. For the Eau Gallie River, because the median TN/TP ratio for the Verified Period (January 1, 1999 through June 30, 2006) was about 7.8, which is smaller than 10, nitrogen is considered the limiting nutrient that caused the observed nutrient impairment. **Table 2.4** shows the assessment results that caused the waterbody to be verified for nutrient impairment. The nutrient impairment of the river was also verified in Cycle 2 water quality assessment.

Table 2.4. Information Used to Verify the Eau Gallie River (WBID 3082) for Nutrient Impairment (Cycle 1 and Cycle 2 Assessments)

WBID	Parameter	Summary of Observation	
		3082 in Cycle 1	**3082 in Cycle 2**
Eau Gallie River (WBID 3082)	Annual Average *ChlaC* Concentration	1999 15.1 µg/L 2000 14.5 µg/L 2001 25.0 µg/L 2002 19.6 µg/L 2003 8.2 µg/L 2004 8.9 µg/L 2005 12.3 µg/L	2004 9.0 µg/L 2005 12 µg/L 2006 8.0 µg/L 2007 8.0 µg/L 2008 16.0 µg/L 2009 26 µg/L 2010 33.3 µg/L
	Median TN Concentration	1.11 mg/L (130 samples)	1.001 mg/L (217 samples)
	Median TP Concentration	0.142 mg/L (131 samples)	0.156 mg/L (235 samples)
	TN/TP Ratio	7.8	6.4
	Final Assessment Result	Impaired. Nitrogen is the limiting nutrient.	Impaired. Nitrogen is the limiting nutrient.

2.2.3 Crane Creek

Crane Creek (3085A) was verified for the low DO impairment during the Department's Cycle 1 water quality assessments for Group 5 basins because 23 of 118 DO measurements were lower than the 4.0 mg/L DO criterion (**Table 2.5**). The median BOD concentration calculated based on 31 BOD measurements was 2.6 mg/L, which exceeded the assessment threshold of 2.1 mg/L for estuary systems (**Table 2.1**). Therefore, BOD was considered the causative pollutant for observed low DO concentrations in the creek. The result of the Cycle 2 assessment showed that the DO condition in Crane Creek was not impaired (**Table 2.5**). However, the Department could not delist from the Verified List because it did not satisfy the delisting requirements.

The WBID was also verified for nutrient impairment during the Department's Cycle 2 water quality assessments (January 1, 2004 through June 30, 2011) for Group 5 basins based on the observation that the annual average *ChlaC* concentration exceeded the 11 µg/L assessment threshold in 2008, 2009 and 2010. The waterbody was put on the Department's Verified List

adopted through a Secretarial Order signed on February 7, 2012. Based on a long-term median value of the TN/TP ratio of 7.5 for the Verified Period (January 1, 2004 through June 30, 2011), at the time the waterbody was verified for nutrient impairment, nitrogen was considered the limiting nutrient for observed elevation in ChlaC concentration. **Table 2.6** shows the assessment results that caused the waterbody to be verified for nutrient impairment.

Table 2.5. Data Used to Verify the DO Impairment in Crane Creek (Cycle 1 and Cycle 2 Water Quality Assessments)

Parameter	Number	
	3085A in Cycle 1	**3085A in Cycle 2**
Total number of samples	118	177
IWR required number of exceedances for the verified list	17	24
Number of observed exceedances	23	19
Number of seasons during which samples were collected	4	4
Highest DO observation (mg/L)	11.01	15.01
Lowest DO observation (mg/L)	0.15	0.14
Median DO observation (mg/L)	5.46	5.85
Mean DO observation (mg/L)	5.49	6.08
Median value for BOD observations (mg/L)	2.6	1.95
Median value for TN observations (mg/L)	0.97	0.962
Median value for TP observations (mg/L)	0.14	0.121
Possible causative pollutant by IWR	BOD	---
FINAL ASSESSMENT	Impaired	Not Impaired

Table 2.6. Information Used to Verify Crane Creek (WBID 3085A) for Nutrient Impairment (Cycle 2 Assessments)

WBID	Parameter	Summary of Observation
Crane Creek (WBID 3085A)	Annual Average *ChlaC* Concentration	2004 9.0 µg/L 2005 9.0 µg/L 2006 9.0 µg/L 2007 10.0 µg/L 2008 12.0 µg/L 2009 21.0 µg/L 2010 27.0 µg/L
	Median TN Concentration	0.962 mg/L (# of samples = 129)
	Median TP Concentration	0.121 mg/L (# of samples =134)
	TN/TP Ratio	7.5
	Final Assessment Result	Impaired. Nitrogen is the limiting nutrient.

2.2.4 North Prong of the Sebastian River

North Prong of the Sebastian River (WBID 3128) was verified for low DO impairments during the Department's Cycle 1 water quality assessments for Group 5 basins because 65 of 105 DO measurements were lower than the 5.0 mg/L DO criterion (**Table 2.7**). The median BOD concentration calculated based on 22 BOD measurements was 2.2 mg/L, which exceeded the assessment threshold of 2.0 mg/L for streams (**Table 2.1**). Therefore, when the waterbody was verified for the DO impairment, BOD was considered the causative pollutant for observed low DO concentrations.

During the Cycle 2 assessment (January 1, 2004 through June 30, 2011), the original WBID was divided into two parts, i.e., freshwater and marine segments. The freshwater part inherited the original waterbody ID (WBID 3128). The marine water part of the original WBID 3128 was combined into a re-delineated WBID (WBID 3135A), which was designated as the "C-54 Canal Confluence with St. Sebastian River." In Cycle 1 assessment, when used data only from the freshwater segment, 25 out of 50 DO measurements were lower than the 5.0 mg/L criterion and DO impairments were still verified. The impairment was confirmed based on the result of WBID 3128A during the Cycle 2 assessment (January 1, 2004, through June 30, 2011) which showed 20 out of 44 DO measurements lower than the 5.0 mg/L DO criterion (**Table 2.7**). However, There was no data available for TN, TP, and BOD data during the Cycle 2 assessment and no causative pollutants were identified for the low DO concentration. **Figure 2.1** shows the waterbody delineation changes of North Prong between the Cycle 1 and Cycle 2 assessments.

Table 2.7. Data Used to Verify the DO Impairment in North Prong Sebastian River (Cycle 1 Assessments)

Parameter	Number	
	3128 in Cycle 1	3128A in Cycle 2
Total number of samples	105	44
IWR required number of exceedances for the verified list	16	8
Number of observed exceedances	65	20
Number of seasons during which samples were collected	4	4
Highest DO observation (mg/L)	10.5	10.42
Lowest DO observation (mg/L)	0.11	0.19
Median DO observation (mg/L)	4.61	4.96
Mean DO observation (mg/L)	4.21	4.82
Median value for BOD observations (mg/L)	2.2	No data
Median value for TN observations (mg/L)	0.97	No data
Median value for TP observations (mg/L)	0.11	No data
Possible causative pollutant by IWR	BOD	No Causative Pollutant
FINAL ASSESSMENT	Impaired	Impaired

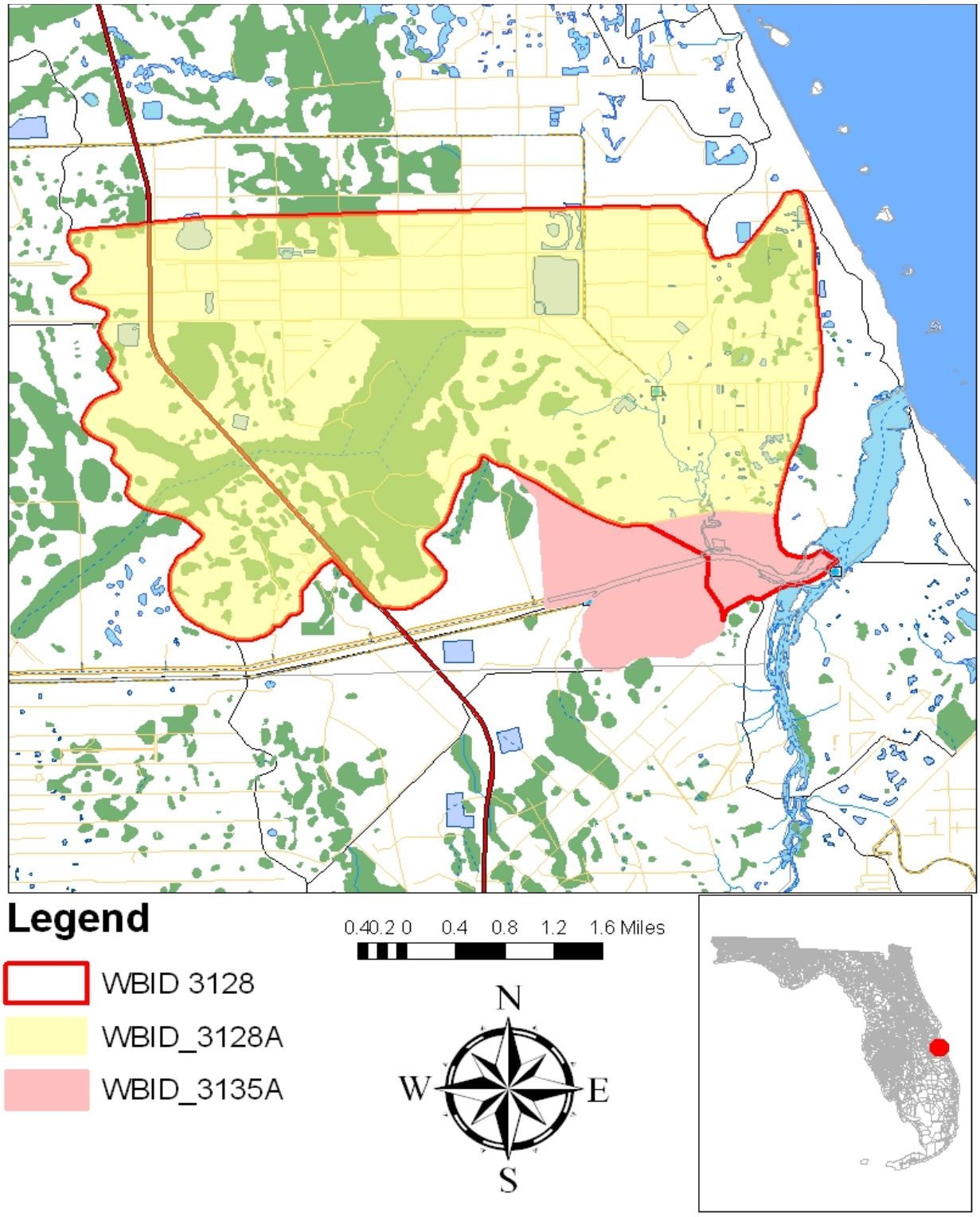


Figure 2.1 The waterbody delineation changes of North Prong between the Cycle 1 and Cycle 2 assessements

2.2.5 South Prong of Sebastian River Estuary Segment (3129B1) and South Prong of Sebastian River Freshwater Segment (3129B2)

South Prong of Sebastian River Estuary Segment (3129B1) and South Prong of Sebastian River Freshwater Segment (3129B2) were originally parts of the single WBID called "Sebastian River" (3129B). The WBID 3129B was listed on the 1998 303(d) list based on low DO. During the Department 's Cycle 1 water quality assessment for Group 5 basins, this WBID was verified for low DO impairments (**Table 2.8**) based on the observation that 120 of 355 DO measurements were lower than the 5.0 mg/L DO criterion. Because the median BOD concentration of 26 BOD measurements was 3.4 mg/L and exceeded the 2.0 mg/L threshold for streams, BOD was considered the causative pollutant for the observed low DO at the time the waterbody was verified for the low DO impairment. The WBID was divided into two parts in the Department's Cycle 2 assessment, including an estuarine segment (South Prong St. Sebastian River Estuarine Segment, WBID 3129B1) and a freshwater segment (South Prong St. Sebastian River Freshwater Segment, 3129B2). The estuarine segment (3129B1) was verified for low DO impairment during the Department's Cycle 2 water quality assessments for Group 5 basins (based on DO data collected in the period from January 1, 2004 through June 30, 2011) because 41 of 124 DO measurements were lower than the 4.0 mg/L DO criterion (**Table 2.8**). The median BOD concentration calculated based on 26 BOD measurements was 3.4 mg/L, which exceeded the assessment threshold of 2.1 mg/L for estuary systems (**Table 2.1**). Therefore, BOD was considered the causative pollutant for observed low DO concentration. During Cycle 1 assessment, 81% of data were collected from estuarine segment and 19% from freshwater segment and both were impaired by low DO concentrations.

The freshwater segment (3129B2) was also impaired for low DO during Department's Cycle 2 water quality assessments due to 15 out of 41 DO measurements lower than the 5.0 mg/L DO criterion. However, no causative pollutants were identified for low DO concentration. **Figure 2.2** shows the waterbody delineation changes of South Prong between the Cycle 1 and Cycle 2 assessments.

Table 2.8. Data Used to Verify the DO Impairment in the Sebastian River (South Prong St. Sebastian River Estuary Segment) (Cycle 1 and Cycle 2 Assessments)

Parameter	3129B in Cycle 1	3129B1 in Cycle 2
Total number of samples	355	124
IWR required number of exceedances for the verified list	44	18
Number of observed exceedances	120	41
Number of seasons during which samples were collected	4	4
Highest DO observation (mg/L)	9.79	9.79
Lowest DO observation (mg/L)	0.17	0.11
Median DO observation (mg/L)	5.52	5.02
Mean DO observation (mg/L)	5.24	4.81
Median value for BOD observations (mg/L)	3.4	3.4
Median value for TN observations (mg/L)	0.94	0.86
Median value for TP observations (mg/L)	0.13	0.13
Possible causative pollutant by IWR	BOD	BOD
FINAL ASSESSMENT	Impaired	Impaired

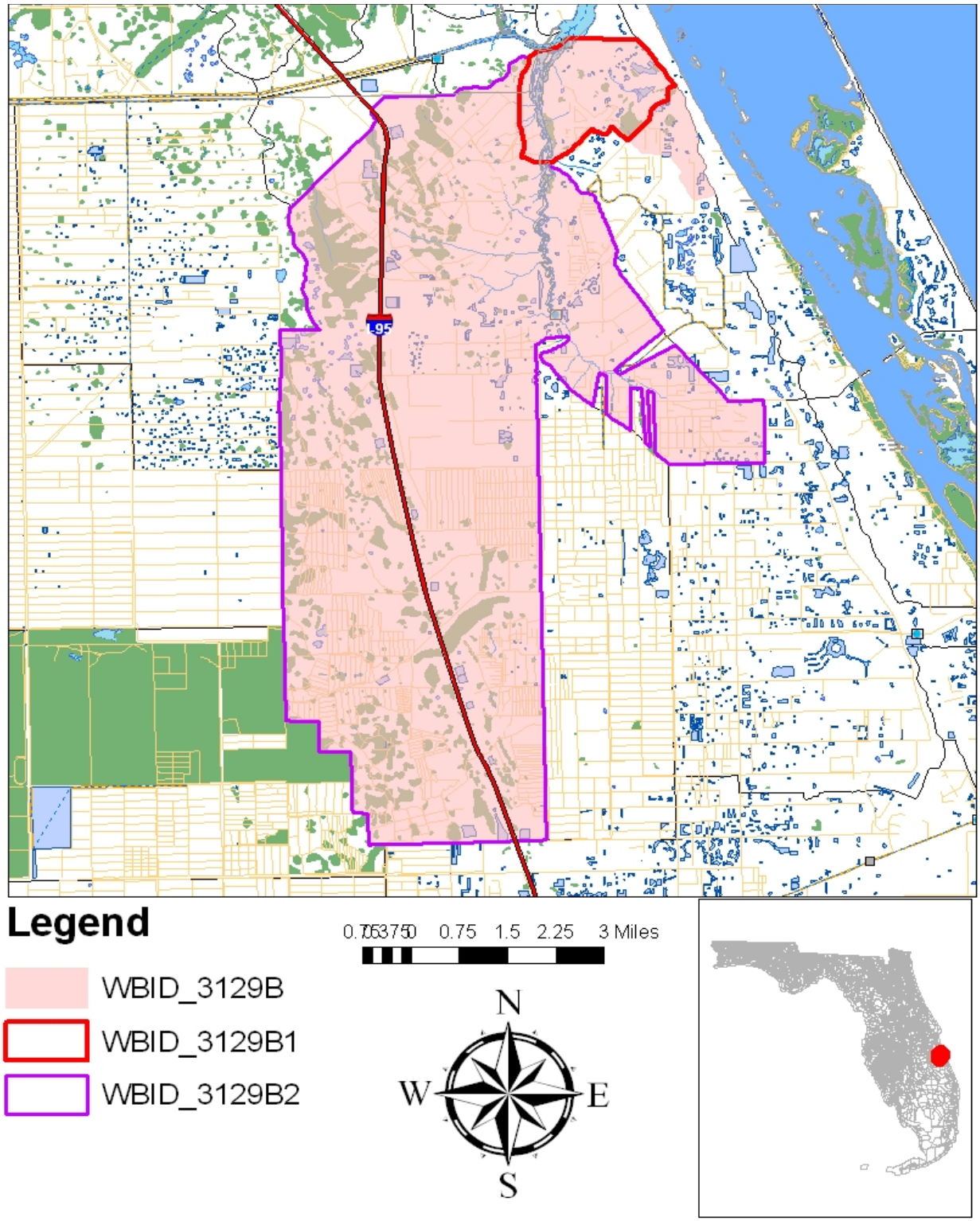


Figure 2.2 The waterbody delineation changes of South Prong between the Cycle 1 and Cycle 2 assessments

WBID 3129B1 was also verified for nutrient impairment during the Department's Cycle 2 water quality assessments (January 1, 2004 through June 30, 2011) for Group 5 basins based on the observation that the annual average *ChlaC* concentrations exceeded the 11 µg/L assessment threshold in 2005 and 2010. The waterbody was put on Department's Verified List adopted through a Secretarial Order signed on February 7, 2012. Because the long-term TN/TP ratio is 6.6 and less than 10, nitrogen was considered the limiting nutrients. **Table 2.9** shows the assessment results that caused the waterbody to be verified for nutrient impairment.

Table 2.9. Information Used to List WBID 3129B1 for Nutrient Impairment (Cycle 2 Assessments)

WBID	Parameter	Summary of Observation
South Prong (WBID 3129B1)	Annual Average *ChlaC* Concentration	2004 6.0 µg/L 2005 13.0 µg/L 2006 5.0 µg/L 2007 5.0 µg/L 2008 8.0 µg/L 2009 9.0µg/L 2010 15.0 µg/L
	Median TN Concentration	0.86 mg/L (# of samples = 111)
	Median TP Concentration	0.13 mg/L (# of samples =122)
	TN/TP Ratio	6.6
	Final Assessment Result	Impaired. Nitrogen is the limiting nutrient.

2.2.6 Sebastian River Above Indian River Lagoon

Sebastian River Above Indian River Lagoon (3129A) is the main stem of the Sebastian River. The river segment was verified for the low DO impairment during the Department's Cycle 1 water quality assessments for Group 5 basins because 74 out of 105 DO measurements were lower than the 4.0 mg/L DO criterion (**Table 2.10**). The median BOD concentration calculated based on 22 BOD measurements was 2.2 mg/L, which exceeded the assessment threshold of 2.1 mg/L for estuary systems (**Table 2.1**). Therefore, BOD was considered the causative pollutant for observed low DO concentration.

The result of the Cycle 2 assessment showed that this water segment was not impaired for low DO (**Table 2.10**). However, the Department could not delist the WBID from the Verified List because it did not satisfy the delisting requirement. Therefore, the Department will develop the DO TMDL for the Sebastian River above IRL.

The WBID was also verified for the nutrient impairment during the Department's Cycle 2 water quality assessments for Group 5 basins based on *ChlaC* data collected in the period from January 1, 2004 through June 30, 2011). In the Cycle 2 assessment, although the annual average *ChlaC* concentration in no Verified Period year exceeded the 11 µg/L threshold, the annual *ChlaC* concentration exceeded the historic minimum (4.9 µg/L, based on data collected in the period from 1999 through 2003) by more than 50% in 2009 and 2010. The nutrient condition of the segment of the river was therefore considered impaired. The waterbody was put on Department's Verified List adopted through a Secretarial Order signed on February 7,

2012. Based on a long-term median TN/TP ratio of 8.4, which is less than 10, nitrogen is considered the limiting nutrient. **Table 2.11** shows the assessment results that caused the WBID 3129A to be verified for nutrient impairment. Based on a median TN/TP ratio of about 8.4, the phytoplankton communities of the creek appear to be nitrogen-limited.

Table 2.10. Data Used to Verify the DO Impairment in the Sebastian River above Indian River Lagoon (Cycle 1 and Cycle 2 Assessments)

Parameter	Number	
	3129A in Cycle 1	3129A in Cycle 2
Total number of samples	537	575
IWR required number of exceedances for the verified list	54	58
Number of observed exceedances	74	49
Number of seasons during which samples were collected	4	4
Highest DO observation (mg/L)	11.5	12.91
Lowest DO observation (mg/L)	0.16	0.08
Median DO observation (mg/L)	5.82	6.01
Mean DO observation (mg/L)	5.76	5.95
Median value for BOD observations (mg/L)	2.6	2.6
Median value for TN observations (mg/L)	0.84	0.698
Median value for TP observations (mg/L)	0.08	0.075
Possible causative pollutant by IWR	BOD	---
FINAL ASSESSMENT	Impaired	Not Impaired

Table 2.11. Information Used to List WBID 3129A for Nutrient Impairment in Sebastian River Above Indian River Lagoon (Cycle 2 Assessments)

WBID	Parameter	Summary of Observation
Sebastian River above Indian River Lagoon (WBID 3129A)	Annual Average *ChlaC* Concentration	2004 3 µg/L 2005 8 µg/L 2006 3 µg/L 2007 4 µg/L 2008 7 µg/L 2009 8 µg/L 2010 10 µg/L
	Historic Minimum Annual Average *ChlaC*	4.9 µg/L based on data from 1999 through 2003
	Median TN Concentration	0.698 mg/L (# of samples = 107)
	Median TP Concentration	0.075 mg/L (# of samples =125)
	TN/TP Ratio	8.4
	Final Assessment Result	Impaired because the annual average *ChlaC* in 2009 and 2010 exceeded the historic minimum by more than 50%. Nitrogen is the limiting nutrient

2.2.7 C-54 Canal

C-54 Canal (3135) was verified for low DO impairments during the Department's Cycle 1 water quality assessments for Group 5 basins because 22 of 74 DO measurements were lower than the 4.0 mg/L DO criterion (**Table 2.7**). The median TN concentration calculated based on 73 TN measurements was 1.4 mg/L, which exceeded the assessment threshold of 1.0 mg/L for estuary systems (**Table 2.1**). Therefore, TN was considered the causative pollutant for observed low DO concentration.

In the Cycle 2 assessment (January 1, 2004 through June 30, 2011), WBID 3135 was extended to the confluence with the main stem of the Sebastian River and re-assigned a WBID number of 3135A. The impairment was confirmed based on the result of the Cycle 2 assessment (January 1, 2004, through June 30, 2011) which showed that 67 out of 173 DO measurements were lower than the 4.0 mg/L DO criterion (**Table 2.12**). The median BOD concentration calculated based on 43 measurements was 2.4 mg/L, which exceeded the assessment threshold of 2.1 mg/L for estuarine systems (**Table 2.1**). BOD was considered the causative pollutant for the low DO concentration during the Cycle 2 assessment.

Table 2.12. Data Used to Verify the DO Impairment in C-54 Canal (Cycle 1 and Cycle 2 Assessments)

Parameter	Number	
	3135 in Cycle 1	3135A in Cycle 2
Total number of samples	74	173
IWR required number of exceedances for the verified list	12	23
Number of observed exceedances	22	67
Number of seasons during which samples were collected	4	4
Highest DO observation (mg/L)	8.96	10.76
Lowest DO observation (mg/L)	0.54	0.06
Median DO observation (mg/L)	5.24	4.46
Mean DO observation (mg/L)	4.98	4.01
Median value for BOD observations (mg/L)	-	2.4
Median value for TN observations (mg/L)	1.4	0.919
Median value for TP observations (mg/L)	0.07	0.122
Possible causative pollutant by IWR	TN	BOD
FINAL ASSESSMENT	Impaired	Impaired

This WBID was verified for nutrient impairment for Group 5 basins, based on the observation that the annual average *ChlaC* concentration exceeded the 11 µg/L assessment threshold in 2005, 2008, 2009, and 2010. The waterbody was put on Department's Verified List adopted through a Secretarial Order signed on February 7, 2012. Based on a long-term median TN/TP ratio of 7.6, which is less than 10, nitrogen was considered the limiting nutrient for the observed elevation in ChlaC concentrations. **Table 2.13** shows the assessment results that caused the waterbody to be verified for nutrient impairment.

Table 2.13. Information Used to List WBID 3135A for Nutrient Impairment (Cycle 2 Assessments)

WBID	Parameter	Summary of Observation
C-54 Canal at Confluence with St. Sebastian River (WBID 3135A)	Annual Average *ChlaC* Concentration	2004 8 µg/L 2005 22 µg/L 2006 10µg/L 2007 7 µg/L 2008 13 µg/L 2009 12 µg/L 2010 45 µg/L
	Median TN Concentration	0.919 mg/L (# of samples = 155)
	Median TP Concentration	0.122mg/L (# of samples =164)
	TN/TP Ratio	7.6
	Final Assessment Result	Impaired. Nitrogen is the limiting nutrient.

Figure 2.3 shows the waterbody delineation changes of C-54 Canal between the Cycle 1 and Cycle 2 assessments.

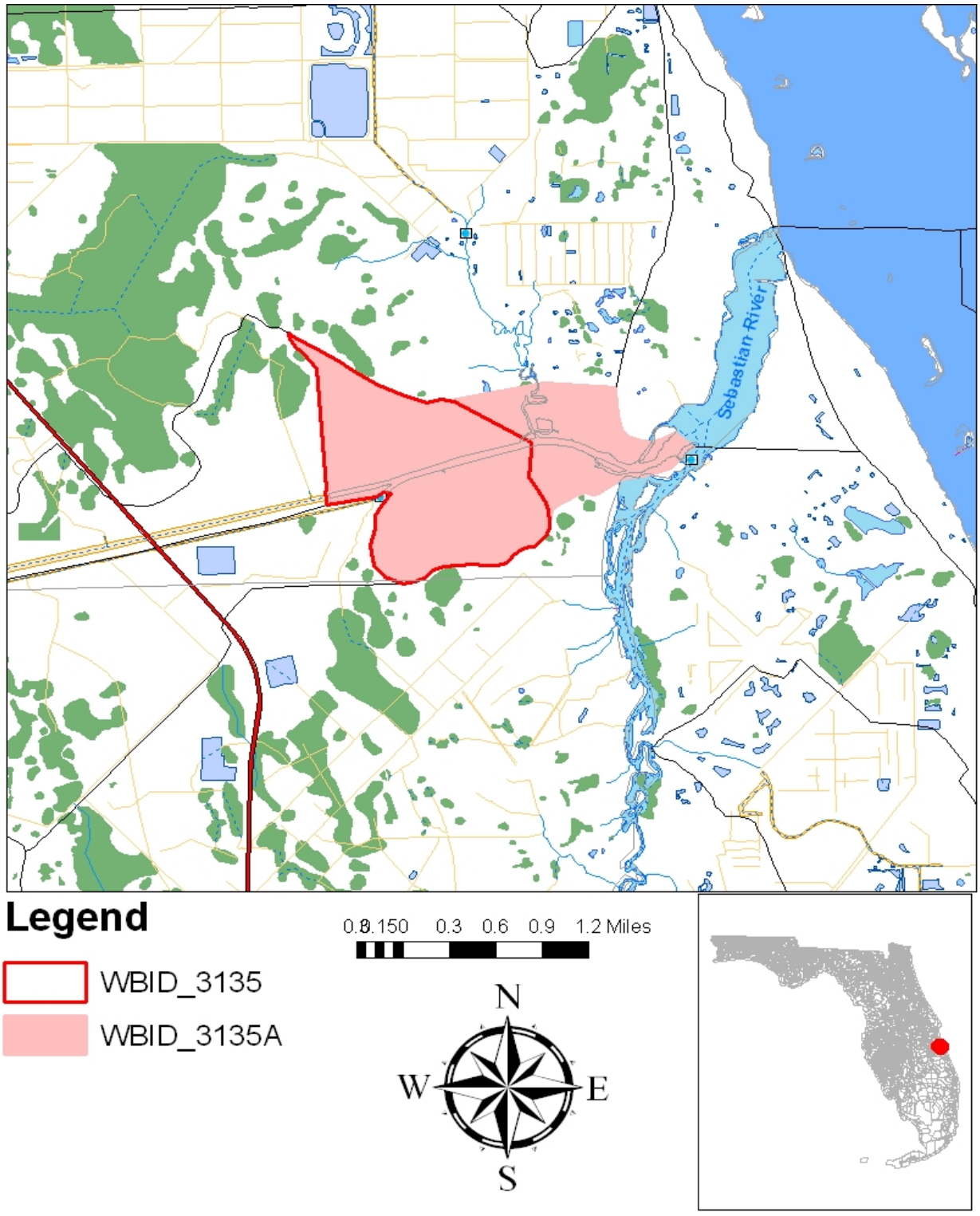


Figure 2.3 The waterbody delineation changes of C-54 Canal between the Cycle 1 and Cycle 2 assessments

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criteria Applicable to the TMDL

Florida's surface waters are protected for five designated use classifications, as follows:

Class I	**Potable water supplies**
Class II	**Shellfish propagation or harvesting**
Class III	**Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife**
Class IV	**Agricultural water supplies**
Class V	**Navigation, utility, and industrial use (there are no state waters currently in this class)**

The Eau Gallie River (WBID 3082), Crane Creek (WBID 3085A), Sebastian River above Indian River Lagoon (WBID 3129A), C-54 Canal (WBID 3135A) are Class III marine waterbodies, with a designated use of recreation, propagation, and maintenance of a healthy, well balanced population of fish and wildlife. The Class III water quality criteria applicable to the observed impairments [dissolved oxygen (DO) and/or nutrients] for these waters are the state of Florida's dissolved oxygen criterion [Rule 62-302.530(30), FAC] and narrative nutrient criterion [Rule 62-302.530(48) (b), FAC]. Therefore, both Class III water quality criteria for nutrients and DO are discussed in this TMDL report.

Addison Creek (WBID 3028) is a Class III fresh waterbodies with a designated use of recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife). The Class III water quality criterion applicable to the observed impairment [dissolved oxygen] for the waterbody is the state of Florida's dissolved oxygen criterion [Rule 62-302.530(30), FAC]. Although the waterbody segment was not verified for nutrient impairment, the possible influence of nutrients on DO could not be fully excluded because of the influence from other non-nutrient factors. Therefore, both Class III water quality criteria for nutrients and DO are discussed in this TMDL report.

The North Prong of the Sebastian River (WBID 3128) used to cover both a freshwater segment and marine segment and was considered a Class III waterbody. In the Department's Cycle 2 assessment, the freshwater and marine segments were split into separate WBIDs. The freshwater segment inherited the original WBID number while the marine segment was merged into the C-54 Canal WBID, which is, by itself, a marine segment. The State water quality criteria applied to Class III freshwater waterbodies apply to the North Prong of Sebastian River freshwater segment.

WBID boundary re-delineation also happened to the Sebastian River. Although this WBID was named in the past as the Sebastian River, the WBID actually represented the south prong of the Sebastian River. This WBID (originally WBID 3129B) included both a freshwater and marine water segments. During Department's Cycle 2 assessment, the

freshwater and marine water segments were split into two separate WBIDs. Both new water segments are still Class III waterbodies. Therefore, the State water quality criteria for Class III freshwater and Class III marine water waterbodies apply to the freshwater WBID and marine water segments, respectively.

3.2 Applicable Water Quality Standards and Numeric Water Quality Target

3.2.1. Interpretation of Narrative Nutrient Criterion

Florida's nutrient criterion, defined in the State's Surface Water Quality Standard (Chapter 62-302 F. A. C.), is narrative only—i.e., nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. Accordingly, a nutrient-related target was needed to represent levels at which an imbalance in flora or fauna is expected to occur. Threshold values commonly used for assessing the nutrient impairment are an annual average ChlaC concentration of 11 µg/L for estuaries and an annual average ChlaC concentration of 20 µg/L for streams. These threshold values are defined in the Impaired Waters Rule (IWR, Chapter 62-303 F.A.C). In addition, the IWR also allows the use of other information indicating imbalance in flora or fauna due to nutrient enrichment, including, but not limited to, algal blooms, excessive macrophyte growth, decrease in the distribution (either in density or areal coverage) of seagrasses or other submerged aquatic vegetation, changes in algal species richness, and excessive diel oxygen swings. It should be noted that these cut-off numbers should be considered only as assessment thresholds. If ChlaC concentration in a given assessed waterbodies higher than the threshold, the corresponding waterbody will be considered impaired for nutrient. However, these threshold values do not necessarily provide sufficient information on whether a given waterbody meets the designated use when the ChlaC concentration is lower (or higher) than the threshold. Therefore, nutrient targets specific to the waterbody of interest should always be examined when related information is available.

All tributary segments included in this TMDL reports were verified for DO impairments. The Eau Gallie River was verified for both DO and nutrient impairments. For several impaired tributary segments, the possible causative pollutants, based on comparing the median values of TN, TP, and BOD data available during the verified period with the threshold values shown in **Table 2.1**, was determined to be TN or TN and BOD, such as Addison Creek and the C-54 Canal. In the majority of the impaired tributaries included in this TMDL report, BOD was considered the sole causative pollutant, which appears not to be directly link to nutrients. However, because BOD, as an index representing the amount of organic carbon compounds in the water, could also come from algal biomass, which could be influenced by the availability of nutrient in the water, the influence of nutrient loading on DO concentration could not be fully excluded without detailed analyses. In addition, nutrient stimulated algal biomass can also be a potential source of organic carbon to the stream sediment, which is a major component of the sediment oxygen demand (SOD) that influence DO concentrations in many streams and tidal rivers. Therefore, gaining an understanding of how nutrient availability influences the DO concentration is an essential part of this TMDL.

In 2009, the Department adopted a set of DO and nutrient TMDLs for the main stems of Indian River Lagoon and Banana River Lagoon. These TMDLs were established based on the Indian River Lagoon and Banana River Lagoon PLRG developed by the SJRWMD (Steward and Green, 2006 and 2007) to restore the seagrass distribution in the Indian River Lagoon and

Banana River Lagoon. As it was defined in the PLRG, the adopted main stem DO and nutrient TMDLs divided the Indian River Lagoon into North Sub-Lagoon and Central Sub-Lagoon areas, and corresponding nutrient load targets were established for each sub-lagoon based on the per acre nutrient loading targets established by the PLRG. Except for Addison Creek and the Eau Gallie River, which are located in the drainage basin of the North Indian River Lagoon, all other impaired tributaries included in this TMDL reports are located in the drainage basin discharges to the Central Indian River Lagoon. Per acre nutrient targets were established for the North and Central Indian River Lagoon drainage areas. No matter whether the DO and nutrient TMDLs included in this report will require further nutrient reduction from the watersheds of these impaired water segments, these per acre loading targets are applicable to the watershed area of these impaired waters for restoring the seagrass communities in the main stem of the Indian River Lagoon.

3.2.2. Applicable DO and BOD Criterion

The State's applicable DO criterion (as defined in 62-303, F.A.C.) for Class III freshwater waterbodies is that the DO concentration "Shall not be less than 5.0. Normal daily and seasonal fluctuations above these levels shall be maintained." For Class III marine waterbodies is that the DO concentration "shall not average less than 5.0 (mg/L) in a 24-hour period and shall never be less than 4.0 (mg/L). Normal daily and seasonal fluctuations above these levels shall be maintained."

The applicable criteria for Biochemical Oxygen Demand (BOD) is narrative, which states that the BOD concentration for waterbodies of all designated uses "shall not be increased to exceed values which would cause dissolved oxygen to be depressed below the limit established for each class and, in no case, shall it be great enough to produce nuisance condition." This narrative criterion applies to both freshwater and marine waterbodies.

It should be noted that water column DO can be influenced by many environmental factors other than nutrients and BOD. For example, water temperature, in many cases, is the dominant factor that controls DO concentration in many aquatic systems through controlling the solubility of DO and influencing the metabolic rate, and therefore, DO consumption rate by water and sediment bacteria and aquatic flora and fauna. Temperature effects on DO concentration should be considered as a natural condition unless the natural temperature regime is changed by human activity, e.g. the temperature elevated cooling water discharge from power plants. In addition, clearance of riparian forest or decrease of water depth for a given river can also cause the water temperature to increase above the normal level because of the loss of shaded areas, which, in turn, may impact the DO dynamics in the receiving water. These impacts, however, are considered as being caused by physical factors instead of chemical factors, and therefore are beyond the consideration of TMDL development. Other non- chemical factors, including flow velocity, which may influence the DO concentration in the system through controlling the reaeration rate, thermal or density stratifications of receiving waters, which will influence mixing and diffusion of oxygen through the water column by isolating the bottom water layer from the top layer, and wind mixing, which influences the reaeration and DO distribution across the water column, are also non-chemical factors that are beyond the consideration of DO and nutrient TMDLs.

Another important factor that controls DO concentrations in many streams, rivers, and estuaries is sediment oxygen demand (SOD). SOD is composed of carbonaceous oxygen demand

(primarily caused by sedimentation of particulate organic carbon in the sediment) and nitrogenous oxygen demand, which results from the DO consumption through nitrification when ammonia compounds are oxidized. In most cases, carbonaceous oxygen demand is the dominant component of SOD.

Effects of SOD on DO concentration can be especially significant in tidally-influenced river systems. Because the density of freshwater is lower than that of marine water, freshwater input from the drainage basin typically floats on top of the marine water. The large density difference between the top layer freshwater and bottom layer marine water creates a strong resistance to the mixing, which results in the density stratification typically observed in tidally-influenced river segments. Because the density stratification prevents the bottom layer low DO water (caused by SOD) from mixing with the top layer DO enriched water (due to direct reaeration), bottom layer low DO concentrations are fairly common in tidal river segments. Although reducing the allochthonous (from watershed) and autochthonous (internally created by algal production) particulate organic carbon can reduce the sources of SOD, because the drainage basin fresh water does not always have direct exchange with the sediment, reducing the particulate organic carbon loading in the input fresh water may not effectively flush out all the legacy SOD materials from the sediment, especially when a certain amount of particulate organic carbon load in input fresh water has to be allowed because even a completely unimpacted natural drainage basin contributes nutrient and organic carbon to the receiving water, which serve as sources of SOD.

3.2.3. Site Specific Alternative Criteria (SSAC) and Alternative Dissolved Oxygen Criteria (ADOC)

Because of the existence of environmental factors that cannot be addressed or completely addressed in order to meet the state DO criterion everywhere and all the time in ambient water, in some cases, an alternative DO criterion can be established usingthe SSAC or ADOC process.

The State's Surface Water Quality Standard (62-302.800, F. A. C) specifies two types of SSACs:

Type I Site Specific Alternative Criteria: A water body, or portion thereof, may not meet a particular ambient water quality criterion specified for its classification, due to natural background conditions or man-induced conditions which cannot be controlled or abated. In such circumstances, and upon petition by an affected person or upon the initiation by the Department, the Secretary may establish a site specific alternative water quality criterion when an affirmative demonstration is made that an alternative criterion is more appropriate for a specified portion of waters of the state. Public notice and an opportunity for public hearing shall be provided prior to issuing any order establishing alternative criteria.

(a) The affirmative demonstration required by this section shall mean a documented showing that the proposed alternative criteria would exist due to natural background conditions or man-induced conditions which cannot be controlled or abated. Such demonstration shall be based upon relevant factors which include:

1. A description of the physical nature of the specified water body and the water pollution sources affecting the criterion to be altered.

2. *A description of the historical and existing water quality of the parameter of concern including, spatial, seasonal, and diurnal variations, and other parameters or conditions which may affect it. Conditions in similar water bodies may be used for comparison.*
3. *A description of the historical and existing biology, including variations, which may be affected by the parameter of concern. Conditions in similar water bodies may be used for comparison.*
4. *A discussion of any impacts of the proposed alternative criteria on the designated use of the waters and adjoining waters.*

(b) *The Secretary shall specify, by order, the site specific criteria for the parameters which the Secretary determines to have been demonstrated by the preponderance of competent substantial evidence to be more appropriate.*

Type II Site Specific Alternative Criteria: Affected persons can also petition for Type II SSACson the basis of site specific reasons other than natural background conditions or man-induced conditions which cannot be controlled or abated.

Alternative Dissolved Oxygen Criteria (ADOC):The State's Surface Water Quality Standard also provides an option to establish site specific DO criteria through the ADOC process. Rule 62-302.500(2)(f) F. A. C states that:

> *Notwithstanding the specific numerical criteria applicable to individual classes of water, dissolved oxygen levels that are attributable to natural background conditions or man-induced conditions which cannot be controlled or abated may be established as alternative dissolved oxygen criteria for a water body or portion of a water body. Alternative dissolved oxygen criteria may be established by the Secretary or a Director of District Management in conjunction with the issuance of a permit or other Department action only after public notice and opportunity for public hearing. The determination of alternative criteria shall be based on consideration of the factors described in Rule 62-302.800(1)(a)1.-4., F.A.C. Alternative criteria shall not result in a lowering of dissolved oxygen levels in the water body, water body segment or any adjacent waters, and shall not violate the minimum criteria specified in Rule 62-302.500(1), F.A.C. Daily and seasonal fluctuations in dissolved oxygen levels shall be maintained.*

As discussed in detail in Chapter 5 of this report, achieving a DO concentration of 5.0 mg/L all the time for the freshwater segments and a DO concentration of 4.0 mg/L at all the times or a daily average DO concentration no less than 5.0 mg/L for marine water segments may be infeasible in these tributaries due to specific hydrologic, hydrodynamic, and sediment characteristics of these systems, the possible use of ADOCs for these tributaries are discussed together with the development of these TMDLs.

Chapter 4: ASSESSMENT OF SOURCES

4.1 Types of Sources

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of the pollutant of concern in the target watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either point sources or nonpoint sources. Historically, the term "point sources" has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, agriculture, silviculture, and mining; discharges from failing septic systems; and atmospheric deposition.

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of pollution as point sources subject to regulation under the EPA's NPDES Program. These nonpoint sources included certain urban stormwater discharges, including those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see **Appendix A** for background information on the federal and state stormwater programs).

To be consistent with Clean Water Act definitions, the term "point source" is used to describe traditional point sources (such as domestic and industrial wastewater discharges) and stormwater systems requiring a National Pollutant Discharge Elimination System (NPDES) stormwater permit when allocating pollutant load reductions required by a TMDL (see **Section 6.1** on **Expression and Allocation of the TMDL).** However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2 Potential Sources of Pollutants in Watersheds of Impaired Tributary Segments

4.2.1 Point Sources

4.2.1.1 Wastewater Point Sources

Within the watersheds of the eight impaired waterbodies covered in this TMDL report, three NPDES permitted wastewater facilities were identified being located in the watersheds of three impaired waterbodies. **Table 4.1** listed the watersheds of impaired waterbodies that these facilities are located, facility names, facility IDs, and types of wastewater facilities. These facilities, which include the Melbourne Grant Street Wastewater Treatment Plant (FL0041122), Melbourne Joe Mullins Demineralization Concentrate (FL0043443), and Barefoot Bay WWTF (FL0042293), were considered potential sources of TN, TP, and BOD to impaired tributaries.

Table 4.1. NPDES Permitted Facilities Located in the Watersheds of Impaired Tributaries

Watershed	Facility Name	Facility ID	Type of Facility	Contributor to Tributary Impairment?
Crane Creek Watershed	Melbourne Grant Street Wastewater Treatment Plant	FL0041122	Domestic Wastewater	Yes
Eau Gallie River Watershed	Melbourne Joe Mullins Demineralization Concentrate	FL0043443	Industrial Wastewater	Yes
North Prong of Sebastian River Watershed	Barefoot Bay Advanced WWTF	FL0042294	Domestic Wastewater	Yes

The Melbourne Grant Street WWTF (FL0041122) was the only NPDES permitted facility identified in the Crane Creek drainage basin (**Figure 4.1**). This facility is located in 2300 South Grant Street, Melbourne, Brevard County. It has an existing 5.5 MGD annual average daily flow (AADF) permitted capacity trickling filter/activated sludge wastewater treatment facility consisting of two wastewater treatment plants connected in parallel, with influent screening, grit removal, aeration, clarification, tertiary filtration and dewatering, lime stabilization and aerobic digestion of residuals. Effluent from both plants is combined at a final effluent storage/chlorine contact tank for disposal at a Class I underground injection well or for discharge to the public access reuse system, after filtration and disinfection by liquid chlorine. Based on a permit issued to the facility in 2005, the facility had a reuse capacity of 0.5 MGD AADF, with a total anticipated reuse capacity of 1.0 MGD AADF. The reuse was primarily applied to a slow-rate public access land application system consisting of a reclaimed water transmission/distribution system within the approved Reuse Service area for public access irrigation of residential lawns, golf courses, parks, playgrounds, landscape areas, highway medians and rights-of-way. The permit was revised by the Department based on a request from the facility to increase the reuse capacity to 2.0 MGD in 2009. Reclaimed water that fails to meet minimum treatment requirements for land application is diverted for underground injection well disposal, which has a permitted capacity of 11.5 MGD AADF.

The facility has a permitted surface discharge to Crane Creek. The discharge is limited to a maximum of five days during Mechanical Integrity Testing of the facility's underground injection well. The discharge is authorized only during the winter months (November through March). In order for the discharge to meet the effluent limits, the permit requires that an average 3-day upstream freshwater flow component of Crane Creek be a minimum of 20 cubic feet per second.

The current permit allows 20 mg/L of BOD, 20 mg/L of TN, and 1.0 mg/L of TP as single sample concentration limits at the point of discharge. Based on the data retrieved from the EPA's Permit Compliance System (PCS) database, for the period from 2000 through 2010, the facility only discharged two times (in March of 2004 and 2009). In the DO and nutrient TMDLs for the main stems of the Indian River Lagoon and Banana River Lagoon adopted by the Department in 2009, the Melbourne Grant Street WWTF was considered a point source that only contributed a small amount of nutrients to the main stem of the Indian River Lagoon. Therefore, the TMDL

assigned 95th percentile of the facility existing loading rates (based on facility's discharge flow and TN and TP concentrations data in the period from April of 2000 to March of 2005) of TN and TP to the facility as its wasteload allocation (WLA), which include 182 lbs/year of TN and 8 lbs/year of TP (FDEP 2009). **Table 4.2** shows the flow, TN, TP, and BOD measurements for the two discharge events that have happened since January of 2000. TN, TP, and BOD loads of these discharge events are also included in the table.

Table 4.2. TN, TP, and BOD Surface Loads from Melbourne Grant Street WWTF into Crane Creek during the Period from 2000 through 2010

Parameter	3/31/2004 Discharge Event	3/31/2009 Discharge Event
Flow (MGD)	3.70	1.08
TN Concentration (mg/L)	12.3	17.3
TP Concentration (mg/L)	0.5	0.7
BOD Concentration (mg/L)	4.7	3.1
TN Loading (lbs)	380	156
TP loading (lbs)	15	6
BOD loading (lbs)	145	28

The Melbourne Joe Mullins Demineralization Concentrate (FL0043443) is an industrial facility that produces potable water. The facility currently has an NPDES permit that allows the facility to discharge demineralization concentrate at 1.25 MGD maximum daily flow to the Eau Gallie River at Outfall D-001 about 100 feet downstream of a salinity barrier (dam). The authorized discharge is the demineralization concentrate generated as a by-product in the production of potable water. The renewed discharge permit issued to the facility in April of 2010 allows the facility to move its discharge point from its existing location to Outfall D-002, which will be about 5,142 feet downstream of the current D-001 and be at the US Highway 1 Bridge that crosses the Eau Gallie River.

In the DO and nutrient TMDLs for the main stems of the Indian River Lagoon and Banana River Lagoon adopted by the Department in 2009, the Melbourne Joe Mullins Demineralization Concentrate was considered a point source that only contributed a small amount of nutrients to the main stem of the Indian River Lagoon. In addition, the long-term average TN and TP concentration of the discharge has been about 1.6 mg/L and 0.2 mg/L, respectively, which are lower than the advanced wastewater treatment level (AWT). Therefore, the TMDL assigned 95th percentile of the facility existing loading rates (based on facility's discharge flow and TN and TP concentrations data in the period from April of 2000 to March of 2005) of TN and TP to the facility as its wasteload allocations (WLAs), which include 9,170 lbs/year of TN and 195 lbs/year of TP (FDEP 2009). **Table 4.3** shows the annual flow and TN, and TP annual loads for the facility in the period from 2005 through 2010. The facility does not have routine BOD measurement. Based on the BOD results included on the facility's permit application form, the BOD concentration in the facility's discharge is undetectable.

Table 4.3. Annual Flow and Annual TN and TP Loads from Melbourne Joe Mullins Demineralization Concentrate in the Period from 2005 through 2010

Year	Annual Flow (Million Gallon)	Annual TN Loads (lbs/year)	Annual TP Loads (lbs/year)
2005	341	3320	64
2006	439	5625	74
2007	423	6157	77
2008	389	6926	354
2009	404	9879	491
2010	391	8620	372
Mean	398	6755	239

The Barefoot Bay Advanced WWTF (FL0042293) is a minor domestic wastewater facility that discharges to a drainage canal leading to the North Prong of Sebastian River. The facility has an existing 0.90 mgd AADF permitted capacity. The wastewater treatment process components include influent screening, flow equalization, two anoxic/aeration basins, secondary clarification, chemical feed, filtration, chlorination, dechlorination, and aerobic digestion of residuals. The facility also utilizes a Micro-C feed system.

The majority of treated wastewater from the facility is reused through land application. The facility has an existing 1.041 MGD AADF permitted capacity slow-rate public access system, consisting of a reclaimed water transmission/distribution system for public access irrigation of a golf course and an infiltration impoundment system near Barefoot Bay Mobile Home Community. Land application system includes an existing 0.13 mgd AADF permitted capacity 40-acre sprayfield, an existing 0.124 mgd AADF permitted capacity 50-Acre Barefoot Bay Golf Course, and the existing 0.787 mgd AADF infiltration impoundment (formerly permitted as a sprayfield) with 12 acres of exfiltration trenches and a total permitted area of 320 acres. Storage facilities include one existing 1.8 mg on-site lined substandard water storage pond and one existing 4.0 mg reclaimed water storage pond.

The facility's 0.75 mgd AADF permitted intermittent surface discharge is a wet weather only discharge which limits the discharge from the facility to 91 days a year (or the equivalent of 2,184 hours). For the 91 days discharge period, the average daily discharge shall not exceed 0.75 mgd.

In the DO and nutrient TMDLs for the main stems of the Indian River Lagoon and Banana River Lagoon, adopted by the Department in 2009, the Barefoot Bay Advanced WWTF was considered a point source that only contributed a small amount of nutrients to the main stem of Indian River Lagoon. Therefore, the mainstem TMDL assigned 95th percentile of the facility existing loading rates (based on facility's discharge flow and TN and TP concentrations data in the period from April of 2000 to March of 2005) of TN and TP to the facility as its wasteload allocation (WLA), which include 476 lbs/year of TN and 78 lbs/year of TP (FDEP 2009). **Table 4.4** shows flow, TN, TP, and BOD loads discharged from the facility in the period from 2000 through 2010.

Table 4.4. TN, TP, and BOD Surface Loads from Barefoot Bay Advanced WWTF into the North Prong of the Sebastian River in the Period from 2000 through 2010

Parameter	October of 2000	July of 2002	August of 2002	September of 2002	February of 2003	February of 2008
Monthly average daily flow (MGD)	0.153	0.669	0.436	0.3	0.041	0.538
Monthly average TN concentration (mg/L)	4.90	2.09	1.65	N/A	N/A	N/A
Monthly average TP concentration (mg/L)	0.46	0.326	0.33	N/A	N/A	N/A
Monthly average BOD concentration (mg/L)	4.2	13.2	6.2	N/A	N/A	1.3
Monthly Total Flow (million gallon)	4.743	20.739	13.516	9.000	1.148	15.064
TN Loading (lbs)	193.95	361.73	186.11	N/A	N/A	N/A
TP loading (lbs)	18.21	56.42	37.22	N/A	N/A	N/A
BOD loading (lbs)	166.25	2284.59	699.34	N/A	N/A	163.43

N/A: not available.

4.2.1.2 Municipal Separate Storm Sewer System Permittees

Like other nonpoint sources of pollution, urban stormwater discharges are associated with land use and human activities, and are driven by rainfall and runoff processes leading to the intermittent discharge of pollutants in response to storms. The 1987 amendments to the Clean Water Act designated certain stormwater discharges from urbanized areas as point sources, hence requiring NPDES stormwater permits. In October 2000, US EPA authorized FDEP to implement the NPDES stormwater program in all areas of Florida, except for Indian Tribal lands. FDEP's authority to administer the NPDES program is set forth in Section 403.0885, Florida Statutes. The three major components of the NPDES stormwater regulations are:

(1) Municipal Separate Storm Sewer Systems (or MS4) permits that are issued to entities that own and operate master stormwater systems, primarily local governments. Permittees are required to implement comprehensive stormwater management programs designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable.

(2) Stormwater Associated with Industrial Activities, which is regulated primarily by a multi-sector general permit that covers various types of industrial facilities. Regulated industrial facilities must obtain NPDES stormwater permit coverage and implement appropriate pollution prevention techniques to reduce contamination of stormwater.

(3) Construction activity generic permits for projects that ultimately disturb one or more acres of land and which require the implementation of stormwater pollution prevention plans to provide for erosion and sediment control during construction.

In addition to the NPDES stormwater construction permitting regulations, Florida was the first state in the country to require the treatment of stormwater for all new developments with the adoption of the State Stormwater Rule in late 1981. The Stormwater Rule is a technology-based program that relies on the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C. In 1994, state legislation created the Environmental Resource Permitting program to consolidate stormwater quantity, stormwater quality, and wetlands protection into a single permit. Presently, the majority of environmental resource permits are issued by the state's five water management districts, although DEP continues to do the permitting for specified projects.

The NPDES stormwater program was implemented in phases, with Phase I MS4 areas including municipalities having a population above 100,000. Because the master drainage systems of most local governments in Florida are interconnected, EPA implemented Phase 1 of the MS4 permitting program on a countywide basis, which brings in all cities, Chapter 298 urban water control districts, and the Florida DOT throughout the fifteen counties meeting the population criteria. Phase II of the NPDES Program was expanded in 2003 and requires stormwater permits to construction sites between one and five acres, and to local governments with as few as 10,000 people.

Although MS4 discharges are technically referred to as "point sources," for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility. All Phase 1 MS4 permits issued in Florida include a re-opener clause allowing permit revisions for implementing TMDLs once they are formally adopted by rule. Florida's Phase II MS4 Generic Permit has a "self-implementing" requirement once TMDLs are adopted that requires the MS4 permittee to update its' stormwater management program (as needed) to meet its' TMDL allocations.

Table 4.5 lists the MS4 permittees that will be impacted by the TMDLs included in this report. The MS4 permit information listed in the table was retrieved from the Department's GIS data library. Although the C-54 Canal watershed overlaps with boundaries of Brevard and Indian River Counties, the watershed is not located in any urban areas as defined by year 2000 census (http://www.dep.state.fl.us/water/stormwater/npdes/docs/census/UA_PalmBay_Melbourne_roads.pdf). Therefore, the Brevard and Indian River County's MS4 permit do not apply to the C-54 Canal watershed.

4.2.2 Nonpoint Sources

Nonpoint source nutrient loads are loads discharged into impaired water segments from diffused sources instead of through pipes or fixed outfalls. For impaired water segments included in this TMDL report, the major nutrient loads come from the runoff created in watershed, possible ground water input, and atmospheric deposition directly onto the surface of the each waterbody. Watersheds of all the impaired segments covered in this TMDL reports are located in the overall Indian River Lagoon basin that is covered by nutrient TMDLs adopted by the Department in 2009 to protect the seagrass in the Indian River Lagoon basin (FDEP 2009). The existing watershed nutrient loadings of the Indian River Lagoon seagrass TMDLs were mostly simulated using a Pollutant Load Screening Model (PLSM) developed by the St. Johns River Water Management District (SJRWMD) (Steward and Green 2006) except for the areas located in the North Indian River Lagoon basin areas. For watershed areas located in the North Indian River Lagoon area, to meet the needs of statistical analyses, TN loadings were simulated using the

Table 4.5. MS4 Permittees Affected by TMDLs Included in this Report

Watershed of Impaired Waters	MS4 Permit Phase	Permit Name	Permit Number	Florida Department of Transportation MS4 Permit
Addison Creek	II	Brevard County	FLR04E052	District 5 (FLR04E024)
	II	City of Titusville	FLR04E079	
Eau Gallie River	II	Brevard County	FLR04E052	District 5 (FLR04E024)
	II	City of Melbourne	FLR04E027	
Crane Creek	II	Brevard County	FLR04E052	District 5 (FLR04E024)
	II	City of Melbourne	FLR04E027	
	II	City of West Melbourne	FLR04E028	
	II	City of Palm Bay	FLR04E077	
North Prong of Sebastian River	II	Brevard County	FLR04E052	District 5 (FLR04E024)
C-54 Canal	N/A	N/A	N/A	N/A
Sebastian River above Indian River	II	Brevard County	FLR04E052	District 5 (FLR04E024)
	II	Indian River County	FLR04E068	District 4 (FLR04E083)
	II	City of Sebastian	FLR04E124	Turnpike (FLR04E049)
Sebastian River	II	Indian River County	FLR04E068	District 4 (FLR04E083)
	II	City of Sebastian	FLR04E124	Turnpike (FLR04E049)

PLSM model. But the TP loadings were simulated using a set of Hydrological Simulation Program – Fortran (HSPF) models developed by the SJRWMD. In order to keep a consistent nutrient estimation approach for impaired waters in the Indian River Lagoon basin, existing TN and TP loadings from watersheds of impaired water segments located in the Central Indian River Lagoon basin, including Crane Creek, North Prong of the Sebastian River, C-54 Canal, and the Sebastian River above the Indian River, Sebastian River (south prong), were all simulated using the PLSM model. Existing TN loadings for impaired water segments located in the North Indian River Lagoon basin, including Addison Creek and Eau Gallie River, were simulated using the PLSM model. The existing TP loadings from the watershed of these two impaired waters were simulated using the HSPF model
simulated by the SJRWMD. Neither the PLSM nor the HSPF models were established by the SJRWMD for seagrass protection had the purpose of simulating BOD loadings. Therefore, the existing watershed loadings of BOD for all impaired water segments covered in this TMDL report were simulated using a set of HSPF model established by Camp Dresser McKee (CDM) under a TMDL modeling contract with the Department.

HSPF (Bicknell et al., 2004) was funded by the United States Environmental Protection Agency (EPA) and developed by the Hydrocomp in late 1970s. The model has since been refined and maintained by Aqua Terra, funded by EPA, and is a comprehensive package that can be used to develop a combined watershed and receiving water model. The model has the capability of simulating watershed loadings of various species of nitrogen and phosphorus, BOD, coliform bacteria, metals, and chlorophyll a and DO concentrations in receiving waters. Three major modules are included in the model to simulate pollutant loadings from the watershed and in-

water transport of the pollutants and their effects on chlorophyll a and DO concentrations. These modules include PERLND, IMPLND, and RCHRES.

The PERLND module performs detailed analysis of surface and subsurface flow for pervious land areas based on the Stanford Watershed Model. The rainfall falling onto a given watershed is first intercepted by the tree canopy pool. Once the canopy pool is saturated, the remaining water will reach the ground and infiltrate into the soil. The percolated water will first saturate the lower zone of the soil, and then upper zone of the soil. Part of the water entering the lower zone and upper zone may also enter the down slope stream as baseflow and interflow. Certain part of the water percolating into the soil may loss to the deep groundwater zone, and therefore leaves the model mass balance processes. Other part of the percolated water may leave the model mass balance process through evapotranspiration. Once the lower zone and upper zone of the soil are saturated, the remaining water will first fill the volume of the depression on land surface, and then become surface runoff.

Water quality calculations for sediment in pervious land runoff can include sediment detachment during rainfall events and reattachment during dry periods, with potential for washoff during runoff events. For other water quality constituents such as nutrients and BOD, runoff water quality can be determined using buildup-washoff algorithms, “potency factor” (e.g., factors relating the pollutant washoff through surface runoff to sediment washoff), or a combination of both. The pollutant loading through subsurface flow, including baseflow and interflow, can be estimated through multiplying the model simulated subsurface water quantity by the user provided subsurface pollutant concentrations.

The IMPLND module simulates the hydrology of the watershed areas that are impervious. No rainfall percolation into the ground happens in the impervious areas. Therefore, the IMPLND performs hydrological analyses on surface processes only and uses buildup-washoff algorithms and/or potency factor approach to determine runoff quality.

The RCHRES module is used to simulate flow routing and water quality in the receiving waters, which are assumed to be one-dimensional. Receiving water constituents can interact with suspended and bed sediments through soil-water partitioning. In addition, HSPF can incorporate “special actions” that utilize user-specified algorithms to account for occurrences such as opening/closing of water control structures to maintain seasonal water stages or other processes beyond the normal scope of the model code.

HSPF drainage basin simulation is primarily driven by the rainfall condition. Another important meteorological factor that influences the watershed water balance is evapotranspiration, which is primarily influenced by wind speed, cloud cover, solar radiance, dew point, and air temperature. These meteorological factors also influence the heat transfer through the system under simulation and impact the soil temperature and gas transport in the watershed, and reareation and photosynthetic activities in receiving waters.

While rainfall acts as the source of water for the watershed hydrology, drainage basin area, landuse pattern, hydrological soil characteristics, and topographic characteristics of the drainage basin determine the portions of the water that are transferred through different pathways such as surface runoff, interflow, and baseflow, to receiving waters. The landuse and soil type influence the water budget fractionation through influencing the surface imperviousness, soil infiltration capacity, and water storage capacity at different soil layers.

Landuse and hydrological soil patterns also influences the concentration of the pollutants associated with the surface runoff and therefore are the major factors influencing the water quality of the receiving waters.

Besides the flow derived from the rainfall onto the immediate drainage basins, water input from the regional aquifer and precipitation directly onto the surface of the receiving waters may also significantly influence the final water budget of the water segments under question. discharges from these sources usually have different concentrations of water quality constituents than the runoff from the immediate drainage basin. In SJRWMD's HSPF model, ground water input from the regional aquifer was considered insignificant (Steward and Green, 2007)

Pollutant loadings not only can be created in the drainage basin, they may also be retained in the drainage basin through various mechanisms. For example, sediment created through the detachment and wash-off process can be removed from the surface runoff through the reattachment therefore does not reach the receiving waters. Pollutants associated with the sediment are also removed from the surface runoff through this process if a potency factor method is used to simulate the pollutant loading. Another mechanism through which pollutant can be removed is the urban and agricultural best management practice (BMP). For the HSPF models developed by the SJRWMD for the Indian River Lagoon and Banana River Lagoon, because no information was available regarding the detailed spatial distribution, types, and treatment efficiencies of stormwater treatment facilities at the time these models were developed, the HSPF model assumed that any urban construction that took place after 1984 (when the state stormwater rule was implemented) was developed with stormwater treatment facilities. To implement this assumption in the model, the SJRWMD further assumed that any constructions did not appear in the 1989 land use GIS coverage, but appears in land use GIS coverages after 1989 represent constructions developed after 1984. Generalized treatment efficiencies were applied in the HSPF model, which include 30% removal of TN and 50% removal of TP by these stormwater treatment facilities. No stormwater treatment types were distinguished in the PLSM model for the lack of detailed BMP information.

In simulating the nutrient loadings from the Indian River Lagoon, Banana River Lagoon, and Mosquito Lagoon basin areas using HSPF models, the SJRWMD divided these basin areas into 45 drainage areas. These drainage areas consist of drainage basins, nearshore drainage, and barrier island drainage (Adkins, et al. 2004). These HSPF models were developed using SJRWMD's Year 1995 land use and rainfall data collected from 25 local rain gauges for the period from 1995 through 2003. Models were developed to simulate the flow, and loadings of total suspended solid (TSS), TN, TP, and phosphate (PO4). Flow data collected from twelve flow gauges were used to calibrate the hydrology of these models. Because of the lack of water quality data collected in the modeled tributaries entering these lagoon systems, at the time when these HSPF models were developed, direct calibration against measured water quality data were only conducted using the water quality data collected from the South Prong of the Sebastian River. Model water quality parameters established through the water quality calibration were then applied to other lagoon drainage basins. These water quality parameters were later refined by comparing model simulated per acre loadings to per acre loadings reported by Harper (1994). Detailed model setup and model parameters of these HSPF models can be obtained from Adkins, et al. (2004).

The PLSM model was originally designed by Adamus and Bergman (1998). It is a GIS model that takes advantage of spatially differentiated information such as watershed land use pattern,

soil distribution, hydrologic boundaries, and rain gauge networks. This model uses the following equation to estimate pollutant loads from the watershed:

$$L = \sum Ai * Ci * P * EMCi * (1 - T)$$

Where:

L is the total nutrient load from a given watershed.
A_i is the acreage of the land use – soil type combination i in the watershed.
C_i is the runoff coefficient for the land use – soil type combination i in the watershed.
P is the annual rainfall.
$EMCi$ is the event mean concentration for a given land use type i.
T is the removal rate of pollutant through best management practice (BMP) measures.

In assessing the model's reliability in predicting nutrient pollutant loads, the PLSM model was calibrated for model-simulated discharge volume and TN and TP loads to measured flow and loading data in four IRL drainage basins: Crane Creek, C-1 Canal of Turkey Creek, South Prong of Sebastian River, and Briar Creek (Green and Steward 2003). The SJRWMD study concluded that PLSM predicted flow, and TN, TP, and TSS loadings derived from measured concentrations and flow within an acceptable margin of error.

Ground water input from the Floridan aquifer does not represent a significant portion of the total water budget for the IRL system (Martin et al. 2004). Depending on the season, input from the surficial aquifer to the lagoon could be important. Nutrient contributions from the surficial aquifer were implicitly included in the SJRWMD's model simulations as part of the budget for watershed flow and nutrient loadings because the modeled flow was calibrated against the total flow instead of only surface runoff.

Atmospheric nutrient loadings include those loads depositing into the watershed of the creek and those depositing directly onto the surface of the creek. The amount of the atmospheric loadings depositing into the watershed were implicitly included in the nutrient loading calculations that used measured event mean concentrations (EMCs) that are influenced by the atmospheric deposition. The atmospheric nutrient loadings depositing directly onto the surface of these impaired waters were not calculated because the surface area of these impaired water segments only account for less than 0.5% of the watershed areas. Loadings from the atmospheric direct deposition onto the surface of these impaired water segments are therefore considered negligible.

In addition to the nutrient loads created through watershed runoff, because the mouths of these impaired water segments are tidally influenced by IRL mainstem segments, it is reasonable to believe that these water segments also receive nutrient-containing waters from the IRL mainstem segments. As the PLSM and HSPF models established by the SJRWMD do not simulate nutrient loads from the mainstem segments, loading simulations for these impaired segments focus on loadings from watersheds. However, it is Department's opinion that, to restore the water quality condition of these impaired segments, loadings from the watersheds of these impaired segments, as well as loadings from other parts of the Indian River Lagoon basin all need to be reduced.

4.2.2.1 Land Uses

Land use distribution is a critical factor that determines the nutrient loads created in a given watershed. Land use patterns influence the imperviousness of the watershed and determine the amount of runoff that can be generated in a given watershed area. Land use patterns also determine the concentrations of pollutants in the runoff produced in different land use areas and therefore determine the amount of a given pollutant that can be produced per acre of drainage basin. Land use information is a key spatially parameter for simulating nutrient load using the PLSM model.

The PLSM model developed by the SJRWMD simulates nutrient loads based on the Level III land use of the Florida Land Use, Cover, and Forms Classification System (FLUCCS). The land use data used in this TMDL analysis was SJRWMD's year 2000 land use. Because the set of HSPF models developed by the SJRWMD uses a 7-land use classification system to simulate watershed TP loadings (Adkins et al., 2004), this TMDL report also uses the 7-land use classification system to summarize the distributions of land use acreage and nutrient loadings from watersheds of these impaired water segments. **Appendix B** demonstrates a look-up table showing how the FLUCCS Level III land uses were aggregated into the HSPF model's 7-landuse classification system.

Table 4.6 summarizes the land use distribution in watersheds of the ten impaired water segments included in this TMDL. **Figures 4.1-a, 4.1-b, 4.1-c, 4.1-d, 4.1-e, 4.1-f,** and **4.1-g** show the spatial distribution of the seven generalized land use categories in watersheds of these ten impaired water segments.

Based on **Table 4.6**, it appears that the land use distributions in the eight watersheds can be divided into three types. Type One includes only the Addison Creek watershed, which was dominated by natural land areas with Forest and Water/Wetland areas accounting for 66.7% and Open Land occupying another 8.6% of the watershed areas. Most human land areas in the watershed area were occupied by urban lands, including the High, Medium, and Low-Intensity Use urban lands, which, in total, occupied about 24.3% of the total watershed area. Agricultural lands only occupied around 0.3% of the total watershed area.

Type Two watersheds include the Eau Gallie River and Crane Creek watersheds. These two watersheds were dominated by the High, Medium, and Low-Intensity Use urban lands, which accounted for about 78.4% and 66.8% of the Eau Gallie River and Crane Creek watersheds, respectively. Natural land areas accounted for about 10.0% – 15.7% in these two watersheds. Agricultural lands only occupied about 0.3% to 1.7% of the total watershed areas.

Type Three watersheds include all the remaining seven watersheds, including the North Prong of Sebastian River, South Prong of Sebastian River, Sebastian River Main Stem, and C-54 Canal. Compared to the Type Two watersheds, Type Three watersheds are relatively rural, with the High, Medium, and Low-Intensity Use urban areas occupying around 14.1% - 36.3% and mostly less about 20% or less of the total areas of their corresponding watershed. Also being different from both Types One and Two watersheds, Type Three watersheds had significantly higher portions of their watershed occupied by Agricultural lands, which ranged between 25.5% to 48.3%. In addition, around 36% - 39% of these watersheds were natural land areas and around 11.4% - 23.3% were open lands.

Rural lands and urban lands differ in their percentage of impervious areas. Urban lands typically have higher impervious areas than rural lands, which tend to create more discharge and pollutant loading through surface runoff. Human lands and natural lands differ in the pollutant concentrations of their discharges. Discharge from human lands typically have higher concentrations of nutrient and organic carbon and therefore tends to carry higher pollutant loads than what is discharged from natural land areas.

Table 4.6. Land Use Distribution in Watersheds of Impaired Water Segments

Impaired Segments	Addison Creek (WBID 3028)		Eau Gallie River (WBID 3082)		Crane Creek (WBID 3085A)	
Land Use	**Acreage**	**Percentage**	**Acreage**	**Percentage**	**Acreage**	**Percentage**
Agriculture	6.3	0.3%	19.2	0.3%	201.5	1.7%
Forest	585.9	31.0%	251.9	4.1%	1,074.4	9.3%
High-Intensity use urban	301.1	16.0%	3,411.3	56.0%	4,025.9	34.8%
Low-Intensity use urban	83.3	4.4%	360.4	5.9%	402.9	3.5%
Medium-intensity use urban	74.0	3.9%	1,005.9	16.5%	3,294.6	28.5%
Open land	162.8	8.6%	685.5	11.2%	1,814.5	15.7%
Water/Wetlands	673.7	35.7%	359.7	5.9%	739.8	6.4%
Total	**1,887.1**	**100.0%**	**6,093.9**	**100.0%**	**11553.6**	**100.0%**

Impaired Segments	North Prong of Sebastian River (WBID 3128)		South Prong of Sebastian River (WBID 3129B)		Sebastian River (WBID 3129A)	
Land Use	**Acreage**	**Percentage**	**Acreage**	**Percentage**	**Acreage**	**Percentage**
Agriculture	5,832.5	25.5%	12,208.6	33.3%	4,305.0	28.7%
Forest	4,150.1	18.2%	4,376.2	11.9%	3,128.7	20.9%
High-Intensity use urban	919.2	4.0%	594.2	1.6%	779.5	5.2%
Low-Intensity use urban	2,250.9	9.8%	3,111.1	8.5%	435.2	2.9%
Medium-intensity use urban	59.0	0.3%	2,567.9	7.0%	2,152.8	14.4%
Open land	5,323.5	23.3%	8,765.9	23.9%	1,932.3	12.9%
Water/Wetlands	4,329.5	18.9%	5,012.4	13.7%	2,268.1	15.1%
Total	**22,864.8**	**100.0%**	**36,636.2**	**100.0%**	**15,001.7**	**100.0%**

Impaired Segments	C-54 Canal (WBID 3135)	
Land Use	**Acreage**	**Percentage**
Agriculture	8,016.7	48.3%
Forest	2,796.7	16.8%
High-Intensity use urban	32.7	0.2%
Low-Intensity use urban	100.9	0.6%
Medium-intensity use urban	56.1	0.3%
Open land	1,898.6	11.4%
Water/Wetlands	3,697.6	22.3%
Total	**16,599.4**	**100.0%**

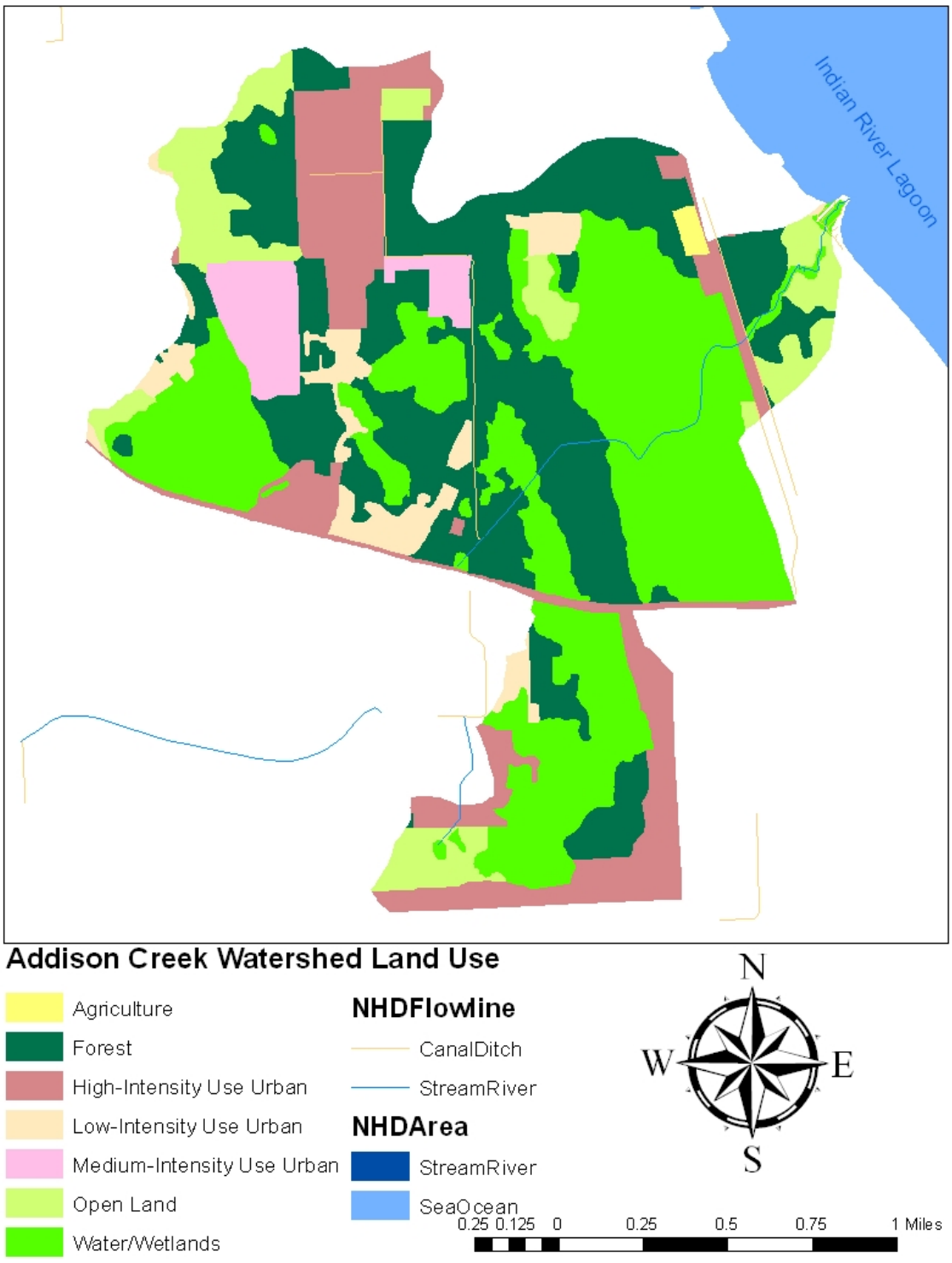


Figure 4.1-a. Distribution of Generalized Land Use Categories in the Addison Creek Watershed

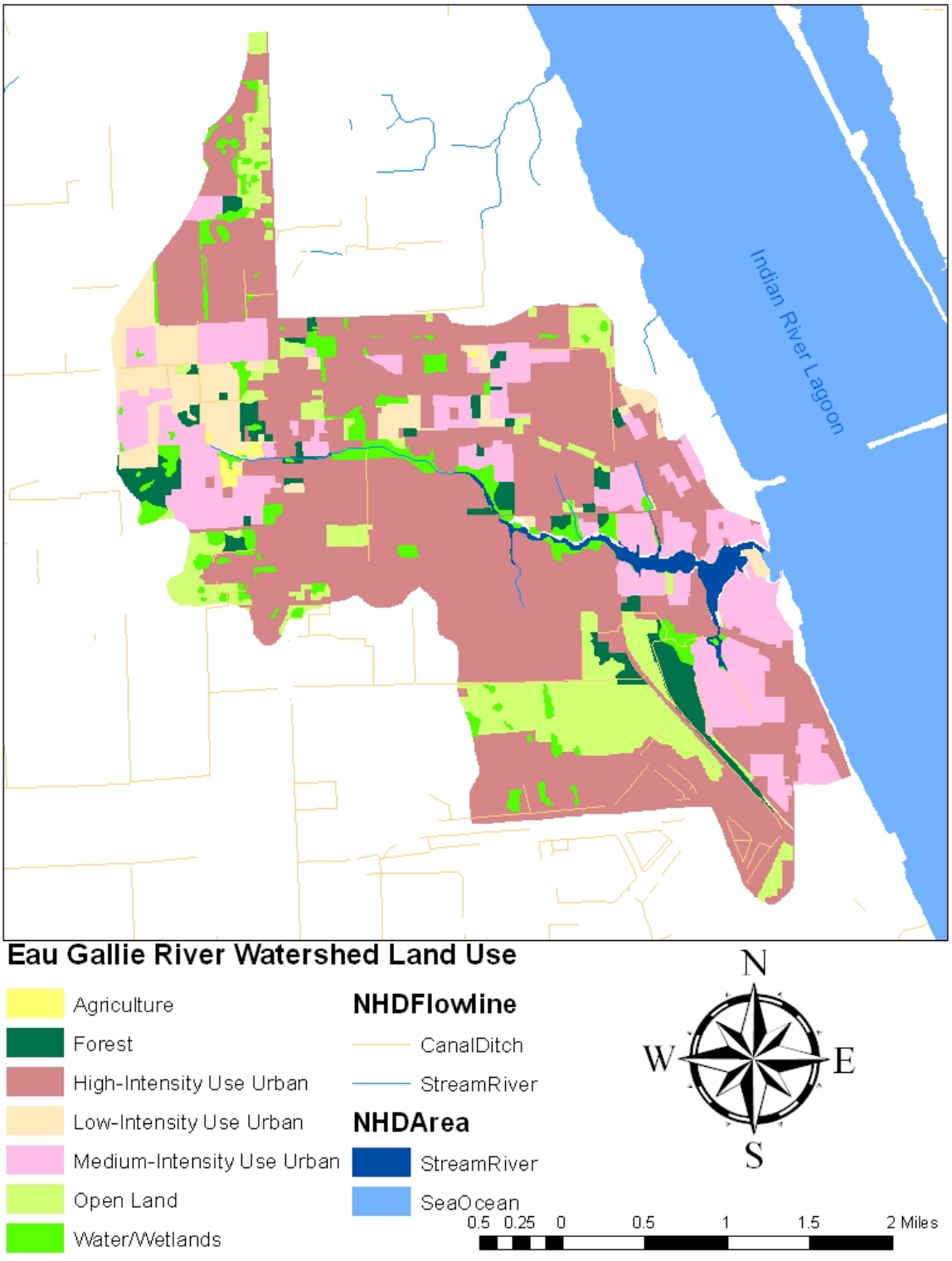


Figure 4.1-b. Distribution of Generalized Land Use Categories in the Eau Gallie River Watershed

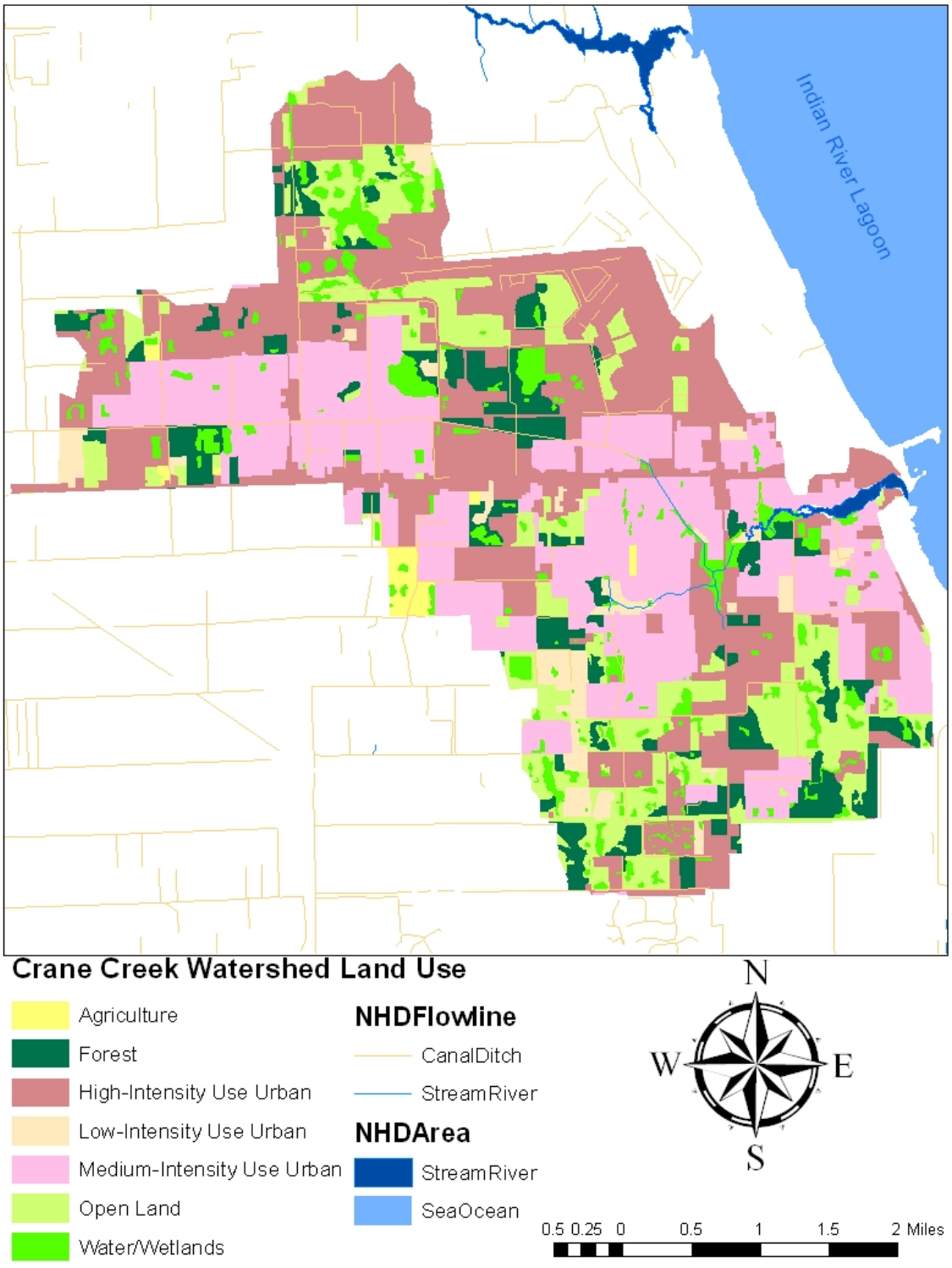


Figure 4.1-c. Distribution of Generalized Land Use Categories in the Crane Creek Watershed

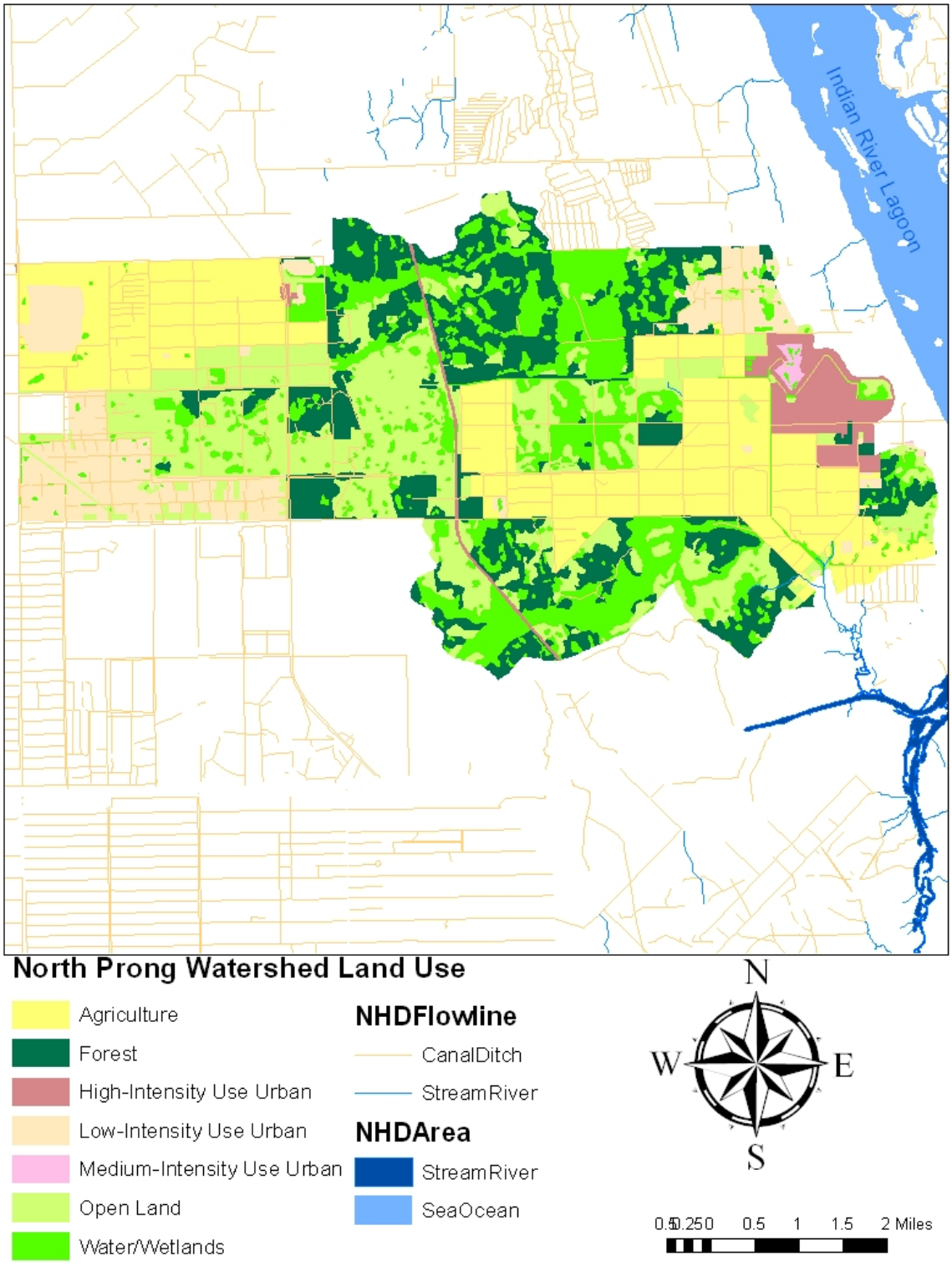


Figure 4.1-d. Distribution of Generalized Land Use Categories in the North Prong of Sebastian River Watershed

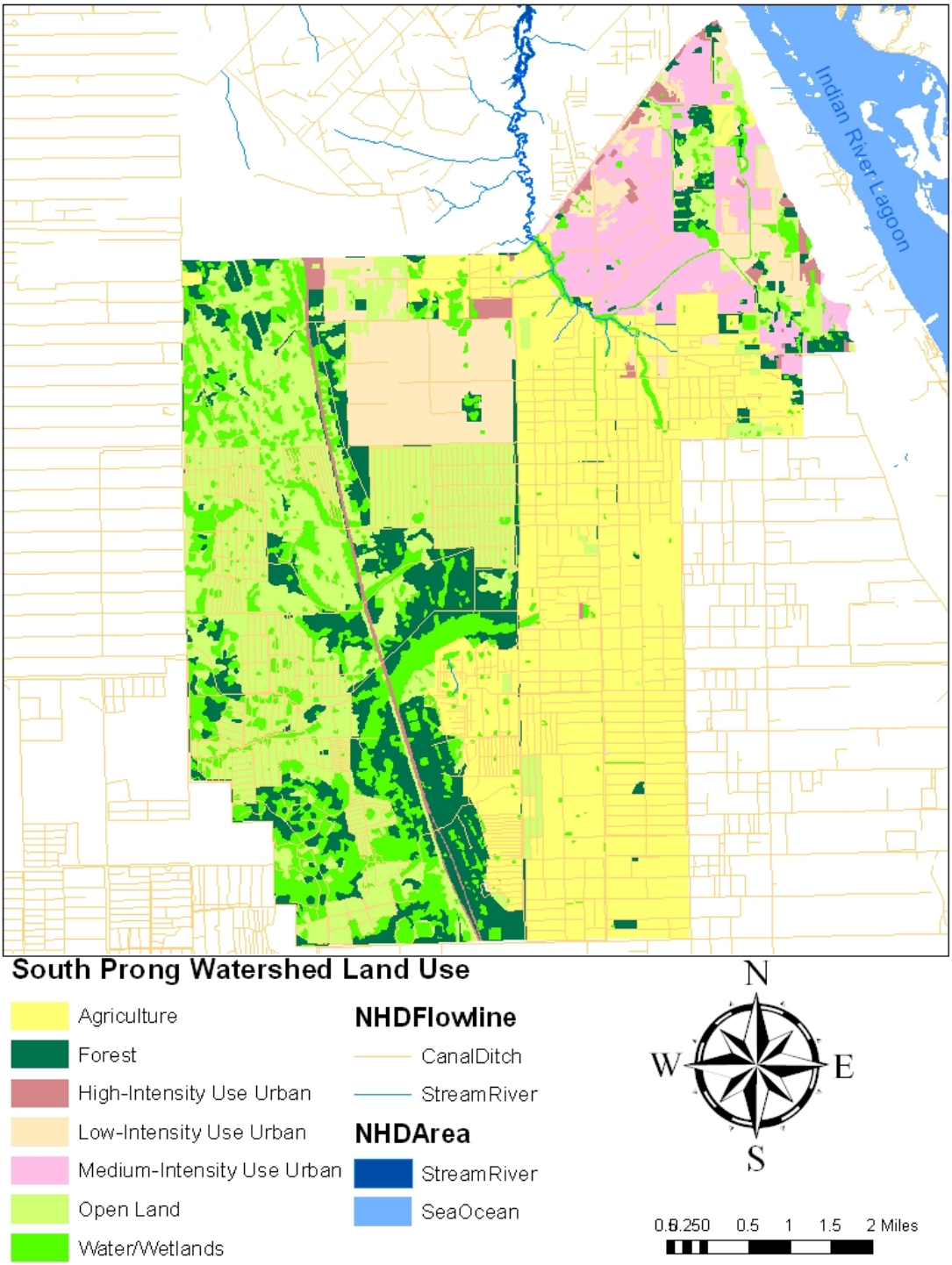


Figure 4.1-e. Distribution of Generalized Land Use Categories in the South Prong of Sebastian River Watershed

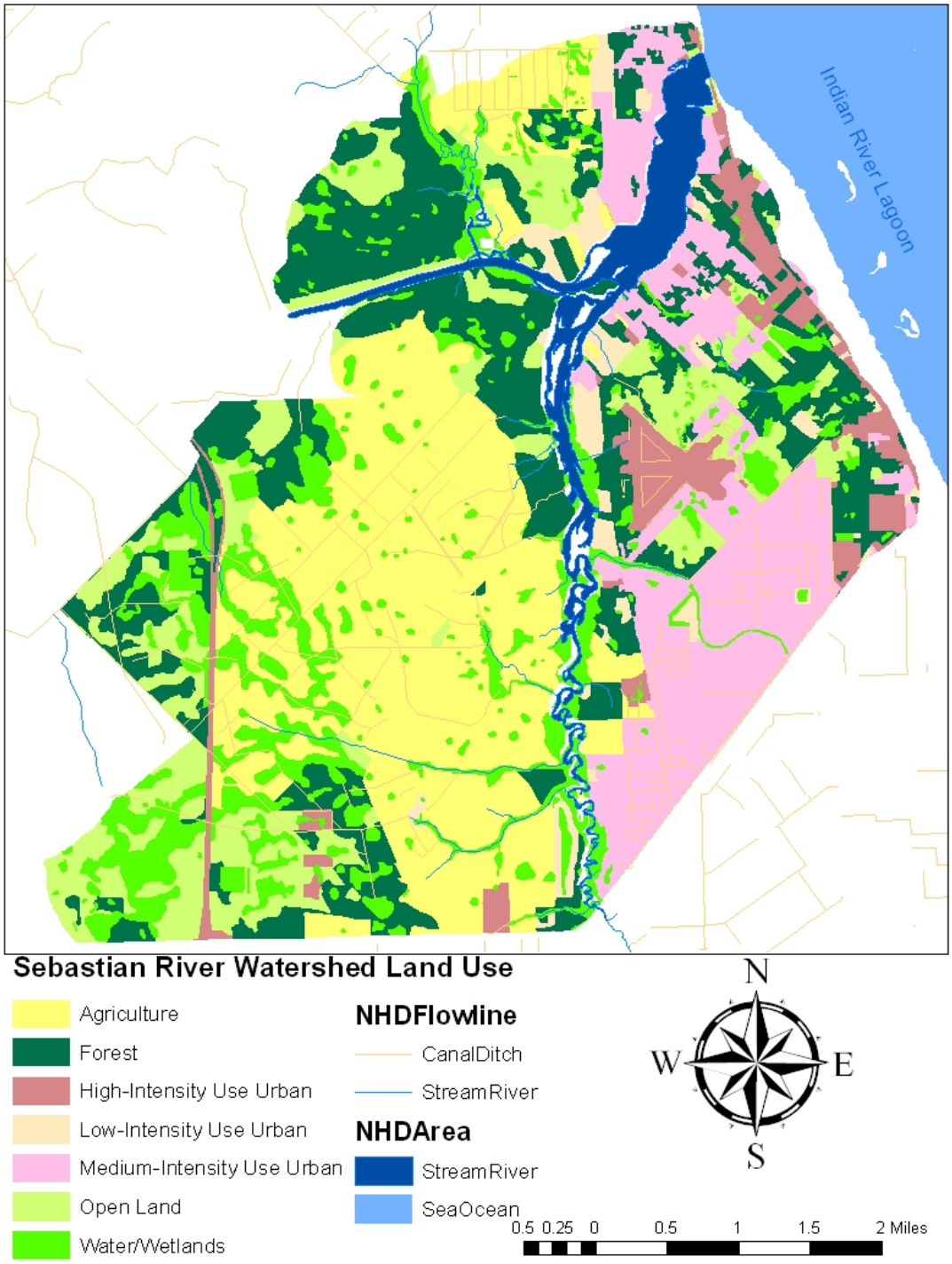


Figure 4.1-f. Distribution of Generalized Land Use Categories in the Sebastian River Main Stem Watershed

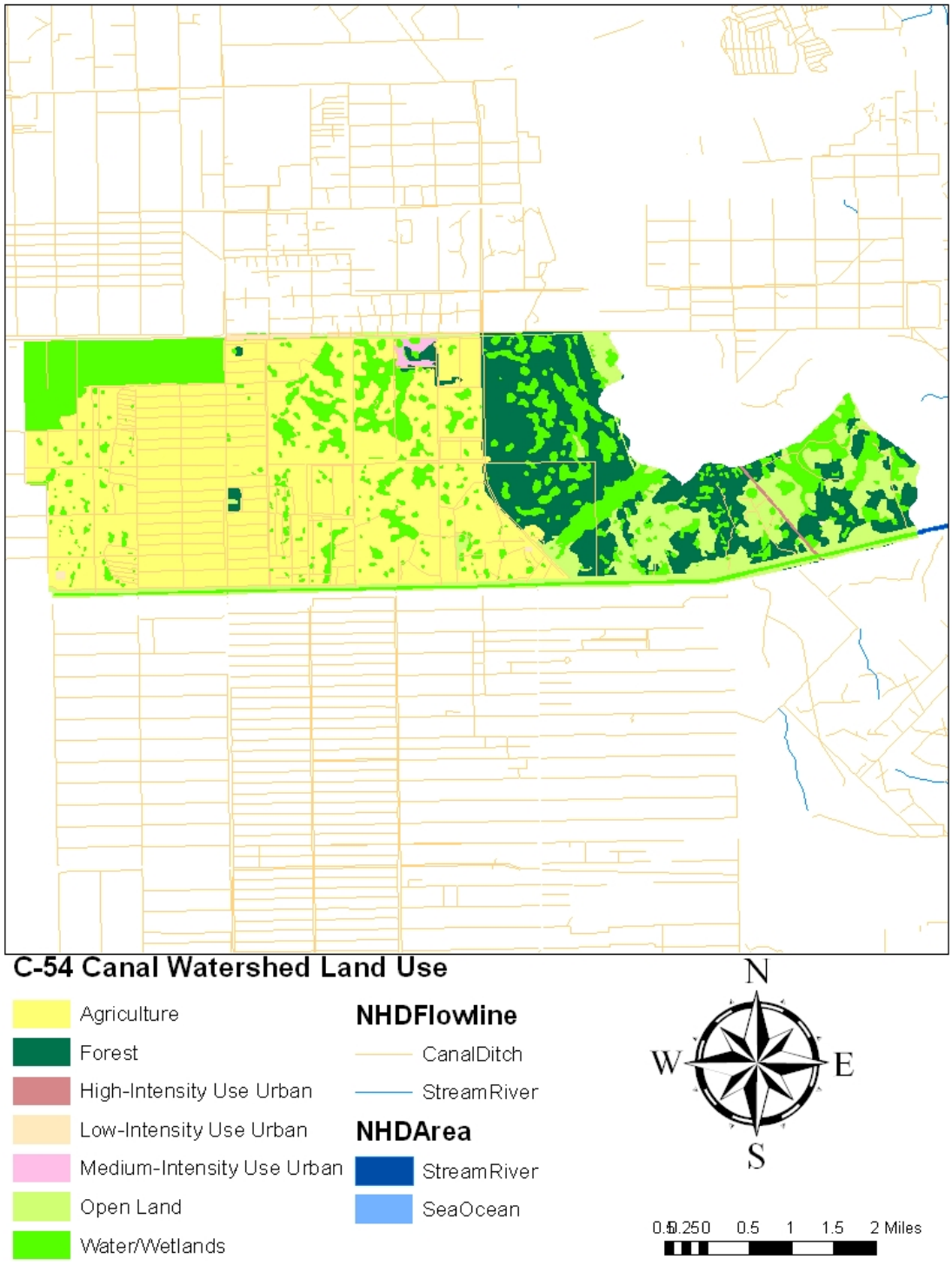


Figure 4.1-g. Distribution of Generalized Land Use Categories in the C-54 Canal Watershed

4.2.2.2 Soil Type

Another important aspect of the watershed is the soil type. Soil type affects the hydrologic characteristics of the watershed through influencing the water transmission capacity of the soil, which in turn determines the potential of the watershed to produce runoff and pollutant loads. Based on United States Department of Agriculture/Natural Resource Conservation Service (USDA/NRCS), soils can be classified based on their hydrologic characteristics into hydrologic soil groups (HSGs). The HSGs are generally determined by the water transmitting soil layer with the lowest saturated hydraulic conductivity and depth to any layer that is more or less water impermeable. A four-HSG classification is generally used to group soils based on their hydrologic characteristics (**Table 4.7**):

Table 4.7. Hydrologic Characteristics of the Four HSGs (NRCS, 2007)

HSGs	Runoff Potential	Clay Content	Sand Content	Saturated Conductivity (inch/hour)	Depth to Impervious Layer (inch)	Depth to Water Table (inch)
Group A	Low	< 10%	> 90%	5.67	> 20	> 24
Group B	Moderately low	10% - 20%	50% - 90%	1.42 – 5.67	> 20	> 24
Group C	Moderately high	20% - 40%	< 50%	0.14 – 1.42	> 20	> 24
Group D	High	>40%	< 50%	< 0.14	< 20	< 24

Certain wet soils are placed in group D based solely on the presence of a water table within 24 inches of the surface even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils can be adequately drained, they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained conduction and the second to the undrained condition. For the purpose of hydrologic soil group classification, adequately drained means that the seasonal high water table is kept at least 24 inches below the surface in a soil where it would be higher in a natural state (NRCS, 2007).

The soil coverage used by SJRWMD in developing the PLSM model was from the USDA/NRCS's 1:24,000 Soil Survey Geographic (SSURGO) coverage. This soil coverage was created by NRCS around 1990. In addition to the four HSGs and their related dual soil groups, this coverage also include a "W" soil group to represent soil areas that are constantly covered by water, and a "U" soil group to represent those soils whose HSG designation could not be determined. **Table 4.8** summarizes the acreages of the watersheds that are covered by different soil types. **Figures 4.2-a, 4.2-b, 4.2-c, 4.2-d, 4.2-e, 4.2-f,** and **4.2-g** show spatial distributions of HSGs in these watersheds.

Based on **Table 4.8**, B/D soil occupies the largest portion in all the watersheds included in this TMDL report. Except in watersheds of Addison Creek, Eau Gallie River, and Sebastian River Main Stem, percent acreage of B/D soil in all the other watersheds are more than 70%. The B/D soil percent acreage in Addison Creek, the Eau Gallie River, and the Sebastian River Main stem are about 44.4%, 50.6%, and 60.6%, respectively. When unsaturated, B/D soil shows the B soil characteristics, which has a relatively high infiltration rate. When saturated, the B/D soil

will show the D soil characteristics with relatively high runoff creation potential. In addition to the B/D soil, Addison Creek and Eau Galllie River watersheds also showed strong presence of A type soils, which account for about 44.6% and 24.0% of the Addison Creek and Eau Gallie River watershed areas, respectively. Other than these two watersheds, the A soil percent acreage in the other watersheds are less than 10%. Other important soil groups include C, C/D, and D soils. These soil types typically occupy between 10% to 30% of total areas of their corresponding watersheds. C, C/D, and D soils have relatively low infiltration rate and therefore have relatively high potential to create surface runoff under the stormwater condition.

Table 4.8. Hydrological Soil Distribution in Watersheds of Impaired Water Segments

Watershed	Addison Creek (WBID 3028)		Eau Gallie River (WBID 3082)		Crane Creek (WBID 3085A)		North Prong of Sebastian River (WBID 3128)	
HSG	Acreage	Percent	Acreage	Percent	Acreage	Percent	Acreage	Percent
A	841.9	44.6%	1,459.8	24.0%	610.3	5.3%	186.6	0.8%
B	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
B/D	833.3	44.2%	3,084.3	50.6%	8,380.5	72.5%	17,239.5	75.4%
C	136.1	7.2%	961.4	15.8%	1,141.1	9.9%	510.8	2.2%
C/D	0.0	0.0%	2.3	0.0%	140.7	1.2%	3,238.4	14.2%
D	65.5	3.5%	355.4	5.8%	841.8	7.3%	1,600.6	7.0%
U	10.2	0.5%	191.5	3.1%	313.5	2.7%	0.0	0.0%
W	0.1	0.0%	39.1	0.6%	125.6	1.1%	88.9	0.4%
Total	1887.1	100.0%	6,093.9	100.0%	11,553.6	100%	22,864.8	100.0%

Watershed	South Prong of Sebastian River (WBID 3129B)		Sebastian River Main Stem (WBID 3129A)		C-54 Canal (WBID 3135)	
HSG	Acreage	Percent	Acreage	Percent	Acreage	Percent
A	627.4	1.7%	12,51.6	8.3%	495.8	3.0%
B	0.0	0.0%	0.0	0.0%	0.0	0.0%
B/D	26,680.4	72.8%	9,092.4	60.6%	12,755.7	76.8%
C	1,293.4	3.5%	1,992.9	13.3%	221.8	1.3%
C/D	2,908.3	7.9%	1,143.4	7.6%	419.3	2.5%
D	4,844.4	13.2%	1,224.4	8.2%	2,465.5	14.9%
U	0.0	0.0%	103.5	0.7%	0.0	0.0%
W	282.3	0.8%	193.6	1.3%	241.3	1.5%
Total	36,636.2	100.0%	15,001.7	100.0%	16,599.4	100.0%

The above analyses were conducted using the NRCS' 1990 soil SSURGO coverage. In 2010, NRCS published its updated SSURGO soil coverage. Based on the analyses conducted by the Department for the Goat Creek and Sykes Creek watershed, significant difference of HSGs exists between these two soil GIS coverages. The percent acreage rate of high infiltration and low runoff potential soils, such as A and B/D soils, significantly increased in NRCS' 2010 SSURGO soil coverage. While it is desirable to evaluate the impact of the HSG distribution change on the loading simulation, it should be pointed out that SJRWMD's PLSM models simulate the total discharge and nutrient loads associated with the total discharge, not just runoff discharge. Change in infiltration and runoff potential of the HSGs may influence the distribution of discharge and nutrient loads between runoff and interflow, but it should not significantly influence the simulation of total discharge and nutrient loads associated with the total discharge. Therefore, this TMDL report uses the NRCS' 1990 soil coverage to simulate existing nutrient loads from watersheds of impaired water segments, as it was used in SJRWMD's PLSM model.

4.2.2.3 Runoff Coefficient and Land Use/Soil Group Combinations

One of the most important parameters allowing the PLSM to simulate the annual discharge volume is the runoff coefficient. In theory, this parameter represents the percent of total rainfall falling onto a given watershed that becomes runoff. In application for TMDL modeling, the coefficients were used to simulate total watershed discharge volume. The runoff coefficient is influenced by the land use type and soil patterns in the watershed. When setting up the PLSM model, SJRWMD staff assigned a unique runoff coefficient to each land use – HSG combination. These runoff coefficients were mostly from Adamus and Bergman (1998) and later modified with data from Harper (1994). Several other modifications were conducted as follows (Whit Green, personal communication):

(1) The runoff coefficients for U soil were calculated as the mean of runoff coefficients of types A, B, C, and D soil group of particular land use.
(2) The runoff coefficients for W soil were assigned runoff coefficients of U soils if the soil survey results did not completely match up with the land use results. Otherwise, the runoff coefficients of W soil would be assigned as 1.000.
(3) The runoff coefficients for C/D and B/D soil groups used the runoff coefficients of D for underdeveloped area. For developed area, the C/D and B/D runoff coefficients were assigned as C or B runoff coefficients.
(4) For low density residential areas, if the housing density is less than 1 unit/acre, the runoff coefficients assumed the runoff coefficients for the D soil. Otherwise, runoff coefficients of B or C soils were used.
(5) For low density residential areas with certain drainage improvements, but the improvement were not sufficient to lower the water table over the entire site, the runoff coefficients of B/D soils assumed the average values of B and D soil for a given land use category. This was used only for select areas subject to on-site assessment

As discussed in previous sections, when the SJRWMD developed these PLSM models, separate PLSM models were developed for the North Indian River Lagoon basin and the Central Indian River Lagoon basin. **Tables 4.9-a** and **4.9-b** show the runoff coefficients assigned to each land use – HSG soil combination in the North Indian River Lagoon and Central Indian River Lagoon areas, respectively.

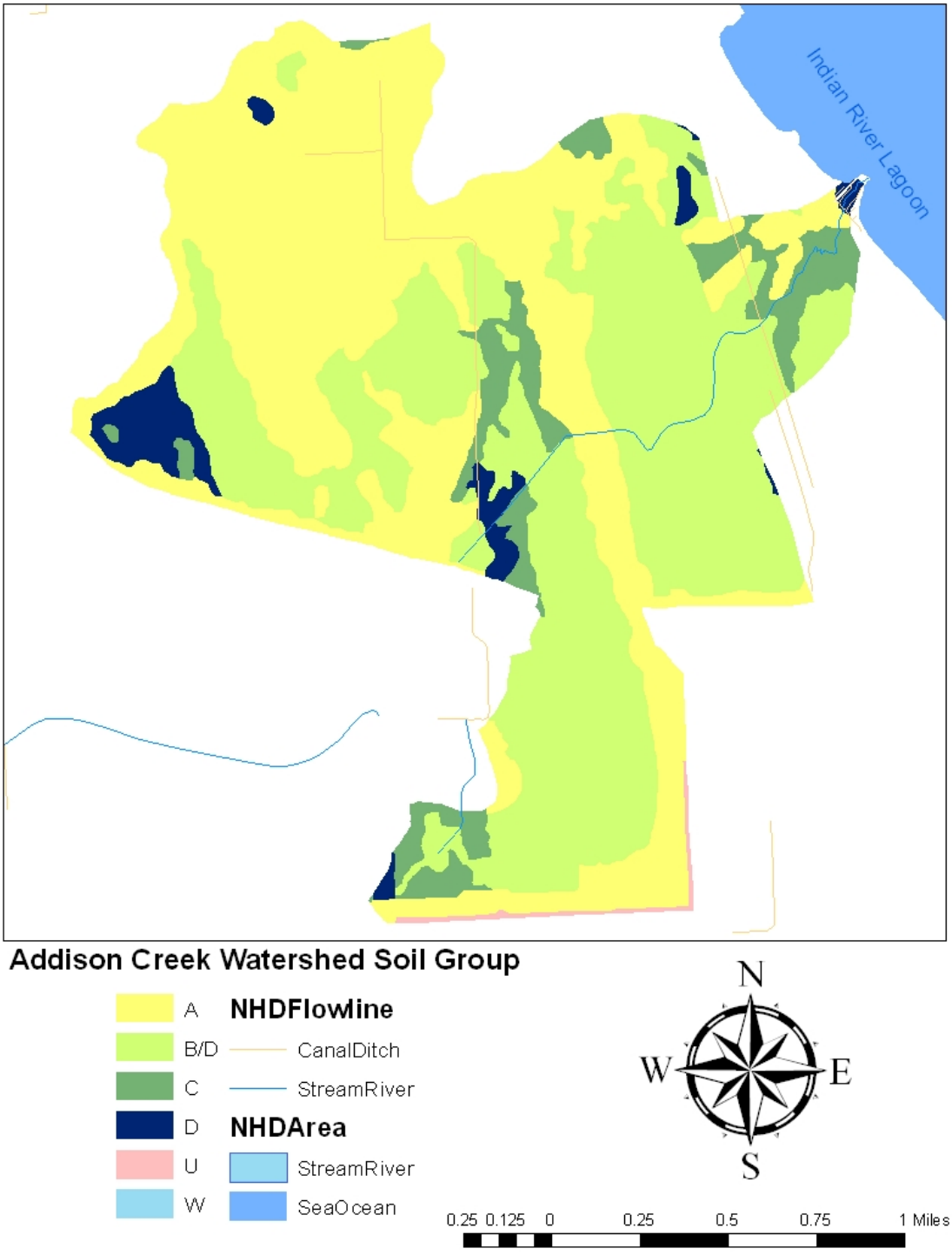


Figure 4.2-a. Distribution of Hydrologic Soil Groups in the Addison Creek Watershed

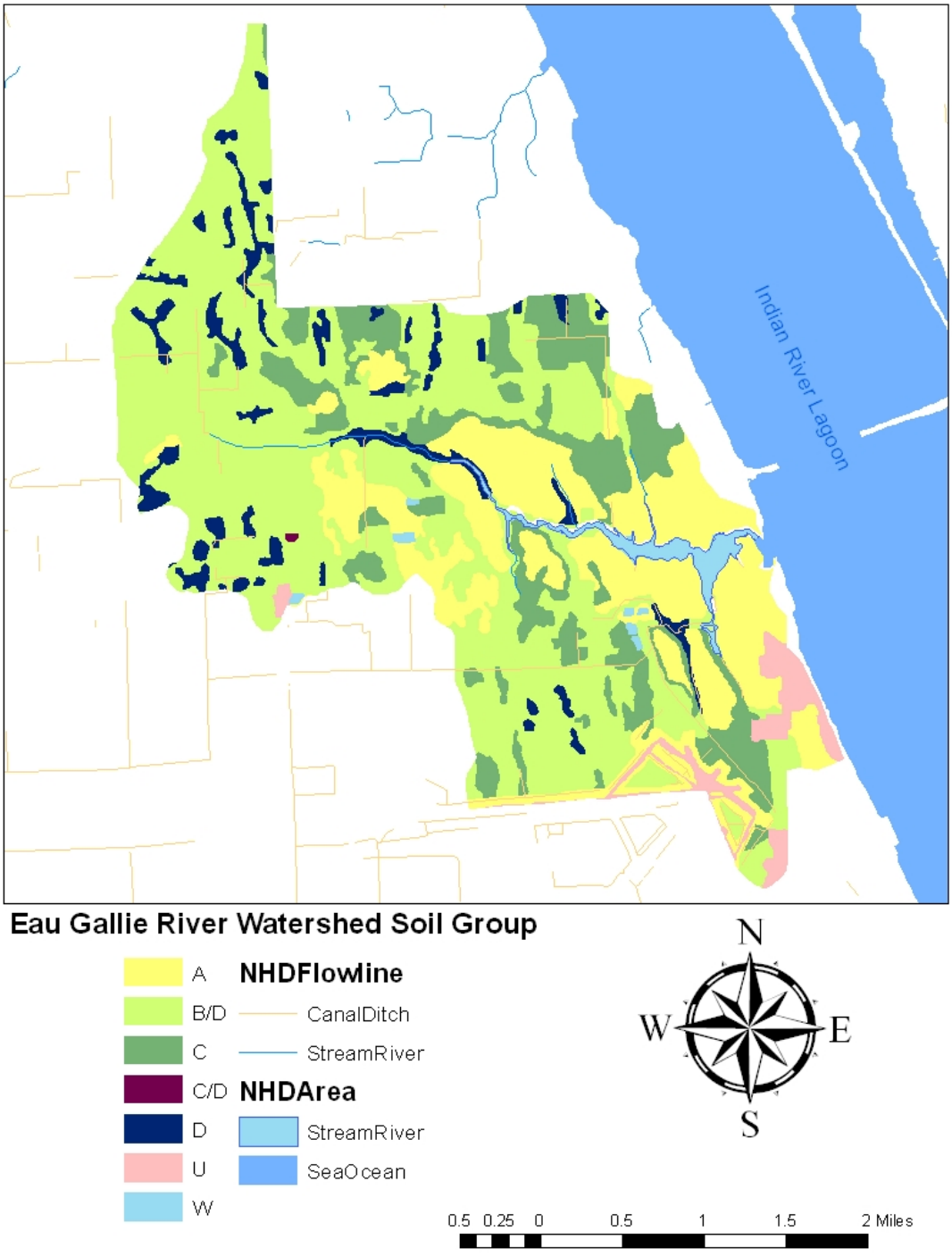


Figure 4.2-b. Distribution of Hydrologic Soil Groups in the Eau Gallie River Watershed

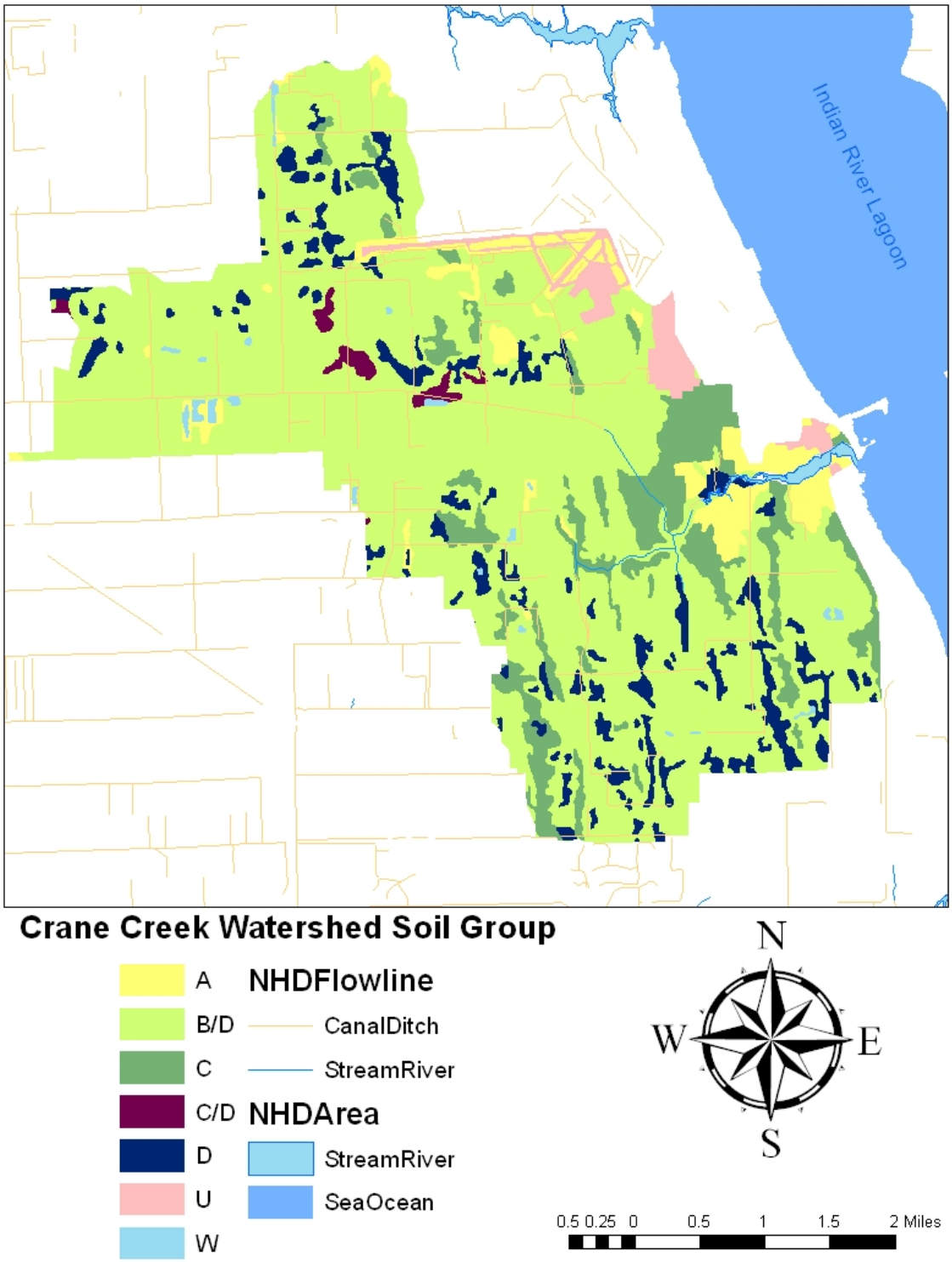


Figure 4.2-c. Distribution of Hydrologic Soil Groups in the Crane Creek Watershed

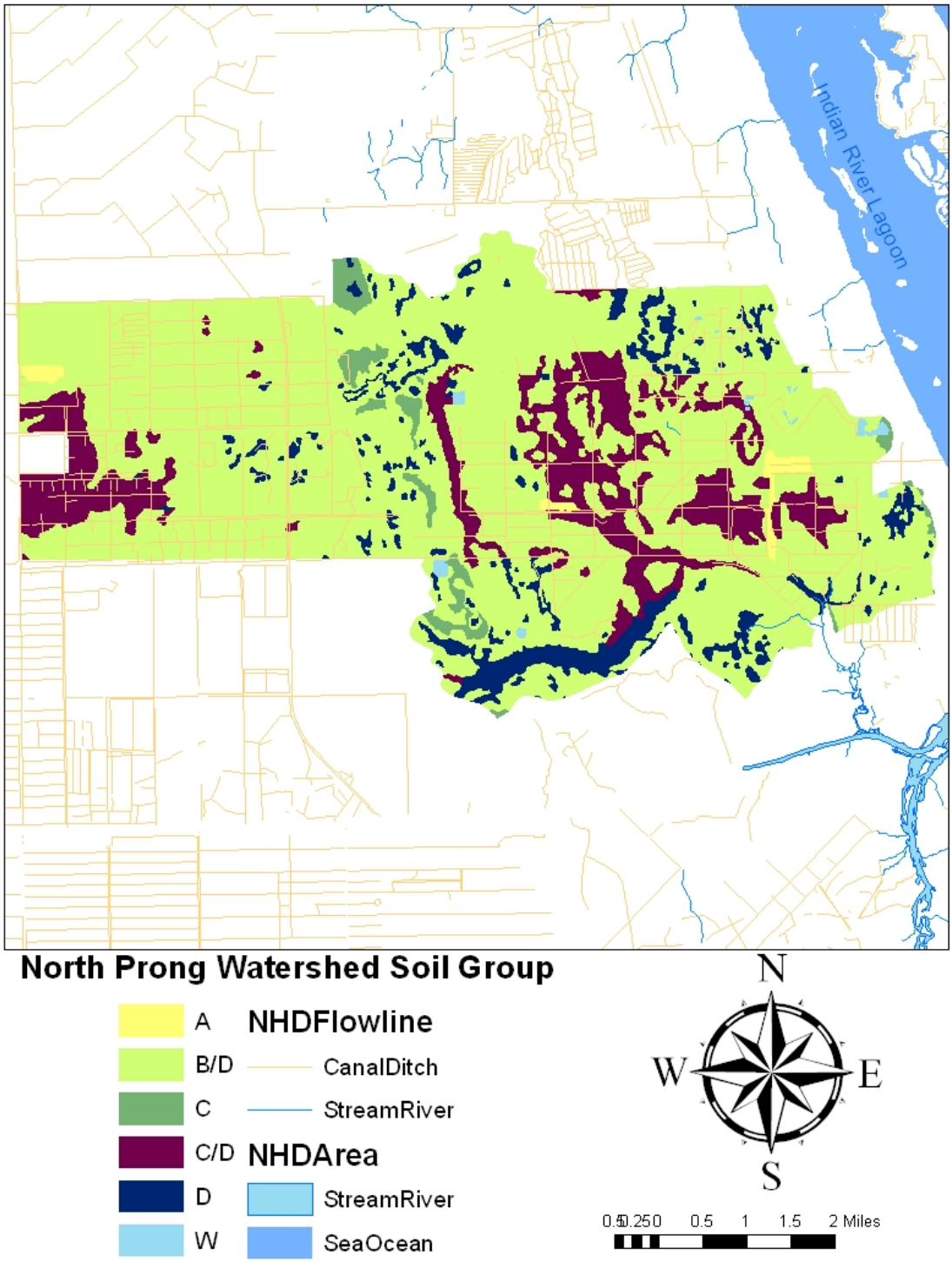


Figure 4.2-d. Distribution of Hydrologic Soil Groups in the North Prong of Sebastian River Watershed

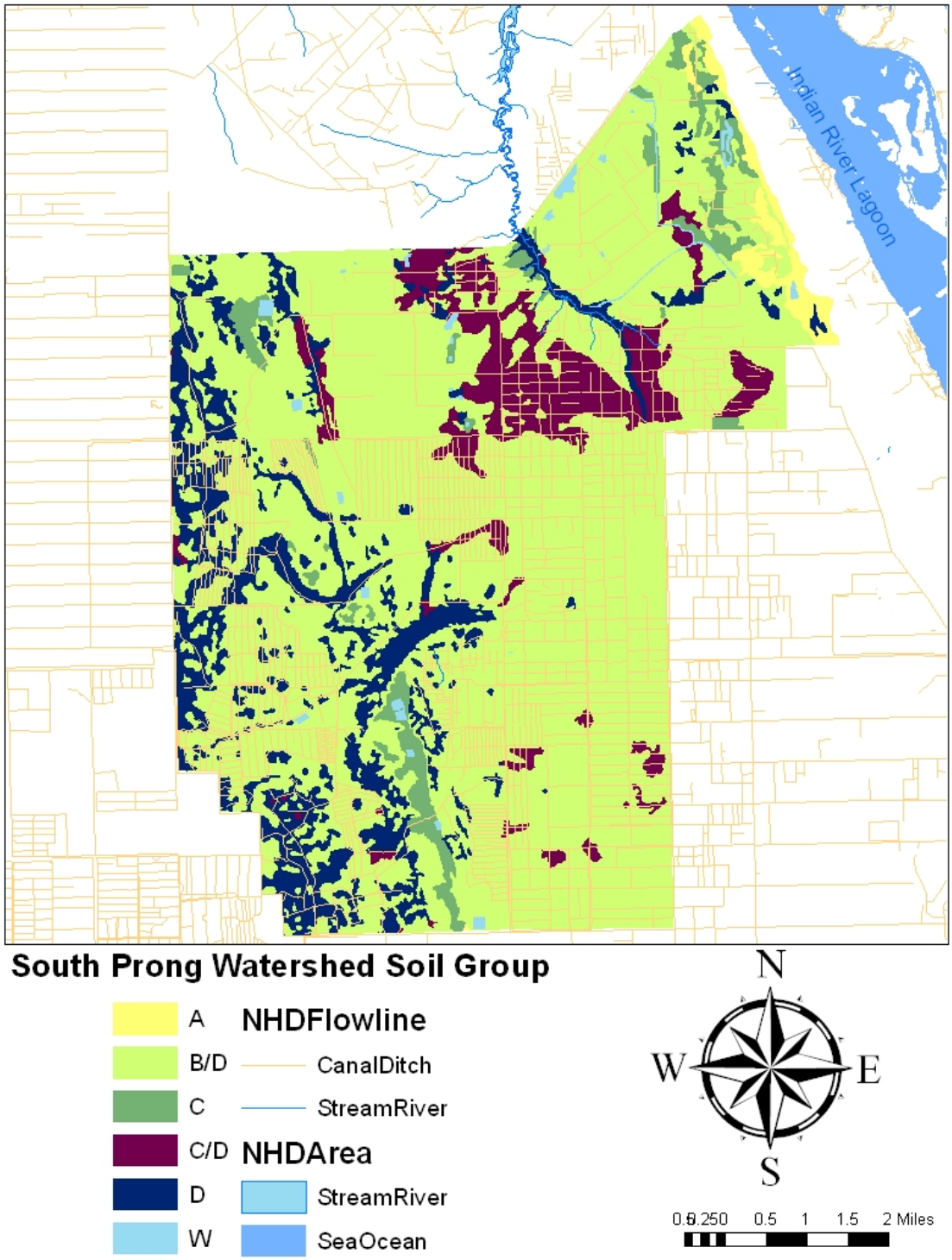


Figure 4.2-e. Distribution of Hydrologic Soil Groups in the South Prong of Sebastian River Watershed

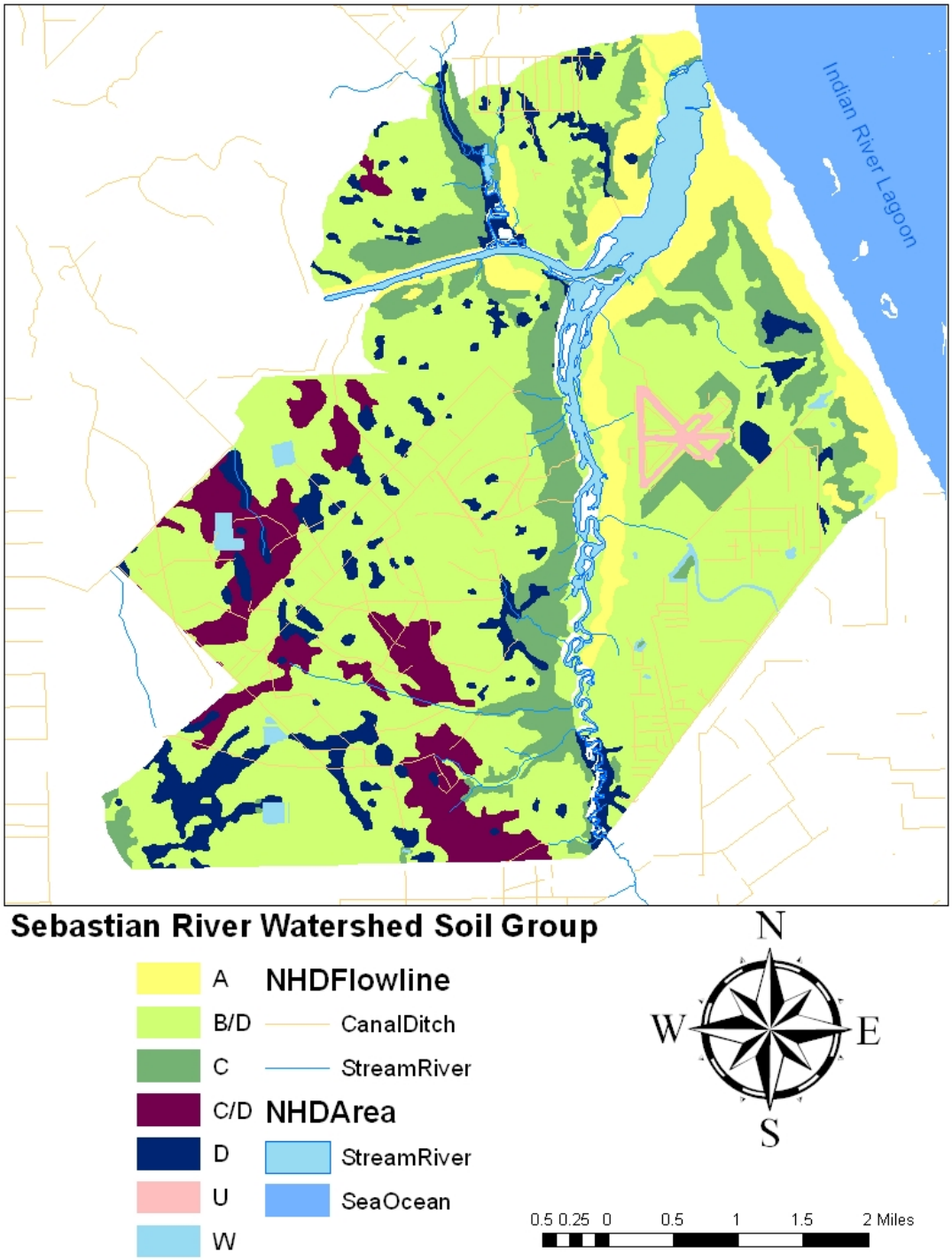


Figure 4.2-f. Distribution of Hydrologic Soil Groups in the Sebastian River Main Stem Watershed

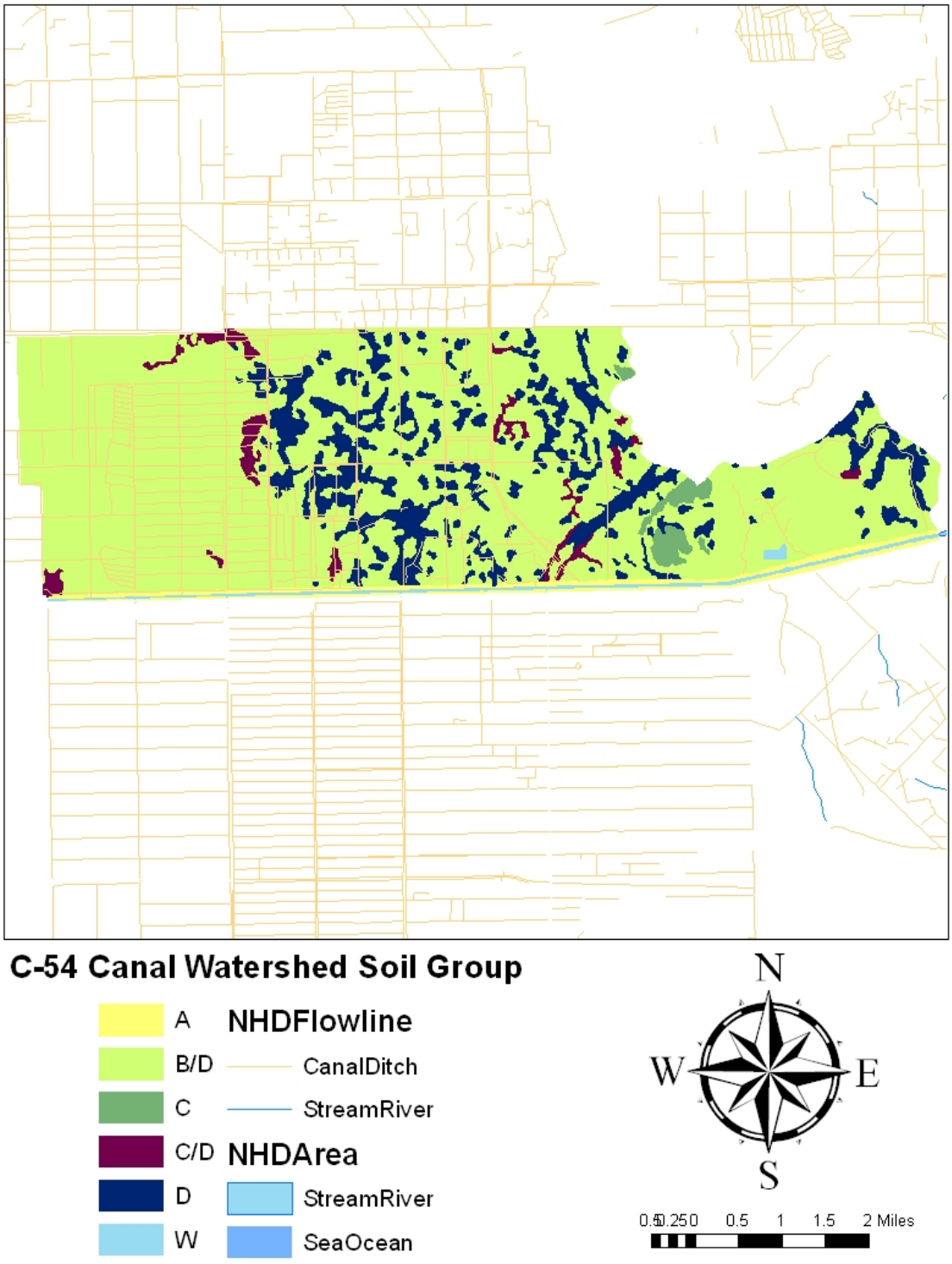


Figure 4.2-g. Distribution of Hydrologic Soil Groups in the C-54 Canal Watershed

Table 4.9-a. Runoff Coefficients Assigned to Each Land Use - HSG Soil Combination for the North Indian River Lagoon Basin

	Hydrological Soil Group							Hydrological Soil Group					
FLUCCS	A	B	B/D	C	C/D	D	FLUCCS	A	B	B/D	C	C/D	D
1100	0.174	0.230	0.342	0.286	0.342	0.342	4120	0.102		0.413	0.309		
1190	0.160		0.223	0.202		0.223	4130	0.102		0.413	0.309		0.413
1200	0.220	0.304	0.304	0.389	0.389	0.473	4200	0.102		0.413	0.309	0.413	0.413
1290	0.160		0.223	0.202		0.223	4210	0.102		0.413	0.309		0.413
1300	0.631		0.662	0.692	0.692	0.733	4340	0.102	0.206	0.413	0.309	0.413	0.413
1400	0.886	0.887	0.887	0.888	0.888	0.900	4370			0.413	0.309	0.413	0.413
1460	0.886		0.887	0.888		0.900	4410	0.102	0.206	0.413	0.309		0.413
1480	0.583		0.629	0.674		0.720	4430	0.102	0.206	0.413	0.309	0.413	0.413
1490	0.160						5100	1.000		1.000	1.000	1.000	1.000
1500			0.793				5200	0.500		0.500	0.500	0.500	0.500
1510	0.760		0.793			0.858	5250			0.500			0.500
1520	0.760		0.793	0.825			5300	0.500	0.500	0.500	0.500	0.500	0.500
1530	0.760			0.825			5340	0.500		0.500	0.500	0.500	0.500
1540	0.760		0.793				5400	1.000		1.000	1.000	1.000	1.000
1550	0.544		0.577	0.609		0.642	5430	1.000		1.000	1.000	1.000	1.000
1560	0.760		0.793	0.825	0.825	0.858	6110			0.303	0.266	0.303	0.303
1562				0.825			6120	0.191		0.303	0.266	0.303	0.303
1600	0.220		0.304	0.389	0.389	0.473	6170	0.191	0.228	0.303	0.266	0.303	0.303
1620	0.220		0.304	0.389		0.473	6180			0.303		0.303	0.303
1660	0.127		0.183	0.182	0.196	0.210	6181	0.124		0.303	0.266	0.303	0.303
1700	0.696		0.741	0.786		0.856	6182			0.303		0.303	0.303
1750	0.680		0.724	0.768	0.768	0.836	6200						0.303
1800	0.127		0.183	0.182		0.210	6210	0.191	0.228	0.303	0.266	0.303	0.303
1820	0.182		0.222	0.258	0.258	0.298	6250	0.191		0.303	0.303	0.303	0.303
1830			0.703			0.850	6300	0.191	0.228	0.303	0.266	0.303	0.303
1840	0.232		0.319	0.407	0.407	0.494	6410	0.191	0.228	0.303	0.266	0.303	0.303
1850	0.126		0.212	0.300		0.387	6420	0.191		0.303	0.266	0.303	0.303
1860	0.127		0.183	0.182		0.210	6430	0.191	0.228	0.303	0.266	0.303	0.303
1870	0.499						6440	0.191		0.303	0.266	0.303	0.303
1890	0.499		0.543	0.589		0.637	6460	0.191		0.303	0.266	0.303	0.303
1900	0.151		0.193	0.234		0.276	6500			0.303	0.266		0.303
1920	0.151		0.193	0.234		0.276	6510						0.303
2110	0.251	0.305	0.405	0.359	0.405	0.405	7100						0.413
2120		0.256	0.411		0.411	0.411	7200	0.102		0.413	0.309		
2130	0.189		0.411	0.334	0.411	0.411	7400	0.160		0.223	0.202		0.223
2140	0.204		0.281	0.358	0.358	0.435	7410	0.151	0.193	0.234	0.234	0.234	0.276
2150	0.189		0.411	0.334	0.411	0.411	7430	0.169	0.169	0.169	0.169	0.169	0.169
2200	0.251		0.268				8110	0.326	0.399	0.399	0.473		0.546
2210	0.251	0.268	0.268	0.285	0.285	0.302	8120	0.200		0.250	0.300	0.300	0.350
2240	0.251		0.268	0.285	0.285	0.302	8130	0.886		0.887	0.888		
2320	0.157		0.190				8140	0.630	0.703	0.703	0.777	0.777	0.850
2410			0.268			0.302	8180				0.888		
2430	0.251		0.268	0.285		0.302	8191			0.703	0.777		0.900
2500			0.405				8200	0.127		0.155	0.182	0.182	0.210
2510		0.260	0.260	0.315		0.370	8310	0.760		0.793	0.825		0.858
2610			0.281			0.435	8320	0.127		0.210	0.182	0.210	0.210
3100	0.100	0.195	0.411	0.300	0.411	0.411	8330	0.174	0.230	0.230	0.286		
3200	0.060	0.176	0.400	0.287	0.400	0.400	8340	0.174	0.230	0.230	0.286		0.342
3300	0.060	0.176	0.400	0.287	0.400	0.400	8350	0.252		0.329	0.407		0.485
4110	0.102	0.206	0.413	0.309	0.413	0.413	8360			0.650			

Note: Blank spaces represent land use – HSG combinations that do not exist in the North Indian River Lagoon Basin.

Table 4.9-b. Runoff Coefficients Assigned to Each Land Use - HSG Soil Combination for the Central Indian River Lagoon Basin

	Hydrological Soil Group							Hydrological Soil Group					
FLUCCS	A	B	B/D	C	C/D	D	FLUCCS	A	B	B/D	C	C/D	D
1100	0.174	0.230	0.342	0.286	0.342	0.342	3300	0.060		0.400	0.287	0.400	0.400
1180	0.174		0.402	0.286	0.402	0.402	4110	0.102	0.206	0.413	0.309	0.413	0.413
1190	0.160		0.223	0.202		0.223	4120	0.102		0.413	0.309	0.413	
1200	0.220	0.304	0.304	0.389	0.389	0.473	4130	0.102	0.206	0.413	0.309	0.413	0.413
1290	0.160		0.223	0.202		0.223	4200	0.102		0.413	0.309	0.413	0.413
1300	0.631	0.662	0.662	0.692	0.692	0.733	4210	0.102		0.413	0.309	0.413	0.413
1390	0.160	0.181	0.223	0.202	0.223	0.223	4280	0.102		0.413	0.309		
1400	0.886	0.887	0.887	0.888	0.888	0.900	4300			0.413	0.309		
1480	0.583	0.629	0.629	0.674	0.674		4340	0.102	0.206	0.413	0.309	0.413	0.413
1500			0.793				4370	0.102		0.413	0.309	0.413	0.413
1510	0.760	0.793	0.793	0.825	0.825	0.858	4410	0.102		0.413			
1520			0.793			0.858	4430			0.413	0.309		0.413
1550	0.544		0.577	0.609	0.609	0.642	5000	1.000			1.000		
1560	0.760						5100	1.000		1.000	1.000	1.000	1.000
1590			0.223				5200	0.500		0.500	0.500	0.500	0.500
1600	0.220		0.304	0.389	0.389		5250	0.500		0.500		0.500	0.500
1610	0.220		0.304		0.389		5300	0.500	0.500	0.500	0.500	0.500	0.500
1620	0.220		0.304	0.389			5400	1.000	1.000	1.000	1.000		1.000
1660	0.127		0.183	0.182			5430	1.000	1.000	1.000	1.000		1.000
1700	0.696	0.741	0.741	0.786	0.786	0.856	6110			0.303			0.303
1730	0.680		0.724	0.768	0.768	0.836	6120	0.191	0.228	0.303	0.266	0.303	0.303
1750	0.680		0.724	0.768	0.768		6170	0.191		0.303	0.266	0.303	0.303
1800	0.127	0.155	0.183	0.182		0.210	6181	0.124		0.303	0.266	0.303	0.303
1810	0.127		0.183	0.182		0.210	6182			0.000		0.000	0.000
1820	0.182	0.222	0.222	0.258	0.258	0.298	6210			0.303	0.266	0.303	0.303
1840	0.232		0.319	0.407		0.494	6220			0.303			
1850	0.126		0.212	0.300		0.387	6250			0.303	0.303	0.303	0.303
1860	0.127		0.183	0.182		0.210	6300	0.191		0.303	0.266	0.303	0.303
1870	0.499		0.543				6410	0.191		0.303	0.266	0.303	0.303
1890			0.543	0.589	0.589	0.637	6420	0.191		0.303	0.266		0.303
1900	0.151		0.193	0.234	0.234	0.276	6430	0.191		0.303	0.266	0.303	0.303
1920	0.151	0.193	0.193	0.234	0.234	0.276	6440	0.191		0.303	0.266	0.303	0.303
2110	0.251		0.405	0.359	0.405	0.405	6460	0.191	0.228	0.303	0.266	0.303	0.303
2120	0.189		0.411	0.334	0.411	0.411	6500	0.191					0.303
2130	0.189		0.411	0.334	0.411	0.411	7100	0.102			0.309		0.413
2140	0.204		0.281		0.358	0.435	7200				0.309		
2150	0.189		0.411	0.334	0.411	0.411	7400	0.160	0.181	0.223	0.202	0.223	0.223
2200			0.268	0.285			7410	0.151		0.234	0.234	0.234	0.276
2210	0.251	0.268	0.268	0.285	0.285	0.302	7420			0.169		0.169	
2240	0.251		0.268	0.285	0.285	0.302	7430	0.169		0.169	0.169	0.169	0.169
2310			0.190				8110	0.326		0.399	0.473	0.473	0.546
2400			0.268				8130	0.886		0.887			
2430	0.251		0.268	0.285	0.285	0.302	8140	0.630		0.703	0.777	0.777	0.850
2500	0.355		0.405	0.454	0.454	0.503	8200	0.127		0.155	0.182	0.182	0.210
2510			0.260		0.315	0.370	8310	0.760	0.793	0.793	0.825	0.825	0.858
2540			0.793	0.825		0.858	8320	0.127		0.210	0.182	0.210	0.210
2600			0.281				8330		0.230	0.230	0.286		0.342
2610			0.281		0.358	0.435	8340	0.174		0.230	0.286	0.286	0.342
3100	0.100	0.195	0.411	0.300	0.411	0.411	8350	0.252		0.329	0.407		0.485
3200	0.060	0.176	0.400	0.287	0.400	0.400	8360	0.650		0.650	0.650		0.650

Note: Blank spaces represent land use – HSG combinations that do not exist in the North Indian River Lagoon Basin.

4.2.2.4 Event Mean Concentrations (EMCs) and Land Uses

Event mean concentrations (EMCs) represent the concentrations of pollutants contained in the runoff, and are required components of the PLSM model in estimating nutrient loads from a given watershed. Most of the EMCs used in this TMDL were cited from Adamus and Bergman (1998), and supplemented with literature values from Dierberg (1994), Harper (1994), Hendrickson and Konwinski (1998), Pandit and Youn(2002), Riekerk (1982), Trefry and Feng (1991), and Zhang et al., (2002). EMC values were also adjusted based on results from local studies and through model calibration. **Tables 4.10-a** and **4.10-b** show a summary of TN and TP EMCs for different land use types included in the SJRWMD's PLSM model for the North Indian River Lagoon and Central Indian River Lagoon basins, respectively.

It should be noted that the PLSM model assumes that the net nutrient loads from wetland areas are zero. This assumption was used primarily because the wetland areas can be either sink or source of nutrients, depending on the vegetative and soil composition, hydroperiod, and hydrological connectivity. At the time when the PLSM model was developed, no detailed local information was available regarding which wetlands were nutrient sources verses sinks, Therefore, the SJRWMD assumed a neutral role for wetlands nutrient dynamics.

4.2.2.5 Rainfall

Rainfall is the driving force in a watershed to create pollutant loads. In simulating the watershed nutrient contribution under the existing condition, the SJRWMD's PLSM model used a 30-year long-term average annual rainfall for the period from 1975 through 2005. In the Indian River Lagoon and adjacent areas, stations that have 30-years of rainfall records are mostly National Weather Service stations, which include stations located at the Daytona Beach International Airport, City of Titusville, Melbourne International Airport, Vero Beach Airport, and Fort Pierce. A 30-year rainfall record was also available at Patrick Air Force Base. The rainfall amount used in a specific IRL basin area in the PLSM model was calculated as the mean average annual rainfall from nearby stations using the Thiessen Polygon method. The weather stations and the 30-year long-term annual average rainfall used to simulate watershed discharge and nutrient loadings for the ten watersheds included in this TMDL report are listed in **Table 4-11**.

Table 4.10-a. TN and TP EMCs for Different Land Uses in the North Indian River Lagoon Basin

FLUCCS	TN EMC (mg/L)	TP EMC (mg/L)	FLUCCS	TN EMC (mg/L)	TP EMC (mg/L)
1100	1.85	0.22	4120	0.70	0.09
1190	1.38	0.08	4130	0.70	0.09
1200	2.23	0.32	4200	0.70	0.09
1290	1.38	0.08	4210	0.70	0.09
1300	2.10	0.52	4340	0.70	0.09
1400	1.93	0.50	4370	0.70	0.09
1460	1.93	0.50	4410	0.70	0.09
1480	1.58	0.18	4430	0.70	0.09
1490	1.38	0.08	5100	0.60	0.05
1500	1.79	0.31	5200	0.60	0.11
1510	1.79	0.31	5250	0.25	0.05
1520	1.25	0.35	5300	0.60	0.13
1530	1.79	0.31	5340	0.60	0.14
1540	1.79	0.31	5400	0.00	0.00
1550	1.55	0.15	5430	0.00	0.00
1560	1.79	0.31	6110	0.00	0.00
1562	1.79	0.31	6120	0.00	0.00
1600	1.18	0.15	6170	0.00	0.00
1620	1.18	0.15	6180	0.00	0.00
1660	0.60	0.11	6181	0.00	0.00
1700	1.80	0.48	6182	0.00	0.00
1750	1.80	0.48	6200	0.00	0.00
1800	1.25	0.08	6210	0.00	0.00
1820	1.78	0.38	6250	0.00	0.00
1830	2.08	0.34	6300	0.00	0.00
1840	1.58	0.15	6410	0.00	0.00
1850	1.25	0.10	6420	0.00	0.00
1860	1.58	0.10	6430	0.00	0.00
1870	2.04	0.24	6440	0.00	0.00
1890	1.58	0.22	6460	0.00	0.00
1900	1.20	0.08	6500	0.00	0.00
1920	1.20	0.08	6510	0.00	0.00
2110	2.70	0.58	7100	1.25	0.05
2120	2.52	0.09	7200	1.25	0.05
2130	2.52	0.09	7400	1.38	0.11
2140	4.56	1.00	7410	1.51	0.12
2150	2.52	0.27	7430	1.25	0.20
2200	1.92	0.51	8110	1.15	0.15
2210	1.92	0.51	8120	1.25	0.05
2240	1.59	0.25	8130	2.00	0.43
2320	3.74	1.13	8140	1.20	0.48
2410	2.30	0.57	8180	1.95	0.43
2430	2.30	0.57	8191	2.08	0.37
2500	2.32	0.50	8200	1.25	0.08
2510	2.32	0.50	8310	1.79	0.31
2610	2.91	0.55	8320	1.25	0.08
3100	1.20	0.06	8330	1.77	0.18
3200	1.20	0.06	8340	1.77	0.18
3300	1.20	0.06	8350	1.39	0.18
4110	0.70	0.09	8360	1.00	0.11

Table 4.10-b. TN and TP EMCs for Different Land Uses in the Central Indian River Lagoon Basin

FLUCCS	TN EMC (mg/L)	TP EMC (mg/L)	FLUCCS	TN EMC (mg/L)	TP EMC (mg/L)
1100	1.85	0.22	3300	1.20	0.06
1180	1.78	0.22	4110	0.70	0.09
1190	1.38	0.08	4120	0.70	0.09
1200	2.23	0.32	4130	0.70	0.09
1290	1.38	0.08	4200	0.70	0.09
1300	2.10	0.52	4210	0.70	0.09
1390	1.38	0.08	4280	0.70	0.09
1400	1.93	0.50	4300	0.70	0.09
1480	1.58	0.18	4340	0.70	0.09
1500	1.79	0.31	4370	0.70	0.09
1510	1.79	0.31	4410	0.70	0.09
1520	1.25	0.35	4430	0.70	0.09
1550	1.55	0.15	5000	0.00	0.00
1560	1.79	0.31	5100	0.60	0.05
1590	1.38	0.08	5200	0.60	0.11
1600	1.18	0.15	5250	0.25	0.11
1610	1.18	0.15	5300	0.60	0.13
1620	1.18	0.15	5400	0.00	0.00
1660	0.60	0.11	5430	0.00	0.00
1700	1.80	0.48	6110	0.00	0.00
1730	1.80	0.48	6120	0.00	0.00
1750	1.80	0.48	6170	0.00	0.00
1800	1.25	0.08	6181	0.00	0.00
1810	1.25	0.08	6182	0.00	0.00
1820	1.78	0.38	6210	0.00	0.00
1840	1.58	0.15	6220	0.00	0.00
1850	1.25	0.09	6250	0.00	0.00
1860	1.58	0.10	6300	0.00	0.00
1870	2.04	0.24	6410	0.00	0.00
1890	1.58	0.22	6420	0.00	0.00
1900	1.20	0.08	6430	0.00	0.00
1920	1.20	0.15	6440	0.00	0.00
2110	2.70	0.58	6460	0.00	0.00
2120	2.55	0.09	6500	0.00	0.00
2130	2.52	0.09	7100	1.25	0.05
2140	4.56	1.00	7200	1.25	0.05
2150	2.52	0.27	7400	1.38	0.11
2200	1.92	0.51	7410	1.51	0.12
2210	1.92	0.51	7420	1.25	0.20
2240	1.59	0.28	7430	1.25	0.20
2310	3.74	1.13	8110	1.15	0.15
2400	2.30	0.57	8130	2.00	0.43
2430	2.30	0.56	8140	1.18	0.48
2500	2.32	0.50	8200	1.25	0.08
2510	2.32	0.50	8310	1.79	0.31
2540	1.87	0.27	8320	1.25	0.08
2600	2.91	0.55	8330	1.77	0.18
2610	2.91	0.55	8340	1.77	0.18
3100	1.20	0.06	8350	1.39	0.18
3200	1.20	0.06	8360	1.00	0.11

Table 4-11. Weather Stations and 30-Year Long-Term Average Annual Rainfall Used in PLSM Model to Simulate Discharge and Nutrients from the Ten Watersheds of Impaired Water Segments

Station	Titusville Station	Melbourne Airport Station	Vero Beach Airport Station	Ft. Pierce Station
Rainfall (inches) Sub-basin	**54.65**	**48.29**	**56.5**	**52.82**
Addison Creek	O			
Eau Gallie River		O		
Crane Creek		O		
North Prong		O	O	
Sebastian River			O	
South Prong			O	
C-54 Canal		O	O	

Note: Empty circles in the table represent the weather stations and long-term average annual rainfall used for watersheds of impaired water segments.

4.2.2.6 BMPs

At the time when the PLSM model was developed for the Indian River Lagoon basin, no information was available regarding the detailed spatial distribution, types, and treatment efficiencies of stormwater treatment facilities in the IRL-BRL basin. Therefore, the PLSM model assumed that any urban construction that took place after 1984 (when the state stormwater rule was implemented) was developed with stormwater treatment facilities. Generalized treatment efficiencies were applied in the PLSM model, which include 30% removal of TN and 50% removal of TP by these stormwater treatment facilities. No stormwater treatment types were distinguished in the PLSM model. **Figures 4.3-a, 4.3-b, 4.3-c, 4.3-d, 4.3-e, 4.3-f,** and **4.3-g** show areas in watersheds of ten impaired water segments that are covered by generalized stormwater treatment facilities.

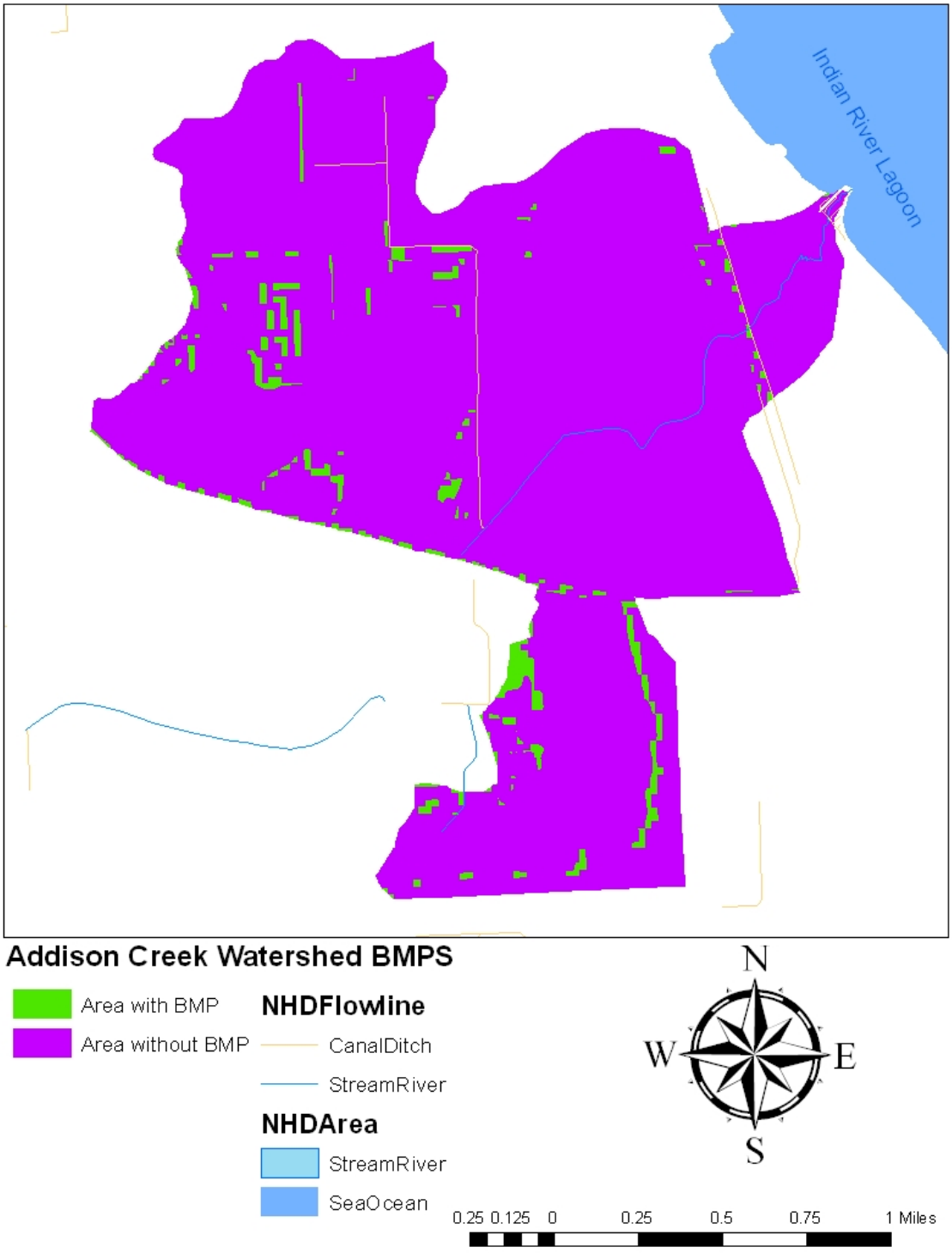


Figure 4.3-a. Distribution of BMPs in the Addison Creek Watershed

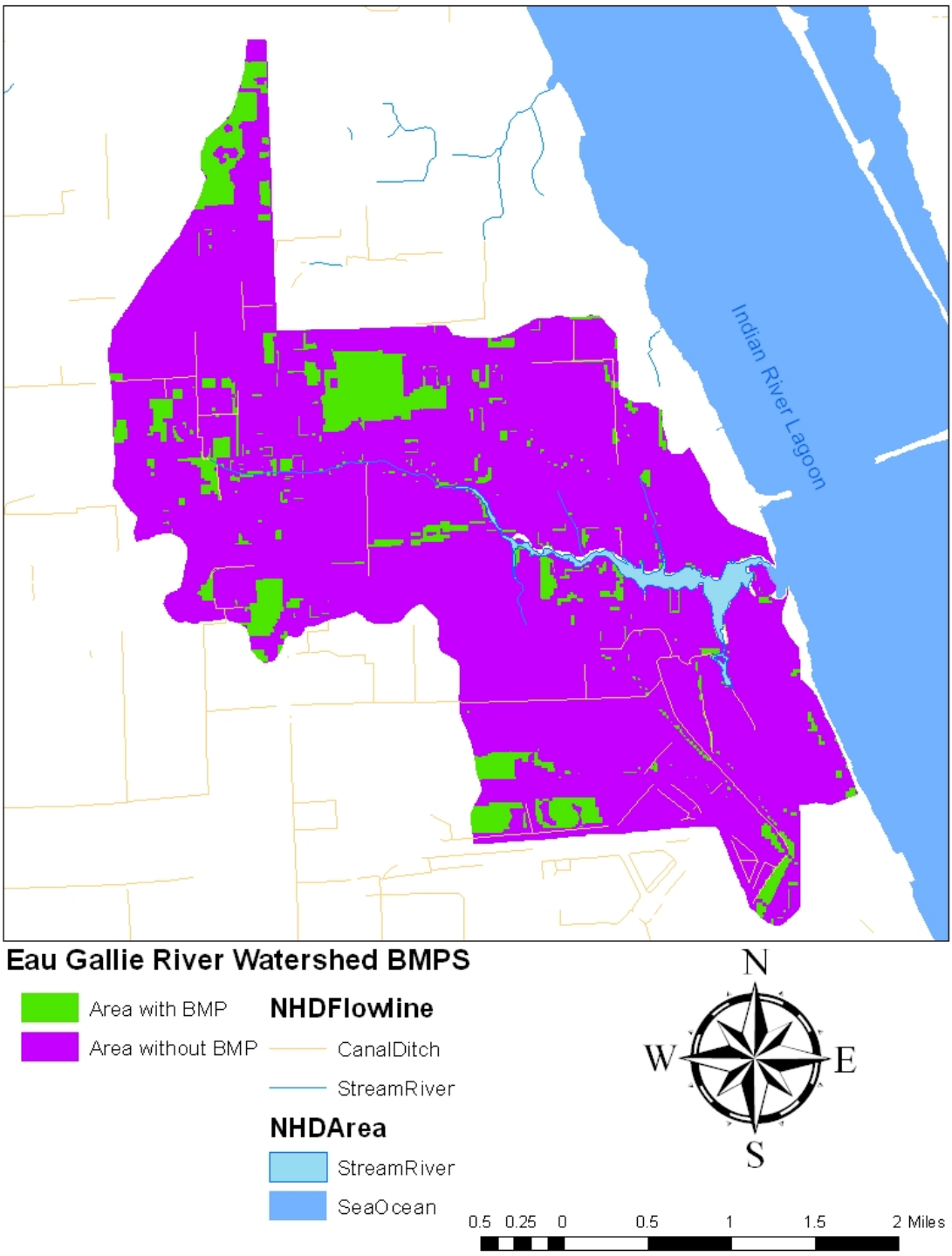


Figure 4.3-b. Distribution of BMPs in the Eau Gallie River Watershed

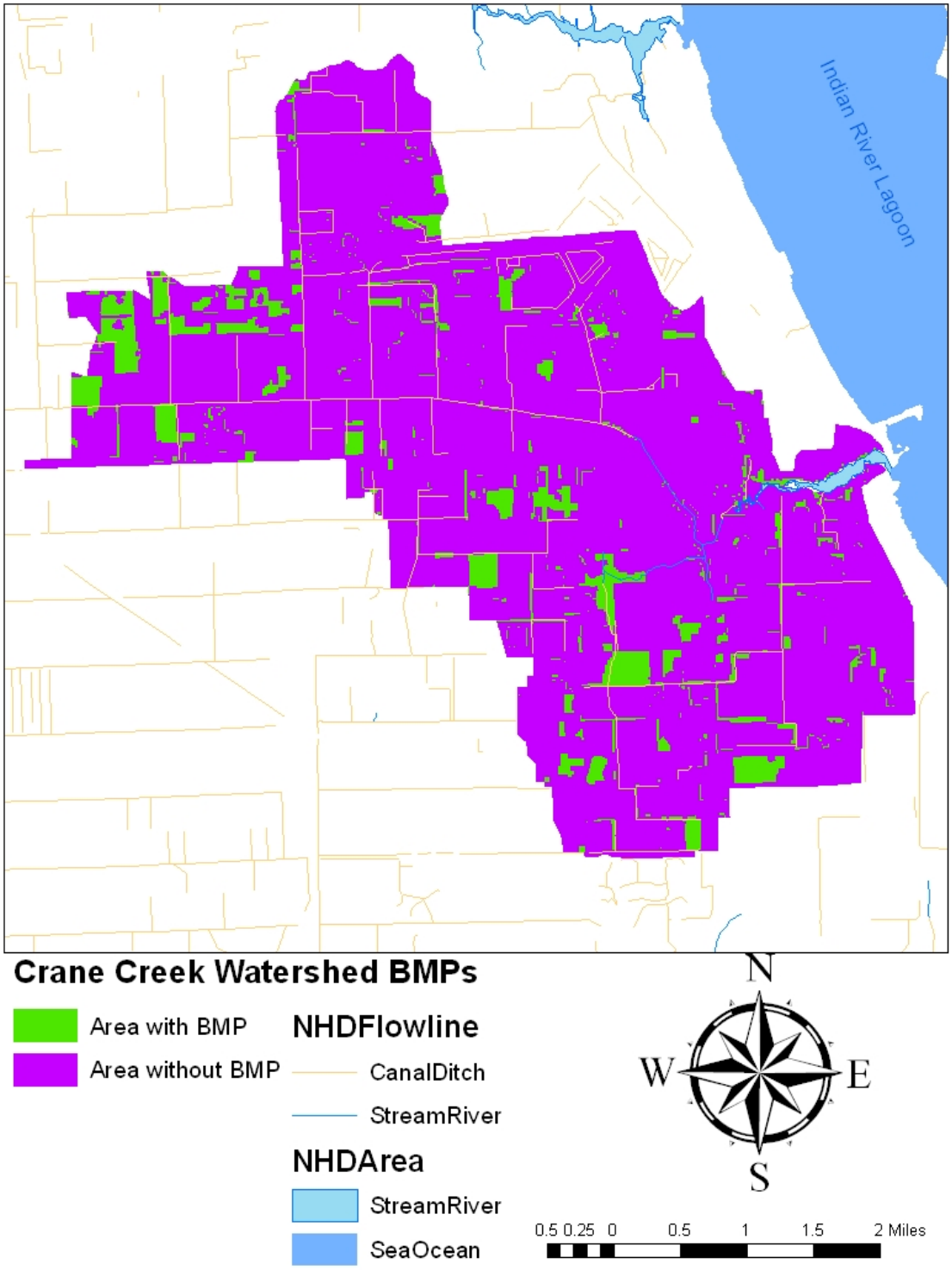


Figure 4.3-c. Distribution of BMPs in the Crane Creek Watershed

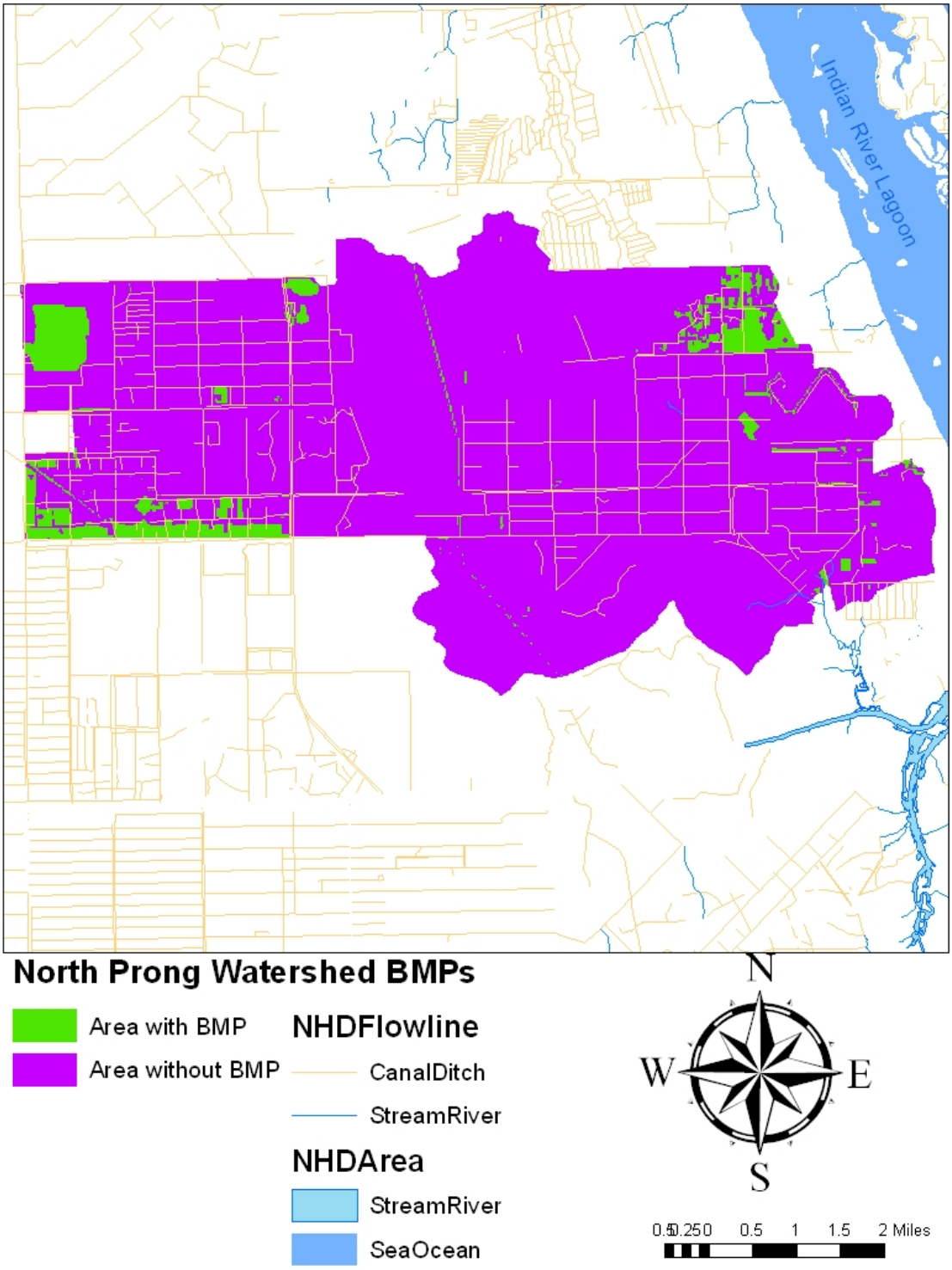


Figure 4.3-d. Distribution of BMPs in the North Prong of Sebastian River Watershed

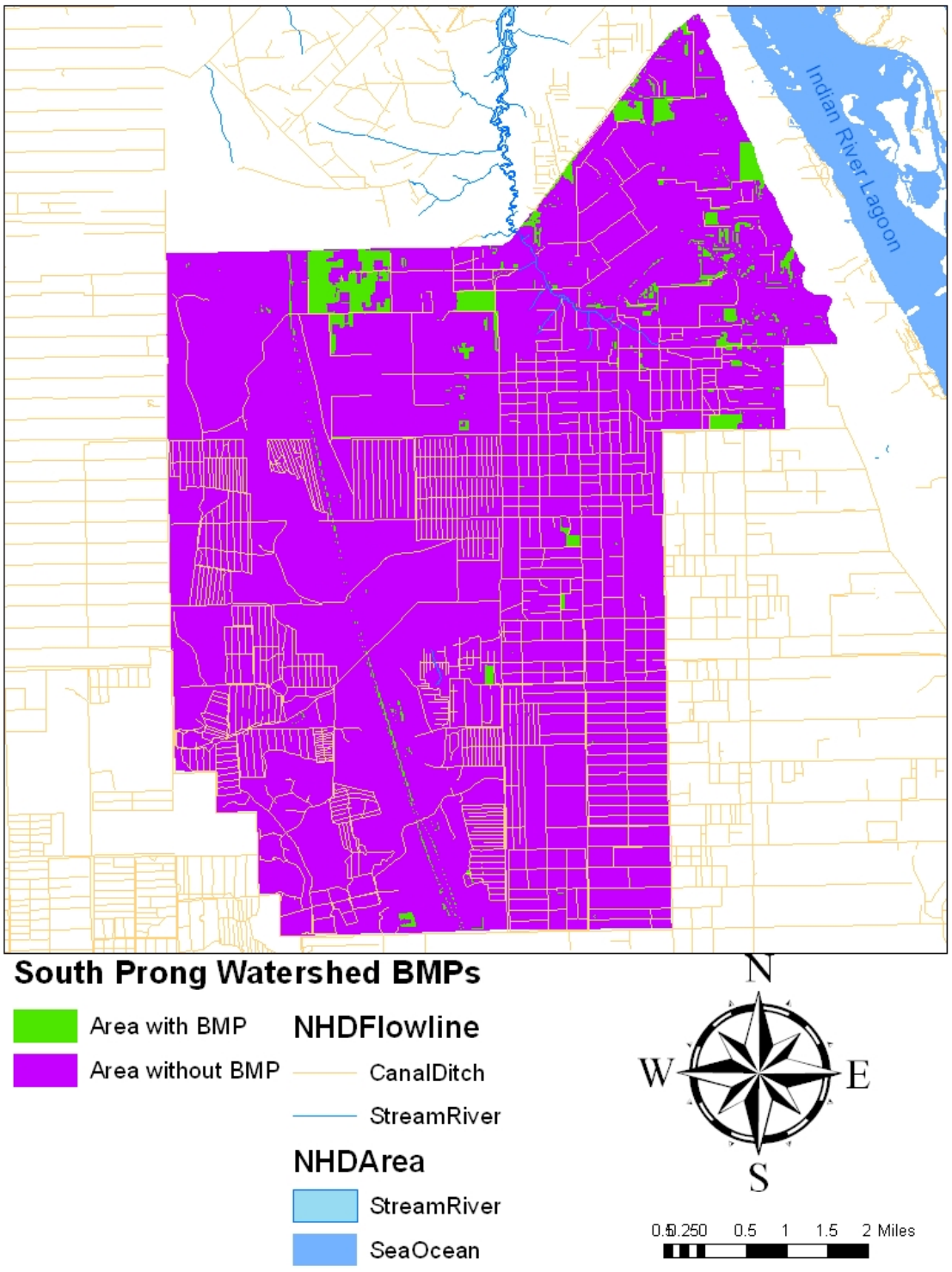


Figure 4.3-e. Distribution of BMPs in the South Prong of Sebastian River Watershed

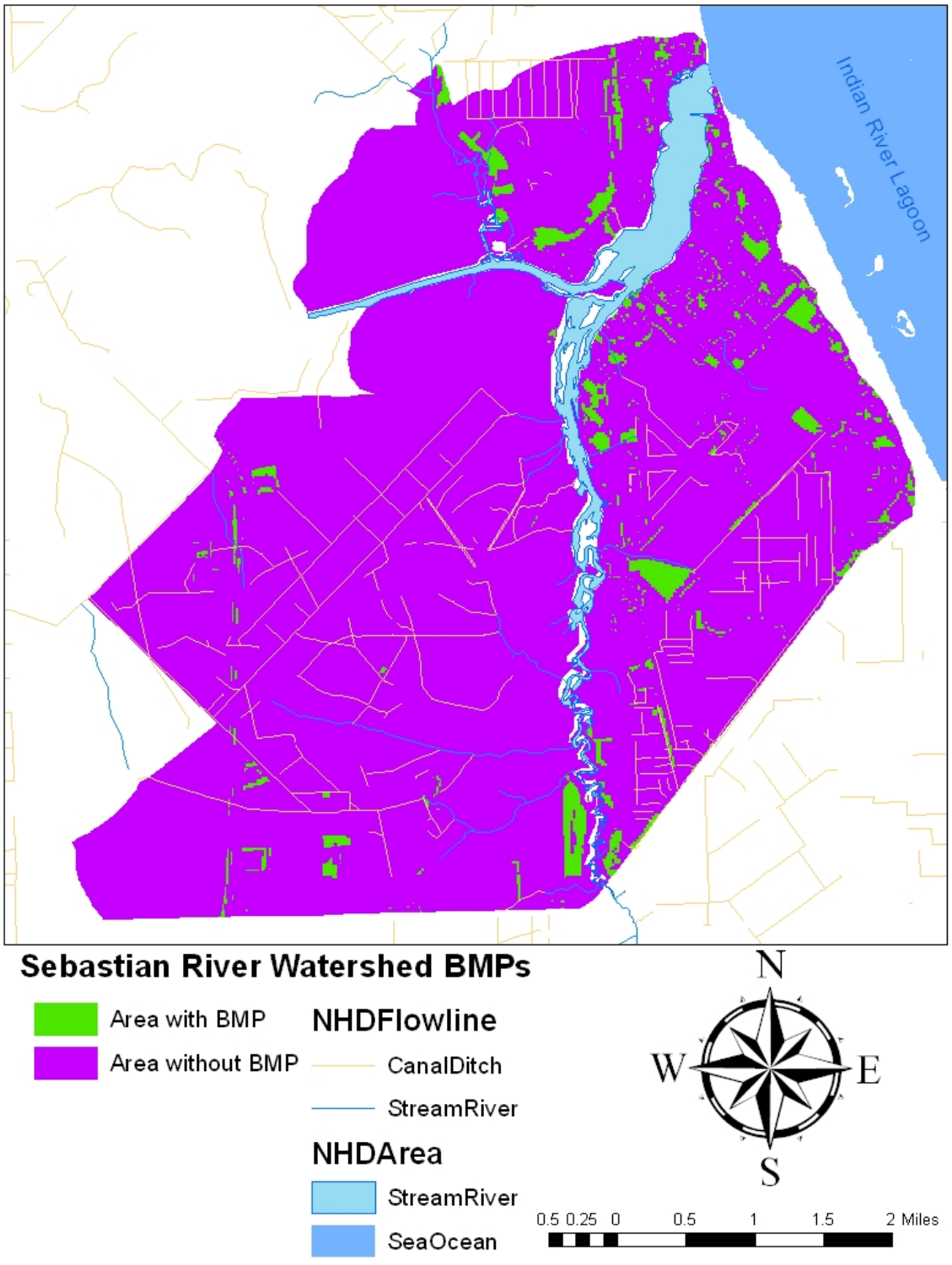


Figure 4.3-f. Distribution of BMPs in the Sebastian River Main Stem Watershed

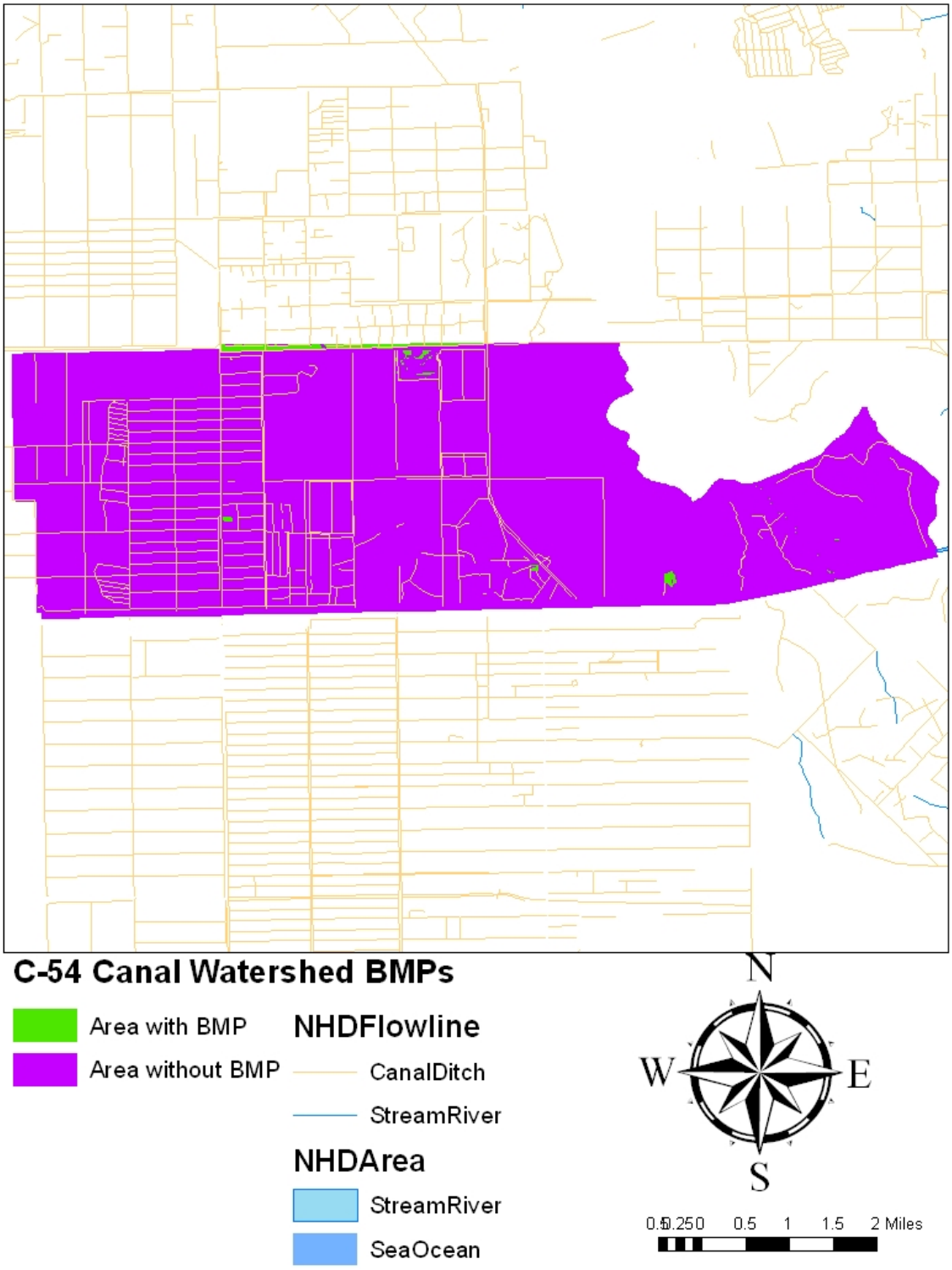


Figure 4.3-g. Distribution of BMPs in the C-54 Watershed

4.2.2.7. Nutrient Loads from Watersheds of Impaired Water Segments

Based on the information provided above, TN loads from watersheds of all the ten impaired water segments included in this report were calculated using the equation on page 64. Except for watersheds of Addison Creek and Eau Gallie River, which are located in the North Indian River Lagoon basin, TP loads from watersheds of all the other impaired segments were also simulated using the same equation used to simulate the TN loads. TP loads from Addison Creek and Eau Gallie River watersheds were estimated using HSPF models, which are discussed in later parts of this chapter. Estimated watershed TN and TP loads using the PLSM model loading equation are summarized in **Tables 4.12-a and 4.12-b**, respectively.

The results shown in **Table 4.12-a** reveal a general spatial pattern of TN loads coming from the watersheds of these impaired water segments. Except for the Addison Creek watershed(in which the natural land areas, including Forest and Water/Wetlands contribute about 20% of the TN loads from the entire watershed), TN loads from watersheds of all the other impaired segments contributed around 10% or less of the total watershed TN loads. TN loads from the urban land use areas dominated the watershed TN loads in Addison Creek, Eau Gallie River, and Crane Creek, which accounted for about 71.8%, 93.1%, and 85.4% of the total TN loads from their corresponding watersheds.

In contrast, TN loads from Agricultural lands in watersheds associated with the Sebastian River system, including watersheds of the North Prong of Sebastian River, the South Prong of Sebastian River, the Sebastian River Main Stem, and the C-54 Canal, played a more important role than TN loads from other land use types. Agricultural TN loads in these watersheds accounted for around 41.2% - 79.0% of the total watershed TN loads. TN loads from urban areas were typically less than 30% in these basins. Agricultural TN loads in watersheds of Addison Creek, the Eau Gallie River, and Crane Creek were insignificant, accounting for less than 2% of the total TN loads from their corresponding watersheds.

Because TP loads from Addison Creek and Eau Gallie River watersheds were simulated using the HSPF model, no discussion can be made regarding relative contributions from different land uses in these two watersheds in this section. However, in the other watersheds, land use specific relative contribution of TP loads appears to follow a similar pattern of the TN loads. Basically, the TP loads from the urban land areas in the Crane Creek watersheds dominated the total TP loads from the Crane Creek watershed. TP loads from urban land areas contributed about 92.8% of the total watershed loads in this watershed. In all the other watersheds, however, Agricultural lands contributed the highest percentage of TP loads among all land use groups. TP loads from agricultural areas accounted for about 48.1% - 86.3% of the total TP loads from these watersheds. Urban land TP contributions in these watershed were all 35% or less. Except in the watershed of North Prong of Sebastian River, where natural lands including Forest and Water/Wetlands contributed about 11.5% of the total watershed TP, natural lands in all the other watersheds contributed less than 10% of TP loads in these watershed.

In summary, Addison Creek has the most natural watershed among the 10 watersheds included in this TMDL report. Nutrient loads from the Eau Gallie River and Crane Creek watersheds were dominated by urban loads. The most important contributors of nutrients in all the other watersheds are agricultural lands.

Table 4.12-a. TN Loads from Watersheds of Impaired Water Segments

	Addison Creek (WBID 3028)		Eau Gallie River (WBID 3082)		Crane Creek (WBID 3085A)	
Land Use	**TN Load**	**Percent**	**TN Load**	**Percent**	**TN Load**	**Percent**
Agriculture	65.9	1.1%	184.3	0.3%	1,571.6	1.7%
Forest	1,136.6	19.6%	600.8	1.0%	3,187.4	3.5%
High-Intensity use urban	3,447.1	59.3%	45,867.9	77.9%	51,888.1	56.7%
Low-Intensity use urban	284.9	4.9%	2,201.4	3.7%	2,130.9	2.3%
Medium-intensity use urban	438.0	7.5%	6,752.6	11.5%	24,096.4	26.3%
Open land	431.0	7.4%	2,845.1	4.8%	7,775.5	8.5%
Water/Wetlands	6.6	0.1%	408.1	0.7%	814.7	0.9%
Total	**5,810.2**	100.0%	**58,860.3**	100.0%	91,464.6	100.0%
	North Prong of Sebastian River (WBID 3128)		**South Prong of Sebastian River (WBID 3129A)**		**Sebastian River (WBID 3129B)**	
Land Use	**TN Load**	**Percent**	**TN Load**	**Percent**	**TN Load**	**Percent**
Agriculture	43,179.0	41.2%	100,612.4	43.6%	56,492.6	52%
Forest	13,498.4	12.9%	15,770.0	6.8%	9,932.8	9%
High-Intensity use urban	12,188.1	11.6%	8,205.0	3.6%	9,880.2	9%
Low-Intensity use urban	7,221.3	6.9%	17,948.2	7.8%	2,110.5	2%
Medium-intensity use urban	261.3	0.2%	22,326.5	9.7%	17,313.5	16%
Open land	27,749.0	26.5%	63,692.6	27.6%	10,968.3	10%
Water/Wetlands	807.5	0.8%	2,011.5	0.9%	1,214.6	1%
Total	**104,904.6**	100.0%	**230,566.3**	100.0%	**107,912.3**	100%
	C-54 Canal (WBID 3135)					
Land Use	**TN Load**	**Percent**				
Agriculture	82,511.3	79.0%				
Forest	9,460.1	9.1%				
High-Intensity use urban	342.6	0.3%				
Low-Intensity use urban	224.2	0.2%				
Medium-intensity use urban	224.6	0.2%				
Open land	9,333.0	8.9%				
Water/Wetlands	2,398.6	2.3%				
Total	**104,494.5**	100.0%				

Note: the unit of TN load is lbs/year

Table 4.12-b. TP Loads from Watersheds of Impaired Water Segments

	Addison Creek (WBID 3028)		Eau Gallie River (WBID 3082)		Crane Creek (WBID 3085A)	
Land Use	**TP Load**	**Percent**	**TP Load**	**Percent**	**TP Load**	**Percent**
Agriculture	---	---	---	---	225.9	1.3%
Forest	---	---	---	---	412.9	2.4%
High-Intensity use urban	---	---	---	---	12,058.9	71.4%
Low-Intensity use urban	---	---	---	---	231.6	1.4%
Medium-intensity use urban	---	---	---	---	3,383.5	20.0%
Open land	---	---	---	---	438.6	2.6%
Water/Wetlands	---	---	---	---	136.7	0.8%
Total	---	---	---	---	16,888.1	100.0%
	North Prong of Sebastian River (WBID 3128)		**South Prong of Sebastian River (WBID 3129A)**		**Sebastian River (WBID 3129B)**	
Land Use	**TP Load**	**Percent**	**TP Load**	**Percent**	**TP Load**	**Percent**
Agriculture	9,198.3	56.5%	24,142.9	59.0%	7,617.0	52%
Forest	1,748.4	10.7%	2,036.8	5.0%	1,277.9	9%
High-Intensity use urban	3,034.1	18.6%	2,192.7	5.4%	2,334.4	16%
Low-Intensity use urban	588.6	3.6%	1,913.8	4.7%	213.3	1%
Medium-intensity use urban	54.9	0.3%	3,137.7	7.7%	2,468.6	17%
Open land	1,537.1	9.4%	7,187.8	17.6%	613.8	4%
Water/Wetlands	123.9	0.8%	314.9	0.8%	175.6	1%
Total	**16,285.3**	100.0%	**40,926.5**	100.0%	**14,700.6**	100%
	C-54 Canal (WBID 3135)					
Land Use	**TP Load**	**Percent**				
Agriculture	14,641.1	86.3%				
Forest	1,216.3	7.2%				
High-Intensity use urban	135.0	0.8%				
Low-Intensity use urban	13.0	0.1%				
Medium-intensity use urban	45.2	0.3%				
Open land	646.8	3.8%				
Water/Wetlands	270.7	1.6%				
Total	**16,968.1**	100.0%				

Note: TP loads unit is lbs/year. ---: Addison Creek and Eau Gallie River TP loads were simulated using HSPF.

4.2.2.8. TP Loading Simulation for Addison Creek and Eau Gallie River Watersheds

While the SJRWMD primarily used the results from the PLSM model to simulate nutrient loads entering the Indian River Lagoon and Banana River Lagoon systems, they also developed a set of HSPF models that covers the entire Indian River and Banana River Lagoon basins to simulate nutrient loads entering the lagoon system. Results of nutrient load simulation from these two models are very comparable (Steward and Green, 2007). However, when loading simulation results were used to correlate with the seagrass depth-limit to create per acre nutrient loading targets, depending on the sub-basin, either the PLSM results or the HSPF results produced stronger correlations. For most parts of the Indian River and Banana River Lagoon basins, the PLSM results produced better correlation with the seagrass depth-limit. HSPF simulated TP loading produced a better correlation with the seagrass depth-limit in the North Indian River Lagoon basin. Therefore, TP loading simulations for the North Indian River Lagoon basin areas were based on HSPF simulated TP results. As Addison Creek and the Eau Gallie River watersheds are located in the North Indian River Lagoon basin, TP existing loadings from these two watersheds were simulated using the SJRWMD's HSPF models.

The Addison Creek watershed occupies part of the HSPF drainage basin 2400 that drains to the North Indian River Lagoon segment IR5. This model uses the rainfall data collected from a rainfall station located at the Addison Creek Grissom Parkway near Port St. John. Other meteorological data used for the model were primarily collected from a National Oceanic and Atmospheric Administration (NOAA) weather station located in Vero Beach (Vero Beach 4W). As the original HSPF model that the Department obtained from the SJRWMD did not have Addison Creek watershed as a separate sub-basin, the Department split the basin 2400 into Addison Creek (designated as a new sub-basin 2500) and used the basin 2400 to represent the remaining portion of the original basin 2400. In doing so, the Department populated the HSPF model with the same land use acreage distribution and percentage of BMP treated developed land areas that are included in the SJRWMD's PLSM model. The percent imperviousness of developed lands in the Addison Creek was assumed to be the same as those included in the original HSPF model for basin 2400. In addition, because SJRWMD's model only output the total TP loading from the watershed, the Department revised the model output so that land use specific TP loadings can be output from the model.

The Eau Gallie River watershed represents part of the HSPF drainage basin 4400 that drains to the North Indian River Lagoon segment IR9-11. This model uses the rainfall data collected from a rainfall station located at the Eau Gallie River at Mossword Dr. in the City of Melbourne. Other meteorological data required for the model were collected from the NOAA weather station located in Vero Beach (Vero Beach 4W). The original model that the Department obtained from the SJRWMD specifically defines the watershed areas that discharge to the Eau Gallie River. Therefore, the only changes that the Department made to the model was to change the model output so that land use specific TP loadings can be output from the model.

In simulating the existing TP loads, the SJRWMD update the 1995 land use acreage of the original HSPF model to the Year 2000 land use acreage. Annual loads of TP were simulated for each year in the period from 1995 through 2003. The existing TP loads for Addison Creek and the Eau Gallie River were represented as the long-term average annual loads for the same period. The existing TP loadings simulated for Addison Creek and the Eau Gallie River watershed are summarized in **Table 4.13**.

Table 4.13. TP Existing Loads from Addison Creek and Eau Gallie River Watersheds

	Addison Creek (WBID 3028)		Eau Gallie River (WBID 3082)	
Land Use	**TP Load**	**Percent**	**TP Load**	**Percent**
Agriculture	4.4	0.3%	19.4	0.2%
Forest	133.5	9.0%	87.8	0.9%
High-Intensity use urban	1,059.4	71.4%	8,720.6	85.0%
Low-Intensity use urban	78.4	5.3%	219.5	2.1%
Medium-intensity use urban	87.8	5.9%	1,005.8	9.8%
Open land	38.9	2.6%	156.2	1.5%
Water/Wetlands	80.8	5.5%	45.5	0.4%
Total	1,483.1	100.0%	10,254.9	100.0%

Based on **Table 4.13**, the dominant sources of TP in both Addison Creek and Eau Gallie River watersheds were from urban land areas, especially from “High-Intensity Use” urban areas, which accounted for about 71.4% and 85.0% of the total TP loads from the Addison Creek and Eau Gallie River watersheds, respectively. In total, urban areas in these two watersheds contributed about 82.6% and 97.0% of the total TP loads from their corresponding watersheds. TP loadings from Agricultural areas in these two watersheds were minimal, with each contributing less than 0.3% of the total TP loads. For the Addison Creek watershed, natural areas contributed about 14.5% of the watershed TP, while natural areas in Eau Gallie River watershed only contributed about 1.3% of the total TP loads. In addition, Open Land areas contributed about 2.6% and 1.5% of the total TP loads in Addison Creek and Eau Gallie River watersheds, respectively.

4.2.2.9. BOD Loads from the Watersheds of Impaired Water Segments and CDM HSPF Models

While nutrients could be important factors controlling water column DO concentrations(by controlling photosynthesis DO enrichment and DO consumption through algae respiration), and by contributing to the sediment oxygen demand (SOD) results from the settling of algal detritus into the sediment, dissolved and particulate organic carbon, usually represented by biochemical oxygen demand (BOD) could also be important factors controlling DO concentration in the water column. BOD controls water column DO concentration mostly through bacterial respiration which occurs when bacteria use these organic carbon sources to produce their own biomass and support metabolic activity. BOD can also settle to the sediment and contribute to the SOD, which, in turn, controls the DO concentration in the water column.

None of the PLSM models or the HSPF models developed by the SJRWMD included BOD as a pollutant to be simulated because those models were specifically developed to estimate the watershed nutrient loadings to protect the seagrass communities in the mainstem of the Indian River and Banana River Lagoon segments. However, as all the water segments included in this report were impaired for low water column DO concentration, it is desirable to simulate the BOD loadings from watersheds of these impaired water segments. These BOD watershed loadings were simulated using the updated HSPF models developed by CDM.

To examine the DO dynamics in the ten impaired tributaries that discharge into the Indian River Lagoon, the Department contracted with CDM to develop HSPF models for these impaired tributaries in 2010. These HSPF models were mostly based on the HSPF models developed by the SJRWMD for watersheds of these impaired tributaries, except that the HSPF model for the C-54 Canal was newly created by the CDM. **Table 4.14** shows the impaired water segments included in this report and their corresponding SJRWMD drainage basins.

Table 4.14. SJRWMD's HSPF Drainage Basins Related to the Impaired Water Segments

Impaired Water Segments	SJRWMD's HSPF Drainage Basins
Addison Creek	2400
Eau Gallie River	4400
Crane Creek	4500
North Prong of Sebastian River	6100
South Prong of Sebastian River	6300
Sebastian River Main Stem	6400
C-54 Canal	6000

Several adjustments were conducted by the CDM to refine SJRWMD's HSPF models. These refinements include:

(1) Addison Creek watershed was split out in SJRWMD's HSPF model for drainage basin 2400 and entered in the revised HSPF model as a separate sub-basin.
(2) SJRWMD's original HSPF models were calibrated based on Year 1995 land use. When developing the seagrass PLRG, the SJRWMD updated their HSPF models to Year 2000 land use for conducting statistical analyses and simulating existing condition nutrient loads for some lagoon basin areas. However, these HSPF models with updated land use were not further calibrated. The CDM re-calibrated these models for hydrology and water quality after the 1995 land use was updated to Year 2000 land use.

One important step of hydrology calibration is to determine the total impervious area in each sub-basin of the model domain. The impervious areas in the HSPF model are directly connected impervious area (DCIA), which are areas discharging directly to given receiving water without going through intermediate pervious area. Based on CDM's previous modeling works, only the high, medium, and low-intensity use urban areas were considered having DCIA. The percent areas of these urban landuse that are considered DCIA are about 70%, 25%, and 15% for the high, medium, and low-intensity urban areas, respectively (CDM, 2002). These values were adjusted through model calibration for each specific watershed. The other land use types, including agriculture, open land, forest, and wetland, were considered composed of only pervious areas.

Several other key parameters were adjusted in the model hydrology calibration to balance the annual total flow:

LZSN (lower zone storage norminal) - This is the key parameter in establishing an annual water balance. Increasing the value of LZSN increases the amount of infiltrated water that is lost by evapo-transpiration, and therefore, decreases the annual stream flow volume.

LZETP (lower zone evapo-transpiration parameter) – the LZETP affects the amount of potential evapo-transpiration that can be satisfied by lower zone storage. Higher LZETP value causes more water stored in the lower zone to loss through the evapo-transpiration. This is also a key factor that controls the total annual flow volume.

INFILT (infiltration) – This parameter can also affect the annual water balance. Increasing the value of INFILT decreases surface runoff and interflow, increases the flow of water to the lower soil storage and ground water, and results in greater evapo-transpiration loss of water.

UZSN (upper zone storage norminal) – Reducing the value of UZSN increases the percentage of flow that is associated with surface runoff as opposed ground water flow. This would be appropriate for areas where receiving water inflows are highly responsive to rainfall events. Increasing UZSN increase the potential for surface water to enter the upper zone water storage and therefore increase the potential through which the water loses through the upper soil zone evapo-transpiration.

Once the simulated annual flow volume is close to the measured annual flow volumes, peak flow and baseflow calibration is performed by adjusting INFILT (infiltration parameter), AGWRC (dail ground water recession constant), and other associated model parameters to ensure that model simulated hydrography match with the hydrography based on measured flow.

The flow in the stream channel is simulated by the RCHRES module. Besides the flow discharging into the stream channel from various sources, the flow is also influenced by the characteristics of the channel, such as the roughness, cross-sectional area, wetted parameter, and slope of water surface. In this TMDL modeling, an initial Manning's roughness coefficient value of 0.03 was used to characterize the roughness of the stream channel under question. The coefficient was adjusted for some channel segment to match the local condition, such as smaller values for well-maintained channels and larger values for highly vegetated, or not well-defined smaller canals. The slope of water surface was approximated using the reach bottom slopes, which were estimated based on the Digital Elevation Mode (DEM) data. The cross-section measurements for the creek were based on the F Table values of the HSPF models developed by the SJRWMD and refined with field measurements during a survey conducted by Department staff in 2008.

Several control structures were identified in the impaired waters included in this report, such as the spillway located in the Eau Gallie River, and the S-96 and S-175 located in the upstream and downstream of the C-54 Canal. Water flows over the top of most of these structures during the modeling time domain. Therefore, influence of these control structures on stream hydrology was defined as flow and elevation relationship in HSPF model's F Tables. The only exception is the structure S-96 located at the upstream end of the C-54 Canal. This structure controls discharge from the St. Johns River Marsh into C-54. As the Upper St. Johns watershed areas were not included as part of the model domain in the C-54 Canal HSPF model, the flow through the S-96 was treated as a boundary condition time series to the C-54 Canal HSPF model.

The following steps were taken to match the model simulations with the measured flow:

- Comparing the NEXRAD data to the gage rainfall data obtained from the station that is located in the same NEXRAD rainfall grid and adjusting the NEXRAD to match the measured rainfall if a significant difference between them occurred;

- Recalibrating the HSPF hydrology model by checking and changing the percentages of DCIA for different land use categories, and several other key hydrologic parameters, including LZSN, LZETP, INFILT, and UZSN described in previous text;

- Confirming whether hysteresis is present in the measured flow data for each WBID and identifying the uncertainty to explain the differences between the measured and the simulated flows.

Table 4.15 lists the USGS gauge stations used for HSPF hydrology calibration. No flow gauge was located in Addison Creek. Therefore, hydrology parameters were mostly kept the same as the original SJRWMD's HSPF model. **Figures 4.4-a, 4.4-b,** and **4.4-c** show the location of USGS gauge stations in the Eau Gallie River watershed, Crane Creek watershed, watersheds for North Prong of Sebastian River, C-54 Canal (include Fellsmere), Sebastian River, and South Prong of Sebastian River, respectively. **Appendix C** shows the flow calibration and validation for these HSPF models as developed by CDM.

Table 4.15. USGS Gauges Used for the Hydrology Calibration

Impaired Water Segments	USGS Station ID	Station Description	Contributing Area (acre)
Eau Gallie River	02249007	Eau Gallie River at Heather Glen Circle at Melbourne, FL	3,382
Crane Creek	02249500	Crane Creek at Melbourne	5,537
North Prong of Sebastian River	02251500	North Prong St. Sebastian River near Micco, FL	22,847
C-54 Canal	02251767	Fellsmere Canal near Micco, FL	20.194
South Prong of Sebastian River	02251000	South Prong St. Sebastian River near Sebastian, FL	36,609

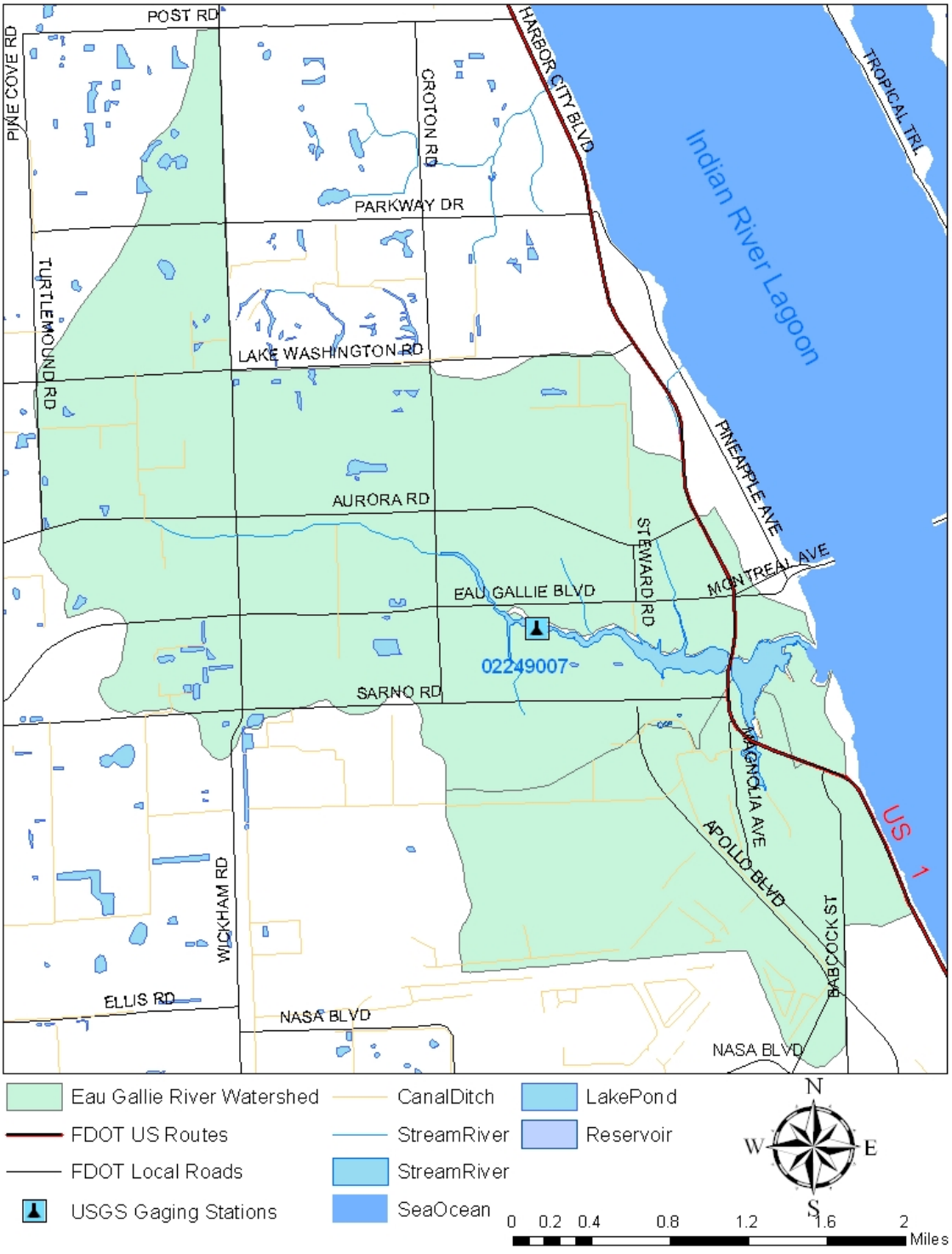


Figure 4.4-a. USGS Gauge Used for the Hydrology Calibration for the Eau Gallie River HSPF Model

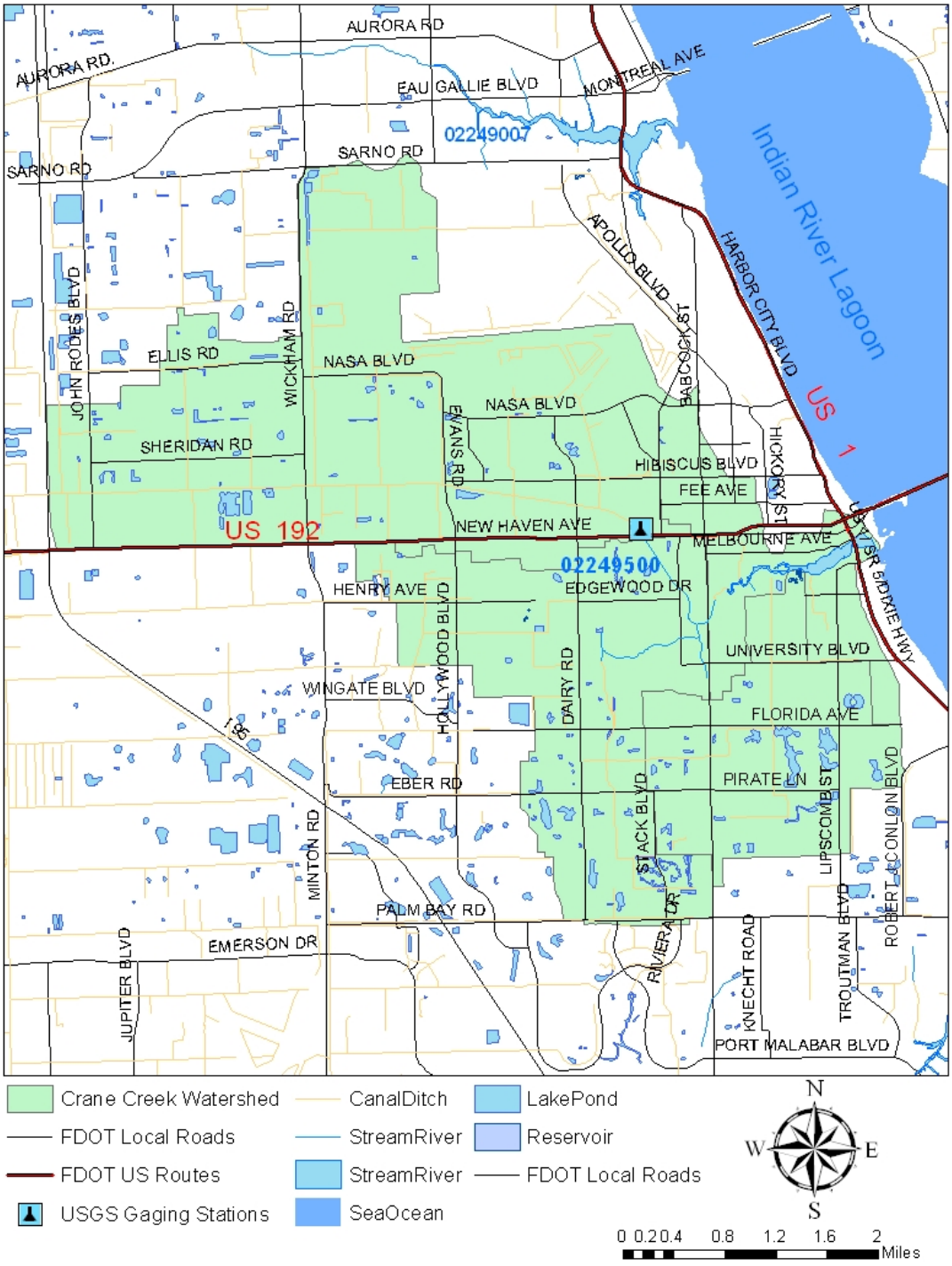


Figure 4.4-b. USGS Gauge Used for the Hydrology Calibration for the Crane Creek HSPF Model

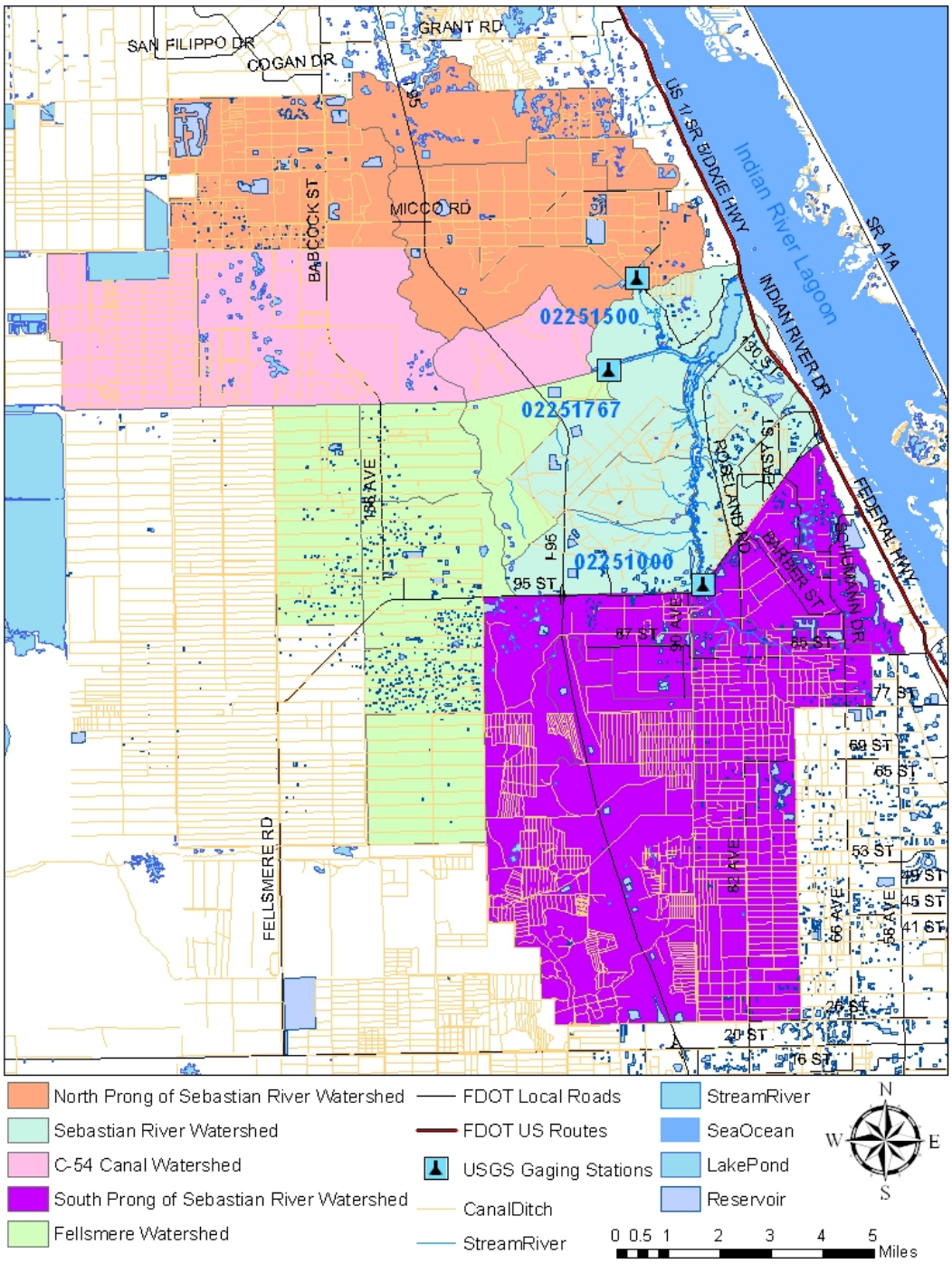


Figure 4.4-c. USGS Gauge Used for the Hydrology Calibration for HSPF Models for the North Prong of the Sebastian River, the C-54 Canal (including Fellsmere), the Sebastian River, and the South Prong of the Sebastian River Watersheds

(3) Instead of using the rainfall data from the limited number of local weather stations, in order to properly represents the spatial variability of the rainfall in these watershed, the updated HSPF models used rainfall estimates from the National Weather Service's (NWS) Multi-sensor Precipitation Estimator (MPE), which blends hourly weather gauge data with estimates from NWS radars onto a 4x4 km2 grid (Vancleve, 2006). The hourly high spatial resolution rainfall data for all watersheds of impaired water segments included in this report were available from 1996 through 2005. During the CDM model contract, the consulting company developed a FORTRAN code called NEXRAD_ASCII to extract the rainfall data related to each watershed. Area-weighted average hourly rainfall data were computed for each modeled sub-basin if more than one rainfall grid was located within the sub-basin. **Figures 4.5-a**, **4.5-b, 4.5-c,** and **4.5-d** display the rainfall grid used in these HSPF models. Using the MPE rainfall in place of gauged rain data, as was used in previous SJRWMD's HSPF models, was another reason for the recalibration of these HSPF models.

In addition to rainfall, evaporation data and potential evapo-transpiration (PET) are also key inputs for simulation of hydrology in HSPF. Solar radiation, cloud cover, air temperature, dewpoint temperature, and wind speed are required to model water temperature and water quality processes (e.g., phytoplankton growth and reaeration). Water temperature, in turn, affects DO and many biochemical reaction rates in waterbodies. Multiple weather stations located in the Indian River Lagoon basin had weather data. However, none of these stations have all the weather parameters that cover the entire model simulation period. Most stations had data gaps for several years. Therefore, combined datasets of meteorological parameters were created by using the data from those weather stations having the longest period of records, and filling the data gap using a data patching process. The following procedure was performed in general in the data patching. If the period of record at a given station was missing for a month or longer, the data from the closest station were used to complete the dataset. If data were missing for only a short period of time (i.e. days), the average of the day before and the day after was used to represent the data for the missing days. **Table 4.16** shows a summary of the weather stations having the longest data sets and their period of records. **Figures 4.6-a** and **4.6-b** show locations of the weather stations used in this TMDL. **Table 4.17** presents the summary of climatological stations that were used for different parameters in the model simulations.

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Table 4.16. Summary of Weather Stations Having the Longest Period of Records for Each Weather Parameter for the Model Simulation Period (1996 – 2005)

Station ID	Air Temperature	Solar Radiation	Wind Speed	Pan Evaporation	Dew Point Temperatur e	Cloud Cover
Ft. Pierce Ap.	1/1/96 – 9/30/04 11/1/04 – 12/31/05				1/1/00 – 12/31/05	
Ft. Drum		2/6/96 – 2/28/96 1/1/97 – 1/4/00				
Titusville-Indian River			6/29/96 – 12/31/03; 3/31/04 – 12/31/05			
Ft. PI 2_E				2,431 daily values available		
Vero Beach Int'l Airport						1/1/96 – 12/31/05

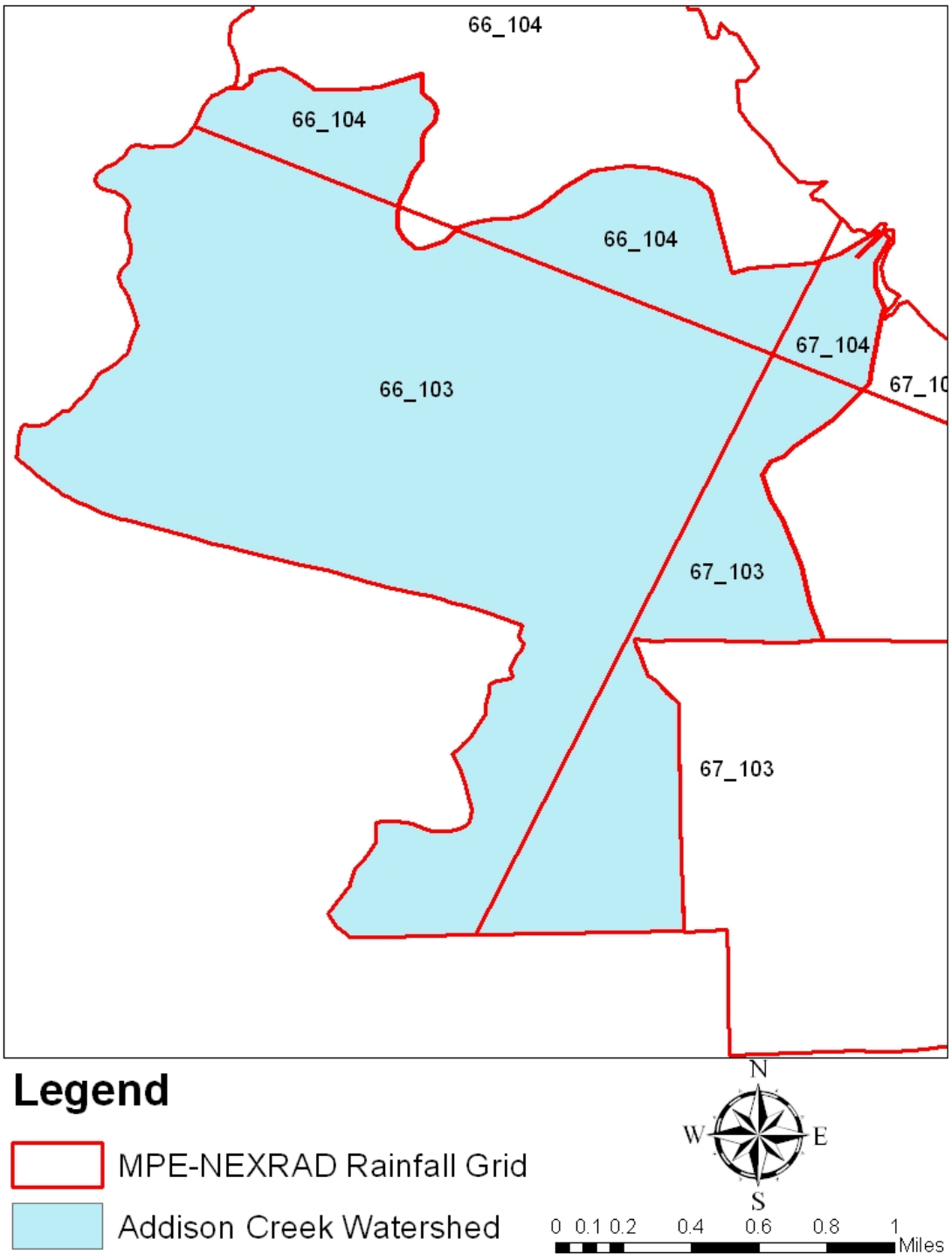


Figure 4.5-a. MPE-NEXRAD Rainfall Grid for the Addison Creek Watershed

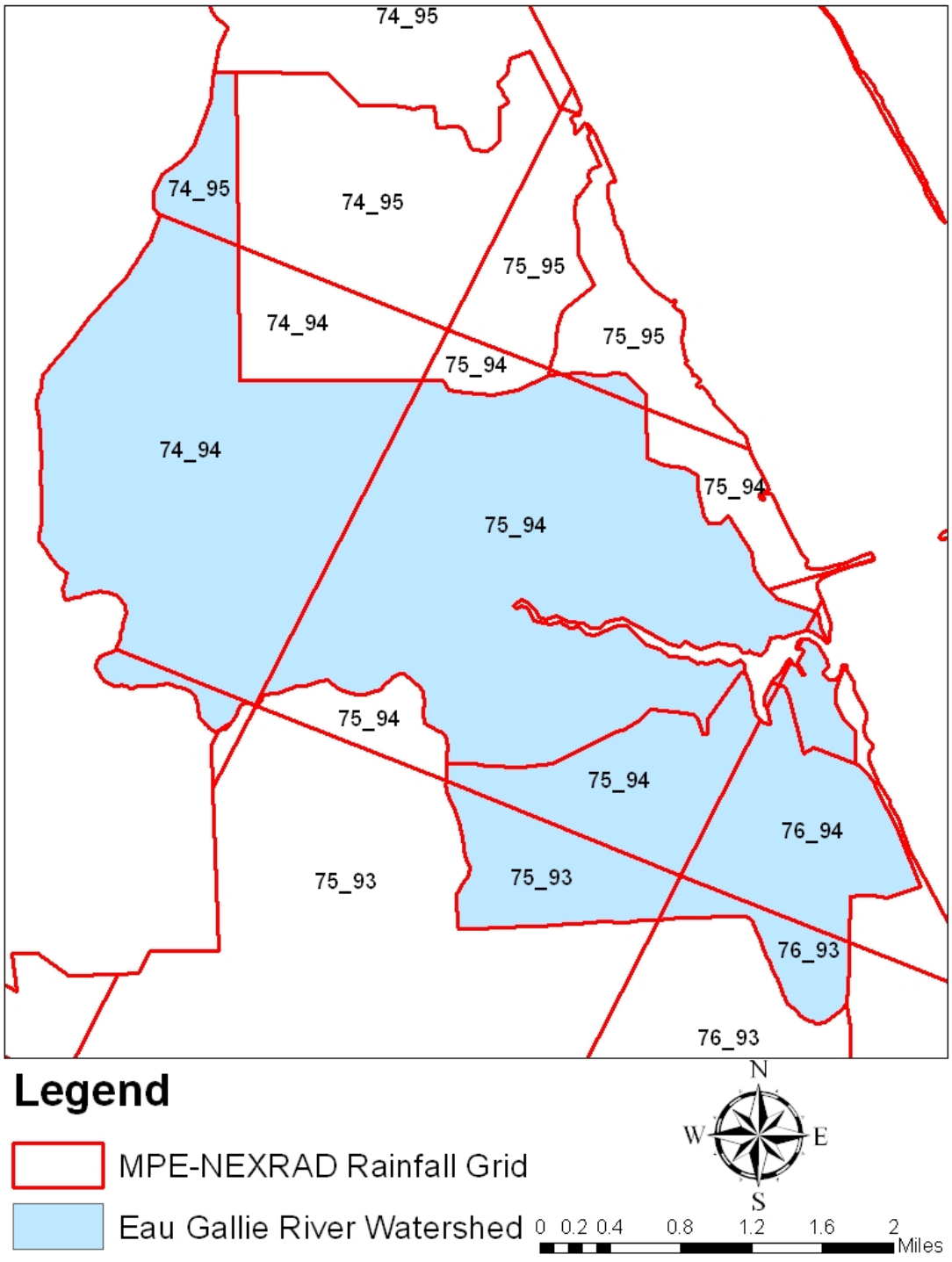


Figure 4.5-b. MPE-NEXRAD Rainfall Grid for the Eau Gallie River Watershed

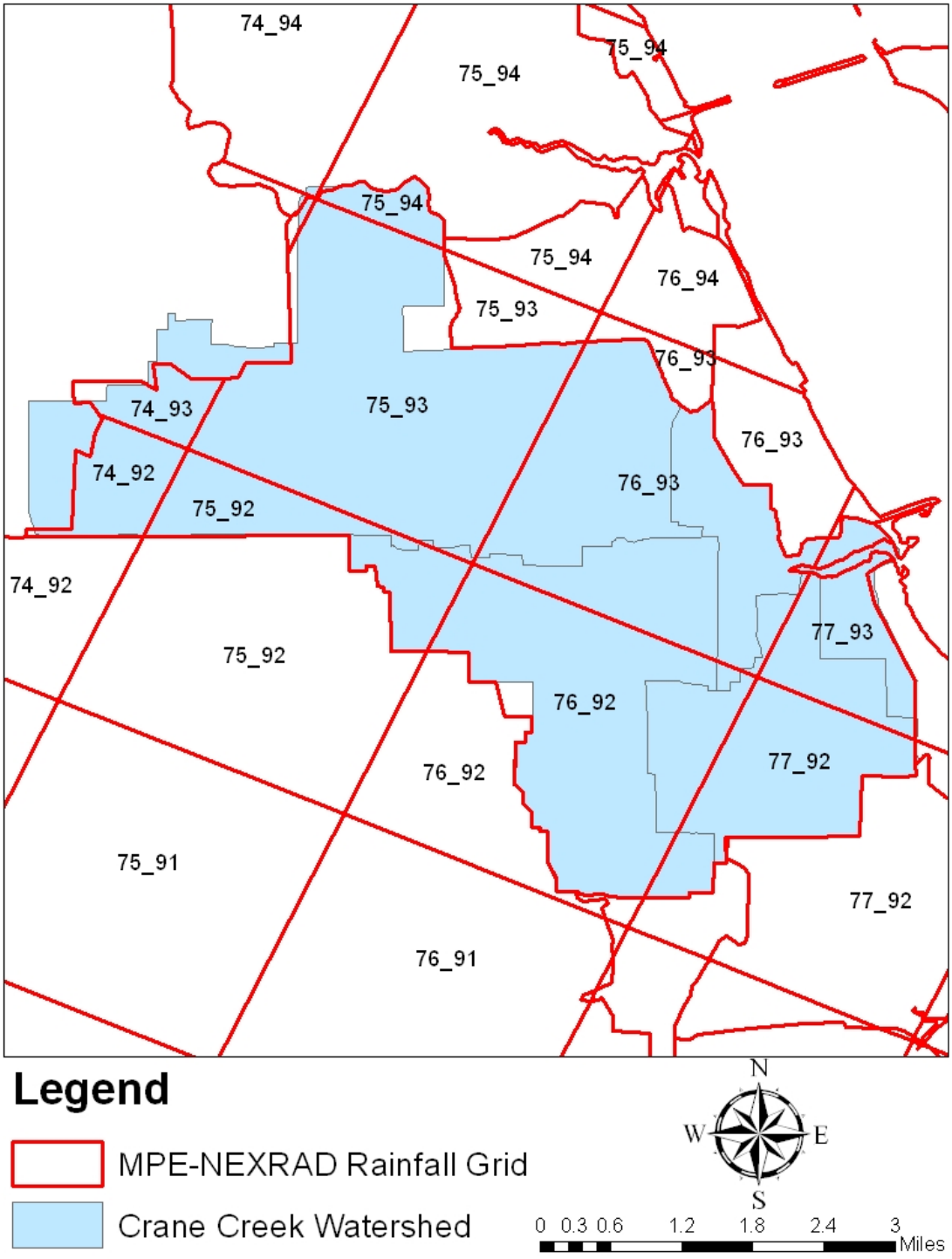


Figure 4.5-c. MPE-NEXRAD Rainfall Grid for the Crane Creek Watershed

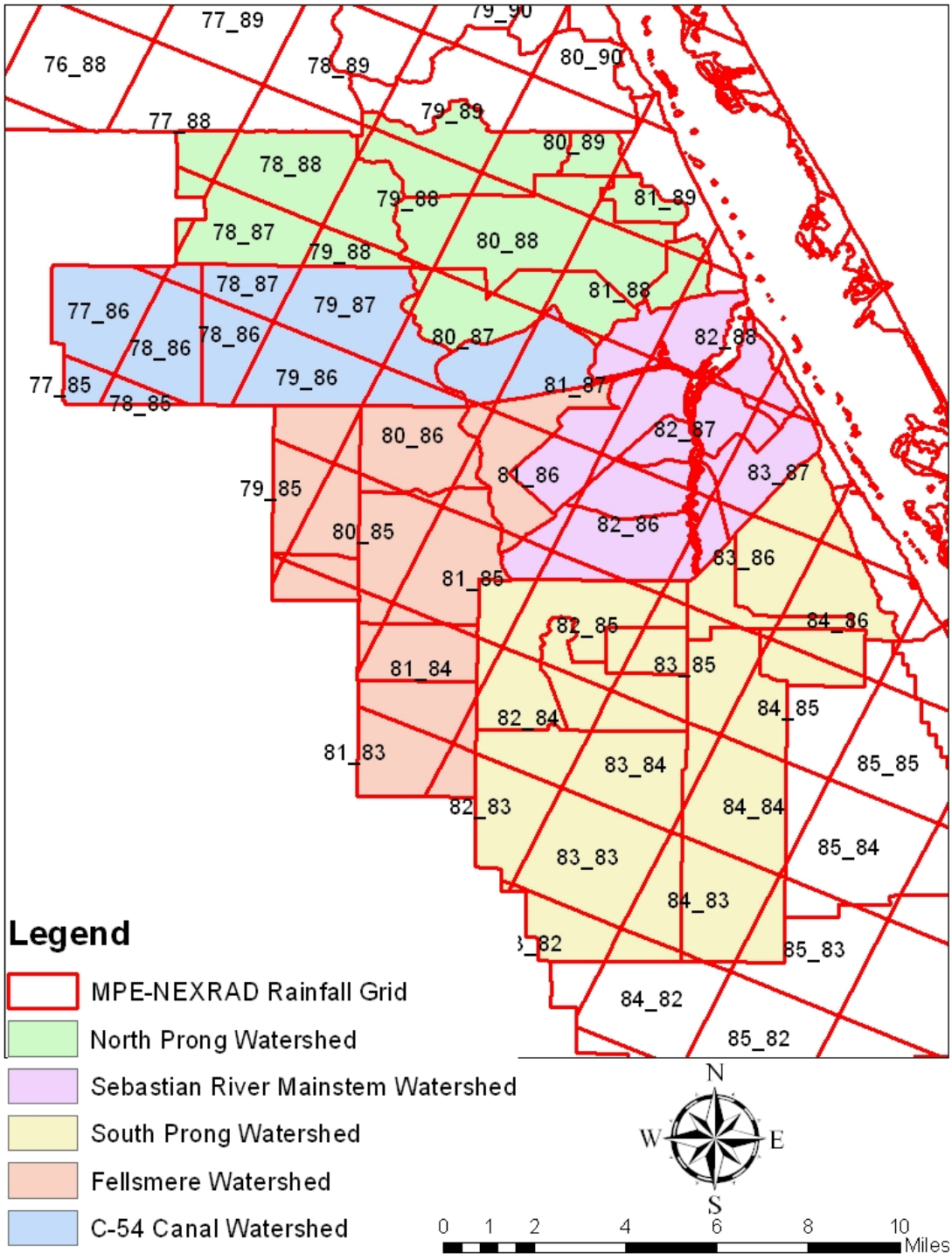


Figure 4.5-d. MPE-NEXRAD Rainfall Grid for the Sebastian River System

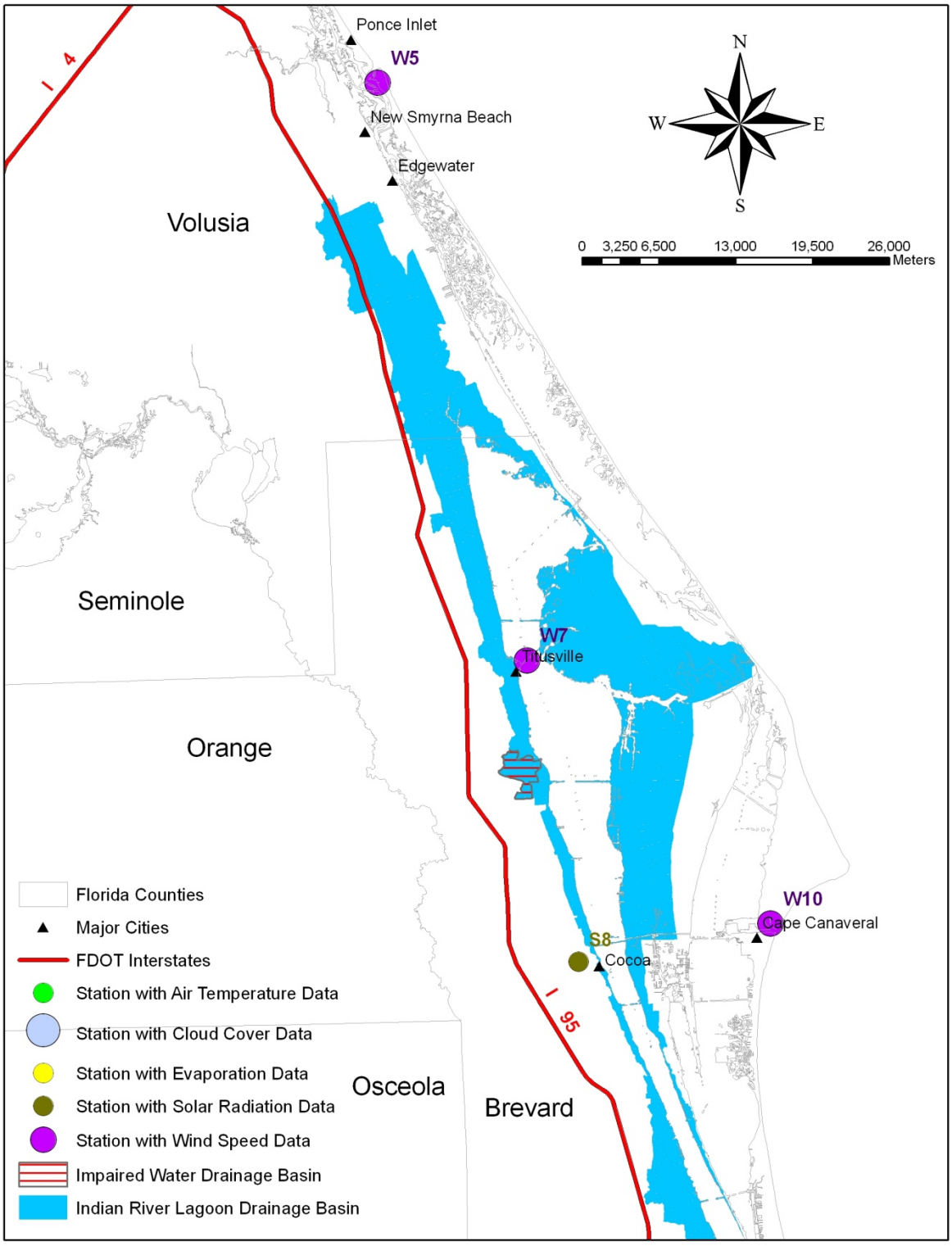


Figure 4.6-a. Weather Stations Located in the Northern Part of the Indian River Lagoon Drainage Basin

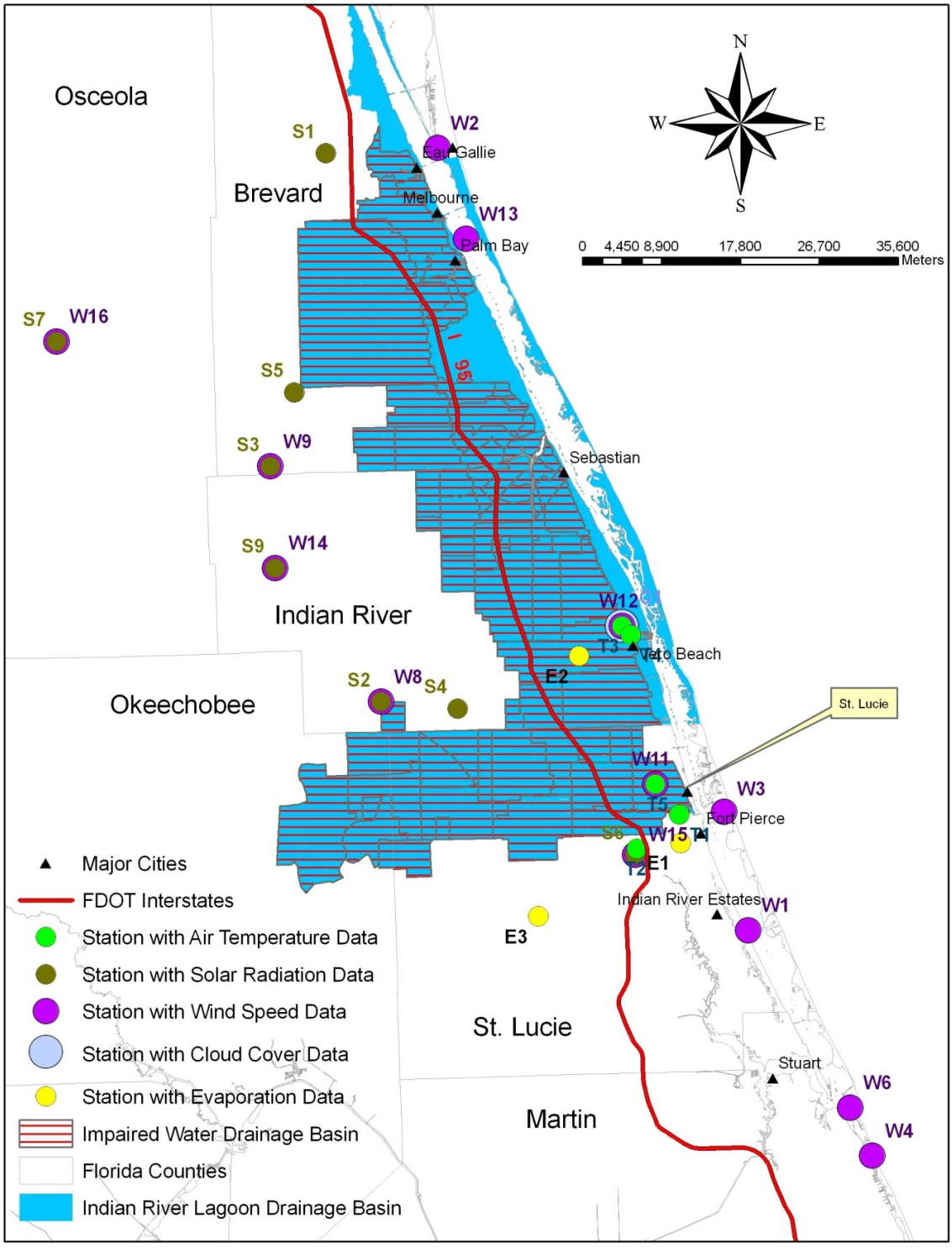


Figure 4.6-b. Weather Stations Located in the Southern Part of the Indian River Lagoon Drainage Basin

Table 4.17. Weather Stations Used to Compile the Combined Data Sets for Weather Parameters

TMDL ID	Data Type	Site Name	Managing Agency	Latitude	Longitude
C1	Cloud Cover	VERO BCH INT'L AP	NOAA	27.65937	80.40937
E1	Pan Evaporation	FT. PIERCE	NCDC	27.43780	80.34980
E2	Pan Evaporation	VERO BEACH 4W	NCDC	27.63030	80.45980
E3	Pan Evaporation	FT. PIERCE FIELD STATION, EVAPORATION	SFWMD	27.36730	80.51470
S1	Solar Radiation	LAKE WASHINGTON	SJRWMD	28.14680	80.73440
S2	Solar Radiation	FT DRUM	SJRWMD	27.58930	80.68800
S3	Solar Radiation	TUCKER	SJRWMD	27.83080	80.80810
S4	Solar Radiation	LINDSEY CITRUS	SJRWMD	27.58030	80.60060
S5	Solar Radiation	MULBERRY MARSH	SJRWMD	27.90530	80.77780
S6	Solar Radiation	FORT PIERCE	FAWN	27.42700	80.40200
S7	Solar Radiation	KENANSVILLE	FAWN	27.96300	81.05000
S8	Solar Radiation	FL SOLAR ENERGY CENTER	NREL	28.39000	80.76000
S9	Solar Radiation	274143080424100	USGS	27.72780	80.80530
T1	Temperature	FT PIERCE	NCDC	27.46667	80.35000
T2	Temperature	FT PIERCE ARC	NCDC	27.43333	80.40000
T3	Temperature	VERO BCH INT'L AP	NCDC	27.65937	80.40937
T4	Temperature	VERO BEACH 4SE	NCDC	27.65000	80.40000
T5	Temperature	FT PIERCE ST LUCIE CO INT'L AP	NCDC	27.49810	80.37670
W1	Wind Speed	ANKONA; IRL	SJRWMD	27.34720	80.27530
W2	Wind Speed	BANANA RIVER - CARTERS CUT	SJRWMD	28.14900	80.60580
W3	Wind Speed	FT PIERCE INLET	SJRWMD	27.46810	80.29920
W4	Wind Speed	JUPITER ISLAND; ICWW; PECK LAKE	SJRWMD	27.11470	80.14220
W5	Wind Speed	PONCE DE LEON INLEST SOUTH	SJRWMD	29.06300	80.91490
W6	Wind Speed	SOUTH POINT; ST LUCIE INLET	SJRWMD	27.16420	80.16530
W7	Wind Speed	TITUSVILLE-INDIAN RIVER	SJRWMD	28.62040	80.79820
W8	Wind Speed	FT DRUM	SJRWMD	27.58930	80.68800
W9	Wind Speed	TUCKER	SJRWMD	27.83080	80.80810
W10	Wind Speed	TRIDENT PIER	NOAA	28.41500	80.59330
W11	Wind Speed	FT PIERCE ST LUCIE CO INT'L AP	NCDC	27.49810	80.37670
W12	Wind Speed	VERO BCH INT'L AP	NCDC	27.65940	80.40940
W13	Wind Speed	280322080343400	USGS	28.05610	80.57610
W14	Wind Speed	274143080424100	USGS	27.72780	80.80530
W15	Wind Speed	FORT PIERCE	FAWN	27.42700	80.40200
W16	Wind Speed	KENANSVILLE	FAWN	27.96300	81.05000

Note: **NOAA** = National Oceanic and Atmospheric Administration; **SJRWMD** = St. Johns River Water Management District; **FAWN** = Florida Automated Weather Network; **NREL** = National Renewable Energy Lab; **USGS**=United States Geological Survey; **NCDC** = National Climate Data Center

(4) Water quality simulations developed in the SJRWMD's original HSPF models were refined. Because the goal of SJRWMD's original HSPF models was to estimate TSS and nutrient loads from the Indian River Lagoon drainage basin in order to protect the seagrass communities, water quality constituents considered in these HSPF models only included TSS, TN, TP, and PO4. The refined HSPF models developed by CDM focused on factors that influence the DO concentration in the water column. Therefore, these models added phosphate (PO4), ammonia (NH4), nitrate/nitrite (NOx), recalcitrant organic carbon (ORN), and biochemical oxygen demand (BOD) into the model simulations. TN and TP loads were not simulated directly in the CDM HSPF models. Instead, TN loads were calculated by the model as the sum of loads of NH4, NOx, ORN, and labile organic nitrogen, which was calculated as a portion of the BOD loads. Similarly, TP loads were calculated by the model as the sum of loads of PO4 and labile organic phosphorus, which was also calculated as a portion of the BOD loads. The CDM's HSPF model also simulated the recalcitrant organic carbon. The recalcitrant organic carbon loads were not directly simulated by these models. Instead, loads of recalcitrant organic carbon was calculated as a portion of the recalcitrant organic carbon – ORN. The total organic carbon loads from the watershed were estimated as the sum of the labile organic carbon included in BOD loads and the recalcitrant organic carbon estimated as the portion of the ORN.

Total nutrient and BOD loads from the watersheds of these impaired water segments included loads from surface runoff, interflow, and baseflow pathways. In CDM's HSPF model, the runoff loads were simulated using the "Potency Factor" method, which simulates the sediment loads first, and then estimates nutrients and BOD loads by assigning a Potency Factor (i.e., the nutrient or BOD loads per unit load of sediment ratio) to the sediment load for each of nutrient and BOD constituents. Nutrient and BOD loads from the interflow and baseflow pathways were calculated as the product between simulated interflow or baseflow and their associated nutrient and BOD concentrations. Potency factors and interflow and baseflow nutrient and BOD concentrations used in these HSPF models were cited from CDM's previous HSPF modeling projects for the nearby areas. These numbers were used as starting values and later adjusted through model calibration. **Table 4-18** shows the interflow and baseflow nutrient and BOD concentrations and potency factors for nutrients and BOD in the surface runoff.

Table 4-18. Typical Land-Based Nutrients and BOD Interflow and Baseflow Concentrations and Potency Factors for Runoff Loads

HSPF Input Parameter	Water Quality Constituents Simulated in CDM's HSPF Models						
	PO4	NH4	NOx	BOD	ORN	TP	TN
Interflow concentration (mg/L)	0.03-0.22	0.03-0.08	0.20-0.63	1.5-19	0.7-1.2	0.04-0.39	1.0-2.8
Baseflow Concentration (mg/L)	0.02-0.04	0.02-0.05	0.13-0.25	1.5-3.0	0.6-0.8	0.03-0.07	0.8-1.2
Potency Factor (lb/ton sediment)	5.4-6.1	4.1	23-25	350	23.8	8.6-9.3	52-53

Evaluation on the importance of septic tanks in contributing nutrient and BOD loads to these impaired water segments was also conducted when TMDLs for these water segments were developed. Information about the effect of existing septic tanks in these impaired watersheds on water quality of the receiving waters is scarce and uncertain at that time. Most comprehensive septic tank surveys for the Indian River Lagoon drainage basin were conducted by Brevard County and Indian River County back in the early 1990s as part of the implementation activities of the SJRWMD's Surface Water Improvement and Management Program (Brevard County Natural Resources Management Division 1995, Indian River County Public Health Unit 1992). Goals of these surveys included: (1) identifying the potential septic tank installation problem areas by assessing soil and ground water characteristics, (2) finding areas in these counties that had a long history of consistent system failures, and (3) locating areas near surface waters where there was a potential risk from septic tank contamination. A problem area index (PAI), which took into consideration of soil permeability, distance to seasonal high water table, septic tank unit density, historic septic tank failure factor, was applied in these surveys to quantity the potential risk of the land units being surveyed and rank the priority of the surveyed areas for further studies and sewer line connections.

Results from these surveys revealed high potential risks that septic tank systems in the Indian River Lagoon basin could pose to the water quality condition of the Indian River Lagoon and its tributaries. Both Brevard and Indian River counties showed that the high ground water table and low soil permeability in this area were among the most important factor that made properly installing septic tanks in the basin difficult. According to the Brevard County survey report, most of the soils in the surveyed area had seasonal high water table ranged between 0 – 10 inches with low to moderate percolation rates (2 inches per hour). Only two percent of Brevard County areas were reported suitable for septic tank installations. More than 70 percent of all surveyed units in the Indian River County had depth to seasonal high water tables of 12 inches or less and 87 percent of all surveyed units were rated as being "moderate" to "severe" for sanitary purposes based on the PAI index.

While these survey results suggested high potential influence from the septic tanks to the water quality of Indian River Lagoon and its tributaries, uncertainties associated with how the survey results should be interpreted were also raised. Brevard County pointed out that selection of the size of the survey unit could have heavy influence on the survey conclusion because the selection of the size of the survey unit influenced the calculation of the septic density (number of septic tank per survey unit), and the septic tank density is the sole denominator in the PAI formula. For a given survey unit, the septic tank density would be lower if the entire survey unit area was used to calculate the density compared to if only the developed areas within the survey unit was used to calculate the density. A high septic tank density meant a low PAI value, which indicated a poor condition for septic tank installation, while a low septic tank density would gave a high PAI value and therefore indication of relatively favorable site condition for septic tanks. Based on Brevard County, if only the developed area within the a survey unit was used to calculate the PAI, 7 of the 16 lagoon sub-basins within the county could be considered septic tank problem areas, and should be included in the septic tank management plan as high priority areas for additional studies and at least 30 subdivisions and other defined areas of the county should be targeted for immediate study. However, if the entire survey unit area was used to calculate the PAI, the results showed no Indian River Lagoon sub-basins were considered septic tank problem areas and therefore no sub-basin need be considered for more intensity study.

Other studies also raised questions on the scale at which septic tanks may pose impact on the nearby receiving waters. Ayres Associates, contracted by the SJRWMD, conducted a septic tank studies in the Turkey Creek drainage basin to investigate the potential impact from septic tanks to the water quality of adjacent canals. The study monitored two residential septic tanks intensively over a two-year period (1990 – 1992) and found that:

- Of the two sites, the drainage field of one site was about 50 feet from the South Brevard Water Authority Canal No. 66, while the other one was about 200 feet to the canal;
- The Soil Survey of Brevard County identied the soil series in the area as Eau Gallie Sand; Eau Gallie, Winder, and Felda Soils, ponded; Malabar sand; and Malabar, Holopaw and Pineda soils. These soils are all nearly level and poorly drained sandy soils. The upper horizons consist of fine sands and may exhibit a hardpan or spodic layer at depths from 24 to 40 inches below the surface;
- The seasonal high water table in the flatwood areas was at a depth of less than ten inches for one to four months out of the year and between ten and forty inches for more than six month;
- Ground water flow direction at both septic tank sites was in the general direction toward Canal 66;
- Analysis of ground water and surface water samples from wells located at different distance from the septic tank drainfields indicated that the concentration of nitrate, nitrite-nitrogen (NO_3, NO_2-N), total Kjeldahl nitrogen (TKN), total phosphorus (TP), and conductivity were generally signficantlly higher in the vicinity of the drainfield when compared to the background wells. However, contaminant concentrations were at or below background concentrations in wells located twenty (20) to forty (40) feet from the drainfield.
- Based on data collected after rainfall events (five occasions), no conclusive cause-effect relationships on either ground water or surface water quality were found;
- Data collected from bromide tracer tests at the site closer to the canal indicated that conservative parameters such as nitrate and chloride should reach the canal from the drainfield in approximately 270 days, yet concentrations of these compounds were measured at background levels within 20 to 40 feet of the drainfields. Calculations of “dilution factors” indicated that, although some dilution may be responsible for these results, it also appeared that phosphorus was significantly attenuated by on-site soils and that denitrification was contributing to substantial nitrogen removal.

The results of the study indicated that, while these septic tanks were impacting ground water in their immediate vicinity, they were not impacting canal water quality significantly at the time of this study.

Because of these uncertainties on the actual impact of septic tanks on the water quality of receiving waters, the Department believes that the information needed to explicitly simulate the nutrient and BOD loadings from septic tank is insufficient. Septic tank loadings to the receiving water were therefore implicitly simulated by adjusting the watershed pollutant loading to ensure that model simulated receiving water pollutant concentrations matched up with the measured water quality data.

Because the surface areas of the impaired water segments included in this report are small compared to the areas of their corresponding watershed, nutrient and BOD loadings directly

deposited onto the surface of these impaired water segments via atmospheric deposition were not estimated in these TMDLs.

Because of the lack of detailed information regarding the distribution, type, and removal efficiencies of best management practices (BMPs) in the watershed of these impaired water segments, simplified methods were used in evaluating the effect of these BMPs on watershed loads of nutrients and BOD. Urban BMP coverages were created based on the difference between historical land use obtained for the year 1988 and the landuse for Year 2000. The new developments appeared after 1988 were expected to have implanted BMPs in compliance with the State's stormwater rule adopted in 1984.

The spatial coverage of agricultural BMPs implementation in the impaired watersheds included in this TMDL report was estimated based on GIS coverage provided by the Florida Department of Agricultural and Consumer Services (FDACS), which was developed by the University of Florida Institute of Food and Agricultural Sciences (IFAS) based on the notices of intent (NOIs) submitted by farmers to be covered by the Department of Community Affairs (DCA)'s BMP rule to reduce agricultural pollution. The database identified a number of land parcels applying BMPs to reduce stormwater runoff pollution. The parcel ID was spatially joined with the County Property Appraiser's parcel spatial coverage to identify those agricultural parcels that potentially had implemented agricultural BMPs.

More than 35 different types of agricultural BMPs were identified in the project area based on the data in the IFAS NOI database. However, minimal information was available regarding the removal efficiency of each individual BMP. Therefore, pollutant removal efficiencies for aggregated BMP groups were used in this TMDL project using the following processes:

- All BMPs were aggregated into three general groups including those of runoff control, fertilizer management, and other BMPs.
- Each BMP group was assigned a set of removal efficiency values for TSS, ortho-phosphate, total ammonia, nitrate/nitrite, refractory organic nitrogen, BOD, and refractory organic carbon, based on CDM's previous modeling experience and the removal efficiencies included in the WAMView model created by Soil and Water Engineering Technology, Inc.
- For each land parcel that applies BMPs, minimal removal efficiency for each pollutant was calculated assuming only the BMP group with the lowest removal efficiency was applied, while the maximal removal efficiencies was estimated assuming that all three BMP groups were applied for the same land parcel. An average removal efficiency for the land parcel for each pollutant was then calculated as the mean between the minimal and maximal removal efficiencies.
- An area weighted average removal efficiency for each pollutant was then calculated for each modeled sub-basin.
- To avoid setting up too complicated pollutant removal schemes in the Schematic block of the model input file, the area weighted removal efficiencies were further aggregated into three agricultural BMP groups including BMP1, BMP2, and BMP3, with BMP1 removal efficiency > BMP2 removal efficiency > BMP3 removal efficiency. Break-point removal efficiency values were assigned to these BMP categories based on CDM's previous modeling studies. For a given pollutant in a given sub-basin, if the area-weighted removal efficiency is larger than the BMP1 efficiency, the BMP removal

efficiency for the pollutant for the sub-basin would be considered equal to the BMP1 efficiency. If an area-weighted removal efficiency falls in between BMP1 and BMP2 efficiencies, its removal efficiency would be considered BMP2 efficiency. If the area-weighted removal efficiency falls in between BMP2 and BMP3 efficiencies, its removal efficiency would be considered BMP3 efficiency. If the area-weighted efficiency is lower than BMP3 efficiency, the removal efficiency would be considered as 0.

Table 4.19 displays removal efficiency values for BMP1, BMP2, and BMP3 for agricultural BMPs and removal efficiency values for general urban BMPs for modeled nutrients and BOD.

Table 4.19. Urban and Agricultural BMP removal Efficiencies by Constituent and BMP Type

Urban and Agricultural BMP Removal Efficiencies	Urban BMP (%)	Agricultural BMP1 (%)	Agricultural BMP2 (%)	Agricultural BMP3 (%)
Total Suspended Solids (TSS)	85	80	67	27
PO4	65	60	50	20
Total Ammonia	35	30	25	10
Nitrate + Nitrite (NO_x)	35	30	25	10
Refractory Organic Nitrogen	45	30	25	10
BOD5	45	40	33	13
Refractory Organic Carbon	35	40	33	13

(5) Because the goal of the SJRWMD's HSPF model was to estimate the watershed TSS and nutrient loadings entering Indian River and Banana River Lagoons, the receiving water processes related to the watershed nutrients were simplified in these models. The only receiving water process related to watershed nutrients is a first order decay for TN, TP, and PO4. Because the CDM HSPF models were developed to examine the effects of possible environmental factors that influence the DO concentration in the water column of impaired water segments, receiving water processes that are likely to influence the water column DO concentration were added into these HSPF models. Once loads of watershed nutrients and BOD reach a receiving water, several modules are used by HSPF to simulate the water quality processes in the receiving water. These models include SEDTRN. HTRCH, OXRX, NUTRX, and PLANK.

The SEDTRN is used to simulate sediment transport process in the model. For this TMDL, sediment particles in the water column of the receiving water were not set up as agents that actively absorb and release waterborne nutrients and organic carbon compounds. Instead, water column sediment was considered to only influence light penetration, which in turn impacts phytoplankton growth through light limitation. Phytoplankton growth influences the DO enrichment in the water column through photosynthesis. The SEDTRN simulation was calibrated against measured total suspended solid (TSS).

Water temperature influences the DO solubility and reaeration. These processes influence the DO concentration in the water column. In addition, temperature is a controlling factor for

almost all the chemical and biochemical processes in the water, such as algal growth and metabolism, algal death rate, BOD decay, ammonification, nitrification, sediment nutrient release, sediment oxygen demand, etc. Temperature is simulated in HSPF using the HTRCH module. Five time series of meteorological data are used to simulate the temperature balance within a RCHRES, which include solar radiation, cloud cover, air temperature, dewpoint temperature, and wind speed. These meteorological conditions influence the heat energy that enters the receiving water due to the solar radiation, and the water-air heat exchange due to long wave radiation, heat conduction and convection, and water surface evaporation. Upstream heat input and precipitation heat input can also influence the water temperature of the receiving water.

Water column DO concentration is simulated using the OXRX module. The major DO controlling processes simulated by HSPF include reaeration, phytoplankton growth (DO enrichment) and respiration (DO consumption), carbonaceous BOD decay, nitrification (oxidation of ammonia), and sediment oxygen demand. In addition, temperature can influence the DO dynamics through controlling the DO solubility and biochemical rates at which DO are consumed. DO input from the upstream segments, from surface runoff, interflow, and baseflow are also important factors that control DO concentration in a given watershed.

Phytoplankton growth not only influences the chlorophyll *a* concentration in receiving waters, it may also influence the DO dynamics in receiving waters through photosynthesis and respiration. When phytoplankton biomass is high, diel DO fluctuation can be significant. In addition, in streams and rivers with significantly long water residence time, phytoplankton biomass may also contribute significantly to sediment oxygen demand. In HSPF, the key processes that affect phytoplankton concentration in receiving waters including phytoplankton growth, phytoplankton respiration, phytoplankton death, and phytoplankton settling. Phytoplankton growth is modeled based on a specified maximum growth rate, which is adjusted by the model based on water temperature and is limited by the model based on available light and inorganic nitrogen and phosphorus. Death and respiration are modeled based on specific rates that are adjusted for water temperature. A higher death rate may be applied by the model under certain conditions (e.g., high water temperature or high chlorophyll a concentration). Settling is modeled based on a constant settling rate. Growth increases the concentration of phytoplankton, whereas the other processes reduce the concentration of phytoplankton.

NUTRX model is used to simulate the nutrient dynamics in the receiving water. Major processes that affect nitrogen concentrations in receiving waters include decay of BOD, BOD settling, phytoplankton growth, respiration, death, and settling, settling of refractory organic nitrogen to sediment, nitrification, denitrification, and sediment ammonia release. Water column phosphorus concentrations are influenced primarily by the similar processes that influence the nitrogen concentration, except that there is no phosphorus redox state change, and sediment flux is dominated by phosphate instead of ammonia.

Table 4.20 shows the HSPF receiving water input parameters and their initial values used in setting up the CDM HSPF models.

Table 4.20. HSPF Receiving Water Input Parameters and Their Initial Values

HSPF Variable	Description	Units	Value	Source
HTRCH Module				
CFSAEX	Correction factor for solar radiation	None	0.50	Calibration
KATRAD	Long wave radiation coefficient	None	9.37	Default
KCOND	Conductive-convection heat transport coefficient	None	6.12	Default
KEVAP	Evaporation coefficient	None	2.24	Default
SEDTRN Module				
KSAND	Coefficient in sand load formula	Complex	6	CDM, 2008
EXPSND	Exponent in sand load formula	Complex	1.5	CDM, 2008
W	Fall velocity in still water – silt	In/s	1.00E-05	Calibration
TAUCD	Critical shear stress for deposition – silt	lb/ft^2	0.02	CDM, 2008
TAUCS	Critical shear stress for scour – silt	lb/ft^2	0.32	CDM, 2008
M	Erodability coefficient of sediment – silt	$lb/ft^2/day$	1.2	CDM, 2008
W	Fall velocity in still water – clay	In/s	1.60E-06	Calibration
TAUCD	Critical shear stress for deposition – clay	lb/ft^2	0.02	CDM, 2008
TAUCS	Critical shear stress for scour – clay	lb/ft^2	0.46	CDM, 2008
M	Erodability coefficient of sediment – clay	$lb/ft^2/day$	1.2	CDM, 2008
OXRX Module				
KBOD20	Unit BOD decay rate at 20 deg c	Hr^{-1}	0.0012 - 0.0025	Calibration
TCBOD	Temperature correction coefficient for BOD decay	None	1.037	Calibration
TCBODSET	Rate of BOD settling	Ft/hr	0	Default
BENOD	Benthal oxygen demand at 20 deg c (assuming sufficient water column DO)	$Mg/m^2/hr$	8.4 – 125.4	Calibration
TCBEN	Temperature correction coefficient for benthal oxygen demand	None	1.037 – 1.070	Calibration
REAKT(2)	Tsivoglou coefficient for stream reaeration	None	0.054	Calibration
REAKT(3)	Coefficient for user-defined reaeration equation	Hr^{-1}	0.004 – 0.010	Calibration
EXPRED	Depth exponent for user-defined reaearation	None	-2 to 0	Calibration
EXPREV	Velocity exponent for user-defined reaeration	None	0	Calibration
TCGINV	Temperature correction factor for reaeration	None	1.024 – 1.047	Calibration

Table 4.20. HSPF Receiving Water Input Parameters and Their Initial Values (Cont.)

HSPF Variable	Description	Units	Value	Source
NUTRX Module				
KTAM20	Nitriication rate of ammonia at 20 deg C	Hr^{-1}	0.002 – 0.003	Calibration
TCNIT	Temperature correction coefficient for nitrification	None	1.07	Default
PLANK Module				
RATCLP	Ratio of chlorophyll a content of biomass to phosphorus content	None	1.0 – 5.4	Calibration
NONREF	Nonrefractory fraction of algae and zooplankton biomass	None	0.5 – 1.0	Calibration
ALNPR	Fraction of nitrogen requirements for phytoplankton growth that is satisfied by nitrate	None	0.75 – 1.00	Calibration
EXTB	Base extinction coefficient for light	Ft^{-1}	0.05 – 1.40	Observed Data
MALGR	Maximum unit algal growth rate	Hr^{-1}	0.107 – 0.125	Calibration
CMMLT	Michaelis-Menton constant for light-limited growth	Ly/min	0.033	Default
CMMN	Nitrate Michaelis-Menton constant for nitrogen limited growth	Mg/l	0.045	Default
CMMNP	Nitrate Michaelis-Menton constant for phosphorus limited growth	Mg/l	0.028	Default
CMMP	Phosphate Michaelis-Menton constant for phosphorus limited growth	Mg/l	0.015	Default
TALGRH	Temperature above which algal growth ceases	Deg F	95.0	Default
TALGRL	Temperature below which algal growth ceases	Deg F	43.0	Default
TALGRM	Temperature below which algal growth is retarded	Deg F	85.0	Calibration
ALR20	Algal unit respiration rate at 20 deg C	Hr^{-1}	0.0015 – 0.0030	Calibration
ALDH	High algal unit death rate	Hr^{-1}	0.002 – 0.008	Calibration
ALDL	Low algal unit death rate	Hr^{-1}	0.000 – 0.002	Calibration
CLALDH	Chlorophyll a concentration above which high algal death rate occurs	µg/l	45 – 90	Default
PHYSET	Rate of phytoplankton settling	Ft/hr	0.0008 – 0.08	Calibration
REFSET	Rate of settling for dead refractory organics	Ft/hr	0 - 0.006	Calibration
CVBO	Conversion from mg biomass to mg oxygen	Mg/mg	1.31	Calibration
CVBPC	Conversion from biomass expressed as phosphorus to carbon	Mols/mol	106	Default
CVBPN	Conversion from biomass expressed as phosphorus to nitrogen	Mols/mol	10	Calibration
BPCNTC	Percentage of biomass which is carbon (by weight)	None	49	Default

Comparisons between simulated and observed in-stream concentrations used several different graphical and statistical methods. These include the following:

Graphical comparison of modeled and observed concentration time series;

Box and whisker plots graphicsl comparing the median and distribution of the observed data and the simulated concentrations on the days corresponding to sampling events; and

Frequency-exceedance graphs of observed data and corresponding model output,

These methods were applied to the calibration period (1997 through 2000) and validation period (2001-2005). Because of the shortage of water quality data in some impaired tributary segments, all water quality data collected for a given tributary segment were pooled together for the model calibration and validation. Complete results from all of these methods are presented for all impaired segments in **Appendix D**.

Using the HSPF model described above, existing BOD loads from the watershed s of these impaired water segments were simulated and summarized in **Table 4.21**.

4.2.2.10. Summary of Nonpoint Source Loads of Nutrients and BOD Entering Impaired Water Segments

Most of the seven impaired segments (the South Prong of the Sebastian River Estuary Segment and the South Prong of the Sebastian River Freshwater Segment were considered as one segment in terms of loading calculation) included in this TMDL report receive pollutant discharges from their own watersheds. There were no upstream segments discharging into these impaired segments. Therefore, pollutant loads from watersheds (including loads through surface runoff, interflow, and baseflow) represent the only nonpoint source loads entering these impaired water segments. However, there are several water segments included in this report receive loads not only from their immediate watersheds, but also from upstream water segments. For example, C-54 Canal receives discharge from the Upper St. Johns River drainage basin through the Control Structure S-96. Nutrients and BOD loads entering C-54 Canal from the Upper St. Johns River drainage basin were not simulated in this TMDL report. Instead, they were estimated as the boundary condition loads entering C-54 Canal. Based on the structure operation data provided by the SJRWMD, during the HSPF model time domain from 1996 through 2005, the S-96 only discharged water into C-54 Canal from October 14, 1999 through October 25, 1999, July 2, 2002, and September 11, 2004 through October 11, 2004. The total TP, TN, and BOD loads entering C-54 Canal during these three discharge periods were 1,896 lbs, 1.5 lbs, and 7,910 lbs for TP, 92,905 lbs, 74 lbs, and 387,573 lbs for TN, and 379,204 lbs, 302 lbs, and 1,581,930 lbs for BOD. These loadings, when average over the entire model period from 1996 through 2005, results in 981 lbs/year, 48,055 lbs/year, and 196,144 lbs/year for TP, TN, and BOD annual loads, respectively.

Another source of nutrients and BOD entering C-54 Canal is from the Fellsmere watershed. This watershed is located immediately south of the C-54 Canal watershed and discharge to the C-54 Canal segment that is downstream of the S-157 Control structure. The Fellsmere watershed occupies about 20,194 acres. Based on SJRWMD's Year 2000 land use GIS coverage, about 41% of the Fellsmere watershed was occupied by agricultural lands. Natural lands, including forest and water/wetland areas, occupied about 27% of the total watershed areas. The remaining 32% of the watershed was occupied by urban and other open land areas.

Table 4.21. BOD Loads from Watersheds of Impaired Water Segments

	Addison Creek (WBID 3028)		Eau Gallie River (WBID 3082)		Crane Creek (WBID 3085A)	
Land Use	**Load**	**Percent**	**Load**	**Percent**	**Load**	**Percent**
Agriculture	290	0.2%	1,678	0.3%	15,072	2.7%
Forest	13,470	10.5%	2,998	0.6%	11,066	2.0%
High-Intensity use urban	82,998	64.5%	399,122	78.1%	306,774	55.2%
Low-Intensity use urban	6,735	5.2%	18,489	3.6%	15,633	2.8%
Medium-intensity use urban	10,604	8.2%	63,774	12.5%	161,435	29.0%
Open land	6,647	5.2%	21,936	4.3%	43,367	7.8%
Water/Wetlands	7,983	6.2%	2,752	0.5%	2,789	0.5%
Total	**128,727**	**100.0%**	**510,748**	**100.0%**	**556,136**	**100.0%**
	North Prong of Sebastian River (WBID 3128)		**South Prong of Sebastian River (WBID 3129A)**		**Sebastian River (WBID 3129B)**	
Land Use	**Load**	**Percent**	**Load**	**Percent**	**Load**	**Percent**
Agriculture	509,094	55.1%	1,672,407	70.9%	137,662	36.9%
Forest	58,696	6.4%	73,566	3.1%	20,656	5.5%
High-Intensity use urban	59,644	6.5%	37,984	1.6%	50,225	13.5%
Low-Intensity use urban	72,418	7.8%	97,981	4.2%	9,120	2.4%
Medium-intensity use urban	1,965	0.2%	74,998	3.2%	48,054	12.9%
Open land	206,219	22.3%	377,629	16.0%	102,026	27.4%
Water/Wetlands	15,486	1.7%	25,776	1.1%	4,906	1.3%
Total	**923,523**	**100.0%**	**2,360,342**	**100.0%**	**372,648**	**100.0%**
	C-54 Canal (WBID 3135)					
Land Use	**Load**	**Percent**				
Agriculture	328,014	56.2%				
Forest	61,616	10.6%				
High-Intensity use urban	4,098	0.7%				
Low-Intensity use urban	4,935	0.8%				
Medium-intensity use urban	4,530	0.8%				
Open land	134,180	23.0%				
Water/Wetlands	46,346	7.9%				
Total	**583,717**	**100.0%**				

Note: BOD loads unit is lbs/year.

Based on SJRWMD's PLSM model, the Fellsmere watershed contributed about 130,527 lbs/year of TN and 23,182 lbs/year of TP. Based on CDM HSPF model analyses, the Fellsmere watershed contributes about 2,232,512 lbs/year of BOD to C-54 Canal.

In addition to the C-54 Canal, the Sebastian River main stem is another impaired segment that receives discharge loads from upstream segments. The Sebastian River main stem segment receives discharge loads from the North Prong of the Sebastian River, the C-54 Canal (including Fellsmere watershed), the South Prong of the Sebastian River, and the discharge from the watershed immediate adjacent to the main stem of the Sebastian River.

Nutrients and BOD loads through the interflow and baseflow have already been included as parts of the watershed loads (listed in **Tables 4.12**, **4.13**, and **4.21)**. Based on CDM's water budget modeling analyses, direct rainfall onto the surface of these impaired water segments accounted for about 1% or less of the total flow entering these segments. The maximum percentage of direct rainfall in the total flow is about 3%, which is for the main stem of the Sebastian River and is still considered insignificant. Therefore, nutrients and BOD loads directly depositing onto the surface of the impaired water segments were not estimated in this report. **Tables 4.22-a**, **4.22-b**, and **4.22-c** summarize the total nonpoint sources of TN, TP, and BOD loads entering the impaired water segments.

Table 4.22-a. Summary of Nonpoint Sources of TN Loads Entering Impaired Water Segments

	Addison Creek (WBID 3028)		Eau Gallie River (WBID 3082)		Crane Creek (WBID 3085A)	
Source	**TN Load**	**Percent**	**TN Load**	**Percent**	**TN Load**	**Percent**
Immediate Watershed	5,810.2	100%	58,860.3	100%	91,464.6	100%
Upstream Discharge	0.0	0%	0.0	0%	0.0	0%
Total	**5,810.2**	**100%**	**58,860.3**	**100%**	**91,464.6**	**100%**

	North Prong of Sebastian River (WBID 3128)		South Prong of Sebastian River (WBID 3129A)		Sebastian River Mainstem[1] (WBID 3129B)	
Source	**TN Load**	**Percent**	**TN Load**	**Percent**	**TN Load**	**Percent**
Immediate Watershed	104,904.6	100%	230,566.3	100%	107,912.3	15%
Upstream Discharge	0.0	0%	0.0	0%	618,547.4	85%
Total	**104,904.6**	100%	**230,566.3**	100%	**726,459.7**	100%

	C-54 Canal[2] (WBID 3135)	
Source	**TN Load**	**Percent**
Immediate Watershed	104,494.50	37%
Upstream Discharge	178,582.0	63%
Total	**283,076.50**	100%

Note: The unit of TN loads is lbs/year.
1: The upstream discharge TN loads entering the Sebastian River Mainstem segment include TN loads from the North Prong, South Prong, and C-54 Canal (including TN loads from the Upper St. Johns River drainage area and Fellsmere watershed).
2. The upstream discharge TN loads entering C-54 Canal include TN loads from the Upper St. Johns River drainage basin and Fellsmere watershed.

Table 4.22-b. Summary of Nonpoint Sources of TP Loads Entering Impaired Water Segments

	Addison Creek (WBID 3028)		Eau Gallie River (WBID 3082)		Crane Creek (WBID 3085A)	
Source	**TP Load**	**Percent**	**TP Load**	**Percent**	**TP Load**	**Percent**
Immediate Watershed	1,483.1	100%	10,254.9	100%	16,888.1	100%
Upstream Discharge	0.0	0%	0.0	0%	0.0	0%
Total	**1,483.1**	**100%**	**10,254.9**	**100%**	**16,888.1**	**100%**

	North Prong of Sebastian River (WBID 3128)		South Prong of Sebastian River (WBID 3129A)		Sebastian River Mainstem[1] (WBID 3129B)	
Source	**TP Load**	**Percent**	**TP Load**	**Percent**	**TP Load**	**Percent**
Immediate Watershed	16,285.3	100%	40,926.5	100%	14,700.6	13%
Upstream Discharge	0.0	0%	0.0	0%	98,342.9	87%
Total	**16,285.3**	100%	**40,926.5**	100%	**113,043.5**	100%

	C-54 Canal[2] (WBID 3135)	
Source	**TP Load**	**Percent**
Immediate Watershed	16,968.1	41%
Upstream Discharge	24,163.0	59%
Total	**41,131.1**	100%

Note: The unit of TP loads is lbs/year.
1: The upstream discharge TP loads entering the Sebastian River Mainstem segment include TP loads from the North Prong, South Prong, and C-54 Canal (including TP loads from the Upper St. Johns River drainage area and Fellsmere watershed).
2. The upstream discharge TP loads entering C-54 Canal include TP loads from the Upper St. Johns River drainage basin and Fellsmere watershed.

Table 4.22-c. Summary of Nonpoint Sources of BOD Loads Entering Impaired Water Segments

	Addison Creek (WBID 3028)		Eau Gallie River (WBID 3082)		Crane Creek (WBID 3085A)	
Source	**BOD Load**	**Percent**	**BOD Load**	**Percent**	**BOD Load**	**Percent**
Immediate Watershed	128,727	100.0%	510,748	100.0%	556,136	100.0%
Upstream Discharge	0	0.0%	0	0.0%	0	0.0%
Total	**128,727**	**100.0%**	**510,748**	**100.0%**	**556,136**	**100.0%**
	North Prong of Sebastian River (WBID 3128)		**South Prong of Sebastian River (WBID 3129A)**		**Sebastian River Mainstem[1] (WBID 3129B)**	
Source	**BOD Load**	**Percent**	**BOD Load**	**Percent**	**BOD Load**	**Percent**
Immediate Watershed	923,523	100.0%	2,360,342	100.0%	372,648	5.6%
Upstream Discharge	0	0.0%	0	0.0%	6,296,238	94.4%
Total	**923,523**	**100.0%**	**2,360,342**	**100.0%**	**6,668,886**	**100.0%**
	C-54 Canal[2] (WBID 3135)					
Source	**BOD Load**	**Percent**				
Immediate Watershed	583,717	19.4%				
Upstream Discharge	2,428,656	80.6%				
Total	**3,012,373**	**100.0%**				

Note: The unit of BOD loads is lbs/year.
1: The upstream discharge BOD loads entering the Sebastian River Main stem segment include BOD loads from the North Prong, South Prong, and C-54 Canal (including BOD loads from the Upper St. Johns River drainage area and Fellsmere watershed).
2. The upstream discharge BOD loads entering C-54 Canal include BOD loads from the Upper St. Johns River drainage basin and Fellsmere watershed.

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

5.1 General Modeling Mechanism and Overall TMDL Approach

All the ten water segments included in this TMDL report were verified as having dissolved oxygen (DO) concentrations that failed to meet the thresholds established in Chapter 62-303, Florida Administrative Code, during the Department's Cycle 1 water quality assessment for Group 5 waters (based on data collected in the period from January of 1999 through June of 2006). The Eau Gallie River was also verified in the Cycle 1 assessment, as being impaired for nutrients, due to elevated chlorophyll a concentrations. Therefore, one of the main goals of this TMDL report is to examine effects of possible pollutants, such as nutrients (typically nitrogen and phosphorus) and biochemical oxygen demand (BOD), on the DO concentrations in the water column of these impaired waters. Watershed and receiving water models were developed to achieve this goal. Because the activities of algal communities are important components that influence water column DO concentrations, when watershed and receiving models were developed to examine the DO dynamics, a fully-functional algal component was included. Therefore, the nutrient impairment of the Eau Gallie River can also be addressed using these models.

Other than the Eau Gallie River, several other water segments, including Crane Creek, the St. Sebastian River above Indian River Lagoon, and the South Prong of the Sebastian River (previously referred to as the Sebastian River) were also verified for nutrient impairment in the Department's Cycle 2 water quality assessment for Group 5 waters. The nutrient impairments of these water segments were primarily verified based on elevated chlorophyll *a* concentration in 2009 and 2010. The Department analyzed the nutrient impairments of these water segments, mainly through comparing the water quality data collected from stream stations and lagoon stations, to show that the observed elevation in chlorophyll a concentrations were caused by receiving water processes due to weather conditions instead of the elevated nutrient loads from the watersheds of these impaired segments. Based on these analyses, the Department does not intend to propose any additional nutrient reductions from these watersheds beyond those already identified by the previously adopted Indian River Lagoon mainstem seagrass nutrient TMDLs.

5.1.1. General Model Structure

As discussed in Chapter 4, the Department contracted with CDM to develop a set of HSPF models for impaired water segments included in this TMDL report. These HSPF models served several different purposes. First, as SJRWMD's PLSM and HSPF models for the seagrass PLRG did not include a BOD component, the CDM HSPF models can be used to simulate BOD watershed loads. Second, for those impaired water segments that are influenced by tidal activities, such as the Eau Gallie River, Crane Creek, the Sebastian River main stem, the C-54 Canal, the North and South Prongs of the Sebastian River, (and therefore covered by the Environmental Fluid Dynamics Code (EFDC) models), CDM's HSPF models served as watershed models that provide flow and loading inputs to the EFDC models. For the impaired

segments that are not significantly influenced by tidal activities, such as Addison Creek, the CDM's HSPF models' RCHRES module was used to evaluate the influence of nutrients and BOD loadings on the water column DO concentrations.

As discussed in Chapter 4, in the HSPF model, the DO dynamic in a given RCHRES (a segment of receiving waterbody) is simulated using the OXRX subroutine. **Figure 5.1** is a diagram that shows processes that influence water column DO concentrations and therefore are simulated by the OXRX subroutine in the HSPF models developed by CDM. The major processes that influence the water column DO concentration include DO enrichment processes such as those related to phytoplankton and, benthic algae photosynthesis DO production, and dissolving of oxygen into the water column through reaeration. There are many ways that DO can be consumed in natural streams and estuaries, such as respiration from phytoplankton, benthic algae, and zooplankton, BOD decay, sediment oxygen demand (SOD), and nitrification. In water segments with short water residence times and without any significant influence by point sources, reaeration and sediment oxygen demand may dominate the DO dynamics in the water column. In waterbodies influenced heavily by point sources that discharge high loads of BOD, BOD decay could be a major process controlling the water column DO. For water segments with relatively low water residence time and therefore allow significant amount of algal biomass to accumulate and deposit into the sediment to elevate the SOD, nutrients input may have a significant impact on the water column DO concentration. As discussed previously, the DO dynamics in Addison Creek were examined using CDM HSPF models. These models considered the following processes that influence the water column DO concentrations:

(1) Photosynthesis DO production,
(2) Reaeration DO enrichment,
(3) DO consumption by phytoplankton respiration,
(4) DO consumption by BOD decay,
(5) DO consumption by nitrification, and
(6) DO consumption by sediment oxygen demand.

Due to the lack of data, benthic algal DO production and consumption, and DO consumption through zooplankton respiration were not considered in these TMDLs.

In water segments with long water residence time, nutrients may play important roles in controlling DO dynamics through controlling the growth of phytoplankton. In HSPF model, nutrients that are available for phytoplankton growth are primarily the inorganic form of the nutrient, including phosphate, ammonia, and nitrate. Depending on the phytoplankton community structure, algal growth may have different preference for either ammonia or nitrate. Modelers can set a preference number in the HSPF model to establish the preference. This can be used as a tool to calibrate ammonia and nitrate concentrations. These inorganic nutrients can come directly from watersheds through PERLND and IMPLND module simulations. In addition, the organic nutrients entering the receiving waters can be decayed and converted into inorganic nutrients. At the same time, phytoplankton can die and the dead biomass can add to the detritus pool, which in turn can decay and add to the inorganic nutrient pool.

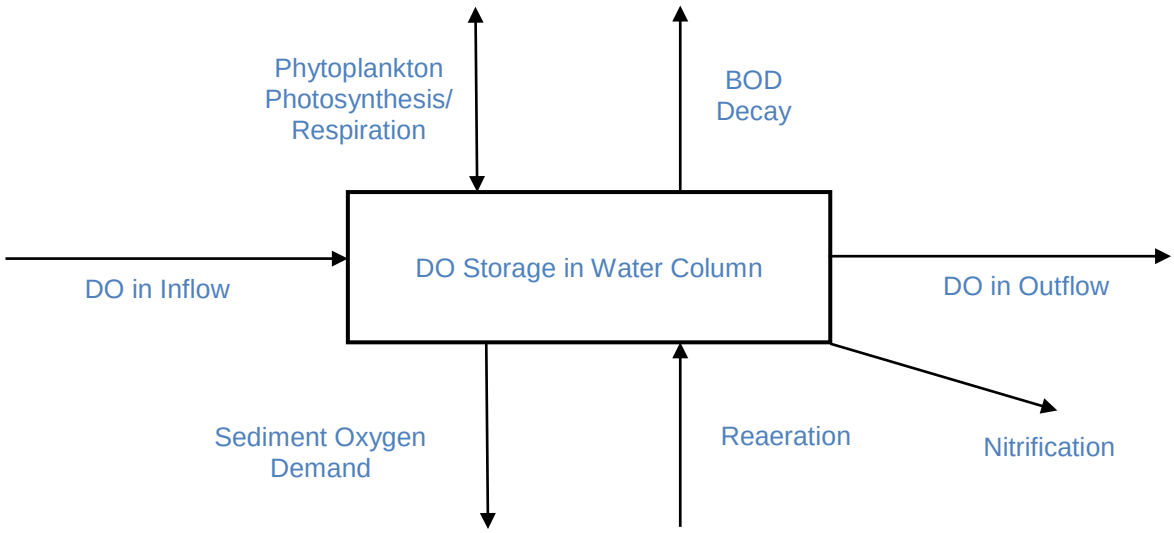


Figure 5.1. Diagram of HSPF DO Dynamics in the Water Column

In the HSPF model, phytoplankton growth, as limited by the availability of nutrients, is applieded using Michaelis-Menten kinetics. This process assumes that the phytoplankton population has a fixed Michealis-Menten constant above which the algal nutrient uptake system will be saturated. If the nutrient concentration in the water column is above the Michealis-Menten constant, more nutrients will not stimulate more phytoplankton growth. However, if the nutrient concentration is lower than the Michealis-Menten constant, the algal growth rate will be a function of the ratio between the nutrient concentration and Michealis-Menten constant.

Both algal cells and dead algal biomass settle to the sediment and contribute to the sediment oxygen demand. In many cases, the sediment oxygen demand is a major factor or even a dominating factor that controls the DO concentration in the water column. The HSPF model does not have a sediment digenesis module. The model does not simulate the dynamics of sediment oxygen demand. The sediment oxygen demand in HSPF model is entered by modelers as a fixed model parameter value.

In the HSPF model, the overall nutrient dynamics are simulated by the NUTRX subroutine. This is a very complicated subroutine that involves all the transformations between dead algal biomass, the particulate organic nutrient pool, the dissolved organic nutrient pool, and the inorganic nutrient pool. This subroutine also simulates the nitrification process that coverts ammonia into nitrite and then to nitrate. The subroutine also simulates the denitrification that converts nitrate to nitrogen gas.

Phytoplankton component in the HSPF model is simulated by the PLANK subroutine. This subroutine simulates phytoplankton growth, metabolism, death, sinking to the sediment, and that fraction grazed by zooplankton. The subroutine also simulates the transfer of algal biomass to detritus pool and settling of detritus to the sediment. In addition, the PLANK subroutine also simulates the zooplankton growth and death and the contribution of zooplankton to the detritus pool.

The HSPF models developed by the CDM focus on the phytoplankton portion of the subroutine. Because of the lack of data, no zooplankton activities were considered in these models. **Figure 5.2** is a diagram shows the major components of the PLANK subroutine that are considered by the CDM HSPF models. In addition, benthic algae community is another component that the PLANK subroutine can simulate, but because of the lack of data, benthic algae activities were not considered in the HSPF models developed by CDM.

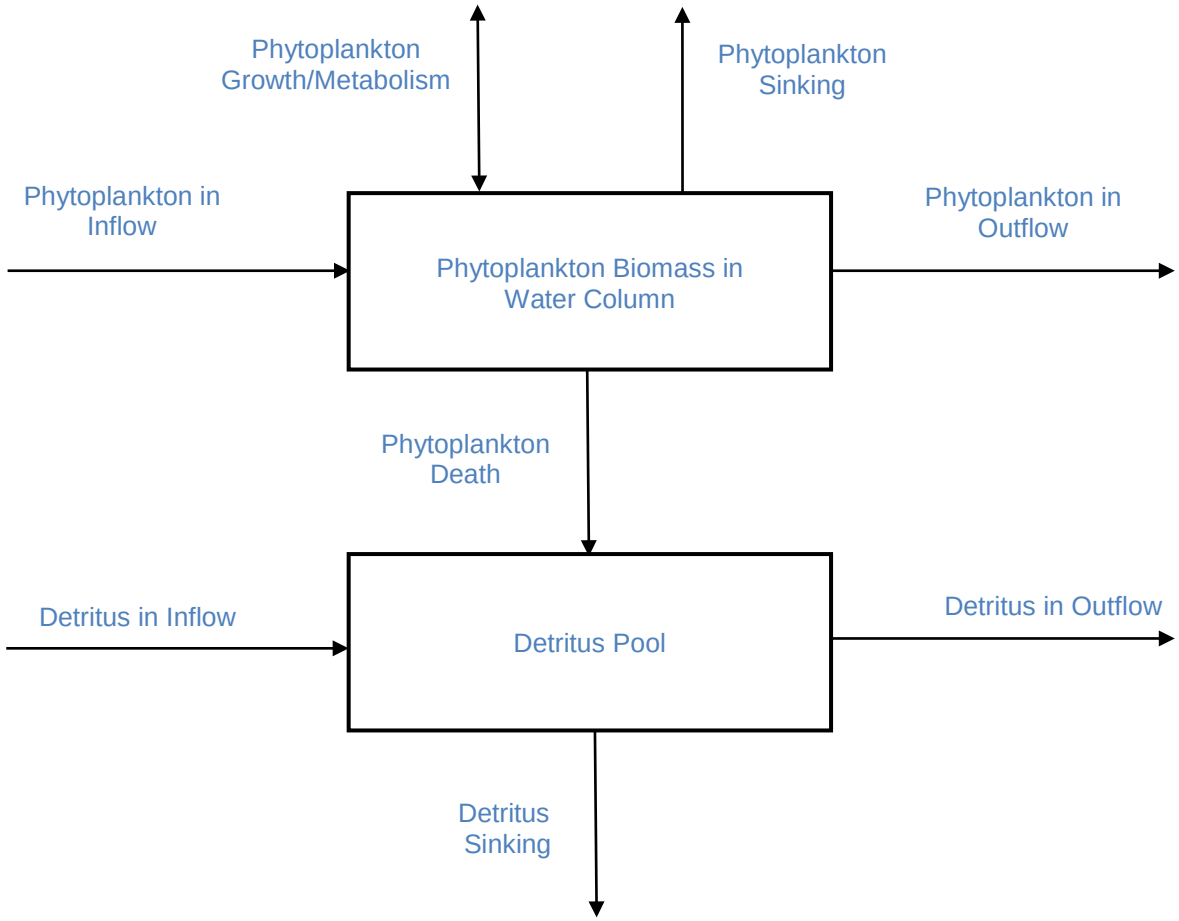


Figure 5.2. Diagram of HSPF Phytoplankton Dynamics in the Water Column

For those impaired segments that are tidally influenced, such as the Eau Gallie River, Crane Creek, and the Sebastian River main stem (including the C-54 Canal, the North Prong, and the South Prong), CDM-developed HSPF models were used to simulate watershed nutrients and BOD loads. These watershed loads were then used as the model inputs for EFDC models to simulate the DO and chlorophyll *a* concentrations in the tidally influenced impaired segments. These EFDC models were developed by Dynamic Solution, LLC (DSLLC). One important goal of developing EFDC models for these tidally influenced waterbodies was to evaluate the importance of several environmental factors, including nutrients, BOD, and SOD, in controlling the water column DO concentrations. One of the important features that the EFDC model has is full sediment diagenesis analysis. This tool allows users to evaluate the change of SOD with the change of watershed nutrients and organic carbon loadings and, therefore, provides an important way to identify important pollutants from the watershed that may depress the receiving water DO concentration. The EFDC model system used in this report includes a main stem

model that covers the segment of the Indian River Lagoon that extends from Titusville in the north to the Ft. Pierce inlet in the south, and one tributary model for each impaired water segment that is tidally influenced.

EFDC is a general-purpose modeling package for simulating three-dimensional flow, transport, and biogeochemical processes in surface water systems including: rivers, lakes, estuaries, reservoirs, wetlands, and near-shore to shelf-scale coastal regions (Hamrick, 1992, 1996). The model was originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications. It is a public domain model and is supported by the United States Environmental Protection Agency (EPA) as part of a family of models available for TMDL development. The main module of the model simulates hydrodynamics, salinity, and temperature. The hydrodynamic module is internally coupled with a sediment transport module, which describes the water column distribution of inorganic cohesive particles resulting from deposition and re-suspension processes; a water quality module that describes biogeochemical processes of nutrients, algae, dissolved oxygen, and other dissolved or particulate water quality constituents; and a sediment digenesis module that describes the coupling of particulate organic matter deposition from the water column to the sediment bed, decomposition of organic matter in the bed, and the exchange of nutrients and dissolved oxygen across the sediment-water interface.

The purpose of setting up a main stem EFDC model is to provide boundary condition time series to tributary models. The main stem model is defined by 2141 horizontal cells and four vertical layers. It simulates the main stem hydrodynamics and water quality conditions with the watershed nutrient loadings simulated using HSPF models, which generated tributary discharges from Addison Creek, the Eau Gallie River, Crane Creek, the Sebastian River, Turkey Creek, the North Canal, Main Canal, South Canal, C-25 Canal, and Ft. Pierce Farm Canal, and hydrological inputs through overland flow from other distributed nonpoint sources, the point source discharges, the measured boundary conditions at Titusville, Banana Canal, Banana Cut, Sebastian Inlet, and Ft. Pierce Inlet, the direct atmospheric deposition onto the lagoon surface, and nutrient flux and sediment oxygen demand simulated at the water column-sediment interface using a sediment digenesis algorithm. Setting up a main stem model that is separated from the tributary model, but being capable of providing a tributary model with open boundary condition time series, allows the flexibility of running tributary model scenarios without the need of repeating very time-consuming model simulations on the main stem model.

All tributary models also include four vertical layers. Model grids of tributary EFDC models include those grids covering the main stem of Indian River Lagoon and those grids that cover the impaired tributary segments that are tidally influenced. The north-to-south span of the grid areas covering the main stem Indian River Lagoon was assigned to each tributary EFDC model as the shortest possible distance that would (a) still maintain a reasonable grid resolution for the tributary model and (b) allow for sufficient mixing and dilution of the tributary discharge in the main stem domain. In determining the north-south distance, the geometry and volume of the tributary sub-model was considered with regards to the size and volume of the main stem model to minimize any artificial losses of significant mass across the north and south boundaries. The nutrient loadings entering the tributary EFDC model were simulated using the CDM's HSPF models (discussed in the previous section and in **Chapter 4**). The open boundary condition time series of the tributary model were provided by the main stem EFDC model. Like the main stem model, the tributary model simulates the hydrodynamic and water quality dynamics in these impaired water segments. The model takes into consideration of the effects of nutrient

loadings from a watershed, direct atmospheric deposition, and nutrient flux and sediment oxygen demand taking place at the sediment-water column interface. **Figure 5.3** shows the spatial range of the main stem EFDC model and general locations of tributary EFDC model domains. **Figures 5.4-a, 5.4-b, and 5.4-c** show the tributary EFDC modes and their HSPF model watersheds.

For both the main stem and tributary models, the EFDC/HEM3D Kinetic Option 1 was selected. This option, which follows the kinetic processes used for the Chesapeake Bay model CE-QUAL_ICM (Cerco and Cole, 1995), has been the most tested and stable of the EFDC water quality kinetic options. Within this option, users can activate, or inactivate, the kinetics and mass transport of individual state variables listed in **Tables 5.1-A and -B**. Details of the state variable equations and kinetic terms for each state variable are presented in Park et al. (2000) and Ji (2008).

Table 5.1-A EFDC Hydrodynamics State Variables

Code	EFDC State Variable	EFDC Parameter ID	EFDC Units	Used in Model?
NA	Water Surface Elevation	WS	M	Yes
NA	Salinity	SAL	ppt	Yes
NA	Water Temperature	TEM	^0C	Yes
NA	Inorganic Cohesive Sediments	COH	mg/L	Yes

Table 5.1-B EFDC Water Quality State Variables

Code	EFDC State Variable	EFDC Parameter ID	EFDC Units	Used in Model?
1	Cyanobacteria	CHC	mg C/L	No
2	Diatoms	CHD	mg C/L	No
3	Green Algae	CHG	mg C/L	Yes
4	Refractory Particulate Organic Carbon	RPOC	mg C/L	Yes
5	Labile Particulate Organic Carbon	LPOC	mg C/L	Yes
6	Dissolved Organic Carbon	DOC	mg C/L	Yes
7	Refractory Particulate Organic Phosphorus	RPOP	mg P/L	Yes
8	Labile Particulate Organic Phosphorus	LPOP	mg P/L	Yes
9	Dissolved Organic Phosphorus	DOP	mg P/L	Yes
10	Phosphate	TPO4	mg P/L	Yes
11	Refractory Particulate Organic Nitrogen	RPON	mg N/L	Yes
12	Labile Particulate Organic Nitrogen	LPON	mg N/L	Yes
13	Dissolved Organic Nitrogen	DON	mg N/L	Yes
14	Ammonia Nitrogen	NHX	mg N/L	Yes
15	Nitrate Nitrogen	NOX	mg N/L	Yes
16	Particulate Biogenic Silica	SUU	mg Si/L	No
17	Dissolved Available Silica	SAA	mg Si/L	No
18	Chemical Oxygen Demand	COD	mg O_2/L	Yes
19	Dissolved Oxygen	DOX	mg O_2/L	Yes
20	Total Active Metals	TAM	mol/M^3	No
21	Fecal Coliform	FCB	MPN/100 ml	No

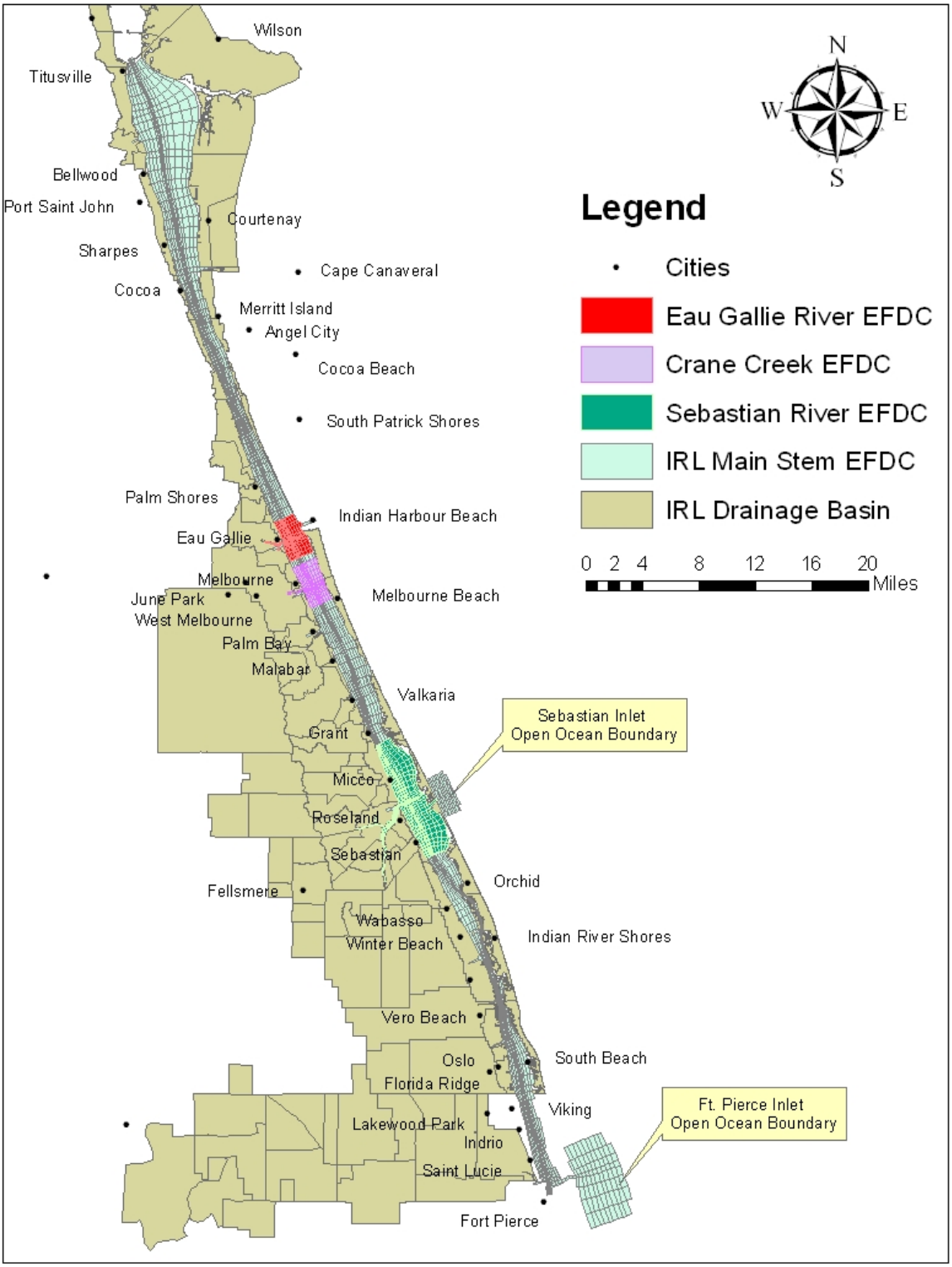


Figure 5.3. Spatial Domain of the IRL Main Stem and Tributary EFDC Models

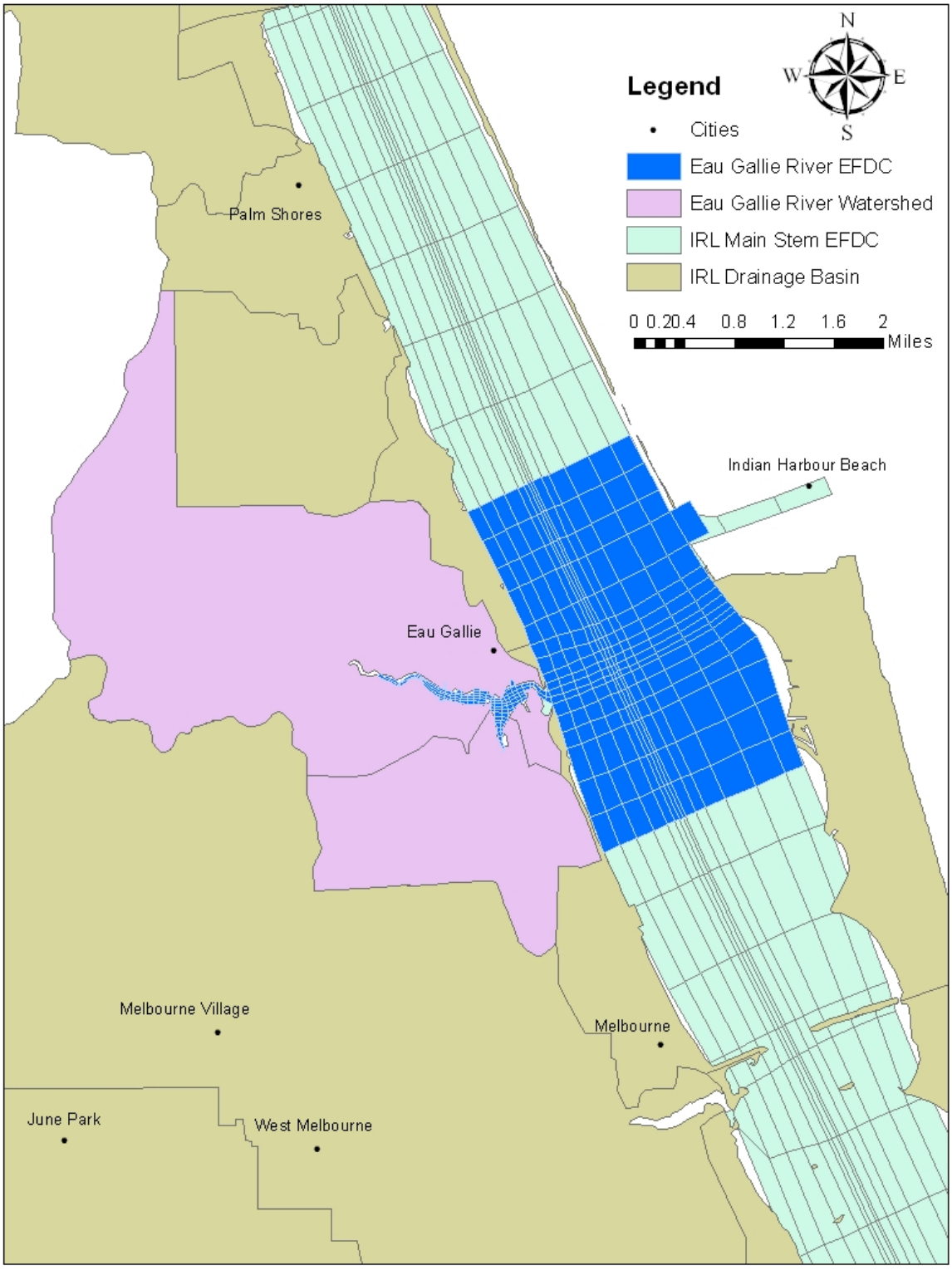


Figure 5.4-a. Eau Gallie River EFDC Model Grid and Eau Gallie River Watershed

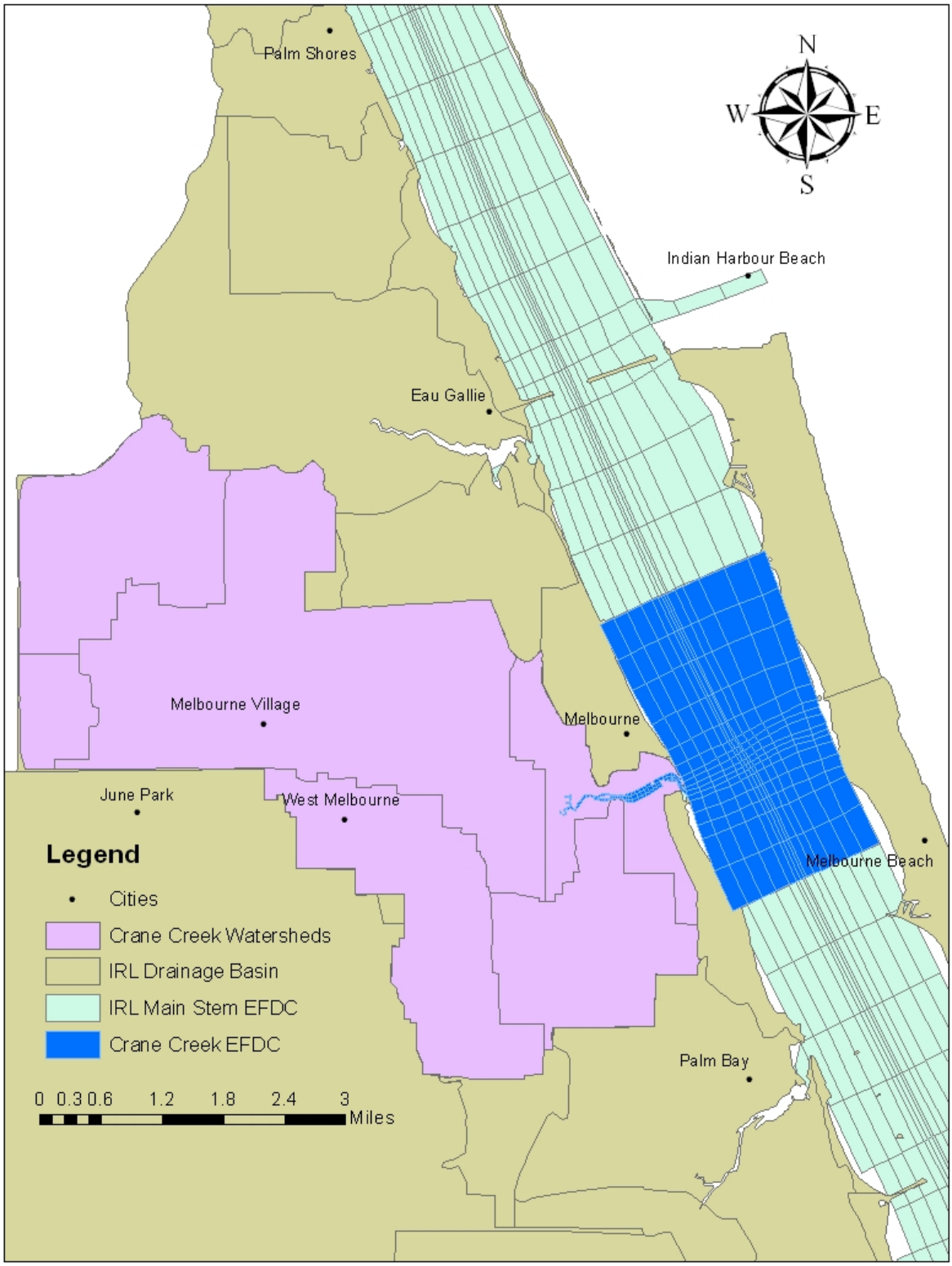


Figure 5.4-b. Crane Creek EFDC Model Grid and Crane Creek Watershed

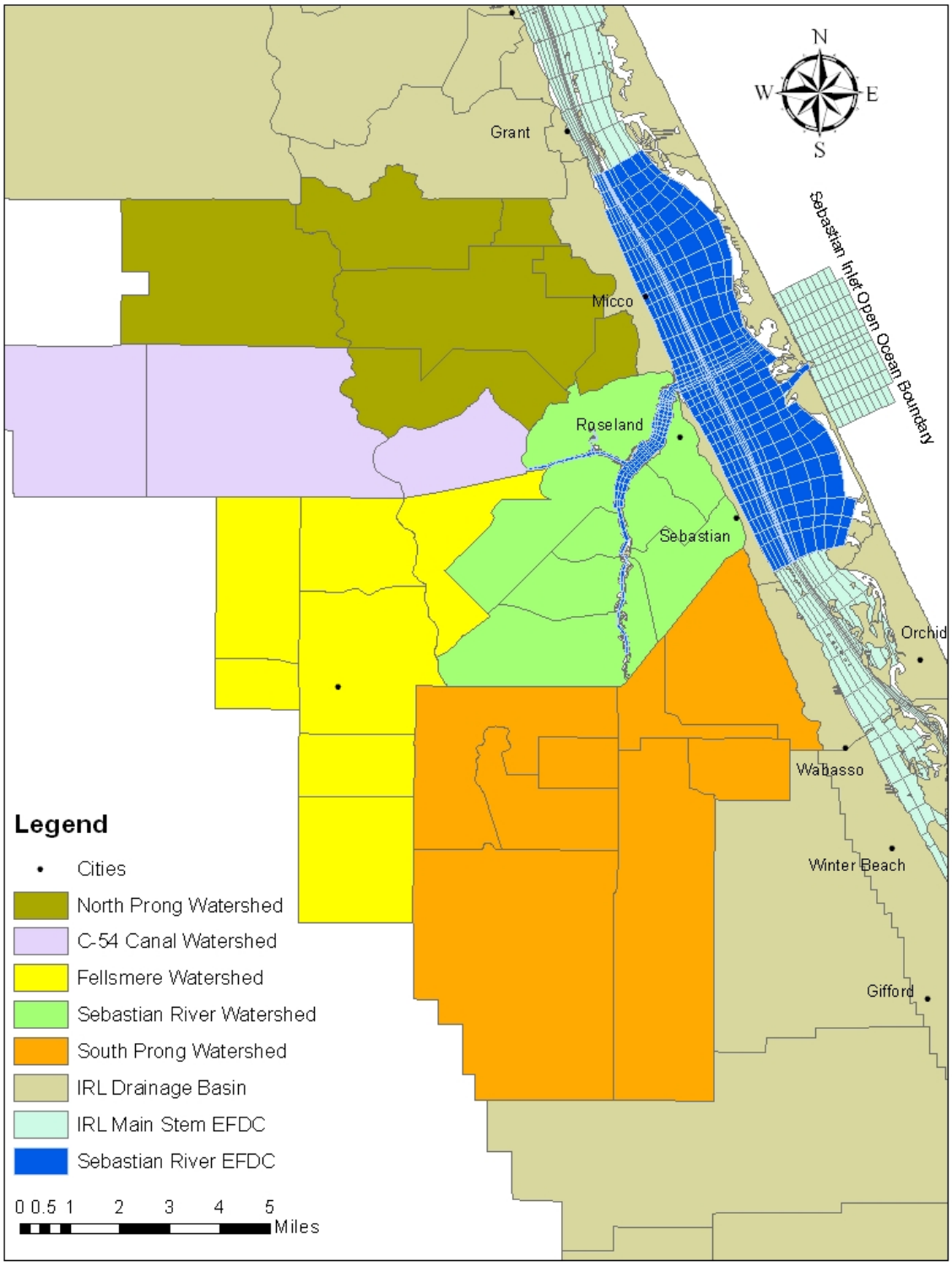


Figure 5.4-c. Sebastian River EFDC Model Grid and Related Watersheds

Based on long-term monitoring data (1988 – 1994) of the Indian River Lagoon, Sigua et al. (2000) noted that there are significant spatial variations in nitrogen and phosphorus distributions along the north-south axis of the lagoon. Total Kjeldahl Nitrogen (TKN) was higher in the north end of the lagoon and lower in the south lagoon. The opposite pattern was found in the Indian River Lagoon for TP. As there is a pronounced north-south gradient for nutrients, it is essential to represent spatial differences in water quality processes in the main stem model that control the spatial distributions of water quality constituents. The main stem model domain for the Indian River Lagoon is thus divided into seven water quality zones based on previous monitoring studies (Philips, 1999; Reddy et al., 1999; Sigua et al., 2000). **Figure 5.5** shows the spatial distribution of water quality zones along the Indian River Lagoon main stem.

5.1.2. EFDC Water Quality Components

Simulation of dissolved oxygen dynamics is a key aspect of this TMDL. Kinetic processes of dissolved oxygen represented in the EFDC model include sources from atmospheric reaeration in the surface layer and algal photosynthetic production. Kinetic loss terms include algal respiration, nitrification, decomposition of DOC, oxidation of COD, and bottom layer consumption of oxygen from sediment oxygen demand. Sediment oxygen demand is coupled with particulate organic carbon deposition and is computed internally in the sediment flux model. The kinetic reaction processes for dissolved oxygen are all temperature dependent.

The EFDC model has the capability of simulating three groups of algae including cyanobacteria, diatoms, and green algae. At the time this TMDL was developed, there was not sufficient information to differentiate the growth and metabolic activities of the three algal groups in the simulated waterbodies. Therefore, algal production for this TMDL was treated as one single lumped group called “green algae.” Kinetic parameters of the algal group were calibrated against the chlorophyll a concentration.

Algal kinetic processes simulated by the EFDC model include photosynthesis, basal metabolism (respiration and excretion), settling, and predation. Photosynthesis is described by a growth rate that is functionally dependent on a maximum growth rate, water temperature, the availability of sunlight at the surface, light extinction in the water column, the optimum light level for growth, and half-saturation dependent nutrient limitation by either nitrogen or phosphorus. Both growth and basal metabolism are temperature-dependent, while settling and predation losses are assigned as constant parameter values. Different maximum algal growth rates were assigned to algal communities in different water quality zones based on data collected by Philips (1999) and model calibration.

In the EFDC model, water column light extinction is control by four major factors, including inorganic suspended solid (InorgSS), particulate organic carbon (POC), algal biomass (Chla), and background light extinction (0), which can be attributed to light attenuation by optically clear water and other attenuation not controlled by InorgSS, POC, and Chla. **Equation 5.1** describes the total light extinction caused by all these processes. The light extinction coefficient for each of these factors was assigned based on numbers reported by Di Toro (1978) and as part of model calibration.

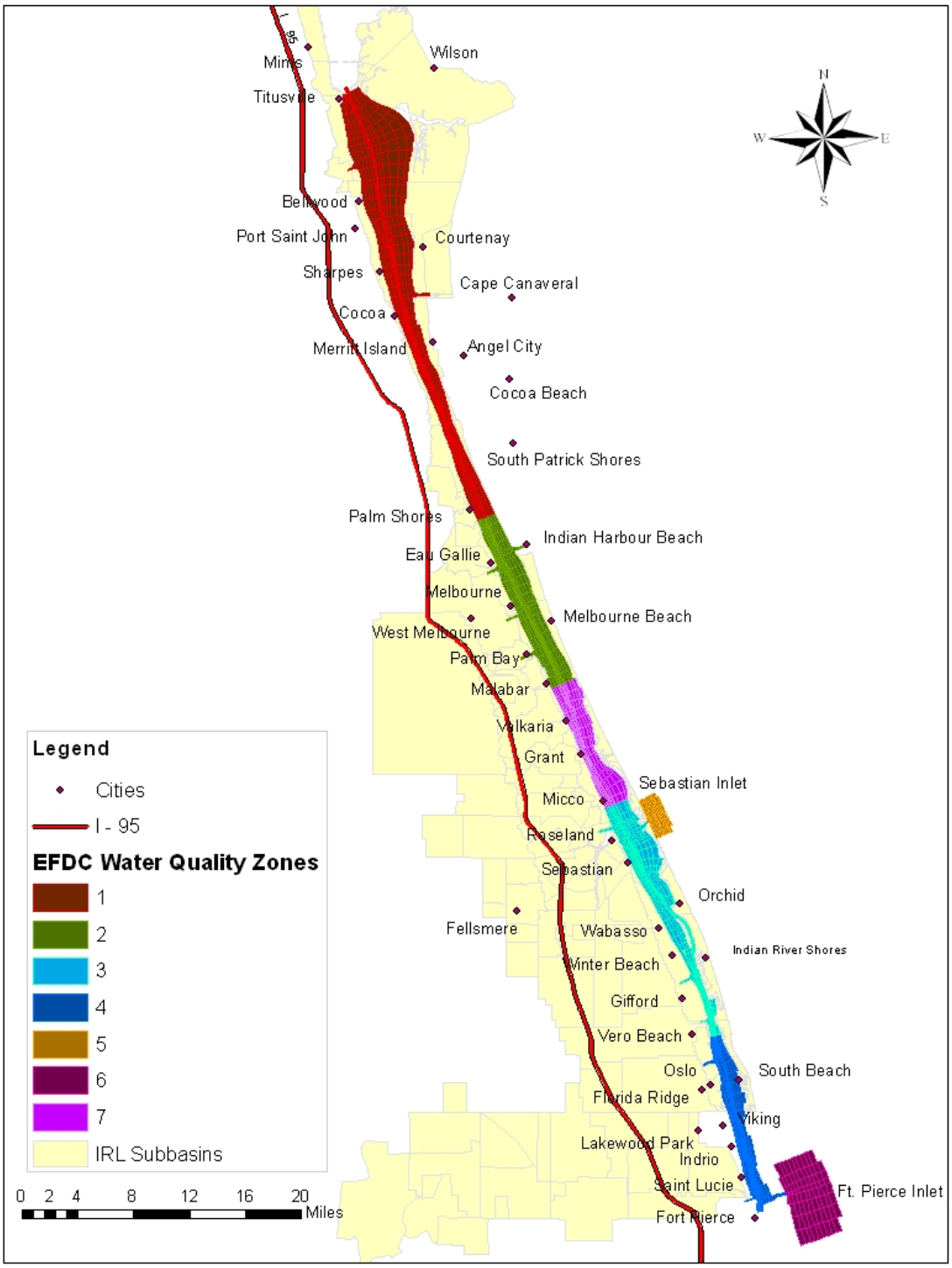


Figure 5.5. Water Quality Zones for the Main Stem EFDC Model

$$K_e = K_e(0) + K_e(InorgSS) + K_e(POC) + K_e(Chla)$$ **Equation 5.1**

Where,

K_e is the total light extinction.
$K_e(0)$ is the background light extinction.
$K_e(InorgSS)$ is the light extinction caused by inorganic suspended solids.
$K_e(POC)$ is the light extinction caused by particulate organic carbon.
$K_e(Chla)$ is the light extinction caused by Chla.

Nutrient dynamics are a key factor that controls algal growth. The state variables of nutrients simulated by the EFDC model include organic nutrients (organic phosphorus and organic nitrogen), total phosphate, ammonia, and nitrate/nitrite. EFDC divided the total organic nutrients into three groups depending on their solubility and ease of degradation, which include dissolved organic nutrients (dissolved organic phosphorus – DOP and dissolved organic nitrogen – DON), labile particulate organic nutrient (labile particulate organic phosphorus – LPOC and labile particulate organic nitrogen – LPON), and refractory particulate organic nutrients (refractory particulate organic phosphorus – RPOP and refractory particulate organic nitrogen – RPON). Labile and refractory organic nutrients were distinguished based on the time scales for decomposition. The labile particulate organic nutrients take on the order of weeks to months to decay, while the refractory particulate organic nutrients may take years to decay. Kinetic processes represented in the EFDC model for particulate organic nutrients include production of particulate organic nutrient through algal metabolism and predation, dissolution of refractory organic nutrients to labile organic nutrients and then to dissolved organic nutrients, and loss of particulate organic nutrients through settling process. Kinetic processes for dissolved organic nutrients include production of dissolved organic nutrient through algal metabolism, predation, and dissolution of particulate organic nutrient to dissolved organic nutrients. The loss of organic nutrients mainly results from mineralization. With the exception of settling of particulate organic nutrients, the kinetic reaction processes are all temperature dependent.

The total phosphate in the EFDC model includes dissolved phosphate and phosphate absorbed to suspended solids. Adsorption and desorption of phosphate is defined on the basis of equilibrium partitioning using an assigned phosphate partition coefficient for suspended solids. The kinetic processes of total phosphate include production of phosphate from algal metabolism and predation and mineralization from dissolved organic phosphorus. Losses for of phosphate are primarily though the settling of the absorbed fraction of total phosphate and uptake by phytoplankton growth. In addition, depending on the concentration gradient between the bottom water column and sediment bed pore water phosphate, the sediment-water interface can serve as either a source or a loss term for phosphate in the water column. With the exception of the partition coefficient and the settling of adsorbed phosphate, the kinetic reaction processes for phosphate are temperature dependent.

Inorganic nitrogen is represented by two state variables in EFDC model including ammonia and nitrate/nitrite. Because the time scale for conversion of nitrite to nitrate is very rapid, nitrite and nitrate are combined as a single state variable in the EFDC model. Kinetic terms for ammonia and nitrate/nitrite include production of ammonia from algal metabolism and predation and mineralization from dissolved organic nitrogen, conversion of ammonia to nitrate/nitrite through bacterially mediated nitrification, uptake of ammonia and nitrate/nitrite by phytoplankton growth,

and conversion of nitrate/nitrite to nitrogen gas through the anaerobic denitrification process. Depending on the concentration gradient between the bottom water column and sediment bed pore water ammonia and nitrate/nitrite, the sediment-water interface can serve as either a source or a loss term for ammonia and nitrate/nitrite in the water column.

Organic carbon is an important state variable in EFDC model. It is the material that causes high color of the water and reduces the availability of photosynthetically active light to phytoplankton. The bacteria facilitated decomposition of dissolved organic carbon is a dissolved oxygen consumption process. In addition, settling of particulate organic matter into the sediment is an important source of materials that result in sediment oxygen demand, which, in turn, influence the dissolved oxygen dynamics in water column. Like organic nutrients, organic carbon in the EFDC model is also represented by three groups including dissolved organic carbon (DOC), labile particulate organic carbon (with a decay time scale of weeks to months), and refractory particulate organic carbon (with a decay time scale of years). Kinetic processes of organic carbon represented in the EFDC model including production of dissolved organic carbon through algal excretion and predation and production of particulate organic carbon through algal predation, dissolution of refractory particulate organic carbon to labile particular organic carbon, and to dissolved organic carbon. Particulate organic carbon can be removed from the water column through sedimentation, decomposition, and denitrification. With the exception of settling of particulate organic carbon, all the kinetic reactions associated with organic carbon are temperature dependent.

5.1.3. Sediment Flux Model

Sediment oxygen demand (SOD) and sediment nutrient flux to the overlay water column are important processes determining the DO and ChlaC dynamics in the water column. As it is discussed in a later section, SOD plays a critical role in the DO dynamics in the impaired water segments included in this TMDL report. The EFDC models used to develop TMDLs for these impaired water segments have three options to characterize SOD and sediment nutrient flux, including (1) spatially and temporally constant fluxes, (2) spatially and temporally variable fluxes, and (3) an internally coupled sediment diagenesis model. For this TMDL, the sediment diagenesis model, coupled with the water column modeling, was used to determine the SOD and sediment nutrient flux.

The sediment diagenesis model takes the nutrient and organic carbon deposition simulated by the water column model as source terms to simulate the decomposition of the particulate organic matters (POM), including particulate organic carbon (POC), particulate organic nitrogen (PON), and particulate organic phosphorus in the sediment, and the sediment oxygen demand (SOD) and flux of soluble nitrogen and phosphorus species back to the water column. The EFDC model splits POMs into three fractions based on how fast these organic materials can be decomposed. If the half life of a given POM is less than 20 days, the POM was assigned to the G1 fraction, which is considered the labile fraction. The POM decomposed with a half-life of one year was considered the refractory fraction and was assigned to the G1 fraction. The non-reactive fraction is the fraction of the POM with negligible decay before it is buried into the deep inactive layer of the sediment. The non-reactive fraction was assign to the G3 fraction.

The sediment diagenesis model represents the sediment bed as a two-layer system, including a thin aerobic layer and a thicker anaerobic layer. The top aerobic layer is very thin, usually in the order of only a millimeter. Its depth is primarily determined by the oxygen concentration in the

sediment, sediment oxygen demand, and diffusivity coefficient for DO. The thickness of the lower anaerobic layer is a model parameter entered by modelers. A most commonly used lower layer thickness is about 10 centimeters (Di Toro, 2001). This number can be derived theoretically and has been verified based on field observation. Model calibration of the Indian River Lagoon main stem and tributary segment showed that the thickness of the anaerobic lower layer ranged between 10 to 20 centimeters. Because the top aerobic layer is so thin, the EFDC model adds the water column deposition directly to the lower anaerobic layer. This is the layer in which most of the sediment diagenesis processes were simulated.

5.1.4. Data Needs for the EFDC Modeling

The hydrodynamics and water quality simulation of EFDC model is driven by a series of model input requirements including:

(1) Physical characteristics of the receiving water segments, such as bathymetry and shoreline characteristics,
(2) Meteorological factors that influence the water balance, as well as hydrodynamic processes through the air-water interface interaction,
(3) Boundary conditions that control the water balance, hydrodynamics, pollutant mass balance, and chemical and biochemical processes in the receiving water,
(4) Atmospheric deposition directly onto the surface of the impaired water segments, and
(5) Sediment characteristics that influence the nutrient exchange at the water-sediment interface and DO concentration in the water column of impaired water segments.

5.1.4.1. Bathymetry and Shoreline Data

The physical domain of the receiving water hydrodynamic model is defined by topographic, bathymetric, and shoreline location data for the Indian River Lagoon and surrounding tributaries. Shoreline data for impaired water segments included in the report and for the main stem of Indian River Lagoon were collected from NOAA National Geophysical Data Center (NGDC) Shoreline Extractor – http://rimmer.ngdc.noaa.gov/mgg/coast/getcoast.html.

Topographic and bathymetric data for the main stem of the Indian River Lagoon and openocean were provided by the SJRWMD. Bathymetry data for the tributaries were collected from several sources, including the SJRWMD, FEMA flood models' HEC-2 cross-sections, CDM, and aerial imaries. **Table 5.2** summarizes the sources of bathymetry and topographic information for each impaired water segment.

Mean seal level (MSL) data for the study area were obtained on-line from the SJRWMD and NOAA – http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=8722004%20Sebastian%20Inlet,%20FL&type=Datums. The data were based on the National Tidal Datum Epoch that has been used since 2001 to calculate MSL for coastal tidal stations using tidal data from 1983 to 2001. All elevation data used in the model is relative to the MSL at Sebastian Inlet. Based on data taken from the NOAA NOS Tide Station # 8722004, the lower low tide elevation is 1.980 ft and the higher high tide elevation is 4.33 ft for Sebastian Inlet. The average daily tidal range is the difference between lower low and higher high which is 2.35 ft. All elevations used in building the model are referenced to MSL.

Table 5.2. Summary of Bathymetry Data for Each Waterbody

Impaired Water Segment	Bathymetry and Topographic Information	Data Source	Bathymetric Assumptions	Shoreline Data
Eau Gallie River	HEC-2 Bathymetry (1986)	FEMA	Width scaled from aerial imagery	Shoreline scaled from aerial imagery
Crane Creek	Post-Dredging Bathymetry (2006-2008)	SJRWMD	None	SJRWMD
Sebastian River System		CDM/SJRWMD	None	CDM/SJRWMD/NOAA
Indian River Lagoon Main Stem	Complete	SJRWMD	None	None

5.1.4.2. Meteorological Data

Atmospheric forcing data are necessary to model hydrodynamic processes, salinity, and water temperature. Needed meteorological data for the EFDC simulation include barometric pressure, air temperature, relative humidity, wind speed and direction, precipitation, evaporation, incident solar radiation, long wave radiation, and cloud cover. Atmospheric forcing data were available from historic archives maintained by the NOAA National Climate Data Center (NCDC). Hourly records of barometric pressure, air temperature, relative humidity, rainfall, wind speed and direction, and cloud cover were obtained from the NCDC stations located at Ft. Pierce and Titusville, Florida. The DSCLL used an inverse distance weighting method to spatially distribute meteorological data to each grid cell.

5.1.4.3. EFDC Model Boundary Condition

For impaired water segments and the Indian River Lagoon main stem segments covered by these EFDC models, three types of water column boundary conditions were used:

(1) Flow boundary,
(2) Open water elevation boundary, and
(3) Withdrawal/return flow boundary.

A flow boundary is defined by paired time series of flow and salinity, temperature, and water quality constituents. An open water elevation boundary is defined for the north, south, east, and west directions as paired time series of tidally forced water surface elevation, salinity, temperature, and water quality constituents. A withdrawal and return flow boundary condition is defined by paired time series of flow and the incremental rise/fall change in constituent concentrations computed as the difference in concentration between the withdrawal and the return flow. Flows across an open water boundary are computed internally in the EFDC model based on the cross-sectional area and the gradient of water surface elevation between the model boundary and the interior grid cell. Mass transport loads into the model domain across either a flow or open water boundary are then computed internally in the model from the flow and constituent concentration data provided as boundary conditions.

Most of the flow boundary conditions for EFDC models covered in this report were derived from HSPF watershed flows, and nutrients and BOD loading simulations. These flows and loadings were either simulated by HSPF models for major tributaries or for as nonpoint source discharges from the Indian River Lagoon drainage basin areas that have no major tributaries. HSPF flow and loads of water quality constituents were split into each of the four vertical layers of the EFDC model grid. In order to shorten the EFDC model running time, multiple nonpoint source HSPF boundary flow conditions were aggregated into a small number of discrete boundary conditions before being input into the EFDC model.

Flow boundary conditions were also defined using the point source discharges. As discussed in Chapter 4, there were four wastewater facilities discharges into the impaired water segments included in this report, including the Melbourne Grant Street Wastewater Treatment Plant (FL0041122) that discharges into Crane Creek, the Barefoot Bay advanced WWTF (FL0042294) that discharges into the North Prong of Sebastian River, the Indian River County – West Regional WWTF (FL0041637) that discharges into Main Canal, and the Indian River County – South County Demineralization Concentrate WTP (FL0037940). Except for the Indian River County – South County Demineralization Concentrate WTP, which discharges directly into the EFDC model domain, all the other three point sources discharge to an affected freshwater segment that were covered by HSPF Model RCHRES, but not directly to the EFDC model domain. There are other nine NPDES point source dischargers that do not discharge into any impaired water segments covered in this report. However, they discharge to the Indian River Lagoon main stem EFDC model domain and therefore were characterized as flow boundary conditions in this TMDL report (**Table 5.3**).

Table 5.3. NPDES Waste Water Facilities Discharging into the EFDC Model Domain

Facility ID	Facility Name
FL0000680	Reliant Energy Indian River
FL0001473	FPL – Cape Canaveral Power Plan
FL0021521	Cocoa Water Reclamation Facility
FL0040622	South Beaches Regional Wastewater Treatment Plant
FL0166511	Indian River County Utility Department – North County Demineralization Concentrate Hobart
FL0021611	Vero Beach WWTF
FL0002984	Vero Beach, City of – Municipal Power Plant
FL0043443	Melbourne Reverse Osmosis WTF
FL0042544	Vero Beach Demineralization Concentrate
FL0037940	Indian River County Utility Department – South County Demineralization Concentrate WTP

The mainstem Indian River Lagoon EFDC model include two types of open elevation boundaries: (1) coastal ocean boundary, and (2) non-ocean interior boundary. The four non-ocean interior elevation boundaries are Titusville at the northern boundary, the Banana River boundary, the Banana Cut boundary, and Fort Pierce at the southern boundary.
There are two tidal connections between the Banana River and the mainstem of the Indian River Lagoon. The first connection is at the Banana Cut near the Eau Gallie River. The second connection is at the Banana Canal which is just north of the Bennett Causeway. Hydrographic and water quality parameters for these boundaries were obtained from the Department's

STORET station data extracted for the Banana River. Boundary data sets were applied to both the Banana Cut and Banana Canal boundaries. The stage data for the Banana Canal boundary were provided by the SJRWMD. Salinity, temperature, and water quality forcing were assumed to be the same as observed records from the nearby Merritt West station in the mainstem lagoon. The stage at the Banana Cut boundary was obtained through the salinity calibration for the IRL main stem model. The salinity boundary for the Banana Cut was assumed to be the same as observed salinity data collected at the nearby Melbourne Causeway station. Temperature and water quality boundary conditions were based on data collected from the Merritt West station. No observed data sets were available from the Department's STORET or NOAA NODC databases. The water quality boundary conditions for the open ocean conditions used to characterize Sebastian Inlet and Ft. Pierce Inlet were based on experience with other near coastal water quality conditions and through the main stem model calibration process.

The EFDC hydrodynamic and sediment transport model has the capability to specify the mass balance of salinity, heat, and sediment based on the withdrawal of flow and mass loading of a constituents from a defined grid cell with a return flow and mass loading of a constituent to a different grid cell. This capability, provided in the EFDC hydrodynamic model to account for cooling water withdrawals and returns from power plants, is typically used for simulations of changes in ambient water temperature that are related to heated water discharges. The data that are specified for a withdrawal and return boundary representation for water temperature include measured time series of cooling water discharge flows from power plants and the incremental difference between ambient temperature and heated discharge temperature.

The EFDC model's capability of simulating the withdrawal and return boundary condition was modified in for the main stem model to include all the water quality state variables related to DO and nutrient dynamics in the lagoon. Three NPDES permitted power plants were identified discharging into the mainstem of Indian River Lagoon, including the Reliant Energy Indian River (FL0000680), the FPL – Cape Canaveral Power Plant (FL0001473), and the City Vero Beach's Municipal Power Plant (FL0002984). Effluent temperature data were compiled for these facilities and compared to the ambient water temperature data collected from the lagoon segments that these facilities discharge into to calculate the incremental difference between the effluent temperature and ambient temperature. The incremental differences of salinity and other water quality constituents between the effluent and ambient water were assume to be zero for the once-through cooling water from these facilities.

5.1.4.4. Atmospheric Deposition Falling Directly onto the Surface of the Indian River Lagoon

Although the loading simulation of atmospheric loads directly deposited onto the surface of impaired water segments were not conducted in HSPF model because of the relatively small stream surface area compared to the area of the watersheds of these impaired water segments, atmospheric direct deposition was considered when developing the mainstem EFDC model because the lagoon surface areas, in some cases, is comparable to the areas of the drainage basins discharge to a given lagoon segments.

The SJRWMD provided atmospheric deposition data collected from a site (IRL 141) located at Sebastian Inlet between 2001 through 2006. Site IRL 141 belongs to the Clear Air Status and Trends Network (CASTNET), which has been sponsored by the EPA since 2006. Between 2001 and 2006, the SJRWMD maintained the site (Rogers 2007).

Typically, CASTNET sites only collect dry deposition data. However, at Site IRL 141, the SJRWMD maintains a wet deposition collector, which collects the wet deposition data using a protocol similar to that used by the National Atmospheric Deposition Program (NADP). The bulk deposition rates for TN and TP used in this TMDL were the sum of the CASTNET dry deposition rate and the NADP-style wet deposition rate. To accommodate the EFDC model's requirement on splitting the organic nutrient into refractory, labile, and dissolved portion, DSLLC split the wet organic nitrogen concentrations into refractory, labile, and dissolved fractions using a ratio of 0.30:0.35:0.35. Wet and dry particulate organic phosphorus and dry organic nitrogen were assumed to be zero. Atmospheric deposition fluxes were assumed to be uniformly distributed across the entire domain for the mainstem model. **Table 5.4** shows the deposition concentrations and fluxes used in the mainstem EFDC model simulation.

Table 5.4. Estimated Dry and Wet Nutrient Deposition Inputs for IRL EFDC Model

IRL-141	Nitrate/Nitrite	Ammonia	Organic Nitrogen	Phosphate
Wet (mg/L)	0.133	0.09117	0	0.00939
Dry ($g/m^2/day$)	1.30×10^{-4}	5.00×10^{-5}	0	1.00×10^{-5}

5.1.4.5. Sediment Diagenesis Model Parameters and Initial Conditions

Sediment diagenesis model parameters, such as decay rates of particulate organic nitrogen and particulate organic phosphorus for the G1, G2, and G3 fractions, ammonia and phosphate sorption partition coefficients, nitrification rate, and denitrification rate, were initially obtained from sediment studies conducted by Reddy et al (1999) across the Indian River Lagoon – Banana River Lagoon – Mosquito Lagoon system. These model kinetic parameters were then adjusted to achieve calibration of the water quality and sediment flux model. For most water quality zones defined in DSLLC's EFDC models, including Zones 1, 2, 3, 4, and 7 (**Figure 5.3**), the sediment diagenesis model initial conditions, including sediment total organic carbon, total organic nitrogen, and total organic phosphorus and pore water concentrations of ammonia, nitrate, and phosphate were also obtained from Reddy et al. (1999). The splits between the G1, G2, and G3 fractions of particulate organic carbon, nitrogen, and phosphorus were assigned a ratio of 1:10:100.

For the coastal ocean Zone 5 (Sebastian Inlet) and Zone 6 (Fort Pierce Inlet) (**Figure 5.3**), percent total organic carbon and organic nitrogen were assigned based on geophysical data compiled by Hathaway (1971). As the total organic carbon and nitrogen were reported in Hathaway's report as percent weight, correlations between percent weight and bulk density of total organic carbon and organic nitrogen were derived based on paired percent weight and bulk density data published in Reddy et al. (1999). A carbon to phosphorus ratio was also derived from the total sediment organic carbon and organic phosphorus based on data published in Reddy et al.'s studies. Using above information, the percent organic carbon and organic nitrogen reported in Hathaway's report were converted to bulk densities and then bulk density of total organic phosphorus were calculated based on the carbon to phosphorus ratio.

Initial pore water concentrations of ammonia, nitrate, and phosphate for Zones 5 and 6 were estimated from the total organic nitrogen and total organic phosphorus bulk density derived above and ratios of ammonia to total organic nitrogen, nitrate to organic nitrogen, and

phosphate to total organic phosphorus derived from sediment bed data reported in Reddy et al. (1999).

As described in **Section 5.1.1**, tributary EFDC models include model grids for tributaries, as well as model grids for the main stem of Indian River Lagoon. The model grids for the main stem portion of the tributary models were developed primarily to extract EFDC simulation results from the main stem EFDC model to provide tributary models with boundary conditions. Sediment diagenesis parameters and initial conditions of the main stem portion of tributary models were extracted from the diagenesis parameters and initial conditions of the main stem model. For the tributary portion of the tributary model, initial conditions were obtained through sediment studies conducted by DB Environmental (2009).

5.2. Conversion of HSPF Model Outputs into EFDC Model Inputs

Because HSPF and EFDC handle state variables differently, before HSPF model outputs were used as EFDC inputs, conversions of HSPF model results to EFDC model inputs were conducted using the following procedures:

5.2.1. Converting HSPF Simulated Flow to EFDC Flow

For the Indian River Lagoon model, flow simulates were generated by HSPF models in two forms. If the flow was simulated for tributaries, it would be in the unit of cubic feet per second (cf/s). If the flow was simulated for the surface runoff from non-tributary watersheds, the unit would be in cubic feet per hr (cf/hr). The internal EFDC unit for flow is cubic meter per second (m^3/s). Therefore, before the HSPF flow results were used, they were first converted into the EFDC flow unit of m^3/s.

5.2.2. Converting HSPF Water Temperature to EFDC Water Temperature

HSPF water temperature results are in degrees Fahrenheit, while EFDC water temperature results are in degrees Celsius. Therefore, HSPF water temperature results were converted to Celsius before used as EFDC inputs.

5.2.3. Converting HSPF Algal Biomass to EFDC Algal Biomass

The Indian River Lagoon tributary HSPF models output algal biomass as chlorophyll *a* concentration (µg/L). In EFDC, algal biomass is represented as carbon biomass (mg carbon/L). Therefore, before using the HSPF algal biomass as the input of EFDC biomass, the HSPF biomass was first converted to the EFDC carbon biomass using carbon to chlorophyll *a* ratio. The ratio used in this report was 65 mg carbon/ mg chlorophyll *a*, which is consistent with the range of carbon to chlorophyll *a* ratio reported by Putland and Iverson (2007) in a study on the seasonal variation of phytoplankton in Apalachicola Bay.

5.2.4. Converting HSPF Organic Carbon to EFDC Organic Carbon

HSPF model simulates organic carbon in two forms, which include the non-living labile organic carbon, usually represented as BOD, as well as the non-living refractory organic carbon. The refractory organic carbon is included as a state variable in the HSPF model and is considered to be non-living organic matter with a decay rate of zero. The total non-living organic carbon simulated by HSPF models is the sum of non-living labile organic carbon and non-living refractory organic carbon.

The total non-living organic carbon in EFDC models is represented by three components, including dissolved organic carbon, labile particulate organic carbon, and refractory particulate organic carbon.

To convert the HSPF organic carbon results to EFDC organic carbon results, the total non-living organic carbon of the HSPF model, which is the sum of non-living labile and refractory organic carbon, was first calculated, and then split into the refractory particulate organic carbon, labile particulate organic carbon, and dissolved organic carbon portions of the EFDC organic carbon results using the 25%, 40%, and 35% split ratio, respectively. These split ratios were assigned based on field data collected for the Lower St. Johns River watershed (Hendrickson et al., 2007).

5.2.5. Converting HSPF Phosphorus to EFDC Phosphorus

In HSPF model, the TP is calculated as the sum of inorganic phosphorus, which is phosphate (PO4), and organic phosphorus components. HSPF model's organic phosphorus includes the labile organic phosphorus and refractory organic phosphorus. The refractory organic phosphorus is represented in the HSPF model as a state variable with a decay rate of zero. The labile organic phosphorus in the HSPF model, on the other hand, is not explicitly represented in the HSPF model as a state variable. Instead, it is calculated as a stoichiometric equivalent of labile organic matter that is defined by the amount of BOD. The carbon to phosphorus ratio used to convert BOD to phosphorus was 41.1 mg carbon / mg phosphorus (Di Toro, 2001).

In EFDC models, the TP is represented as the sum of total orthophosphate and total organic phosphorus. The organic phosphorus is presented as the sum of dissolved organic phosphorus, refractory particulate organic phosphorus, and labile organic phosphorus.

To convert the HSPF model TP into the EFDC model TP, the HSPF model inorganic phosphorus was directly input into the EFDC model as the total orthophosphate. The HSPF model's total organic phosphorus was calculated as the sum of labile and refractory organic phosphorus. The HSPF total organic phosphorus were then split into the refractory particulate organic phosphorus, labile particulate organic phosphorus, and dissolved organic phosphorus portions using split ratios of 10%, 37%, and 53%, respectively. These split ratios were assigned based on field data collected in the Lower St. Johns River watershed study (Hendrickson et al., 2007).

5.2.6. Converting HSPF Nitrogen to EFDC Nitrogen

In the HSPF model, TN is represented as the sum of inorganic nitrogen and organic nitrogen. The inorganic nitrogen includes ammonia and nitrate/nitrite. The organic nitrogen includes the labile organic nitrogen, which is simulated as a stoichiometric portion of the organic matter represented by BOD, and the refractory organic nitrogen, which is an HSPF model state variable with a decay rate of zero. The stoichiometric ratio used to convert BOD to labile organic nitrogen is a carbon to nitrogen ratio of 5.7 mg carbon / mg nitrogen (Di Toro, 2001).

In the EFDC model, TN is also represented as the sum of inorganic nitrogen, which include ammonia and nitrate/nitrite, and organic nitrogen, which is represented as the sum of dissolved organic nitrogen, labile particulate organic nitrogen, and refractory particulate organic nitrogen.

To convert HSPF nitrogen to EFDC nitrogen, the HSPF ammonia and nitrate/nitrite components were input into EFDC models as EFDC ammonia and nitrate/nitrite. The HSPF organic nitrogen was calculated as the sum of labile organic nitrogen and refractory organic nitrogen and then split into EFDC's refractory particulate organic nitrogen, labile particulate organic nitrogen, and dissolved organic nitrogen using split ratios of 30%, 35%, and 35%, respectively. These split ratios were derived from the field data collected for the Lower St. Johns River study (Hendrickson et al., 2007).

5.2.7. Converting HSPF DO to EFDC DO

HSPF simulated DO results were assigned for input to EFDC model directly.

5.3. EFDC Model Calibration and Validation

The EFDC model simulation period for the main stem of Indian River Lagoon and impaired tributaries included in this report was from the January 1, 2000 through December 31, 2001. This was the period when all the required data, such as time series of atmospheric forcing, tidal forcing, flow data, and water quality data needed for constructing and calibrating the hydrodynamic and water quality models, were the most complete.

The period selected for hydrodynamic model calibration was January 1, 2000 to December 31, 2000. This was a relatively dry year. Based on the daily flow records in the period from 1940 through 2008 obtained from a USGS gauge (022320000) located in St. Johns River near Melbourne, Florida, the year 2000 mean annual flow was about 125 cfs, which was significantly lower than the 685 cfs long-term average annual mean flow calculated based on the 68 years of flow records measured at the gauge. The dry weather condition in 2000 should result in a long water residence time, which can provide more opportunities to nutrients and BOD to take effect to influence the water column DO concentration. Therefore, choosing year 2000 as a model calibration year is conservative in addressing the low DO condition.

The period selected for model validation was January 1, 2001 to December 31, 2001. Based on the flow data obtained from USGS gauge 022320000, the annual mean flow in 2001 was about 745 cfs, which is considered close to the 685 cfs long-term average annual mean flow. Using 2001 as the validation year for the EFDC modeling results provide a chance to examine the

dynamic of water quality constituents in the impaired tributary segments under a more normal rainfall condition.

5.3.1. Hydrodynamic Model Calibration

5.3.1.1. Hydrodynamic Calibration for the Indian River Lagoon Main Stem Model

The main stem EFDC model was calibrated first before tributary EFDC models were calibrated because the main stem model provides boundary conditions to tributary models. The hydrodynamic calibration was conducted through comparing model simulated water surface elevation, water temperature, and salinity results to measured surface elevation, water temperature, and salinity. The water surface elevation was calibrated first as the model must be able to accurately represent changes in elevation based on changes in cell volume that are driven by freshwater inflow, tidal forcing, and bathymetry of the model domain. One model parameter, the bottom roughness, can influence the water surface elevation, but it only becomes a sensitive model parameter in shallow water areas. Therefore, rather than adjusting model coefficients, hydrodynamic calibration of water surface evaluation is accomplished mainly through ensuring that the data used for model input to describe bathymetry, freshwater flows, and tidal forcing were accurate. Calibration of water temperature and salinity were also achieved through ensuring that the station data used for model-data comparison and the input data used to describe freshwater inflows and the open water boundary time series assigned for water temperature and salinity were accurate.

Water surface elevation was calibrated and validated against the tidal data collected from four tide stations located at Melbourne Causeway, Sebastian Inlet, Vero Bridge, and Fort Pierce Causeway. Locations of these stations are shown in **Figure 5.6**. This figure also shows stations used for water temperature and salinity calibration.

The DSLLC evaluated the model performance for the calibration and validation periods using a two-step process, which include (1) visual inspection of plots of model results compared to measured data, and (2) an examination of the scale of the root mean square (RMS) error, which can be calculated using the following equation:

$$RMS = \frac{\sqrt{\sum_1^N (Oi - Xi)^2}}{N}$$

Where:

O – The observed value,
X – The corresponding model value in space and time, and
N – The number of valid observed value/model value pairs.

Tables 5.5-a and **5.5-b**, **5.6-a** and **5.6-b**, and **5.7-a** and **5.7-b** show the RMS errors in the calibration period (January 1, 2000 through December 31, 2000) and validation period (January 1, 2001 through December 31, 2001) for water surface elevation, water temperature, and salinity calibration and validation at different locations of the Indian River Lagoon main stem, respectively. Figures in **Appendix F** show the comparison between model simulated surface elevation, water temperature, and salinity and the observed values of surface elevation, water temperature, and salinity at different locations of the Indian River Lagoon main stem.

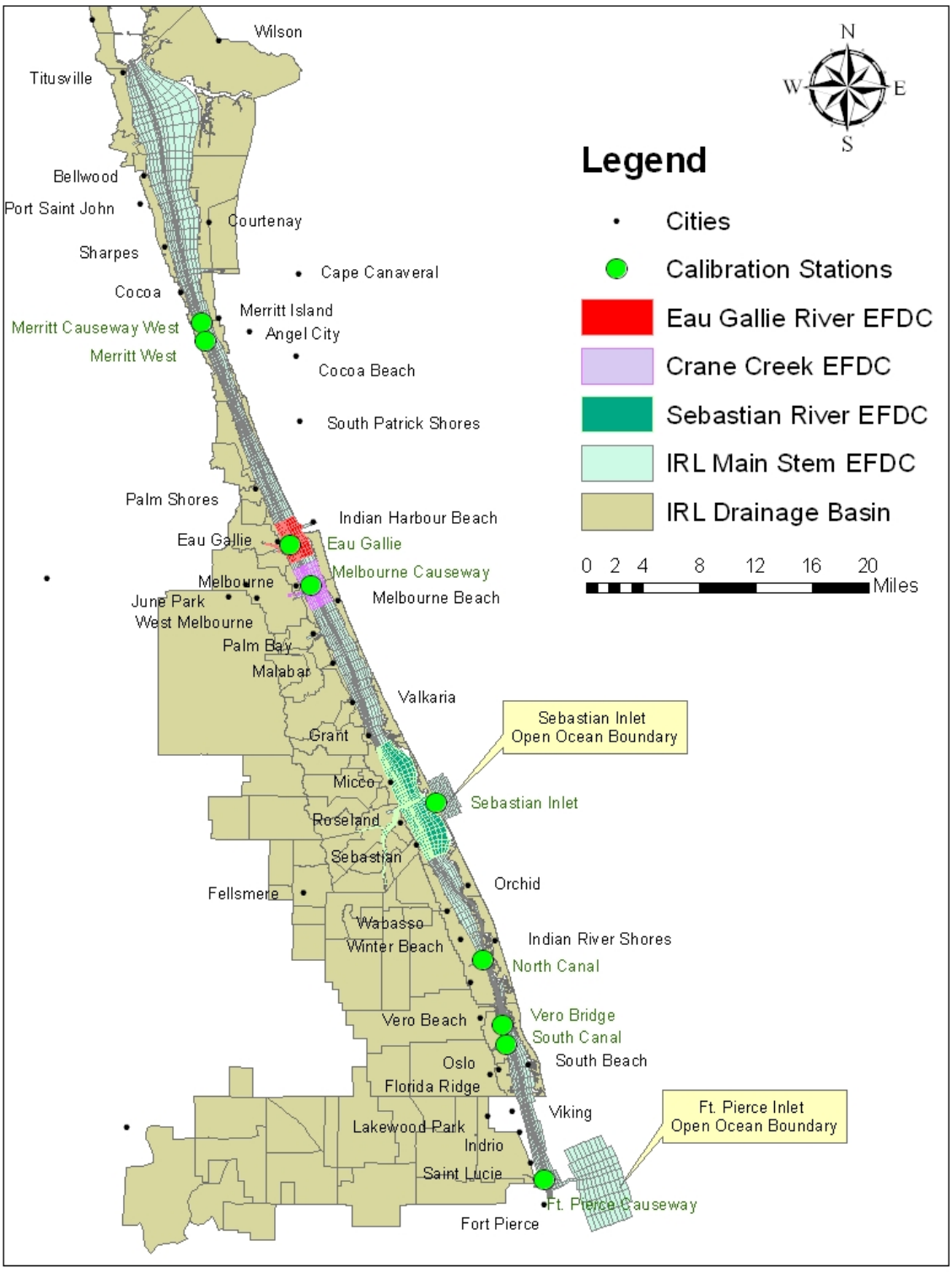


Figure 5.6. Location of Tide Stations Used for the Main Stem Model Hydrodynamic Calibration

Table 5.5-a. RMS Errors for the Main Stem Model Water Surface Elevation Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (ft)	Observation Average (ft)	Model Result Average (ft)
Merritt Causeway West	1/1/2000	12/31/2000	8346	0.19	0.57	0.66
Melbourne Causeway	1/1/2000	9/22/2000	2416	0.35	0.22	0.27
Vero Bridge	1/1/2000	12/31/2000	8753	0.40	0.43	0.50
Ft. Pierce Causeway	1/1/2000	12/31/2000	7909	0.23	0.43	0.41
Composite			27424	0.29		

Table 5.5-b. RMS Errors for the Main Stem Model Water Surface Elevation Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (ft)	Observation Average (ft)	Model Result Average (ft)
Merritt Causeway West	No Data	No Data	No Data	No Data	No Data	No Data
Melbourne Causeway	1/1/2001	12/31/2001	6485	0.24	0.63	0.75
Vero Bridge	1/1/2001	12/31/2001	8757	0.40	0.36	0.46
Ft. Pierce Causeway	1/1/2001	12/31/2001	8559	0.22	0.31	0.34
Composite			23801	0.29		

Table 5.6-a. RMS Errors for the Main Stem Model Salinity Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (ppt)	Observation Average (ppt)	Model Result Average (ppt)
Merritt Causeway West	1/1/2000	12/31/2000	8282	3.38	24.86	25.21
Melbourne Causeway	1/1/2000	9/22/2000	7998	3.94	24.50	24.83
Vero Bridge	1/1/2000	12/31/2000	8607	3.53	27.20	27.52
Ft. Pierce Causeway	1/1/2000	12/31/2000	No Data	No Data	No Data	No Data
Merritt West	1/12/2000	12/12/2000	12	4.11	24.75	25.01
Eau Gallie	1/11/2000	12/12/2000	12	3.83	24.05	24.73
North Canal	1/12/2000	12/12/2000	12	3.01	27.63	27.33
South Canal	1/12/2000	12/12/2000	12	3.91	28.29	27.12
Composite			24935	3.67		

Note: The model simulations used for salinity calibration were for the surface layer.

Table 5.6-b. RMS Errors for the Main Stem Model Salinity Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (ppt)	Observation Average (ppt)	Model Result Average (ppt)
Merritt Causeway West	1/1/2001	12/31/2001	8224	3.07	28.87	27.69
Melbourne Causeway	1/1/2001	12/31/2001	8709	2.95	22.46	24.49
Vero Bridge	1/1/2001	12/31/2001	8444	5.71	25.48	27.56
Ft. Pierce Causeway	1/1/2001	12/31/2001	7340	4.37	31.71	29.99
Merritt West	1/10/2001	12/17/2001	12	2.54	26.78	27.05
Eau Gallie	1/10/2001	12/13/2001	11	3.23	25.70	25.00
North Canal	1/9/2000	12/11/2001	11	4.21	27.95	28.36
South Canal	1/9/2000	12/11/2001	10	4.59	27.50	27.76
Composite			32761	3.83		

Note: The model simulations used for salinity validation were for the surface layer.

Table 5.7-a. RMS Errors for the Main Stem Model Water Temperature Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (^{0}F)	Observation Average (^{0}F)	Model Result Average (^{0}F)
Merritt Causeway West	1/1/2000	12/31/2000	8367	2.44	76.30	77.75
Melbourne Causeway	1/1/2000	12/31/2000	8020	1.84	75.83	76.65
Vero Bridge	1/1/2000	12/31/2000	8662	1.77	77.13	76.95
Ft. Pierce Causeway	1/1/2000	12/30/2000	8679	2.63	76.31	76.57
Merritt West	1/12/2000	12/12/2000	12	2.77	75.85	77.81
Eau Gallie	1/11/2000	12/12/2000	12	2.01	75.75	76.99
North Canal	1/12/2000	12/12/2000	12	1.83	76.85	77.55
South Canal	1/12/2000	12/12/2000	12	1.97	77.71	78.37
Composite			33776	2.16		

Note: The model simulations used for temperature calibration were for the surface layer.

Table 5.7-b. RMS Errors for the Main Stem Model Water Temperature Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (^{0}F)	Observation Average (^{0}F)	Model Result Average (^{0}F)
Merritt Causeway West	1/1/2000	12/31/2000	8275	2.51	77.34	78.68
Melbourne Causeway	1/1/2000	9/22/2000	8721	2.41	75.96	77.18
Vero Bridge	1/1/2000	12/31/2000	8629	2.11	77.36	77.40
Ft. Pierce Causeway	1/1/2000	12/31/2000	8089	2.57	76.26	76.64
Merritt West	1/12/2000	12/12/2000	12	3.49	76.47	79.25
Eau Gallie	1/11/2000	12/12/2000	11	2.51	75.73	77.37
North Canal	1/12/2000	12/12/2000	11	2.05	77.84	77.97
South Canal	1/12/2000	12/12/2000	10	2.12	78.09	78.28
Composite			33758	2.47		

Note: The model simulations used for temperature validation were for the surface layer.

Indian River Lagoon is a system relatively isolated from the astronomic tide activities because of the low astronomic height at the mouth of the ocean inlet, the narrow water path and the shallow water depth of the lagoon proper, and the relatively long distance of the lagoon feature, which renders that majority part of the lagoon is relative far away from ocean inlets (Woodward-Clyde, 1994). According to Evink (1980) and Dombrowski et al. (1987), the height of a spring tide quickly decreased from about 2.2 ft at the mouth of the Sebastian Inlet to about 1 ft in the lagoon segments near the Sebastian River (about 1 mile north of the Sebastian Inlet), and to 0.2 ft in the lagoon segment between the Melbourne and Eau Gallie Causeways about 17 miles north of the inlet, indicating a rapid decrease of tidal amplitude within a short distance from the inlet. The very limited tidal activity in the lagoon posed challenges to simulating the change of water surface elevation very accurately. However, based on the model calibration and validation results for the surface elevation listed on **Tables 5.5-a** and **5.5-b**, and also the model calibration and validation figures in **Appendix F** showing the comparison of model simulated surface elevation to the observed surface elevation, it is clear that the model simulated surface elevations at different tide stations along Indian River Lagoon match up with the trend and magnitude of the observed surface elevation reasonably well.

Reasonabe calibration and validation results were also obtained for water temperature and salinity. Based on the RMS error results shown in **Tables 5.6 (a and b)** and **5.7 (a and b)**, temperature calibration and validation mostly show a relative RMS error of less than 4%. Although no RMS error criteria was set up for model calibration, a relative error of 15% or less is typically considered very good and 15% to 25% is usually considered good for water quality

model calibration (Donigian, 2000). Based on **Tables 5.6-a** and **5.6-b**, the RMS errors of salinity calibration and validation were all "good" while the salinity calibration and validation at many tide stations show "very good" modeling results.

The above results show that the hydrodynamics of the main stem EFDC model were reasonably calibrated and validated for this project.

5.3.1.1. Hydrodynamic calibration for tributary efdc models

After the calibration and validation of the main stem EFDC model was done, boundary conditions were established to calibrate each of the tributary sub-models. A data station located as near as possible to the mouth of the tributary, but within the tributary waterbody, containing data during the calibration (and validation) period was chosen for comparison of salinity and temperature. Depth-averaged model data was used for calibration and validation comparisons because the natural tributary water bodies are typically shallow and well mixed. **Figure 5.7** shows the location of stations used for tributary hydrodynamic calibration. **Tables 5.8-a** and **5.8-b**, and **5.9-a** and **5.9-b** show the error statistics of salinity and water temperature calibration and validation, respectively. **Appendix F** shows the comparison of model simulated salinity and temperature to observed salinity and temperature at different stations in impaired tributaries during the calibration and validation periods. Based on the statistics and model calibration and validation figures, tributary EFDC models were reasonably well calibrated and validated for hydrodynamics.

Table 5.8-a. RMS Errors for the Tributary Models Salinity Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (ppt)	Observation Average (ppt)	Model Result Average (ppt)
Eau Gallie River (IRLEGU)	1/10/2000	12/11/2000	12	4.50	16.23	13.46
Crane Creek (IRLCCU)	1/10/2000	12/11/2000	12	4.08	14.80	17.16
Sebastian Inlet (IRLSUS)	1/10/2000	12/11/2000	12	6.84	25.95	23.74

Note: The model simulations used for salinity calibration of the Eau Gallie River, Crane Creek, and the Sebastian Inlet were depth average values.

Table 5.8-b. RMS Errors for the Tributary Models Salinity Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (ppt)	Observation Average (ppt)	Model Result Average (ppt)
Eau Gallie River (IRLEGU)	1/10/2001	12/11/2001	10	3.98	16.77	14.44
Crane Creek (IRLCCU)	1/10/2001	12/11/2001	11	2.95	17.47	17.34
Sebastian Inlet (IRLSUS)	1/10/2001	12/11/2001	11	5.02	22.90	22.13

Note: The model simulations used for salinity validation of the Eau Gallie River, Crane Creek, and the Sebastian Inlet were depth average values.

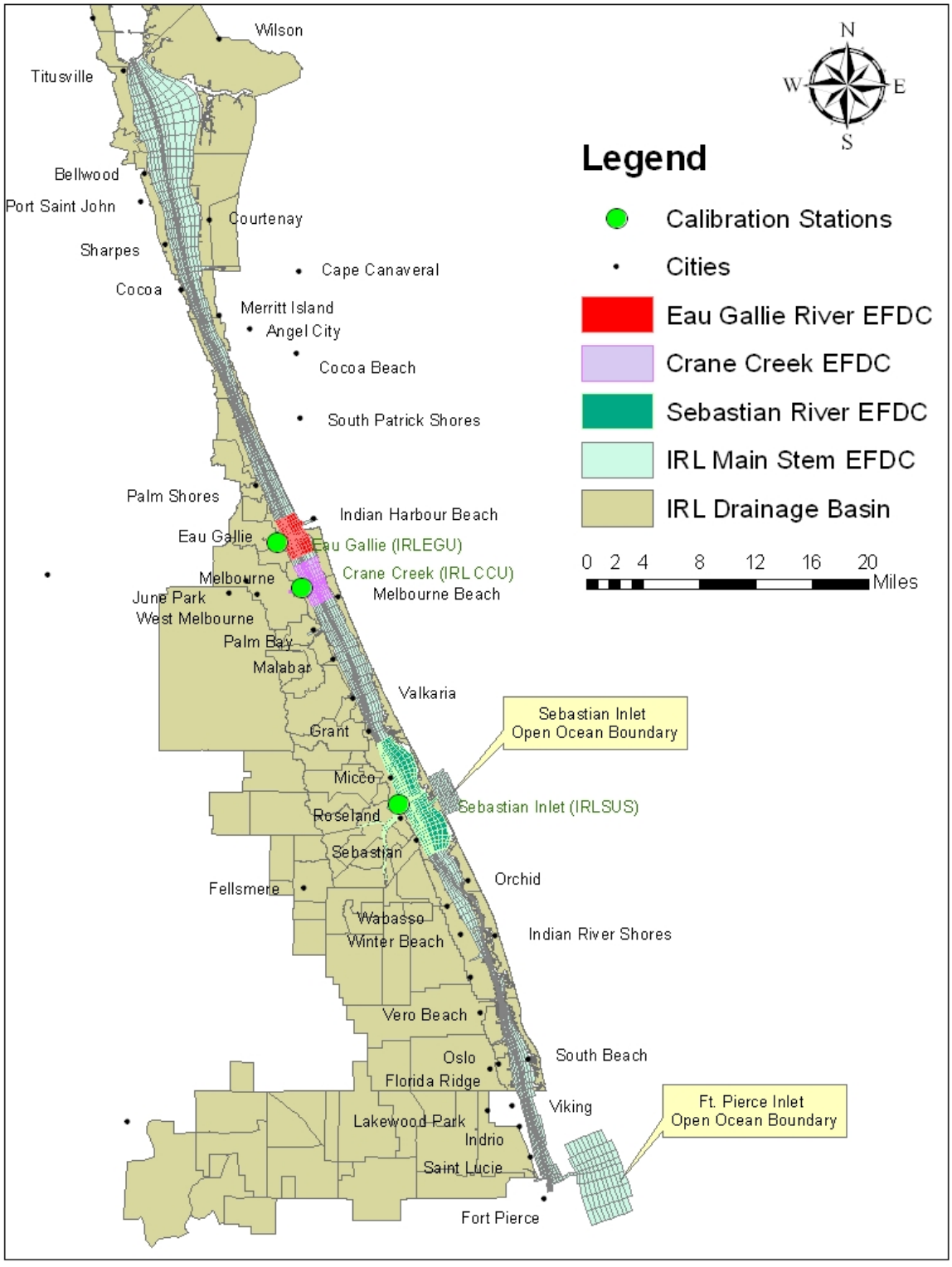


Figure 5.7. Location of Stations Used for Tributary Models Hydrodynamic Calibration

Table 5.9-a. RMS Errors for the Tributary Models Water Temperature Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (^{0}F)	Observation Average (^{0}F)	Model Result Average (^{0}F)
Eau Gallie River (IRLEGU)	1/10/2000	12/11/2000	12	2.51	76.40	77.04
Crane Creek (IRLCCU)	1/10/2000	12/11/2000	12	1.07	74.50	74.16
Sebastian Inlet (IRLSUS)	1/10/2000	12/11/2000	12	1.66	76.02	75.54

Note: The model simulations used for water temperature calibration were depth average values.

Table 5.9-b. RMS Errors for the Tributary Models Water Temperature Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (^{0}F)	Observation Average (^{0}F)	Model Result Average (^{0}F)
Eau Gallie River (IRLEGU)	1/10/2001	12/11/2001	10	3.46	78.03	79.25
Crane Creek (IRLCCU)	1/10/2001	12/11/2001	11	1.57	77.49	77.18
Sebastian Inlet (IRLSUS)	1/10/2001	12/11/2001	11	2.03	76.71	76.46

Note: The model simulations used for water temperature validation were depth average values.

5.3.2. EFDC Model Water Quality Calibration

5.3.2.1. Water Quality Calibration for the Indian River Lagoon Main Stem Model

Like the calibration and validation of hydrodynamics, the Indian River Lagoon main stem EFDC model was first calibrated and validated for water quality constituents before the calibration and validation of tributary EFDC models. The calibrated and validated main stem EFDC water quality model provided boundary conditions for tributary models.

The water quality data used for calibrating and validating the main stem EFDC water quality modeling were retrieved from the Department's IWR database. **Table 5.10** shows a list of stations used for the main stem EFDC model water quality calibration and validation. **Figure 5.8** shows the location of these water quality stations.

Table 5.10. Water Quality Stations Used for Water Quality Calibration and Validation of the Main Stem EFDC Model

Station ID	Station Name
IRLI10	IRL 2.8 KM south of NASA CSWY west side
IRLI15	IRL West side 1.0 KM south of SR 528 Bridge
IRLI21	IRL East of mouth of Eau Gallie River
IRLI27	IRL at Center of ICW near Grant Farm Island
IRLIRJ01	IRL at CM70 off Spratt Point south of SEBASTIAN
IRLIRJ05	IRL at CM135 East of ICWW
IRLIRJ10	IRL at confluence of Vero North Canal
IRLIRJ12	IRL at confluence of Vero South Canal

Water quality calibration and validation focused on several water quality constituents including DO, chlorophyll *a*, nitrate, TN, total phosphate, TP, and total organic carbon (TOC). These water quality constituents are closely related to the DO dynamics in receiving waters. During calibration, key model parameters that significantly influence the simulated state variable were identified and adjusted to make the model simulates matching up with the observed data. For

example, other than the loadings entering the receiving water from various sources on the land and from air, the model results for nutrients were very sensitive to changes in model coefficients for the internally-coupled sediment diagenesis model. These model coefficients include the thickness of the anaerobic active sediment layer, diffusive mixing coefficients, burial rate of the particulate materials, mineralization rate for particulate organic matters, the nitrification and denitrification rate, and partition coefficients of ammonia and phosphate. These model coefficients were adjusted to achieve the model calibration and validation for nutrients.

The same approach used to evaluate the calibration and validation of hydrodynamics of the model was used for the calibration and validation of modeled water quality. Basically, a visual comparison between model simulations and observed data were conducted, and then RMS errors were calculated for different water quality constituents simulated for different location of the lagoon main stem. The summary of the RMS errors were listed in **Tables 5.11-a** through **5.17-b.** Comparisons of model simulated results to observed water quality data are demonstrated in figures included in **Appendix G**.

Based on above tables and calibration and validation curves included in **Appendix G**, the main stem EFDC model simulates the water quality constituents of interest reasonably well in both the calibration and validation periods. The observed water quality data show that Indian River Lagoon has a north to south gradient of TN and TP concentrations. The TN concentration is high in the northern parts of the lagoon and gradually decreases towards the south. The TP concentration shows an opposite trend with the concentration in the northern part of the lagoon being generally low and gradually becomes higher towards the south. The main stem EFDC model accurately simulated this spatial trend.

The EFDC model also tracts the temporal trends of the interested water quality constituents reasonably well. The model accurately represented the seasonal variations of DO, with higher values in spring and winter, and the lowest values in summer. The magnitudes of simulated chlorophyll *a* concentrations were consistent with the observed data for all sampling stations for all seasons. Total phosphate and TP show similar temporal trends to one another with total phosphate and TP increasing from January with a peak in June/July, and then decreasing back to the early winter level. The EFDC model replicates the temporal trends of total phosphate and TP reasonably well. The main stem EFDC model also captured the seasonal variation of TN for the northern-most station (IRLI10 Bellwood) and the four stations south of the Sebastian River, with good agreement between the model results and the observed data. The model simulated TN concentrations at Merritt West (IRLI15), Eau Gallie (IRLI21), and North Sebastian (IRLI27) were slightly higher than the observed data. TOC is not characterized by a significant temporal trend, but there are small variations of TOC data at all the sampling stations. The observed TOC concentrations in the northern IRL were generally higher than those at the south end of the lagoon and the EFDC model reflected those spatial variations of TOC.

Overall, the EFDC main stem model results are in reasonable agreement with the temporal and spatial variations of the water quality constituents. The main stem water quality model is considered to be calibrated and validated.



Figure 5.8. Water Quality Stations Used for Water Quality Calibration and Validation for the Main Stem EFDC Model

Table 5.11-a. RMS Errors for the Main Stem Model DO Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/12/2000	12/12/2000	12	0.62	6.56	6.66
Merritt West (IRLI15)	1/12/2000	12/12/2000	12	0.83	7.04	6.72
Eau Gallie (IRLI27)	1/11/2000	12/12/2000	12	0.58	6.92	6.91
North Sebastian (IRLI27)	1/11/2000	12/12/2000	13	0.45	6.74	6.76
South Sebastian (IRLIRJ01)	1/12/2000	12/12/2000	12	0.76	6.02	6.23
North Canal (IRLIRJ10)	1/12/2000	12/12/2000	12	0.70	5.67	6.24
Main Canal (IRLIRJ05)	1/10/2000	12/12/2000	12	0.90	5.77	6.35
South Canal (IRLIRJ12)	1/12/2000	12/12/2000	12	0.49	5.74	6.69

Note: The model simulations used for calibration were for the surface layer.

Table 5.11-b. RMS Errors for the Main Stem Model DO Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/10/2001	12/18/2001	16	1.18	6.46	6.56
Merritt West (IRLI15)	1/10/2001	12/17/2001	12	1.31	6.64	6.63
Eau Gallie (IRLI27)	1/10/2001	12/13/2001	11	0.86	6.37	6.76
North Sebastian (IRLI27)	1/10/2001	12/13/2001	11	0.82	6.68	6.46
South Sebastian (IRLIRJ01)	1/9/2001	12/13/2001	8	1.37	6.27	6.35
North Canal (IRLIRJ10)	1/9/2001	12/11/2001	9	1.17	5.74	6.34
Main Canal (IRLIRJ05)	1/9/2001	12/11/2001	9	1.02	6.43	6.37
South Canal (IRLIRJ12)	1/9/2001	12/11/2001	8	1.24	7.06	6.86

Note: The model simulations used for validation were for the surface layer.

Table 5.12-a. RMS Errors for the Main Stem Model Chlorophyll *a* Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (µg/L)	Observation Average (µg/L)	Model Result Average (µg/L)
Bellwood (IRLI10)	1/12/2000	12/12/2000	11	3.91	5.46	7.88
Merritt West (IRLI15)	1/12/2000	12/12/2000	11	4.58	8.09	4.84
Eau Gallie (IRLI27)	1/11/2000	12/12/2000	12	5.38	6.89	7.91
North Sebastian (IRLI27)	1/11/2000	12/12/2000	13	2.52	5.64	4.98
South Sebastian (IRLIRJ01)	1/12/2000	12/12/2000	11	3.47	4.80	7.03
North Canal (IRLIRJ10)	1/12/2000	12/12/2000	11	5.38	5.52	5.43
Main Canal (IRLIRJ05)	1/10/2000	12/12/2000	11	6.93	8.04	5.19
South Canal (IRLIRJ12)	1/12/2000	12/12/2000	11	3.94	6.87	5.26

Note: The model simulations used for calibration were for the surface layer.

Table 5.12-b. RMS Errors for the Main Stem Model Chlorophyll *a* Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (µg/L)	Observation Average (µg/L)	Model Result Average (µg/L)
Bellwood (IRLI10)	1/10/2001	12/18/2001	16	6.93	7.36	5.03
Merritt West (IRLI15)	1/10/2001	12/17/2001	12	15.29	12.10	4.45
Eau Gallie (IRLI27)	1/10/2001	12/13/2001	11	16.33	16.80	10.72
North Sebastian (IRLI27)	1/10/2001	12/13/2001	11	16.40	15.47	8.11
South Sebastian (IRLIRJ01)	1/9/2001	12/13/2001	10	3.81	7.54	9.23
North Canal (IRLIRJ10)	1/9/2001	12/11/2001	11	10.18	11.05	6.25
Main Canal (IRLIRJ05)	1/9/2001	12/8/2001	10	7.75	10.11	5.97
South Canal (IRLIRJ12)	1/9/2001	12/11/2001	10	9.09	11.04	5.95

Note: The model simulations used for validation were for the surface layer.

Table 5.13-a. RMS Errors for the Main Stem Model Nitrate Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/12/2000	12/12/2000	12	0.030	0.014	0.011
Merritt West (IRLI15)	1/12/2000	12/12/2000	12	0.009	0.008	0.009
Eau Gallie (IRLI27)	1/11/2000	12/12/2000	12	0.008	0.007	0.007
North Sebastian (IRLI27)	1/11/2000	12/12/2000	13	0.010	0.005	0.008
South Sebastian (IRLIRJ01)	1/12/2000	12/12/2000	12	0.011	0.007	0.008
North Canal (IRLIRJ10)	1/12/2000	12/12/2000	12	0.025	0.015	0.008
Main Canal (IRLIRJ05)	1/10/2000	12/12/2000	12	0.024	0.016	0.007
South Canal (IRLIRJ12)	1/12/2000	12/12/2000	12	0.021	0.013	0.009

Note: The model simulations used for calibration were for the surface layer.

Table 5.13-b. RMS Errors for the Main Stem Model Nitrate Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/10/2001	12/17/2001	12	0.068	0.033	0.007
Merritt West (IRLI15)	1/10/2001	12/17/2001	12	0.058	0.031	0.004
Eau Gallie (IRLI27)	1/10/2001	12/13/2001	11	0.018	0.013	0.008
North Sebastian (IRLI27)	1/10/2001	12/13/2001	11	0.007	0.006	0.005
South Sebastian (IRLIRJ01)	1/9/2001	12/26/2001	9	0.009	0.006	0.002
North Canal (IRLIRJ10)	1/9/2001	12/11/2001	11	0.011	0.010	0.003
Main Canal (IRLIRJ05)	1/9/2001	12/112001	11	0.010	0.008	0.002
South Canal (IRLIRJ12)	1/9/2001	12/11/2001	10	0.010	0.009	0.003

Note: The model simulations used for validation were for the surface layer.

Table 5.14-a. RMS Errors for the Main Stem Model TN Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/12/2000	12/12/2000	12	0.19	1.33	1.34
Merritt West (IRLI15)	1/12/2000	12/12/2000	12	0.31	1.22	1.23
Eau Gallie (IRLI27)	1/11/2000	12/12/2000	12	0.32	1.01	1.07
North Sebastian (IRLI27)	1/11/2000	12/12/2000	13	0.35	0.69	0.85
South Sebastian (IRLIRJ01)	1/12/2000	12/12/2000	12	0.15	0.59	0.70
North Canal (IRLIRJ10)	1/12/2000	12/12/2000	12	0.10	0.70	0.68
Main Canal (IRLIRJ05)	1/10/2000	12/12/2000	12	0.12	0.71	0.68
South Canal (IRLIRJ12)	1/12/2000	12/12/2000	12	0.12	0.64	0.68

Note: The model simulations used for calibration were for the surface layer.

Table 5.14-b. RMS Errors for the Main Stem Model TN Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/10/2001	12/17/2001	12	0.24	1.22	1.15
Merritt West (IRLI15)	1/10/2001	12/17/2001	12	0.31	1.36	1.16
Eau Gallie (IRLI27)	1/10/2001	12/13/2001	11	0.35	1.32	1.18
North Sebastian (IRLI27)	1/10/2001	12/13/2001	11	0.31	0.98	0.95
South Sebastian (IRLIRJ01)	1/9/2001	12/13/2001	10	0.24	0.74	0.73
North Canal (IRLIRJ10)	1/9/2001	12/11/2001	11	0.32	0.82	0.75
Main Canal (IRLIRJ05)	1/9/2001	12/112001	11	0.27	0.79	0.75
South Canal (IRLIRJ12)	1/9/2001	12/11/2001	10	0.27	0.76	0.76

Note: The model simulations used for validation were for the surface layer.

Table 5.15-a. RMS Errors for the Main Stem Model Total Phosphate Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/12/2000	12/12/2000	12	0.009	0.006	0.009
Merritt West (IRLI15)	1/12/2000	12/12/2000	12	0.014	0.007	0.015
Eau Gallie (IRLI27)	1/11/2000	12/12/2000	12	0.016	0.020	0.022
North Sebastian (IRLI27)	1/11/2000	12/12/2000	13	0.011	0.008	0.017
South Sebastian (IRLIRJ01)	1/12/2000	12/12/2000	12	0.014	0.027	0.035
North Canal (IRLIRJ10)	1/12/2000	12/12/2000	12	0.017	0.054	0.045
Main Canal (IRLIRJ05)	1/10/2000	12/12/2000	12	0.012	0.049	0.043
South Canal (IRLIRJ12)	1/12/2000	12/12/2000	12	0.021	0.032	0.040

Note: The model simulations used for calibration were for the surface layer.

Table 5.15-b. RMS Errors for the Main Stem Model Total Phosphate Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/10/2001	12/17/2001	12	0.006	0.007	0.006
Merritt West (IRLI15)	1/10/2001	12/17/2001	12	0.007	0.008	0.009
Eau Gallie (IRLI27)	1/10/2001	12/13/2001	11	0.013	0.011	0.018
North Sebastian (IRLI27)	1/10/2001	12/13/2001	11	0.014	0.007	0.017
South Sebastian (IRLIRJ01)	1/9/2001	12/26/2001	9	0.011	0.016	0.019
North Canal (IRLIRJ10)	1/9/2001	12/11/2001	11	0.014	0.026	0.023
Main Canal (IRLIRJ05)	1/9/2001	12/112001	11	0.019	0.024	0.023
South Canal (IRLIRJ12)	1/9/2001	12/11/2001	10	0.017	0.021	0.022

Note: The model simulations used for validation were for the surface layer.

Table 5.16-a. RMS Errors for the Main Stem Model TP Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/12/2000	12/12/2000	12	0.010	0.028	0.030
Merritt West (IRLI15)	1/12/2000	12/12/2000	12	0.014	0.040	0.033
Eau Gallie (IRLI27)	1/11/2000	12/12/2000	12	0.025	0.052	0.044
North Sebastian (IRLI27)	1/11/2000	12/12/2000	13	0.011	0.034	0.038
South Sebastian (IRLIRJ01)	1/12/2000	12/12/2000	12	0.016	0.060	0.063
North Canal (IRLIRJ10)	1/12/2000	12/12/2000	12	0.023	0.086	0.072
Main Canal (IRLIRJ05)	1/10/2000	12/12/2000	12	0.023	0.087	0.069
South Canal (IRLIRJ12)	1/12/2000	12/12/2000	12	0.020	0.068	0.068

Note: The model simulations used for calibration were for the surface layer.

Table 5.16-b. RMS Errors for the Main Stem Model TP Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/10/2001	12/18/2001	16	0.014	0.027	0.018
Merritt West (IRLI15)	1/10/2001	12/17/2001	12	0.019	0.036	0.025
Eau Gallie (IRLI27)	1/10/2001	12/13/2001	11	0.014	0.050	0.046
North Sebastian (IRLI27)	1/10/2001	12/13/2001	11	0.021	0.039	0.046
South Sebastian (IRLIRJ01)	1/9/2001	12/26/2001	9	0.023	0.047	0.051
North Canal (IRLIRJ10)	1/9/2001	12/11/2001	11	0.022	0.068	0.054
Main Canal (IRLIRJ05)	1/9/2001	12/112001	11	0.030	0.067	0.052
South Canal (IRLIRJ12)	1/9/2001	12/11/2001	10	0.024	0.058	0.053

Note: The model simulations used for validation were for the surface layer.

Table 5.17-a. RMS Errors for the Main Stem Model TOC Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/12/2000	12/12/2000	12	4.75	12.90	11.60
Merritt West (IRLI15)	1/12/2000	12/12/2000	12	4.04	12.36	9.90
Eau Gallie (IRLI27)	1/11/2000	12/12/2000	12	4.49	9.49	10.88
North Sebastian (IRLI27)	1/11/2000	12/12/2000	13	3.56	6.71	6.90
South Sebastian (IRLIRJ01)	1/12/2000	12/12/2000	12	3.07	5.47	3.92
North Canal (IRLIRJ10)	1/12/2000	12/12/2000	12	2.48	6.12	3.73
Main Canal (IRLIRJ05)	1/10/2000	12/12/2000	12	3.48	6.51	3.57
South Canal (IRLIRJ12)	1/12/2000	12/12/2000	12	2.21	5.84	4.10

Note: The model simulations used for calibration were for the surface layer.

Table 5.17-b. RMS Errors for the Main Stem Model TOC Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error (mg/L)	Observation Average (mg/L)	Model Result Average (mg/L)
Bellwood (IRLI10)	1/10/2001	12/17/2001	12	4.67	11.47	9.40
Merritt West (IRLI15)	1/10/2001	12/17/2001	12	4.27	12.45	9.97
Eau Gallie (IRLI27)	1/10/2001	12/13/2001	11	4.50	12.87	12.91
North Sebastian (IRLI27)	1/10/2001	12/13/2001	11	4.87	9.48	8.12
South Sebastian (IRLIRJ01)	1/9/2001	12/26/2001	9	4.23	7.01	5.08
North Canal (IRLIRJ10)	1/9/2001	12/11/2001	11	4.72	7.45	4.70
Main Canal (IRLIRJ05)	1/9/2001	12/112001	11	5.15	7.55	4.54
South Canal (IRLIRJ12)	1/9/2001	12/11/2001	10	4.98	7.66	4.78

Note: The model simulations used for validation were for the surface layer.

5.3.2.2. Water Quality Calibration for Tributary Models

Calibration and validation of simulated water quality constituents for the tributary models were performed using a single monitoring station located within the tributary portion of the sub-model domain. The water quality stations used for model calibration and validation were the same as those used for salinity and water temperature calibration and validation (**Figure 5.5**).

Water quality calibration and validation for tributary models focused on the same set of water quality constituents as those being used for calibrating and validating the main stem water quality model. **Tables 5.18-a** through **5.20-b** summarize the RMS errors of model simulations in the calibration and validation periods for all tributary models. **Appendix G** includes figures comparing the model simulations to the observed data.

Generally, tributary models water quality simulations matched the temporal trends and magnitudes of the observed water quality data. Model simulated DO concentration, which is a key focus of these models, followed the seasonal pattern of measured DO concentrations reasonably well.

Table 5.18-a. RMS Errors for the Eau Gallie River (IRLEGU) Model Water Quality Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error	Observation Average	Model Result Average
DO (mg/L)	1/10/2000	12/11/2000	12	1.386	7.071	7.568
Chlorophyll *a* (µg/L)	2/14/2000	12/11/2000	11	5.664	13.881	13.700
Nitrate (mg/L)	1/10/2000	12/11/2000	12	0.045	0.026	0.008
TN (mg/L)	1/10/2000	12/11/2000	12	0.304	1.074	1.051
Total Phosphate (mg/L)	1/10/2000	12/11/2000	12	0.027	0.043	0.039
TP (mg/L)	1/10/2000	12/11/2000	12	0.038	0.111	0.086
TOC (mg/L)	1/10/2000	12/11/2000	12	2.775	11.056	10.181

Note: The model simulations used for calibration were for the surface layer.11.056

Table 5.18-b. RMS Errors for the Eau Gallie River (IRLEGU) Model Water Quality Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error	Observation Average	Model Result Average
DO (mg/L)	1/8/2001	12/10/2001	11	1.888	6.461	7.278
Chlorophyll *a* (µg/L)	2/12/2001	12/10/2001	11	14.486	25.110	15.121
Nitrate (mg/L)	2/12/2001	12/10/2001	10	0.070	0.031	0.016
TN (mg/L)	2/12/2001	12/10/2001	10	0.338	1.328	1.321
Total Phosphate (mg/L)	2/12/2001	12/10/2001	10	0.030	0.030	0.047
TP (mg/L)	2/12/2001	12/10/2001	10	0.047	0.106	0.117
TOC (mg/L)	2/12/2001	12/10/2001	10	4.296	14.683	14.552

Note: The model simulations used for validation were for the surface layer.

Table 5.19-a. RMS Errors for the Crane Creek (IRLCCU) Model Water Quality Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error	Observation Average	Model Result Average
DO (mg/L)	1/10/2000	12/11/2000	12	1.714	5.191	6.272
Chlorophyll *a* (µg/L)	2/14/2000	12/11/2000	11	5.609	9.612	7.186
Nitrate (mg/L)	1/10/2000	12/11/2000	12	0.043	0.063	0.044
TN (mg/L)	1/10/2000	12/11/2000	12	0.181	0.937	0.897
Total Phosphate (mg/L)	1/10/2000	12/11/2000	12	0.029	0.057	0.076
TP (mg/L)	1/10/2000	12/11/2000	12	0.017	0.110	0.105
TOC (mg/L)	1/10/2000	12/11/2000	12	2.128	10.798	9.908

Note: The model simulations used for calibration were for the surface layer.

Table 5.19-b. RMS Errors for the Crane Creek (IRLCCU) Model Water Quality Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error	Observation Average	Model Result Average
DO (mg/L)	1/8/2001	12/10/2001	12	1.559	5.752	5.786
Chlorophyll *a* (µg/L)	1/8/2001	12/10/2001	12	18.507	16.068	9.641
Nitrate (mg/L)	1/8/2001	12/10/2001	12	0.061	0.074	0.056
TN (mg/L)	1/8/2001	12/10/2001	12	0.349	1.116	1.073
Total Phosphate (mg/L)	1/8/2001	12/10/2001	12	0.022	0.055	0.057
TP (mg/L)	1/8/2001	12/10/2001	12	0.042	0.108	0.098
TOC (mg/L)	1/8/2001	12/10/2001	12	4.216	12.833	12.855

Note: The model simulations used for validation were for the surface layer.

Table 5.20-a. RMS Errors for the Sebastian River (IRLSUS) Model Water Quality Calibration

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error	Observation Average	Model Result Average
DO (mg/L)	1/10/2000	12/11/2000	12	0.606	6.008	6.513
Chlorophyll *a* (µg/L)	2/14/2000	12/11/2000	11	3.423	4.898	3.458
Nitrate (mg/L)	1/10/2000	12/11/2000	12	0.071	0.074	0.092
TN (mg/L)	1/10/2000	12/11/2000	12	0.331	0.775	1.045
Total Phosphate (mg/L)	1/10/2000	12/11/2000	12	0.019	0.047	0.052
TP (mg/L)	1/10/2000	12/11/2000	12	0.022	0.079	0.090
TOC (mg/L)	1/10/2000	12/11/2000	12	5.181	8.250	9.756

Note: The model simulations used for calibration were for the surface layer.

Table 5.20-b. RMS Errors for the Sebastian River (IRLSUS) Model Water Quality Validation

Station Name	Starting Date	Ending Date	# of Value Pairs	RMS Error	Observation Average	Model Result Average
DO (mg/L)	1/8/2001	12/10/2001	12	1.439	6.010	6.289
Chlorophyll *a* (µg/L)	1/8/2001	12/10/2001	12	7.864	6.943	4.827
Nitrate (mg/L)	1/8/2001	12/10/2001	11	0.082	0.036	0.086
TN (mg/L)	1/8/2001	12/10/2001	11	0.473	0.905	1.108
Total Phosphate (mg/L)	1/8/2001	12/10/2001	11	0.052	0.059	0.039
TP (mg/L)	1/8/2001	12/10/2001	11	0.064	0.059	0.084
TOC (mg/L)	1/8/2001	12/10/2001	11	5.216	11.174	11.335

Note: The model simulations used for validation were for the surface layer.

Another trend of water quality constituent calibration and validation is that TN and TP concentrations were calibrated and validated better than nitrate and phosphate. This might be due to the fact that nitrate and phosphate are the form of nutrients readily available to phytoplankton and usually exist in water column in relatively short period of time once become available. Nitrate and phosphate concentrations in natural waters are usually in low concentration except for in very polluted waterbodies. The low concentration of these nutrient forms can pose challenges to the measurement accuracy. The transient nature of these nutrient forms also making model simulation more difficult. In contrary, TN and TP include those nutrients being taken up by phytoplankton. Even though inorganic nutrients can be quickly taken up by phyotoplankton, they stay in the water column total TN and TP pool and will not cause a significant change on the TN and TP concentrations. Therefore, compared to inorganic nutrients, in most ambient water, TN and TP are relatively easier to be measured accurately and also relatively easier to be simulated accurately.

TOC calibration and validation for most stations are reasonably good. However, chlorophyll *a* concentration calibration and validation were not as good as the other water quality constituents. This is normal because most water quality models, including HSPF and EFDC, assume fixed chlorophyll *a* to algal biomass ratio in model simulation. This is a common practice in most water quality models. However, phytoplankton chlorophyll a content can change with light availability, phytoplankton physiological stage, nutrient availability, phytoplankton species composition, and many other factors. In addition, heterogeneous distribution of phytoplankton in natural waters is very common. All these factors contribute to the challenge of chlorophyll concentration calibration. However, for the EFDC models used in this report, the chlorophyll simulations generally matches the magnitude and central tendency of the measured chlorophyll *a* values.

Overall, the water quality constituents of the EFDC models were reasonably calibrated and validated, and were considered appropriate to be used to evaluate the effects of nutrient and organic carbon on the DO dynamics in impaired Indian River Lagoon tributaries.

5.4. Sensitivity Analysis – What Important Pollutants Influence Water Column DO?

Before target pollutant loads from watersheds can be determined to address the low DO condition in the impaired tributaries, it is necessary to identify the important pollutants that control the DO dynamics in these impaired tributaries. In order to do this, the Department conducted a series of sensitivity runs of EFDC models to asking the following questions:

(1) If watershed nutrient loads are reduced by 90%, will the DO condition in these tributaries be significantly improved?
(2) If watershed BOD loads are reduced by 90%, will the DO condition in these tributaries be significantly improved?
(3) If the sediment oxygen demand (SOD) is reduced by 90%, will the DO condition in these tributaries be significantly improved?

The above sensitivity scenarios were conducted because nutrients drive phytoplankton processes, BOD (organic carbon) drives bacteria detritus processes, and SOD drives sediment processes are usually considered major processes in ambient waters that may reduce DO concentrations.

To conduct these analyses, the impaired tributaries were divided into two groups. The first group includes the Eau Gallie River, Crane Creek, and the Sebastian River system (including the Sebastian River Main Stem, C-54 Canal, North Prong, and South Prong). These tributaries have calibrated and validated EFDC models. Therefore, the DO dynamics in these waterbodies were primarily examined using EFDC models. To examining the effects of nutrients and BOD loads on DO dynamics in these systems, nutrients (including chlorophyll *a*) and BOD loadings were reduced by 90% at all HSPF model flow boundaries and tributary model open boundaries. Then these models were executed and DO results from these scenario runs were compared to the DO dynamics under the existing condition to evaluate whether nutrients and BOD (organic carbon) have any major effects on DO dynamics.

Reducing the SOD by 90% in EFDC models was used as a scenario to show how important the SOD is in controlling DO dynamics in impaired segments. This scenario was achieved by assuming an SOD Scaling Factor of 0.1 so that the model simulated SOD will be constantly reduced by 90%. If SOD has a significant impact on DO in these impaired tributaries, DO dynamics of the reduced-SOD scenario should be significantly different from the DO dynamics under the existing condition.

It should be noted that the above procedures were used to separately evaluate the impact of each individual factor on water column DO dynamics. Therefore, when nutrients entering a tributary were reduced by 90%, the BOD load entering the system was set at its loading rate under the existing condition. Similarly, when the BOD load was reduced by 90%, the nutrients entering the system were set at their loading rate under the existing condition. When the SOD rate was reduced by 90%, nutrients and BOD loads were both set at their loading rate under the existing condition. The 90% reduction was chosen arbitrarily as a large change on each of

these possible DO controlling factors to ensure that, if they have any impact on the water column DO, the impact is visible.

There is one caveat related to this sensitivity test. The 90% reduction in nutrients and BOD loads were achieved by applying a 0.1 scale factor to the EFDC model boundaries. In other words, the test was not done by applying a 90% reduction to related HSPF models and then entering the 90% reduction HSPF model results into the EFDC model. Reducing nutrients and BOD loadings at the EFDC boundaries saved many modeling steps and therefore the needed data processing time was shortened. However, because no new HSPF model runs were conducted, the EFDC DO boundary conditions were not changed with the change of nutrients and BOD boundary loads. Therefore, the results from the sensitivity analysis may, to certain extent, be influenced by the unchanged DO boundary condition and therefore more or less diminished comparing to if an HSPF run was conducted. However, as the purpose of conducting the sensitivity analysis is to distinguish among the effect of nutrients, BOD, and SOD, and all these three scenarios were influenced by the same DO boundary condition. As long as the scenario run results show difference among these three major factors, we will have the information to determine which component(s) is/are the major factor(s) on which we should focus our load reduction effort.

For Addison Creek, sensitivity analyses were conducted using the HSPF model. As discussed in Chapter 4, the HSPF model for the waterbody was set up in such a way that watershed loads of refractory organic carbon loads, which, although to a lesser extent than the labile organic carbon loads associated with BOD, still contribute to SOD, was not simulated by HSPF models directly. Instead, these organic carbon loads were calculated based on HSPF model simulated refractory organic nitrogen loads from the watershed. Likewise, the model did not simulate labile organic nitrogen and labile organic phosphorus. Instead, the HSPF model derived the watershed labile organic nitrogen and labile organic phosphorus from the watershed BOD loads, which was simulated by the model. Because of these intricate model setups, it is impossible to separate the effects of nutrients and BOD loads through revising model parameters. Therefore, the HSPF sensitive analysis only include two scenarios, including (1) reducing the nutrients and BOD loads by 90% and (2) reducing the SOD rate by 90%. Results from these two scenarios will provide information on whether nutrients and BOD loads were more important than SOD in controlling the DO concentration in the impaired water segments.

In order to tell whether nutrients or BOD is more important in controlling the water column DO concentration, the percent organic carbon contained in algal biomass in the total organic carbon loads is estimated for each waterbody. Di Toro (1990) demonstrated a direct relationship between the total organic carbon content loads and sediment SOD. The change of SOD is the square root of the ratio between the changed organic carbon loads and the total organic carbon loads under the existing condition. This relationship can be described using the following equation:

TOC Load = (BOD * C/O2 + Refractory OrgC + Algae Biomass (ug Chl/L) * C/Chl) * Flow Rate

Where,

- BOD is the BOD concentration in the receiving water.
- C/O2 is the carbon/oxygen stoichiometric ratio that is used to convert the biochemical oxygen demand into organic carbon amount.

- Refractory OrgC is the concentration of the refractory organic carbon in the receiving water.
- C/Chl is the carbon chlorophyll ratio used to convert the chlorophyll concentration to organic carbon amount.
- Flow Rate is the flow rate of the receiving water.

It can be seen that, the higher the portion of the total organic carbon loads contributed by the organic carbon contained in the algal biomass, the more important the algal biomass will be in the change of SOD. Because the algal biomass is supported by nutrients, if the algal biomass is important in contributing to SOD, nutrients will be important in controlling the DO concentration in impaired water segments. In contrast, if the organic carbon contained in algal biomass only accounts for a small portion of the total organic carbon loads, nutrient loads will be considered unimportant in controlling the water column DO concentration.

5.4.1. Sensitivity Analyses for Eau Gallie River, Crane Creek, and the Sebastian River System (Including the Main Stem, C-54 Canal, North Prong, And South Prong) – EFDC Model Analyses

The sensitivity analyses for the Eau Gallie River, Crane Creek, and the Sebastian River system were conducted using EFDC models developed for these tributaries. For the Eau Gallie River, Crane Creek, and the main stem of the Sebastian River, the model simulation results used for the sensitivity analyses were from the model grid where the water quality stations used for water quality calibration and validation were located. The location of water quality stations used for the water quality calibration and validation are presented in **Figure 5.5**. These stations are maintained by the SJRWMD. For the North and South Prongs of the Sebastian River and C-54 Canal, model results were extracted from the downstream most grid in each of these tributaries so that the influence from the HSPF flow boundary conditions can be avoid as much as possible. **Figures 5.9**, **5.10**, and **5.11** show the location of these water quality stations in their corresponding EFDC model grids. **Figure 5.11** also shows grids in the North and South Prongs of the Sebastian River and the C-54 Canal where EFDC DO results were extracted for the sensitivity analysis.

Figures 5.12-a, -b, and **-c**, **5.13-a, -b**, and **-c**, **5.14-a, -b**, and **–c**, **5.15-a, -b**, and **–c**, **5.16-a, -b**, and **–c**, and **5.17-a, -b**, and **–c** show results of reducing nutrients, organic carbon, and SOD by 90% for the Eau Gallie River, Crane Creek, the Sebastian River main stem, the North Prong of the Sebastian River, the South Prong of the Sebastian River, and the C-54 Canal using the EFDC model, respectively. These figures all show a clear pattern: reducing the nutrient loadings by 90% do not results in any significant improvement of DO concentrations in these impaired water segments. However, reducing organic carbon loads by 90% to these system does result in significant improvement in DO concentrations. The most significant improvement of DO concentration was observed when the SOD was reduced by 90%, suggesting that, in these impaired water segments, the dominating factor controlling the water column DO concentration is SOD. Further EFDC analyses following the sensitivity test found that, when nutrient loads were reduced by 90%, SOD in these impaired segments only showed very small decrease. However, a significant decrease in SOD was observed when organic carbon loads were reduced by 90%. This indicates that, while SOD is the dominant source of DO consumption in

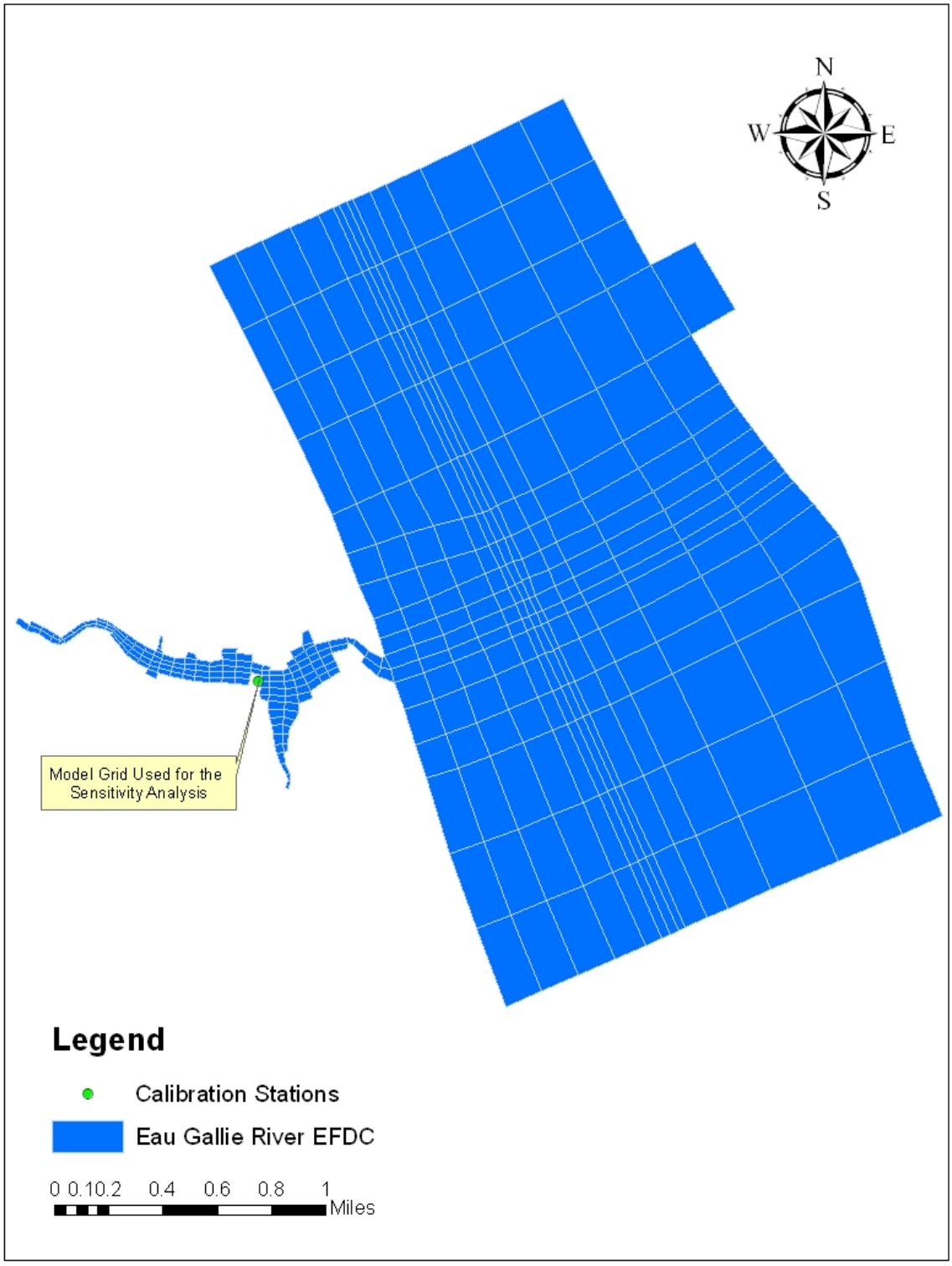


Figure 5.9. The Model Grid Used for Sensitivity Analysis in the Eau Gallie River EFDC Model

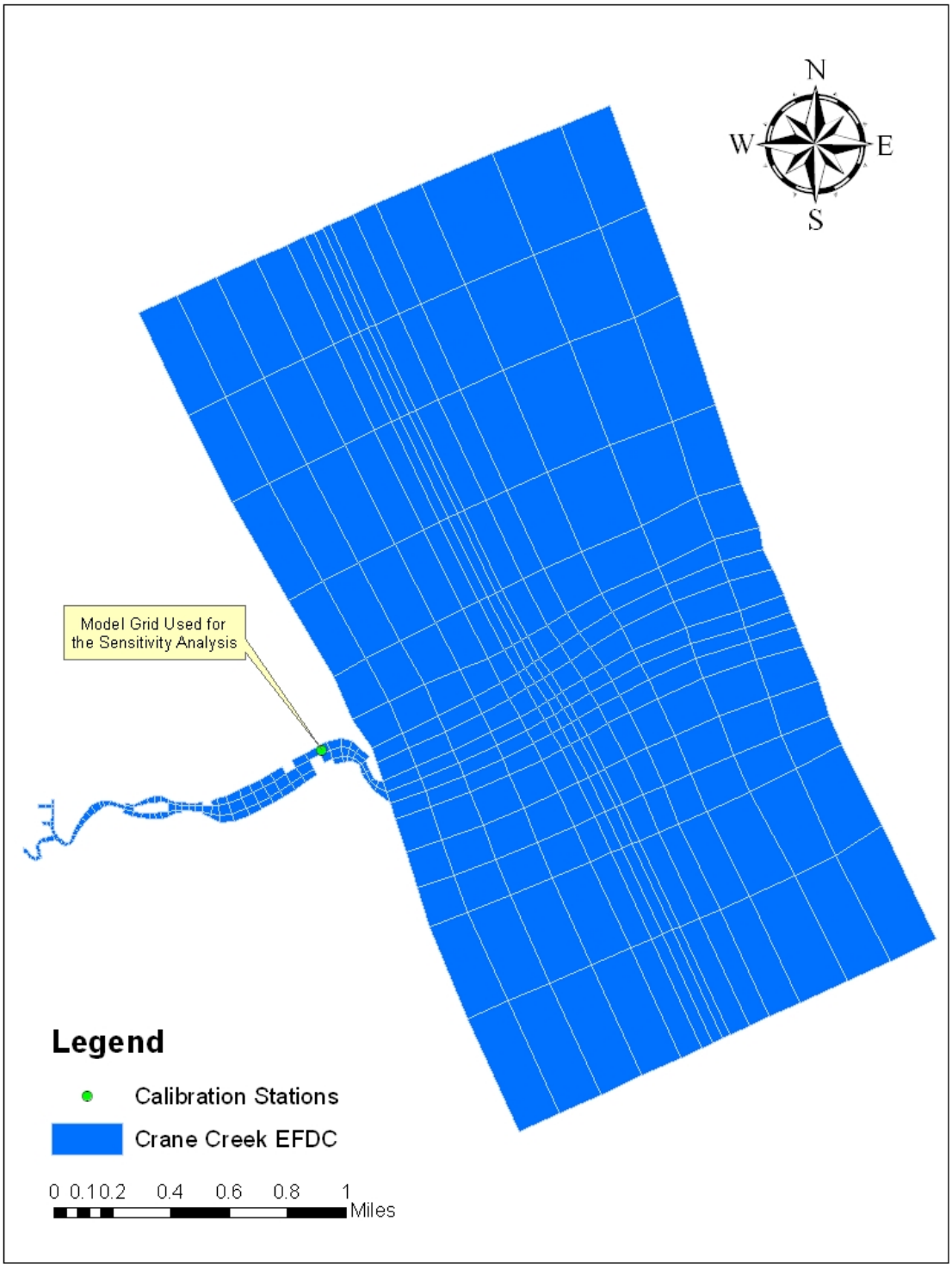


Figure 5.10. The Model Grid Used for Sensitivity Analysis in the Crane Creek EFDC Model

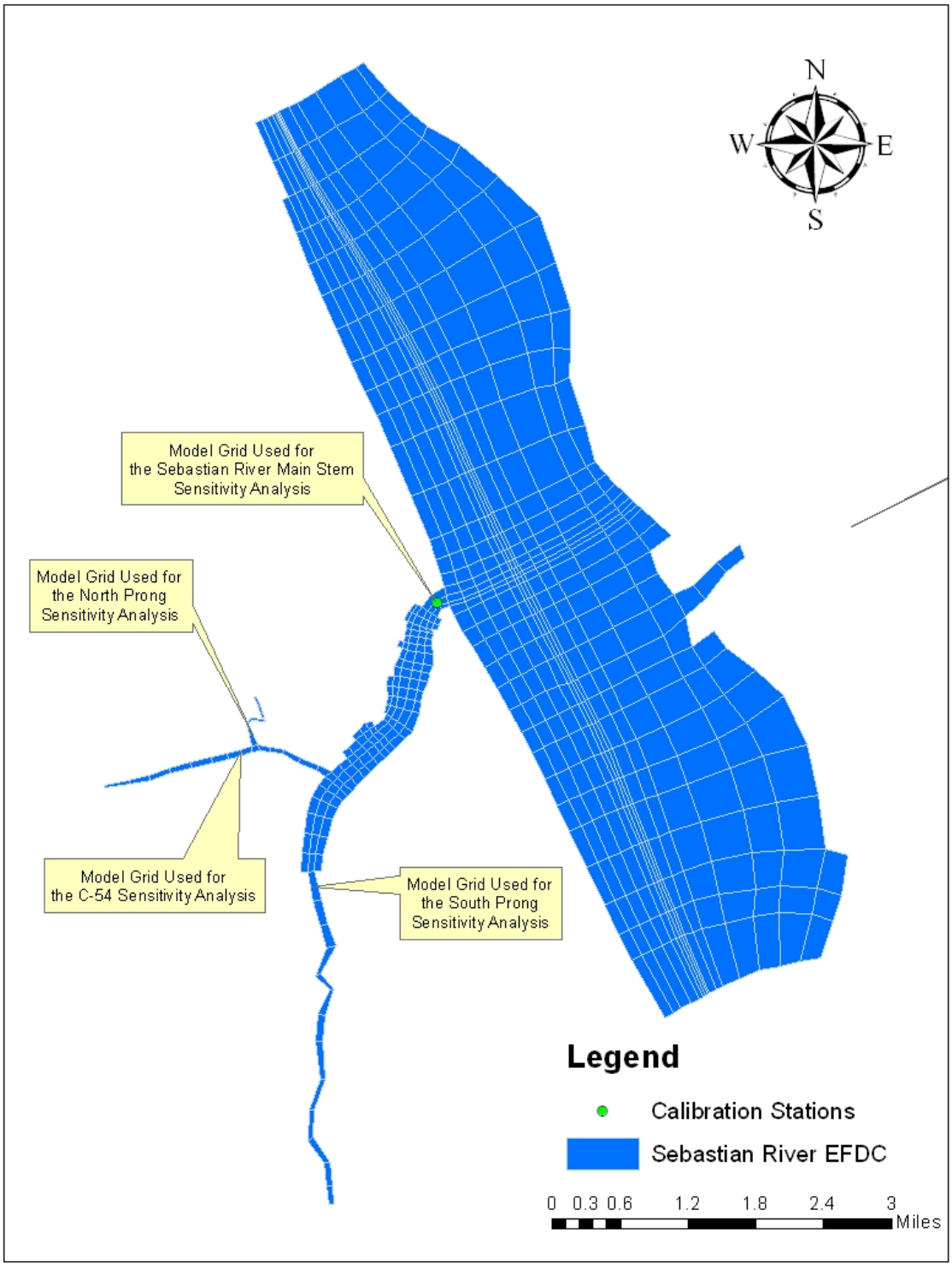


Figure 5.11. The Model Grids Used for Sensitivity Analyses in the Sebastian River System EFDC Model

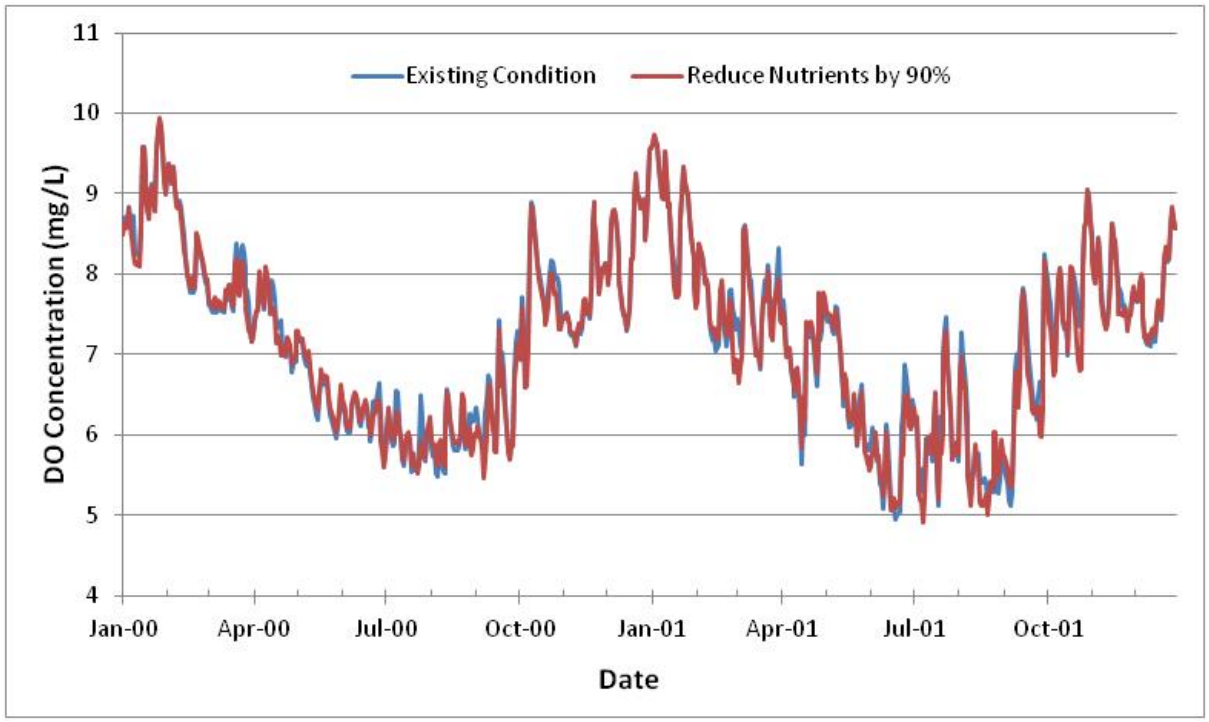


Figure 5.12-a. EFDC Sensitivity Analysis for the Eau Gallie River – Reducing Nutrient Loads by 90%

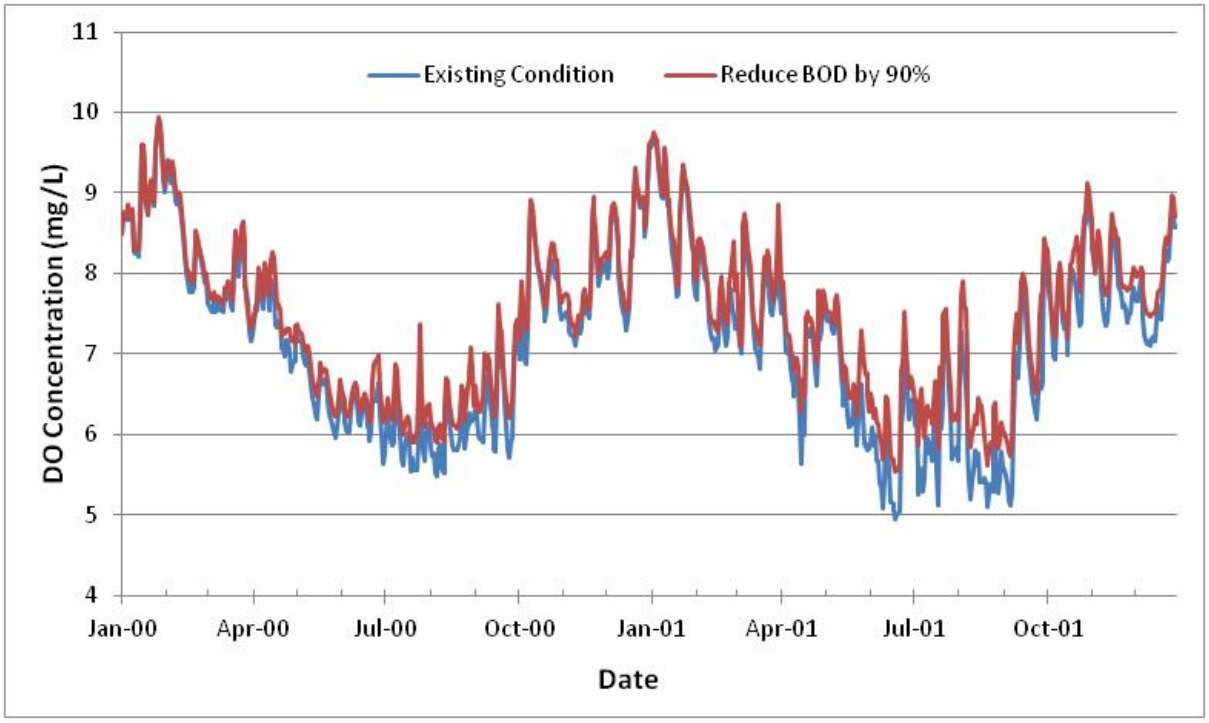


Figure 5.12-b. EFDC Sensitivity Analysis for the Eau Gallie River – Reducing Organic Carbon by 90%

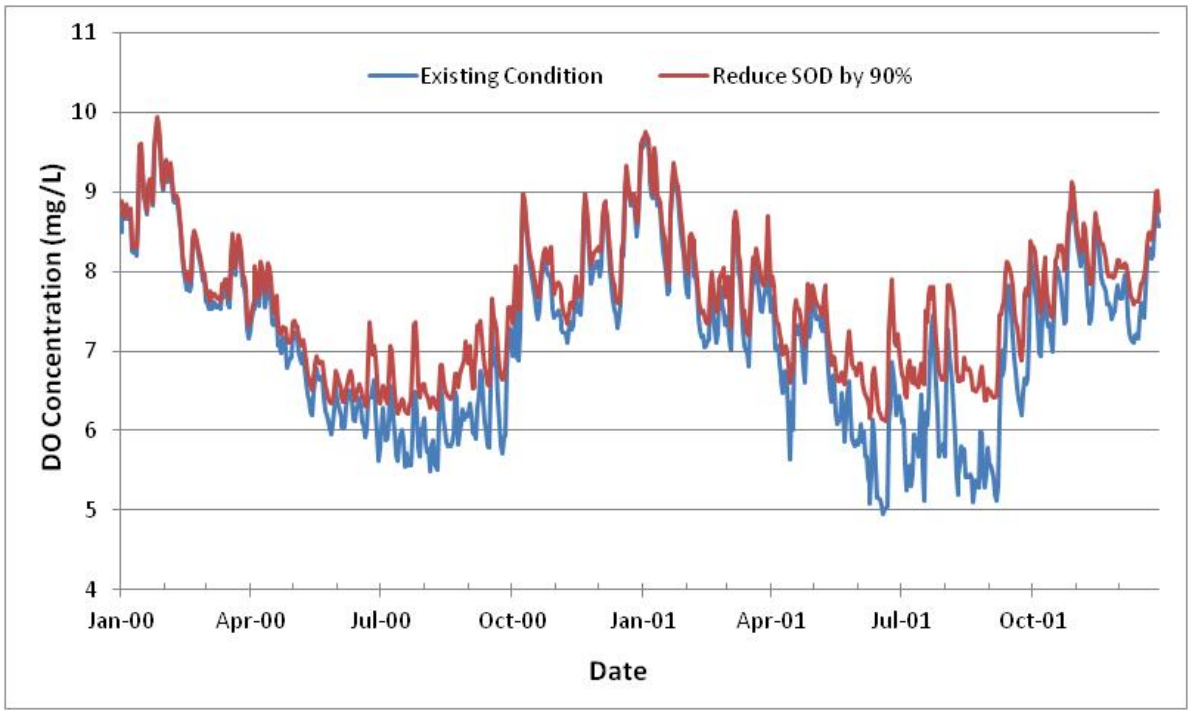


Figure 5.12-c. EFDC Sensitivity Analysis for the Eau Gallie River – Reducing SOD by 90%

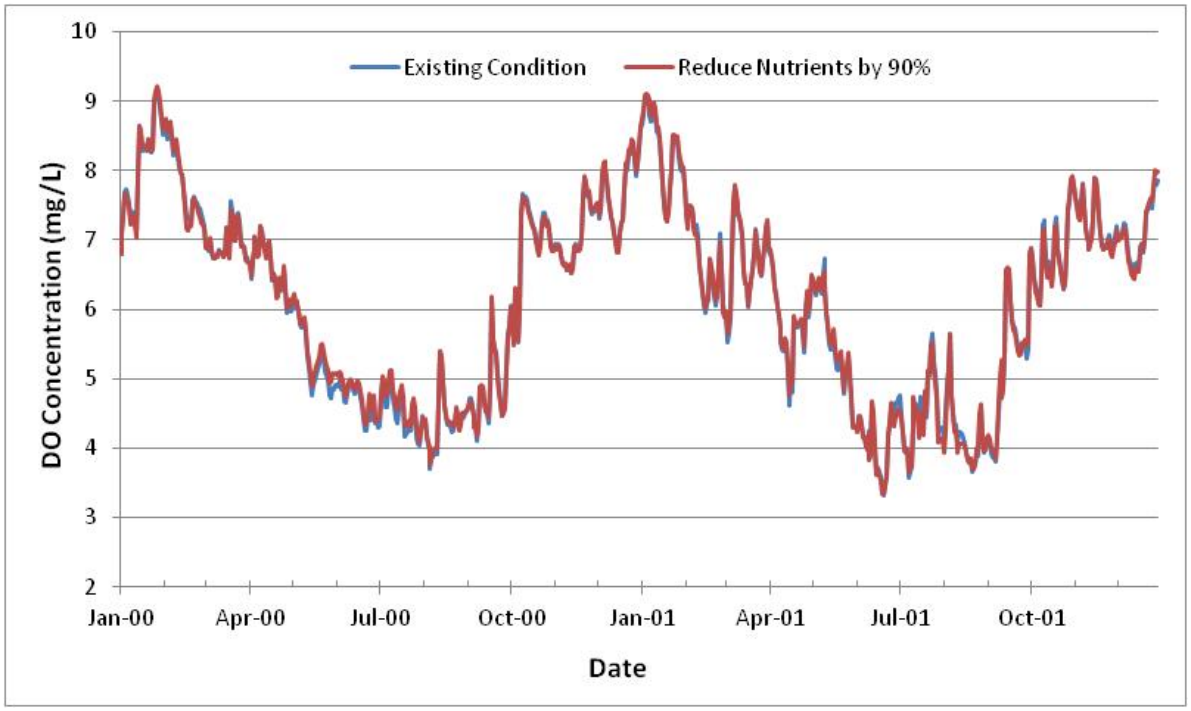


Figure 5.13-a. EFDC Sensitivity Analysis for Crane Creek – Reducing Nutrients by 90%

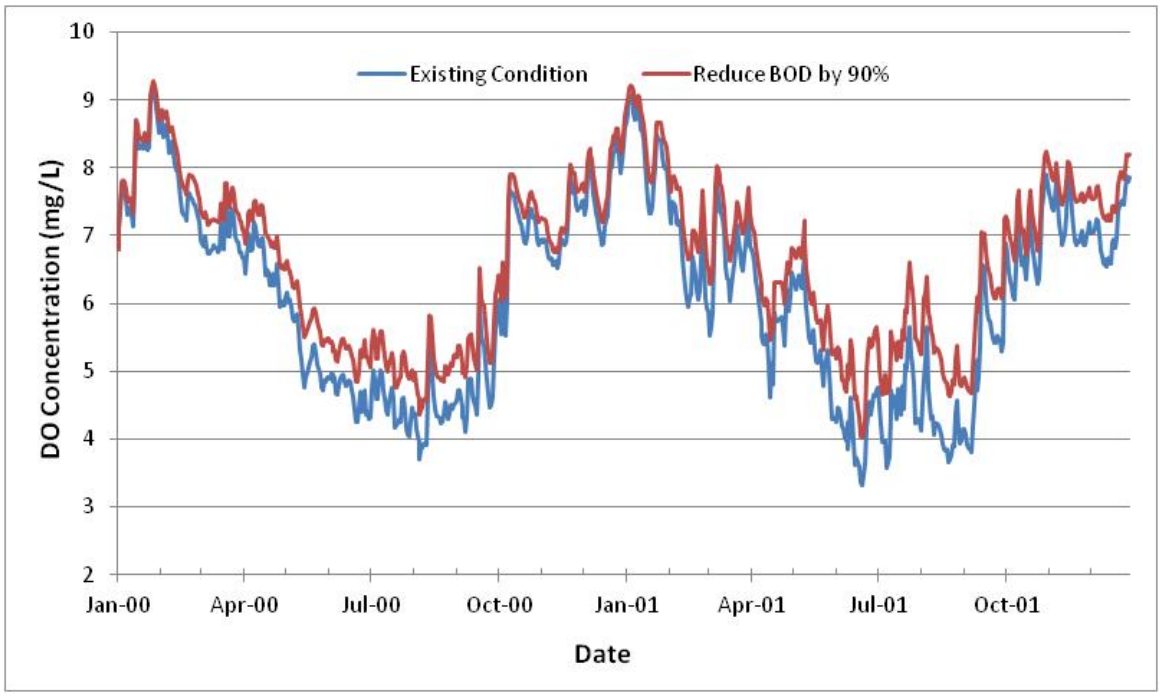


Figure 5.13-b. EFDC Sensitivity Analysis for Crane Creek – Reducing Organic Carbon by 90%

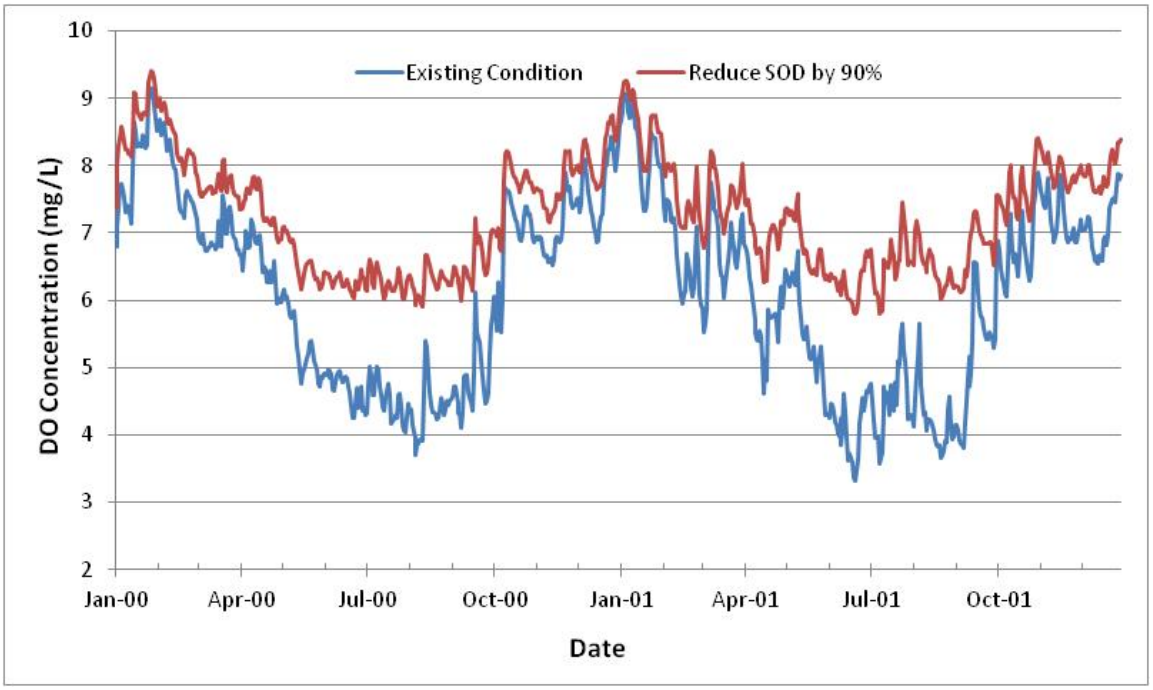


Figure 5.13-c. EFDC Sensitivity Analysis for Crane Creek – Reducing SOD by 90%

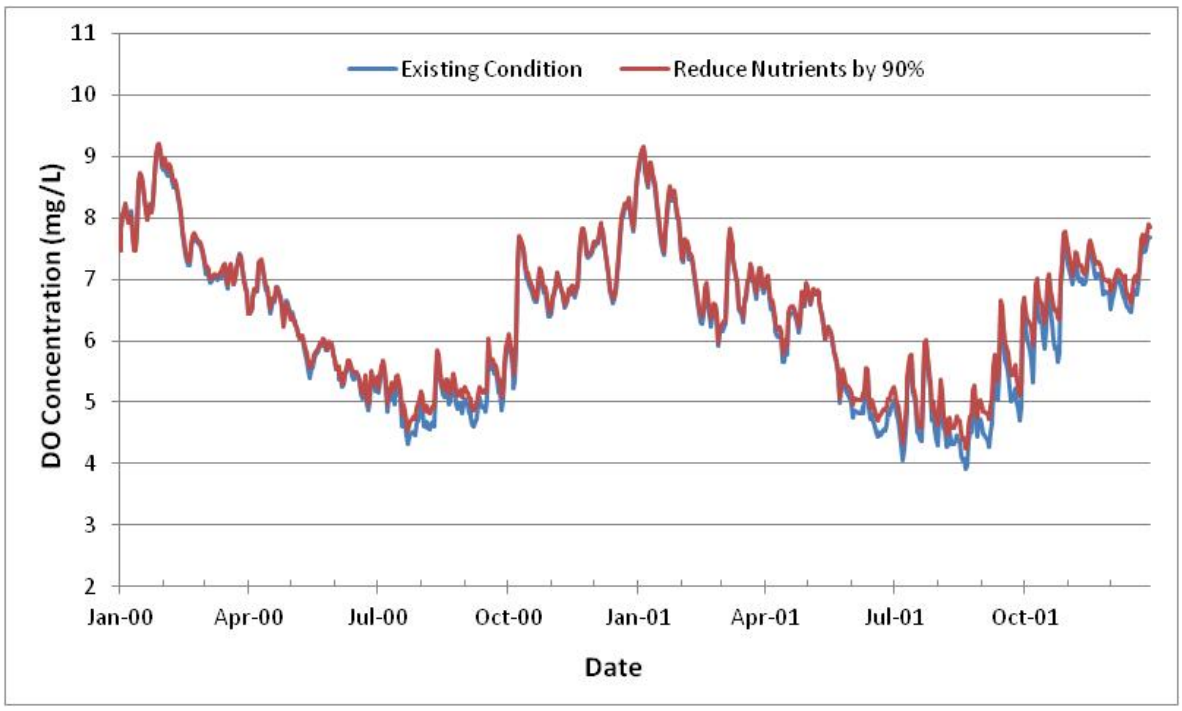


Figure 5.14-a. EFDC Sensitivity Analysis for the Sebastian River Main Stem – Reducing Nutrients by 90%

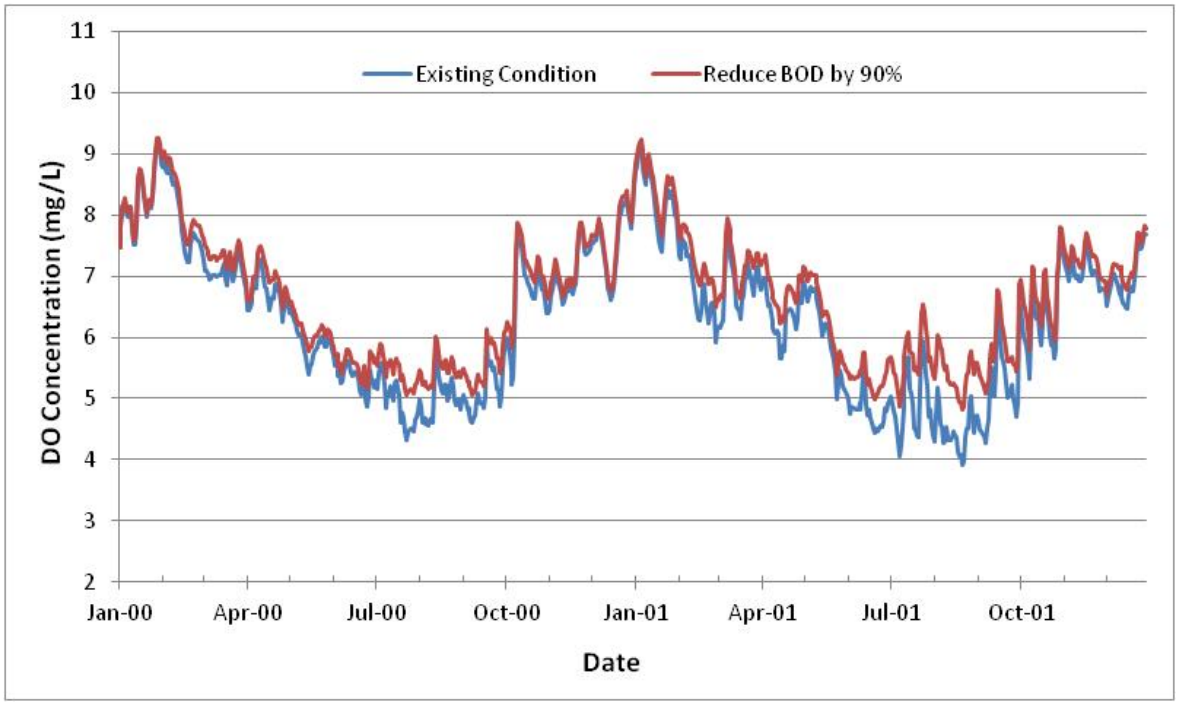


Figure 5.14-b. EFDC Sensitivity Analysis for the Sebastian River Main Stem – Reducing Organic Carbon by 90%

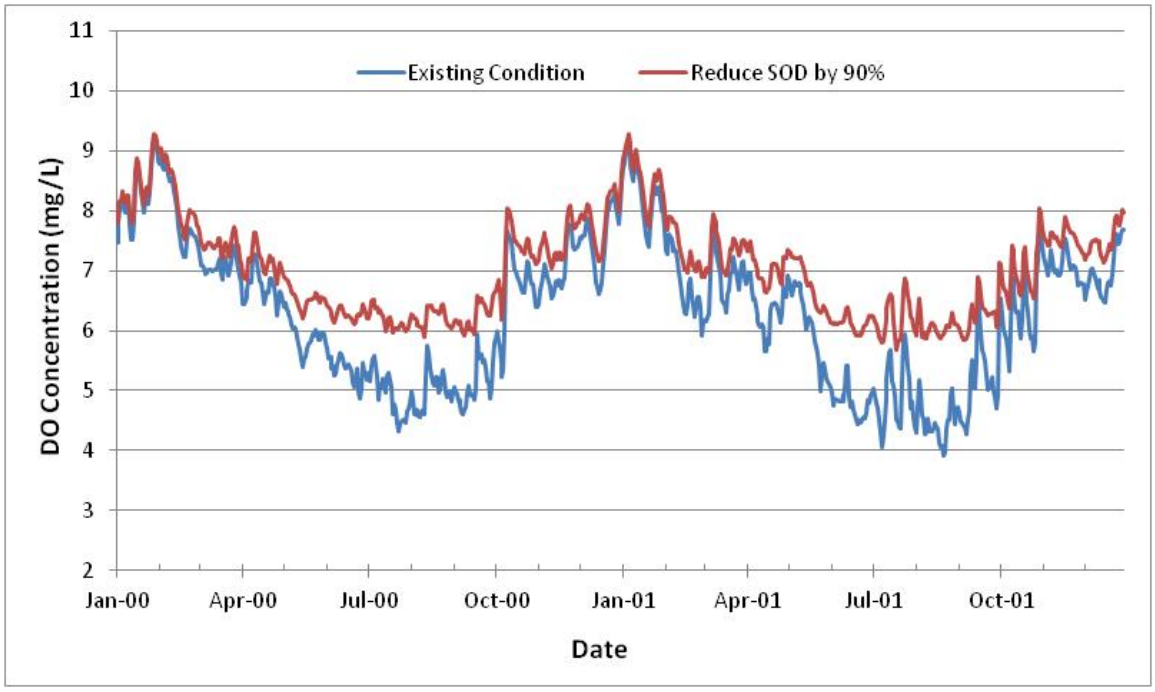


Figure 5.14-c. EFDC Sensitivity Analysis for the Sebastian River Main Stem – Reducing SOD by 90%

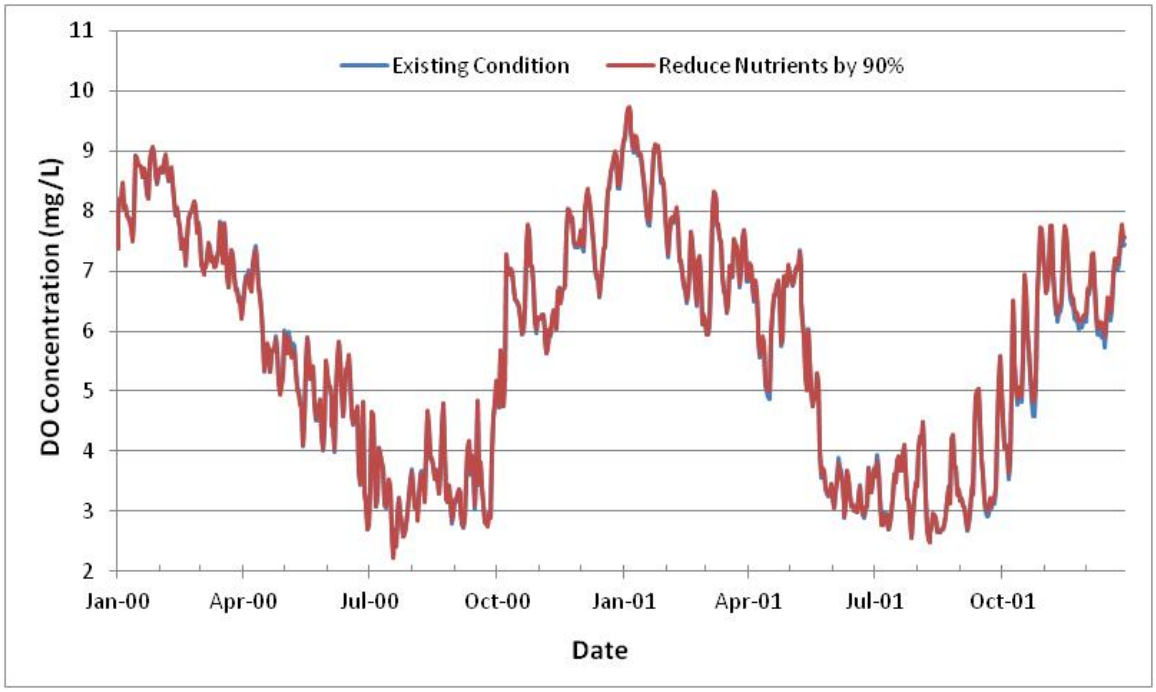


Figure 5.15-a. EFDC Sensitivity Analysis for the North Prong – Reducing Nutrients by 90%

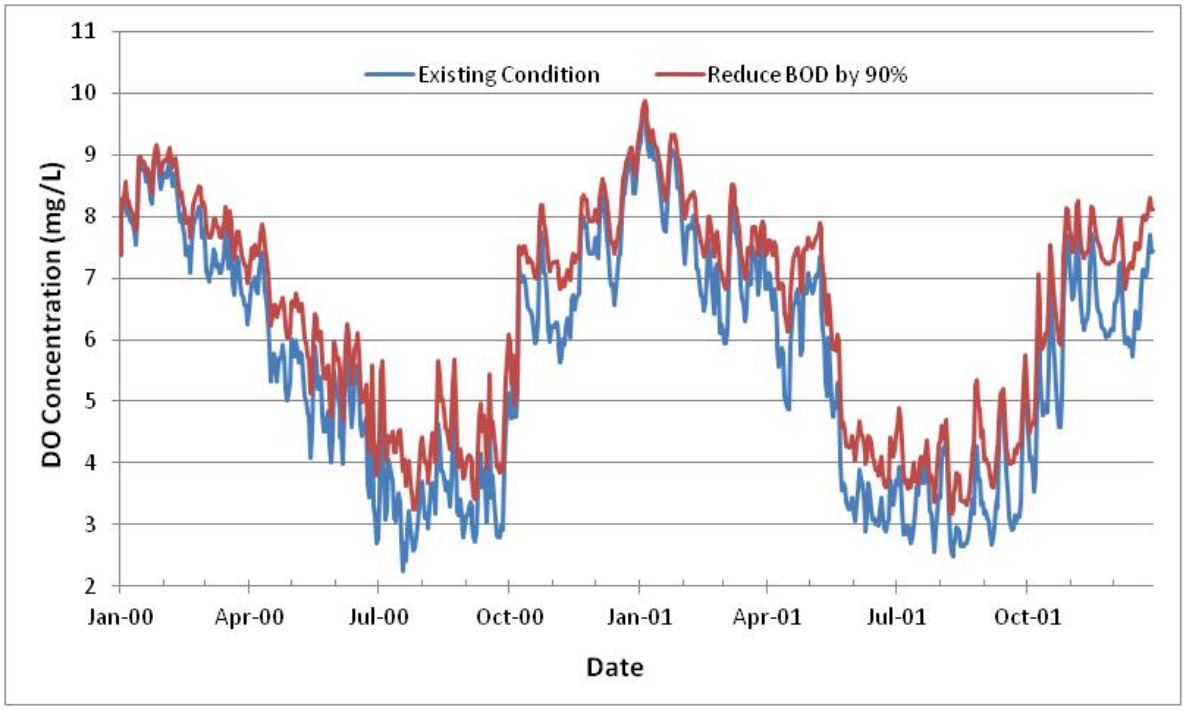


Figure 5.15-b. EFDC Sensitivity Analysis for the North Prong – Reducing Organic Carbon by 90%

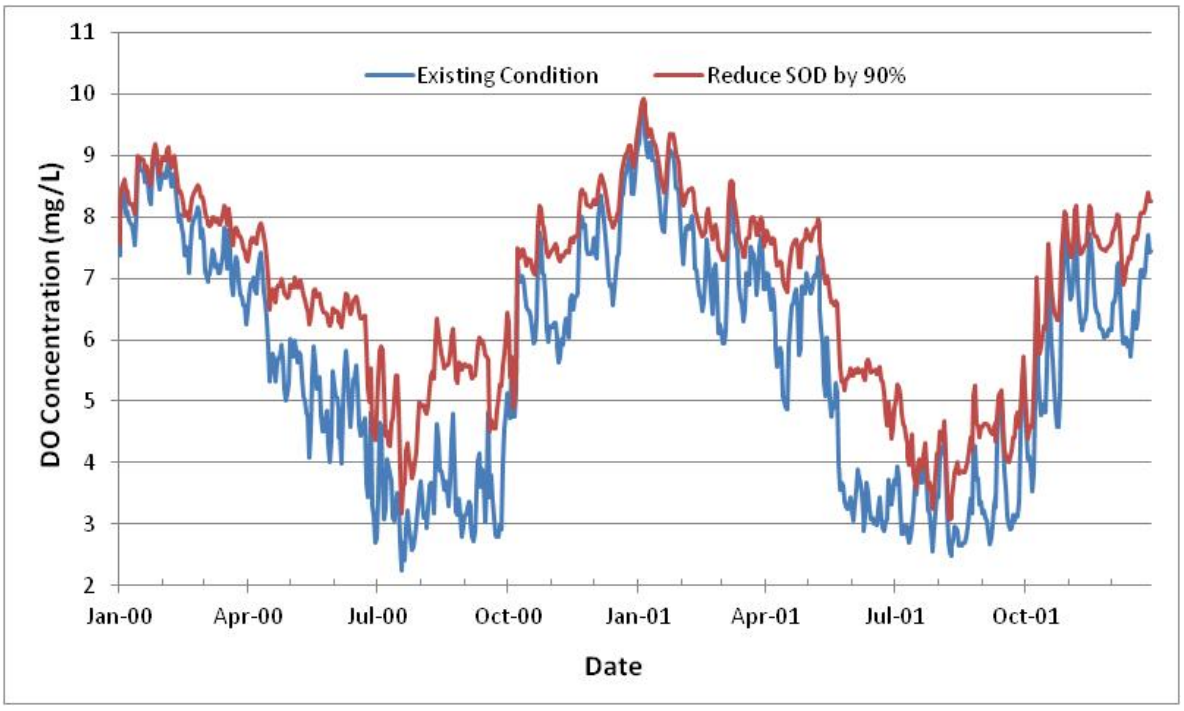


Figure 5.15-c. EFDC Sensitivity Analysis for the North Prong – Reducing SOD by 90%

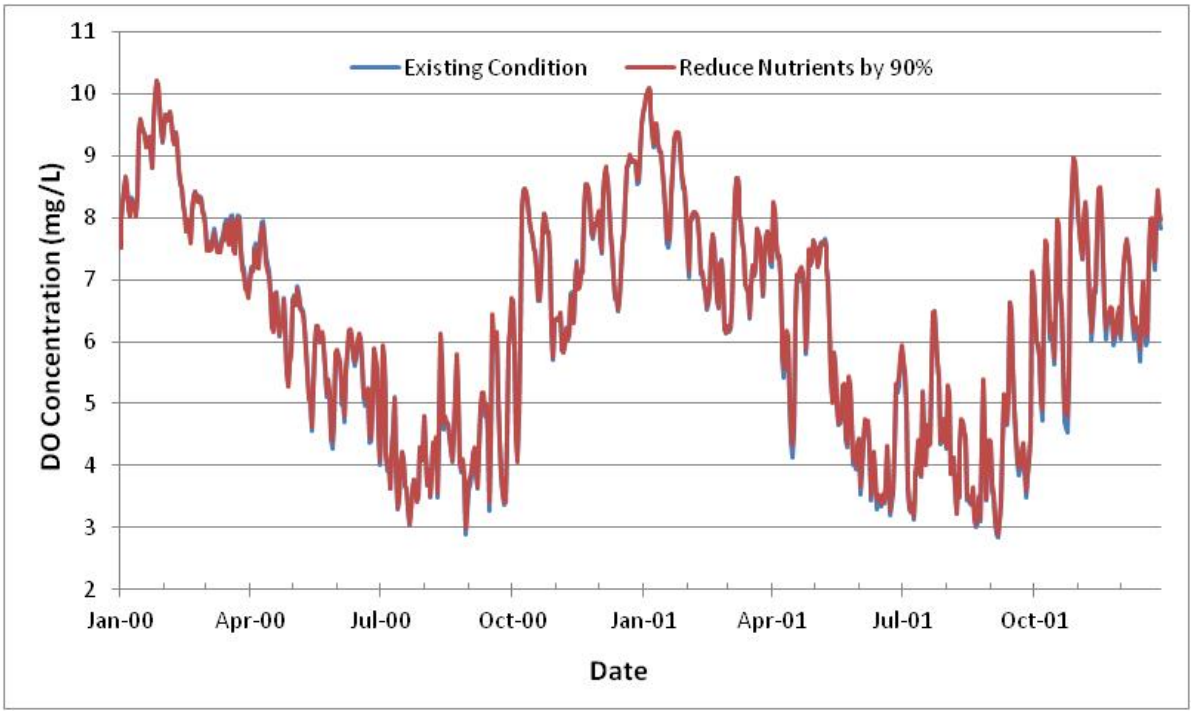


Figure 5.16-a. EFDC Sensitivity Analysis for the South Prong – Reducing Nutrients by 90%

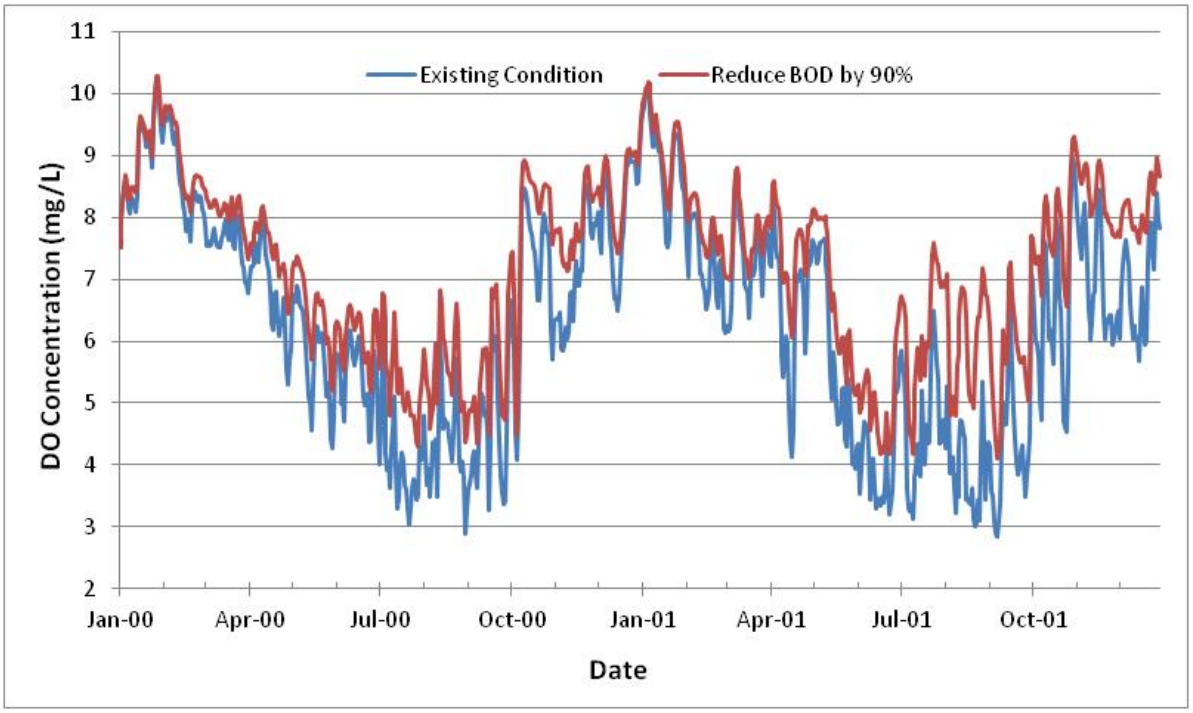


Figure 5.16-b. EFDC Sensitivity Analysis for the South Prong – Reducing Organic Carbon by 90%

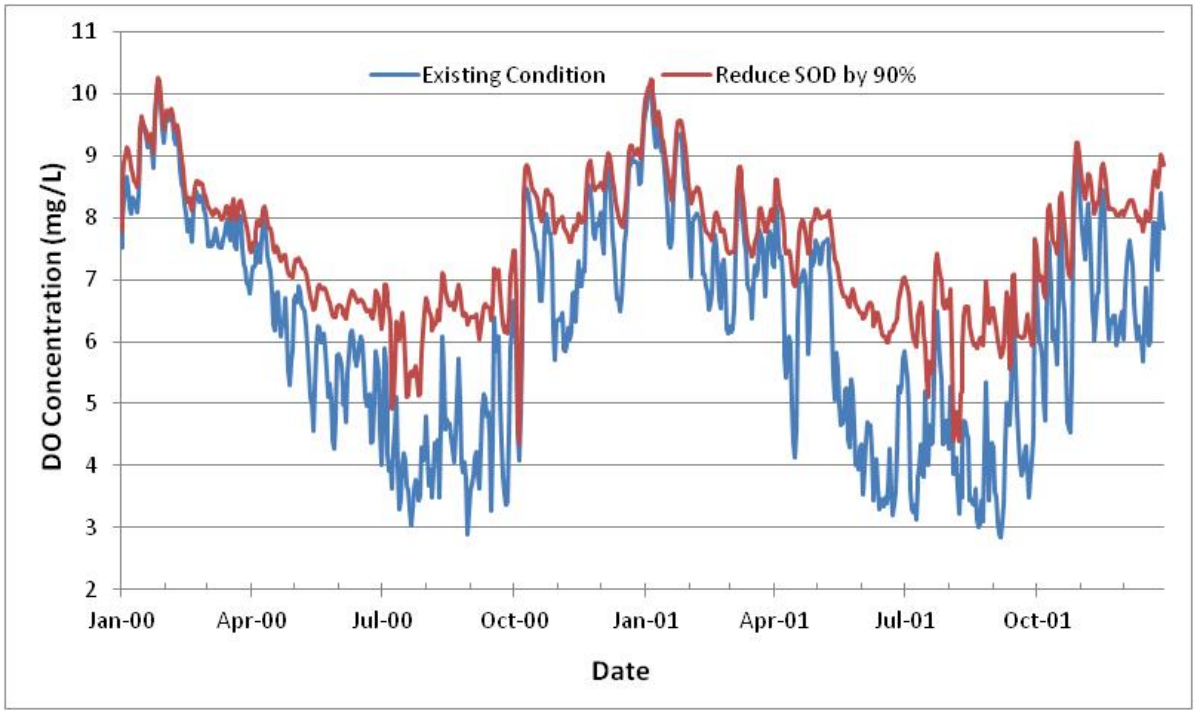


Figure 5.16-c. EFDC Sensitivity Analysis for the South Prong – Reducing SOD by 90%

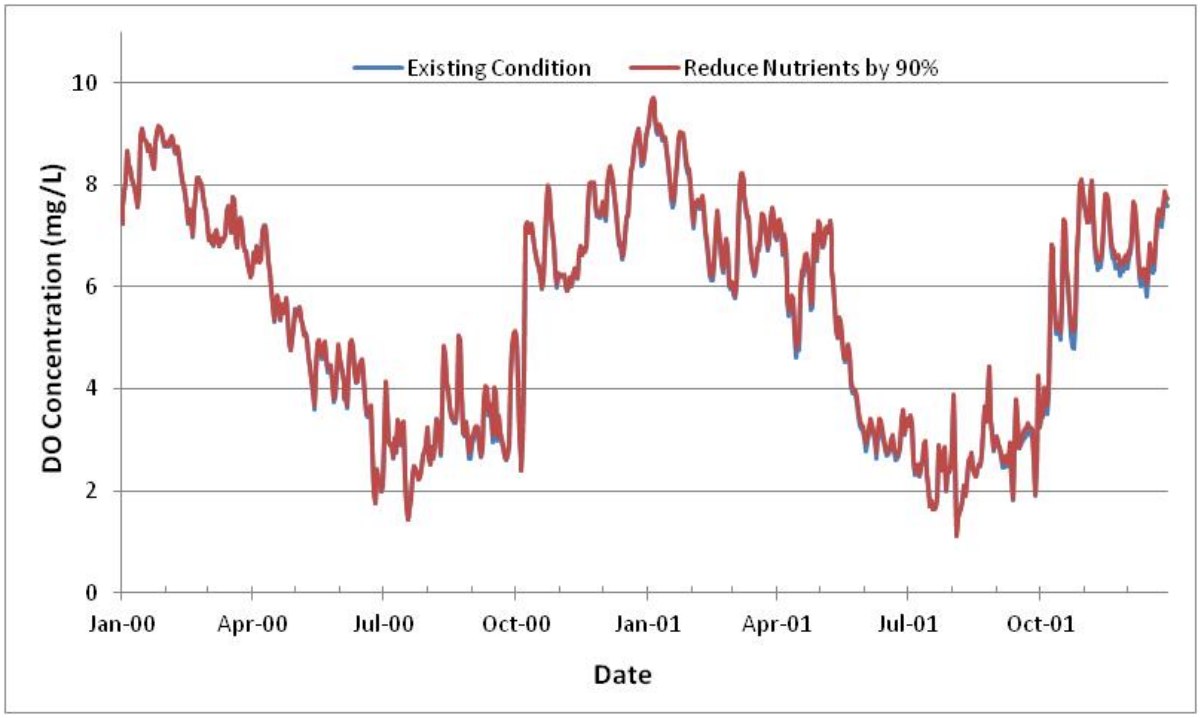


Figure 5.17-a. EFDC Sensitivity Analysis for C-54 Canal – Reducing Nutrients by 90%

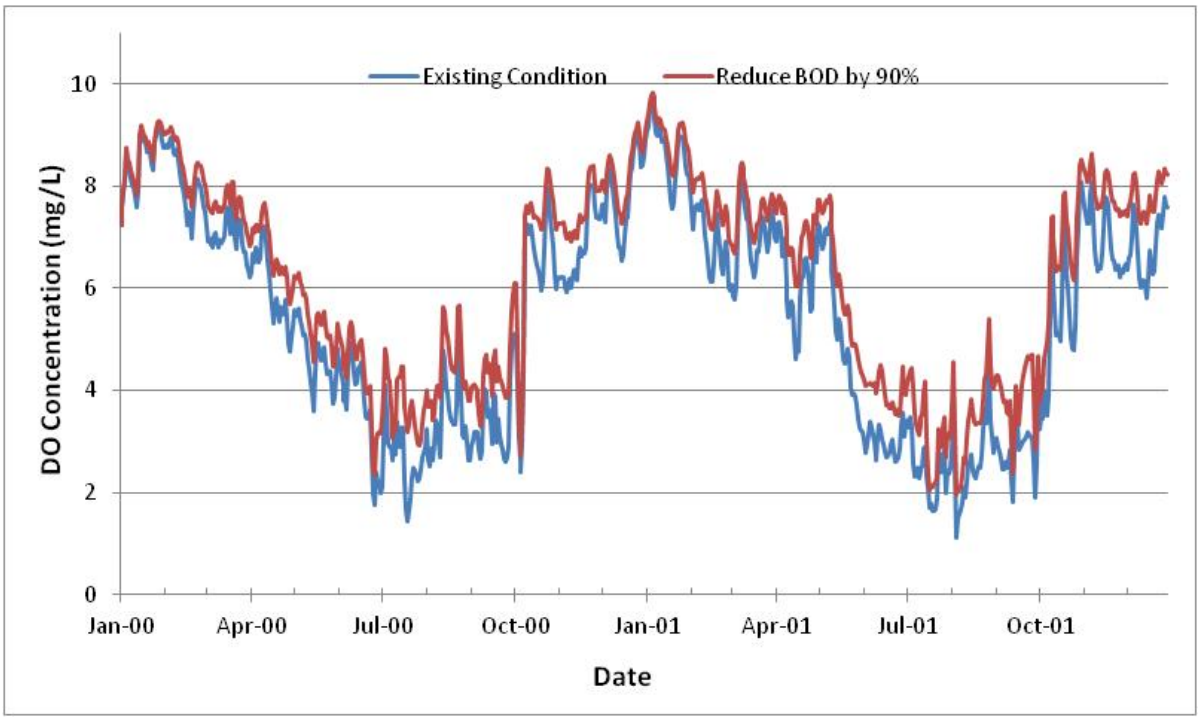


Figure 5.17-b. EFDC Sensitivity Analysis for C-54 Canal – Reducing Organic Carbon by 90%

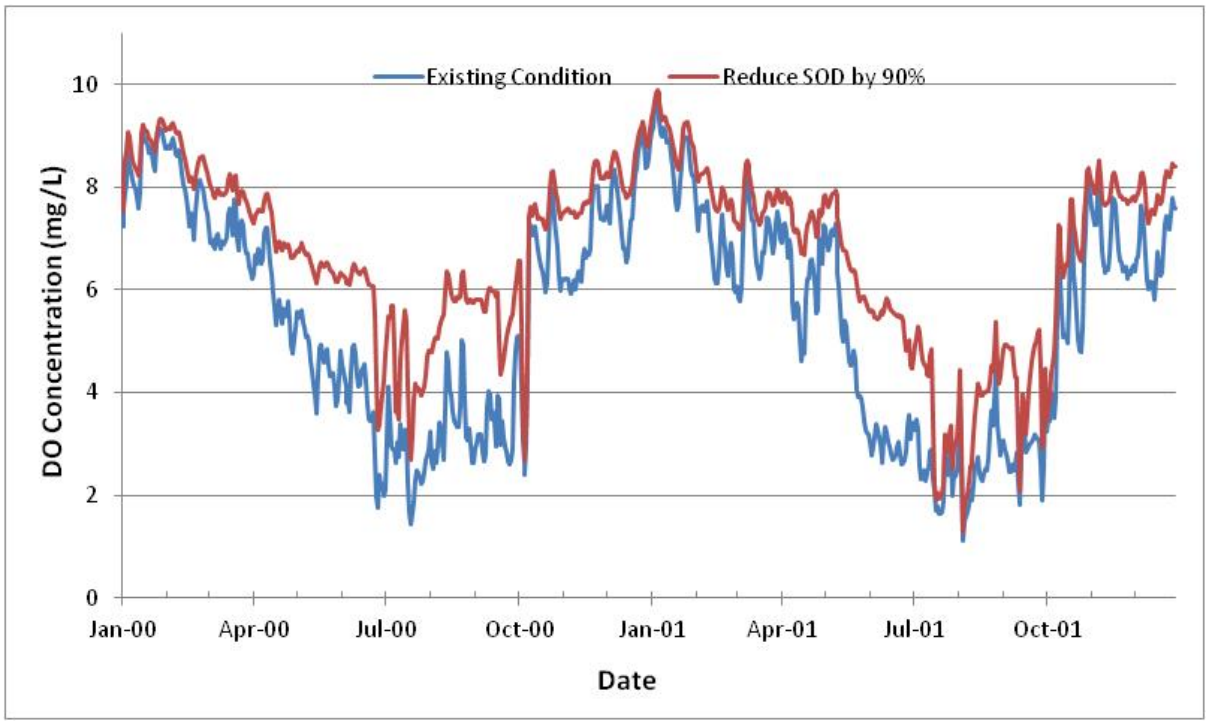


Figure 5.17-c. EFDC Sensitivity Analysis for C-54 Canal – Reducing SOD by 90%

these systems, the organic carbon load entering these systems is the major factor that controlling the SOD in these systems. The reason why nutrients did not contribute to SOD might be because the short water residence time in these impaired segments did not provide long enough time for nutrients to grow a large quantity of algal biomass and also allow a significant amount of the algal biomass grown in the system to settle to the sediment and add to SOD. Therefore, in order to improve DO concentrations in these impaired systems, the focus should be put on controlling organic carbon loads entering these systems.

5.4.2. Sensitivity Analyses for Addison Creek – HSPF Model Analyses

Results from the two scenarios for the HSPF sensitivity analyses are displayed in **Figures 5.18-a** and **5.18-b**. **Figure 5.18-a** shows the result of reducing nutrients and BOD by 90%. **Figure 5.18-b** shows the result of reducing SOD by 90%.

For Addison Creek, the DO improvement achieved through reducing nutrient and BOD loads by 90% alone is limited (**Figure 5.18-a**). Reducing SOD by 90% apparently has a more significant effect than reducing the nutrient and BOD loads (**Figure 5.18-b**). This suggests that the water column DO consumption processes, such as algal respiration and BOD decay, are not as important processes as DO consumption processes caused by SOD. Over the ten-year HSPF model simulation period, the long-term average percent organic carbon contained in algal biomass only accounts for about 0.5% of the total organic carbon load, which suggests that, even the algal biomass is totally removed from the water, the total organic carbon load in the creek will only be changed by 0.5% or less, which, in turn, suggests that reducing nutrient loads into the system will not have any major effect on the water column DO concentration. In order to improve the DO condition in the Addison Creek, BOD reductions should be the focus of loading control.

In summary, in all tributaries included in this report, reducing nutrient loadings from watersheds do not appear to be effective in improving the water column DO concentration. One major reason is that algal biomass in these systems does not contribute significantly to the water column DO consumption, and it does not contribute significantly to the SOD either. The relatively low algal organic carbon among the total carbon loads in these systems could be a major reason for the small influence from nutrients. This suggests that, in order to improve the DO condition in these systems, BOD, instead of nutrients, should be the focus of pollutant loading control. However, it is important to remember that, natural land use areas, including upland forests and wetlands can also create BOD loads. Therefore, the watershed BOD loading targets to these impaired waterbodies should not be lower than the natural background condition (i.e., under which these watershed are covered by upland forests, waters, and wetlands). In addition, other natural processes, such as low DO interflow and baseflow discharges entering these systems also influence DO dynamics in these system. Even when watershed BOD loads are reduced to the natural background condition, DO concentration may not achieve the 5.0 mg/L all the time for freshwater systems, and 4.0 mg/L all the time for marine systems.

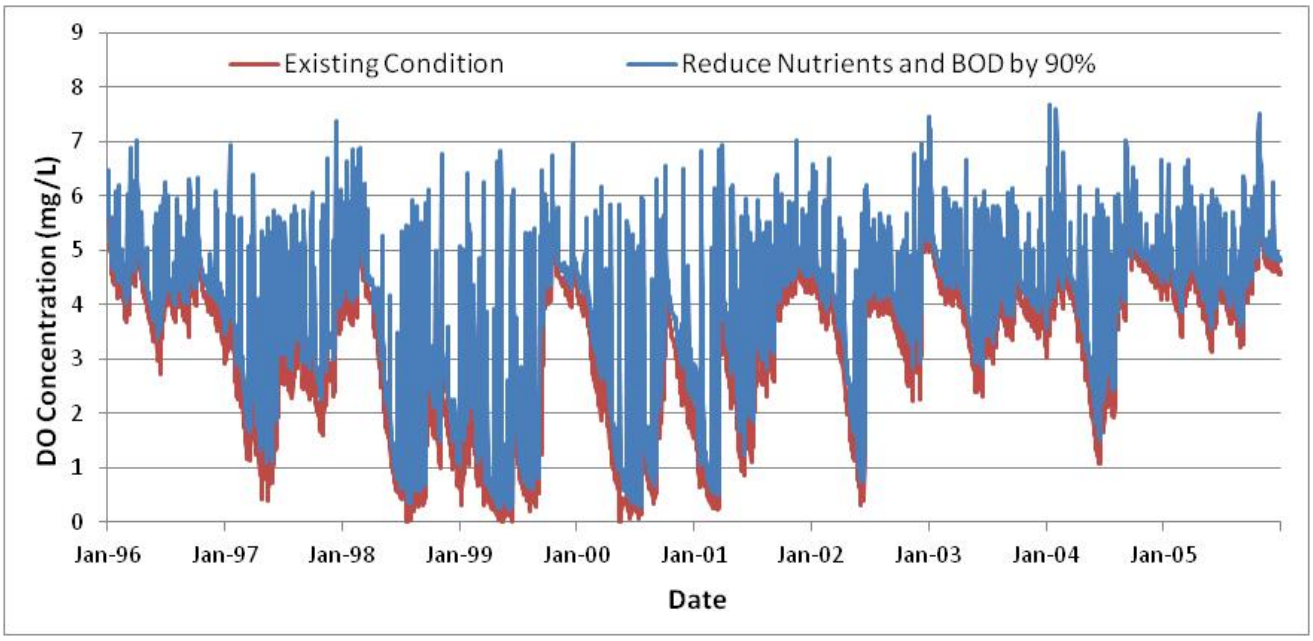


Figure 5.18-a. HSPF Sensitivity Analysis for Addison Creek – Reducing Nutrients and BOD by 90%

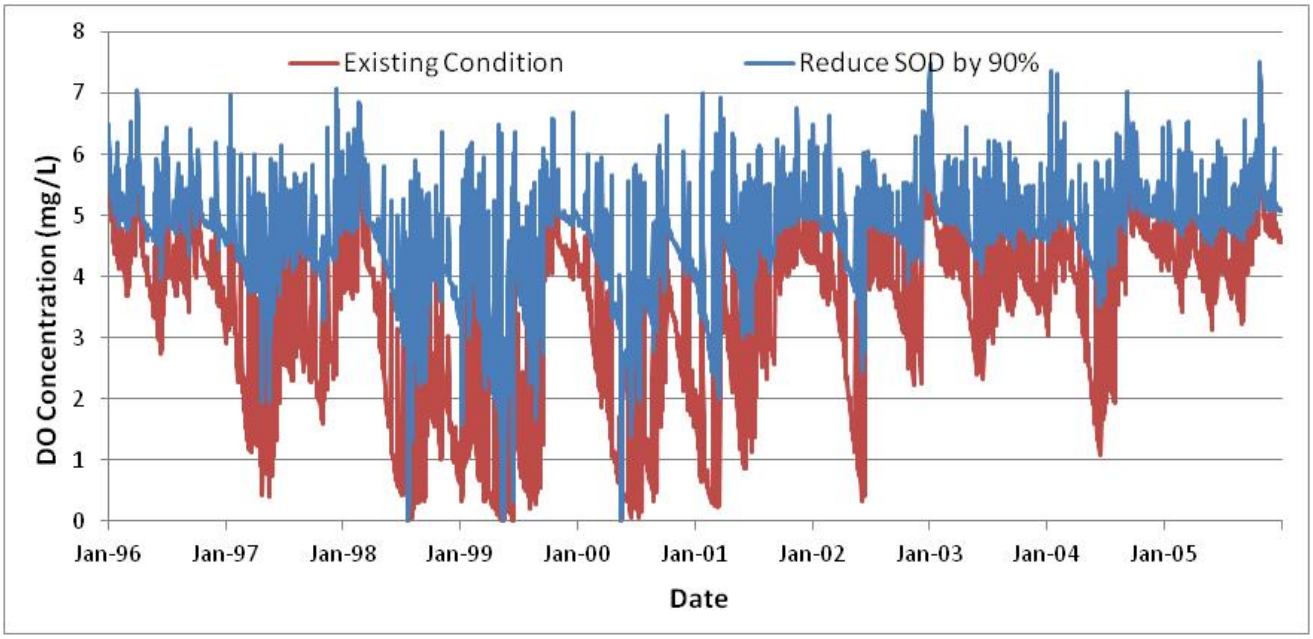


Figure 5.18-b. HSPF Sensitivity Analysis for Addison Creek – Reducing SOD by 90%

5.5. BOD Loading Targets

The goal of a TMDL is to define a maximum pollutant load that can be assimilated by waterbodies without causing impairment. However, it is not the Department's intention to pursue the pollutant loading condition beyond the natural background condition. In the Indian River Lagoon tributary systems included in this TMDL report, BOD, in addition to other natural processes, appears to be a major pollutant that causes observed low DO. BOD primarily depresses the DO concentration in these tributaries through contributing to SOD. Therefore, controlling BOD loads from the watershed should be a focus in the effort to improve the low DO condition in these impaired tributaries.

BOD loading targets for these impaired tributaries are defined as the BOD loadings from the watersheds of these tributaries under the condition that all human impacts on pollutant loads are removed. In other words, the target BOD loadings are those loadings produced from watersheds that are only covered by natural lands, including forest, waters, and wetlands. These background BOD loadings were simulated using HSPF models. In order to define the BOD loading target for each of the impaired tributaries, all human land areas in the watersheds were converted to either forests or wetlands. This was achieved by examining soil distribution in the watershed using the Department of Agriculture/Natural Resource Conservation Service's (USDA/NRCS) Soil Survey Geographic (SSURGO) 1990 shapefile. Human influenced land uses that are located in areas dominated by the D hydrological soil group, which is soil type typically located in low land wetland areas and has low infiltrate but high runoff creation potential, were all converted to wetlands. The other developed lands were converted to forest areas. The land use conversion was made to all calibrated HSPF models and the natural background watershed BOD loadings were simulated using HSPF models with the changed land uses. **Table 5-21** shows the existing BOD loads and target BOD loads from the watersheds of the impaired tributaries and the percent reduction needed to achieve these target BOD loads.

It should be noted that, based on the effluent loading calculations for point source dischargers discussed in **Section 4.2.1.1**, BOD loadings from all wastewater dischargers, including the Grant Street WWTF (FL0041122) discharging to Crane Creek, and the Barefoot Bay Advanced WWTF (FL0042293) discharging to the North Prong of the Sebastian River, are all less than 5% of the total background BOD loadings entering the impaired tributaries, these facilities were allowed to discharge at the 95th percentile of their current discharge capacities (calculated based on discharge numbers listed in **Tables 4.2,** and **4.4** for the Grant Street WWTF and Barefoot Bay Advanced WWTF, respectively. BOD discharge from the Melbourne Joe Mullins Demineralization Concentrate was insignificant based on the BOD measurement shown in the facility's permit application. The facility's current permit does not require the facility to measure BOD concentration in its effluent.

Table 5-21. Existing and Target Loads of BOD to Impaired Tributary Segments and Needed Percent Reduction

	Addison Creek (WBID 3028)			Eau Gallie River (WBID 3082)			Crane Creek (WBID 3085A)		
Source	**Existing Loads**	**Target Loads**	**Needed Percent Reduction**	**Existing Loads**	**Target Loads**	**Needed Percent Reduction**	**Existing Loads**	**Target Loads**	**Needed Percent Reduction**
Immediate Watershed	128,727	35,605	72.3%	510,748	70,056	86.3%	556,136	110,408	80.1%
Upstream Discharge	0	0		0	0		0	0	
Wastewater Facility	0	0		0	0		139	139	0%
Total	**128,727**	**35,605**	**72.3%**	**510,748**	**70,056**	**86.3%**	**556,275**	**110,547**	**80.1%**
	North Prong of Sebastian River (WBID 3128)			**South Prong of Sebastian River (WBID 3129B)**			**Sebastian River Mainstem[1] (WBID 3129A)**		
Source	**Existing Loads**	**Target Loads**	**Needed Percent Reduction**	**Existing Loads**	**Target Loads**	**Needed Percent Reduction**	**Existing Loads**	**Target Loads**	**Needed Percent Reduction**
Immediate Watershed	923,523	279,639	69.7%	2,360,342	515,178	78.2%	372,648	92,916	75.1%
Upstream Discharge	0	0		0	0		6,298,945	1,629,213	74.1%
Wastewater Facility	2,707	2,707	0.0%	0	0		0	0	
Total	**926,230**	**282,346**	69.5%	**2,360,342**	**515,178**	**78.2%**	**6,671,593**	**1,722,130**	74.2%
	C-54 Canal[2] (WBID 3135)								
Source	**Existing Loads**	**Target Loads**	**Needed Percent Reduction**						
Immediate Watershed	583,717	314,381	46.1%						
Upstream Discharge	2,428,656	520,016	78.6%						
Wastewater Facility	0	0							
Total	**3,012,373**	**834,397**	72.3%						

Note:

- The unit of BOD loads is lbs/year.
- BOD loadings entering C-54 Canal from the Upstream Discharge include discharges from the Upper St. Johns basin through the control structure S-157 and from Fellsmere watershed. The BOD loadings from the Upper St. Johns River were not reduced. The loadings from the Fellsmere watershed were reduced to its background condition.
- Upstream BOD loadings entering the main stem of the Sebastian River Include those from the North and South Prongs and C-54 Canal.
- The wastewater facility BOD loads in the table represent the 95th percentile of facilities' existing discharge rate. Because BOD discharge loads from wastewater facilities were all less than 5% of the total BOD loads entering into related tributaries, the facility dischargers were allowed to discharge at the 95th percentile of their existing discharge capacity.

Based on **Table 5-21**, the percent reduction of BOD loadings needed to achieve the target loads ranges from 69.5% to about 86.3%. Higher percent reductions are needed for watersheds of the Eau Gallie River and Crane Creek, which are all above 80%. As shown in **Table 4.8** of **Chapter 4**, the watersheds of the Eau Gallie River and Crane Creek are dominated by urban lands. Therefore, BOD loads from human-impacted land areas are high and higher percent reductions are needed to achieve the background BOD loading targets. Relatively low percent reduction needs are for Addison Creek and the North Prong of Sebastian River. In the Addison Creek watershed, natural lands, including forest and wetlands, occupy about 66% of the watershed. In the watershed of the North Prong of the Sebastian River, natural lands occupy about 37% of the watershed area. In addition, 23% of the North Prong watershed areas are occupied by open lands, which have unit BOD loads close to those of the natural lands. The landuse pattern in these two relatively natural watershed results in relatively lower percent reductions for BOD in order to achieve the target. However, under the existing condition, BOD loadings from natural land areas in all the impaired watersheds included in this report are less than 20%. In fact, in most watersheds, BOD loadings from natural land areas contributed less than 10% of the total watershed BOD loads (**Table 4-22**). This is the reason why, overall, the needed percent reduction to achieve the BOD target loads are high for these watersheds.

HSPF model and EFDC models were used to demonstrate the DO condition in these impaired tributary segments once the target BOD loadings are achieved. Frequency distributions of DO concentrations were used to characterized the achievable DO when target BOD loadings were achieved. For the Crane Creek, North Prong of the Sebastian River, C-54 Canal, and South Prong of the Sebastian River, the EFDC model results were used to develop the frequency distributions. EFDC model background runs were conducted by entering all the flow and water constituent loadings from the background HSPF model runs. Tributary EFDC model boundary water quality constituents were kept as those under the existing condition. Because wastewater effluent BOD loads all only account for less than 5% of the total BOD loads into these tributaries, their existing discharge capacities were remained when conducting the EFDC model background runs. The background EFDC run DO results were extracted from the same EFDC grids used for the sensitivity analyses shown in **Figures 5.9**, **5.10**, and **5.11**. Data period used for developing the frequency distribution was the EFDC model time domain from January 1st of 2000 to December 31 of 2001.

For Addison Creek, as there was no EFDC model being developed, the distribution frequency was established using DO simulation results from HSPF models' background runs. The same model simulation period from January 1st of 2000 to December 31 of 2001 was used to ensure the time period consistency between the waterbodies covered by HSPF models and waterbodies covered by EFDC models.

Although the Eau Gallie River is covered by an EFDC model, a close examination of the measured data demonstrated that the DO measurements in 2000 and 2001 had a lower exceedance rate than in the other years. Therefore, an EFDC model calibrated using these two years of data may overestimate the long-term trend of the DO dynamics in this river segment. In contrast, the HSPF model for the Eau Gallie River was calibrated against the whole ten-year period from 1996 through 2005, which reflects the long-term trend better than the EFDC model. Therefore, in establishing the frequency distribution of DO dynamics for the Eau Gallie River under the background condition, results from the HSPF model were used.

As discussed in previous sections, DO concentrations in impaired tributaries included in this report were more influenced by SOD than by water column processes, such as algal respiration

and BOD decay. Therefore, to simulate the background DO concentration, it is important to set the background SOD properly. Because HSPF models do not simulate the SOD change with the change of watershed nutrients and BOD loads, the following procedure was used to calculate the SOD under the background loading condition:

(1) Calculating the total organic carbon (TOC) loads entering an impaired water segment was conducted using the following equation:

TOC Load = (BOD * C/O2 + Refractory OrgC + Algae Biomass (ug Chl/L) * C/Chl) * Flow Rate

Where,

- BOD is the BOD concentration in the receiving water.
- C/O2 is the carbon/oxygen stoichiometric ratio that is used to convert the biochemical oxygen demand into organic carbon amount.
- Refractory OrgC is the concentration of the refractory organic carbon in the receiving water.
- C/Chl is the carbon chlorophyll ratio used to convert the chlorophyll concentration to organic carbon amount.
- Flow Rate is the flow rate of the receiving water.

Parameters included in the above equation are all outputs from HSPF model simulation. HSPF models can be used to simulate these equation parameters for both the existing condition and background condition. Therefore, total TOC loads for existing and background conditions can be estimated using the above equation.

(2) As HSPF models output parameters using an hourly time step for the ten-year period from 1996 through 2005, the total TOC loads can be calculated for each hourly time step. Long-term average daily TOC loads for the ten-year period were then estimated for both the existing and background condition based on the hourly TOC time series simulated for the period.
(3) Calculating the ratio between the long-term average daily TOC loads under the background condition and the long-term average daily TOC loads under the existing condition.
(4) Calculating the square root of the ratio.
(5) Applying the ratio to the existing SOD of the model to calculate the SOD under the background condition.

After the above procedures were conducted, a newly calculated SOD number was entered into the HSPF model to re-simulate the background DO concentration. These DO time series were then used to develop the DO frequency distribution. **Table 5-22** shows the frequency distribution of DO concentration for each impaired tributaries after the BOD loading targets are achieved.

5.6. Nutrient Impairment:

As discussed in **Chapter 2**, in addition to the DO impairments verified for these tributaries, several tributaries, including the Eau Gallie River, Crane Creek, the main stem of the Sebastian River, the South Prong of the Sebastian River (marine segment), and the C-54 Canal, were also

verified as being impaired for nutrients. Among these nutrient impaired segments, the Eau Gallie River was verified for nutrients in the Department's Cycle 1 assessment because the annual average correct chlorophyll ***a*** concentration exceeded the 11 µg/L assessment threshold in 1999, 2000, 2001, and 2005. All the other tributary segments were verified for nutrient impairment as part of the Cycle 2 assessment. Crane Creek was verified for the nutrient impairment because its annual average correct chlorophyll a concentration exceeded the 11 µg/L threshold in 2008, 2009, and 2010. The South Prong of the Sebastian River was verified based on exceeding annual average chlorophyll a concentrations in 2005 and 2010. The C-54 Canal was verified for nutrients by exceeding annual chlorophyll a thresholds in 2005, 2008, and 2009. The main stem of the Sebastian River (previously the Sebastian River above Indian River) was verified for nutrient impairment due to its annual average chlorophyll a concentration exceeding the historic minimum of 4.9 µg/L by more than 50% in two consecutive years in 2009 and 2010. Because the time domain of the HSPF and EFDC model sets do not cover the period of those water segments verified in the Cycle 2 assessment, the Department used two approaches to address the nutrient impairment in these segments:

(1) Examining the long-term trend of corrected chlorophyll a in these tributaries. If the long-term trend of chlorophyll a concentration is relatively stable and part of the period of record can be covered by the HSPF models used in this project, the HSPF model will be used to examine the effect of nutrient on the chlorophyll a concentration and setting up nutrient target.

(2) If higher chlorophyll a concentrations were only observed in recent years, especially in years after 2008, the Department would compare the upstream and downstream trend of chlorophyll a in the impaired tributary segments and also compare the tributary chlorophyll a concentration to the chlorophyll a concentration in the main stem of the Indian River Lagoon to evaluate whether the observed elevation in tributary chlorophyll a concentration could be caused by processes within the receiving water or influenced by the processes in the Indian River Lagoon being brought into the tributary through tidal movement (i.e., not only related to elevated watershed nutrient loadings). If the Department could show that the elevated chlorophyll a concentration is not related to the elevation of the watershed nutrient loadings, the Department would not propose any further nutrient reductions beyond those already requested by the Indian River Lagoon main stem seagrass nutrient TMDLs previously adopted by the Department.

Table 5-22. Frequency Distribution of DO in Impaired Tributary Segments Under the Target BOD Condition

DO Unit: mg/L

Exceedance Frequency	Addison Creek	Eau Gallie River	Crane Creek	North Prong of Sebastian River	C-54 Canal	South Prong of Sebastian River	Sebastian River Main Stem
0%	0.32	2.43	3.37	2.24	1.99	2.71	3.42
10%	0.93	3.37	4.32	3.42	3.24	4.32	4.98
15%	1.31	3.53	4.52	3.65	3.46	4.65	5.16
20%	1.73	3.66	4.70	3.93	3.73	5.00	5.31
25%	2.18	3.76	4.89	4.28	4.01	5.33	5.46
30%	2.60	3.85	5.17	4.77	4.44	5.76	5.63
35%	2.95	3.94	5.47	5.30	4.97	6.08	5.86
40%	3.11	4.06	5.83	5.75	5.51	6.37	6.11
45%	3.34	4.26	6.19	6.26	6.13	6.63	6.36
50%	3.49	4.45	6.46	6.53	6.57	6.87	6.57
55%	3.68	4.71	6.69	6.74	6.83	7.07	6.73
60%	3.79	4.94	6.89	6.97	7.01	7.29	6.85
65%	3.87	5.10	7.02	7.19	7.18	7.52	6.97
70%	4.01	5.30	7.14	7.39	7.38	7.72	7.13
75%	4.23	5.48	7.30	7.58	7.56	7.87	7.26
80%	4.47	5.68	7.48	7.75	7.77	8.09	7.46
85%	4.61	5.97	7.65	8.03	8.01	8.33	7.67
90%	4.69	6.06	8.01	8.33	8.36	8.69	7.96
95%	4.80	6.33	8.48	8.81	8.93	9.31	8.47
100%	5.62	7.05	9.20	9.80	9.78	10.13	9.19

5.6.1 Eau Gallie River Nutrient Impairment:

Nutrient impairment for the Eau Gallie River was verified in Department's Cycle 1 water quality assessment based on the observation that the annual average chlorophyll a concentration exceeded the 11 µg/L threshold in 1999, 2000, 2001, and 2005. Chlorophyll a data collected in the following years also verified the high chlorophyll *a* concentration in the river. In the Eau Gallie River, the SJRWMD maintains two long-term water quality monitoring stations. One is located in the river at the highway US-1 (21FLSJWMIRLEGU). The other one is located upstream of the control structure (21FLSJWMIRLUPEGWR), which is about 1 mile upstream of the highway US-1. These two stations showed very different nutrient condition. The downstream station is the station that constantly show chlorophyll a concentrations higher than the 11 µg/L threshold. Data started to be collected at the upstream sites since 2004. The chlorophyll *a* measurements at the upstream site have been consistently lower than the downstream site. In contrast, TP concentrations at the upstream site were consistently higher than the downstream site, but the TN concentrations at the upstream site were consistently lower than the downstream site. **Figure 5-19** shows the location of two water quality stations. **Figures 5.20**, **5.21**, and **5.22** show the annual average chlorophyll *a*, TN, and TP concentrations at these two sites.

Eau Gallie River is covered by both HSPF and EFDC models in this project. The HSPF model was calibrated using the chlorophyll a concentration data collected from the upstream site, and the EFDC model was calibrated using the chlorophyll a data collected from the downstream site. As shown in **Figure 5.20**, the vast majority of the data used to verify the nutrient impairment of the river were collected from the downstream site. Therefore, it is reasonable that, when setting the nutrient target, the chlorophyll simulated by the EFDC model, which represent the downstream chlorophyll a condition, can be used as a major bench mark. However, because the EFDC model's time domain only include 2000 and 2001, the Department originally planned to use the HSPF model chlorophyll a concentration results to established the target nutrient loads because the HSPF model covers a period of ten years. When establishing the ADOC for the Eau Gallie River, because DO concentrations in 2000 and 2001 at the downstream site appeared to be better than DO concentrations in years after 2001, the Department used HSPF model simulated DO to established the alternative DO criteria to avoid overestimate the DO concentration. That decision was made based on the observation that the DO dynamics at both the upstream and downstream sites were very similar since 2004 when DO data started to be collected from the upstream site. However, base on the chlorophyll *a* and nutrient concentrations shown in **Figures 5.20**, **5.21**, and **5.22,** unlike the DO dynamic, the chlorophyll *a* dynamics at the upstream and downstream sites were very different. Using the HSPF simulated chlorophyll a concentration for the upstream segment to represent the downstream chlorophyll a condition is not appropriate. Therefore, although the EFDC model for the Eau Gallie River only covers 2000 and 2001, the Department decided to use it to set the nutrient targets for the river. Examining the annual chlorophyll a concentration distribution at the downstream site in the period from 1999 through 2005 appears to support this decision. The average annual mean chlorophyll a concentration in 2000 and 2001 was about 19.75 µg/L while the long-term average chlorophyll a concentration for the period from 1999 through 2005 were about 17.04 µg/L. The difference between the two means is about 2.71 µg/L. Considering that the standard deviation of the chlorophyll a concentration in the period from 1999 through 2005 was about 4.33 µg/L, the mean chlorophyll a trend in the 2000-2001 period appears to represent the long-term trend of the chlorophyll at the downstream station.



Figure 5-19. Water Quality Stations in the Eau Gallie River

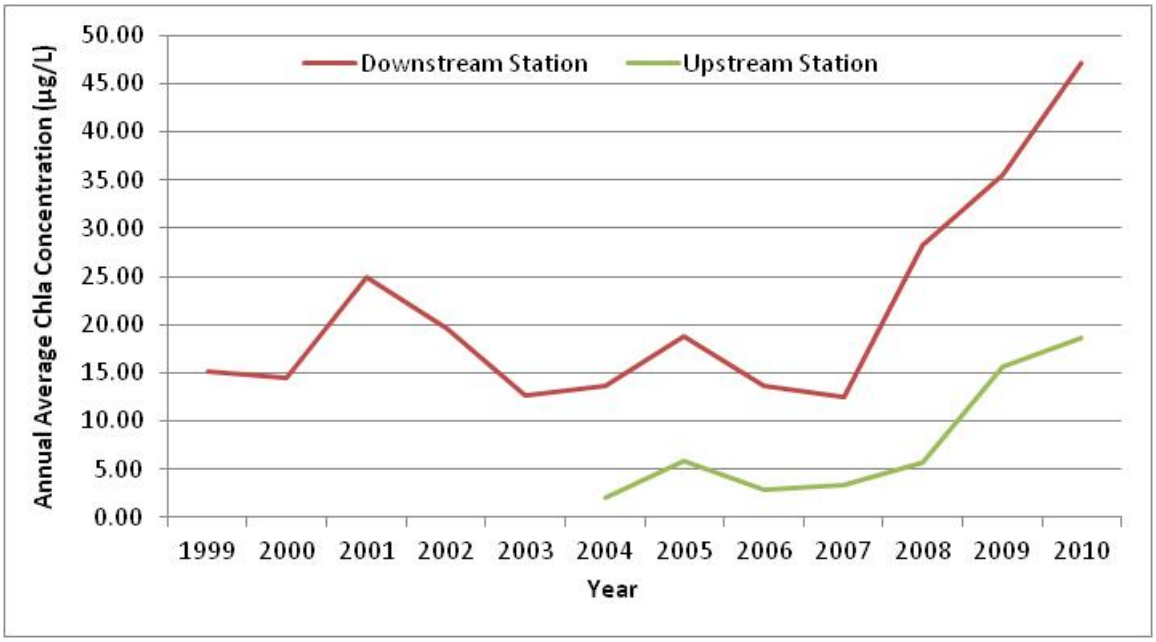


Figure 5-20. Annual Average Chlorophyll a Concentration at the Upstream and Downstream Sites in the Eau Gallie River

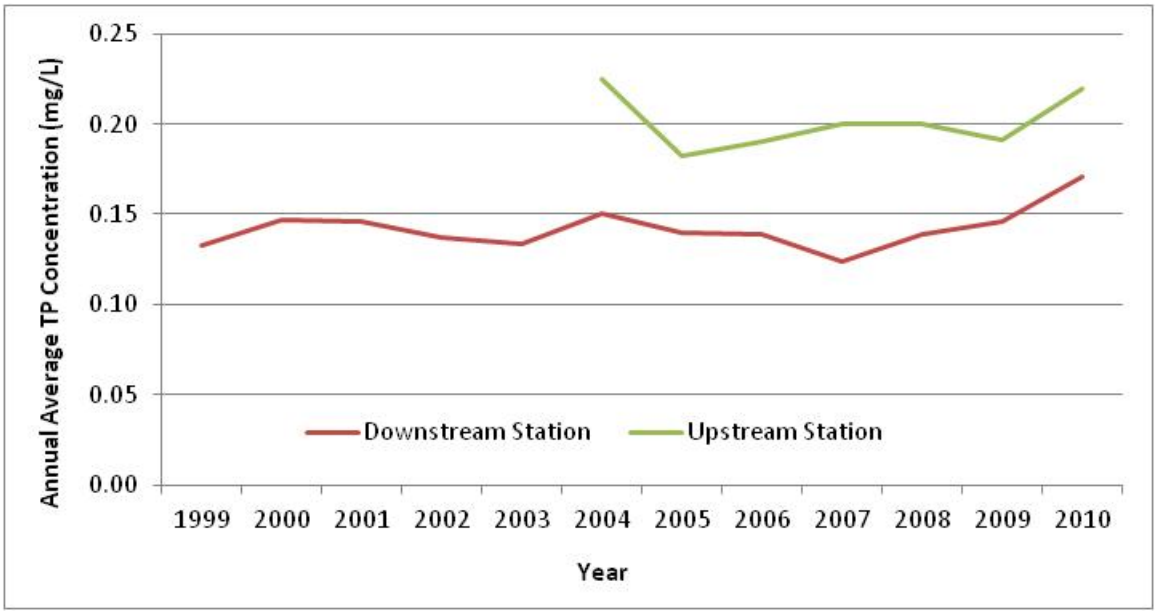


Figure 5-21. Annual Average TP Concentration at the Upstream and Downstream Sites in the Eau Gallie River

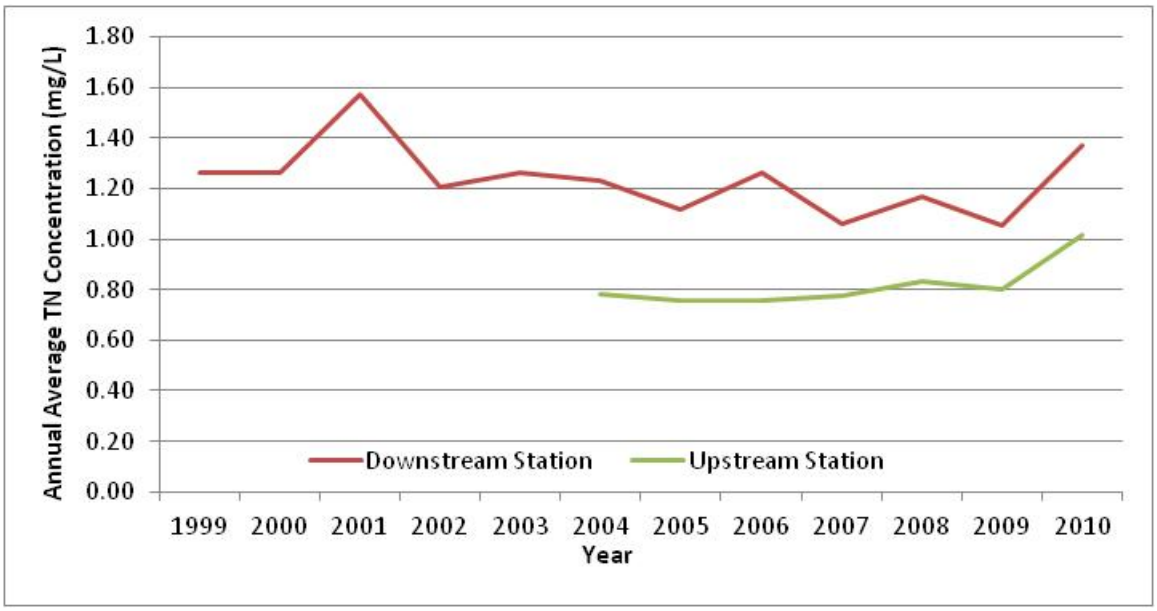


Figure 5-22. Annual Average TN Concentration at the Upstream and Downstream Sites in the Eau Gallie River

Because the Eau Gallie River watershed is located in the part of the Indian River Lagoon drainage areas that discharge to the lagoon segment IR 9-11, which has a nutrient reduction requirement of 36% of TN and 48% of TP adopted by the Department through the adoption of the Indian River Lagoon main stem nutrient TMDLs to protect the seagrass (FDEP, 2009), the Department first applied these percent reductions to the HSPF-EFDC model set, but the resulted annual average chlorophyll a concentrations were still higher than the 11 µg/L. The department then used the HSPF model to simulate the background nutrient loads and entered these loads into the EFDC model to simulate the chlorophyll *a* concentration under the background condition. The background HSPF model was set up the same way as it is discussed in **Section 5.5**. The EFDC model simulated the annual average chlorophyll a concentrations under the background condition were 9.06 µg/L and 11.3 µg/L for 2000 and 2001, respectively. On average, the annual average chlorophyll a concentration under the background condition was estimated as about 10.18 µg/L. **Table 5.23** shows the existing and background TN and TP loads simulated by the HSPF model and the needed percent reductions of TN and TP from the existing loadings in order to achieve the background loadings. Because it is the Department's policy not to reduce pollutant loadings below the natural background condition, the background nutrient loads were considered the target nutrients to address the nutrient impairment in the Eau Gallie River. Based on **Table 5.23**, in order to achieve the target TN and TP loads, the needed percent reductions for TN and TP from the existing condition are about 51% for TN and 58% for TP.

It should be noted that, because the existing watershed TN loads to the Eau Gallie River listed in **Table 4.13-a**, which is 58,860 lbs/year, was simulated using the PLSM model with a fixed 30-year long-term average annual rainfall and fixed runoff coefficient and event mean concentration, it is not surprise that the PLSM loadings will be different from the loadings

simulated by the HSPF model, which uses hourly varied rainfall, to simulate runoff based on different runoff creation rate based on the soil moisture condition and different nutrient loadings based on different buildup and wash-off of pollutant from the land surface. The long-term average existing TN loadings simulated by the HSPF model for the period from 1996 through 2005, based on **Table 5.23**, is about 79,175 lbs/year. The PLSM simulated TN loading was about 26% less than the HSPF model simulated results, which, considering all the uncertainties associated with these model, is considered reasonable. At the same time, although the TP existing loading entering the Eau Gallie River listed on **Table 4.14** was simulated using the HSPF model developed by the SJRWMD, which is about 10,254 lbs/year, because both the SJRWMD's HSPF model and CDM HSPF model used the similar modeling mechanism, the existing TP loads from both HSPF models were very similar. The existing condition TP loadings simulated using the CDM HSPF model is about 10,504 lbs/year, which is only about 2% different from the TP loadings results from the SJRWMD's HSPF model. In order to use a consistent load allocation system, when establishing the load allocation and waste load allocation, which will be discussed in details in **Chapter 6**, the Department used the PLSM model simulated existing TN loads (**Table 4.13-a**), and SJRWMD's HSPF model simulated existing TP loads (**Table 4.14**) as the allocation basis. The existing and background TN and TP loadings listed in **Table 5.23** were only used to calculate the needed percent reductions to achieve the target nutrient loadings. These percent reductions were then applied to the existing TN and TP loadings listed in tables **4.13-a** and **4.14** to estimate the final target TN and TP loads.

Table 5.23. Existing TN and TP Loads, Target TN and TP Loads, and Needed Percent Reductions for the Eau Gallie River

Year	Existing TP Loads (lbs/year)	Target TP Loads (lbs/year)	Needed Percent Reduction	Existing TN Loads (lbs/year)	Target TN Loads (lbs/year)	Needed Percent Reduction
1996	9,604	3,445	64%	72,224	27,620	62%
1997	10,864	3,991	63%	80,379	34,444	57%
1998	9,234	3,987	57%	68,454	31,826	54%
1999	14,368	6,899	52%	108,756	57,691	47%
2000	7,021	3,484	50%	52,796	27,308	48%
2001	10,459	4,653	56%	79,328	41,030	48%
2002	11,144	4,091	63%	83,700	38,130	54%
2003	9,587	3,588	63%	70,457	30,898	56%
2004	10,351	4,563	56%	80,073	43,112	46%
2005	12,407	5,210	58%	95,582	52,812	45%
Mean	10,504	4,391	58%	79,175	38,487	51%

5.6.2 Nutrient Impairments Verified in the Cycle 2 Assessment

The other four tributary segments, including Crane Creek (marine segment), the main stem of the Sebastian River, C-54 Canal, and the South Prong of the Sebastian River, were all verified for nutrient impairment in the Department's Cycle 2 water quality assessment. A common trend shown by all these four tributary segments was that, during the Cycle 2 Verified Period (2004 through 2010, in all or part of the period 2008 to 2010, showed significantly increased chlorophyll a concentration in these tributaries. **Table 5.24** shows the annual average chlorophyll a concentrations in each of these impaired segments in the period from 2004 through 2010.

Table 5.24. Annual Average Chlorophyll *a* Concentrations of the Four Tributary Segments Verified for Nutrient Impairment in the Cycle 2 Assessment

Year	Crane Creek	Main Stem of Sebastian River	South Prong of Sebastian River	C-54 Canal
2004	8.61	3.28	6.37	8.24
2005	5.96	7.42	13.29	9.77
2006	9.08	3.11	5.48	9.38
2007	9.93	3.54	5.32	6.77
2008	11.88	6.77	8.91	14.00
2009	21.04	7.62	9.28	11.68
2010	27.45	10.31	15.40	19.86

A natural question in examining these elevated chlorophyll a concentrations is whether the observed chlorophyll hike was caused by elevated watershed nutrient loadings. If the elevated chlorophyll a concentrations were not directly related to the elevated watershed nutrient loadings from the watershed, requesting nutrient load reduction beyond those already requested by the main stem Indian River Lagoon seagrass TMDLs may not be the most efficient way of controlling the chlorophyll a concentration in these tributary segments.

Because 2008, 2009, and 2010 were all beyond the time domain of the HSPF models set up for these impaired tributaries, it is infeasible to estimate nutrient loads from watersheds of these impaired tributaries directly and compare them to the nutrient loads in years before these three years. In addition, as shown in **Table 5.24**, the elevated chlorophyll a in 2008, 2009, and 2010 did not quite follow the chlorophyll a trend in years before these three years. There is a possibility that the elevation could be caused by something other than nutrients, which may not be included in the hypotheses of the existing HSPF-EFDC modeling set. Therefore, instead of using the HSPF-EFDC modeling set to set nutrient loading targets, some hydrology and water chemistry characteristics of these tributaries were examined to evaluate whether the observed elevation was caused by the elevated nutrient loadings from the watershed. These hydrology

and water chemistry characteristics include regional rainfall, available flow measurements, water column conductance, and TN and TP concentrations.

Because there are no watershed loading models that covered the watersheds of nutrient impaired segments for years 2008, 2009, and 2010, the Department examined the regional rainfall data collected from four weather stations located in the Melbourne and Vero Beach areas that are close to these nutrient impaired tributary segments for the period from 2004 through 2010 (the Verified Period for these nutrient impaired water segments). These stations included ones located at Melbourne International Airport, Melbourne WFO, Vero Beach International Airport, and Vero Beach 4SE. Rainfall data from these stations were obtained from the Southeast Regional Climate Center (SERCC)'s CLimate Information for Management and Operational Decisions (CLIMOD) system (http://climod.meas.ncsu.edu/). The goal was to examine whether the annual rainfall increased in 2008, 2009, and 2010. Because rainfall is a driving force for watershed nutrient loadings, an increased annual rainfall can be used to represent increased loadings and vise versa.

Figure 5.23 shows the location of the weather stations used in this analysis. **Tables 5.25-a, 5.25-b, 5.25-c, and 5.25-d** list monthly and annual rainfall estimations for these weather stations.

Table 5.25-a. Monthly and Annual Rainfall at Melbourne Intl Airport

Year	Monthly Rainfall (in/month)												Annual Total (in/yr.)
	1	2	3	4	5	6	7	8	9	10	11	12	
2004	2.13	2.56	1.05	1.03	0.99	10.59	2.48	10.56	7.11	4.89	1.21	3.01	47.61
2005	1.67	3.5	4.13	2.25	4.09	11.37	2.35	7.17	8	11.85	1.2	2.23	59.81
2006	0.54	2.15	0.3	1.15	1.73	7.06	8.19	6.92	5.98	1.02	3.67	1.32	40.03
2007	2.01	1.76	0.52	1.46	1.36	9.49	11.47	1.17	8.95	4.14	0.94	0.69	43.96
2008	2.97	2.21	2.7	2.18	0.46	6.33	11.01	21.06	3.31	9.07	2.43	0.76	64.49
2009	0.93	1.06	0.86	2.16	9.28	3.97	7.61	3.49	8.99	0.74	0.37	5.52	44.98
2010	0.94	2.57	8.74	2.13	0.29	2.9	1.23	5.59	5.94	0	3.43	1.95	35.71

Table 5.25-b. Monthly and Annual Rainfall at Melbourne WFO

Month	Monthly Rainfall (in/month)												Annual Total (in/yr.)
	1	2	3	4	5	6	7	8	9	10	11	12	
2004	1.48	3.75	1.01	1.16	1.15	8.93	2.81	11.72	16.65	3.95	0.99	3.53	57.13
2005	1.75	4.19	4.77	2.45	3.57	12.87	2.63	7.19	8.94	13.36	1.39	2.9	66.01
2006	0.61	2.2	0.28	1.1	2.06	6.4	8.17	8.99	6.19	0.73	3.73	1.72	42.18
2007	2.79	2.14	0.62	1.94	1.74	10.72	15.05	1.34	8.97	5.53	1.17	1	53.01
2008	3.79	2.99	2.82	2.58	1.16	6.72	11.15	26.87	4.24	10.24	2.35	1.19	76.10
2009	0.97	0.84	0.98	2.27	11.72	4.4	8.33	5.44	8.08	1.01	0.38	5.96	50.38
2010	0.98	3.19	9.5	2.6	0.3	4.85	1.35	7.32	7.07	0.13	2.31	1.95	41.55

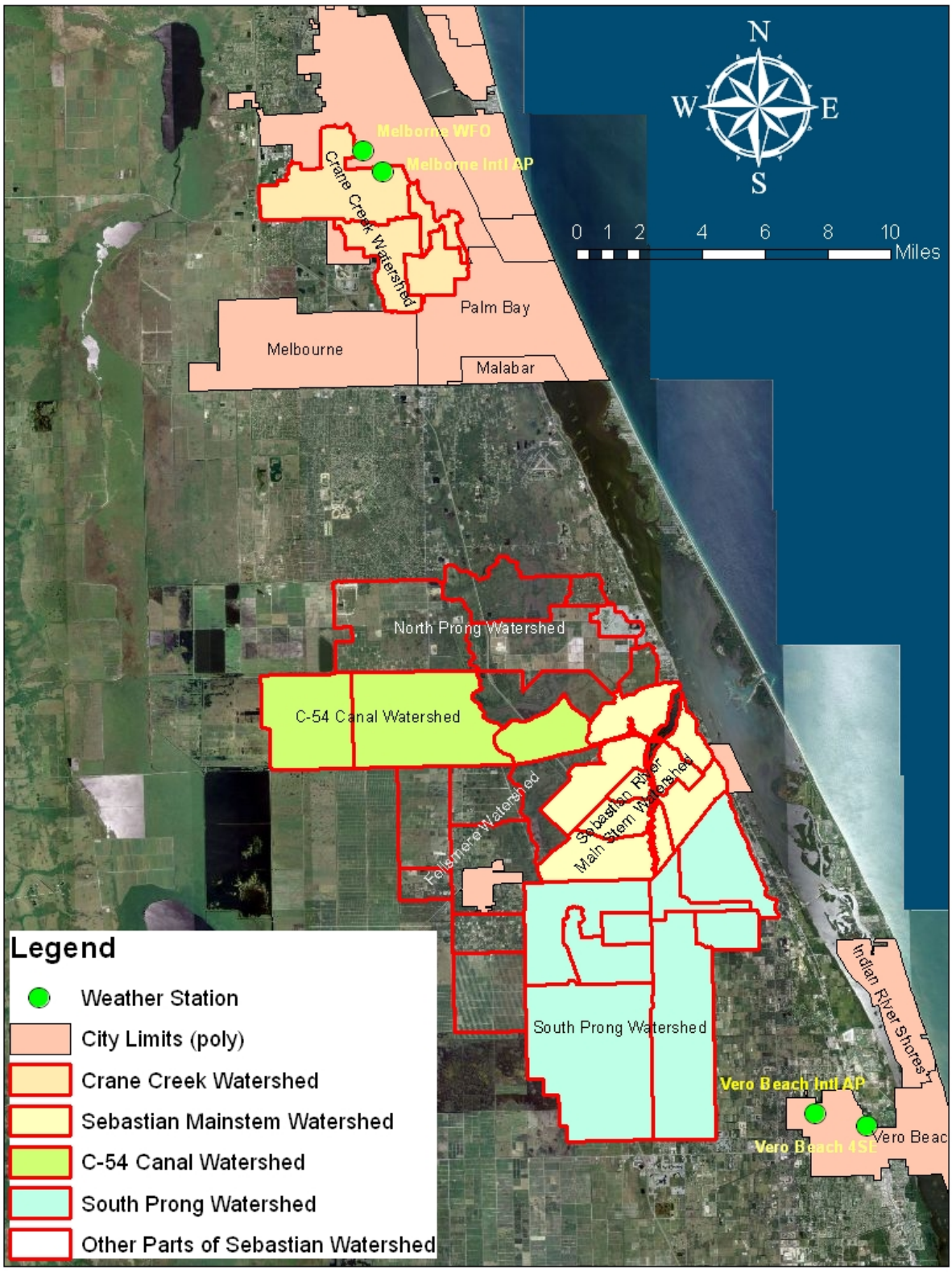


Figure 5.23. Weather Stations Used for the Rainfall Analysis

Table 5.25-c. Monthly and Annual Rainfall at Vero Beach Intl Airport

Row Labels	Monthly Rainfall (in/month)												Annual Total (in/yr.)
	1	2	3	4	5	6	7	8	9	10	11	12	
2004	2.78	2.95	0.84	1.5	0.09	3.87	3.86	9.71	23.01	3.59	0.95	2.55	55.7
2005	1.14	2.12	7.78	3.18	4.8	12.11	1.51	3.81	5.06	7.89	5.86	2.15	57.41
2006	0.33	3.53	0.53	1.09	1.37	7.96	4.23	4.89	5.64	0.98	1.12	1.89	33.56
2007	0.76	1.1	1.04	2.16	1.97	7.31	13.72	2.4	6.01	7.92	2.49	2.1	48.98
2008	1.22	1.46	3.87	3.96	2.08	3	6.97	18.91	2.62	7.91	3.4	0.45	55.85
2009	1.57	0.16	2.62	0.44	10.52	4.5	4.76	3.66	4.79	0.48	2.89	5.58	41.97
2010	0.94	2.14	9.42	3.91	3.16	5.11	1.67	2.89	4.8	0.01	2.43	0.56	37.04

Table 5.25-d. Monthly and Annual Rainfall at Vero Beach 4SE

Row Labels	Monthly Rainfall (in/month)												Annual Total (in/yr.)
	1	2	3	4	5	6	7	8	9	10	11	12	
2004	1.88	3.3	1.05	1.86	1.09	7.78	2.85	8.92	23.24	3.41	1.32	4.92	61.62
2005	1.72	2.11	8.26	3.2	4.18	13.77	3.39	4.53	6.9	12.1	5.38	2.49	68.05
2006	2.3	3.61	0.53	1.82	1.65	9.57	4.31	4.95	6.32	1.17	1.97	1.92	40.12
2007	1.1	1.23	1.1	2.14	2.16	7.58	13.14	3.5	6.77	8.16	2.27	2.1	51.25
2008	1.68	1.83	4.12	5.21	2.45	3.74	8.15	20.26	3.21	8.13	3.41	1.63	63.82
2009	1.26	0.28	1	1.68	11.45	4.1	4.96	4.21	6.04	0.48	2.9	5.1	43.46
2010	0.98	2.16	9.12	4.06	3.16	5.27	1.45	2.45	5.94	0.02	1.95	0.68	37.24

Rainfall records summarized for the four weather stations all show that, while the annual rainfall increased in 2008, mainly due to Hurricane Fay hitting Florida's east coast in August, the total annual rainfall for both 2009 and 2010 all decreased compared to most other years in the Verified Period from 2004 through 2010. This implies the reduced nonpoint source nutrient loadings from watersheds of these impaired tributaries. The elevated annual rainfall in 2008 might have brought more nutrients into these impaired systems. However, in most of these nutrient impaired watershed, higher chlorophyll a concentrations were observed in 2009 and 2010, which were the two dry years expected to produce lower watershed nutrient loads. Considering that, in ambient water, the phytoplankton population doubling time ranged from several days to about a week, it is not very likely that phytoplankton population would wait for one or two years to respond to the nutrient being brought into these systems. In addition, the watersheds of these impaired tributaries also experienced the high rainfall years in 2004 and 2005. Chlorophyll a concentration in 2006 and 2007 for most tributaries remained relatively low compared to 2009 and 2010. Therefore, possible increase in nutrient loadings in 2008 is likely not to be a major factor contributing to the chlorophyll a concentrations in 2009 and 2010.

In order to confirm that the decreased rainfall in 2009 and 2010 indeed resulted in lowered watershed nutrient loads. Flow measurements collected from two USGS gauges, including one

located in Crane Creek (02249500) and one located in the South Prong of the Sebastian River (02251000). These flow measurements were obtained from the USGS Surface-Water Data for the Nation website (http://waterdata.usgs.gov/usa/nwis/sw). **Table 5.26-a and 5.26-b** show the monthly and annual flow measured at these two gauges.

Table 5.26-a. Monthly and Annual Flow Measured in Crane Creek

Year	Months (ac-ft/month)												Annual Total (ac-ft/yr)
	1	2	3	4	5	6	7	8	9	10	11	12	
2004	561	607	539	454	357	855	473	1,736	5,927	2,376	863	926	15,674
2005	845	976	1,361	1,049	1,109	2,650	1,954	1,317	1,868	3,572	1,791	1,297	19,789
2006	715	513	402	362	337	645	954	1,912	2,041	1,281	1,109	604	10,873
2007	513	488	532	536	497	1,197	2,527	1,287	1,936	1,847	696	512	12,568
2008	539	523	306	601	853	670	2,404	8,977	2,918	3,039	1,347	885	23,061
2009	774	586	592	629	1,439	1,710	2,009	2,021	1,884	861	445	658	13,607
2010	612	635	1,652	1,448	1,085	780	1,248	1,492	2,007	1,033	610	543	13,145

Table 5.26-b. Monthly and Annual Flow Measured in the South Prong of the Sebastian River

Year	Monthly Flow (ac-ft/month)												Annual Total (ac-ft/yr)
	1	2	3	4	5	6	7	8	9	10	11	12	
2004	3,178	4,128	1,791	1,299	1,482	1,841	2,065	6,188	41,958	21,376	3,838	3,683	92,826
2005	4,740	3,866	10,528	4,979	6,728	20,983	8,275	5,689	5,572	15,824	7,531	7,422	102,137
2006	3,283	5,377	2,505	1,779	1,460	6,264	8,337	2,801	4,076	1,347	1,706	1,993	40,927
2007	2,208	1,942	1,474	1,327	1,529	3,312	10,225	5,191	9,037	17,984	2,805	2,087	59,119
2008	1,916	1,654	1,819	2,340	553	446	11,185	23,219	12,516	10,449	4,818	2,285	73,200
2009	1,615	1,355	1,071	1,055	3,977	6,926	15,816	8,864	6,065	2,085	1,664	6,619	57,112
2010	3,398	3,408	12,065	5,558	3,927	5,064	2,713	2,047	2,999	2,216	1,894	1,860	47,149

As shown in **Tables 5.26-a** and **5.26-b**, annual flow in both Crane Creek and the South Prong of the Sebastian River increased in 2008. For Crane Creek, the 2008 was the highest flow year during the Verified Period. In the South Prong of the Sebastian River, total annual flow in 2008 was lower than annual flows in 2004 and 2005, but higher than in 2009 and 2010. In both creeks, 2009 and 2010 annual flows were similar to the annual flows in two dry years in 2006 and 2007. These data confirm the rainfall data trend that total flows created from the general areas where these impaired tributaries are located did not increase significantly in 2009 and 2010 compared to years before them.

That these nutrient impaired segments were controlled more by the marine water than by the freshwater discharge from their watersheds can also be shown based on water column conductivity measurements collected from these systems. **Table 5.27** shows the annual average conductivities measured in these impaired tributaries. As these table shows,

conductivity values in all impaired tributaries rose to their highest levels in 2009 and 2010, suggesting less freshwater and input and increased sea water intrusion. This also suggests that 2009 and 2010 should not be the two years that higher nutrient loads would be entering these impaired segments.

Table 5.27. Water Column Conductivity Measurements in Nutrient-Impaired Tributary Segments (Unit: µmhos/cm)

Year	Crane Creek	Main Stem of Sebastian River	South Prong of Sebastian River	C-54 Canal
2004	21362	34911	22735	31109
2005	9303	32874	15867	30881
2006	14182	41920	25574	37411
2007	29683	42681	27502	37078
2008	28896	39263	23099	33654
2009	34201	44403	30535	39923
2010	37405	45133	34629	41744

In most nutrient-impaired water segments, no significant increase in TN and TP concentrations was observed in these high chlorophyll a years. **Tables 5.28** and **5.29** show annual average TN and TP concentrations in these impaired waters in the Verified Period.

Table 5.28. TP Concentrations in Nutrient-Impaired Tributary Segments (Unit: mg/L)

Year	Crane Creek	Main Stem of Sebastian River	South Prong of Sebastian River	C-54 Canal
2004	0.14	0.11	0.18	0.14
2005	0.13	0.09	0.15	0.13
2006	0.15	0.06	0.12	0.11
2007	0.11	0.11	0.15	0.12
2008	0.12	0.10	0.16	0.13
2009	0.10	0.12	0.20	0.15
2010	0.13	0.10	0.14	0.14

Table 5.29. TN Concentrations in Nutrient-Impaired Tributary Segments (Unit: mg/L)

Year	Crane Creek	Main Stem of Sebastian River	South Prong of Sebastian River	C-54 Canal
2004	1.00	0.90	1.02	1.05
2005	0.93	0.95	1.10	1.01
2006	1.05	0.56	0.77	0.79
2007	0.89	0.77	0.88	0.89
2008	0.83	0.67	0.79	0.77
2009	0.73	0.80	0.98	0.77
2010	1.05	0.72	0.89	1.10

Summarizing the data presented above, it can be seen that, while chlorophyll a concentrations started to increase in some of these nutrient-impaired tributary segments, in most cases, the highest chlorophyll a concentrations appeared in 2009 and 2010. However, based on the rainfall and flow data collected for the general areas where these impaired segments are located, it is not very likely that nutrient loadings entering these water segments were significantly increased in 2009 and 2010. The conductivity measurements also confirmed that these water segments were more controlled by marine water input than influenced by the freshwater discharges from their watersheds in 2009 and 2010 than in previous years. In addition, no significant increase of TN and TP concentrations were observed when high chlorophyll a concentrations were observed in these impaired segments, which is another line of evidence that the elevation of chlorophyll a concentrations in these impaired segments might not be caused by the increased nutrient loadings from their watersheds.

It is currently not clear what caused the elevated chlorophyll a concentrations in recent years. The SJRWMD is now actively working with several universities and other research institutes to identify possible causes that contribute to the observed algal blooms that appeared in the Indian River Lagoon systems in recent years. So far, the Department does not have sufficient information and evidence to link the observed elevations in chlorophyll a concentrations to increased watershed nutrient loadings. Many other factors may cause chlorophyll a concentration to increase in the lagoon and tributary system. Die-off of maco-algae can release nutrients into the water column and stimulate phytoplankton growth, a cold winter might have killed some of the zooplankton population and thereby removed the local phytoplankton population from the top-down control, or a switch of the phytoplankton community structure may be facilitated by switching to algal species that can take advantage of organic nutrient. Elevated chlorophyll a concentrations may also be caused by dominance of the phytoplankton communities by species that have higher chlorophyll a content. There can be even more hypotheses regarding the observed elevation in chlorophyll a concentration in recent years that can be tested. Until the real cause(s) are identified and linked to watershed nutrient loadings, the Department will not propose nutrient reductions beyond those already identified by currently adopted the main stem seagrass nutrient loading targets.

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (wasteload allocations, or WLAs), nonpoint source loads (load allocations, or LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

As discussed earlier, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$TMDL \cong \sum WLAs_{wastewater} + \sum WLAs_{NPDES\ Stormwater} + \sum LAs + MOS$$

It should be noted that the various components of the revised TMDL equation may not sum up to the value of the TMDL because (1) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is also accounted for within the LA, and (2) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as percent reduction because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish the loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges also differs from the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the "maximum extent practical" through the implementation of BMPs.

This approach is consistent with federal regulations (40 CFR § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or other appropriate measure. TMDLs for the impaired tributaries of Indian River Lagoon are expressed in terms of pounds per year, pounds per day, and percent reduction of TN, TP, and BOD, and represent the long-term average TN, TP, and BOD loadings that these Indian River Lagoon tributary segments can assimilate and maintain a balanced aquatic flora and fauna **(Tables 6.1-a, 6.1-b, and 6.1-c**). It should be noted that the expression of the TMDL on a mass per day basis is for informational purposes only. The implementation of these TMDLs should be using an annual time scale.

Table 6.1-a. TN TMDL Components for DO and Nutrient Impaired Tributary Segments in Indian River Lagoon Basin

WBID	Parameter	TMDL (lb/yr)	$WLA_{NPDES\ wastewater}$ (lb/yr)	$WLA_{NPDES\ Stormwater}$ *	LA (lb/yr)	MOS
Addison Creek (3028)	TN	North IRL TN Target[1]	N/A	North IRL TN Target	North IRL TN Target	Implicit
Eau Gallie River (3082)	TN	28,842	Must meet the WLA of the IRL main stem TMDL allocated to the Joe Mullins Demineralization Concentrate (FL0043443)	51%	51%	Implicit
Crane Creek (3085A)	TN	Central IRL TN Target[2]	Must meet the WLA of the IRL main stem TMDL allocated to the Grant Street WWTF (FL0041122)	Central IRL TN Target	Central IRL TN Target	Implicit
North Prong of the Sebastian River (3128)	TN	Central IRL TN Target	Must meet the WLA of the IRL main stem TMDL allocated to the Barefoot Bay Advanced WWTF (FL0042293)	Central IRL TN Target	Central IRL TN Target	Implicit
South Prong St. Sebastian River Estuary Segment (3129B1)[3]	TN	Central IRL TN Target	N/A	Central IRL TN Target	Central IRL TN Target	Implicit
South Prong St. Sebastian River Estuary Segment (3129B2)[3]	TN	Central IRL TN Target	N/A	Central IRL TN Target	Central IRL TN Target	Implicit
Sebastian River above Indian River (3129A)	TN	Central IRL TN Target	N/A	Central IRL TN Target	Central IRL TN Target	Implicit
C-54 Canal (previous 3135 now 3135A)	TP	Central IRL TN Target	N/A	Central IRL TN Target	Central IRL TN Target	Implicit

N/A in this table means not applicable.
1: Watershed area of the tributary segment must meet the TMDL targets set for the North Indian River Lagoon drainage areas.
2: Watershed area of the tributary segment must meet the TMDL targets set for the Central Indian River Lagoon drainage areas.
3: This TMDL addresses the DO impairment of the original WBID 3129B, which was named the “Sebastian River” and included both the estuary and freshwater segments of the South Prong of the Sebastian River. The TMDL developed for WBID 3129B applies to both the estuary (3129B1) and freshwater (3129B2) segments of the South Prong.

Table 6.1-b. TP TMDL Components for DO and Nutrient Impaired Tributary Segments in the Indian River Lagoon Basin

WBID	Parameter	TMDL (lb/yr)	$WLA_{NPDES\ wastewater}$ (lb/yr)	$WLA_{NPDES\ Stormwater}$	LA (lb/yr)	MOS
Addison Creek (3028)	TP	North IRL TP Target[1]	N/A	North IRL TP Target	North IRL TP Target	Implicit
Eau Gallie River (3082)	TP	4,307	Must meet the WLA of the IRL main stem TMDL allocated to the Joe Mullins Demineralization Concentrate (FL0043443)	58%	58%	Implicit
Crane Creek (3085A)	TP	Central IRL TP Target[2]	Must meet the WLA of the IRL main stem TMDL allocated to the Grant Street WWTF (FL0041122)	Central IRL TP Target	Central IRL TP Target	Implicit
North Prong of the Sebastian River (3128)	TP	Central IRL TP Target	Must meet the WLA of the IRL main stem TMDL allocated to the Barefoot Bay Advanced WWTF (FL0042293)	Central IRL TP Target	Central IRL TP Target	Implicit
South Prong St. Sebastian River Estuary Segment (3129B1)[3]	TP	Central IRL TP Target	N/A	Central IRL TP Target	Central IRL TP Target	Implicit
South Prong St. Sebastian River Freshwater Segment (3129B2)[3]	TP	Central IRL TP Target	N/A	Central IRL TP Target	Central IRL TP Target	Implicit
Sebastian River above Indian River (3129A)	TP	Central IRL TP Target	N/A	Central IRL TP Target	Central IRL TP Target	Implicit
C-54 Canal (previous 3135 now 3135A)	TP	Central IRL TP Target	N/A	Central IRL TP Target	Central IRL TP Target	Implicit

N/A in this table means not applicable.
1: Watershed area of the tributary segment must meet the TMDL targets set for the North Indian River Lagoon drainage areas.
2: Watershed area of the tributary segment must meet the TMDL targets set for the Central Indian River Lagoon drainage areas.
3: This TMDL addresses the DO impairment of the original WBID 3129B, which was named the “Sebastian River” and included both the estuary and freshwater segments of the South Prong of the Sebastian River. The TMDL developed for WBID 3129B applies to both the estuary (3129B1) and freshwater (3129B2) segments of the South Prong.

Table 6.1-c. BOD TMDL Components for DO Impaired Tributary Segments in the Indian River Lagoon Basin

WBID	*Parameter*	TMDL (lb/yr)	$WLA_{NPDES\ wastewater}$ (lb/yr)	$WLA_{NPDES\ Stormwater}$	LA (lb/yr)	MOS
Addison Creek (3028)	*BOD*	35,605	N/A	72.3%	72.3%	Implicit
Eau Gallie River (3082)	*BOD*	70,056	N/A	86.3%	86.3%	Implicit
Crane Creek (3085A)	*BOD*	110,547	139	80.1%	80.1%	Implicit
North Prong of the Sebastian River (3128)	*BOD*	282,346	2,707	69.7%	69.7%	Implicit
South Prong St. Sebastian River Estuary Segment (3129B1)[1]	*BOD*	515,178	N/A	78.2%	78.2%	Implicit
South Prong St. Sebastian River Freshwater Segment (3129B2)[1]	*BOD*		N/A			Implicit
Sebastian River above Indian River (3129A)	*BOD*	1,722,130	N/A	74.2%	74.2%	Implicit
C-54 Canal (previous 3135 now 3135A)	*BOD*	834,397	N/A	72.3%	72.3%	Implicit

N/A in this table means not applicable.

1: This TMDL addresses the DO impairment of the original WBID 3129B, which was named the "Sebastian River" and included both the estuary and freshwater segments of the South Prong of the Sebastian River. The TMDL developed for WBID 3129B applies to both the estuary (3129B1) and freshwater (3129B2) segments of the South Prong.

Based on a memorandum that USEPA issued in November of 2006 regarding "Establishing "daily" loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et. al., No. 05-5015 (April 25, 2006) and Implications for NPDES permits," daily loads of BOD from point and nonpoint sources were also calculated and listed in **Table 6.2**. For most DO and nutrient impaired tributaries included in this TMDL report, except for the Eau Gallie River, no further nutrient load reductions were requested beyond those already requested by the main stem seagrass nutrient TMDLs (FDEP, 2009). The daily TN and TP loads of seagrass nutrients TMDLs have already been calculated in the main stem nutrient TMDL report previously (FDEP, 2009). Therefore, TN and TP daily loads for most impaired tributaries included in this TMDL report were not re-calculated. The Eau Gallie River, however, has TN and TP target loads defined in this TMDL report that are different from the main stem TN and TP loading targets for the drainage basin where the river is located. Therefore, daily TN and TP loads were calculated in this report as the annual TMDLs being divided by 365 days, which are 790 lbs/day and 12 lbs/day for TN and TP daily loads, respectively. The daily BOD loads included in **Table 6.2** were also calculated by dividing the annual loads by 365 days/year. Again, these daily loads are only provided in this report for informational purposes. The implementation of the TMDLs covered in this TMDL report should be using an annual time scale.

Table 6.2. BOD TMDL Daily Loads for DO Impaired Tributary Segments in the Indian River Lagoon Basin

WBID	Parameter	TMDL (lb/day)	WLA_{NPDES} wastewater (lb/day)	WLA_{NPDES} Stormwater	LA (lb/day)	MOS
3028	BOD	98	N/A	72.30%	72.30%	Implicit
3082	BOD	192	N/A	86.30%	86.30%	Implicit
3085A	BOD	303	0.4**	80.10%	80.10%	Implicit
3128	BOD	774	7**	69.70%	69.70%	Implicit
3129B1	BOD	1411	N/A	78.20%	78.20%	Implicit
3129B2	BOD		N/A			Implicit
3129A	BOD	4312	N/A	75.90%	75.90%	Implicit
3135A	BOD	1880	N/A	76.00%	76.00%	Implicit

N/A in this table means not applicable.

** Daily WLAs were calculated by dividing the annual loads by 365 days. In reality, WLAs for different facilities have different applicable time scales. Daily WLAs of different time scales are not directly addable. The daily WLAs on this table are only for informational purposes. Detailed WLA for each facility and the applicable time scale are described in **section 6.3.1**.

6.2 Load Allocation

All impaired tributary segments included in this TMDL reports were verified for DO impairment. In order to address the low DO condition in these tributaries, controlling BOD loads from the watershed should be the focus of future pollutant loading controls because results from sensitivity analyses clearly indicate that nutrient loadings into these tributary segments do not significantly impact the DO dynamics in the water column. Therefore, for most of these impaired segments, the Department will not propose any further nutrient reduction beyond those already requested by the Indian River Lagoon main stem seagrass nutrient TMDLs (FDEP, 200). However, the Eau Gallie River is an exception. The tidal portion of the river consistently showed high annual average chlorophyll a concentrations, which are not only higher than the 11 µg/L assessment threshold, but also higher than the chlorophyll a concentrations observed in

most major tributaries into Indian River Lagoon. The nutrient loading targets the Department is setting for the Eau Gallie River to address the nutrient condition is the natural background TN and TP loads, which require a 51% reduction of TN and a 58% reduction of TP for nonpoint source loads from the watershed of the river based on HSPF model simulation results for the period from 1996 through 2005. The watershed of the river is located in a part of the Indian River Lagoon drainage basin area that discharges to the main stem lagoon segment of IR 9-11, as is defined in the main stem TMDL report (FDEP, 2009). The percent reductions required for the watershed to achieve the target nutrient loads by the main stem seagrass nutrient TMDLs for this area are 35% reduction of TN and 48% reduction of TP. Considering that 90% of the Eau Gallie River watershed is occupied by anthropogenic lands and close to 80% of the total watershed is occupied by urban lands, a significant portion of the nutrient reduction needs from the general drainage areas discharging to IR 9-11 may come from the Eau Gallie River watershed. In other words, even for the purpose of protecting the seagrass in Indian River Lagoon main stem, the actual reduction needs from the Eau Gallie River watershed higher than the previously adopted TMDL reductions of 35% for TN load and 48% for TP load.

Control of BOD loadings from watersheds of low DO-impaired tributary segments should be the focus of watershed pollutant loading control in order to improve the water column DO condition. This is because the watershed loadings of organic carbon, especially the labile organic carbon compounds represented by the carbonaceous BOD, is a major oxygen consumption material that not only contributes to lowering of DO in the water column, but also contributes to the sediment oxygen demand, which, in many of these impaired tributaries, is the dominant factor that controls the water column DO concentration. The BOD loading targets set up for all impaired tributary segments are background loads. This requires BOD loadings from nonpoint sources in the watersheds of these impaired segments to be reduced by about 70% to 86% based on HSPF model simulation results for the time period from 1996 through 2005. It should be noted that reducing BOD loads from the watersheds is not independent of reducing watershed nutrient loads. Considering that a very large portion of the TN and TP loads from the watershed are organic nitrogen and organic phosphorus, and a major part of the organic nitrogen and organic phosphorus is organic carbon. Therefore, when reducing the watershed TN and TP loads, a significant portion of the BOD loadings can also be reduced.

Another aspect of the BOD loading control is that, even when the background BOD loadings are achieved, DO concentration in many of the Indian River Lagoon tributaries may still be unable to achieve the 5.0 mg/L for freshwater and 4.0 mg/L for marine waters. This is because there is always a background BOD loading coming from the natural land areas in a given watershed. In addition, factors as low DO ground water input may also help to depress the DO concentration in ambient waters. Therefore, stakeholder and the Department may investigate whether to establish either site specific alternative criteria (SSAC) or alternative DO criteria (ADOC) for these DO impaired waters.

6.3 Wasteload Allocation

6.3.1 National Pollutant Discharge Elimination System Wastewater Discharges

Three NPDES permitted wastewater facilities were identified discharging to three impaired tributary segments. These include the Melbourne Grant Street WWTF that discharges to Crane Creek, the Melbourne Joe Mullins Demineralization Concentrate that discharges to the Eau

Gallie River, and the Barefoot Bay Advanced WWTF that discharges to the North Prong of the Sebastian River. Two of these facilities discharge to impaired tributaries that the Department will not request further nutrient reduction beyond those already requested by the Indian River Lagoon main stem seagrass nutrient TMDLs (FDEP 2009), no further reduction of nutrient loads from these facilities will be requested by this TMDL project. Instead, these facilities are expected to follow the nutrient reduction needs described in the IRL main stem seagrass TMDL report (FDEP, 2009). The Eau Gallie River nutrient TMDLs require more nutrient reduction than those requested by the IRL mainstem nutrient TMDLs. However, Because the TN and TP concentrations of the discharge from the Joe Mullins Demineralization Concentrate has been mostly better than the level of Advanced Wastewater Treatment and the nutrient discharge loads from the facility account for only a small portion of the total nutrient loads entering the Eau Gallie River, the facility was allowed by the Eau Gallie River TMDLs to discharge at the 95th percentile of its existing discharge capacity, which is the same as those requested by the existing IRL mainstem nutrient TMDLs.

BOD effluent concentrations were also retrieved from the EPA's Permit Compliance system database. Based on the discharge records of these facilities in the period from 2000 through 2010, the annual total BOD loadings from these facilities typically accounted for less than 5% of the total BOD loadings entering the impaired tributary segments (**Table 5.21**). Therefore, these facilities were assigned the 95th percentile of their existing discharge capacity as their target waste load allocation (WLA).

The permitted surface discharge for the Grant Street WWTF is limited to a maximum of five days during the mechanical integrity testing of the facility's underground injection well. During the period from 2000 to 2010, the facility only discharged two times (3/31/2004 and 3/31/2009). Discharge loads of BOD for these two events were 145 lbs and 28 lbs (**Table 4.2**). Assuming these were annual loads for each year, the 95th percentile BOD load is 139 lbs/year. This annual load is assigned to the facility as its WLA.

No WLA of BOD were assigned to the Melbourne Joe Mullins Demineralization Concentrate. The facility's existing discharge permit does not require the facility to measure BOD concentrations of its effluent. The BOD measurement included in the facility's permit application showed that the effluent BOD concentration was undetectable.

The Barefoot Bay Advanced WWTF's 0.75 MGD AADF permitted intermittent surface discharge is a wet weather only discharge limit which limits the discharge from the facility to 91 days a year (or the equivalent of 2,184 hours). In the period from 2000 through 2010, the facility only discharged in 2000, 2002, 2003, and 2008 (**Table 4.3**). In these years, the facility discharged one month in 2000, 2003, and 2008, but discharged three months in 2002. No water quality measurements were available for one discharge month in 2002 and the discharge month in 2003. With the available data, the facility discharged 166 lbs, 2984 lbs, and 163 lbs of BOD in these three years. The 95th percentile annual discharge rate is 2702 lbs/year and is assigned to the facility as its target WLA for BOD.

6.3.2 National Pollutant Discharge Elimination System Stormwater Discharges

Because no information was available to the Department at the time this analysis was conducted regarding the boundaries and locations of all the NPDES stormwater dischargers, the exact stormwater TN, TP, and BOD loadings from MS4 areas were not explicitly estimated.

The wasteload allocations for each of the MS4s are the same percent TN, TP, and BOD reductions required for the load allocation (LA) assigned to the nonpoint sources in watersheds of impaired tributary segments that belong to each county and municipality. The MS4 permits that will be influenced by the TMDLs covered in this report are listed in **Table 4.6**.

It should be noted that any MS4 permittee is only responsible for reducing the loads associated with stormwater outfalls that it owns or otherwise has responsible control over, and is not responsible for reducing other nonpoint source loads within its jurisdiction.

6.4 Margin of Safety

Consistent with the recommendations of the Allocation Technical Advisory Committee (Department, February 2001), an implicit MOS was used in the development of this TMDL. An implicit MOS was provided by the conservative decisions associated with a number of modeling assumptions, the development of site-specific alternative water quality targets, and the development of assimilative capacity.

Addressing the DO impairment in tributaries discharging into Indian River Lagoon is the main focus of this TMDL report. Ideally, the target DO concentration should be developed based on biological and ecological data so that a target DO will be at a level that is protective of sensitive species. At the time these TMDLs were developed, there were no such data available that would allow the Department to develop robust and protective DO targets. Therefore, the target DO level chosen for each tributary included in this report is its background DO level. The target BOD loadings associated with these background DO levels are the background BOD loadings. Target BOD loadings calculated this way do not include the possible assimilative capacity that aquatic biological communities may have, and therefore, is more stringent than it is needed to protect the aquatic fauna. BOD TMDLs developed this way adds to the margin of safety for protecting the balance of aquatic fauna. The same can also be said for the nutrient loading targets established to address the chlorophyll a condition in the Eau Gallie River. The nutrient TMDLs established for the river is the background TN and TP loads, which could be more stringent than if the loading targets were established based on measured biological data, which were not available at the time these loading targets were developed. The background nutrient loading approach adds to the margin of safety to protect the local aquatic flora and fauna.

6.5 Recommendations for Further Studies

One major issue that this project encountered is that, while HSPF models cover a time period of 10 years, EFDC models only include two years as their modeling time domain. This is mainly because EFDC model is a grid based program and requires much longer run time than the HSPF model for simulating the hydraulic and water quality condition within a same time period., This was why when setting up the EFDC models, efforts were made by the DSLLC to ensure that year 2000 and 2001 are hydrologically representative to the period that HSPF models covered. However, there is always the possibility that some water quality constituents in some waterbodies may not always behave the same way in the relatively short model calibration and validation period as they would behave in the long run. The Eau Gallie River DO concentration is an example. Based on the measured data, the low DO level in the Eau Gallie River, for some reason, was higher in 2000 and 2001 than the years after these two years. Therefore, using a

model calibrated against the measured DO in 2000 and 2001 may overestimate the low DO level in the long run. That was why, when estimating the DO dynamics after the target BOD loadings were achieved, the Department used model simulations from the HSPF model instead of the EFDC model. It is desirable that the time domain of these EFDC models can be extended to cover longer period of time to allow a better assessment of the uncertainties associated with the representativeness of the short time period simulation.

Another improvement that can be made to improve the model calibration and validation is to collect more stormwater data. The water quality data used for model calibration and validation of this project were data collected for general water quality monitoring purposes. These data typically do not necessarily represent the water quality conditions that exist when stormwater influences the system. That is why many water quality calibration and validation figures show that, while model simulations, especially for nutrient concentrations, show many concentration peaks, the measured data only appear at the baseline of the model simulations. This is because the model is programmed to simulate the nutrient concentrations under stormwater conditions, but we simply do not have sufficient stormwater data to fully confirm these model simulations. So, for future model improvement, more stormwater sample collection would be desirable.

One issue associated with the elevated chlorophyll a concentrations observed in 2008, 2009, and 2010 is that no consensus has been reached regarding what caused the observed chlorophyll a elevation. The Department examined the available hydrological data, including rainfall and flow, and water quality constituents (including water column conductivity and nutrient concentrations) in tributaries verified for nutrient impairment based on elevated chlorophyll a concentrations observed in 2008, 2009, and 2010. The Department found that the current available data do not support the hypothesis that the elevated chlorophyll a concentration is linked to the elevated watershed nutrient loadings. Therefore, proposing further nutrient loading reductions beyond those already requested by the Indian River Lagoon main stem seagrass nutrient TMDLs may not be the most effective approach to address the elevated chlorophyll a concentrations observed in these impaired tributaries. However, the Department realizes that the SJRWMD is working actively with several universities and research institutes to identify the cause or causes that resulted in the algal bloom in the Indian River Lagoon segments in recent years. Conclusions from these studies may be used to refine the TMDLs developed for the tributaries included in this report.

Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

7.1 Basin Management Action Plan

Following the adoption of this TMDL by rule, the Department will determine the best course of action regarding its implementation. Depending upon the pollutant(s) causing the waterbody impairment and the significance of the waterbody, the Department will select the best course of action leading to the development of a plan to restore the waterbody. Often this will be accomplished cooperatively with stakeholders by creating a Basin Management Action Plan, referred to as the BMAP. Basin Management Action Plans are the primary mechanism through which TMDLs are implemented in Florida [see Subsection 403.067(7) F.S.]. A single BMAP may provide the conceptual plan for the restoration of one or many impaired waterbodies.

If the Department determines a BMAP is needed to support the implementation of this TMDL, a BMAP will be developed through a transparent stakeholder-driven process intended to result in a plan that is cost-effective, technically feasible, and meets the restoration needs of the applicable waterbodies. Once adopted by order of the Department Secretary, BMAPs are enforceable through wastewater and municipal stormwater permits for point sources and through BMP implementation for nonpoint sources. Among other components, BMAPs typically include the following:

- *Water quality goals (based directly on the TMDL);*
- *Refined source identification;*
- *Load reduction requirements for stakeholders (quantitative detailed allocations, if technically feasible);*
- *A description of the load reduction activities to be undertaken, including structural projects, nonstructural BMPs, and public education and outreach;*
- *A description of further research, data collection, or source identification needed in order to achieve the TMDL;*
- *Timetables for implementation;*
- *Implementation funding mechanisms;*
- *An evaluation of future increases in pollutant loading due to population growth;*
- *Implementation milestones, project tracking, water quality monitoring, and adaptive management procedures; and*
- *Stakeholder statements of commitment (typically a local government resolution).*

BMAPs are updated through annual meetings and may be officially revised every five years. Completed BMAPs in the state have improved communication and cooperation among local stakeholders and state agencies; improved internal communication within local governments;

applied high-quality science and local information in managing water resources; clarified obligations of wastewater point source, MS4, and non-MS4 stakeholders in TMDL implementation; enhanced transparency in Department decision making; and built strong relationships between the Department and local stakeholders that have benefited other program areas.

7.2 Other TMDL Implementation Tools

However, in some basins, and for some parameters, particularly those with fecal coliform impairments, the development of a BMAP using the process described above will not be the most efficient way to restore a waterbody, such that it meets its designated uses. This is because fecal coliform impairments result from the cumulative effects of a multitude of potential sources, both natural and anthropogenic. Addressing these problems requires good old-fashioned detective work that is best done by those in the area.

Many assessment tools are available to assist local governments and interested stakeholders in this work. The tools range from the simple (such as Walk the WBIDs and GIS mapping) to the complex (such as bacteria source tracking). Department staff will provide technical assistance, guidance, and oversight of local efforts to identify and minimize fecal coliform sources of pollution. Based on work in the Lower St Johns River Tributaries and Hillsborough Basins, the Department and local stakeholders have developed a logical process and tools to serve as a foundation for this detective work.

In the near future, the Department will be releasing these tools to assist local stakeholders with the development of local implementation plans to address fecal coliform impairments. In such cases, the Department will rely on these local initiatives as a more cost-effective and simplified approach to identify the actions needed to put in place a road map for restoration activities, while still meeting the requirements of Subsection 403.067(7), F.S.

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Florida Department of Environmental Protection
Division of Water Resource Management
Bureau of Watershed Management
2600 Blair Stone Road, Mail Station 3565
Tallahassee, Florida 32399-2400
(850) 245-8561
www2.dep.state.fl.us/water/