WAM ENHANCEMENT and APPLICATION In the LAKE OKEECHOBEE WATERSHED

Contract No. 3600001244
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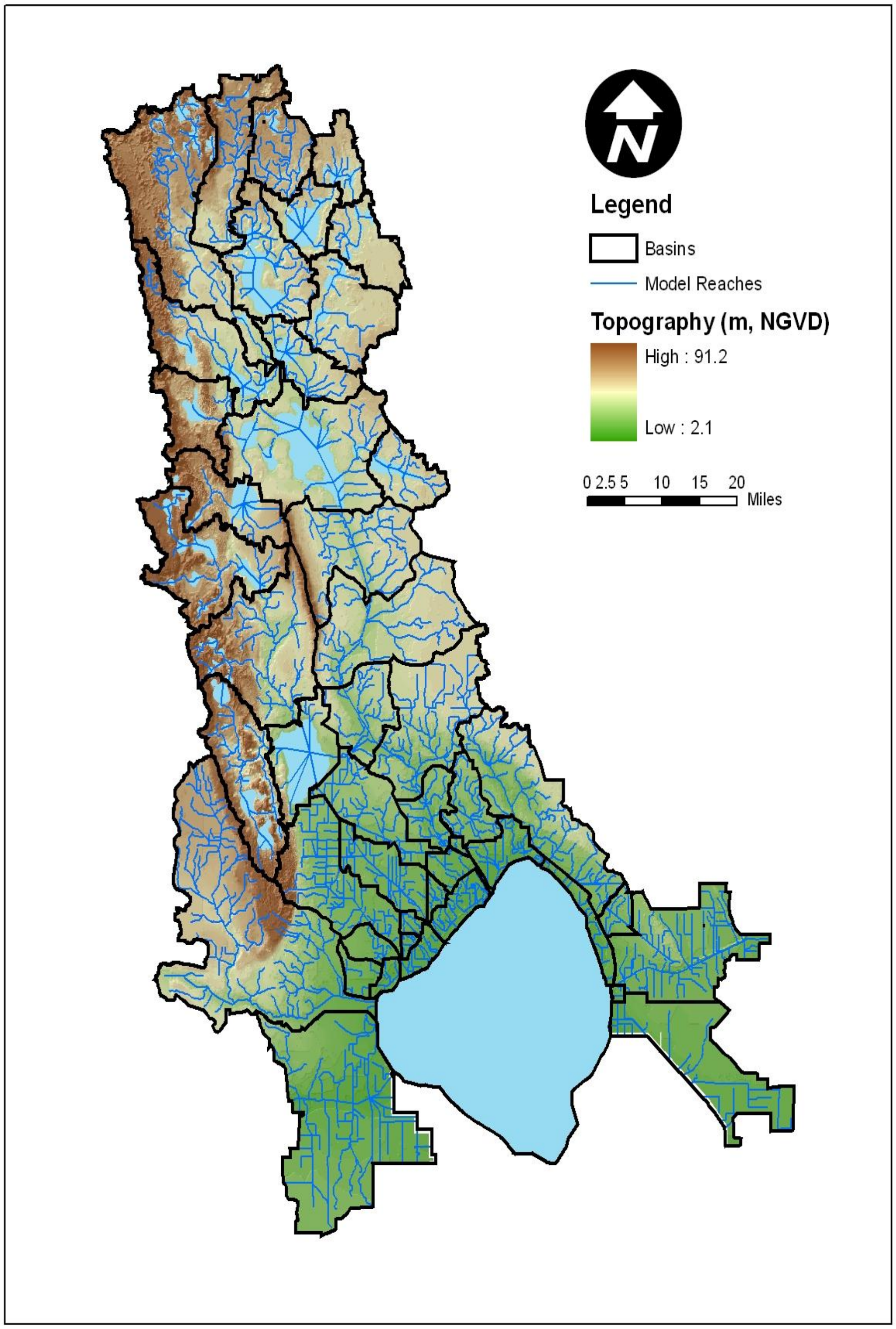

Final Report

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TABLE OF CONTENTS

List of Tables

List of Figures

Appendices

1.0 Introduction and Background

1.1. Background

The goal of this project is to develop an assessment tool that will enable evaluation of ongoing and proposed phosphorus control measures at the Lake Okeechobee Watershed scale. This will enable South Florida Water Management District (SFWMD) to refine prior evaluations of the Phase II Technical Plan of the Lake Okeechobee Construction Project (SFWMD 2008) and adapt it to better meet the Total Maximum Daily Load (TMDL) goal of 140 metric tons of phosphorus per year.

This document is the product of the fifth of five tasks:

Task 1 – Data Gathering and Formatting
Task 2 – Large Lake Nutrient Assimilation Enhancement
Task 3 – Model Calibration and Verification
Task 4 – Evaluating the Effectiveness of Phosphorus Control Programs on Phosphorus Load Reductions to Lake Okeechobee
Task 5 – Final Documentation and Presentation

WAM has previously been applied to several individual basins in the Northern Everglades; however it had not been set up for an integrated watershed scale simulation of the entire area. This project involved compiling and formatting all data required for simulation of the entire Northern Lake Okeechobee watershed as shown in **Figure 1-1**. An algorithm or sub-model has been developed and is being incorporated into WAM to assess nutrient assimilation in large Florida lakes such as Lakes Kissimmee and Istokpoga. The WAM model has been calibrated and verified using the new WAM/ArcGIS 9.2 interface. Future steps will include iterative simulations to evaluate the phosphorus load reduction benefits of agricultural and urban BMPs implementation, existing source control and regional projects, and future load reduction management measures.

1.2. Approach

In order to successfully develop an assessment tool to meet the needs of the project, a multi-step approach was taken. It consisted of the four previously mentioned tasks culminating into one final comprehensive report. Data gathering and formatting was the first step in the process to develop a WAM for the northern Lake Okeechobee watershed. Once obtained, the data was analyzed and reviewed to make sure that the best available data was being utilized to create the model. The next step in the process was to develop a lake assimilation algorithm or sub-model that would be compatible with WAM. The WAM was then calibrated against measured TP concentration and flow data in each basin. The model was utilized to evaluate the effectiveness of phosphorus control programs on phosphorus load reduction to the lake. Various control programs were simulated to approximate their potential impact. The results are compiled and reported in this document, which explains in detail the entire modeling process and results.

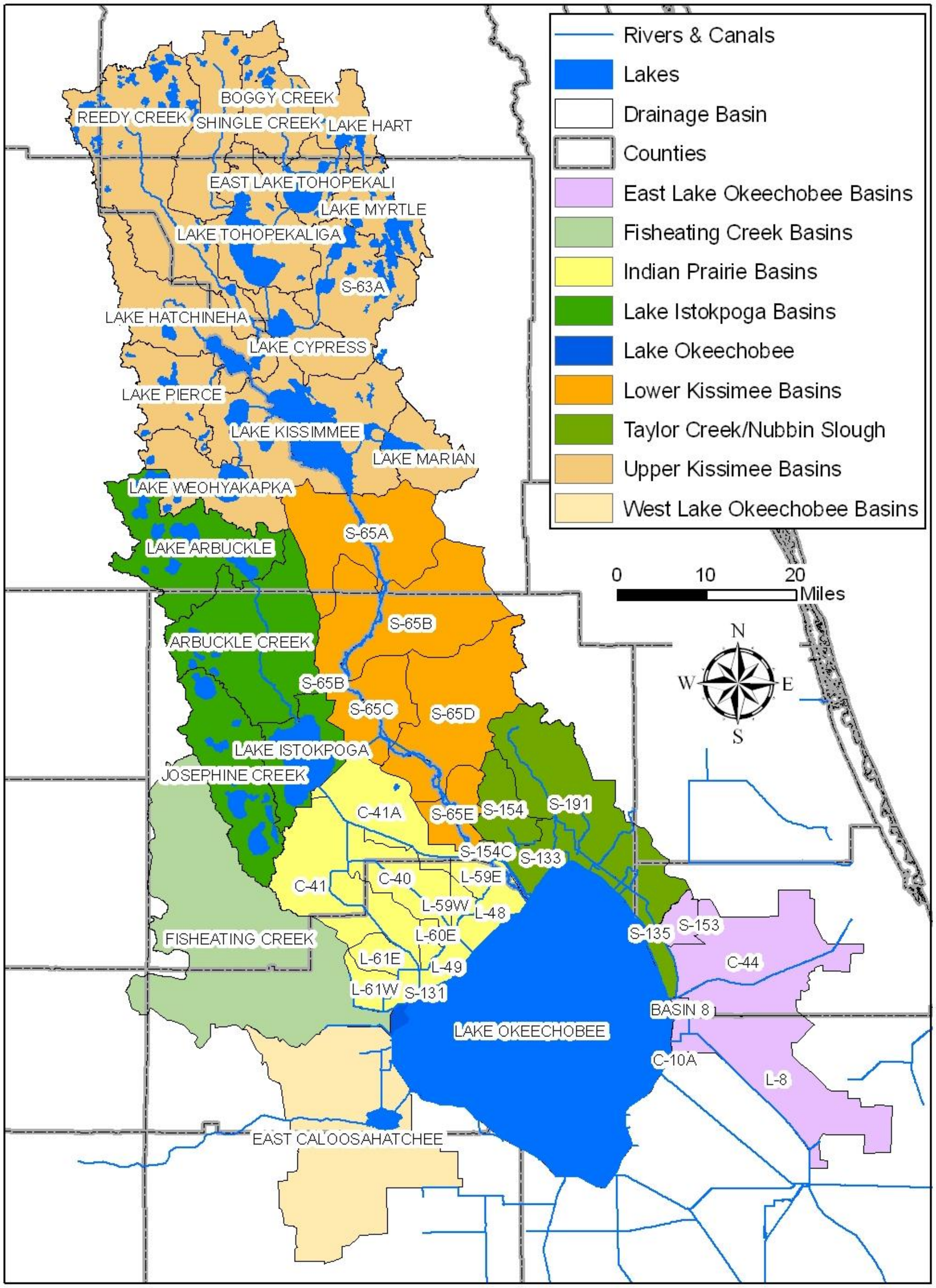

Figure 1-1: Project Drainage Areas

2.0 Data Gathering and Formatting

2.1. Data Acquisition and Review

2.1.A. GIS Datasets

2.1.A.1. Land Use

Two sets of land use data were collected and evaluated for model development; one from the South Florida Water Management District's (SFWMD) GIS Catalog (http://my.sfwmd.gov/gisapps/sfwmdxwebdc/) dated 2004-2005; and the other from SFWMD's Lake Okeechobee Division (Division) from 2006. An analysis was performed to determine the extent of the differences between the two datasets, and ultimately, the District selected the 2006 dataset for incorporation into WAM.

The 2004-2005 SFWMD land use dataset was interpreted from aerial photography flown in 2004 and 2005. The dataset covers the entire area within the SFWMD including the majority of the area to be modeled. The dataset was completed in early 2008 and the land use classification is to FLUCCS Level IV. Throughout the rest of this report this land use coverage data will be referred to as the 2004-2005 dataset.

The Lake Okeechobee Division's land use dataset is based on the SFWMD 1999-2000 land use dataset and has been continuously updated since then. It was most recently updated for the 2006 Lake Okeechobee Protection Plan Update. The 2006 land use classification is also to FLUCCS Level IV but these are assembled into higher level categories (Land Use column of **Table 2-1** that were used to summarize the data in the Lake Okeechobee Protection Plan Evaluation Report (LOPP Update) and the Lake Okeechobee Watershed Construction Project Phase II Technical Plan (P2TP) (SFWMD 2007 and SFWMD 2008, respectively). This land use coverage will be referred to as the 2006 dataset throughout the rest of this report.

For the comparison of the two land use datasets, data for the areas outside of the boundaries of the SFWMD (not included in the 2004-2005 SFWMD dataset) were copied from the 2006 LOPP dataset. The 2006 LOPP land use code categorization was applied to the 2004-2005 SFWMD data. However, the 2004-2005 SFWMD data contained 16 land use codes that were not used in the 2006 land use data. Of these 16 codes, 12 were considered Natural Areas, 2 Urban and the remaining 2 classified as Woodland Pastures/Rangeland and Other Areas. The complete list of land use codes included in both datasets and the corresponding LOPP categories is in Appendix A. The 2004-2005 data were summarized based on the same categories and are shown in the columns with the heading 04-05 for each basin in **Table 2-1**. For this analysis, the basins include sub-basins outlined in a feature class of drainage basins provided by the District which match the boundaries shown in the LOPP Update and the P2TP. The Division's drainage basin boundaries do not match the basin boundaries that will be used for the WAM simulations. The difference in the basin boundaries used for the WAM simulations was the result of the basin delineation procedure described in detail in Section 0**.** The major difference was that, for the

District's boundaries, Nicodemus slough is included in Fisheating Creek instead of the East Caloosahatchee basin. Other differences are small areas around the perimeter of the model domain. **Table 2-1** presents the percentage of each land use category in each basin for both the 2004-2005 and 2006 land use datasets. For some of the land use categories, the difference between the 2004-2005 and 2006 values were significant. For example, in the second column "Entire Watershed" in **Table 2-1** the Woodland/Rangeland percentage was found to be approximately 12 percent for the 2004-2005 dataset. By contrast, the 2006 LOPP dataset had a value of about 6 percent.

Table 2-1: Comparison of Land Uses in Acres by Sub-Watershed for 2004-2005 and 2006 Land Use Datasets

Land Use	Entire Watershed		Upper Kissimmee		Lower Kissimmee (S65A-E)		Taylor Creek/Nubbin Slough (S191,S154,S133, S135)		Lake Istokpoga		Indian Prairie (12 basins)		Fisheating Creek and Nic. Slough***		West LO Besins***		East LO Basins (C-44 and L-8)	
	Acres		Acres		Acres		Acres		Acres		Acres		Acres		Acres		Acres	
	04-05*	2006**	04-05*	2006**	04-05	2006	04-05	2006	04-05	2006	04-05	2006	04-05	2006	04-05	2006	04-05	2006
Citrus	254,423	232,702	59,106	57,478	15,461	11,666	3,857	3,572	55,965	55,918	33,233	30,331	11,465	10,681	26,642	23,770	48,694	39,287
Dairy	6,541	22,432			1,714	5,950	4,162	11,085	652	3,031		177		26	13	2,164		
Improved Pasture	664,046	669,818	126,887	133,437	121,014	134,894	98,764	86,186	46,756	48,228	121,455	108,424	87,416	80,152	37,176	58,355	24,578	20,143
Natural Areas	1,163,493	1,264,306	502,807	529,079	140,620	146,449	31,040	38,989	172,271	173,433	60,857	72,880	108,423	111,241	43,644	62,991	103,831	129,243
Ornamentals	1,962	4,335	503	187	30	12	57	542	483	348	54	2,667	417	451	16	2	402	126
Other Areas	36,215	26,462	11,244	8,396	5,683	2,358	10,888	1,517	3,695	3,626	1,601	1,707	822	4,583	762	1,971	1,520	2,303
Row Crops	18,085	23,157	1,344	3,391	6,575	7,814	516	817	1,072	1,646	1,093	3,456	62	212	1,369	4,717	6,054	1,104
Sod Farms	7,175	29,849	3,819	9,505	770	2,335	1,519	2,314	641	2,933		10,222	132	2,315		9	294	216
Sugarcane	97,535	78,786					7,195	9,123	2,306		18,165	12,674	5,494	1,990	54,447	42,193	9,928	12,806
Tree Plantations	59,362	49,512	6,777	3,743	8,504	8,358			10,750	12,710	847	58	19,716	17,661	12,768	6,983		
Unimproved Pasture	185,070	139,702	41,268	27,828	42,510	23,468	7,762	1,090	18,008	24,374	22,066	28,845	45,457	18,206	5,770	9,386	2,229	6,505
Urban	228,440	357,225	148,539	207,006	4,554	21,758	10,330	39,444	40,184	50,976	2,202	6,987	749	4,066	2,291	3,758	19,591	23,230
Woodland/Rangeland	367,031	184,131	119,380	41,623	81,848	64,220	22,209	3,620	39,364	14,924	32,575	15,720	34,853	30,823	16,093	10,332	20,709	2,868
Total	3,089,378	3,089,380	1,021,674	1,021,674	429,283	429,283	198,299	198,299	392,147	392,147	294,148	294,147	315,006	315,007	200,991	200,993	237,830	237,831

* The majority of the SFWMD 04-05 summary data - shown in columns labeled 04-05 - was taken from Land Use geodatabase created for the SFWMD from aerial photography flown in 2004-2005. The geodatabase covers only the area within the legal boundaries of the SFWMD. The data for the basin areas outside of the legal boundaries of the SFWMD was copied from the Lake Okeechobee Division's Land Use dataset updated for the 2006 Lake Okeechobee Protection Plan (2006 LOPP).

** The data shown in the columns labeled 2006 LOPP - shown in columns labeled 2006 - is summarized entirely from the Land Use dataset (shapefiles) for the 2006 LOPP update. This update focused mainly on the urban areas in the watershed. The updated dataset contains data from many sources. The sources listed include, LODivision_03, LODivision_04, LODivision_05, LODivision_06, hdr2003, mr2003, sfwmd_95, sjrwmd-00, sjrwmd-95, swf99.

*** The numbers in the 2006 columns for Fisheating Creek and West Lake Okeechobee basins have been summarized based on a different shared basin boundary that is not consistent with the LOPP Plan Evaluation Report or the LOW Phase II Technical Plan. It is consistent with the boundary used to summarize data in the 04-05 columns.

The following figures show the 2004-2005 and 2006 land use for each sub-watershed.

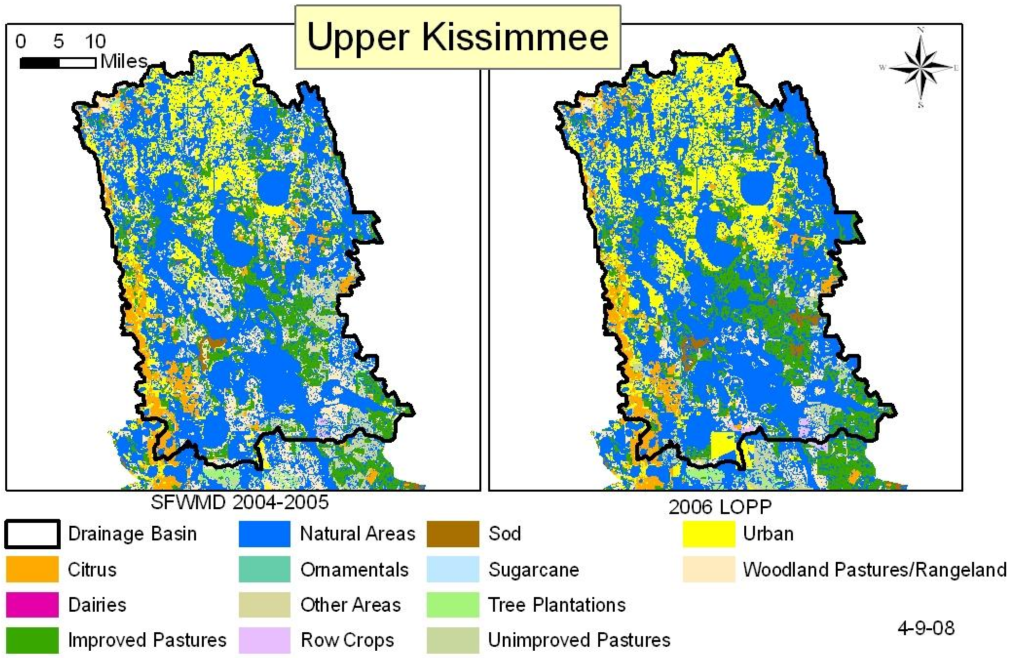

Figure 2-1: Upper Kissimmee Sub-Watershed Land Use Comparison

In the Upper Kissimmee sub-watershed (**Figure 2-1**) both datasets indicated that the most extensive land use was Natural Areas which accounted for approximately 50% of the total sub-watershed area. Urban Land was the second most prominent land cover and the 2006 dataset had a higher percentage of Urban Land (20.3%) than the 2004-2005 dataset (14.5%). However, more land was classified as Woodland Pastures/Rangeland in the 2004-2005 dataset (11.7%) than in the 2006 dataset (4.1%). Neither dataset indicated any land as Dairy, Ornamentals, or Sugarcane.

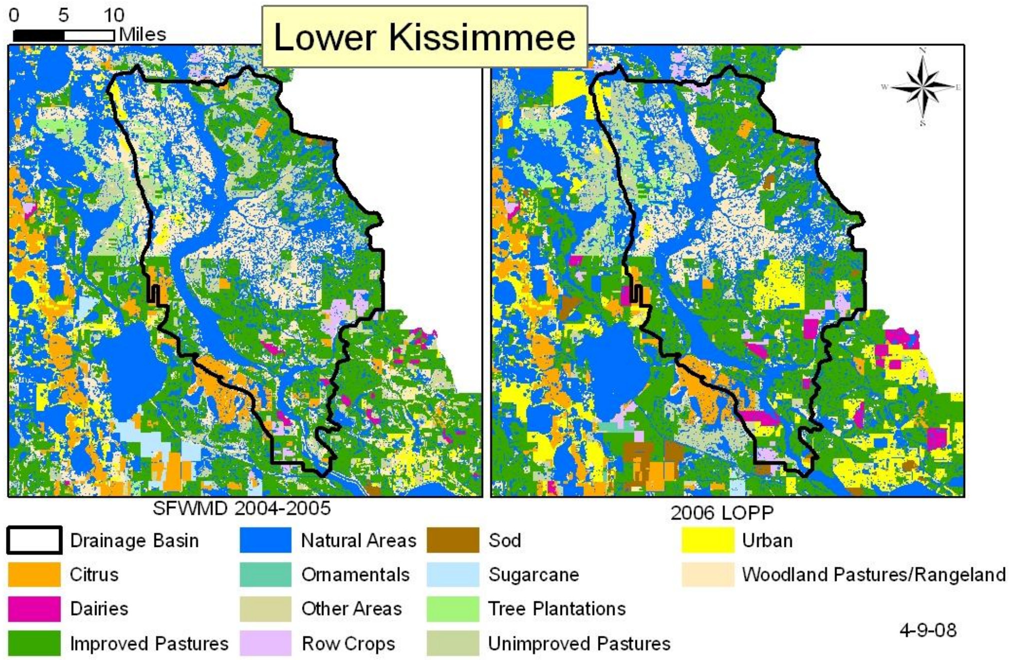

Figure 2-2: Lower Kissimmee Sub-Watershed Land Use Comparison

In the Lower Kissimmee sub-watershed (**Figure 2-2**) the 2004-2005 dataset had less diary land use than the 2006 dataset. In both datasets Dairy was a small percentage (less than 2%) of the overall land use in the sub-watershed. While there were no differences greater than 5 percent between the two datasets, there were differences of approximately 4 percent in the Improved Pasture, Urban, and Woodland Pastures/Rangeland categories. The acreage of Unimproved Pasture and Woodland Pastures/Rangeland was higher in the 2004-2005 dataset, but the acreage of Urban land was higher in the 2006 dataset. In both datasets the biggest land use was Natural Area. For this sub-watershed there was no land classified as Ornamentals or Sugarcane in either dataset.

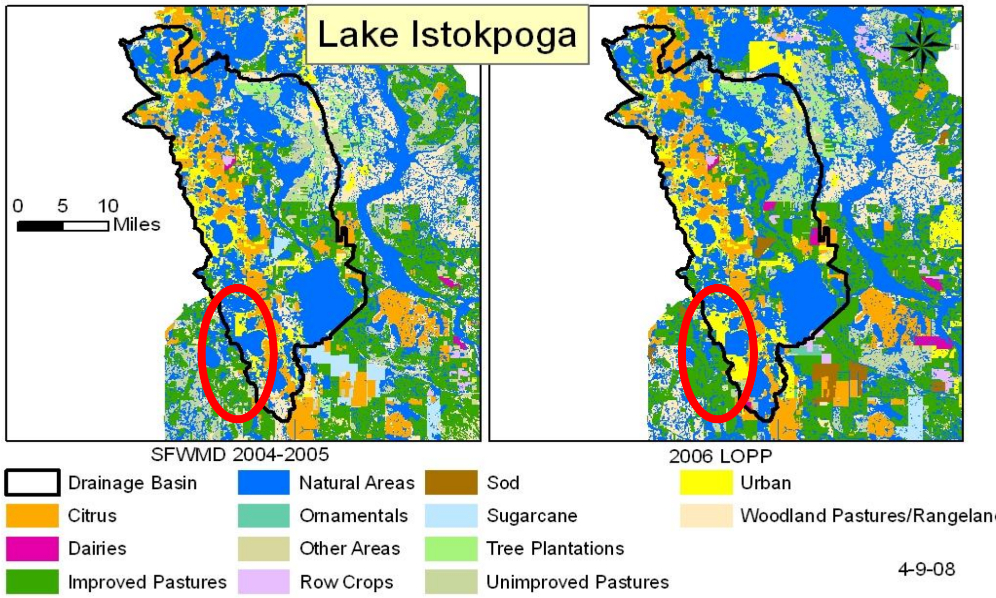

Figure 2-3: Lake Istokpoga Sub-Watershed Land Use Comparison

Roughly 44% of the Lake Istokpoga sub-watershed (**Figure 2-3**) area for both datasets was Natural Area. Both datasets also indicated that Citrus production made up 14.3 percent of the total land area. Since some of this sub-watershed falls outside of the SFWMD boundary and was not mapped in the 2004-2005 effort, some of the land use data in this sub-watershed are from the Division's 2006 coverage. There were some apparent differences between the two datasets in the area that was mapped in the 2004-2005 effort. The most notable difference was in the Woodland/Rangeland category which differs by about 6.2 percent, (10% in the 2004-2005 dataset compared with 3.8% in the 2006 dataset. Areas classified as Urban in the 2006 dataset were interpreted differently from 2004-2005 aerial photography as shown in the area circled in red in **Figure 2-3**.

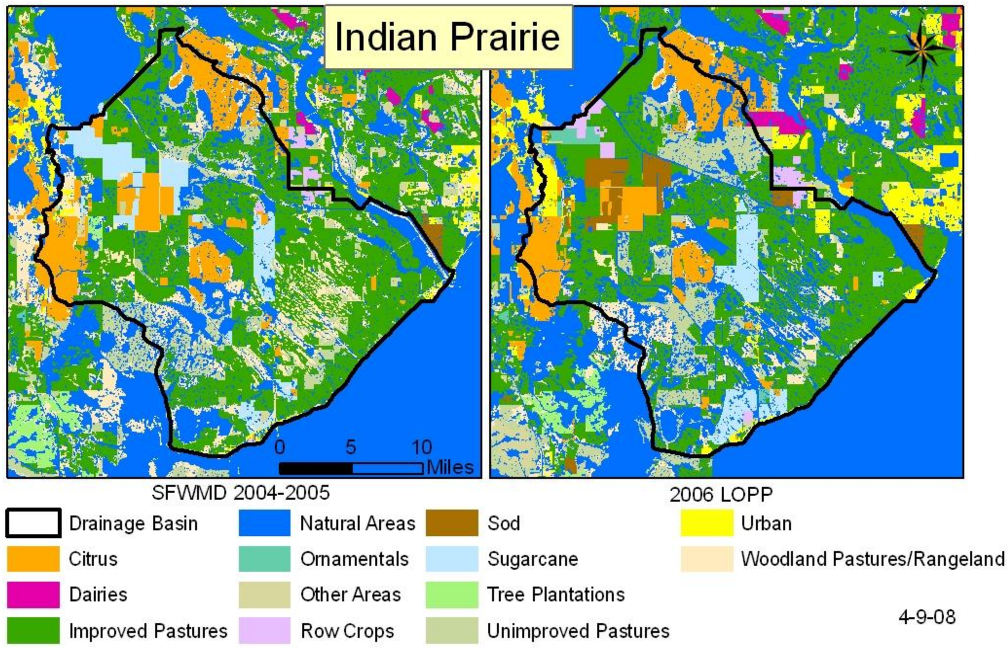

Figure 2-4: Indian Prairie Sub-Watershed Land Use Comparison

Improved Pasture was the most extensive land use in the Indian Prairie sub-watershed (**Figure 2-4**) for both datasets and the second largest land use was Natural Area. The 2004-2005 dataset showed 41.3% of the sub-watershed as Improved Pasture while the 2006 dataset showed 36.9%; a difference of 4.4 percent. Land area classified as Unimproved Pasture was 7.5% in the 2004-2005 dataset and 9.8% in the 2006 dataset. The combined Improved and Unimproved Pasture categories accounted for roughly half of the sub-watershed area in both datasets. The 2004-2005 dataset showed 20.7% of the sub-watershed as Natural Area while the 2006 dataset showed 24.8%; a difference of 4.1 percent. Citrus production was the next biggest land use – on the order of 10% of the sub-watershed area – for both datasets. The largest difference between the two datasets was Woodland/Rangeland which differed by 5.8 percent.

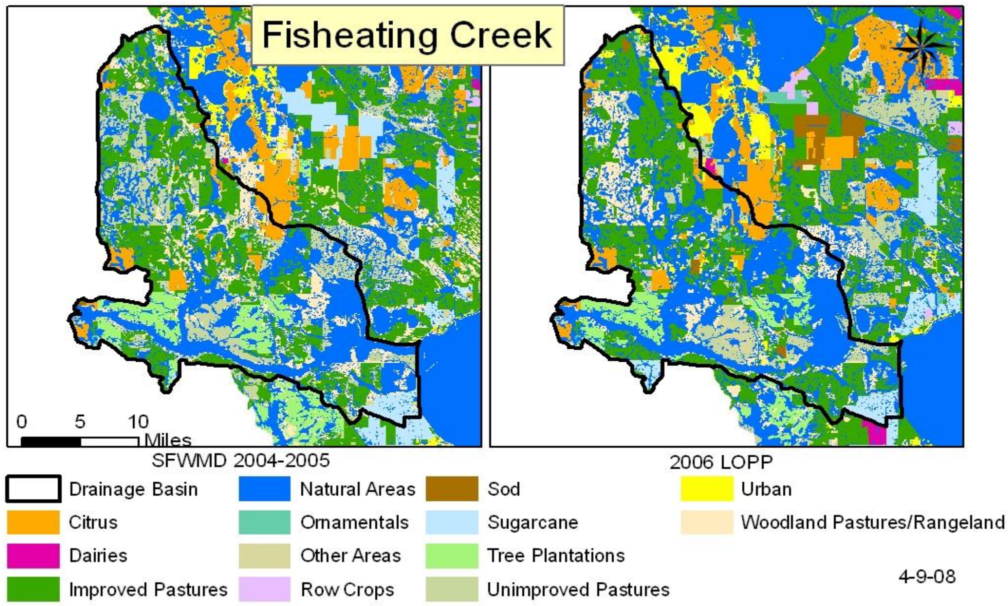

Figure 2-5: Fisheating Creek Sub-Watershed Land Use Comparison

In Fisheating Creek (**Figure 2-5**), both datasets showed relatively similar values with a few exceptions. The two largest land uses were Natural Areas and Improved Pasture. In this sub-watershed, both datasets showed that roughly a third of the area was classified as Natural Area; while approximately a quarter was Improved Pasture; and 10% was Woodland/Rangeland. Tree Plantations and Citrus groves were roughly 6% and 3.5% respectively. Unimproved Pasture land use differed between the datasets accounting for 14.4% of the sub-watershed in the 2004-2005 dataset compared with 5.8% in the 2006 dataset. In both datasets, Urban area was one of the smallest land uses in the sub-watershed. Neither of the datasets showed Dairies within the sub-watershed.

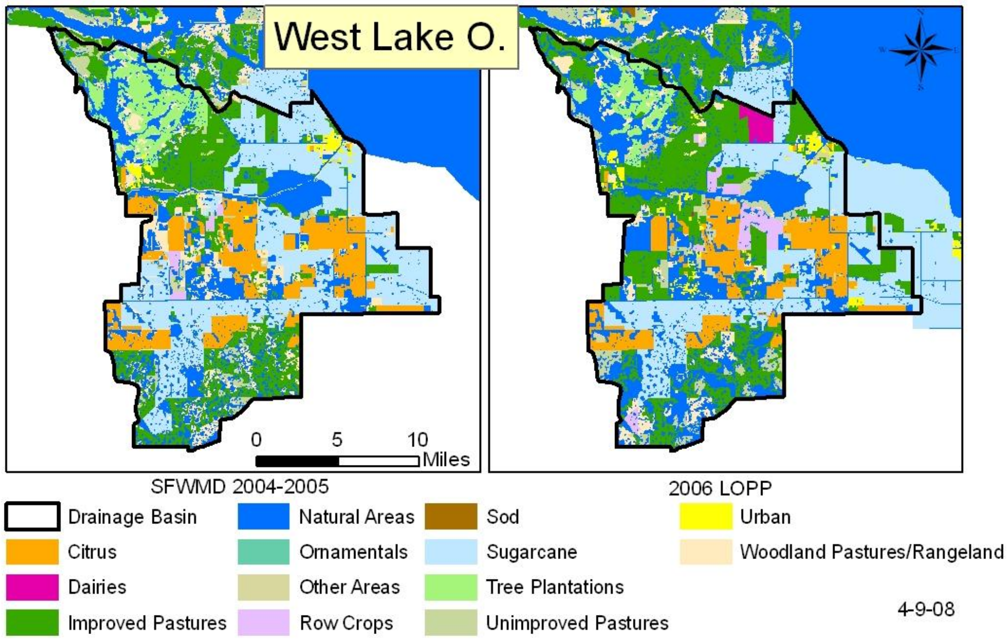

Figure 2-6: West Lake Okeechobee sub-Watershed Land Use Comparison

Figure 2-6 shows the West Lake Okeechobee sub-watershed had a small percentage of Urban area. The biggest differences between the two datasets were found in the Improved Pasture and Natural Areas categories. For the 2006 dataset, each of those land uses was close to 30% of the sub-watershed area. In the 2004-2005 dataset each of those land uses was closer to 20% of the area.

For the West Lake Okeechobee sub-watershed, Sugarcane was the most extensive land use in the 2004-2005 dataset (27.1%), while it was only the third most extensive land use in the 2006 dataset (21.0%). The difference in acreage for Sugarcane production was about 12,000 acres; ~54,400 acres in the 2004-2005 dataset and ~42,200 acres in the 2006 dataset. Both datasets clearly indicated that Sugarcane land area was greater in this sub-watershed than in any of the other sub-watersheds. The Indian Prairie and East Lake Okeechobee sub-watersheds each had on the order of 5% of their sub-watershed area classified as Sugarcane. But, when comparing the acreages, the West Lake Okeechobee sub-watershed had at least three times more land used for Sugarcane production than East Lake Okeechobee or Indian Prairie.

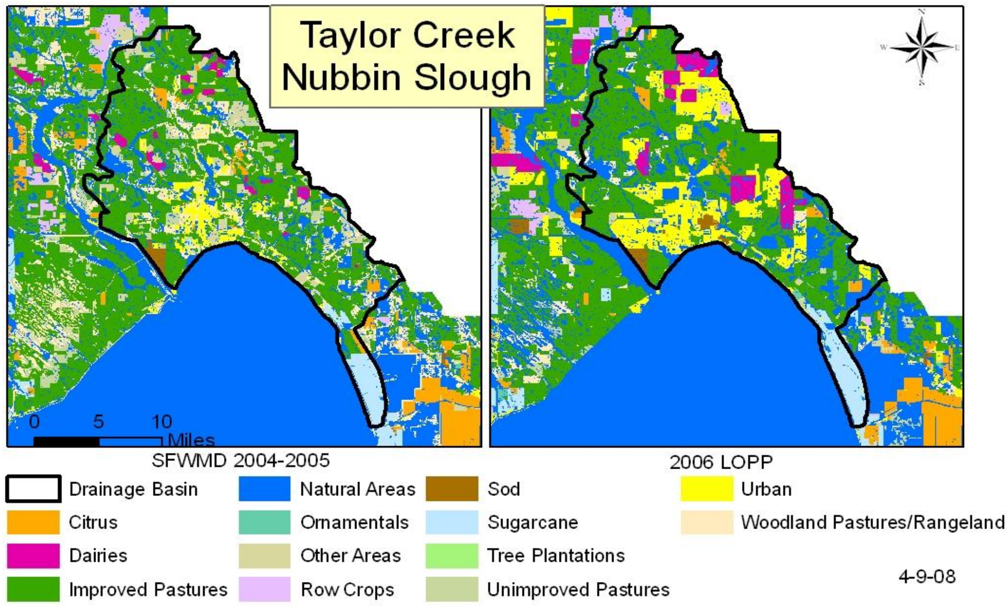

Figure 2-7: Taylor Creek/Nubbin Slough Sub-Watershed Land Use Comparison

In the Taylor Creek/Nubbin Slough sub-watershed (**Figure 2-7**) the most extensive land use was Improved Pasture; 49.8% in the 2004-2005 dataset and 43.5% in the 2006 dataset, a difference of more than 5 percent. Urban and Woodland/Rangeland also differed by 5 points or more between the two datasets, the largest being in the Urban category with 19.9% in the 2006 dataset compared with 5.2% in the 2004-2005 dataset. The acreage classified as Natural Areas in the 2004-2005 dataset was 4 percent lower than in the 2006 dataset, 15.7% versus 19.7% respectively. Unimproved Pasture accounted for 3.9% of the basin area in the 2004-2005 dataset but only 0.5% of the area in the 2006 dataset.

As with Indian Prairie, the two biggest land uses in the Taylor Creek/Nubbin Slough sub-watershed were Improved Pasture and Natural Area. In contrast, Taylor Creek/Nubbin Slough had more Urban area and less Citrus – in both datasets. Both datasets showed no, or minimal Tree Plantation area.

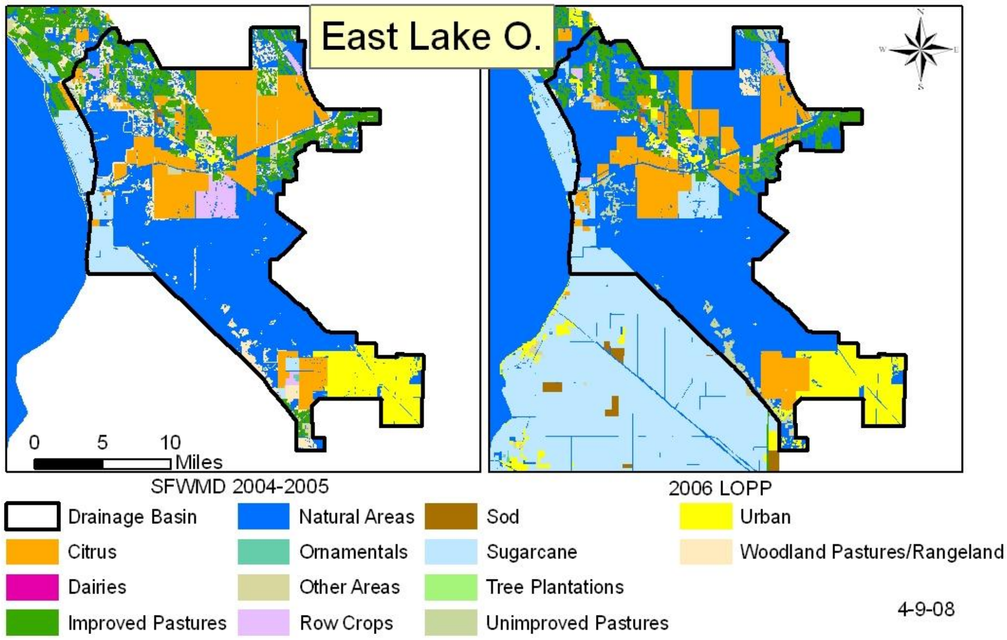

Figure 2-8: East Lake Okeechobee sub-Watershed Land Use Comparison

In the East Lake Okeechobee sub-watershed (**Figure 2-8**) the most extensive land cover was Natural Area. However in the 2006 dataset, 54.3% of the area was Natural Area compared with 43.7% in the 2004-2005 dataset – a difference of 10.6 percent or about 25,000 acres. Citrus was the second largest land use, but the two datasets differed by 4 percent (more than 9,000 acres). The Woodland/Rangeland land use classification differed by almost 18,000 acres. There were no Dairies or Tree Plantations in the sub-watershed.

The East Lake Okeechobee and Lake Istokpoga sub-watersheds had some similarities in the distribution of land use, with the exception that there was Sugarcane grown in the East Lake Okeechobee sub-watershed and none in the Lake Istokpoga sub-watershed. The total area of the Lake Istokpoga sub-watershed was also larger that the East Lake Okeechobee by more than 150,000 acres.

Overall in the entire watershed, most of the area was classified as Natural Area - approximately 1.2 million acres. Improved Pasture was the next most extensive land use in the study area. The land use category with acreages that differed most frequently between the two datasets at the sub-watershed scale was Woodland/Rangeland – 5 out of 8 sub-watersheds. This was the only category where the two datasets differed by more than 5 percent on the entire watershed scale. However, Urban area differed by 4.2% (~130,000 acres) and Natural Areas by 3.3% (~100,000 acres) of the entire watershed area. For both of these categories the 2004-2005 dataset was lower than the 2006 dataset.

2.1.A.2. Soils

The spatial distribution of soils is a required input to WAM and because of previous modeling efforts with WAM, the WAM database of soil parameters already contained data for 429 soil categories common to Florida. The existing database was used with a newly collected and compiled feature class of Soil Survey Geographic (SSURGO) data. The source feature classes of the soil data for each county in the study area were downloaded from the Florida Geographic Data Library (FGDL) (http://www.fgdl.org/metadataexplorer/explorer.jsp).

The soil data available from the SFWMD was also downloaded from their GIS Data Catalog and reviewed. This dataset was compiled from older SSURGO data and its metadata contained a warning about accuracy concerns. A review of the data found that the SFWMD database contained a more detailed classification of soil types than was needed for the WAM model, and although the SFWMD soils data covered over 99 percent of the study area, it was not used primarily because of the warning about its accuracy and the unneeded level of detail.

The final soils information used in the project came from the U.S. Department of Agriculture, Natural Resource Conservation Service published SSURGO data for 2005 and 2006. This data was derived from each of the county soils feature classes downloaded from FGDL which were clipped and combined to cover the entire study area. The projected coordinate system for the source data was Albers Conical Equal Area. The units are meters and the default geographic coordinate system was GCS North American HARN. Data for a portion of Osceola County which was missing from the NRCS dataset was collected from JGH Engineering. Section 2.2.B.2 contains a description of how the compiled data was reconciled with the existing WAM soils database.

2.1.A.3. Topography

WAM was applied in separate water quality assessment studies to approximately 90 percent of the study area before it was collectively applied as part of a phosphorus budget (P-Budget) analysis of the entire Lake Okeechobee Protection Plan (LOPP) Area (JGH, et al. 2005). The LOPP P-Budget assessment collected model datasets for topography, hydrographs, basins and sub-basins and produced new similar datasets for the areas where WAM had not been previously run.

Topography datasets in the previous WAM modeling efforts were created by obtaining and merging Digital Elevation Model (DEM) data. The data consisted of over 150 Spatial Data Transfer Standard (SDTS) files that were converted to DEMs. The DEMs were created by the USGS from 1:24,000 and 1:100,000 scale 5-foot contour maps in the 1990s. The DEMs were converted into ARC/INFO raster grids (1.0-hectare cell size), appended together and projected to the District's NAD 83 Florida East Zone datum for use with WAM.

The WAM modeling effort on the Caloosahatchee River (C-43) Basin began with the above referenced topography, but the topography was replaced in a later modeling phase with much more detailed LIDAR (Light Detection and Ranging) data, which became available in 2006 and was completed as part of the data preparation for the Southwest Florida Feasibility Study (USACE, 2002). This data was also converted to a 1.0 ha raster grid.

Topography raster grids were obtained from the Kissimmee Basin Modeling and Optimization Study (KBMOS) and reviewed. The datasets were derived from various sources of information including USGS 5-foot contours, District bathymetry and LIDAR (Earth-Tech, 2006). The original sources were merged as vector contours, converted to raster DEMs and reviewed. The review compared the LIDAR data to the USGS information. The two datasets appeared compatible and there did not appear to be any discontinuity that could affect the overland routing performed in WAM. The C-43 LIDAR and KBMOS datasets were therefore used to supplement the LOPP P-Budget composite grid.

The new version of WAM, like the previous version, uses a raster grid for surface topography. WAM uses this information to determine the directions of flow and distances to (and through) hydrologic features such as lakes, streams, canals, sloughs, riparian wetlands and depressions.

The topography dataset used for LOPP P-Budget project is shown in **Figure 2-9** and **Figure 2-10** identifies the areas where the KBMOS and C-43 LIDAR were used.

2.1.A.4. <u>Hydrography</u>

For each of the previous WAM and P-Budget modeling projects, USGS National Hydrologic Datasets (NHDs) were obtained and reviewed in comparison to the District hydrography coverage. NHDs include routing information. In some areas, such as Lower Kissimmee, the District hydrography coverage appeared to be more complete and was utilized to form the stream networks required in WAM. The Primary Basin Setup procedure (available in the previous version of WAM's interface) was used to layout and code the stream networks. The line segments of the hydrography were coded with numbers in descending order from upstream to downstream. Not all of the segments were utilized. For modeling purposes, it was possible to represent clusters of segments as one reach. The selected segments were referred to in WAM as model reaches within the hydrologic network. The WAM model reaches used in the LOPP P-Budget project are shown in **Figure 2-9**Figure .

The Arc Hydro data model is a geographic database containing relevant hydrological information under a specific database design (Maidment, 2002). It represents spatial data in a Relational Database Management System (RDBMS), geodatabase model. It is a combination of GIS objects enhanced with the capabilities of a relational database to allow for relationships, topologies, and geometric networks.

For the past four years, the District has been developing the District-wide Arc Hydro Enhanced Database (AHED). Approximately half of the study area has been completed in terms of hydrography. The rest of the study area will be finished in one to three years for the AHED project. Early in the development process of ArcWam, direct utilization of ArcHydro datasets was considered, but later abandoned because of ArcHydro's inability to handle looping and other modeling considerations. Instead, the District's standard hydrography datasets, which are the basis for AHED, were utilized.

Hydrography has also been cleaned and corrected in the Upper Kissimmee region where KBMOS project is being conducted. This information was obtained and reviewed to verify assumed flow direction and reach connectivity.

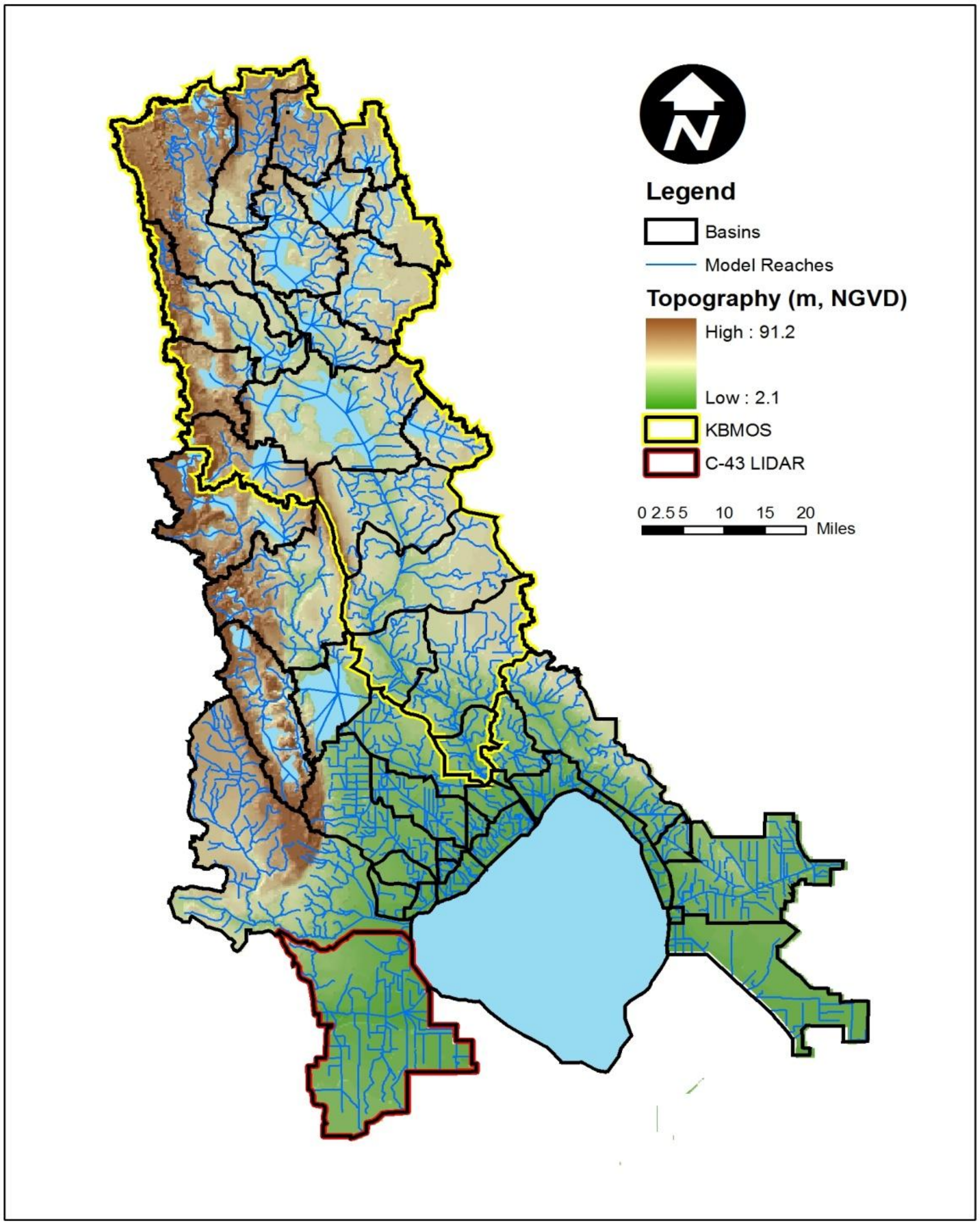

Figure 2-9: WAM Model Reaches and Topography

2.1.A.5. Basins and Subbasins

The District has historically been divided into several basins, e.g., S-65A, C-40, etc. Most of the basin boundaries within the study area were established several decades ago through a process that has been termed "windshield survey." The USGS maintains a nationwide basin layer of Hydrologic Unit Codes (HUCs), which are generally much smaller in size than the District's basins. The HUCs basins, however, do not extend into the District. Before 2000, the District's basins within the study area were loosely defined and incomplete (the Lake Istokpoga watershed had not been defined as a District basin). Furthermore, only a few of these basins had been subdivided into subbasins.

It is important in WAM that sufficient drainage divides (subbasin boundaries) adequately represent hydrologic boundaries in order to direct the flow to the correct hydrologic reach. Subbasin delineation in ten of the basins located immediately north of Lake Okeechobee were defined in the development of the LOW CERP WAM model (HDR, 2003). This was accomplished by using watershed functions available in ESRI™'s GIS software, which were applied in a prescribed sequence. These functions are the same functions used in Arc Hydro. The first step involved determining and filling topographic sinks (or depressions) in the USGS DEM grid. The next step included creating a direction grid which was calculated based on slopes between cells of the DEM grid. The final grid function uses the direction and stream grids to produce a grid of subbasins. This grid was then converted to a vector polygon dataset and reviewed. The subbasin dataset was edited to correct any anomalies by visually examining the lines over the DEMs. Many of the small polygons were merged together if there was no benefit to keeping them separated from a hydrologic modeling standpoint. The feature class was edited to align subbasin boundaries with roadways if the roadways were in the vicinity (approximately 1,000 feet) of the boundaries. It should be noted that the broader previously defined basin boundaries, e.g., S-191, were not updated; only subdivided.

When WAM was applied to the Lake Istokpoga and Upper Kissimmee watersheds (Mock-Roos, et al. 2003), the same procedure was used as described above to create subbasin datasets. This analysis, however, went a step further by defining or redefining the basin and overall watershed boundaries so that they would be consistent with the topographic DEM. Between 2003 and 2005, WAM was applied to other CERP projects including Northern Palm Beach County and the Caloosahatchee River. Subbasins in these areas were obtained from previous modeling efforts and defined further using aerials and permits.

In 2005, WAM was applied to the remainder of the LOPP area (JGH, et al. 2005). Subbasins for the S-65A, B and C basins were prepared in the same manner as performed for the LOW CERP WAM model (HDR, 2003). Subbasins for the C-44 basin were created primarily from the District's C-44 Basin Atlas and District issued permits.

Basins and subbasins used in the previous WAM modeling efforts are shown in **Figure 2-10** and were used as input to the models developed for this project.

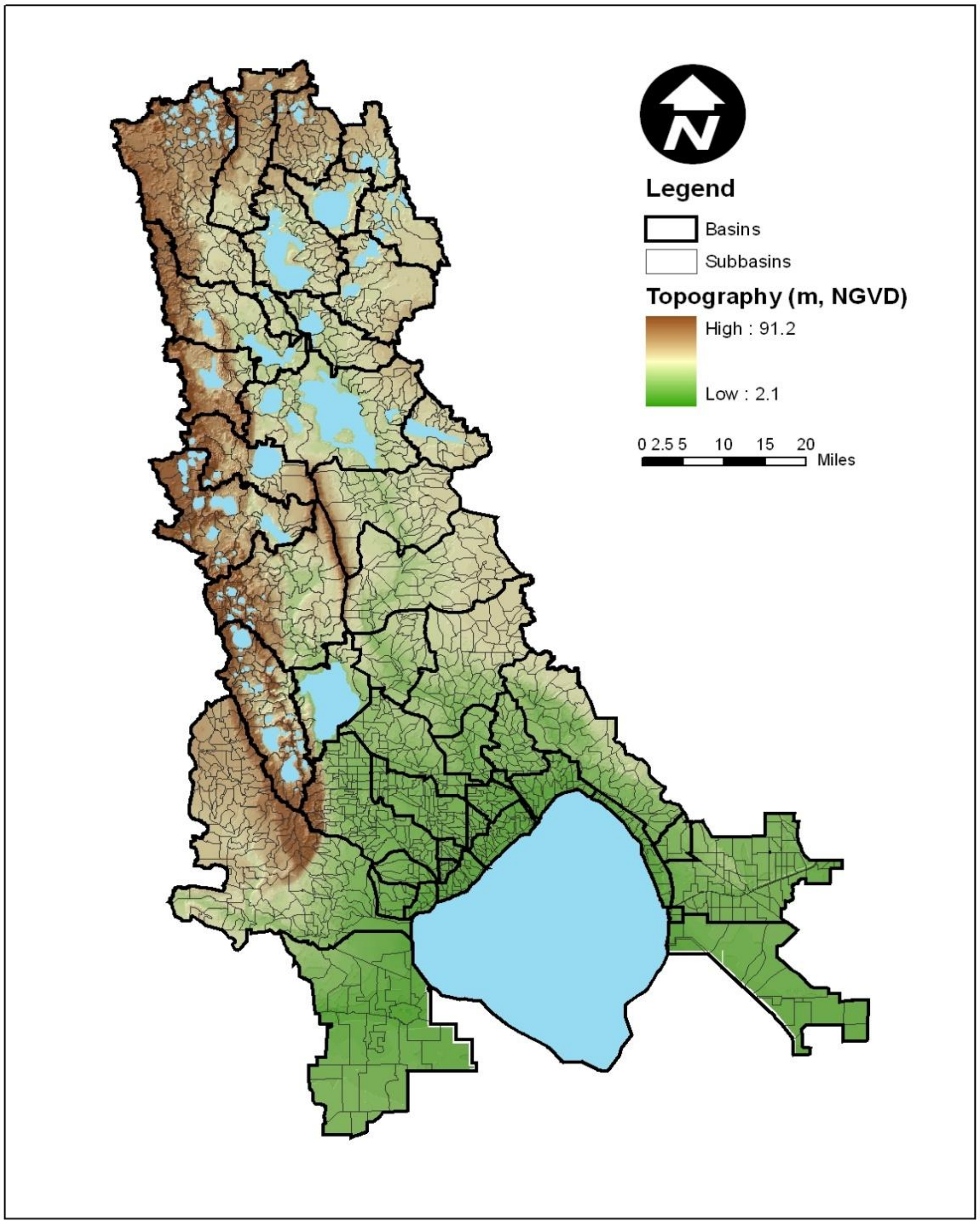

Figure 2-10: Basins, Subbasins, and Topography

2.1.A.6. Major Control Structures

Major control structures important for comparison of modeled flow, stage and Phosphorus concentration were determined during previous WAM application in the study area. The locations of the previously used structures were collected in the form of a feature class from JGH Engineering. Major structures at the boundaries of the East Lake Okeechobee basins were added to this dataset. **Figure 2-11** shows structure locations where stage and flow data were collected.

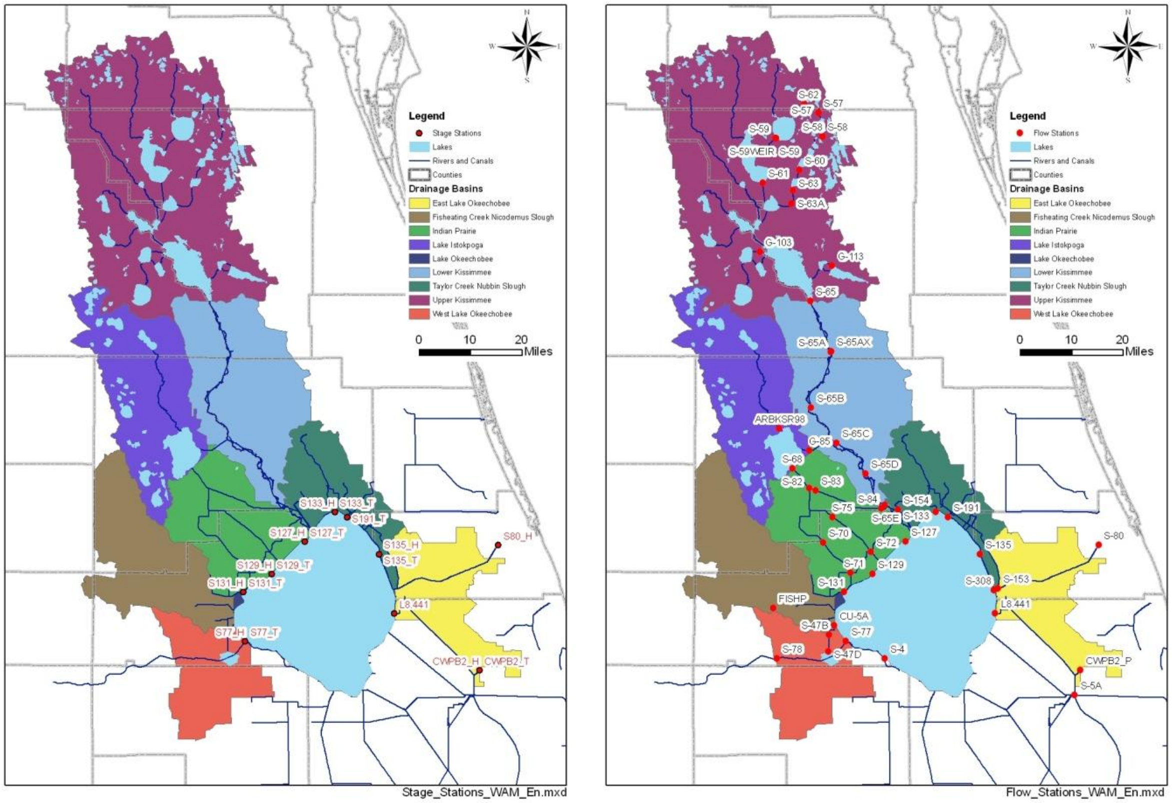

Figure 2-11: Stage and Flow Station Locations

2.1.A.7. Rainfall and Water Quality Monitoring Stations and PET

Locations and names of rainfall stations previously used in WAM and P-Budget models developed within the study area were collected in the form of a feature class from JGH Engineering. These stations are shown in **Figure 2-12.** The Hydrologic and Environmental Systems Modeling (HESM) department of the District has also developed an interpolated daily rainfall grid. The 2 mile by 2 mile grid is also shown in **Figure 2-12**. Further discussion of the rainfall data is in Section 2.1.B.2.

District-wide potential evapotranspiration (PET) data has also been interpolated to the 2x2 grid. Summary PET data will be collected from the SFWMD when it is available. The rainfall and PET datasets were developed as input to the District's South Florida Water Management Model (SFWMM or 2x2).

Surface water phosphorus concentration (mg/L) data was downloaded from DBHYDRO for major water control structures and other locations shown in **Figure 2-11**. Further information on the collection of water quality data is in Section 2.1.B.4.

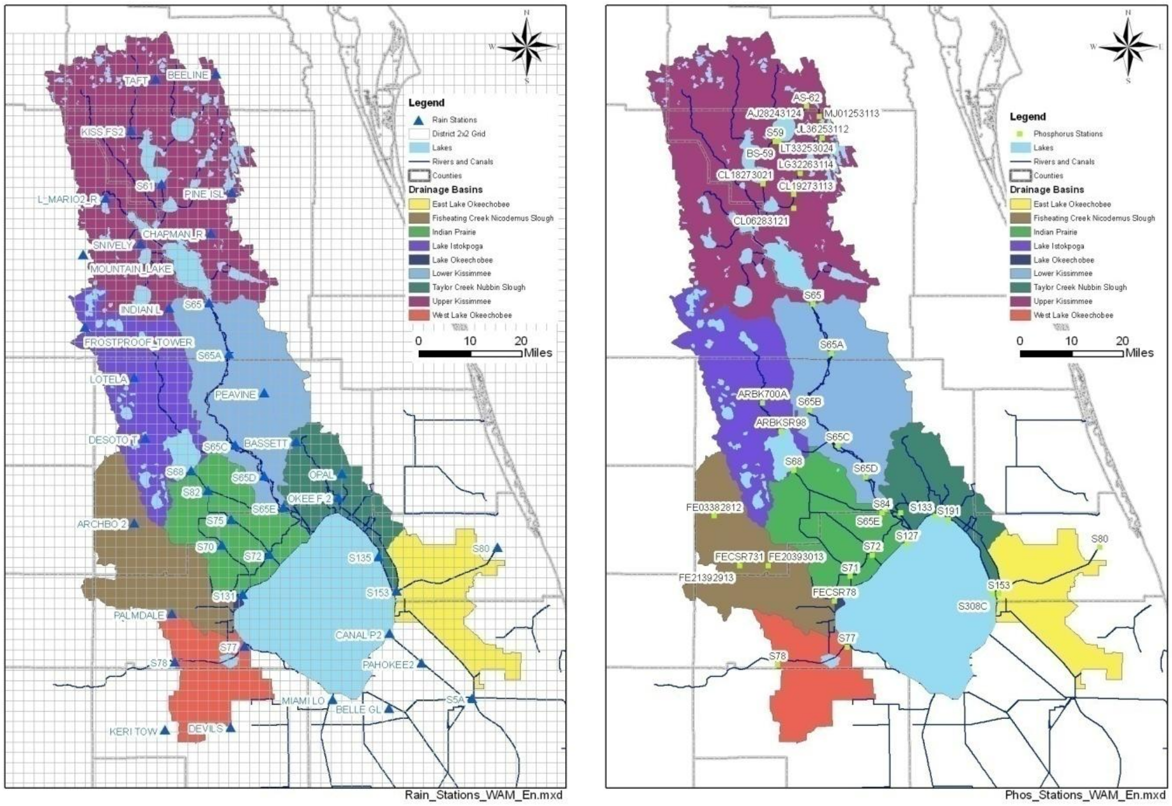

Figure 2-12: Locations of Rainfall and Water Quality Monitoring Stations

2.1.A.8. Base Map Layers

Separate feature classes of the study area, primary basins and sub-basins were collected for the project. These feature classes delineated the hydrologic units used to summarize the output of the models developed for the project. The feature class containing the primary basin boundaries – the next level of delineation below the entire study area – that was used as a base layer was developed for the Phase II Technical Plan (SFWMD 2008). The hydrography feature class described in Section 2.1.4 and a feature class of lakes downloaded from SFWMD GIS Data Catalog will be used with a county boundary feature class downloaded from the FGDL website to provide spatial reference and a schematic representation of the model.

2.1.B. Databases

All newly collected flow, stage, rainfall and water quality data described in the following sections were stored in a Microsoft Access database. For each type of data there are two tables; one table is a list of the stations and related information, and the other table houses the measured data. For example, there is one table listing all the flow stations with data in the database. Another table contains the average daily flow values for every structure. These tables were imported to an ArcGIS 9.2 personal geodatabase.

2.1.B.1. Flow and Stage

Time series flow data – mean daily flow in cubic feet per second (cfs) – was collected for the structures shown in **Figure 2-11**. Generally, the time series data covers the period of record (POR) from the beginning of calendar year 1972 through the end of 2007. Time series in DBHYDRO that were marked as "MOD1" and "PREF" were downloaded where available. Time series marked as MOD1 are baseline hydrologic datasets developed for regional modeling. But it was often the time series labeled PREF, denoting preferred, that covered the entire POR and influenced the decision to use 1972 to 2007 as the POR. For some stations, data for the entire period was not available – whether marked as modeling or preferred time series. Since the flow data was primarily used to calibrate the model developed with WAM, it was not critical to have data of the entire POR at every flow station.

The historical record of stage, or water surface elevation, was collected for the structure in the L-8 Tieback which discharges to the Grassy Waters Preserve as well as structures around Lake Okeechobee. The time series of headwater and tailwater stages (feet NGVD 29) for the L-8 Tieback structure begin in May 2006 and end in March 2008.

2.1.B.2. Rainfall

There were 42 rainfall stations, shown in **Figure 2-12**, where rainfall data was previously collected and input to WAM models of the study area. The format of the existing pre-processed time series data files (GLEAMS) for these stations was not compatible with the Arc Hydro framework. Initially, the rainfall stations feature class collected as described in Section 2.1.A.7 was used as a guide to download the daily sum rainfall data in inches from DBHYDRO.

Time series rainfall data for most of the 42 stations was collected from the SFWMD's DBHYDRO database. Of the 42 stations, DBHYDRO did not contain the full POR time series for seven stations and did not contain any data for 1 station. For this initial effort, some data for Frostproof Tower, the rainfall station with no rainfall data in DBHYDRO, was collected from the Southwest Florida Water Management District (SWFWMD) website.

After the District reviewed the initial approach of using recently downloaded DBHYDRO rainfall data, the possibility of using the District's (HESM) interpolated grid data was considered. The interpolated grid data was previously used in a WAM model developed for the C-43 Basin under contract to the USACE. For that project, data for the middle cell of every block of nine cells was input to WAM. This level of simplification increased run times unacceptably. Therefore, instead of attempting to simplify the grid data in that way, the dataset of time series, prepared as input to the grid interpolation routine, was collected from the HESM. This dataset is made up of HEC-DSS files – databases – that are named by county. HESM used the data in the HEC-DSS files to create the interpolated grid for the period from 1914 through 2005. More discussion of the preparation of rainfall data is presented in Section 2.2.C.1.

2.1.B.3. Evapotranspiration

WAM generates is own PET values based on latitude, solar radiation, temperature, and wind.

2.1.B.4. Water Quality

Water quality data of surface water phosphorus concentration was collected from DBHYDRO for major water control structures shown in **Figure 2-11**. The DBHYDRO code for some water quality stations did not match the names of the major flow control structures where the measurements were taken. The SFWMD website mapping water quality monitoring stations (https://my.sfwmd.gov/portal/page?_pageid=2954,19761104&_dad=portal&_schema=PORTAL) was used to find the less obviously named time series in DBHYDRO. The original time series names were maintained in the Access database so that in the future it would be possible to go directly to DBHYDRO and collect the latest data. A third water quality station table contains two columns to relate the DBHYDRO time series name with the more recognizable names of flow stations in the Access and Arc Hydro database to facilitate the comparison of modeled output and observed data.

2.1.C. System Operations

Descriptions of major control structures were collected from the Structure Information Site available on the internal SFWMD website. The descriptions of general operating criteria and the design data for 53 structures are included in their original form in **Appendix A-2**. **Tables 2-2** and **2-3** summarize some of the information from the downloaded descriptions.

Table 2-2: Summary of Major Control Structures in Study Watershed

Structure ID	Structure Type	Flashboard(s) (F) or Gate(s) (G)	Basin	Stream
C-10A	Culvert	G	L-8	L-8
C-5	Culvert	G	Nicodemus Slough	Nicodemus Slough
CU-5A	Culvert		West Lake O.	L-41
G-103	Spillway/Weir - Sheetpile	F	Upper Kissimmee	Zipperer Canal
G-113	Culvert	F	Upper Kissimmee	Outlet of lake Marian
G-85	Spillway/Weir - Sheetpile	F	Lake Istokpoga	Istokpoga Canal
S-127	Pump with Lock	-	Indian Prairie	L-48
S-129	Pump/Culvert	-	Indian Prairie	L-49
S-131	Pump with Lock	-	Indian Prairie	L-50
S-133	Pump/Culvert	-	Taylor Creek/Nubbin Slough	Taylor Creek
S-135	Pump with Lock	-	Taylor Creek/Nubbin Slough	L-47
S-153	Spillway - Concrete	G	Taylor Creek/Nubbin Slough	L-65 Borrow Canal
S-154	Culvert - Box	G	Taylor Creek/Nubbin Slough	LD-4
S-154C	Culvert	G	Taylor Creek/Nubbin Slough	LD-4
S-155A	Spillway - Concrete	G		C-51
S-169	Culvert	G	South Lake O.	Industrial Canal
S-191	Spillway - Concrete	G	Taylor Creek/Nubbin Slough	Nubbin Slough
S-235	Culvert	G	West Lake O.	LD-3
S-308	Spillway/Lock - Concrete	G	East Lake O.	St. Lucie
S-342	Culvert	G	Fisheating Creek	Nicodemus Slough into C-19 extension
S-352	Spillway - Concrete	G	East Lake O.	West Palm Beach Canal - L-10
S-4	Pump Station	-	South Lake O.	To LO from Ag Land via L-D1, C-20, C-21
S-47				
S-47B	Culvert	G	Fisheating Creek/West Lake O.	From C-19ext and L-42 to south
S-47D	Spillway - Concrete	G	West Lake O.	To and from C-43
S-57	Culvert	G	Upper Kissimmee	C-30
S-58	Culvert	G	Upper Kissimmee	C-32
S-59	Culvert	G	Upper Kissimmee	C-31
S-5A	Pump Station	-	East Lake O.	Located on the C-51 - Discharges out of basin to the south
S-5AE	Culvert - Box	G	East Lake O.	Located on the C-51 - Discharges out of basin to the east or brings water from east to be pumped by S-5A
S-5AS	Spillway - Concrete	G	East Lake O.	Located on L-40 Borrow Canal - Flood operation to WCA 1 - Irrigation operation from WCA 1
S-5AW	Culvert - Box	G	East Lake O.	Located on the C-51 - Discharges to and from L-8
S-5AX	Culvert	G	South Lake O.	L-13 Borrow Canal - divides drainage area for WPB Canal and Hillsboro Canal
S-60	Spillway - Concrete	G	Upper Kissimmee	C-33
S-61	Spillway - Concrete	G	Upper Kissimmee	C-35
S-62	Spillway - Concrete	G	Upper Kissimmee	C-29
S-63	Spillway - Concrete	G	Upper Kissimmee	C-34
S-65	Spillway - Concrete	G	Upper Kissimmee	C-38
S-65a	Spillway - Concrete	G	Lower Kissimmee	C-38
S-65c	Spillway - Concrete	G	Lower Kissimmee	C-38
S-65d	Spillway - Concrete	G	Lower Kissimmee	C-38
S-65e	Spillway - Concrete	G	Lower Kissimmee	C-38
S-68	Spillway - Concrete	G	Lake Istokpoga	To C-41A from Lake Istokpoga
S-70	Spillway - Concrete	G	Indian Prairie	C-41
S-71	Spillway - Concrete	G	Indian Prairie	C-41
S-72	Spillway - Concrete	G	Indian Prairie	C-40
S-75	Spillway - Concrete	G	Indian Prairie	C-40
S-76	Spillway - Concrete	G	East Lake O.	L-8
S-77	Spillway - Concrete	G	West Lake O.	C-43
S-78	Spillway - Concrete	G	West Lake O.	C-43
S-80	Spillway - Concrete	G	East Lake O.	St. Lucie
S-82	Spillway - Concrete	G	Indian Prairie	C-41A to C-41
S-83	Spillway - Concrete	G	Indian Prairie	C-41A
S-84	Spillway - Concrete	G	Indian Prairie	C-41A

Table 2-3: Summary of time series data for Major Control Structures

DBKEY	STATION	COUNTY	TYPE	UNITS	START	END	LAT	LONG
00210	ARBKSR98	HIG	FLOW	CFS	1939	2008	272633	811750
TW073	CWPB2_H	PAL	STG	FT NGVD29	2006	2008	264519	802044
TW079	CWPB2_P	PAL	FLOW	CFS	2006	2008	264519	802044
TW075	CWPB2_T	PAL	STG	FT NGVD29	2006	2008	264519	802044
15627	FISHP	GLA	FLOW	CFS	1972	2007	265557	811853
02854	L8.441	PAL	STG	FT NGVD29	1976	2008	265502	803648
15640	L8.441	PAL	FLOW	CFS	1970	2007	265502	803648
15817	S127_H	GLA	STG	FT NGVD29	1994	2008	270720	805345
15641	S127_P	GLA	FLOW	CFS	1972	2007	270720	805345
15818	S127_T	GLA	STG	FT NGVD29	1994	2008	270720	805345
15642	S129 PMP_P	GLA	FLOW	CFS	1972	2007	270147	810005
15821	S129_H	GLA	STG	FT NGVD29	1994	2008	270147	810005
15822	S129_T	GLA	STG	FT NGVD29	1994	2008	270147	810005
15643	S131 PMP_P	GLA	FLOW	CFS	1972	2007	265843	810524
15719	S131_H	GLA	STG	FT NGVD29	1992	2008	265845	810524
15720	S131_T	GLA	STG	FT NGVD29	1992	2008	265845	810524
15825	S133_H	OKE	STG	FT NGVD29	1994	2008	271222	804803
15637	S133_P	OKE	FLOW	CFS	1972	2007	271222	804803
15828	S133_T	OKE	STG	FT NGVD29	1994	2008	271222	804803
15638	S135 PMP_P	MAR	FLOW	CFS	1972	2007	270511	803940
15803	S135_H	MAR	STG	FT NGVD29	1994	2008	270511	803940
15802	S135_T	MAR	STG	FT NGVD29	1994	2008	270511	803940
04512	S153_S	MAR	FLOW	CFS	1983	1988	265920	803616
04868	S153_S	MAR	FLOW	CFS	1983	1988	265920	803616
06766	S153L_S	MAR	FLOW	CFS	1985	2008	265919	803617
15805	S191_H	OKE	STG	FT NGVD29	1994	2008	271131	804545
15639	S191_S	OKE	FLOW	CFS	1972	2007	271131	804545
15806	S191_T	OKE	STG	FT NGVD29	1994	2008	271131	804545
15626	S308.DS	MAR	FLOW	CFS	1972	2007	265901	803659
15630	S4_P	GLA	FLOW	CFS	1974	2007	264723	805742
04376	S47D_S	GLA	FLOW	CFS	1977	1994	264835	810822
15578	S47D_S	GLA	FLOW	CFS	1993	2008	264835	810822
04394	S57_C	OSC	FLOW	CFS	1969	1994	282020	811027
15525	S57_C	OSC	FLOW	CFS	1992	2008	282020	811027
04400	S58_C	OSC	FLOW	CFS	1969	1994	281619	810940
15528	S58_C	OSC	FLOW	CFS	1993	2008	281619	810940
04406	S59_S	OSC	FLOW	CFS	1963	1994	281556	811840
15533	S59_S	OSC	FLOW	CFS	1993	2008	281556	811840
06889	S59WEIR_W	OSC	FLOW	CFS	1971	1997	281558	811835
04608	S60_S	OSC	FLOW	CFS	1967	1994	281036	811403
15536	S60_S	OSC	FLOW	CFS	1993	2008	281036	811403
04412	S61_S	OSC	FLOW	CFS	1963	1994	280824	812105
15560	S61_S	OSC	FLOW	CFS	1993	2008	280824	812105

DBKEY	STATION	COUNTY	TYPE	UNITS	START	END	LAT	LONG
04418	S62_S	ORA	FLOW	CFS	1969	1993	282147	811304
15539	S62_S	ORA	FLOW	CFS	1993	2008	282147	811304
04424	S63_S	OSC	FLOW	CFS	1967	1994	280708	811515
15542	S63_S	OSC	FLOW	CFS	1993	2008	280708	811515
04796	S63A_S	OSC	FLOW	CFS	1968	1993	280448	811535
15798	S63A_S	OSC	FLOW	CFS	1991	2008	280448	811535
H0289	S65_S	OSC	FLOW	CFS	1933	2007	274814	811153
J9202	S65A_S	POL	FLOW	CFS	1986	2007	273936	810803
12570	S65AX_C	OSC	FLOW	CFS	1988	2008	273939	810753
HG238	S65B_S	OKE	FLOW	CFS	1967	1998	273010	811144
06959	S65C_S	OKE	FLOW	CFS	1987	2008	272405	810653
06962	S65D_S	OKE	FLOW	CFS	1987	2008	271852	810122
15631	S65E	OKE	FLOW	CFS	1972	2007	271331	805745
15632	S68_S	HIG	FLOW	CFS	1972	2007	271948	811515
04808	S70_S	GLA	FLOW	CFS	1976	1994	270707	810926
05428	S70_S	GLA	FLOW	CFS	1986	1994	270707	810926
15766	S70_S	GLA	FLOW	CFS	1994	2008	270707	810926
15633	S71_S	GLA	FLOW	CFS	1972	2007	270201	810416
15634	S72_S	GLA	FLOW	CFS	1972	2007	270533	810022
04826	S75_S	GLA	FLOW	CFS	1961	1997	271130	810738
05433	S75_S	GLA	FLOW	CFS	1986	1994	271130	810738
15774	S75_S	GLA	FLOW	CFS	1994	2008	271130	810738
J8188	S77_H	GLA	STG	FT NGVD29	1998	2003	265021	810507
JI497	S77_T	GLA	STG	FT NGVD29	1998	2003	265021	810507
15635	S77_T	GLA	FLOW	CFS	1972	2007	265021	810507
DJ236	S78_S	GLA	FLOW	CFS	1996	2008	264723	811810
J8184	S78_S	GLA	FLOW	CFS	1998	2003	264723	811810
00285	S80_H	MAR	STG	FT NGVD29	1987	2003	270640	801705
JW224	S80_S	MAR	FLOW	CFS	1952	2007	270640	801705
04832	S82_S	HIG	FLOW	CFS	1962	1990	271622	811207
05434	S82_S	HIG	FLOW	CFS	1986	1993	271622	811207
15960	S82_S	HIG	FLOW	CFS	1993	2008	271622	811207
04838	S83_S	HIG	FLOW	CFS	1962	1993	271600	811051
05439	S83_S	HIG	FLOW	CFS	1986	1996	271600	811051
15965	S83_S	HIG	FLOW	CFS	1993	2008	271600	811051
15636	S84_S	HIG	FLOW	CFS	1972	2007	271258	805824

2.2. Data preparation

2.2.A. <u>Reach Delineation</u>

The new version of WAM was able to use previously created Arc Hydro geodatabases for building stream model networks, such as the District-wide Arc Hydro Enhanced Database (AHED) which is not yet completed. WAM includes tools that allow users to group hydrography segments together to form a model reach. This was necessary because typical hydrography feature classes such as NHDs are more detailed than needed for modeling purposes. WAM assigned what are called ReachIDs to each group, but used the Arc Hydro framework to determine the direction of flow with an attribute that was called NextDownID.

A detailed Arc Hydro geodatabase for the entire study area is not yet available, but fortunately, previous versions of WAM have been used to simulate the study area with reach networks that are useful for this project. This information is readily available and can be replaced in the future with the District's Arc Hydro geodatabase when it is completed.

The previously developed model reach networks were used to create an Arc Hydro geodatabase for this project. The process used the combined model reach network that was developed for the LOPP P-Budget project and the segments in ArcGIS™. There are approximately 2,500 model reaches in the dataset. Many of these include gaps or dangle nodes as well as other connectivity issues that need to be resolved before simulation. A tool that will be available in the new version of WAM was used to "flip" the direction of lines so that the start and end points of the lines match the direction of flow. This, together with clean topology (one reach's end point to the next reach's start point) is necessary to move into Arc Hydro.

Once the editing was completed, Arc Hydro was used to assign HydroIDs. These IDs were copied to a field called ReachID. Normally at this stage, excess hydrography segments would be grouped using tools in WAM for model reaches. However, since this grouping was already performed in the previous modeling effort, additional grouping was not necessary. An example of the reach Arc Hydro network is shown in **Figure 2-13**.

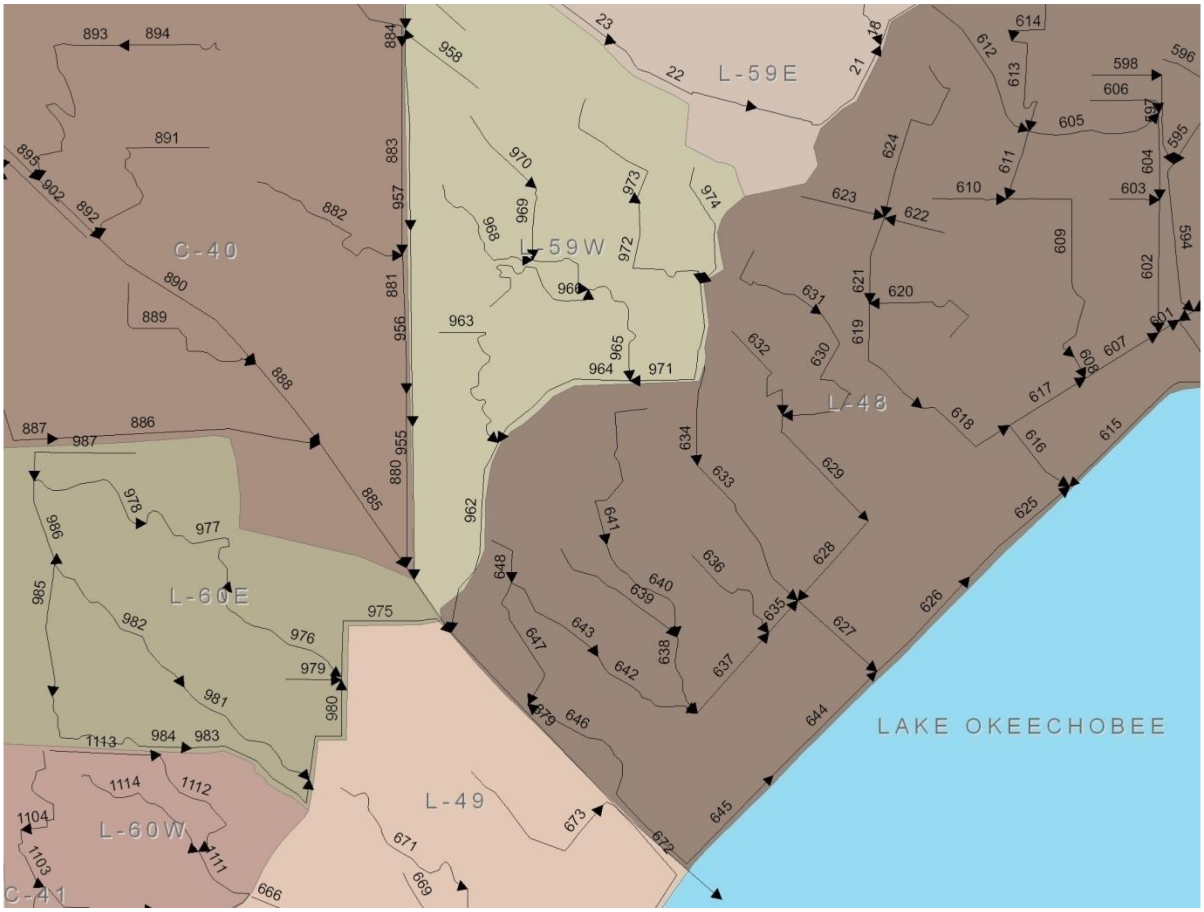

Figure 2-13: Sample Reach Arc Hydro Network

2.2.B. GIS Dataset Reconciliation

2.2.B.1. Land Use

The new version of WAM uses the same land use database as in previous versions. All of the land use codes present in the 2004-2005 and 2006 data sets are listed in the WAM land use database. No new land uses or land use parameters needed to be defined in the WAM land use database. Based on the comparison of 2004-2005 and 2006 land use datasets presented herein, the District will establish which data will be used for this project.

2.2.B.2. Soils

As mentioned in Section 2.1.A.2, the collected soils data was checked for consistency with the existing WAM database soils. The WAM database contains data for 429 soils (SWET 2003). In the compiled feature class, there were 113 uniquely named soils. Most of these soil types were found to be in the WAM soil database. Because some of the names were truncated in the WAM database, a lookup table relating the lists of names in the feature class and the database was created. **Table 2-4** shows which WAM soils types were matched to soil types in the feature class used in this project.

Table 2-4: Lookup table for relating mapped soils to WAM soil parameter database

IN FEATURE CLASS	IN WAM DB	IN FEATURE CLASS	IN WAM DB	IN FEATURE CLASS	IN WAM DB
ADAMSVILLE	ADAMSVILL	HOLOPAW	HOLOPAW	PLACID VARIANT	PLACID
ADAMSVILLE VARIANT	ADAMSVILL	HONTOON	HONTOON	PLANTATION	PLANTATIO
ANCLOTE	ANCLOTE	HYDRAQUENTS, CLAYEY	HYDRAQUEN	POMELLO	POMELLO
ANKONA	ANKONA	IMMOKALEE	IMMOKALEE	POMONA	POMONA
APOPKA	APOPKA	JONATHAN	JONATHAN	POMPANO	POMPANO
AQUENTS	AQUENTS	JUPITER	JUPITER	POPLE	POPLE
ARCHBOLD	ARCHBOLD	KALIGA	KALIGA	PUNTA	PUNTA
ARENTS	ARENTS	KENDRICK	KENDRICK	RIVERIA	RIVERIA
ASTATULA	ASTATULA	LAKE	LAKE	RIVIERA	RIVERIA
ASTOR	ASTOR	LAUDERHILL	LAUDERHIL	SALERNO	SALERNO
BASINGER	BASINGER	LAWNWOOD	LAWNWOOD	SAMSULA	SAMSULA
BOCA	BOCA	LOCHLOOSA	LOCHLOOSA	SANIBEL	SANIBEL
BORROW PITS	ARENTS	LOKOSEE	LOKOSEE	SATELLITE	SATELLITE
BRADENTON	BRADENTON	LYNNE	LYNN	SEFFNER	SEFFNER
BRIGHTON	BRIGHTON	MALABAR	MALABAR	SMYRNA	SMYRNA
CANDLER	CANDLER	MANATEE	MANATEE	SPARR	SPARR
CANOVA VARIANT	CANOVA	MARGATE	MARGATE	ST. AUGUSTINE	ST AUGUST
CASSIA	CASSIA	MILLHOPPER	MILLHOPPE	ST. JOHNS	ST. JOHNS
CHOBEE	CHOBEE	MINERAL SOIL	ARENTS	ST. LUCIE	ST. LUCIE
DANIA	DANIA	MYAKKA	MYAKKA	TAVARES	TAVARES
DAYTONA	DAYTONA	NARCOOSSEE	NARCOOSSE	TEQUESTA	TEQUESTA
DELRAY	DELRAY	NEILHURST	NEILHURST	TERRA CEIA	TERRA
DENAUD	DENAUD	NITTAW	NITTAW	TORRY	TORRY
DUETTE	DUETTE	OKEELANTA	OKEELANTA	TUSCAWILLA	TUSCAWILL
EATON	EATON	OKLAWAHA	OKLAWAHA	UDIFLUVENTS	UDIFLUVEN
EAUGALLIE	EAUGALLIE	OLDSMAR	OLDSMAR	UDORTHENTS	UDORTHENT
ELECTRA	ELECTRA	ONA	ONA	URBAN LAND	URBAN
FELDA	FELDA	ORLANDO	ORLANDO	VALKARIA	VALKARIA
FLORAHOME	FLORAHOME	ORSINO	ORSINO	VERO	VERO
FLORIDANA	FLORIDANA	PAHOKEE	PAHOKEE	WABASSO	WABASSO
FORT MEADE	FORT MEAD	PAISLEY	PAISLEY	WATER	WATER
FT. DRUM	FT. DRUM	PAOLA	PAOLA	WAUBERG	WAUBERG
GATOR	GATOR	PARKWOOD	PARKWOOD	WAUCHULA	WAUCHULA
GENTRY	GENTRY	PENDARVIS	PENDARVIS	WAVELAND	WAVELAND
HALLANDALE	HALLANDAL	PINEDA	PINEDA	WINDER	WINDER
HAPLAQUENTS	HAPLAQUEN	PINELLAS	PINELLAS	WULFERT	WULFERT
HICORIA	HICORIA	PITS	PITS	ZOLFO	ZOLFO
HOBE	HOBE	PLACID	PLACID		

Some portions of Osceola County within the study area were not mapped in the feature class downloaded from FGDL. These areas are hatched in **Figure 2-14**. The SFWMD soils data discussed previously was checked but also lacked data for this area. The remainder of the area was patched with data developed for a previous WAM application (JGH et. al. 2005) for the Upper Kissimmee Basin. The patch data was interpreted from aerials.

In order to reduce simulation run times, the 113 uniquely named soils were combined into categories of soils types with similar characteristics. Some grouping is required by WAM since the software decides which sub-model to use – GLEAMS or EAAMOD – based on soil type. The 35 most extensive soil types in the dataset for the study watershed account for 92% of the watershed. These soil types are listed in **Table 2-5**. Further simplification was performed and documented when developing the model input.

The end results of the soils analysis for this report were a dataset mapping soil types and the table for relating them to soils types that exist in the WAM soils database. The data displayed in **Figure 2-14** was used as input for the models developed for this project. An insert is included in to provide a more detailed example of the spatial distribution of soil types.

Table 2-5: Top 35 Soil Types in the Study Watershed

COMPNAME	Count	Acres	% of Total Watershed
WATER	2100	664396	19%
IMMOKALEE	2518	318850	9%
BASINGER	9373	298282	8%
MYAKKA	1655	283573	8%
SMYRNA	1721	260668	7%
RIVIERA	2884	95936	3%
FLORIDANA	2648	93228	3%
VALKARIA	456	90991	3%
MALABAR	1022	85520	2%
ASTATULA	187	82879	2%
SAMSULA	1736	81926	2%
CANDLER	766	72319	2%
PINEDA	1006	70209	2%
FELDA	608	67219	2%
OLDSMAR	617	54323	2%
HONTOON	441	53409	2%
TAVARES	1034	49300	1%
EAUGALLIE	313	44069	1%
Total			79%

COMPNAME	Count	Acres	% of Total Watershed
PLACID	3048	41763	1%
POMELLO	1300	38346	1%
KALIGA	408	36859	1%
SATELLITE	566	36448	1%
BOCA	600	34136	1%
WAVELAND	259	29140	1%
WABASSO	441	25377	1%
HOLOPAW	603	24659	1%
POMPANO	329	22803	1%
TEQUESTA	298	21735	1%
SANIBEL	998	21696	1%
OKEELANTA	922	21244	1%
GATOR	862	20419	1%
HALLANDALE	814	20310	1%
MANATEE	74	20107	1%
ARENTS	422	19651	1%
ARCHBOLD	299	19623	1%
Total			13%

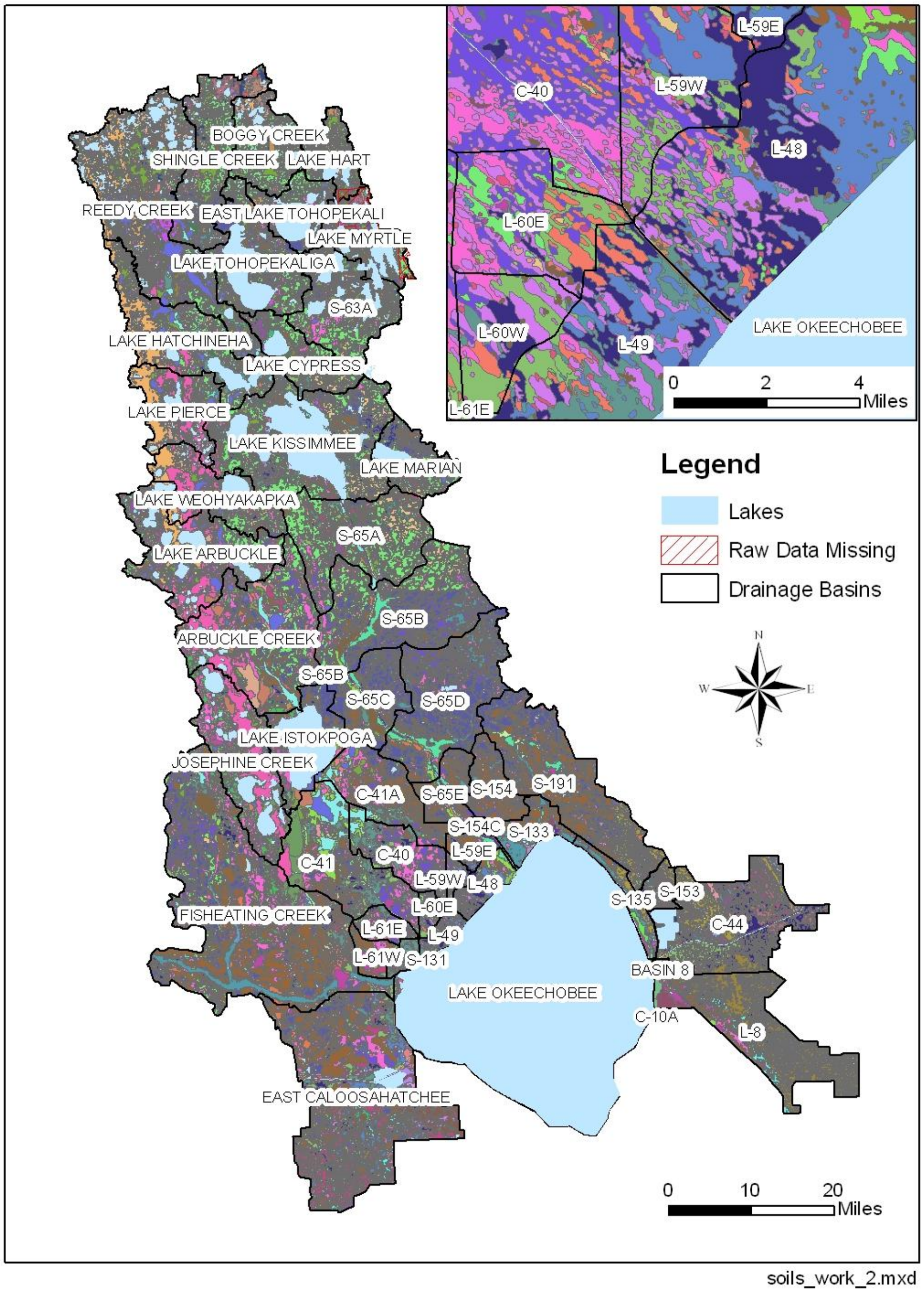

Figure 2-14: Map of Soil Types Used as Input to WAM

2.2.C. Time Series Dataset Preparation

Time series datasets for flow, stage, and water quality was used for comparison with WAM output. No processing of the collected datasets for flow, stage, and water quality was performed. Rainfall and ET time series were input to WAM and had the ability to be applied to sub-regions of the model domain or uniformly over the entire model domain.

2.2.C.1. Rainfall

Rainfall is a primary input to WAM and as such, missing portions of the time series must be patched with the best available rainfall data. A detailed review of the rainfall data collected initially from DBHYDRO was conducted for this report as described below. HESM performed quality control for the time series data that were stored in HEC-DSS files. The time series data in the HEC-DSS databases came from the same sources as those described in Section 2.1.B.2 of this report and also retain DBKEY identifiers.

It was apparent from the initial effort to collect rainfall data that at some rainfall monitoring stations separate time series were available which, when combined, covered the entire POR. At ten stations, there were time series that overlapped the same time period (**Table 2-6**).

Table 2-6: Overlapping Rainfall Monitoring Station Time Series

DBKEY	STATION	AGENCY	COUNTY	START	END	ALTERNATE ID
06207	BELLE GL_R	NOAA	PAL	1924	1998	MRF6119
15200	BELLE GL_R	WMD	PAL	1973	2007	
06206	DEVILS_R	NOAA	HEN	1956	1998	MRF6118
IV150	DEVILS_R	WMD	HEN	1978	2008	
05859	KISS.FS2_R	WMD	OSC	1972	2002	MRF162
16617	KISS.FS2_R	WMD	OSC	1991	2008	
06070	OKEE F 2_R	WMD	OKE	1960	1994	MRF44
16285	OKEE F 2_R	WMD	OKE	1995	2008	OKEEFS+R
16697	OKEE F 2_R	WMD	OKE	1991	2008	
06093	PALMDALE_R	FS	GLA	1963	2003	MRF5022
15786	PALMDALE_R	WMD	GLA	1992	2008	PALM+R
06120	S131_R	WMD	GLA	1965	1999	MRF52
16575	S131_R	WMD	GLA	1991	2008	
K8635	S131_R	WMD	GLA	1997	2008	S131-R
05849	S135_R	WMD	MAR	1971	1999	MRF150
16580	S135_R	WMD	MAR	1991	2008	
06068	S65D_R	WMD	OKE	1965	1995	MRF43
16658	S65D_R	WMD	OKE	1991	2008	
06071	S65E_R	WMD	OKE	1964	1998	MRF45
F9542	S65E_R	WMD	OKE	1996	2007	
06066	S68_R	WMD	HIG	1965	1999	MRF41
16654	S68_R	WMD	HIG	1991	2008	

Each collected time series was summarized on a yearly basis and inspected to determine if the data was a viable input to WAM. This quality check was important because WAM generates a time series of flow and concentration for unique combinations of soils, landuse, rainfall and ET values in the model domain on a one hectare scale. The routing module of WAM will simulate no reach flow if there is insufficient rainfall to generate runoff. This may be a valid occurrence, or, because a rainfall gage only represents rainfall measured at a discrete point, applying that rainfall over a large area may not be accurate. In cases where observed flow is different from simulated flow by roughly 10%, the accuracy of the contributing rain stations may be re-examined. The enhanced version of WAM used for this project also produced a warning result if it determined that the rainfall data may be suspicious.

Missing portions of the time series were filled with the data of the closest station, which originally contained data during that time. Time series, identified by DBHYDRO code, that were used for each rain station in WAM are listed in **Appendix A-3**.

While the above analysis was performed with the data initially downloaded from DBHYDRO, the resulting list shown in **Appendix A-3** were used to identify the HESM data stored in HEC-DSS files that were input to the models developed for this project.

2.2.C.2. Evapotranspiration

District-wide potential evapotranspiration (PET) data was interpolated to the 2x2 grid. Summary PET data will be collected from the SFWMD when it is available. The rainfall and PET datasets were developed as input to the District's South Florida Water Management Model (SFWMM or 2x2).

2.3. Conclusions

The information collected and formatted in this task was sufficient to use in WAM to simulate nutrient runoff in the basins. As with any study, however, there is always room for improvement in terms of the input information. Higher quality basin-wide topographic DEMs would improve surface flow simulations. A study-wide version of an Arc Hydro geodatabase, which is under development, would provide a more accurate accounting of flow paths and quantities. These datasets, when available, can be used by WAM in future simulations.

3.0 Large Lake Nutrient Assimilation Enhancement

3.1. Development of Lake Assimilation Algorithm

A model evaluation process was conducted to decide on the most appropriate existing model or models that could be incorporated into WAM to simulate the nutrients and sediment dynamics within lakes, reservoirs, and large wetland features in the Lake Okeechobee watershed. In order to be compatible with WAM and suitable for south Florida, the selected model(s) met the following minimum selection criteria;

1) simulates nitrogen, phosphorus, and BOD,
2) runs using the available state variables within WAM,
3) runs using a variable time step and is computationally efficient, and
4) has been calibrated for various lake and wetland conditions in south Florida.

The models evaluated were the Lake Okeechobee Water Quality Model (LOWQM) (James et al, 2007), the limnology model by Vollenweider (1975), the BathTub model (Walker, 2006), the DMSTA2 model (Walker and Kadlec, 2005), the WASP model (EPA, 2007), and a simplified regression model for a phosphorus-chlorophyll relationship by Dillion and Rigler (1974). These models vary in their approach, parameters simulated, input parameter requirements, time steps, and available calibrations for south Florida conditions.

The Vollenweider and Dillon and Rigler models were rejected because they only simulated phosphorus. The LOWQM model and WASP, which was the underlying model of LOWQM, were considered very strong candidates because they are robust models and WASP has been previously linked to WAM. However, during two previous WASP/WAM linkage projects it was determined that the structure and complexity of WASP would make it difficult to integrate into WAM’s code, so the linkage was done via WAM’s generation of WASP input files. This limitation and the fact that LOWQM has only been calibrated and verified for Lake Okeechobee and has not been shown to work for wetland systems, lowered LOWQM and WASP rankings as candidate models. The Bathtub model was conceptually simpler than LOWQM or WASP, but still met the selection criteria for lakes. However, it was not well suited for wetland systems. The DMSTA2 was also a conceptually simple model allowing straight forward integration into WAM and could handle both lakes and wetland systems, though its calibration work has focused on phosphorus dynamics. The DMSTA2 was calibrated for several Florida lakes and wetlands and should provide more reliable predictions. Black and Veatch (2006) did a similar evaluation of the LOWQM, DMSTA2, and CE-QUAL-W2 for the EAA A-1 reservoir and concluded that the DMSTA2 model would provide the most accurate long-term phosphorus predictions for the similar reasons stated previously, i.e. lack of calibration for the other models for Florida conditions.

Based on the model evaluation, DMSTA2 was ranked the highest with Bathtub next. Since BathTub has some features, like algal and chlorophyll-a responses and better nitrogen handling that are considered better than those in DMSTA2, it was decided to look into the possibility of integrating both models in to WAM. A combined sub-model was successfully developed, as described below.

As indicated earlier, the sub-model was based on the BathTub and DMSTA models by Dr. Bill Walker. These models are spreadsheet models using Excel and Visual Basic for Applications (VBA). In order to link the models to the existing WAM models, which are in Fortran and C++, the VBA code for DMSTA and BathTub were ported to C++.

For the shallow lakes in Florida, the sub-model runs DMSTA algorithms to generate the nutrient assimilation rates for the lake. During the algae growing season, results of the DMSTA algorithms are used as inputs to the BathTub trophic response algorithms (Chl-a, secchi, etc.) in order to simulate their effects on the nutrient concentrations. For each timestep, BathTub algorithms provide the final TP/TN output using DMSTA results as input. BathTub output also serves as DMSTA input for the following timestep.

3.2. Verification of Lake Assimilation Algorithm

The developed lake assimilation module was tested for coding integrity and functionality by comparing the results from the VBA and C++ versions. Using the same input values, the results were the same for both versions to 6 decimal places. This provides sufficient evidence that the code was correctly ported to C++. Because the DMSTA and BathTub model had already been verified for simulating lakes in south Florida, no additional verification of the lake assimilation module was needed.

Documentation is provided in the following Appendices:

- B-1 Model Linkage
- B-2 DMSTA P Cycling Kinetics for Lakes & Emergent Marshes, further described at http://www.wwwalker.net/dmsta
- B-3 BATHTUB Trophic Response Models for Lakes & Reservoirs, further described at http://www.wwwalker.net/bathtub
- B-4 Typical Input Values, Including Default Values for Florida Lakes
- B-5 Alternative Calibrations, Data Sources, and Data Ranges

Total Phosphorus can be simulated using DMSTA, first-order, or second-order kinetics. The DMSTA calibrations are based upon input/output time series data from Florida Lakes. Other calibrations are based upon seasonal-average concentrations in Florida Lakes or Corps of Engineers reservoirs (nationwide). See **Appendix B-5**. Either the DMSTA reservoir calibration or first-order model is recommended for application to Florida Lakes.

The DMSTA calibration was slightly more complex, and it involved simulation of two phosphorus storage compartments (water column and fixed biomass). Simulations of the latter can be sensitive to the assumed initial condition, typically for a period of one to three years. The initial biomass P storage was estimated based upon the specified initial water column P concentration, which initialized to an appropriate value for the period of record in order to avoid the initial condition strongly impacting the simulation results or requiring a long spin-up period. If available, observed data or literature for P concentrations or chlorophyll-a and P/CHLA ratios was used. After the simulation was run, the results were analyzed for a trend due to initial conditions. The initial water column P concentration was then adjusted to fall within the dynamic range of the simulation with the later portion of the simulation being weighted more heavily.

Total Nitrogen was simulated using first-order or second-order kinetics. The calibrations were based upon seasonal-average concentrations in Florida Lakes or Corps of Engineers reservoirs (nationwide) (See **Appendix B-5**). The nitrogen calibrations were not tested for dynamic simulations.

Total P and Total N concentrations predicted in the WAM mass-balance simulation were linked to BATHTUB empirical models for predicting chlorophyll-a and related trophic state indicators. The BATHTUB chlorophyll-a and Secchi models were tested against EPA National Eutrophication Survey data from lakes in Florida and elsewhere. The BATHTUB calibrations were based upon seasonal-average concentrations (May-September). Daily values provided by the simulation were averaged to support trophic state assessments.

Recommended default input values for Florida lakes are listed in **Appendices B-4 & B-5**. Site-specific calibrations were required in some applications, provided sufficient data are available. Users were encouraged to test sensitivity predictions to assumed input coefficients varied over ranges listed in **Appendices B-4 & B-5**.

While each of the sub-models was calibrated and tested individually against various datasets (**Appendix B-5**), it was recommended that the model linkage (**Appendix B-1**) as implemented in WAM be tested against data from one or more Florida Lakes. The lakes had multi-year time series of observed inflow loads and lake trophic state indicators, preferably over periods with significant changes in external nutrient load. It was important to test the accuracy of input loads predicted by WAM in addition to testing the lake response models. The stabilization period depended on the lake and was determined by analyzing the trends in the observed data. If the stabilization period was 1-3 years, then a 5 year period of data was desirable. If less, all available data was used, but it was noted that the accuracy of the results may have been reduced.

4.0 Model Calibration and Verification

4.1. Model Setup

The Watershed Assessment Model (WAM) has been applied to the Lake Okeechobee Protection Plan (LOPP) area in several previous studies over the past several years as described in Section 2 (Task 1). The previous studies have been related to either the Comprehensive Everglades Restoration Plan (CERP) performed for the District and the Army Corps of Engineers, or phosphorus budget analysis conducted for the District. For the first time, these efforts were being combined to coincide with a new version of WAM was designed to run within ESRI ArcGIS 9.2 software. It should be noted that no fundamental changes were made to WAM, and that the update was exclusively an enhancement based on an improved user interface, related functionality and increased flexibility provided to the user for running the model and reviewing the output.

4.1.A. GIS Datasets

4.1.A.1. Land Use

As mentioned in Section 2.1.A.1, two different land use datasets were acquired and analyzed for possible incorporation into the model, the SFWMD 2004-2005 dataset and the Divisions 2006 dataset. Ultimately, the latter was selected for use.

It should be noted that there were some changes made to the selected dataset. A more detailed dairy dataset know as dairy2k was incorporated which subdivided the Dairy land use into varying degrees of intensity in terms of cow density and other onsite activities. Abandoned dairies were also incorporated from previous WAM modeling efforts. Because the STAs in S-191 had just recently come online, they were not included in the calibration setup for S-191. However, a second S-191 setup was developed to reflect the addition of the Nubbin Slough and Taylor Creek Stormwater Treatment Areas (STAs) as shown in **Figures 4-1, 4-2, & 4-3**. These areas were edited to reflect a reservoir land use.

The resulting land use dataset was linked to the land use database used by WAM, which related the Florida Land Use Code Classification System (FLUCCS) to the land use codes used by WAM. Steps were taken to ensure that each of the FLUCCS codes in the District's land use dataset had a matching code in the WAM model.

4.1.A.2. Soils

The Soil Survey Geographic (SSURGO) dataset obtained in Task 1 was the same dataset used in the previous WAM modeling efforts. There were two areas within the Upper Chain of Lakes region that were void of information. When this area was originally modeled in 2002, Mock, Roos & Associates, Inc. used GIS to digitize the soils data for these missing areas using aerial photographs and vegetation types, and reconciled the digitized zones with neighboring soil types to fill in these gaps. This information was utilized again for the new modeling effort. WAM's soil database includes the entire state's list of soil types by component name (compname). The coverage was linked to the database to confirm a match for each soil type.

It was necessary to add a new soil to the database to correctly represent the abandoned dairies within this area. For these areas the existing soil type mapped did not account for the historic manure and P build accumulation that would have occurred through the operation of a dairy. Thus, a new soil "P impacted immokalee" was added to the database.

4.1.A.3. Topography

The topographic dataset compiled in Task 1 and as described in Section 2.1.A.3 was utilized with no further changes. This dataset utilized a combination of USGS and LIDAR (Light Detection and Ranging) data.

4.1.A.4. Hydrography

The hydrography dataset compiled in Task 1 and as described in Section 2.1.A.4 was used. This dataset was originally built to be consistent with the Arc Hydro data model format within a geodatabase and consisted of model reaches. However, the ArcHydro aspect of the dataset was not utilized as it was later determined that database structure was inconsistent with the needs of the ArcWAM submodels. Instead the dataset was utilized as vector files coded to match ArcWAM's requirements and stored in individual geodatabases, one per model basin, set up specifically for WAM input.

A change was made to the stream network to accommodate the STAs that have been constructed in the S-191 Basin. Additionally, through the calibration process, it was discovered that a portion of basin S-131 that was previously thought to drain west, did in fact drain south to Fisheating Creek. Further details on this change are discussed in Section 4.2.B of this report. This area was modified to more accurately simulate the flow through these canals.

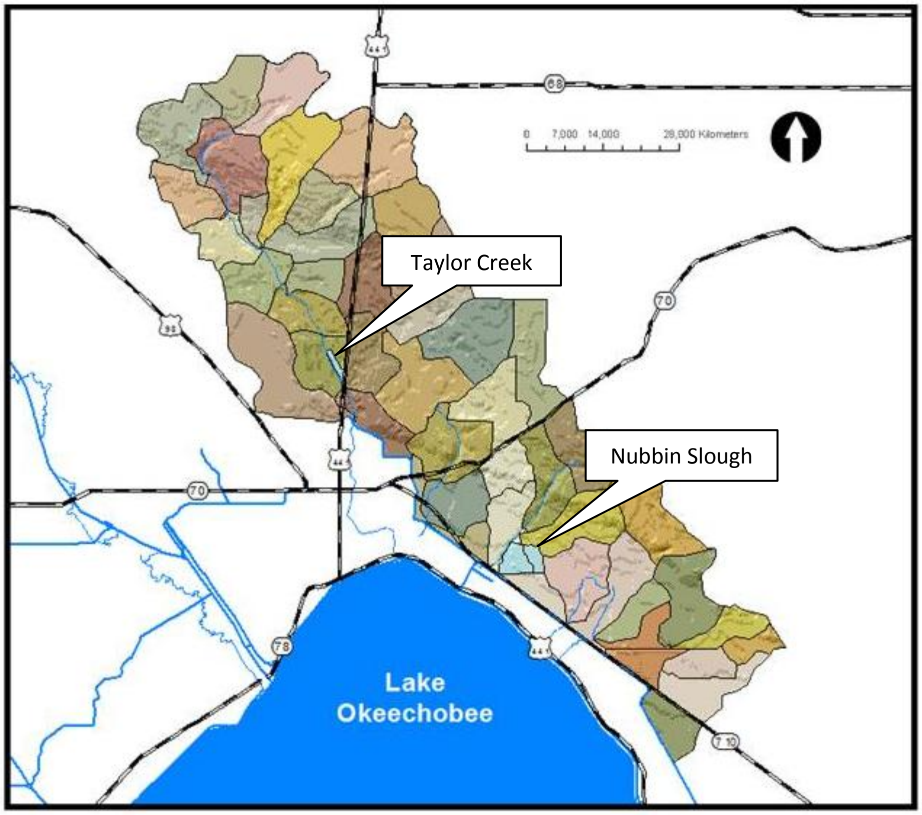

Figure 4-1: STA Locations

Figure 4-1 shows the locations of the STAs. **Figures 4-2 and 4-3** show the reach configurations of the Taylor Creek and Nubbin Slough STAs, respectively. The dark blue color indicates new reaches and the light blue color represents old reaches that will remain. Seepage reaches were added which include small weirs to simulate the seepage losses through the levees based on a seepage rate of 2.15 cfs/mile levee/ft of head which was researched and used in the C-139 Basin for similar STAs modeled in WAM. It should be noted that the Taylor Creek STA was modeled as a single cell because of its relative small size and low internal head differential.

Figure 4-2: Taylor Creek STA Reaches

Figure 4-3: Nubbin Slough STA Reaches

4.1.A.5. Basins and Subbasins

The basins and subbasins as described in Section 2.1.A.5 were used, but again, with one exception. The subbasins were edited to form hydrologic divides at the STA impoundment levees and to represent internal cells. It should be noted that the Taylor Creek STA was modeled as a single cell because of its relatively small size and low internal head differential.

WAM was originally run for individual basins for the CERP Lake Okeechobee Watershed analyses. The Kissimmee River (C-38) was not included, but rather, was treated as a receiving body to basins such as S-154, S-65D and S-65E. In later phases of CERP, these basins and several others extending west to Lake Istokpoga were joined to form a single basin called C-38. This was done to more accurately simulate flow in C-38 and to account for flows from Lake Istokpoga that can either flow south to Lake Okeechobee via C-40 and C-41 or can flow east into C-38 depending on water levels and structural controls.

For modeling purposes, it was decided that the inter-basin setup should be maintained and expanded on by including the Lake Istokpoga and Upper Chain of Lakes basins along with the S-65A, B and C Basins to form one large C-38 Basin. All other basins have direct and independent discharges to Lake Okeechobee and were set up as separate model basins in WAM. **Figure 4-4** shows the modeling areas in relation the basins.

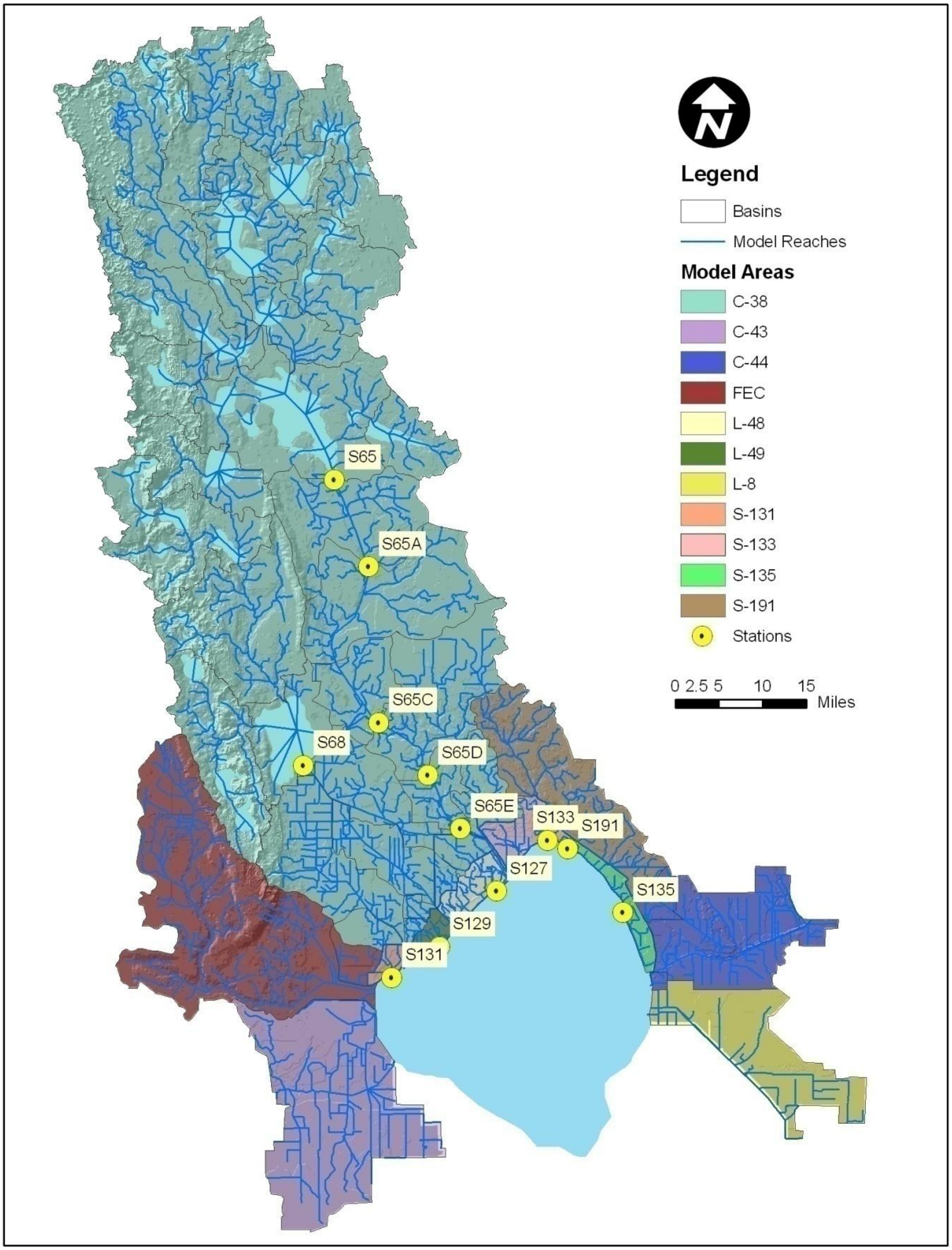

Figure 4-4: Model Areas and Monitoring Stations

4.1.B. Other Model Datasets

4.1.B.1. Control Structures

The data collected in Task 1 regarding the capacities, size and operational criteria for major water control structures were used in the WAM model. WAM's hydrodynamic routing algorithm allows for complex hydraulic structures to be placed at the top or bottom of any stream reach within the stream network. WAM can currently simulate weirs, top or bottom opening gated structures, culverts and pumps into its hydrodynamic routing network. The user describes the location, size and operational protocols for each structure in the *structures.in* input file. WAM's hydrodynamic model, "Blasroute" reads the structure information and applies the appropriate hydraulic formula in the stream routing. For more detail on this please refer to the WAM Technical Users Manual.

The following structures were incorporated into WAM to simulate operable controls or boundary conditions within the watershed (**Table 4-1**):

Table 4-1: Water Control Structures Incorporated into WAM

Structure	Type	Model Area	Structure	Type	Model Area
S-154	Gate	C-38	S-63	Gate	C-38
S-65E	Gate	C-38	S-60	Gate	C-38
S-65D	Gate	C-38	S-61	Gate	C-38
S-72	Gate	C-38	S-59	Gate	C-38
S-75	Gate	C-38	S-62	Gate	C-38
S-82	Gate	C-38	S-57	Weir	C-38
S-71	Gate	C-38	S-58	Weir	C-38
S-70	Gate	C-38	S-191	Weir	S-191
S-84	Gate	C-38	S-131	Pump	S-131
S-83	Gate	C-38	S-133	Pump	S-133
S-65	Gate	C-38	S-135	Pump	S-135
S-65A	Gate	C-38	S-127	Pump	L-48
S-65C	Gate	C-38	S-129	Pump	L-49
S-65D	Gate	C-38	S-78	Gate	C-43
S-65E	Gate	C-38	S-80	Gate	C-44
S-68	Gate	C-38	S-308	Gate	C-44
G-113	Weir	C-38	WPB Ctrl 2	Pump	L-8
S-63A	Gate	C-38	S5AE	Gate	L-8

4.1.B.2. Rainfall

Rainfall stations with excessive “gaps” in data (of several consecutive months) were eliminated. Stations with moderate or minimal “gaps” (less than one or two consecutive months) were “patched” with data from nearby stations. This was done using a program written by Soil and Water Engineering Technology, Inc. that worked specifically with data from the District’s DBHydro database. Geographic coordinates were used to determine the stations to use for filling in missing data. Further review found several areas where prolonged periods of zero rainfall had been recorded. These areas were re-coded in order that the data during these periods would be replaced by data from neighboring stations. Note that the Palmdale station in Fisheating Creek was found to be unusually high for several years in a row, so it was removed and substituted with

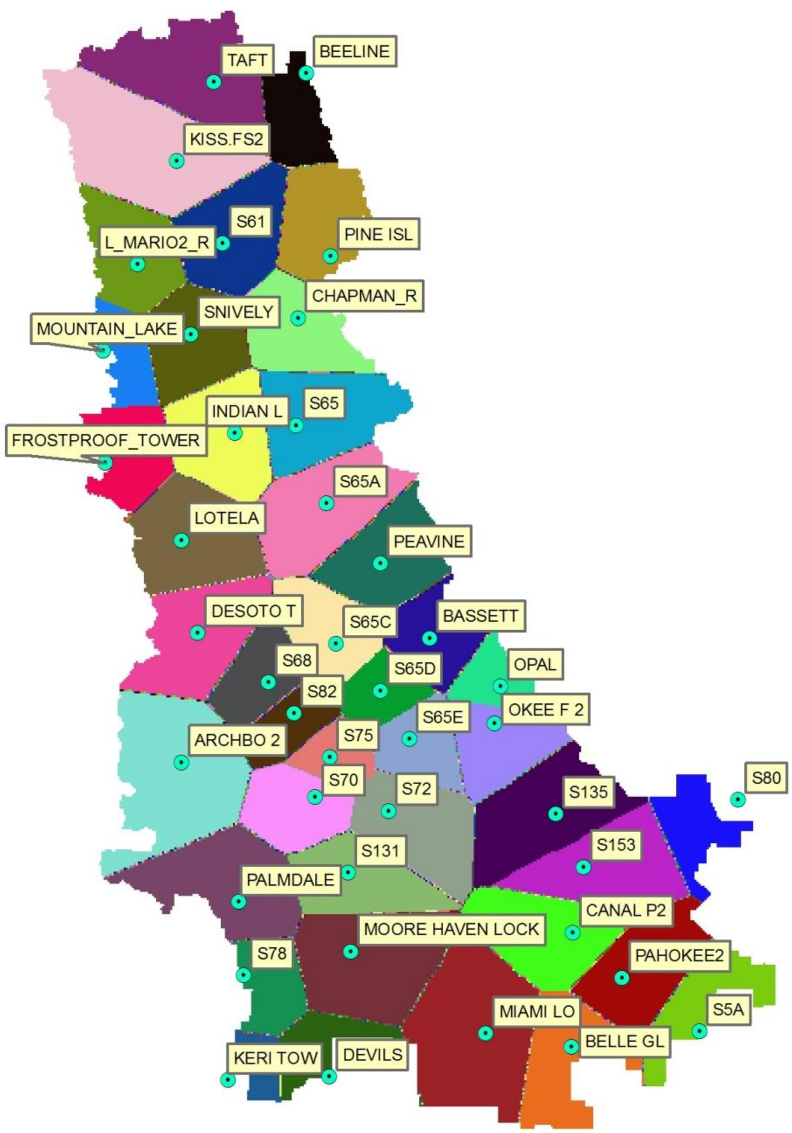

Figure 4-5: Rain Stations and Zones

the S-70 station. A total of 42 rainfall stations were used covering the entire LOPP area. A rain distribution grid was created using Thiessen's method and is shown in **Figure 4-5**. The rainfall datasets were then formatted to meet the requirements of the WAM model. **Figure 4-6** shows the annual rainfall measured at the stations.

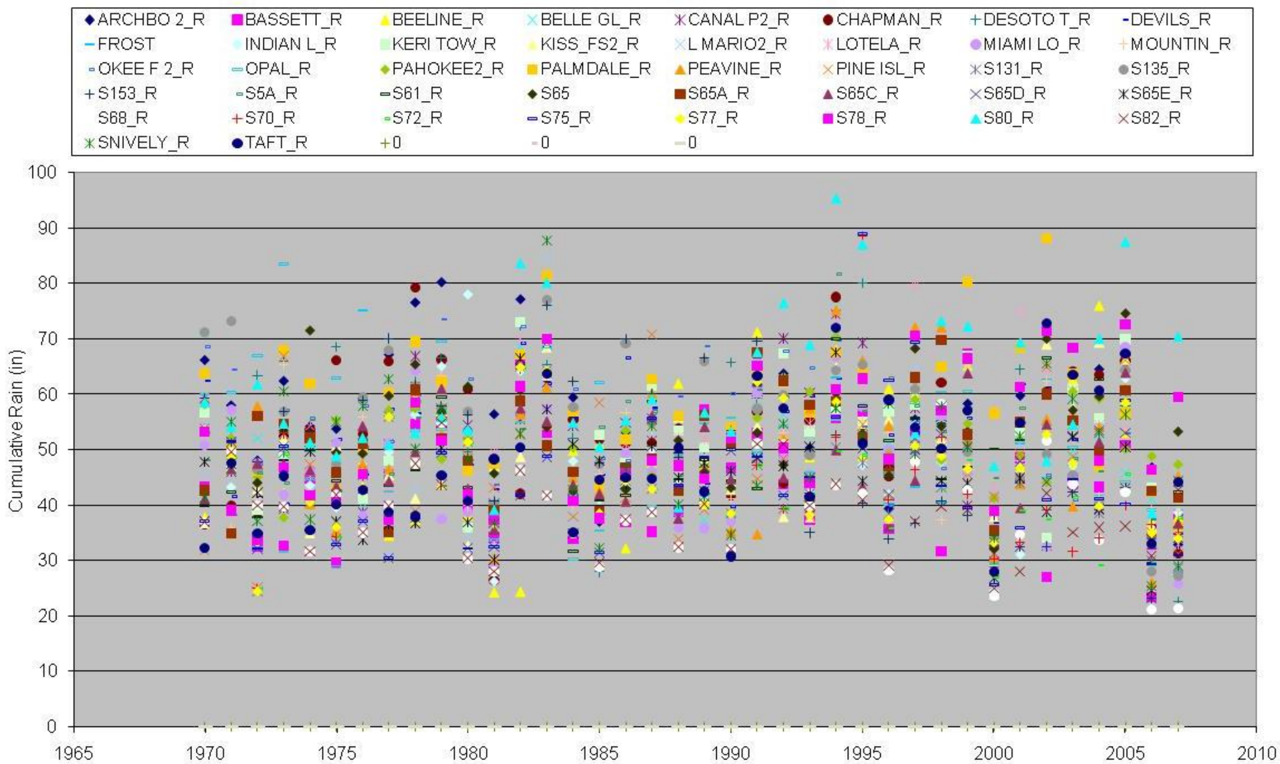

Figure 4-6: Annual Rainfall

4.2. DMSTA Setup and Verification

The DMSTA model developed by William Walker (http://www.wwwalker.net/dmsta) has been successfully integrated into the WAM model. The WAM sub-model BlasRoute was modified to provide an additional alternative to assimilate nitrogen and phosphorus within lakes and wetland systems, such as the stormwater treatment areas (STAs) being constructed within the Okeechobee watershed. The DMSTA module can be run for any reach or combination of reaches with unique characterization input parameters available for each reach condition, such as marshes, shallow/deep lakes, and sandy/muck bottom lakes. To use the DMSTA module within WAM, follow the steps described below.

The first step is to identify the reaches where the DMSTA module is to be run, which are typically lakes and marshes. WAM will recognize these reaches as DMSTA reaches by use of the ReachCode in the streams.in file where a ReachCode of 9800 to 9899 will tell WAM to look for the DMSTA input parameters for this ReachCode in the DMSTA.in file. Up to 100 individual lakes or marshes conditions can be represented, but typically lakes or marshes of similar conditions will simply be given the same ReachCode thus requiring only a few unique ReachCodes. The DMSTA.in file will have one line of input parameters for each ReachCode. The DMSTA input parameters, which are entered as comma or space delimited, are given in **Table 4-2.**

Table 4-2: Parameter Definitions for DMSTA as Set Up in the DMSTA.in File

Parameter	Description	Units
ReachCode	Code in Streams.in, DMSTA.in, Attenuate.in	
c0	Water Column conc. at 0 g/m^2 storage	ppb
c1	Water Column conc. at 1 g/m^2 storage	ppb
c2	Half-saturation conc. For P uptake	ppb
k	Net settling rate at steady state	m/yr
kMin	Min. net settling rate at steady state	m/yr
Z1	Depth at maximum uptake	cm
z2	Transition depth	cm
z3	Depth at minimum uptake	cm
uFirstP	First-Order Settling Rate	m/yr
kFirstP	First-Order Volumetric Loss	1/yr
kSecondP	Second-Order Loss	m^3/mg-yr
sedReleaseP	Sediment Release	mg/m^2-day
uFirstN	First-Order Settling Rate	m/yr
kFirstN	First-Order Volumetric Loss	1/yr
kSecondN	Second-Order Loss	m^3/mg-yr
sedReleaseN	Sediment Release	mg/m^2-day
sP	P Storage	mg/m^2
cPInit	Initial TP Conc	ppb
cNInit	Initial TN Conc	ppb
fSolP	Output fraction of TP as soluble P	Decimal
fSedP	Output fraction of TP as sediment P	Decimal
fSolNO3	Output fraction of TN as nitrate N	Decimal
fSolNH4	Output fraction of TN as ammonia N	Decimal
fSedNH4	Output fraction of TN as sediment N	Decimal
fSolOrgN	Output fraction of TN as soluble organic N	Decimal
fSedOrgN	Output fraction of TN as sediment organic N	Decimal

Default values for various wetland and lake conditions and further details for these parameters are available at http://www.wwwalker.net/dmsta. Note that if a zero is entered then DMSTA will assign a default value automatically.

Note that the standard assimilation algorithms in WAM can be applied in combination with the DMSTA module, i.e. using the DMSTA module does not automatically turn off the assimilation algorithms. Therefore, it will be necessary to turn off the assimilation algorithm by entering a data line in the attenuate.in file for the DMSTA ReachCode with the assimilation parameters (a=1 and b=0) for all surface water constituents. The bk coefficient can be any dummy value. There must be at least one line for each ReachCode in the DMSTA.in file in the attenuate.in file.

The coding and performance of the DMSTA module was verified by simulating a RASTA in the Fisheating Creek basin (**Figure 4-7**) where the DMSTA module was used for the two reaches (12 and 10) within the STA portion of the RASTA. **Figure 4-8** shows the flows at the inflow to the storage reservoir, flow from the storage reservoir into the STA, and flow out of the STA. **Figures 4-9 and 4-10** show the accumulative TP and TN loads, respectively, at each of the above flow points. The TP assimilation within the STA after ten years is approximately 1.7 g/m2/yr, which is within the appropriate range.

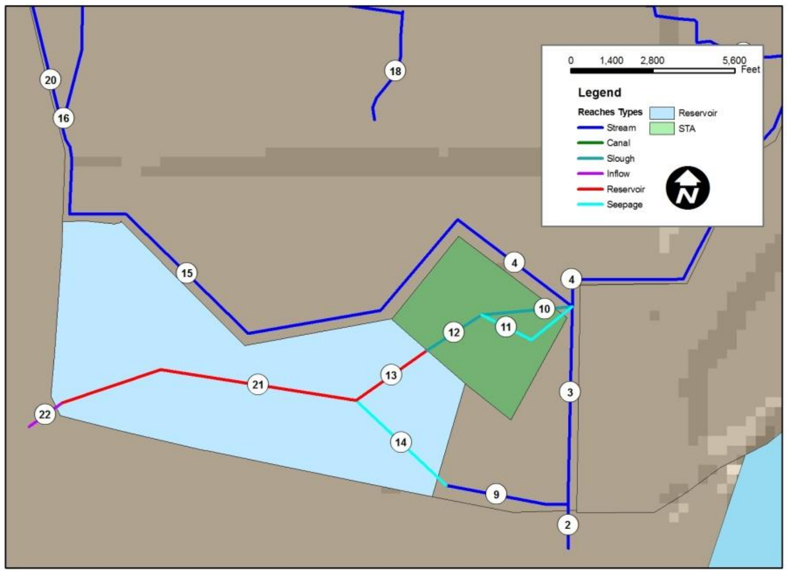

Figure 4-7: Layout of Fisheating Creek RASTA.

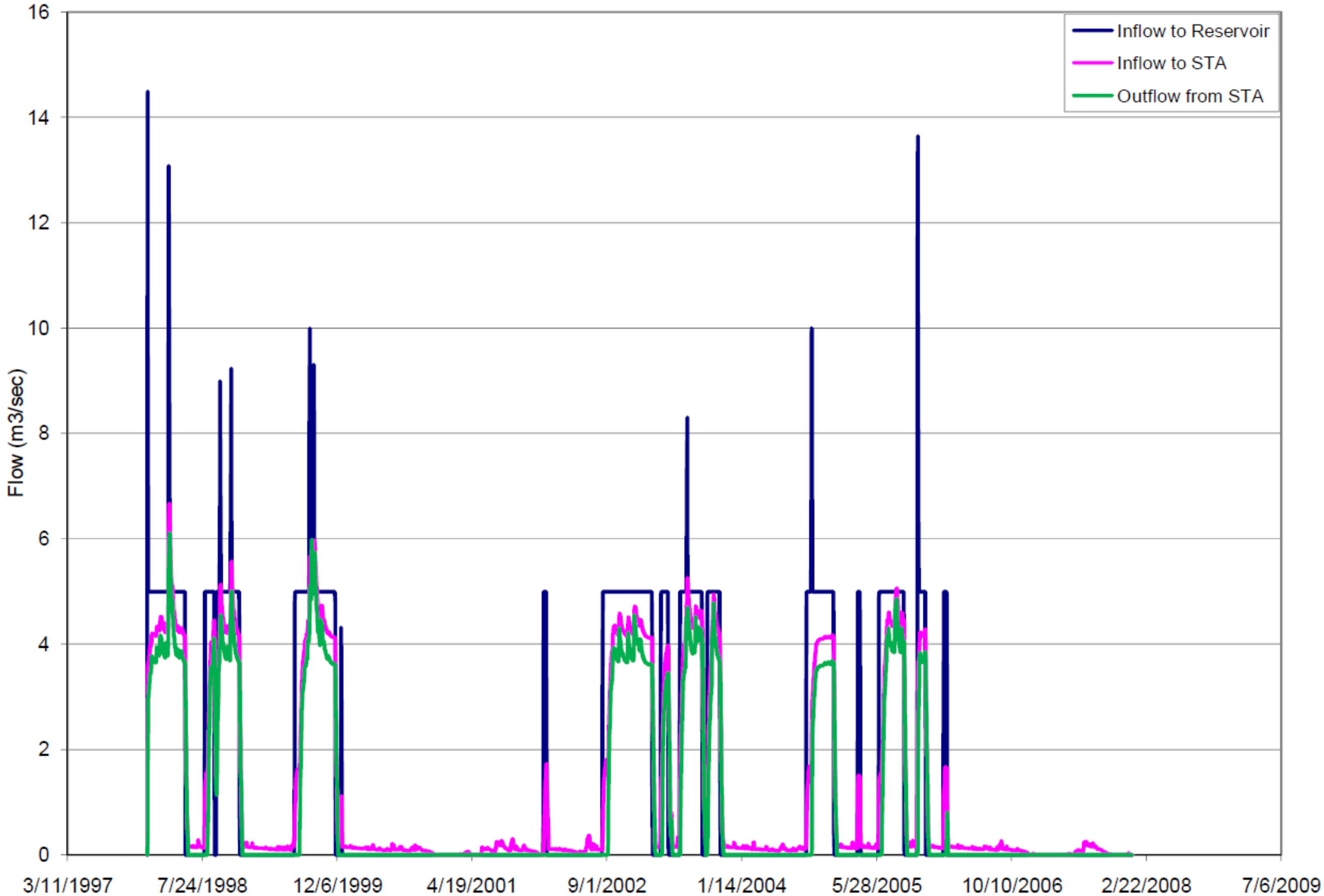

Figure 4-8: Simulated Flows for the Fisheating Creek RASTA.

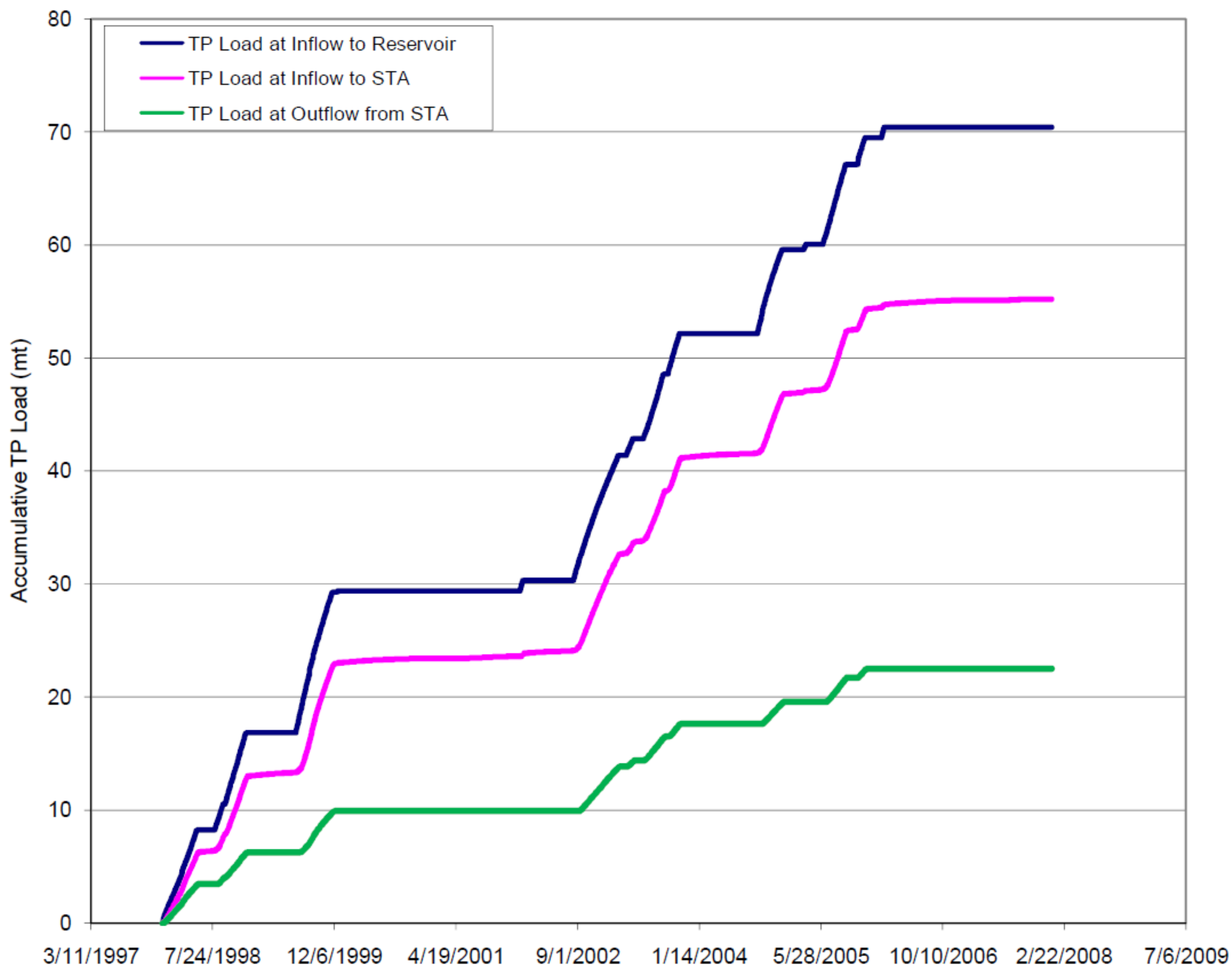

Figure 4-9: Simulated Accumulative Total Phosphorus (TP) for the Fisheating Creek RASTA.

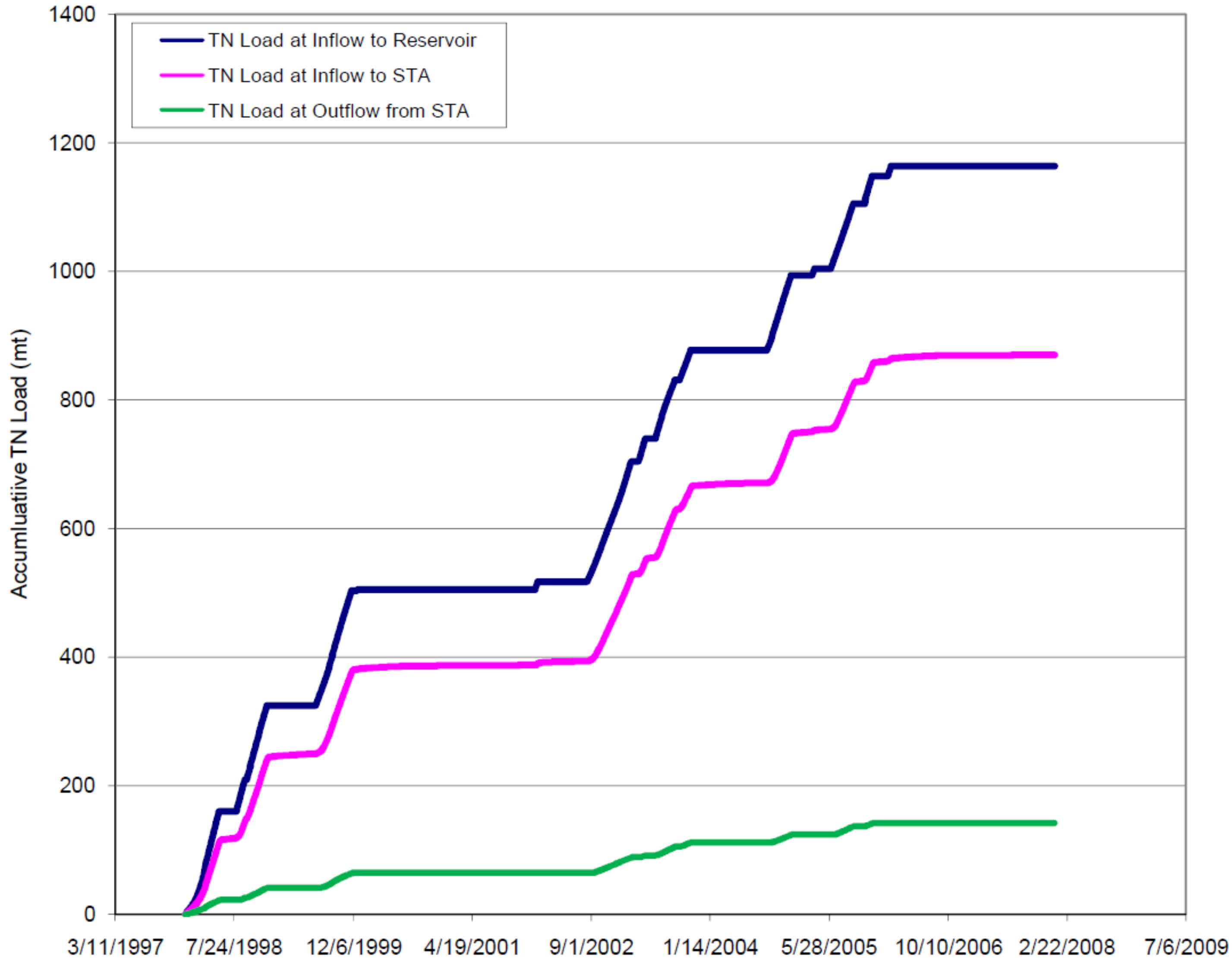

Figure 4-10: Simulated Accumulative Total Nitrogen (TN) Loading for the Fisheating Creek RASTA.

4.3. Data Comparisons

It is important to note that WAM relies on physical based information such as land use practices, soils and rainfall to estimate water quality runoff. As such, it must be understood how calibration is conducted. It is primarily a comparison process to verify that the physical information, ie: land use, soils, reaches, etc. have been adequately set up to represent a given watershed. An example of this is found within the Northern Okeechobee Watershed, with the "buyout dairy" sites. These sites were mapped as improved pasture land use on Immokalee soil. In this case the land use was correct, but the soil has had years of manure and P build accumulation that was not reflected in a typical Immokalee soil. For example, in order to properly calibrate this basin, the soils coverage had to be identified and updated so that the "impacted" Immokalee soil was correctly mapped. For this and other reasons, the calibration process is more an adjustment of the physical components of the model than an adjustment of an attenuation coefficient to force a fit. However, ultimately some calibration of attenuation coefficients and land use practices was typically performed to fine tune the calibration. Adjustment of attenuation coefficients can help compensate for the presence of legacy phosphorus which may affect the hydrography's ability to attenuate phosphorus.

Another calibration parameter that was adjusted for each relevant basin was seepage. Seepage reaches were added to basins immediately adjacent to Lake Okeechobee. The amount of seepage was controlled using weirs sized to bring the total flow of each basin within 10 percent of the measured flows. Individual seepage rates were calculated for each basin based on this calibration.

Because of the minor amount of flow to Lake Okeechobee from the C-43, C-44 and L-8 Basins, the comparisons focused on the primary contributors to the Lake where there was ample monitoring data available. The monitoring stations chosen for the comparisons are shown in **Figure 4-4**.

Thirty eight years of data were collected (1970-2007) for WAM simulations, however, for comparison purposes, a period closer to the time of the 2006 land use was more appropriate. A ten year span from 1998 to 2007 was selected. It should be noted that this period included two droughts and four major hurricanes, which was less than ideal for comparisons to measured data. From a modeling perspective, there are a variety of reasons why droughts and hurricanes can have a negative impact on calibration. There are no known limitations within WAM in this regard. Monitoring data can be compromised during these periods and systems may be operated under emergency protocols, e.g. gates are sometimes open before a storm. In consideration of this study, it was assumed that the District followed normal operating procedures during these periods and there are no known deficiencies in the monitoring data.

The calibration was conducted using WAM's new interface which includes improved tools for viewing the model output. The new graphing feature (**Figure 4-11**) was particularly useful in comparing model output to measured data on either a daily or cumulative basis. Graphs could be overlaid with left and right axes or on separate vertical panes. For this project, cumulative flow and total phosphorus were reviewed.

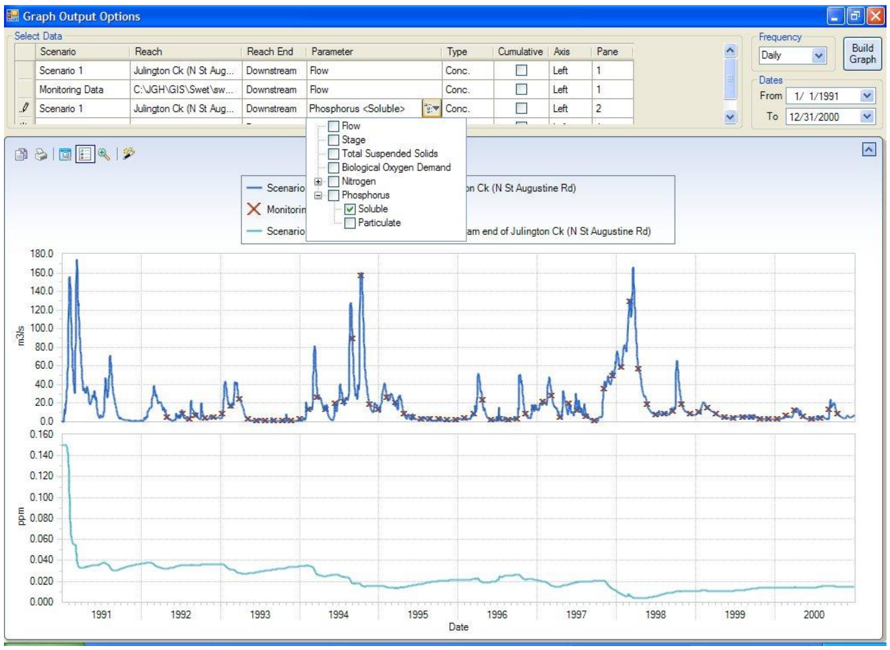

Figure 4-11: WAM Graphing Interface Example

4.3.A. <u>L-49 Basin</u>

This basin is served by the S-129 Pump Station. For most of the period of record, cumulative flow volumes appeared to track each other very well, as seen in **Figure 4-12**. There seemed to be two periods where the rainfall data collection may have missed some large storm events. These periods occurred in the third quarter of 2004 and in the fourth quarter of 2005. Coincidently, Hurricanes Francis, Jeanne, and Wilma occurred at these times. The calibrated seepage rate for this basin was 1.3 cfs/mile levee/ft of head. Total phosphorus concentrations matched very well with the recorded data, as shown in **Figure 4-13**.

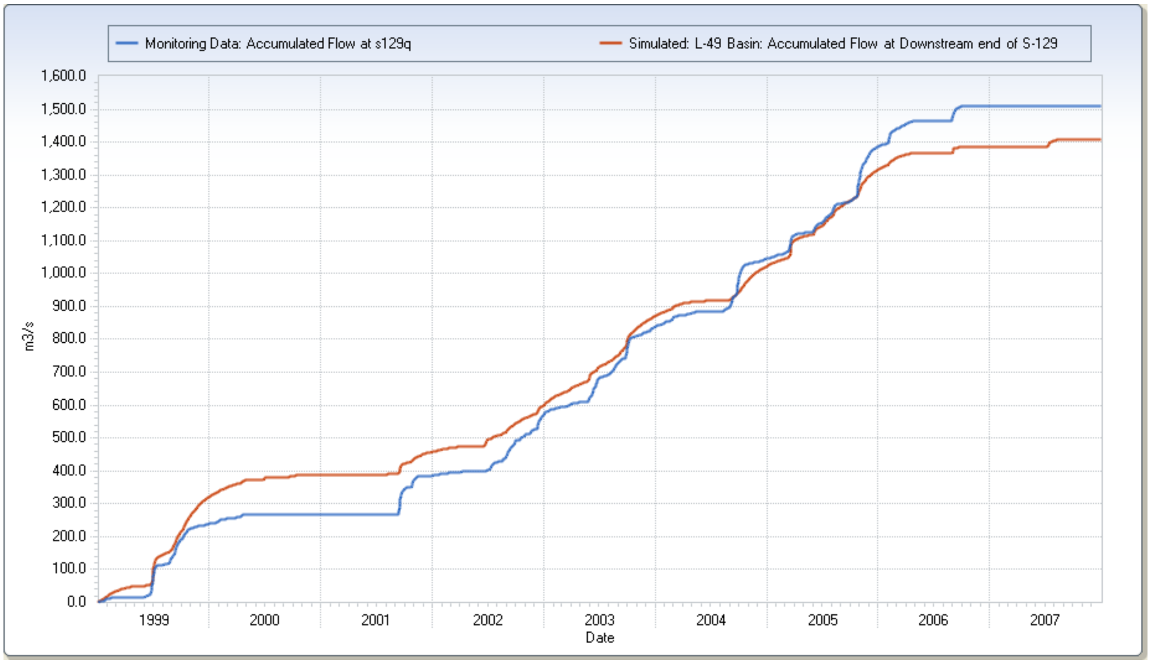

Figure 4-12: Cumulative Flow at S-129

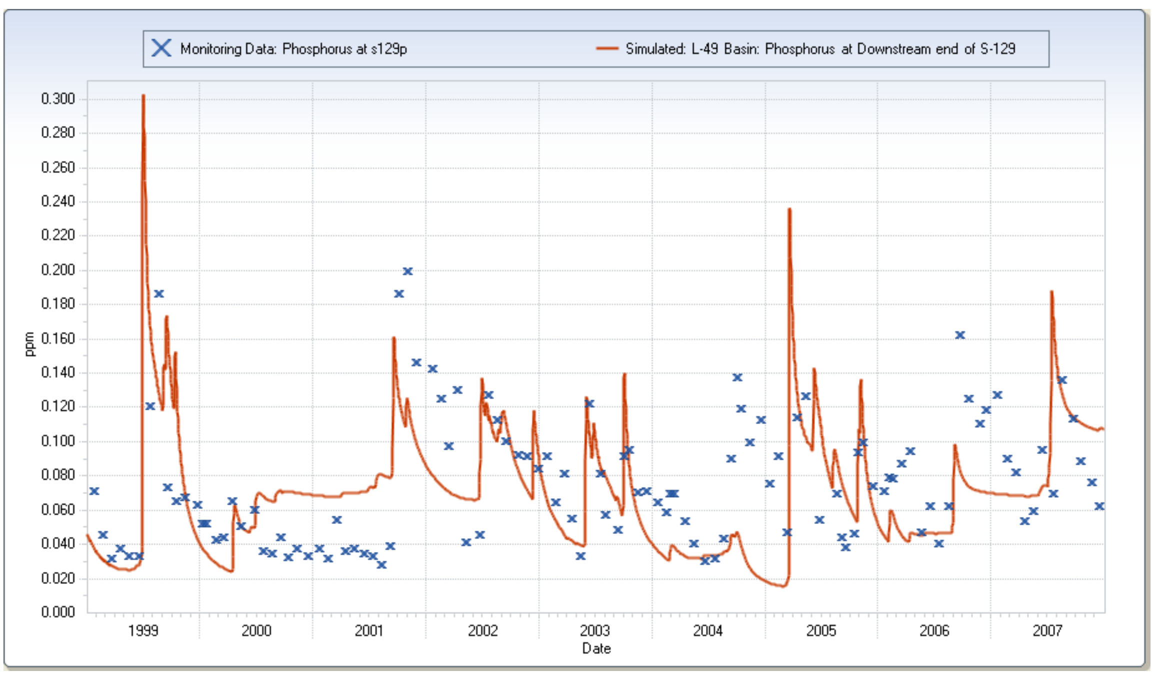

Figure 4-13: Total Phosphorus Concentration at S-129

4.3.B. L-48 Basin

This basin is served by the S-127 Pump Station. There was a clear separation of cumulative flow volumes when comparing modeled data to measured. There are extended periods of time when there were no flows reported, despite the fact that there were significant rain amounts during some of these periods. The measured data files were rechecked to determine if any special codes were applied, such as "M" for missing data. No such codes were found. It is noteworthy that some spikes in phosphorus occurred during these periods which are indicative of discharge. It is recommended that actual pump operation records be examined. With the exception of these periods, the flows seemed to track well (**Figure 4-14**). Phosphorus also tracks reasonably well (**Figure 4-15**). The calibrated seepage rate for this basin was 1.0 cfs/mile levee/ft of head.

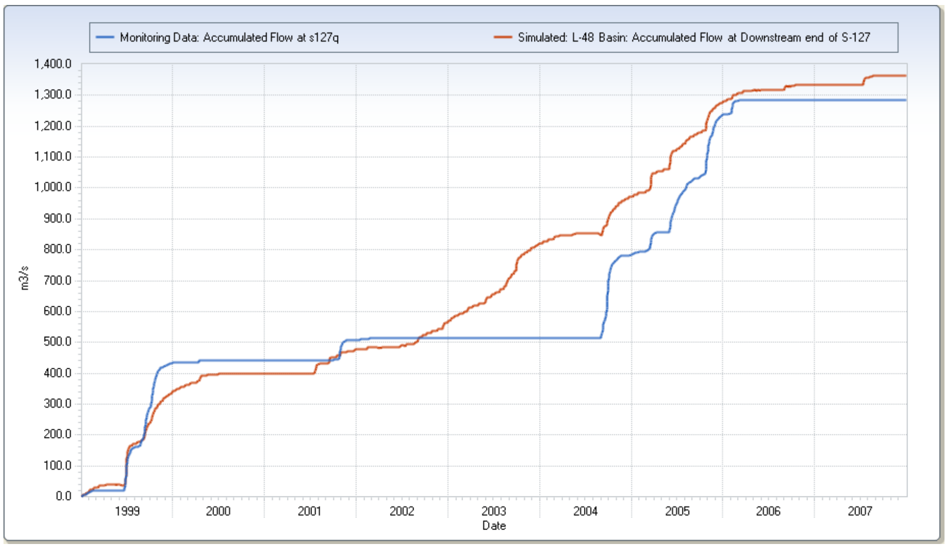

Figure 4-14: Cumulative Flow at S-127

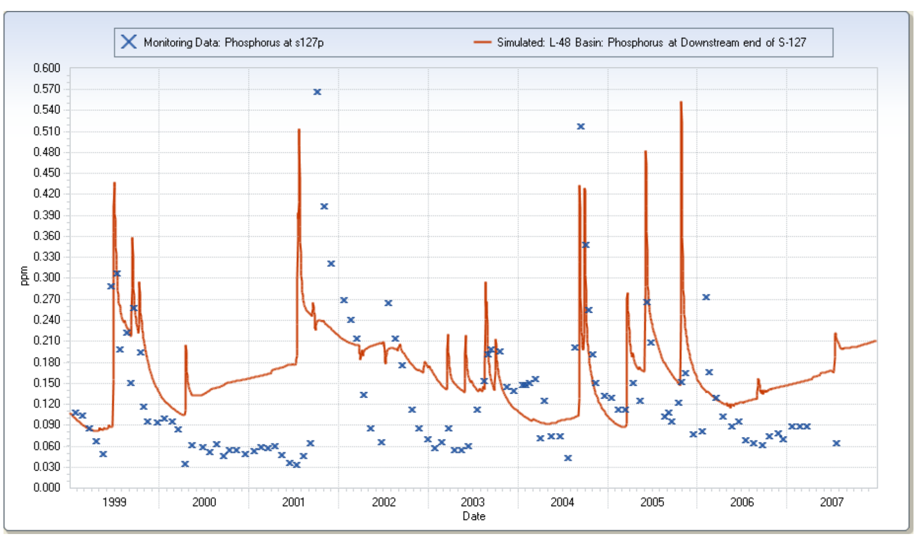

Figure 4-15: Total Phosphorus Concentration at S-127

4.3.C. S-191 Basin

This basin is served by the S-191 Structure. When compared, the cumulative flow volumes appeared to track each other fairly well, as seen in **Figure 4-16**. There were significant jumps in measured flow corresponding to the 2004/2005 hurricanes. Phosphorus concentrations in this basin tracked very well between measured and modeled data (**Figure 4-17**).

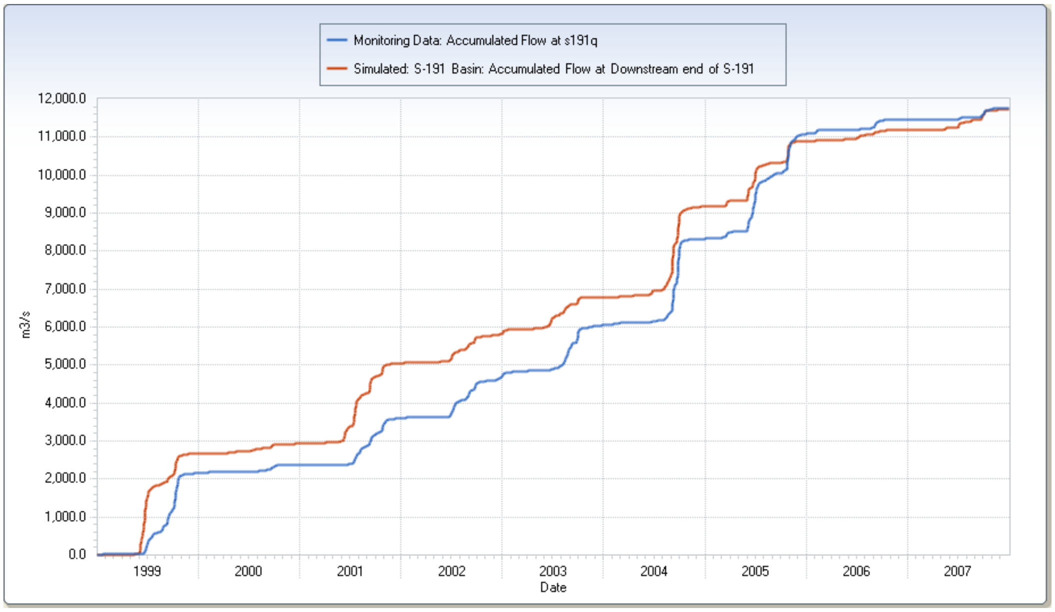

Figure 4-16: Cumulative Flow at S-191

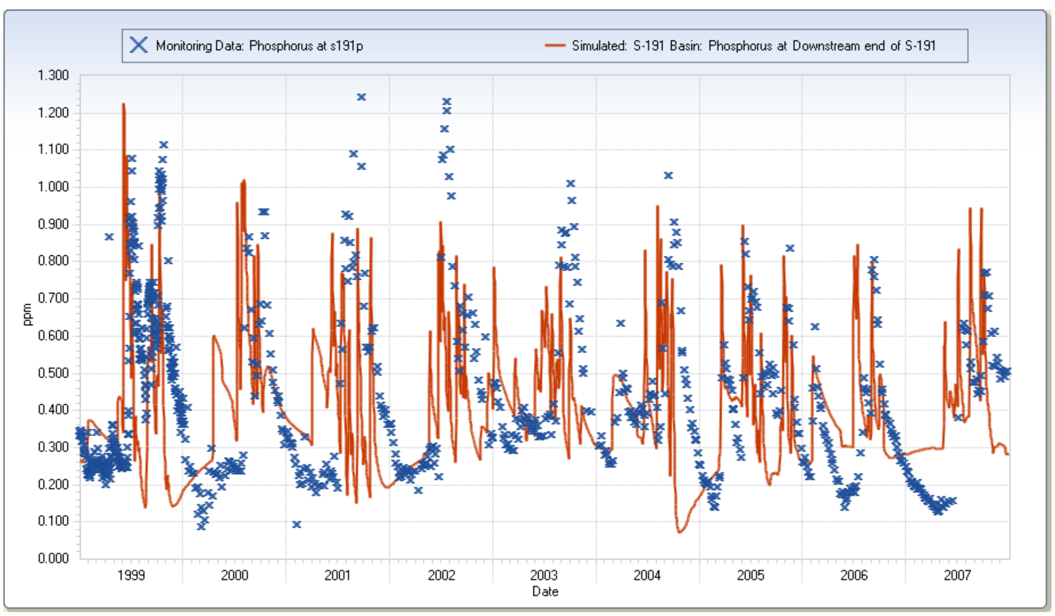

Figure 4-17: Total Phosphorus Concentration at S-191

4.3.D. S-131 Basin

This basin is served by the S-131 Pump Station. In the initial modeling, there was a clear separation between cumulative flow volumes, when modeled data was compared to measured as shown in **Figure 4-18**. Three notable separations occurred, between 2000-2001, 2003-2004 and 2006-2007 with the most notable occurring in 2000-2001. While a drought did, occur in 2000 resulting in heightened water conservation efforts. However, a more consistent separation seemed to exist throughout the period of record which warranted further investigation. It was found that the measured flow volume per acre for this basin was less than half that of the neighboring L-49 Basin, even when land use and rainfall between the two basins was identical. This implies that the differences were a result of incorrect basin's boundaries or erroneous measured data. Phosphorus concentrations overall appeared high, which further suggested that the basin was not correctly simulated.

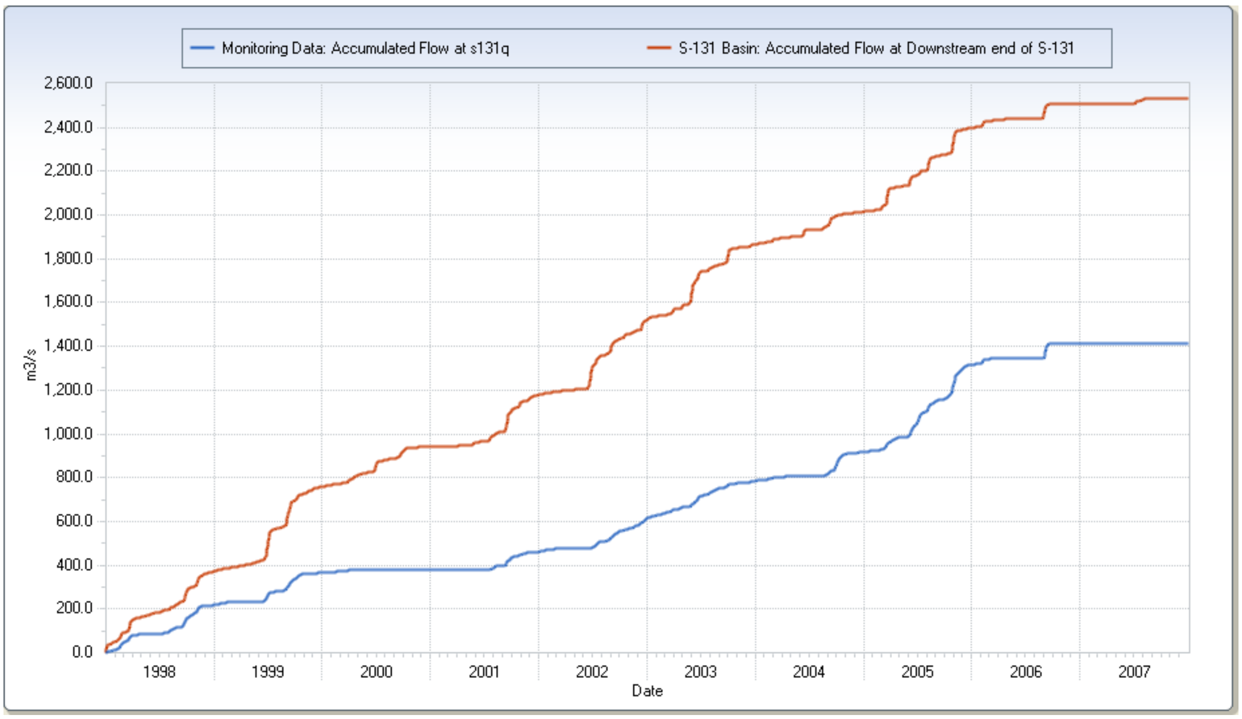

Figure 4-18: Cumulative Flow at S-131

This basin, which includes the L-50 Canal, was assumed to be hydraulically connected, via the same canal, to the L-61W Basin. However, further research was conducted to verify that the L-61W Basin, did in fact, discharge south into Fisheating Creek near its outlet to Lake Okeechobee. The reach network of the model was revised to better simulate this. The results from this rerun had greater similarity to the measured data, as shown in **Figures 4-19 and 4-20**. The peak phosphorus concentrations (**Figure 4-20**) were also reduced creating a better match to the measured data because higher intensity land uses, such as pasture, were located more in the S-63W Basin. This was an excellent example of how a physical based model can help identify watershed characterization errors. The calibrated seepage rate for this basin was 1.2 cfs/mile levee/ft of head.

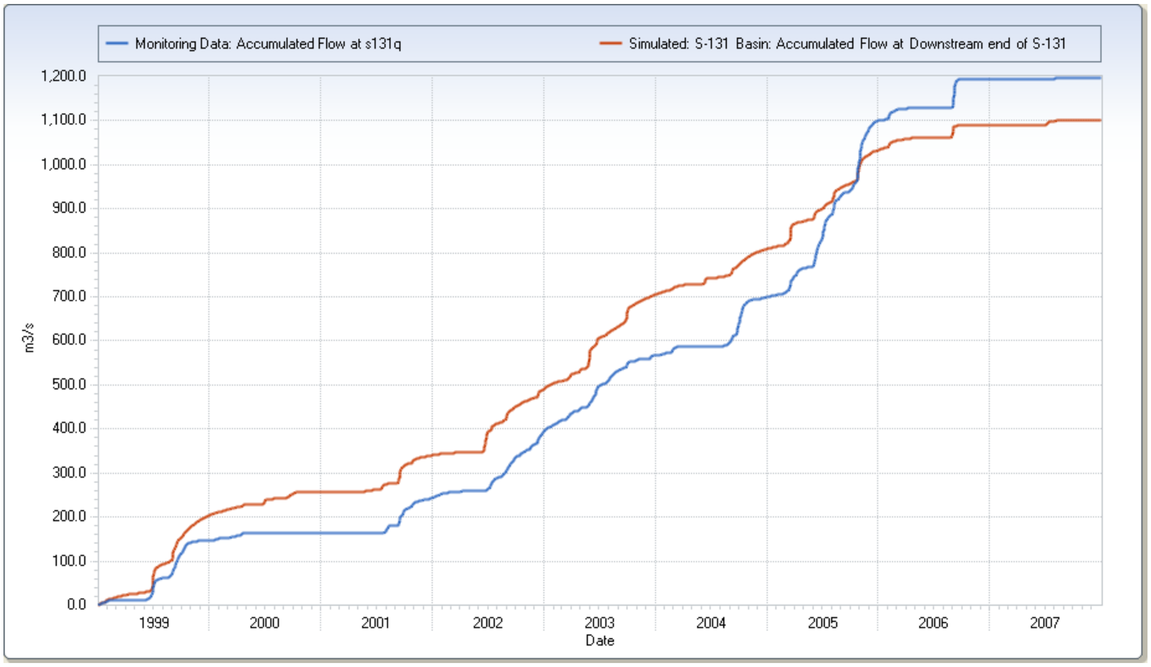

Figure 4-19: Cumulative Flow at S-131 (Revised)

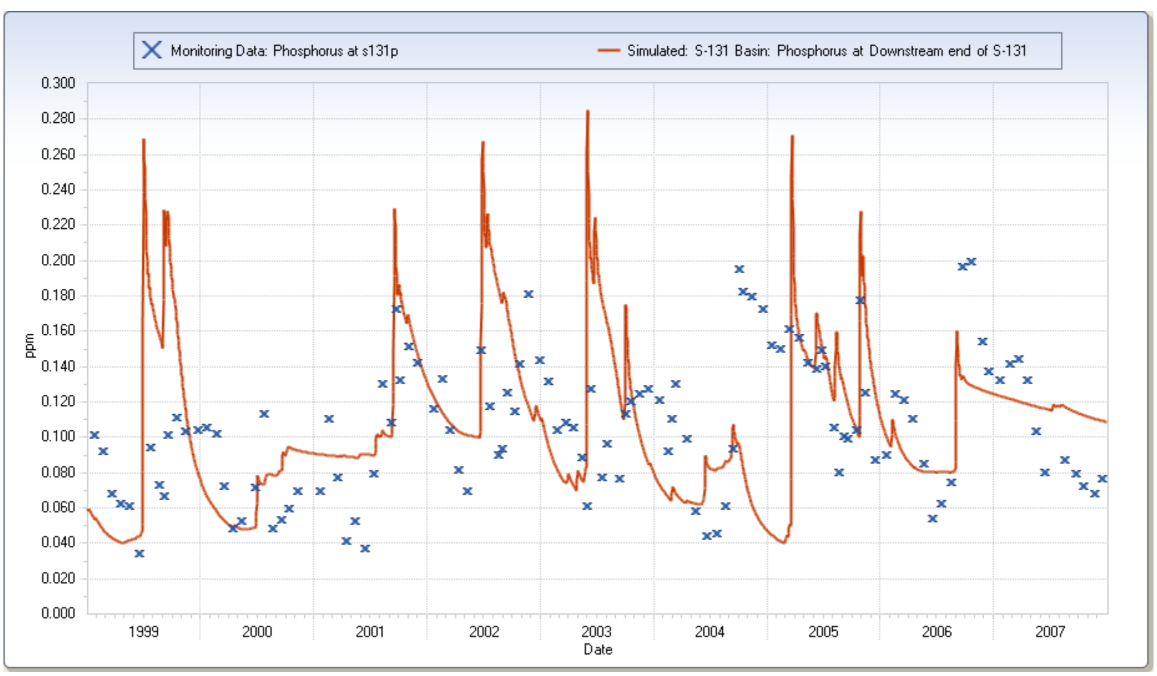

Figure 4-20: Total Phosphorus Concentration at S-131

4.3.E. S-133 Basin

This basin, which includes the City of Okeechobee, is served by the S-133 Pump Station. This basin, like S-131, was originally modeled with an incorrect physical attribute. Gravity flow discharge had been assumed to occur at the pump station when stages permitted. The gravity flow component for this basin, however, discharges approximately 1,000 feet to the east of the station at a nearby lock and, therefore, does not appear in the recorded data for this station. The gravity structure used in the model was moved to a new nearby reach to separate it from the pump station flows. As a result, both modeled flows (**Figure 4-21**) and phosphorus concentrations (**Figure 4-22**) tracked very well when compared to measured values. The calibrated seepage rate for this basin was 0.6 cfs/mile levee/ft of head.

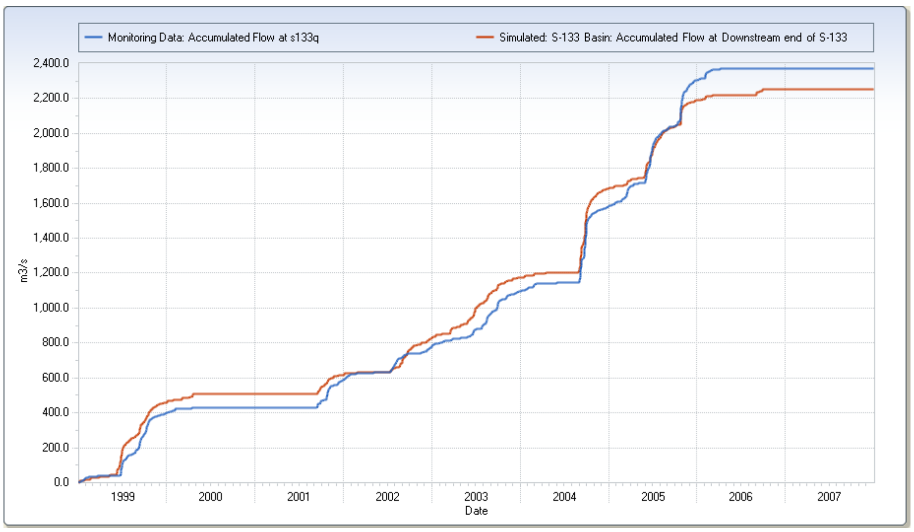

Figure 4-21: Cumulative Flow at S-133

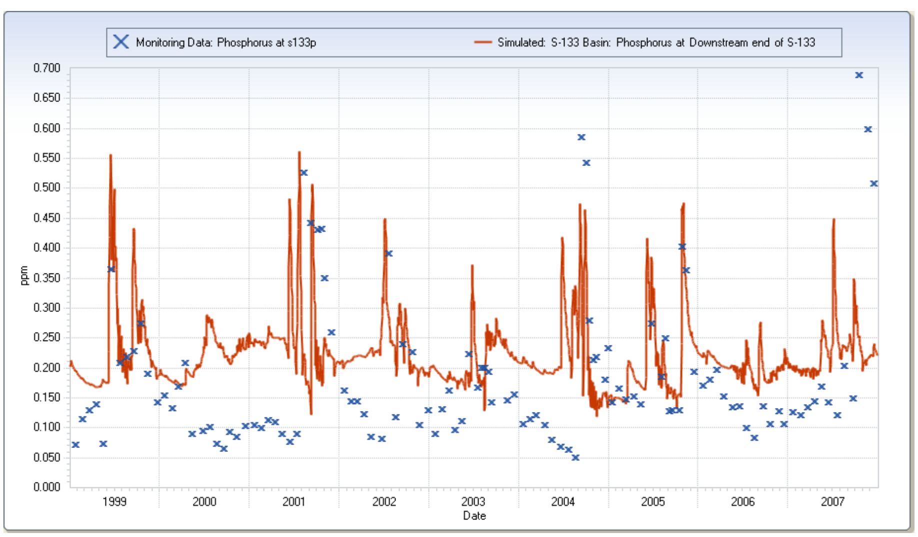

Figure 4-22: Total Phosphorus Concentration at S-133

4.3.F. S-135 Basin

This basin is served by the S-135 Pump Station. When modeled data was compared to measured data, cumulative flow volumes appeared to track each other fairly well as seen in **Figure 4-23**. Total phosphorus concentrations compared very well to the recorded data in this basin (**Figure 4-24**). The calibrated seepage rate for this basin was 0.9 cfs/mile levee/ft of head.

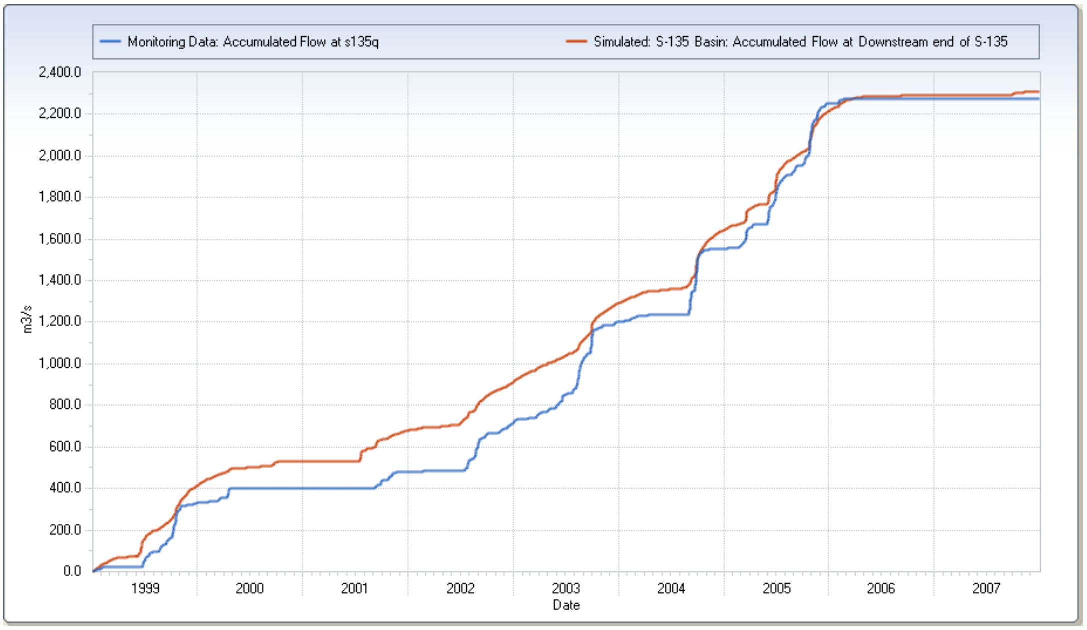

Figure 4-23: Cumulative Flow at S-135

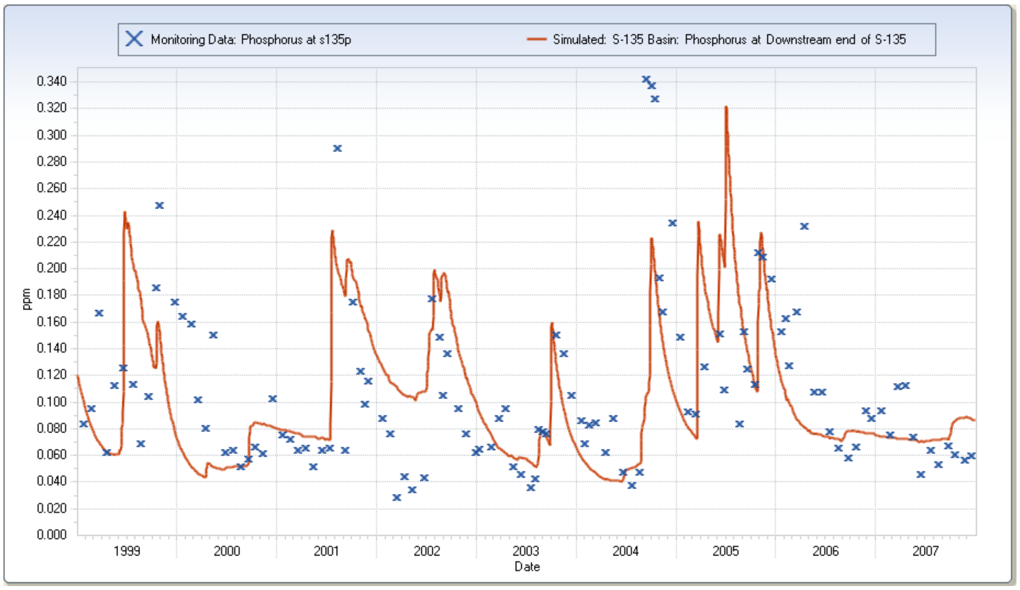

Figure 4-24: Total Phosphorus Concentration at S-135

4.3.G. Fisheating Creek (FEC) Basin

Fisheating Creek has a USGS flow monitoring station at US27 and a water quality monitoring station located at SR78. The flow monitoring station based on a flow rating curve applied to a stage recorder. It has been rated as having moderate accuracy, but it generally represents the flow events. The flow monitoring station is located 16 miles upstream of the water quality station, so it was not possible to predict P loadings precisely at either location. However, the general responses should be well represented. **Figures 4-25 and 4-26** show the measured and simulated flows and TP loads for these stations. In spite of the data issues for these sites, there appeared to be in good agreement for both flow and TP concentrations. However, it should be pointed out that this agreement came after replacing the unusually high rainfall data collected at at the Palmdale station with the S-70 rainfall station. Just to get an idea of the potential impact that the rainfall data may have, it was found that the annual average flow at US27 can vary from 34% too low to 55% too high just based on which rainfall station data were used across the watershed.

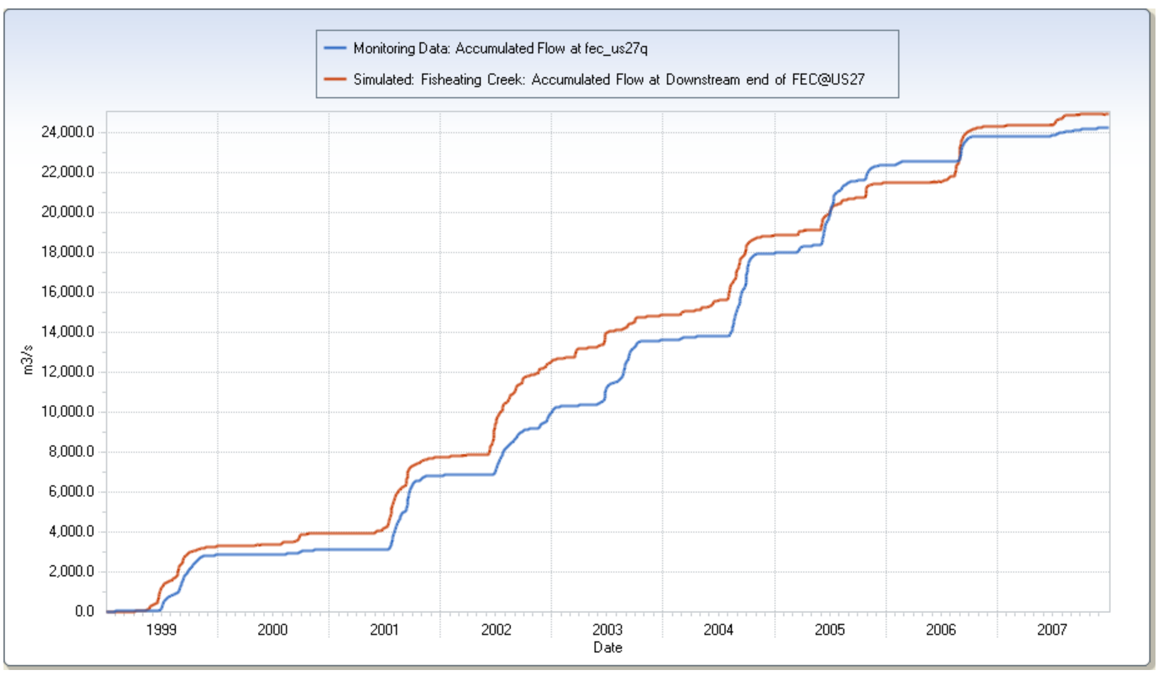

Figure 4-25: Cumulative Flow at US 27 on Fisheating Creek

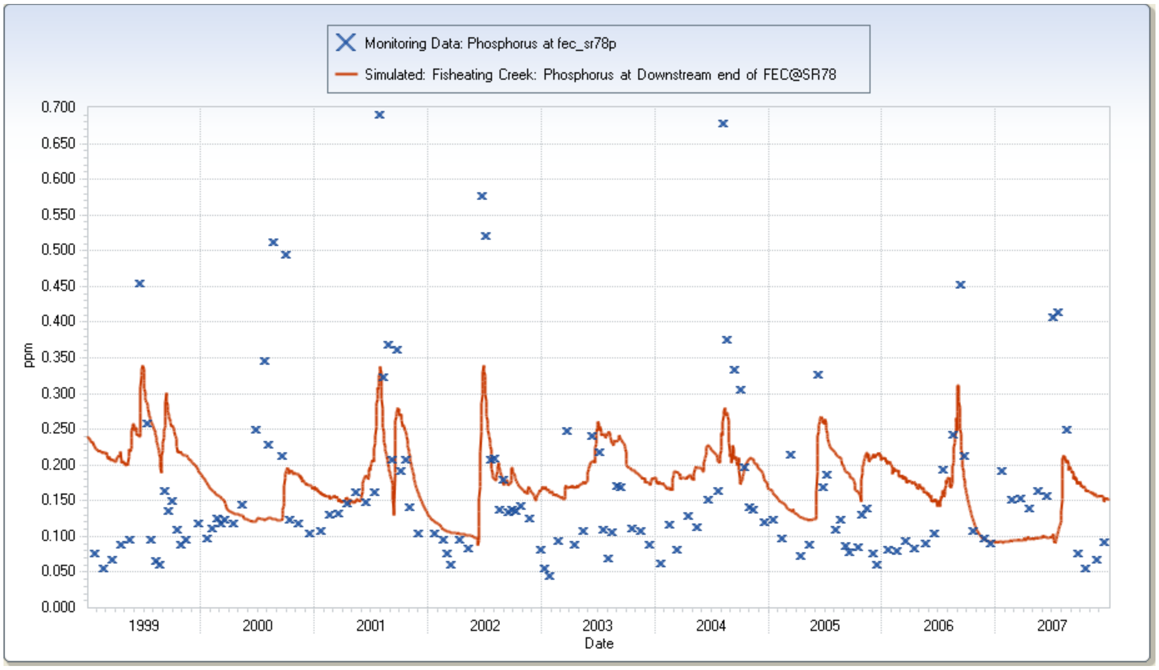

Figure 4-26: Total Phosphorus Concentration at SR78 on Fisheating Creek

4.3.H. Lake Kissimmee

DMSTA was utilized for the WAM simulation of Lake Kissimmee. The predicted average TP concentrations matched the recorded data relatively well. However, the temporal variability in TP concentrations did not match as well. The TN predictions from DMSTA need additional evaluation. **Figures 4-27 and 4-28** compare simulated and observed TP and TN concentrations in Lake Kissimmee.

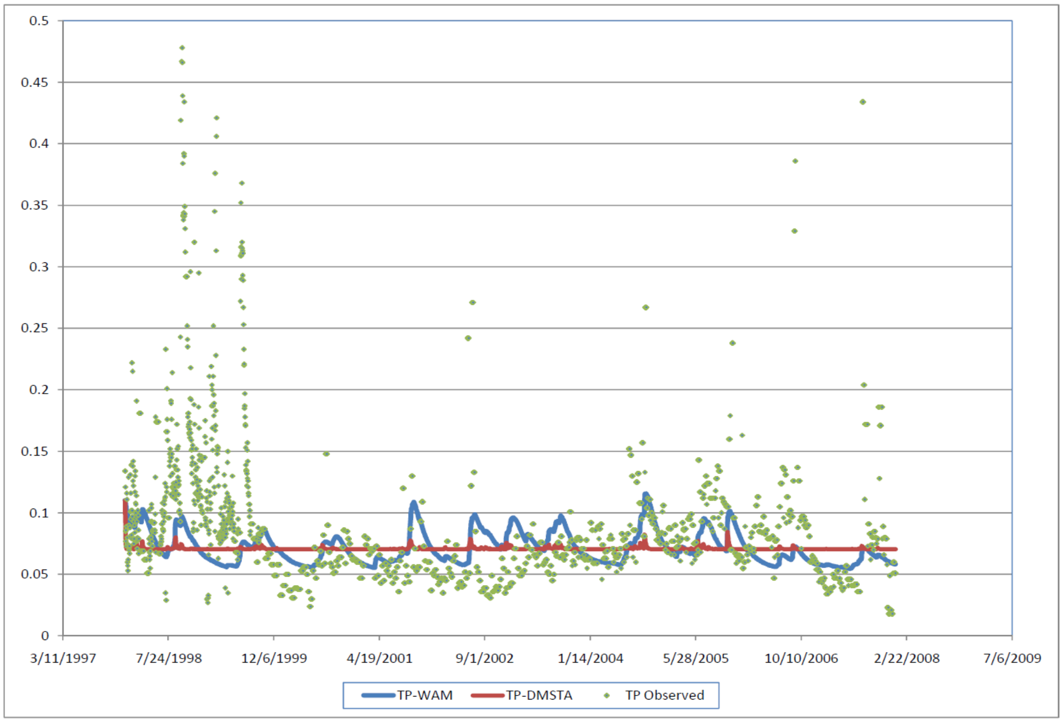

Figure 4-27: Total Phosphorus concentration in Lake Kissimmee

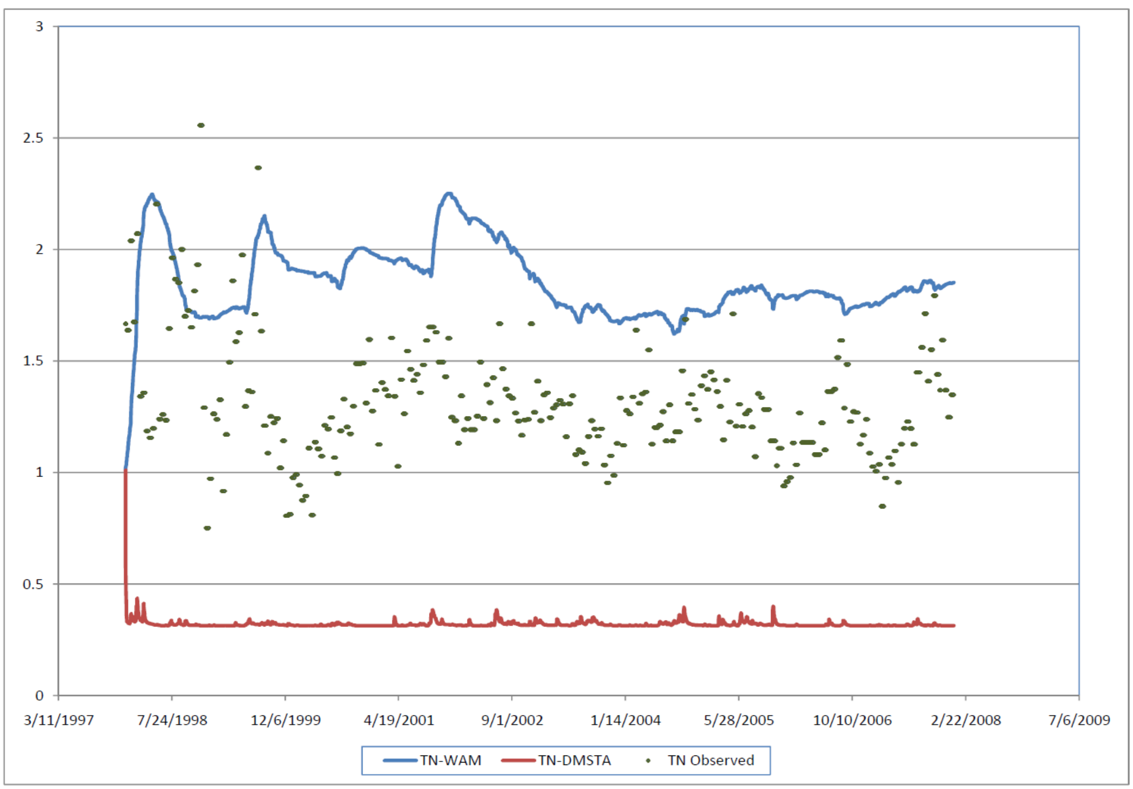

Figure 4-28: Total Nitrogen concentration in Lake Kissimmee

4.3.I. C-38 Basin

There are several water control structures within this modeled area that allowed a good comparison of measured and simulated data. Six structures were chosen. The S-68 Structure serves the entire Lake Istokpoga watershed. The S-65 Structure serves the entire Upper Chain of Lakes watershed. The S-65A, C, D and E Structures provide excellent locations, as flow moves downstream, to compare data. Monitoring stations on Reedy and Arbuckle Creeks provided additional TP comparisons up within the Upper Kissimmee and Lake Istokpoga basins, respectively. The calibration/verification process for the C-38 was first done for the hydrology, i.e. to get flows to match reasonably and was then calibrated for TP concentration/loads. Initially when it was simulated for the calibration period of 1999 to 2007 using recorded rainfall from 1995 to 2007 and default ET model parameters, it was found that WAM was predicting about 28% too much outflow from the Upper Kissimmee and Lake Istokpoga basins. Since there was no justification for changing the ET coefficients (ET matched observed records and worked well in other basins), it became apparent that significant groundwater losses must be occurring within these basins. Potentiometric surface maps of the Floridan Aquifer, and a groundwater modeling study by Butler and Herr as part of the Kissimmee Basin Water Supply Plan (Chris Sweazy,

2006), were reviewed in search of possible explanations for this issue. It was determined that a significant amount of leakage from the upper surficial perched aquifers around lakes and streams and some direct recharge to the Floridan Aquifer was occurring throughout these basins. From the Floridan potentiometric surface maps, it appeared that some areas along the boundaries of these basins, recharged directly to the Floridan Aquifer which clearly flowed out of the basins. **Figure 4-29** shows the areas estimated to have all recharge waters flowing away from the basins. The other areas which are suspected of having partial leakage to the lower Floridan Aquifer are also shown in **Figure 4-29**. The leakage to the Floridan aquifer in these areas will also discharge outside of these basins. This leakage was assumed to mostly occur from the lakes and streams, which were adjusted within the Stream.in file separately for the two basins. Note, no leakage was assumed for the Lower Kissimmee Basin below the S65 structure. **Figure 4-29** shows the estimated recharge and discharge zones used for the model. After calibration, as seen in **Table 4-3**, the water balances for all the C-38 basins were within 5%.

The TP concentrations within the C-38 basins were calibrated by adjustment of the lake attenuation coefficients because the lakes dominate the TP characteristics at the monitoring locations except for the Reedy and Arbuckle Creeks sites, which did not have associated flow data, and the lower S65 structures. Most of the sites were currently over-estimating the TP concentrations, but the TP dynamics were being well represented. Additional calibration work was done for the C-38 basin. **Figures 4-30 through 4-43** show the flow and total phosphorus comparisons to recorded data for the latest calibration run.

Note that the existing WAM lake algorithm was used for these calibrations because the new DMSTA lake sub-model has not been fully integrated into WAM at this time. This lake sub-model integration was within days of completion before Dr. Jacobson made his departure from SWET, which prevented him from completing this integration to date. However, tests with the

DMSTA lake sub-model in the spreadsheet format using WAM simulated inflow data to the lake sub-model was found to provide nearly identical TP assimilation responses for waters passing through the Lake Kissimmee, so we are confident that once integrated the DMSTA lake sub-model will provide similar responses. Dr. Jacobson has promised to complete this integration by the end of March, 2009, but SWET has initiated alternative plans to complete the integration if Dr. Jacobson in unable to complete this. We have waited on Dr. Jacobson because it would take a significant amount of time and resources to complete this task without his involvement since he is the developer of the Blasroute module in which the lake sub-model is being integrated in to. As mentioned, we anticipate very little differences in the overall calibration accuracy, but are looking forward to the new model's ability to better respond to long term P loadings.

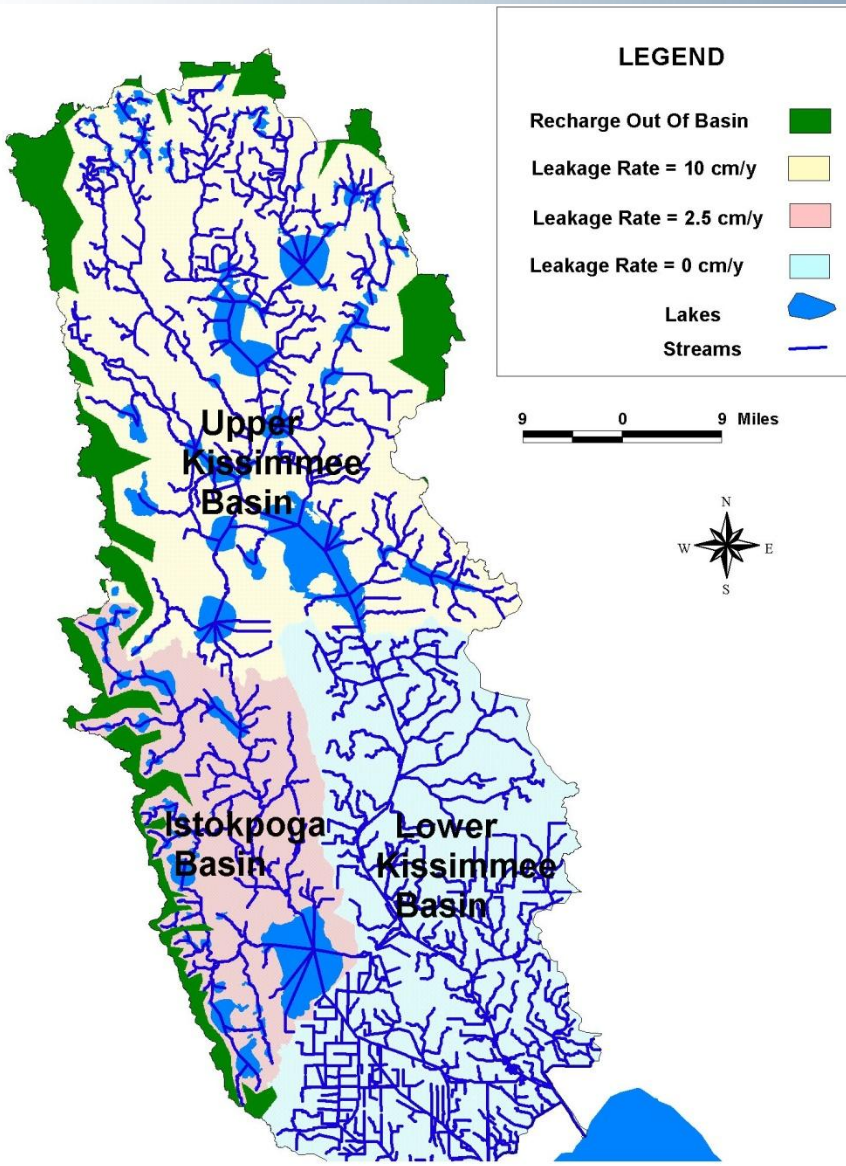

Figure 4-29: Direct Groundwater Recharge Areas and Assumed Lake and Streams Leakages Rates to Floridan Aquifer for WAM Calibration

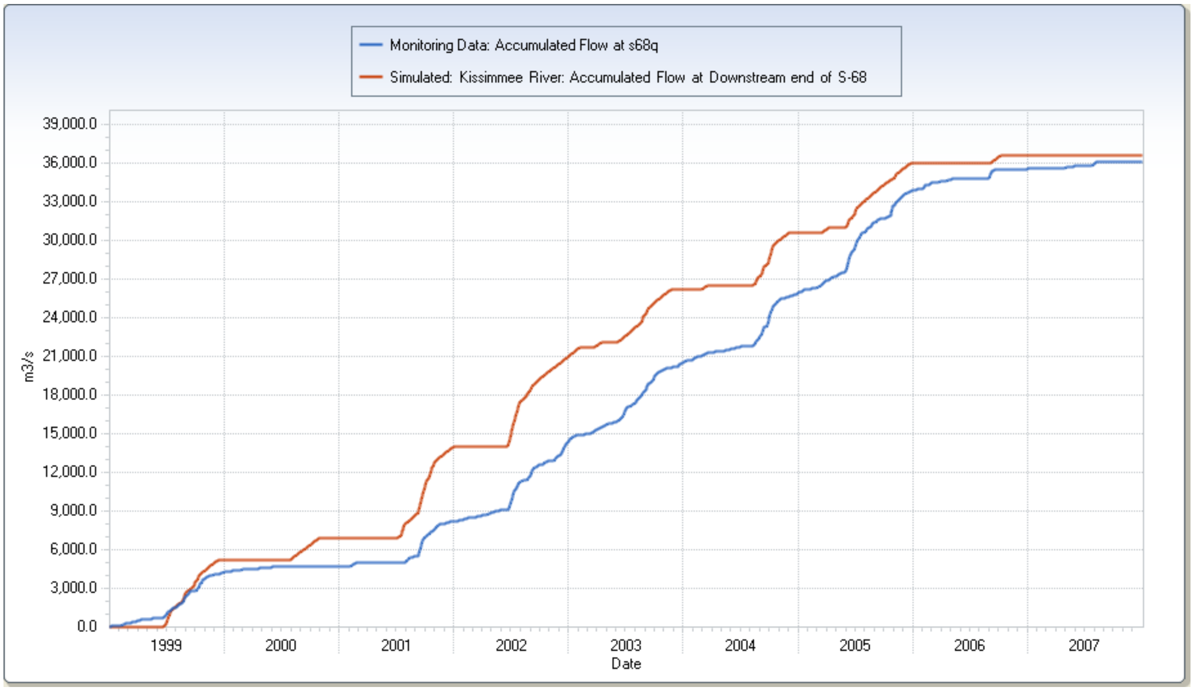

Figure 4-30: Cumulative Flow at S-68

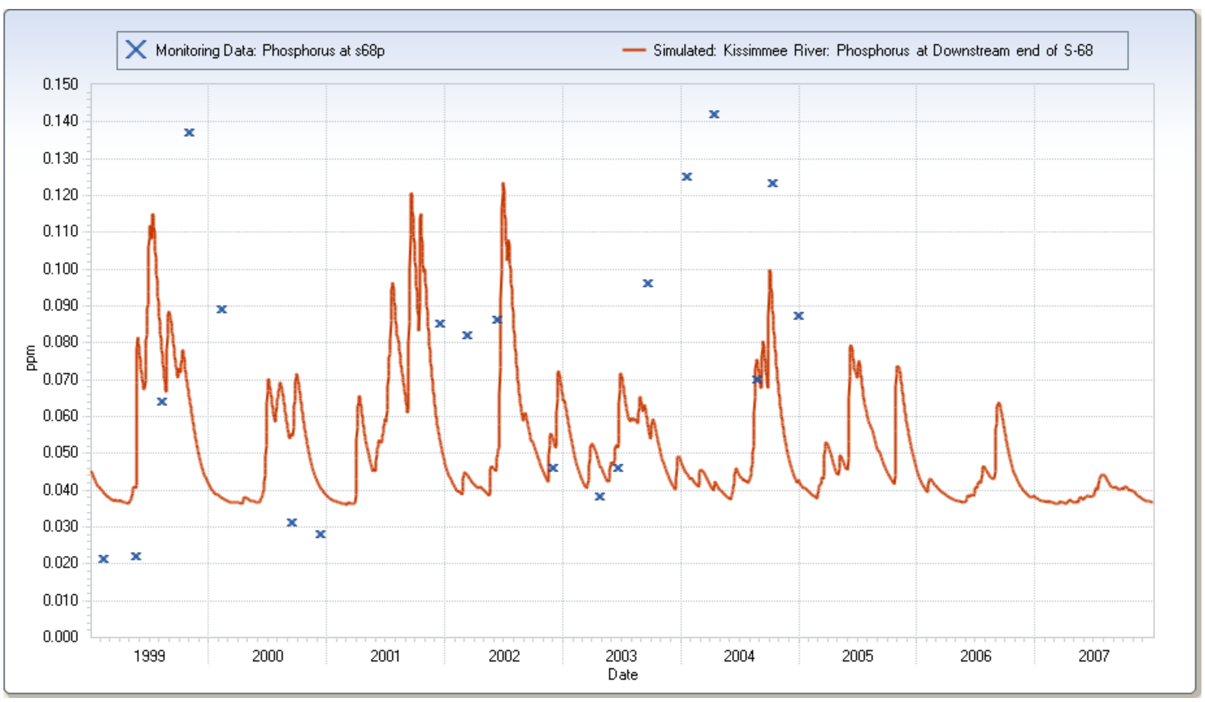

Figure 4-31: Total Phosphorus Concentration at S-68

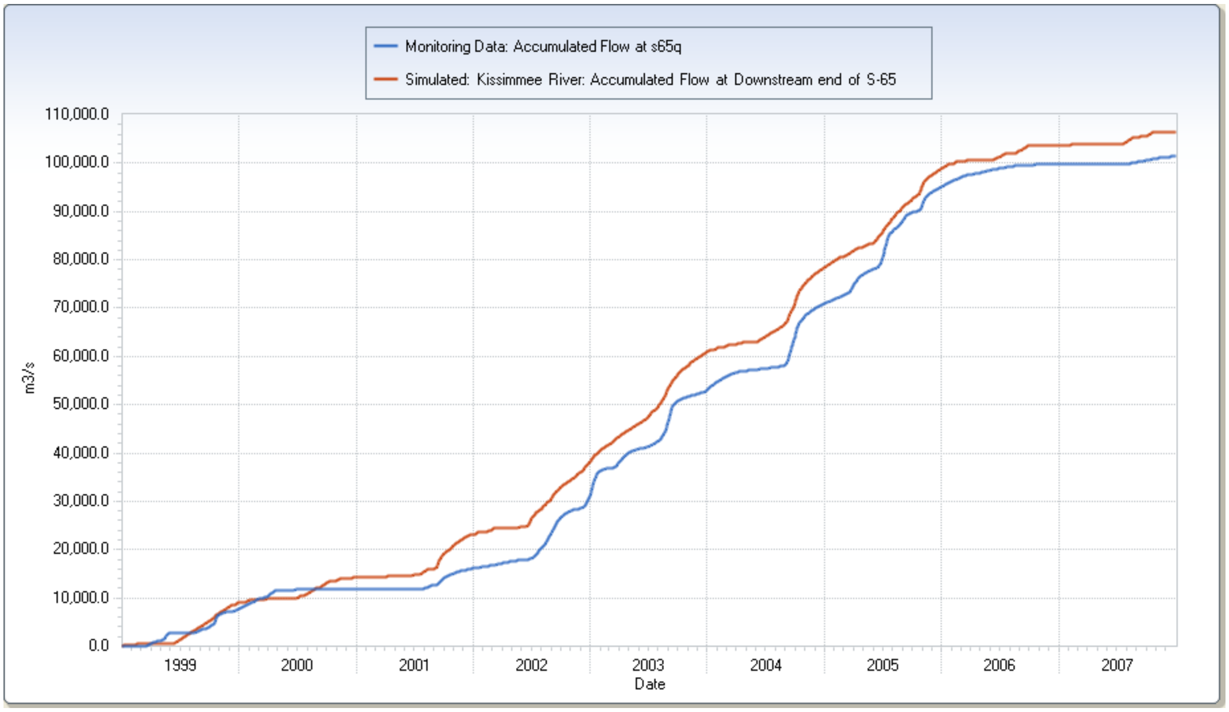

Figure 4-32: Cumulative Flow at S-65

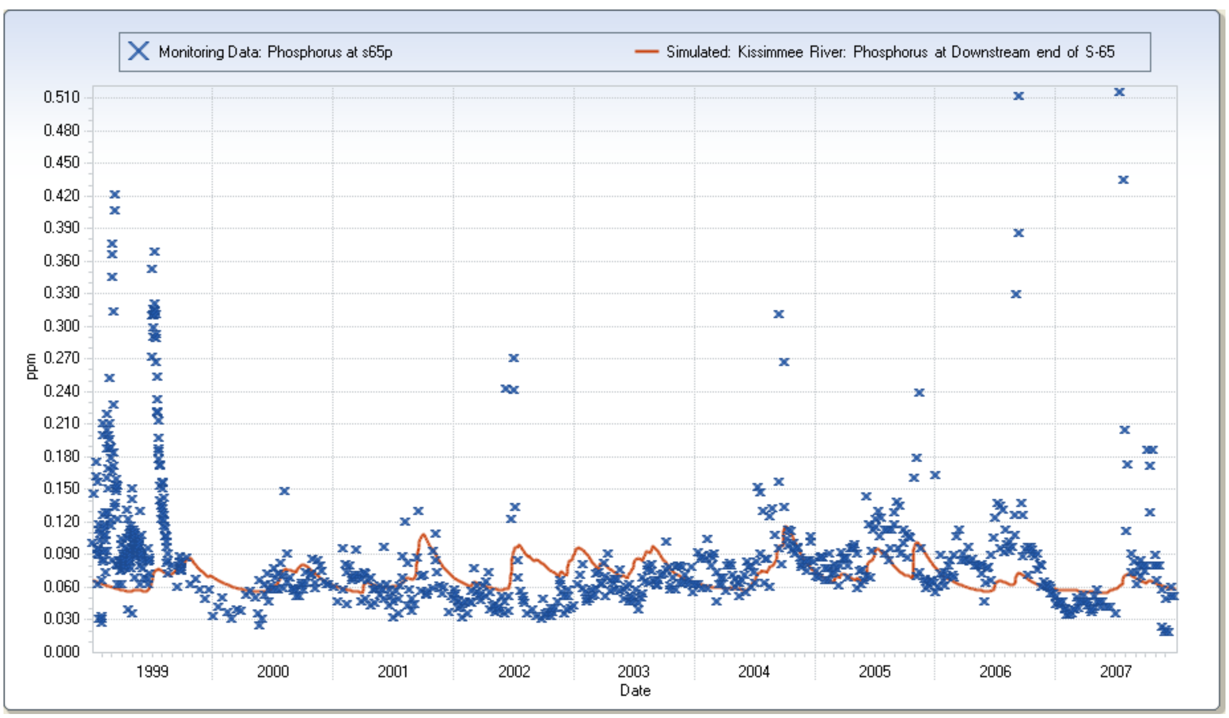

Figure 4-33: Total Phosphorus Concentration at S-65

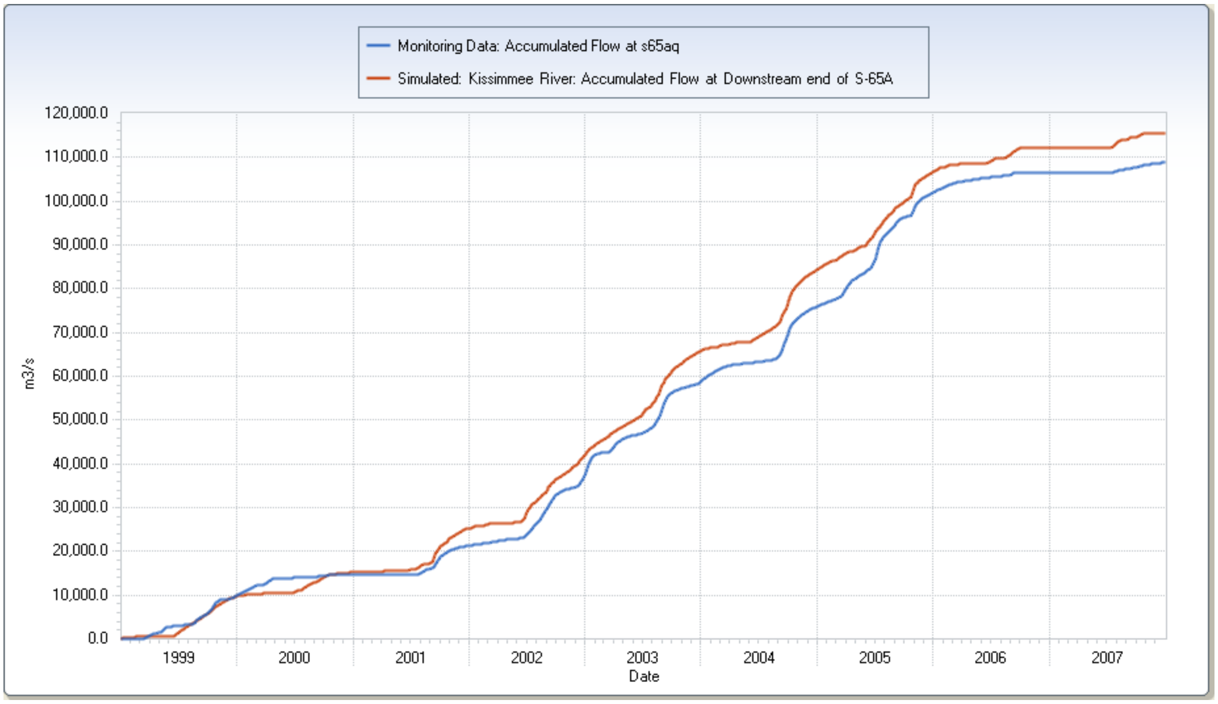

Figure 4-34: Cumulative Flow at S-65A

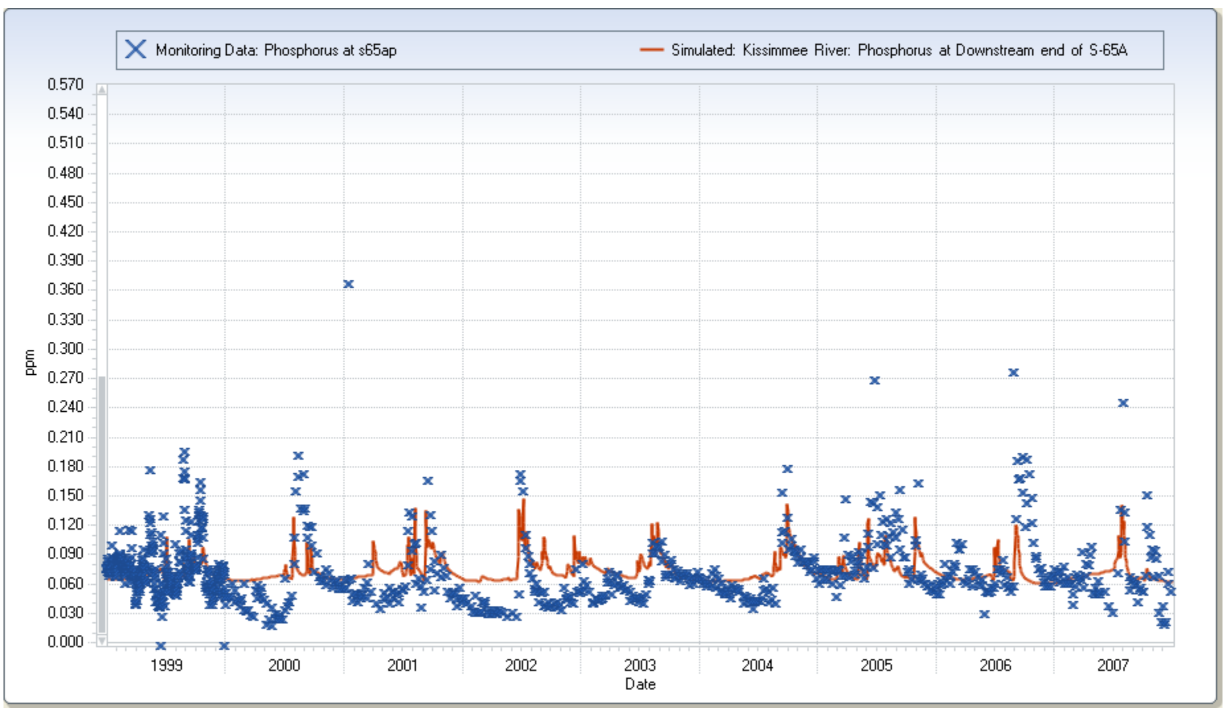

Figure 4-35: Total Phosphorus Concentration at S-65A

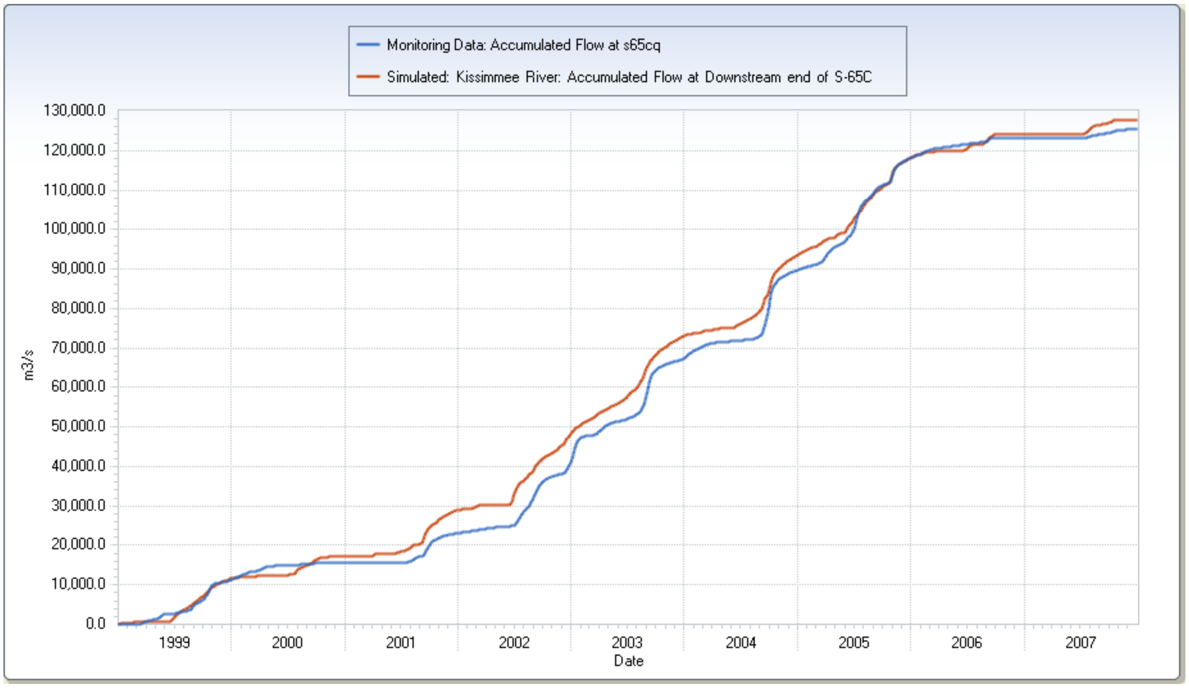

Figure 4-36: Cumulative Flow at S-65C

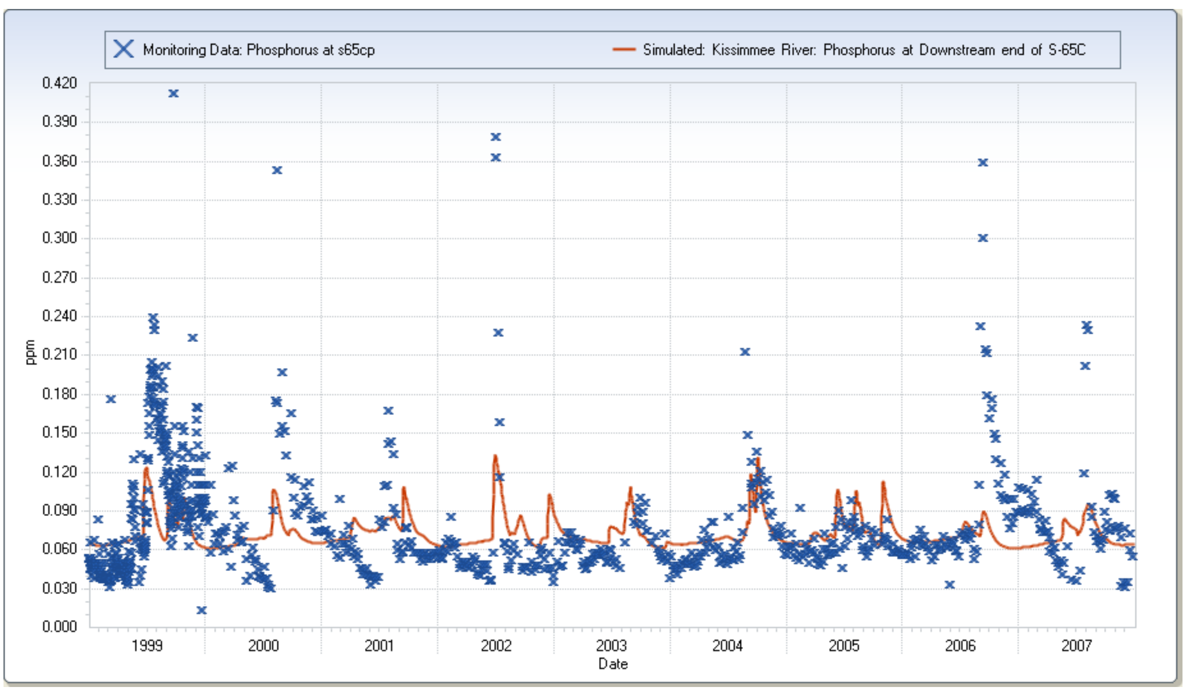

Figure 4-37: Total Phosphorus Concentration at S-65C

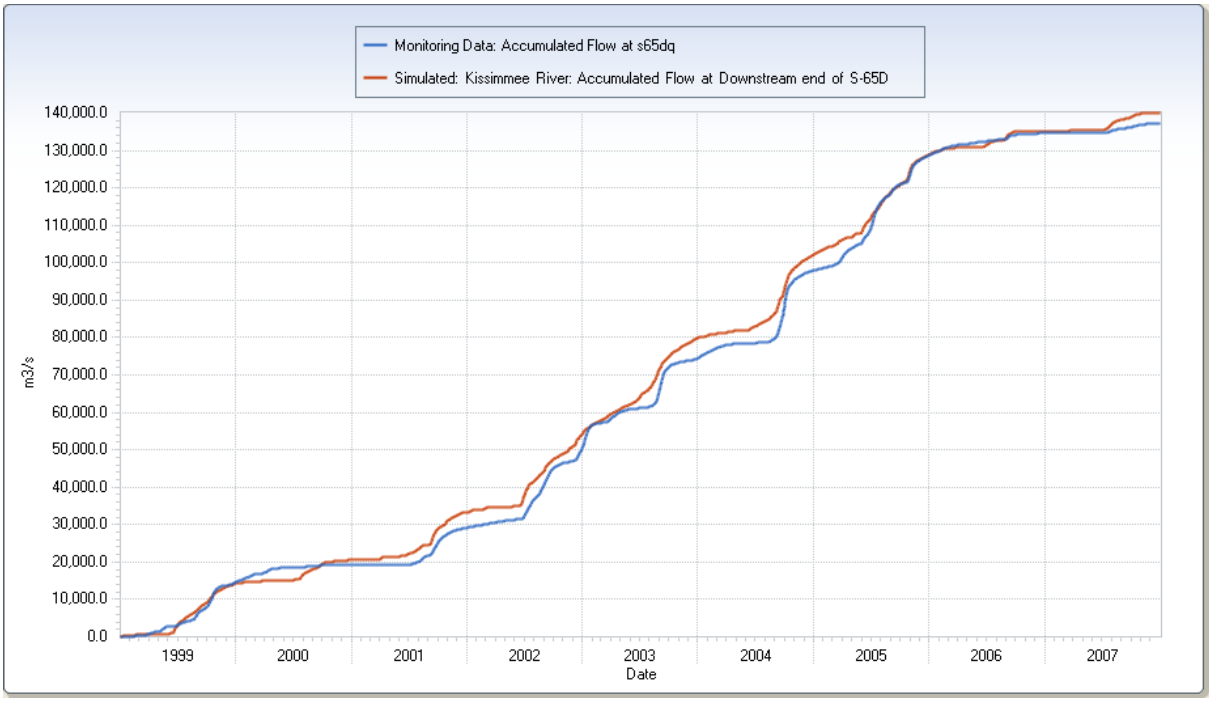

Figure 4-38: Cumulative Flow at S-65D

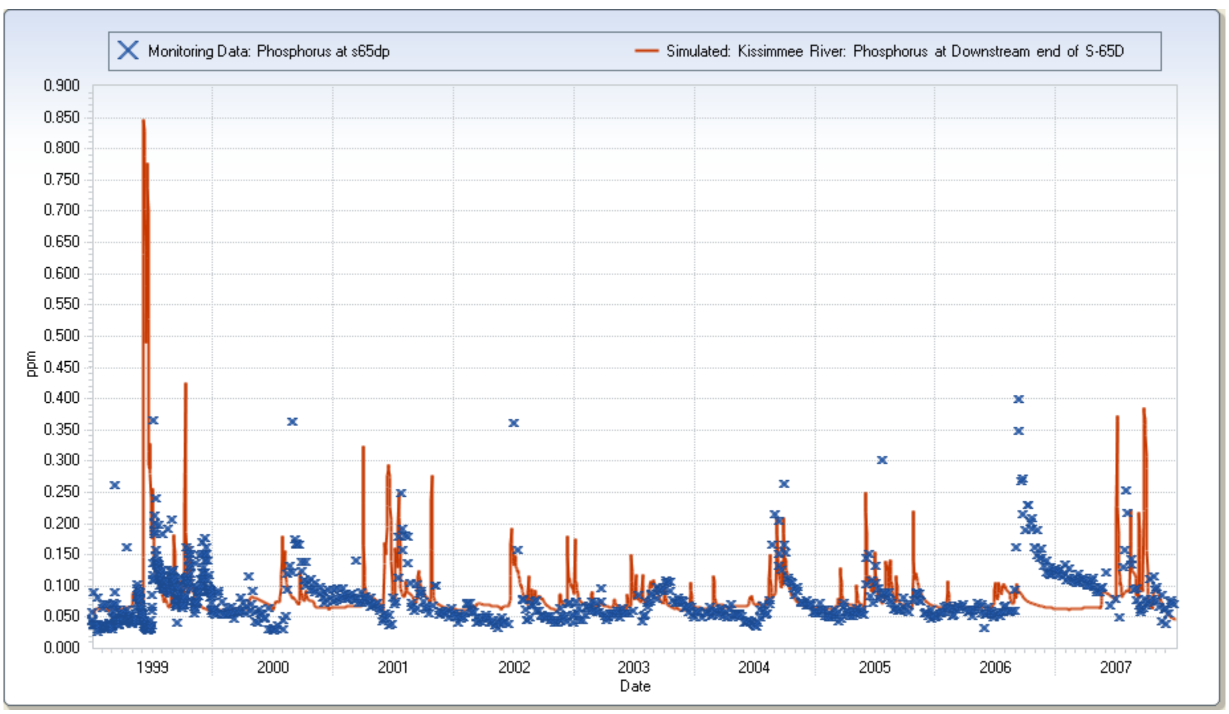

Figure 4-39: Total Phosphorus Concentration at S-65D

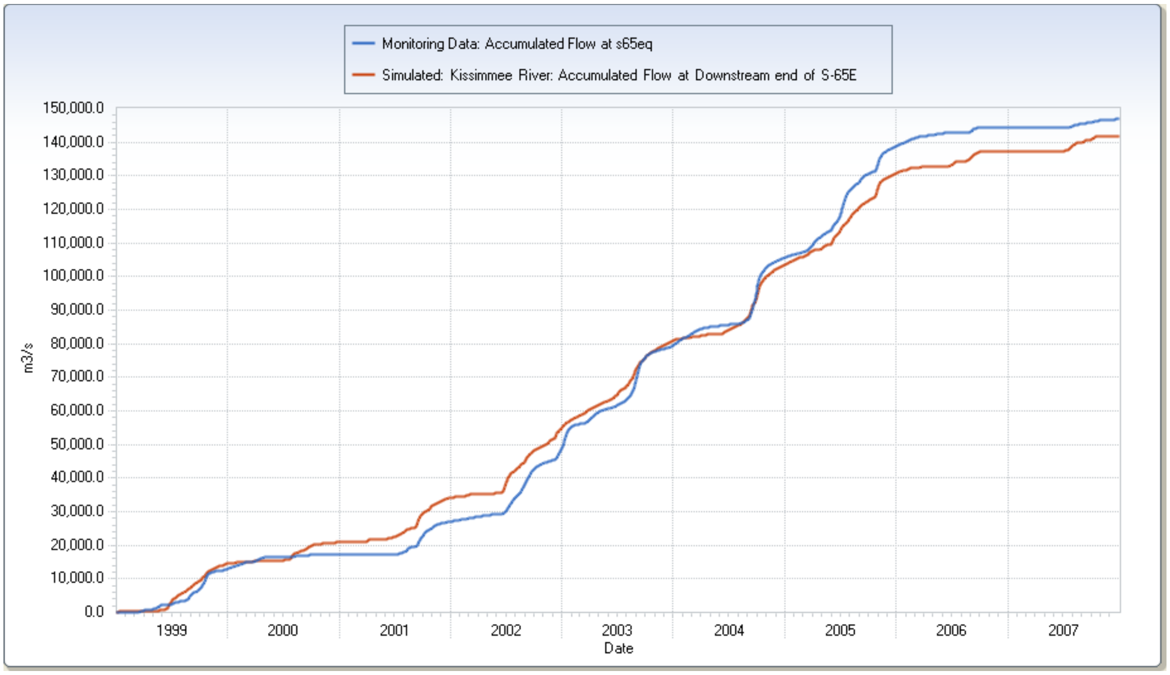

Figure 4-40: Cumulative Flow at S-65E

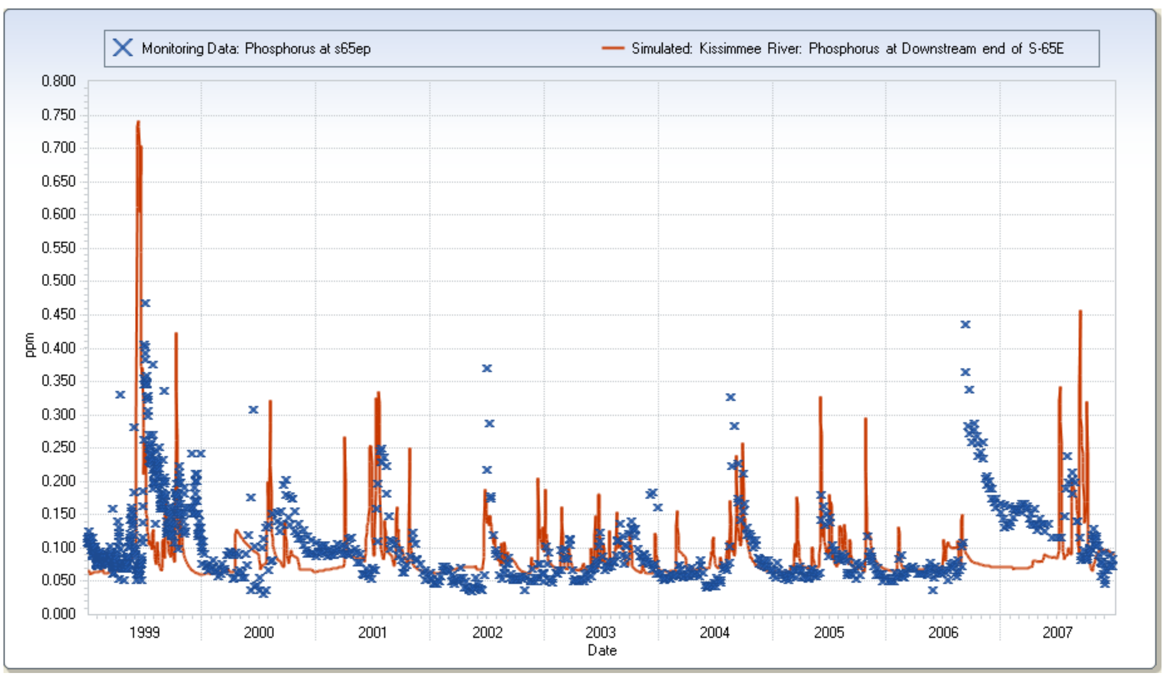

Figure 4-41: Total Phosphorus Concentration at S-65E

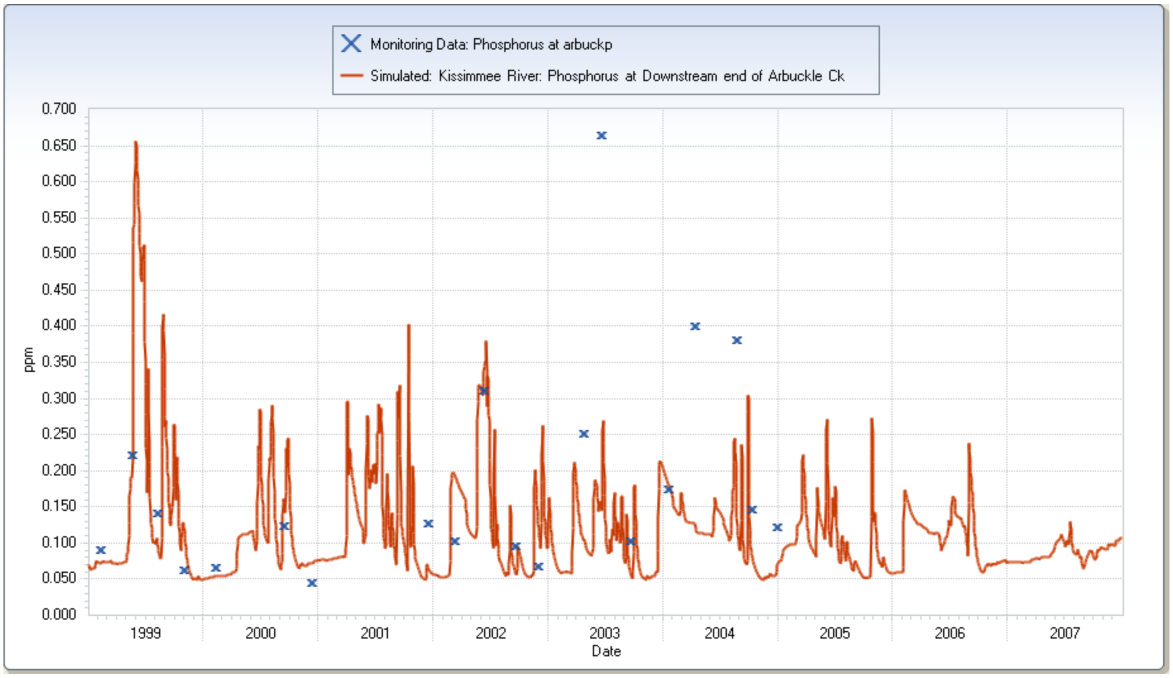

Figure 4-42: Total Phosphorus Concentration at Arbuckle Creek

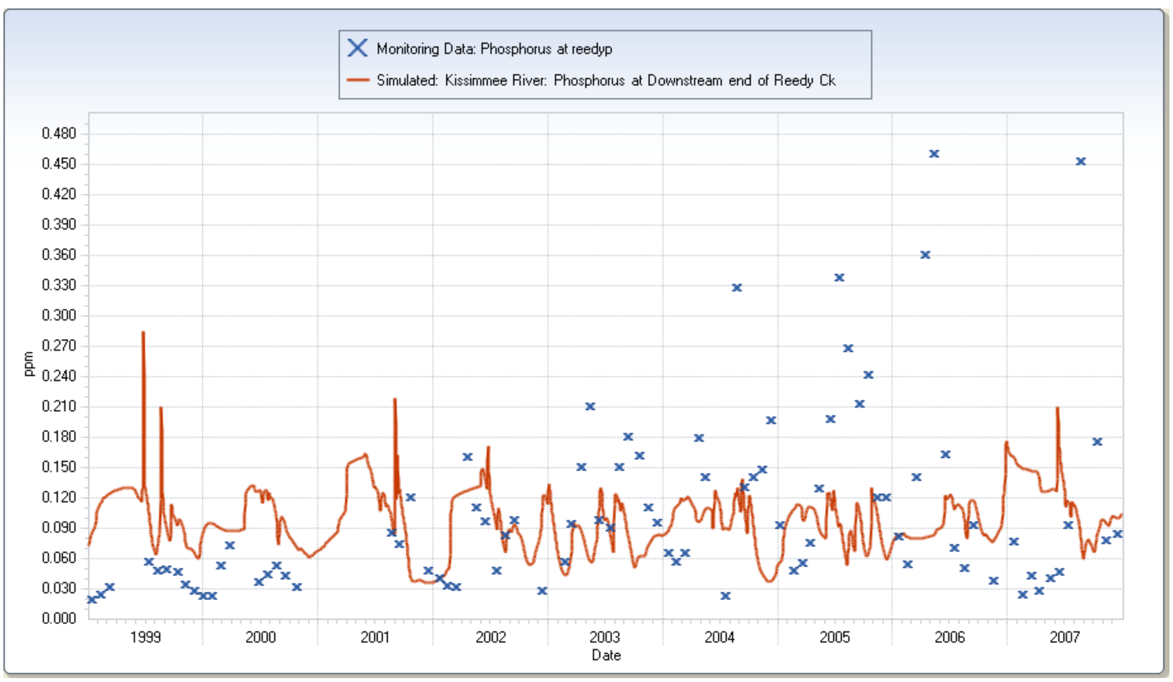

Figure 4-43: Total Phosphorus Concentration at Reedy Creek

4.3.J. Other Basins

The C-43 East, C-44, S-153, Basin 8 and L-8 Basins flank the west and east sides of the Lake and contribute relatively little water to the Lake. These basins, in fact, typically are associated with lake releases to coastal estuaries. S-153 and Basin 8 were combined with the C-44 Basin. S-153 discharges into C-44. Basin 8 was included because a portion discharges to C-44 and a portion discharges directly to Lake. The three resulting WAM basins (C-43 East, C-44 and L-8) include regulated inflows from the Lake, which because of the nature of the flows (some required Governing Board approval), had to be simulated with inflow boundary conditions including measured flows and pollutant concentrations. The comparisons were therefore performed at the (normally) downstream side of the basins. Refer to **Figures 4-44 and 4-45** the C-43 comparisons.

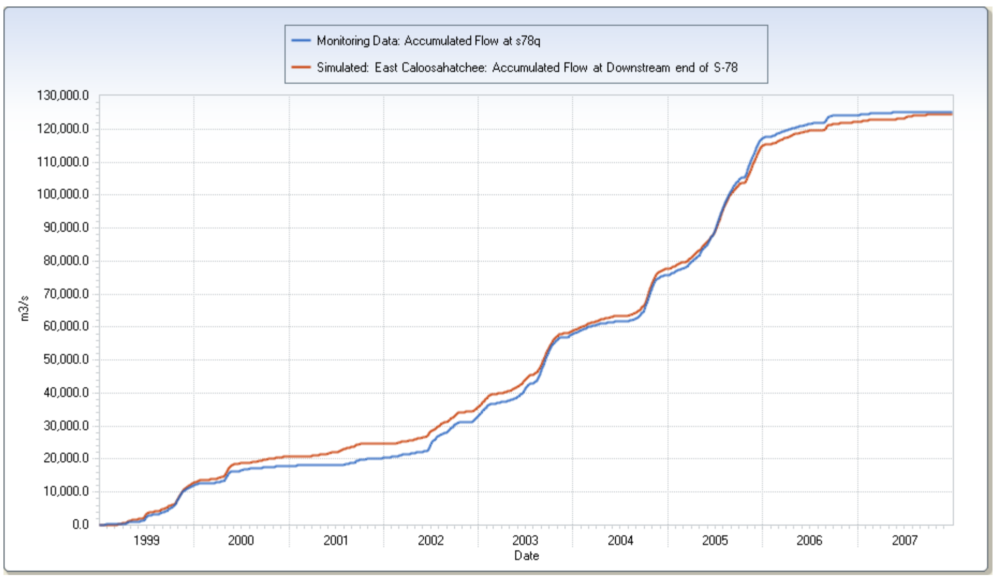

Figure 4-44: Cumulative Flow at S-78 in C-43 East Basin

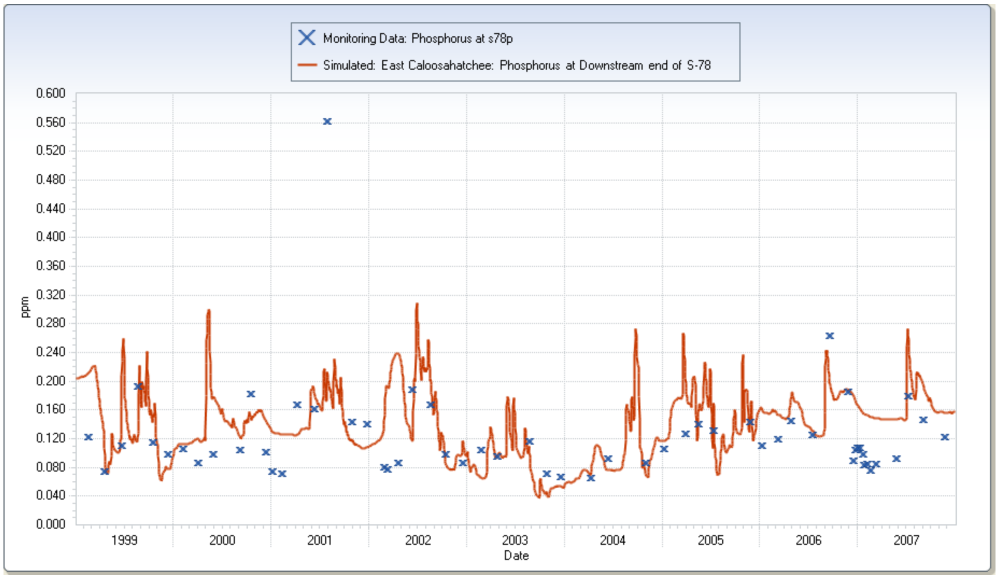

Figure 4-45: Total Phosphorus Concentration at S-78 in C-43 East Basin

Some land use adjustments were made in the C-44 Basin after it was discovered that the District's 2006 land use dataset had assumed that the C-44 Reservoir and STA projects would be in operation. These projects, totaling approximately 11,000 acres, have not been completed and have been put on hold indefinitely. In 2006, the land was still in citrus production, but has since been cleared. For calibration purposes, these areas were changed from open water and wetlands back to citrus. Refer to **Figures 4-46 and 4-47** the C-44 comparisons.

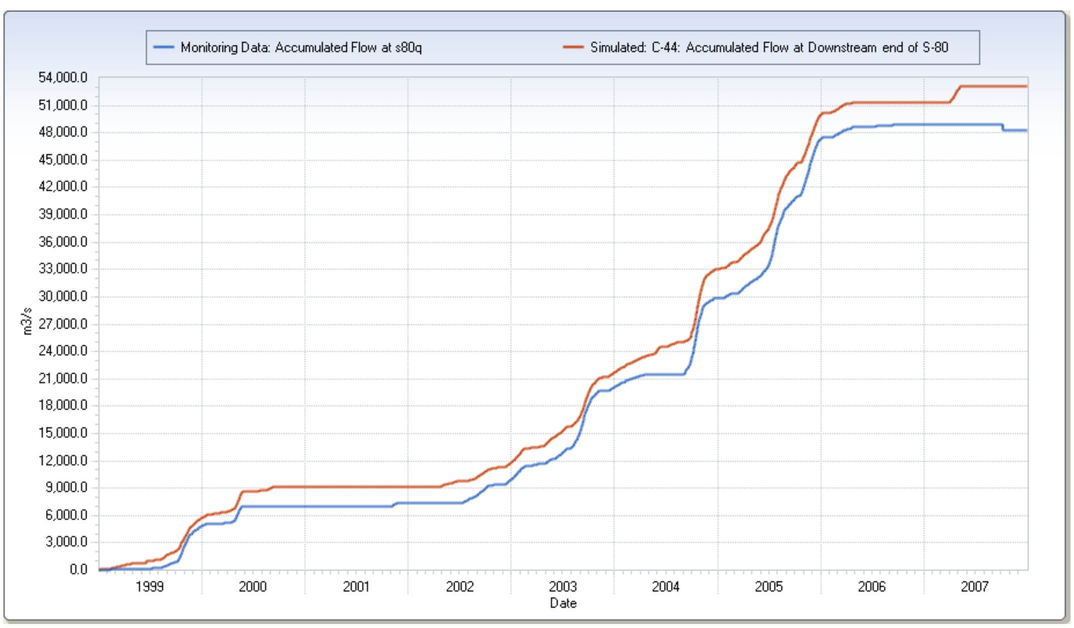

Figure 4-46: Cumulative Flow at S-80 in C-44 East Basin

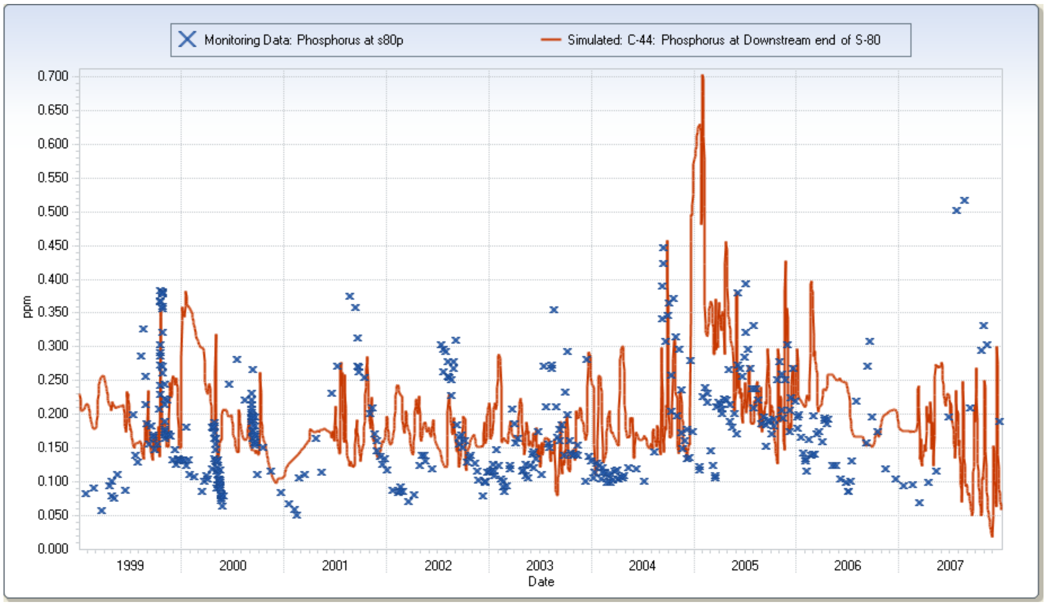

Figure 4-47: Total Phosphorus Concentration at S-80 in C-44 East Basin

Comparing data in the L-8 Basin was problematic. The basin terminates at the intersection of the C-51, L-12 and L-40 Canals where there are three separate structures that allow flow in any direction. The control parameters for these structures are based on water levels in canals that are outside of the study area. For modeling purposes, a stage boundary condition was created at this intersection. The amount of water the model discharged to or withdrew from this boundary was then compared to the recorded net flows of the three structures. However, considering that and the fact that about a quarter of the recorded flows were flagged as “E” Estimated, the comparison was better than expected. Total phosphorus was compared at the WPB Control 2 Pump Station. Most of the monitoring data obtained was collected about a mile downstream of the pump station and probably reflects some assimilation compared to the water quality at the pump station. Refer to **Figures 4-48 and 4-49** for the L-8 Basin comparisons.

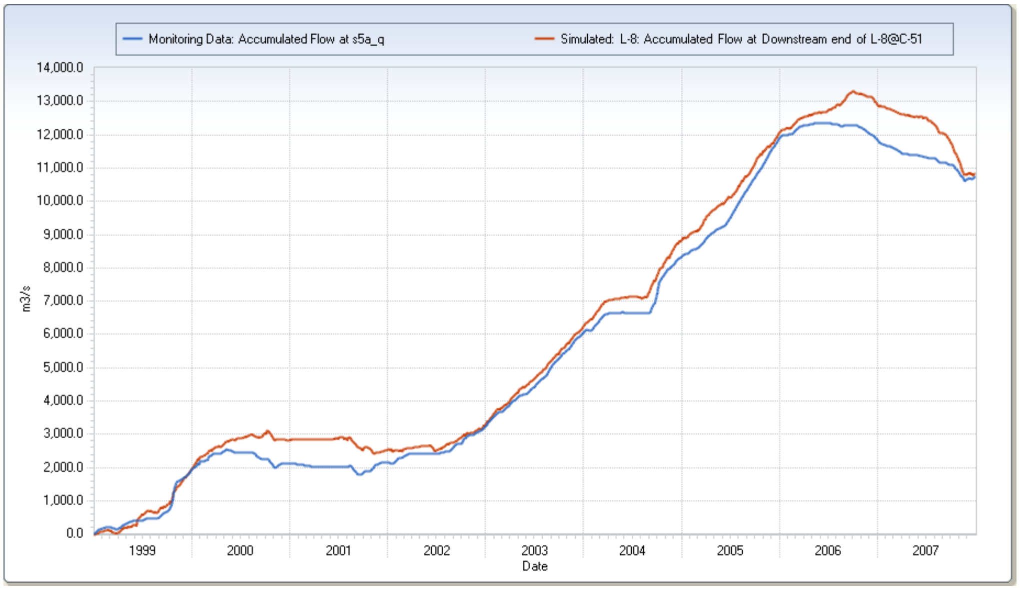

Figure 4-48: Cumulative Flow at Intersection with C-51 Canal in L-8 Basin

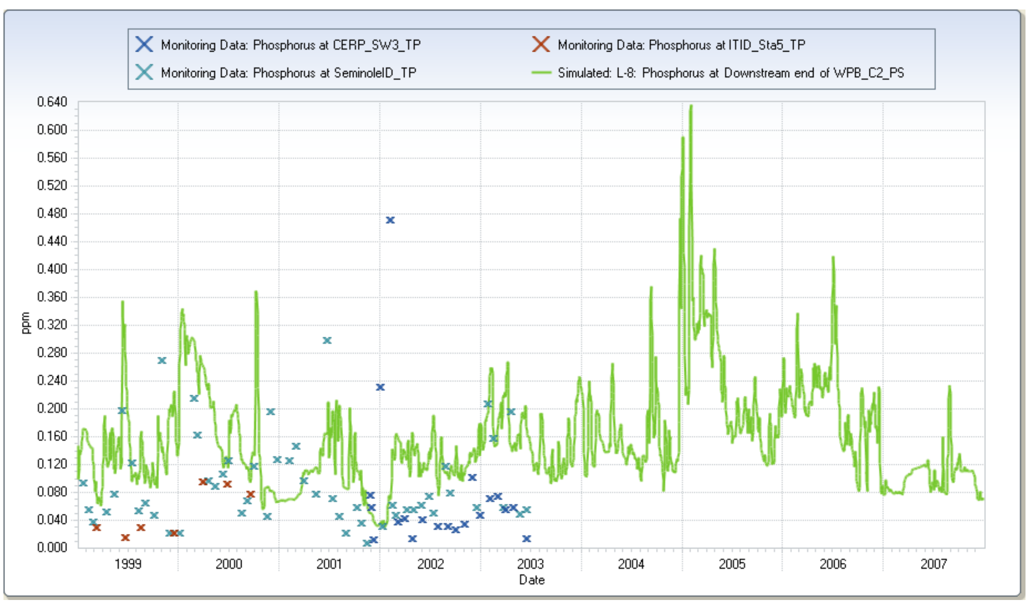

Figure 4-49: Total Phosphorus Concentration at WPB Control 2 Pump Station in L-8 Basin

4.3.K. Summary of Basins Flow and TP Loads

Table 4-3 summarizes the results of the WAM modeling compared to measured data for several monitoring locations. It should be noted that the simulated results are being compared to measured data with an unknown error, which means that the model can never be calibrated to accuracy greater than the observed data. With data errors often exceeding ± 10%, it becomes very difficult to get good matches across a large number of basins without individual basin calibration parameters, which is not desirable for several reasons. For example, this may model results in a basin to match to poor observed data, including rainfall.

The preliminary calibration work has identified several issues as far as the model's ability to directly match the measured data. In general, flows are matching reasonably well. The large number of lakes in the C-38 basin is causing over prediction of flow because it appears that lake evaporation is not being adequately represented. Additional tests will be run to verify the lake model water balance. Also, L-48 appears to have measured data problems because of significant periods of no flow.

Table 4-3: Summary of Flows and TP Loads from the Okeechobee Basins

Basin	Structure	WAM Reach	Annual Average Flow (m^3x10^6)			Annual Average TP Load (mt)			Years
			Measured	Simulated	% Diff	Measured	Simulated	% Diff	
C-38	S-65	836	974	1021	5%	82.1	83.5	2%	99-07
	S-65A	602	1045	1108	6%	87.4	92.0	5%	99-07
	S-65C	519	1204	1227	2%	96.5	101.7	5%	99-07
	S-65D	87	1318	1343	2%	125.3	137.6	10%	99-07
	S-65E	79	1410	1362	-3%	150.8	153.1	1%	99-07
	S-68	657	346	352	2%	25.4	26.6	5%	99-07
C-43	S-78	2	1201	1195	0%	149	160	7%	99-07
C-44	S-80	5	470	542	15%	102	115	12%	99-07
L-8	L-8 @ C-51	3	108	98	-9%				99-07
	WPB PS2	49				2.1	3	67%	98-02
L-48	S-127	2	12	13	6%	3.0	3.0	-1%	99-07
L-49	S-129	2	14	14	-7%	1.1	1.2	10%	99-07
S-131	S-131	2	11	11	-8%	1.3	1.5	10%	99-07
S-133	S-133	2	23	22	-5%	5.6	6.1	8%	99-07
S-135	S-135	2	22	22	1%	2.8	3.1	10%	99-07
S-191	S-191	2	116	116	0%	72.7	75.3	4%	99-07
FEC	US-27	60	233	239	3%				99-07
	SR-78	4				57.8	52.3	-10%	99-07

Table 4-4 provides the annual flow and TP loads for a sample of the primary basins. As previously seen in the flow accumulation plots, there were significant variations that could occur between years due primarily to rainfall variability and measured data problems, particularly during hurricanes and other abnormal events.

Table 4-4: Sample Annual Flow and Total P Loads

Basin	Date	Measured		Simulated		Percent Diff	
		Flow m^3x1000000	TP mt	Flow m^3x1000000	TP mt	Flow	TP
S-191	1999	186	144	231	175	24%	22%
	2000	19	10	22	14	12%	34%
	2001	106	72	184	115	74%	59%
	2002	95	64	66	38	-31%	-40%
	2003	116	70	84	47	-28%	-32%
	2004	196	125	206	126	5%	1%
	2005	239	128	150	99	-37%	-23%
	2006	32	15	25	14	-21%	-11%
	2007	26	13	46	31	73%	133%
	Average	116	73	116	75	0%	4%
FEC	1999	247	44	284	73	15%	66%
	2000	21	6	56	8	168%	37%
	2001	323	101	331	79	2%	-22%
	2002	275	74	414	87	50%	18%
	2003	310	48	201	41	-35%	-14%
	2004	376	141	344	75	-8%	-47%
	2005	383	64	227	45	-41%	-29%
	2006	123	33	247	56	100%	72%
	2007	34	10	50	6	45%	-35%
	Average	233	58	239	52	3%	-10%
S-65	1999	666	56	783	64	18%	14%
	2000	360	15	447	35	24%	128%
	2001	366	27	772	72	111%	166%
	2002	1310	69	1307	116	0%	69%
	2003	1878	122	1958	180	4%	47%
	2004	1549	175	1510	145	-3%	-17%
	2005	2090	221	1769	160	-15%	-28%
	2006	397	35	409	30	3%	-15%
	2007	148	17	238	17	61%	-3%
	Average	974	82	1021	91	5%	11%
S-68	1999	367	20	445	45	21%	127%
	2000	40	4	148	11	273%	172%
	2001	300	9	614	66	105%	673%
	2002	536	42	608	58	13%	38%
	2003	531	31	448	31	-16%	2%
	2004	466	47	384	33	-18%	-30%
	2005	688	60	463	34	-33%	-44%
	2006	144	13	57	4	-60%	-69%
	2007	44	4	0	0	100%	-100%
	Average	346	25	352	31	2%	24%

4.4. Conclusions

WAM has been successfully setup for the Okeechobee basins and preliminary modeling results show that WAM is doing a reasonable job of simulating flows and TP through the basins. However, there are clearly some remaining issues related to observed data accuracy, proper land use characterization, proper characterization of impacted soils, TP from historic P loading, and the in-lake water balances that all need further attention.

The preliminary calibration work has identified several issues as far as the model's ability to directly match the measured flow data. In general, flows are matching reasonably well except for two observed issues. First, the large number of lakes in the C-38 basin is causing over prediction of flow because it appears that lake evaporation is not being adequately represented. Additional tests will be run to verify the lake model water balance. This is a simple assessment, but could not be completed in time for this draft submission. Secondly, L-48 appears to have measured data problems because of significant periods of no flow.

In general, the TP loads are much more variable than the flow data. These variations are suspected to be caused by a combination of model variability, measurement errors, poor land use representation within the basins, and limited information for historic TP build up in soils. Measurement errors are hard to quantify without secondary data being available for verification. Such errors can be caused by the limitations of grab sample data missing peak flows, sampling and laboratory errors, equipment failures, and missing or poor flow measurement algorithms. Land use characterization data are always difficult to spatially verify because land management variations across the watershed are not available. And finally the spatial variability of legacy P for given land uses is not well defined because the historical practices determine legacy P rather than current land use practices. For example, if an old closed dairy site that was historically overloaded with TP is not mapped as an abandoned dairy, its legacy P will be missed. Plus, the length of time a dairy was in operation influences legacy P, but this information was not available. In addition to the above causes of variability, the near lake basins also have poorly defined seepage rates of TP from the lake. To the extent practicable, these issues were addressed during the calibration process, but further investigations of these sources of errors are recommended for future study.

5.0 Evaluating the Effectiveness of Phosphorus Control Programs on Phosphorus Load Reduction to Lake Okeechobee

5.1. Model Simulation Alternatives

For Task 3 of this project, baseline simulations of each basin in the WAM Enhancement study area were performed to represent existing conditions. The existing conditions were based on mapped land uses. Each land use was assigned parameters to represent current fertilization and water management practices that affect water quality. Those parameters are the input to field scale hydrologic models, GLEAMS and/or EAAMOD. This report describes the setup and results of the following three "what if" scenarios:

- **Scenario 1** - agricultural and urban best management practices (BMPs),
- **Scenario 2** – agricultural and urban BMPs and existing source control and regional projects, and
- **Scenario 3** – agricultural and urban BMPs, existing source control and regional projects, and regional treatments systems (STAs and RASTAs).

5.1.A. Scenario 1- Agricultural and Urban BMPs

Scenario 1 is intended to simulate the expected phosphorus and nitrogen reductions from implementing the BMPs – owner-implemented and cost-shared (typical), as specified in the Lake Okeechobee Protection Plan (LOPP). Owner-implemented BMPs are based on existing cow/calf and citrus water-quality BMP manuals' assessment checklists. Cost-shared (typical) BMPs are based on more comprehensive site-specific plans with implementation being cost-shared by Florida Department of Agriculture and Consumer Services (FDACS) and the National Resource Conservation Service (NRCS).

Existing sets of GLEAMS and/or EAAMOD input parameters for various land use types were copied and then altered to represent land uses where BMPs were implemented. Next, test GLEAMS and/or EAAMOD simulations were executed for each base land use and its corresponding BMP land use. These preliminary tests considered only one rainfall time series and the predominant soil type (Immokalee). Analysis of other soil types would have provided little additional improvement. The cumulative phosphorus runoff (kg/ha) from the modified BMPs were compared to the baseline land use. Relevant input parameters for BMPs were changed until the expected phosphorus reductions were achieved. The cumulative flow (m3) and nitrogen runoff (kg/ha) also were compared to verify consistency among the runoff values. The main input parameters included: legacy phosphorus, nitrogen / phosphorus fertilization rates, water management criteria, irrigation practices, water/feed placement, wetland restoration/retention, and stormwater retention/detention.

Legacy phosphorus is the amount of phosphorus in the soil that has built up as a result of anthropogenic practices, such as fertilization and animal management practices. Legacy P is set in the model as an organic P addition to the soil at the start of simulation and is used for land uses that are simulated with EAAMOD. Organic P was used because it represents a slower release of P than inorganic. Applying inorganic P would cause excessive initial flushes of P.

Changing the legacy P value was deemed appropriate for certain land uses, while it was not changed for others. It was appropriate for land uses where the net effect of the land use BMP would be to mine P from the soil. In the case of improved and unimproved pasture, the legacy phosphorus value was reduced by 20 kg/ha based on the assumption that roughly 2 kg/ha/yr of phosphorus was effectively removed from the soil and stored in cattle that were eventually removed from the land. This assumption is based on cow/calf production rates, i.e. body mass gained per year per hectare and P content of body mass. Data was obtained from cattle extension specialists from the Ona Cattle Research and Education Center, IFAS. Reducing by 20 kg/ha implies that BMPs have been in effect for ten years before the start of the simulation.

As a starting point, nitrogen and phosphorus fertilization rates were reduced by the same percentage (30%, typical from IFAS recommendations) based on the expected percent reduction of downstream phosphorus after BMP implementation (Table 1: SFWMD 2007). Water management BMPs for agricultural systems like row crop and citrus were changed from a rainfall based board removal to a water table based board removal which significantly reduces irrigation demand and related drainage. The irrigation pumping BMP was set to not exceed the water elevation at the discharge weir crest elevation to prevent any pass-through flow during irrigation.

Variable levels of wetland restoration or retention/detention systems were turned on for most agricultural and urban land uses as BMPs. The parameters that were changed specify the maximum depth of water in the retention/detention system, the relative volume of storage, and whether it was a wet or dry based system. Typically wet or wetland based retention/detention was used for agricultural systems while dry stormwater retention/detention was used for urban land uses (**Table 5-1**).

BMPs that cannot be directly simulated in WAM as a physical process (fencing streams, moving watering/feed facilities, etc.) were represented in the model by BMPs factors, which are simply reduction multiplication factors that represent potential nutrient reductions. The factors used for the BMPs are represented in the final column in **Table 5-1**.

Subsequent to the initial test simulations of hydrology only, with one rainfall time series and soil type, each basin in the study area was simulated with the BMPs in effect for the currently mapped land uses. Further changes to the parameters were made during this stage such that the expected phosphorus runoff reductions were achieved at the basin wide scale. In general this required reducing the retention system storage ratio parameter since the phosphorus reductions were higher than expected at the basin scale. The difference between the simulated source cell loads and those reaching the Lake is explained by the attenuation/assimilation that occurs between sources and the receiving water bodies and as water makes its way through the surface water system of streams, canals, and lakes.

Table 5-1: Parameters assumed by WAM for representing BMP implementation

Land Use	WAM Code	Fertility Reduction P (%)	Fertility Reduction N (%)	Water Manag. (Y/N)	Increase of R/D Storage[1] (m^3/hectare)	Other BMPs Factors (% Red.)[2]
Imp.Pasture	126	100[3]	30	-	100	5
Semi-Imp. Pasture	127	100[3]	30	-	50	2
Woodland Pasture	128	100[3]	30	-	10	2
Dairy General	139	100[3]	30	-	300	0
Intensive Pasture	185	100[3]	30	-	200	0
Boundary Dairy Pasture	190	0 (none[4])	30	-	200	0
Sprayfields	186	0 (none[4])	30	Yes	500	0
Hayland	162	20	20	-	200	0
Abandoned Dairy	189	0 (none[4])	30	-	300	0
Citrus	184	12	12	Yes	300	0
Row Crop	125	30	30	Yes	300	0
Pine Plantation	108	33	33	-	50	0
Sod Farms	136	20	20	Yes	250	0
Sugar Cane	168	30	10	Yes	400	0
Ornamentals/Nursery	137	30	30	Yes	1500	0
Tree Nurseries	135	30	38	Yes	150	0
Low Residential	102	25	20	-	250	0
Med. Residential	119	30	30	Yes	100	0
High Residential	120	30	30	Yes	100	0
Multiply Units	121	30	30	-	100	0
Commercial	103	5	5	-	40	0
Industrial	122	5	5	-	100	0
Managed Landscape	123	10	10	Yes	100	0
Transportation	118	100[3]	30	-	40	0

1 R/D = retention/detention.
2 Includes unsimulated practices, such as critical area fencing and water/feed placement
3 Reduction to zero applications of P from existing levels of about 2 to 5 lbs/ac
4 No existing application of P fertilizer

5.1.B. Scenario 2 – Agricultural and Urban BMPs and Phosphorus Source Control and Regional Projects

Scenario 2 simulated existing and planned P source control projects that have been or are being implemented to reduce phosphorus loads to Lake Okeechobee (**Figure 5-1** and **Table 5-2**). These projects fall into seven categories/programs, as follows:

- Phosphorus Source Control Grant Program
- Hybrid Wetland Treatment Technology Program
- Isolated Wetland Restoration Program
- Former Dairy Remediation
- Dairy Best Available Technology
- Public Private Partnership
- Florida Ranchland Environmental Services Project
- Aquatic Based Treatment System

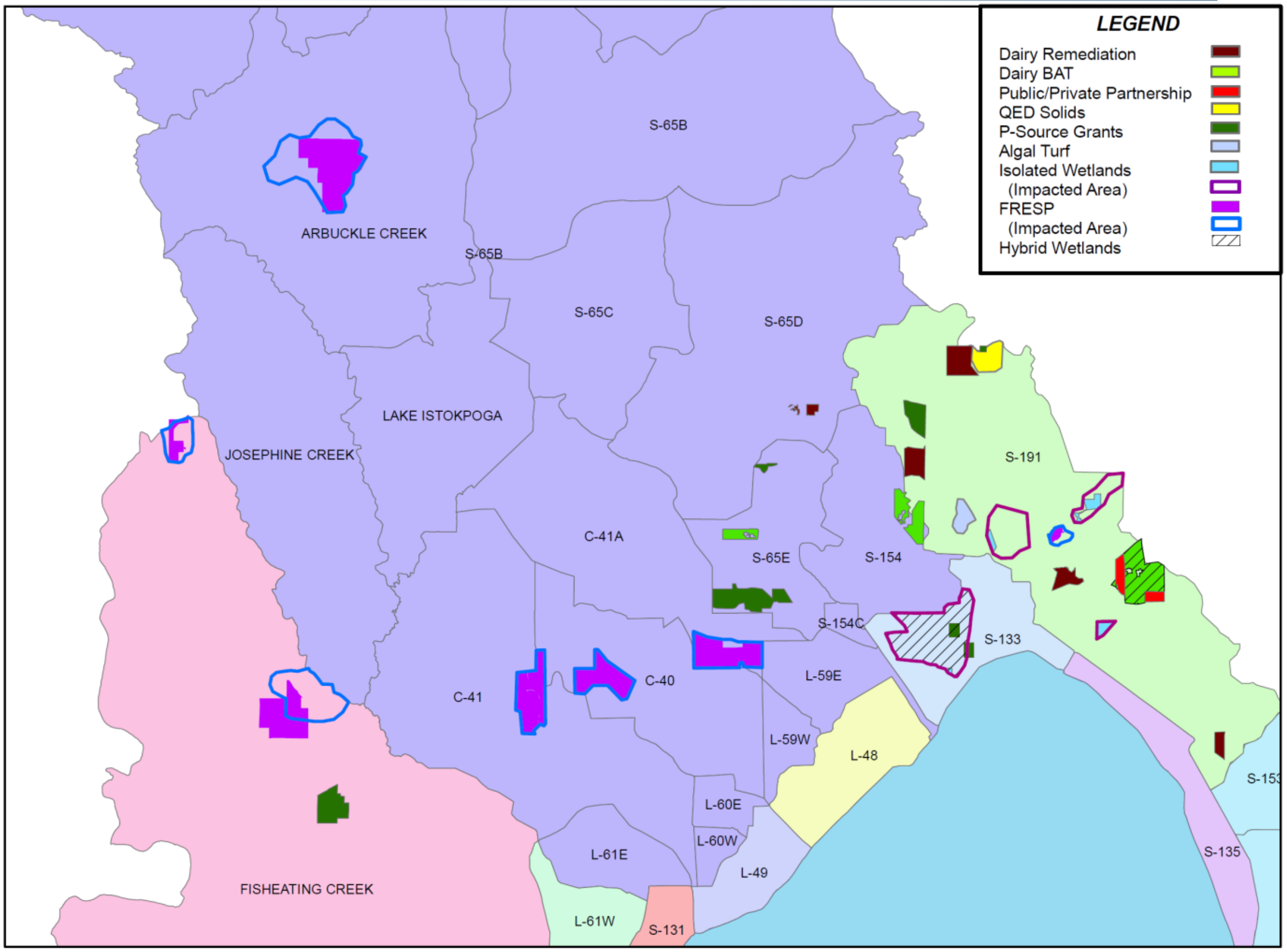

Figure 5-1: SFWMD Phosphorus Source Control Projects

Table 5-2: SFWMD Lake Okeechobee Watershed source control projects

Program	Project
Phosphorus Source Control Grant Program	Tampa Farms – Indiantown
	QED – McArthur Farms 3
	Davie-Dairy Cooling Pond
	Evans Properties – Bassett Grove
	OUA-Ousley
	Smith Okeechobee Farms
	Lofton Ranch
	Solid Waste Authority
	Lazy S Ranch Iron Humate
Hybrid Wetland Treatment Technology Projects	Larson Dairy Lagoon
	Upper Nubbin Slough Treatment
	Upper Mosquito Creek Watershed
	Lemkin Creek Urban HWTT
Isolated Wetland Restoration Projects	Kirton Ranch
	Nubbin Slough Area A Restoration
	Eckerd Youth Center
	Lemkin Creek
Former Dairy Remediation Projects	Mattson
	McArthur 5
	Candler
	Larson Dairy 7
	Lamb Island Dairy – East
	Lamb Island Dairy – West
Dairy Best Available Technology Projects	Dry Lake 1 (now Hudson Lakes Ranchettes)
	Milking R
	Butler Oaks
	Davie Dairy 1 and 2
Public/Private Partnership Project	Davie Dairy Stormwater Treatment
Florida Ranchlands Environmental Services	Williamson Cattle Company
	Buck Island Ranch
	Lykes Brothers - West Watering Hole
	C.M. Payne & Son
	Lightsey Cattle Company
	Syfrett Ranch West
	Rafter T. Ranch

5.1.B.1. Phosphorus Source Control Grant Program

The P source control projects were represented in WAM by three approaches, which were to represent the P reductions at the source cells using BMP factors, modifying retention practices, or by direct P removal from the affected stream using the point source algorithm within WAM (**Table 5-3**). These methods were used because the specific infield P reduction processes and operational protocols for the individual projects were not available or the processes were not able to be directly represented within WAM. However, the drainage areas impacted by the project were delineated based on topography and drainage features and placed in a shape file/feature class called P-SourceGrant.shp. Within these drainage areas the BMP factors for the land uses were used to represent constant P removal rates of between 10% and 80% depending on the LOPP estimated P reductions. Nitrogen reduction factors are also provided; however, these were only roughly estimated by the author based on the P reduction estimated because LOPP did not provide nitrogen reductions. This method was used for all the P source control projects with the exception of the Tampa Farms project near Indiantown, dairy remediation, and FRESP projects. The Tampa Farms project has resulted in reduced litter applications within the S-191 and lower C-38 basins including S-154 and S65E basins because these materials are now going to their new composting facility near Indiantown. The LOPP estimated P reduction within these basins was about 2.15 mt and 2.9 mt of P, respectively. This removal was accomplished by using the point source algorithm, which allows WAM to remove P at a constant continuous rate. The FRESP and dairy remediation projects were represented by using additional wetland retention.

5.1.B.2. Hybrid Wetland Treatment Technology Projects

The Hybrid Wetland Treatment Technology combines the attributes of treatment wetlands and chemical treatment systems. The following hybrid wetland treatment technology projects were included using the same techniques described above.

5.1.B.2.1 Larson Dairy Lagoon HWTT Project

The Larson Dairy Lagoon HWTT reduced P concentrations in the second and third stage of the dairy lagoon, thereby reducing potential P loadings to downstream areas. This multi-stage HWTT is approximately 0.2 acre in size, and is deployed within the second stage of Larson Dairy Barn #8 Lagoon. The system was designed to treat ~100,000 gallons of lagoon water per day, which is comparable to the daily hydraulic loading of barn wash into the lagoon. The HWTT was designed to reduce total P concentrations in the dairy lagoon from the range of 6 – 10 mg/L to below 0.2 mg/L. Initial monitoring showed reductions from a mean of 16.7 to 0.95 mg/l.

Table 5-3: Parameters used in WAM to simulate phosphorus control projects

P-Control Practices[1]		WAM Code	Increase in Wetland Ret. Ratio[2]	Reductioin Factors[3]	
	Land Use			N (%)	P (%)
Dairy Remediation					
	Improved Pasture	326	0.025	0	0
	Abandoned Dairy	289	0.02	0	0
Dairy Bat[4]					
	Boundary Pastures	390	0	50	80
	Intensive Pasture	385	0	50	80
	Hayland	362	0	50	80
	Sprayfields	386	0	50	80
	Improved Pasture	426	0	50	80
QED Solids Removal					
	Boundary Pastures	290	0	10	10
	Intensive Pasture	285	0	10	10
	Hayland	262	0	10	10
	Sprayfields	286	0	10	10
P-Control Projects					
	Improved Pasture	326	0	60	60
	Unimproved Pasture	327	0	60	60
	Woody Pasture	328	0	60	60
	Med.Density Residential	219	0	60	60
	Row Crops	225	0	60	60
	Citrus Groves	284	0	60	60
Isolated/Hybrid Wetlands					
	Improved Pasture	326	0	60	60
	Unimproved Pasture	327	0	60	60
	Woody Pasture	328	0	60	60
	Industrial	222	0	60	60
	Managed Landscape	223	0	60	60
	Med.Density Residential	219	0	60	60
Tampa Farms Composting[5]					
FRESP					
	Improved Pasture	326	0.025	0	0
	Unimproved Pasture	327	0.032	0	0
	Woody Pasture	328	0.032	0	0
	Abandoned Dairy	389	0.02	0	0

1 P-Control includes practices listed in Table 2.
2 As compared to BMPs, given as pond volume per unit area,
i.e. actual volume (m3) = Ratio(m) * 10000m2 (hectare), Wetlands
3 Nutrient reductions achieved by applying constrant reduction factor to land use outflows
4 Includes Public/Private Partnership project at Davie Dairy
5 Tampa Farms handled by a WAM load removal algorithm, i.e. CERP predicted P load reduction removed from outflow reaches of basins S154, S65E, and S191

5.1.B.2.2 Upper Nubbin Slough Tributary HWTT Project

Located adjacent to Nubbin Slough on Davie Dairy, this 6,880 m^2 system is sized to treat stream flows from < 0.02 to 0.7 m^3/second. The HWTT is designed to reduce total P concentrations in the tributary waters from the range of 0.4 – 0.9 mg/L to below 0.08 mg/L. Initial monitoring showed reductions of a mean of 0.754 to 0.118 mg/l.

5.1.B.2.3 Upper Mosquito Creek Watershed Treatment System

Located adjacent to Mosquito Creek on Larson Dairy property, this two-pond, 1.8 acre system is sized to treat stream flows from < 0.02 to 0.4 m^3/second. The HWTT is designed to reduce total P concentrations in the tributary waters from the range of 0.4 – 0.8 mg/L to below 0.08 mg/L. Initial monitoring of a 0.2 hectare treatment cell showed reductions from a mean of .492 to .035 mg/l.

5.1.B.2.4 Lemkin Creek Urban HWTT

This project is located 1.7 miles west of the junction of SR 78 and US 441. Two parallel HWTT systems will treat flows from both Wolff Ditch and Lemkin Creek (**Figure 5-2**). The inflow pump from Wolff Ditch will discharge to the HWTT at rates between 0.01 and 0.6 m^3/second. The inflow pump from Lemkin Creek will discharge to the HWTT at rates between 0.01 and 0.14 m^3/second. The system is designed for a 1.5 to 2 day retention time at maximum flow rates. Discharges from the HWTT will be to a 26 hectares wetland to the south. This wetland was created under the Lake Okeechobee Isolated Wetland Restoration Program. An outflow structure from the wetland discharges to Lemkin Creek and subsequently, flows are discharged to Lake Okeechobee.

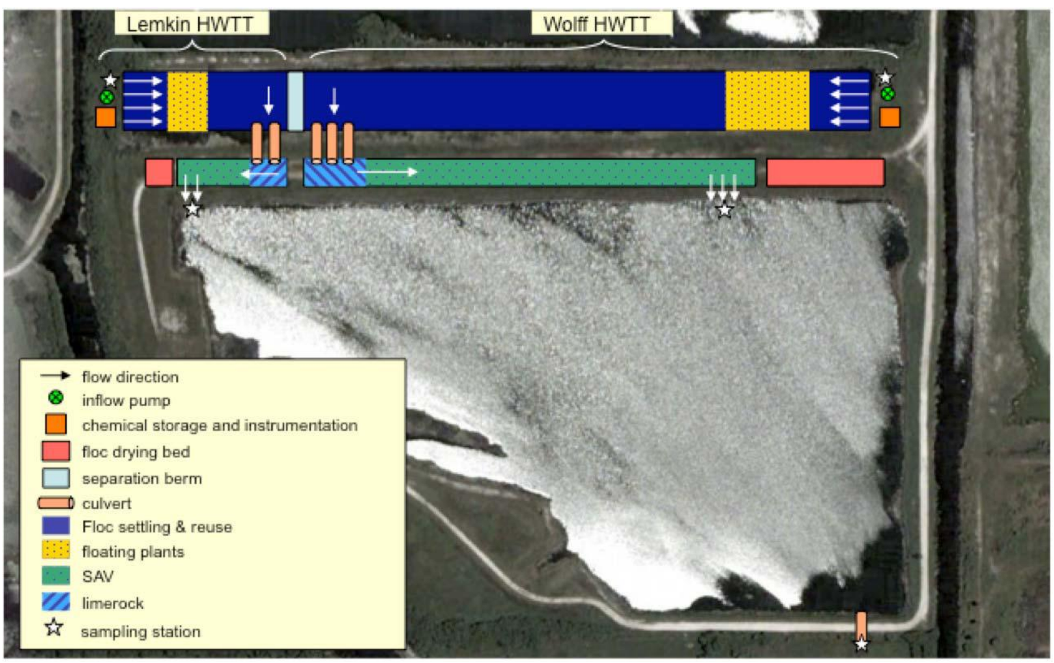

Figure 5-2: Lemkin Creek Urban HWTT

5.1.B.3. Isolated Wetland Restoration Projects

Four isolated wetland restoration projects (**Figure 5-1**) located within the S-191 basin were simulated by WAM. These projects involved the construction of weir structures that would rehydrate previously drained isolated wetlands. The associated drainage basins were delineated based on the local hydrography. This exercise produced a shape file/feature class polygon coverage of the area contributing water to these projects. Using these polygons, a wetland retention system was then associated with its drainage area using maximum depth of storage and relative storage (volume/unit area of drainage area) parameters. Wetland P attenuation coefficients were used for these projects because they were assumed to be wetland based systems.

5.1.B.4. Former Dairy Remediation Projects

Six former dairy remediation projects (**Figure 5-1**) located in several basins were simulated by WAM. These projects involved the removal or stabilization of manure products as well as the construction of stormwater retention systems. The details of the individual systems could not be directly input to WAM because of the small scale of the hydraulic features, therefore these projects were represented in WAM as enhanced wetland retention systems, which where typical of the designs. The additional wet retention for these projects provides P reductions in the order of 60%.

5.1.B.5. Dairy Best Available Technology Projects

Four dairy best available technology (BAT) projects (**Figure 5-1**) located in the S-191 and C-38 basins were simulated by WAM. These projects involved the collection and retention of all dairy stormwater in retention facilities with water reuse and chemical treatment in three of the projects and a pass-through chemical treatment facility at the remaining dairy. The details of the individual systems could not be directly input to WAM because of the small scale of the hydraulic features, therefore these projects were represented in WAM as BMP factors for the drainage area being treated by the project. These areas were delineated in a shape file for easy BMP assignment. The BMPs for the land uses within the treatment areas was set to 80% P reduction as predicted by the Dairy BAT report.

5.1.B.6. Public/Private Partnership Project at Davie Dairy

This project involved the treatment of stormwater coming onto the Davie Dairy within the Dairy BAT system described above. This project was represented with WAM by expanding the service area of the Dairy BAT system.

5.1.B.7. Florida Ranchlands Environmental Services Projects

The permit application documentation for all seven of the Florida Ranchlands Environmental Services Projects (FRESP) which fall within the study area were obtained and reviewed for information that would allow the projects to be parameterized within the WAM model. The

FRESP projects, though designed for water storage, are very similar to wetland restoration and stormwater retention systems and therefore are represented in WAM as such. The designs and permit packets for each project were reviewed. Associated drainage basins were delineated based on the permit documents and local hydrography. A shape file/feature class polygon coverage of the area contributing water to the FRESP projects was developed. Using these polygons, a wetland retention system was then associated with its drainage area using maximum depth of storage and relative storage (volume/unit area of drainage area) parameters. The wetland retention parameters were increased for the FRESP storage facilities because they were assumed to become wetland based systems (**Table 5-3**). Descriptions of the individual FRESP Projects follow:

5.1.B.7.1 Williamson Cattle Company

The riser/culvert in the Dynamite Ditch along the north side of Burn-Out Marsh provides 3,700 m^3 of on-site storage and treatment of drainage from approximately 100 hectares of improved pasture land. The culvert is a 48" pipe with a 60" riser. The riser has a fixed weir up to 9.0 m, NGVD and boards up to 9.9 m, NGVD. The culvert/riser discharges to the Williamson Ditch and ultimately to Taylor Creek and Lake Okeechobee.

5.1.B.7.2 Buck Island Ranch

The Buck Island Ranch FRESP Project provides 1,119,000 m^3 of storage and treatment. The source water is the C-41 canal.

5.1.B.7.3 Lykes Brothers – West Water Hole

The project at the Lykes Bros, Inc. West Water Hole Pasture provides 6,200,000 m^3 of regional water storage and treatment of water pumped primarily from C-40 (upstream of S-75). The pump has a 3.8 m^3/second capacity. Water may also be pumped in from a Citrus grove southeast of the detention area. Phosphorus is removed from the detained water by the uptake of plants in the uplands and associated marshes of the detention area. Inflow and outflow water volumes and water quality are recorded. From November to March, the detention area may be maintained at 9.0 m, NGVD. From June through the middle of July the water level is maintained at 8.2 m, NGVD.

5.1.B.7.4 Planned FRESP Projects

The following projects have not been implemented, but they are included in WAM simulations for Scenario 2.

- C.M. Payne & Son: 1,200,000 m^3 of on-site storage from Fisheating Creek
- Lightsey Cattle Company: 167,000 m^3 of on-site storage in the Fisheating Creek Basin
- Syfrett Ranch West: 173,000 m^3 of regional water storage from C-41A

- Rafter T Ranch: 1,400,000 m^3 of on-site storage from Arbuckle Creek

5.1.B.8. Aquatic Based Treatment System (Algal Turf System)

The algal turf system was constructed along upper Taylor Creek (**Figure 5-1**) to remove P through uptake by algae. An estimated drainage area that contributes stormwater to the system was delineated for potential treatment. To date, the performance of the system for P removal has been poor and therefore the project was not included in this assessment. It is shown for informational purposes only.

5.1.C. Scenario 3 - Agricultural and Urban BMPs, Phosphorus Source Control and Regional Projects, and Regional Treatment Systems (RASTAs and STAs)

Three RASTAs and three STAs were added to the WAM model (**Figure 5-3**). Two of the STAs, Taylor Creek and Nubbin Slough have already been designed and constructed. Design is underway for the Lakeside Ranch STA, a component of the Lake Okeechobee and Estuary Restoration (LOER) Program. The Fisheating Creek (FEC) 1 & 2 and Nicodemus Slough RASTAs are in the early planning stages with limited design information.

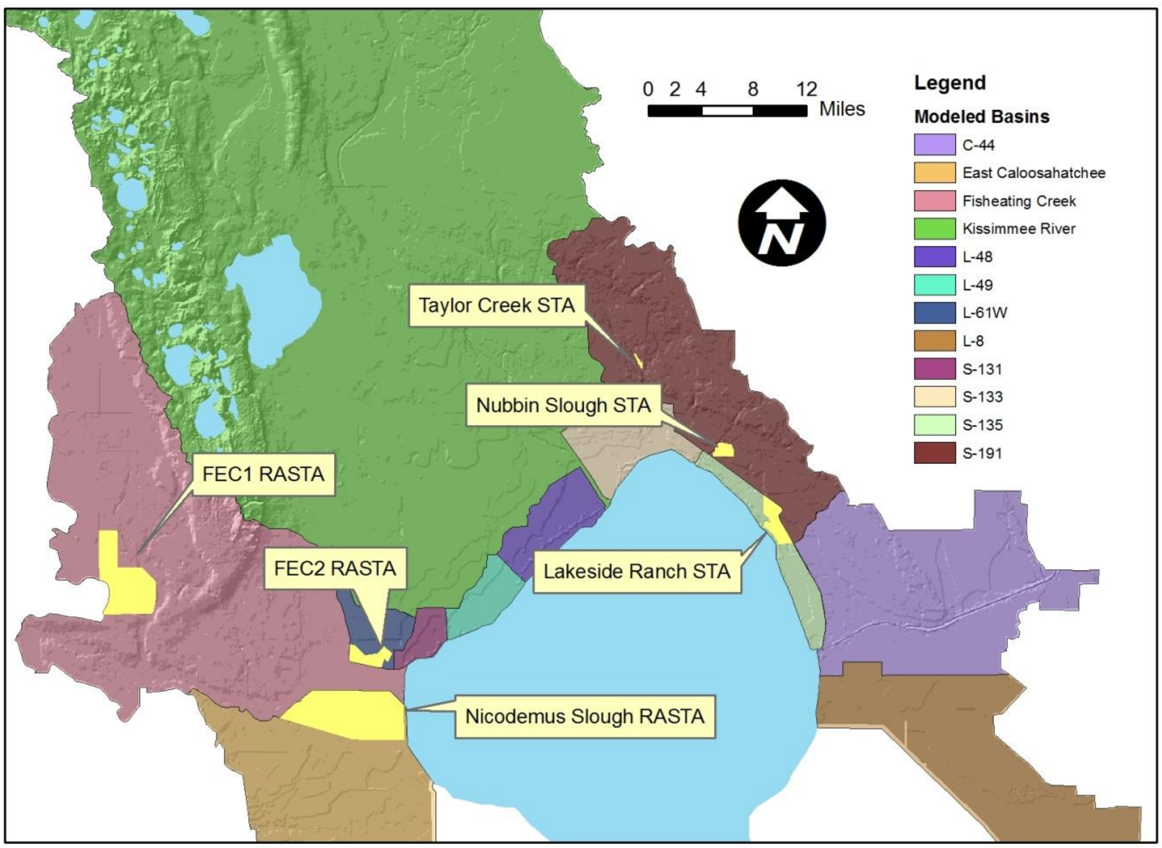

Figure 5-3: STAs and RASTAs Added to the WAM Model as part of Scenario Three Simulation

Although the Lakeside Ranch STA resides in the S-135 Basin, it is intended to treat runoff from S-191, which was modeled separately from S-135. To account for this separation, an additional outlet reach was added to the S-191 basin model's hydrologic network. The inflow pump station for the Lakeside Ranch STA was added to the model and assigned to this reach. The model output for this reach was used as a boundary inflow reach for the S-135 Basin.

Similarly, the FEC2 and Nicodemus Slough RASTAs are intended to treat runoff from Fisheating Creek, but are located in other neighboring basins. Like S-191, additional outlet reaches were added to the Fisheating Creek basin model to be used as boundary inflow reaches to the L-61W and C-43 basin models. The FEC1 RASTA is located further upstream in the Fisheating Creek basin.

The available information regarding future RASTAs is limited. Basic information (size, capacity, and maximum water depths) was obtained from the Lake Okeechobee Construction Project Phase II Technical Plan. For modeling purposes, the inflow was assumed to be spread amongst four equally sized pumps that are turned on in succession based on upstream water levels. The turn on elevations were set six inches apart with the first pump coming on approximately six inches above the normal/average water level of the source canal/stream with the goal of not interfering with the base flows of the source.

The sub-basin boundaries were edited to represent the RASTA levees. The land use was modified to reflect a reservoir (>200 hectares) FLUCCS code of 5300. This code corresponds to the WAM land code of 92 which was intended for this purpose. The evaporation parameter associated with this code was turned off because the evaporation was accounted for in hydrologic reaches designed for RASTAs and STAs.

The reach network for a RASTA consists of a combination of reservoir, slough and seepage reaches, each with their own set of attenuation coefficients. The seepage reach was used to account for the water that seeps through the levees to surrounding streams and canals. Seepage was simulated using a weir that was sized based on an estimated seepage rate and measured levee lengths. The seepage rates determined during model calibration (between Lake Okeechobee and adjacent canals) were used. A separate seepage reach was used, instead of simply adding a weir to a reservoir or slough reach, because of the relatively high attenuation that occurred. Three RASTAs and STAs were included (**Figures 5-4 through 5-9)**.

Figure 5-4: Taylor Creek STA

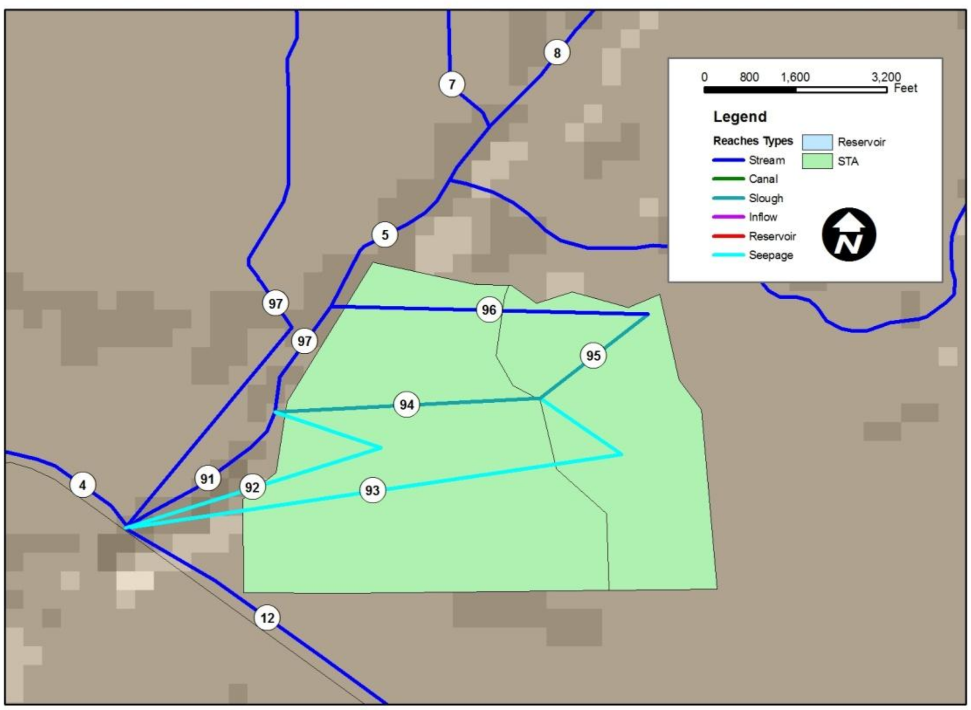

Figure 5-5: Nubbin Slough STA

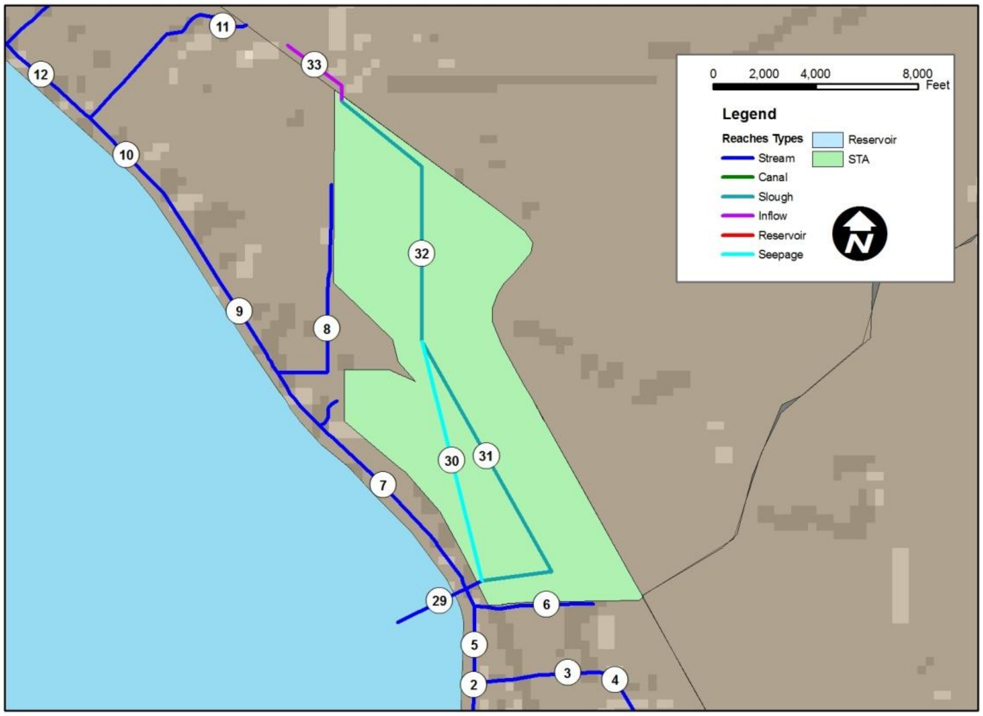

Figure 5-6: Lakeside Ranch STA

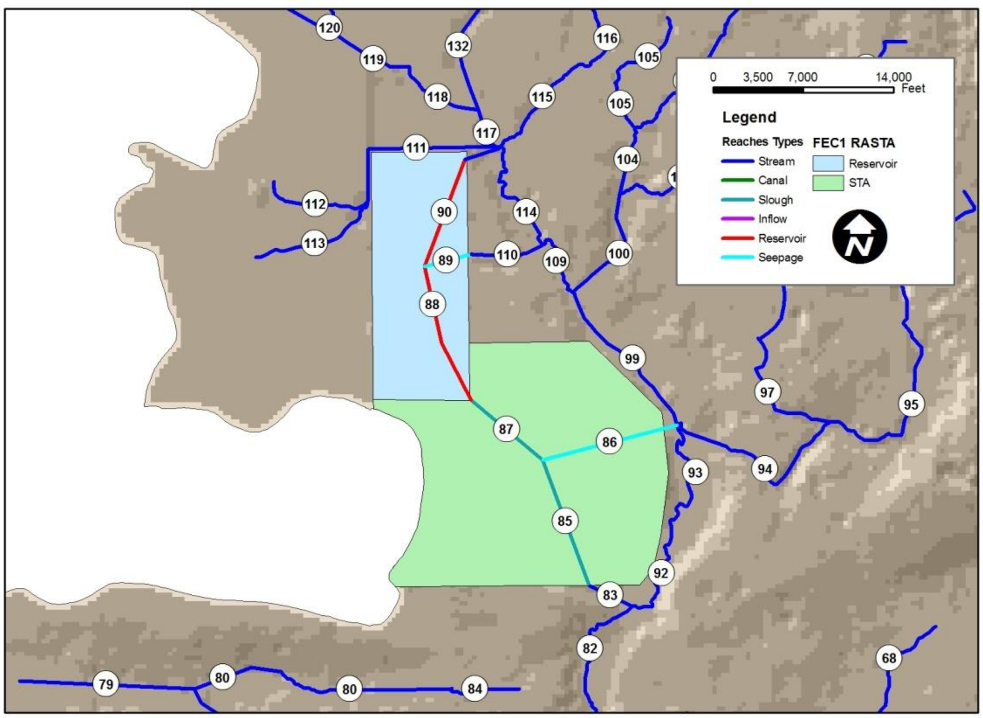

Figure 5-7: Fisheating Creek (FEC) RASTA 1

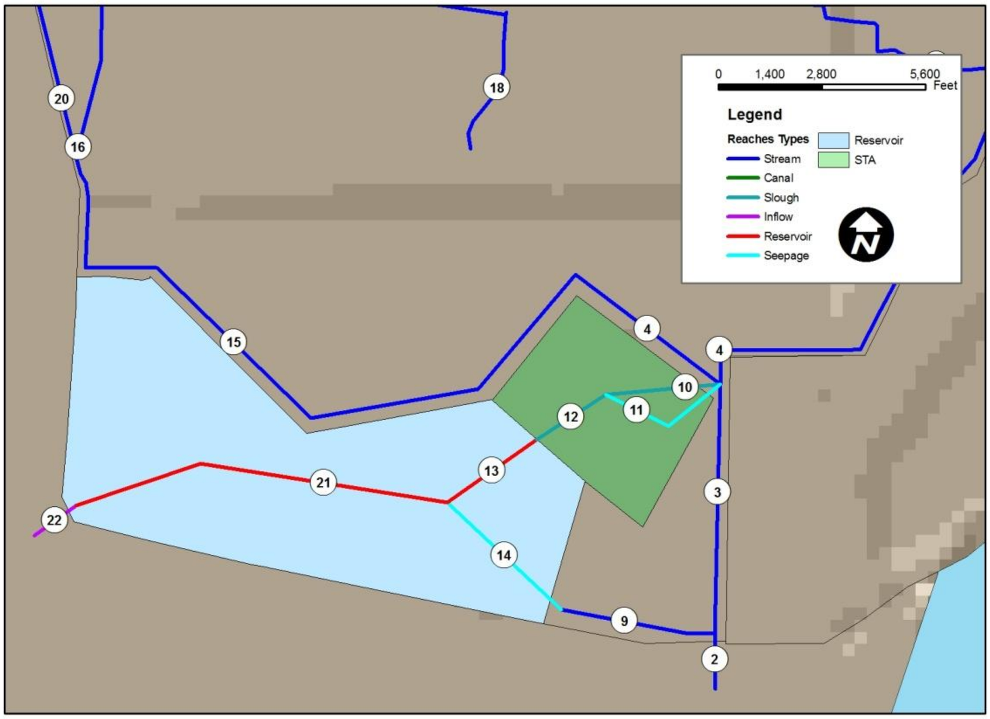

Figure 5-8: Fisheating Creek (FEC) RASTA 2

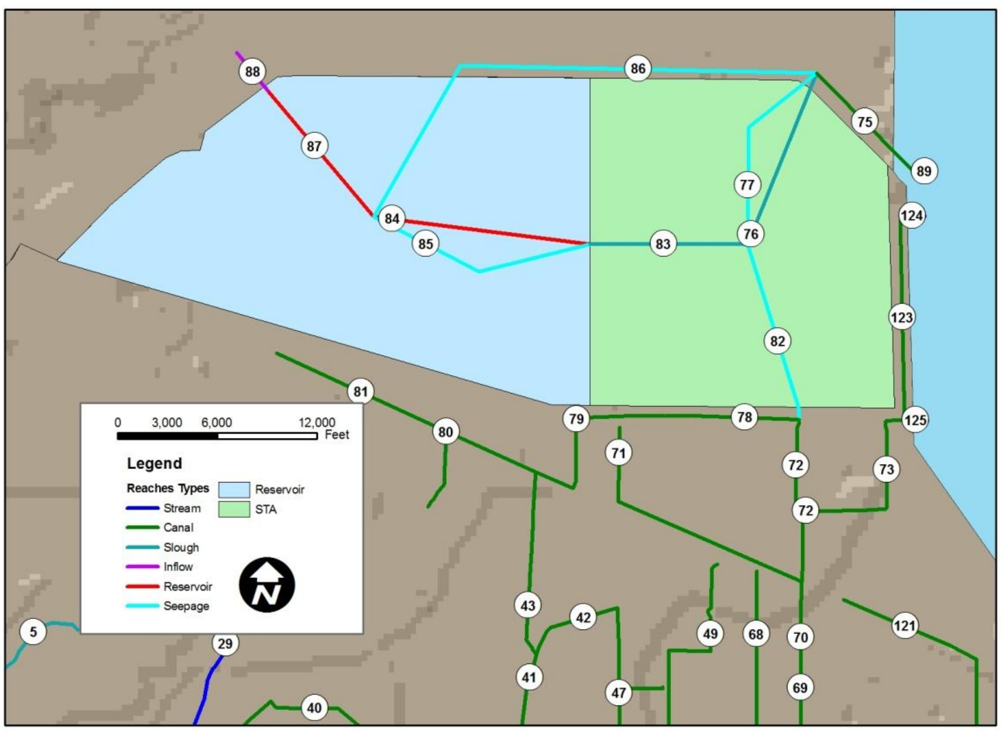

Figure 5-9: Nicodemus Slough RASTA

The reservoirs associated with RASTAs are intended to store large volumes of water (>3 meters above ground). A weir was sized between the reservoir and STA based on the design peak stage and inflow rate. A weir was similarly sized for the outlet of the STA. But since the design stage of an STA was much lower (<1.2 meters above ground), the weir was much longer.

WAM's setup algorithms were rerun with the revised GIS datasets and the model parameter files, boundary.in, structures.in, streams.in and streamprofile.in were edited accordingly before rerunning the basin models.

5.1.C.1. STA Operating Rules

Operating rules for all standalone STAs and STAs attached to reservoirs will be as follows:

- Inflows will be maintained when water is available at the optimum hydraulic loading rate (HLR) between 10 and 14 cm/day (HLR = the flow rate equivalent to HLR (in cm/day) over the area of the STA).
- Inflows should stop when water depths are greater than 1.1 meters
- Maximum water depth will be no greater than 1.2 meters for a period of 2 weeks or less.
- Outflows are based on the following equation
  If depth > .46 meters
  FLOW [m^3/day] = (depth[cm]3.5 * width[km]) / 10,000,000
  else
  FLOW = 0
  Width = average width of the STA flow path

5.2. WAM Simulation Results for Scenarios 1, 2, and 3 as Compared to the Base Run

Three scenarios and the base run were simulated for the period of record from 1998 through 2007 (**Table 5-4).** The scenarios were;

Scenario 1: Only the LOPP BMPs (Bottcher, 2006) were applied across all basins south of the S-65 and S-68 structures at the outlets of Lakes Kissimmee and Lake Istokpoga, respectively.

Scenario 2: Includes the implementation of all of the BMPs simulated in Scenario 1 plus all of the P control projects listed in **Table 5-2**.

Scenario 3: Includes the implementation of Scenarios 1 and 2, plus the regional treatment facilities (STAs and RASTAs) in four basins.

The net nutrient reductions to Lake Okeechobee for the three scenarios as compared to the base run are about 72, 84, and 114 mt of P per year and 1180, 1200, and 1390 mt per year of N across all of the basins, respectively. As expected, the largest P reductions were seen in the S-191 basin with the lower C-38 basins and FEC having the next largest reductions. Estimated reductions, though lower than LOPP estimates, appear to be reasonable. The nitrogen estimates are expected to have greater variability and error than the phosphorus estimates because of less available parameterization and verification data for nitrogen.

Table 5-4: WAM results for Scenarios 1, 2, and 3 compared to the Base Run

Basin	Structure	WAM Reach	Flow				TP Load				TN Load			
			Base Run	Scenarios			Base Run	Scenarios			Base Run	Scenarios		
				1 BMPs	2 1+Projects	3 1&2+STAs		1 BMPs	2 1+Projects	3 1&2+STAs		1 BMPs	2 1+Projects	3 1&2+STAs
			(Mm3/yr)	(Mm3/yr)	(Mm3/yr)	(Mm3/yr)	(mt/yr)	(mt/yr)	(mt/yr)	(mt/yr)	(mt/yr)	(mt/yr)	(mt/yr)	(mt/yr)
To Lake Okeechobee														
C-38	LO*	4,199,308	1900	1700	1700	1700	260	240	230	230	4900	3800	3800	3800
C-43	STA-Nic	89				82				8				52
C-44	SW	2	0.8	0.5	0.5	0.5	0.2	0.1	0.1	0.1	3.2	2.0	2.0	2.0
L-48	S-127	2	13	12	12	12	3.0	2.1	2.1	2.1	27	22	22	22
L-49	S-129	2	14	13	13	13	1.3	0.8	0.8	0.8	27	23	23	23
S-131	S-131	2	11	9.2	9.2	9.2	1.5	1.0	1.0	1.0	14	12	12	12
S-133	S-133	2	24	24.0	24.0	24.0	6.9	4.7	4.3	4.3	45	34	33	33
S-135	S-135	2	28	26	26	43	4.0	2.7	2.7	3	53	47	47	55
S-191	S-191	2	110	95	96	76	73	47	42	23	270	200	200	120
FEC	SR-78	4	282	254	254	128	61	45	44	22	556	516	515	301
L61W		2	10.0	9.8	9.8	49	2.2	1.8	1.8	4.9	19	18	18	59
TOTAL to LO			2400	2200	2200	2200	410	340	330	300	5900	4700	4700	4500
P Reduction			-	10%	10%	11%	-	17%	20%	28%	-	20%	20%	24%
Not To Lake Okeechobee														
C-43	S-78	2	1200	1100	1100	1200	160	140	140	140	2200	2100	2100	2100
C-44	S-80	5	540	530	530	530	120	110	110	110	1300	1200	1200	1200
L-8	L-8 @ C-51	3	100	99	99	99	23	20	20	20	210	190	190	190
	WPB PS2	49	44	44	44	44	7.5	7.2	7.2	7.2	87	86	86	86
TOTAL not to LO			1900	1800	1800	1900	300	270	270	270	3900	3500	3600	3600
P Reduction			-	2%	2%	-1%	-	9%	9%	8%	-	8%	7%	7%
TOTAL ALL BASINS			**4300**	**4000**	**4000**	**4000**	**710**	**620**	**600**	**580**	**9800**	**8300**	**8300**	**8100**
P Reduction			**-**	**7%**	**7%**	**6%**	**-**	**14%**	**16%**	**19%**	**-**	**15%**	**15%**	**17%**

* The C38 outflows to Lake Okeechobee includes C38, C40, and C41

Table 5-5 provides a comparison of P load reductions estimated in the Lake Okeechobee Construction Project Phase II Technical Plan (P2TP) with those estimated through WAM simulations of Scenarios 1 and 2. The following factors should be considered when comparing these estimates:

- The WAM simulations and the P2TP estimates do not include P reductions to Lake Okeechobee associated with BMPs implemented north of Lakes Kissimmee and Istokpoga.
- The EAA was not simulated with WAM.
- The S-154 Basin is included in the C-38 Basin in WAM and in the Taylor Creek Nubbin Slough Sub-watershed in the P2TP.
- The C-44 basin was simulated in WAM as having all flow going east through the S-80 structure, while P2TP had about 25% of this basin's (East Lake Okeechobee) flow going back into the Lake Okeechobee, which was accounted for by assuming 25% of WAM predicted P reduction through S-80 would represent P reductions to the lake.
- The P2TP estimates were based on a 1991 – 2005 period of record while the WAM simulations used a 1998 – 2007 period of record.
- BMPs in the Lower Kissimmee Basin are buffered by the effects of the Kissimmee River Restoration. This is reflected in the WAM results and is a partial explanation for why the WAM predicted P load reduction is less than the P2TP estimates.
- WAM accounted for the impacts of stream assimilation on the differential load reductions while the P2TP did not.

While these factors limit direct comparisons at the sub-watershed level between the two analyses, the total P loads to Lake Okeechobee should be comparable. As seen in Table 5-5, WAM is predicting about 36% and 38% less total P load reductions than P2TP for scenarios 1 and 2, respectively. The primary reason for the differences is believed to be the fact that the interrelationship between the assimilation processes and predicted source cell BMP load reductions are dynamically simulated within WAM where as P2TP assumed the source cell BMP percentage reductions would carry through to the lake, which is not the case. The cleaner water from BMPs will reduce the assimilation rates of P within the conveyance systems. Being able to represent these dynamic assimilation processes is the major advantage of WAM over the P2TP estimates. This, in combination with WAM's ability to dynamically represent the interrelationship of the BMPs and the P Control projects means the WAM model simulations can provide a better spatial depiction of the sources and transport processes (assimilation) thereby providing a more realistic picture of the interrelationship between the various abatement strategies. This expanded knowledge should allow for additional refinement to the nutrient abatement strategies within the Lake Okeechobee Watershed to minimize adverse impacts on Lake Okeechobee.

Table 5-5: Comparison of P load reductions (mt/yr) estimated in the Lake Okeechobee Construction Project Phase II Technical Plan (P2TP) and by WAM simulations.

Sub-watershed/region	P2TP		WAM	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Taylor Creek/Nubbin Slough (S-191, S154*, S-133, S-135)	39	58	30	35
Lower Kissimmee, Indian Prairie Basin (C-38, S-131, L-61W, L-48, L-49)	52	65	22	32
Fisheating Creek	12	12	16	17
West Lake Okeechobee	0	0	0	0
EAA Basins	2	2		
East Lake Okeechobee	4	4	2	2
Total	110	140	70	86

6.0 Current Model Limitations

All models have limitations for representing reality that need to be well understood to prevent inappropriate use of modeling results. The WAM is no exception and therefore this section will attempt to highlight limitations of WAM and how they may impact its utility. In general, models are limited by the availability and quality of the input data and secondly by the completeness and accuracy of the underlying algorithms within the model that attempt to represent the physical processes within the watershed.

Input data limitations are associated with the accuracy and availability of watershed characterization parameters, as well as weather forcing parameters. Any errors or omissions in these datasets will carry through the model simulations and therefore must be carefully assessed prior to running the model. For the Okeechobee watershed, the ability of WAM to predict water and nutrient transport was most influenced by the accuracy of the rainfall data and the land use characterization data. As pointed out in Section 4, the use of one rainfall station over another within the Fisheating Creek basin could account for as much as 50% variability in the predicted flows and nutrient loads. Though this is a major problem when trying to match observed flows, it is not as large a concern when the model is being used for scenario testing, i.e. determining relative impacts of management activities within the watershed.

The relative importance of other weather and soil and land use parameters vary considerably and can only be assessed through comprehensive sensitivity analyses. Such an analysis was performed when the WAM model was developed. **Table 6-1** provides the relative sensitivity of the more important WAM parameters. Again, the accuracy of these parameters is more critical for matching observed conditions than for doing a relative comparison of scenarios.

Table 6-1: Relative Sensitivity of Selected Parameters on WAM Predicted Outputs

WAM PARAMETER	RELATIVE SENSITIVITY
Weather	
Rainfall	Very High
Solar	High
Wind	Low
Temperature	Low
Soil	
Hyd. Conductivity	Medium
Organic Matter	Medium
Water Table Response Curve	Medium
Hydrologic Soil Group	High
Available Moist. Capacity	Medium
Land Use	
NRCS Curve #	High
Crop ET Coefficient	High
Nutrient Uptake Rates	Medium
Fertilizer Rates	High
Drainage and Irrigation	High
Plant/Harvest Dates	Low
Irrigation Source	Low

Though the algorithms within WAM attempt to represent the most critical processes for predicting flow and nutrient transport, these algorithms are often only a partial representation of the highly complex processes within the soil/plant environment and flow conveyance systems, thus introducing prediction errors. The simplified algorithms are required due to both our limited knowledge of the processes and the lack of available data to parameterize more complex process relationships. However, the general ability of WAM to predict both surface and groundwater flow and nutrient transport based on soil, land use, hydrography, and weather conditions is quite robust, but does have process based limitations. A few of the more important ones are listed below:

1. Temporal changes in land use are not addressed without multiple runs.
2. Only monthly average solar, wind, and temperature data are allowed and cannot be spatially varied across watershed.
3. Some site specific practices, such as fencing and feed/water placement, are not handled physically, so must be represented with constant BMP factors.
4. The hydrodynamic reach routing algorithm assumes reaches are linear reservoirs, i.e. two dimensional horizontal flow is not handled.
5. Dynamic interaction between reaches and regional groundwater is limited to a simple leakage relationship.
6. Assimilation processes for nutrients within flow conveyance reaches are limited to an exponential decay relationship.
7. Rainfall is input as a daily parameter so within storm responses, on an hourly time scale, it is not well represented.

8. EAAMOD (high water table land source sub-model) is currently limited to agricultural land uses and therefore, native forest and brush lands are simulated with GLEAMS, which tends to over predict groundwater recharge for Flatwood soils. The GLEAMS soil conductivity parameters were adjusted to partially compensate.
9. Wetlands are modeled using a relatively simple water balance model that does not have seasonal adjustments for other weather variations.

The reader is advised to review the Technical Manuals for the WAM model to gain a complete understanding of the data requirements and the flow and nutrient processes within WAM.

7.0 Recommendations & Conclusions

The WAM modeling results are in general agreement with the P reductions that were estimated by CERP and LOPP. However, the spatial and temporal benefits of the three primary P abatement strategies have been better characterized by the WAM modeling process. The first P abatement strategy evaluated was the implementation of BMPs (Scenario 1 in Section 5) across the Okeechobee watershed. BMPs were found to be the most cost effective approach for initial P load reductions, but are limited as to the level of net P reductions that could be achieved. Across all basins it was predicted that roughly a 17% P reduction could be achieved by implementing the owner/cost share based BMP program. However, for the more intensively farmed basins, such S-191 and the near-Lake basins, BMPs produced higher P reductions ranging from 30% to 35%. BMPs are clearly cost effective, but will not on their own meet the Lake Okeechobee or the northern Lake Okeechobee tributary TMDL targets. More intensive BMP programs for the watershed might be considered, but the relative cost effectiveness of intensive BMPs should be compared with other approaches.

The second P abatement strategy evaluated was the implementation of a variety of P source control practices (Scenario 2 in Section 5), such as Phosphorus Source Control Grants, Hybrid Wetland Treatment Technologies, Isolated Wetlands, Former Dairy Remediation, Public/Private Partnerships, and FRESP. The existing and proposed projects were simulated and found to provide limited P reductions (~3%) across the watershed. However, these projects were only applied at relatively small scales and therefore, the low P reductions on a watershed-scale may not be reflective of their potential. It is anticipated that if the more cost effective P control technologies, such as chemical treatment, are broadly implemented, significant additional P reductions can be achieved. These practices will be particularly beneficial if targeted to the high P source land uses, such as dairy, vegetables, ornamentals, intensive calf cow, and citrus operations that do not currently have retention.

The final P abatement strategy evaluated was the implementation of the reservoir assisted stormwater treatment areas (RASTAs) (Scenario 3 in Section 5). Though RASTAs were simulated for the S-191 and Fisheating Creek Sub-watersheds, they provided about an 8% P reduction across the entire northern Okeechobee watershed. The STAs within the S-191 basin provided about a 19 mt/yr P reduction or about a 26% P reduction from the base run - about a 47% additional P reduction after the BMPs and P Control practices had been implemented. The STAs in the Fisheating Creek basin were not as efficient due to the lower P inflow concentrations, but still provided about an 11 mt/yr P reduction or about an 18% P reduction from the base run - about a 25% additional P reduction after the BMPs and P Control practices had been implemented.

The conclusion from these assessments is that all three of the P abatement strategies will be needed to achieve the P reduction goals for the northern Lake Okeechobee watershed. From a Lake Okeechobee perspective, the BMPs and P Control projects should be focused south of Lake Istokpoga and Lake Kissimmee because of the buffering effects of these lakes. The STAs should be placed as close to Lake Okeechobee as possible and on tributaries with the highest P concentrations. Proximity to the Lake is important to minimize desorption of legacy P from wetlands and streams between the STA and the Lake.

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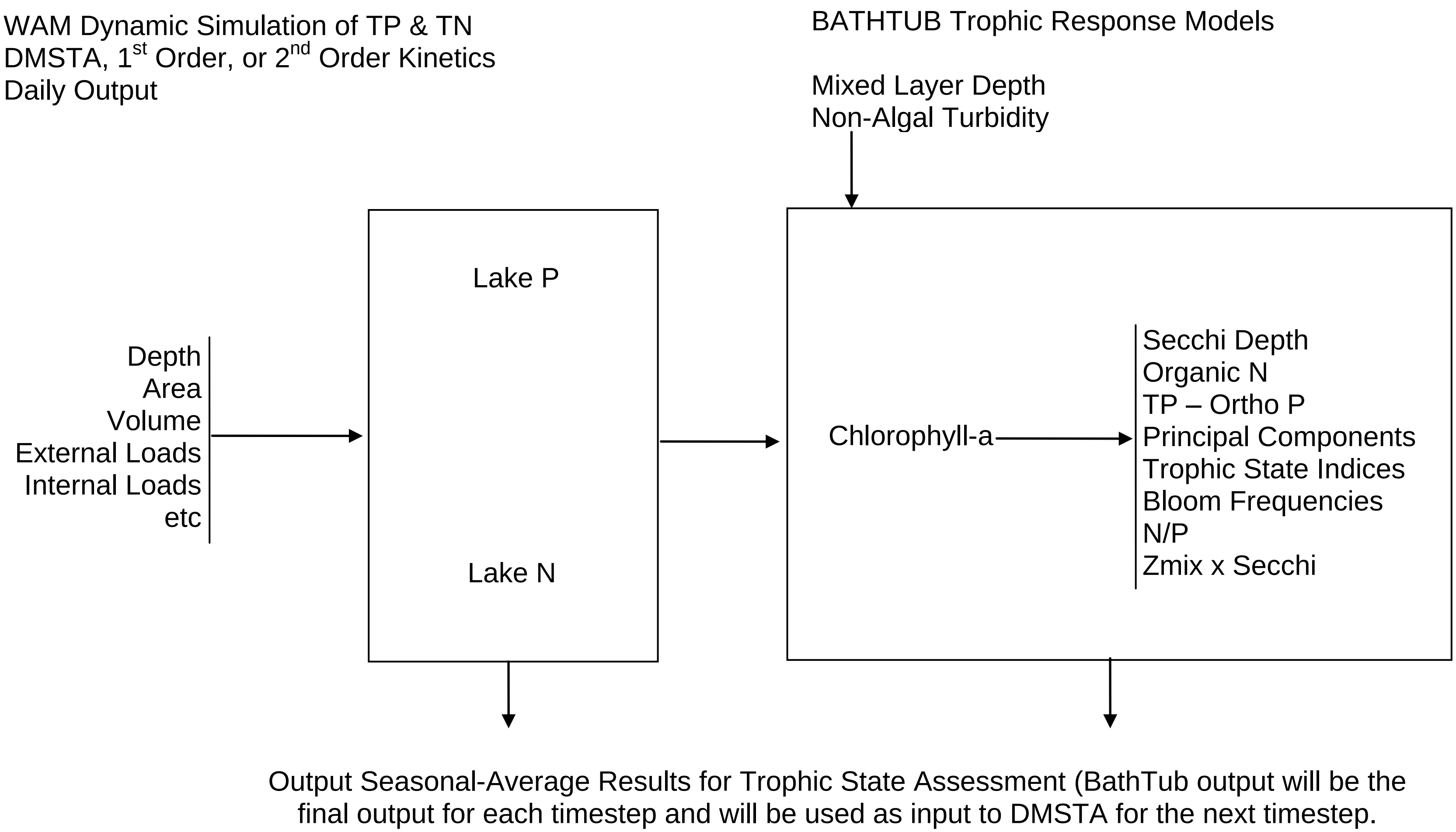
APPENDIX A: Data

APPENDIX B: Large Lake Nutrient Assimilation Enhancement

Appendix B-1

Water Quality Module for WAM – Model Linkage



Info: http://www.wwwalker.net/dmsta

DMSTA2 Phosphorus Cycling Model 03/

Appendix B- 2

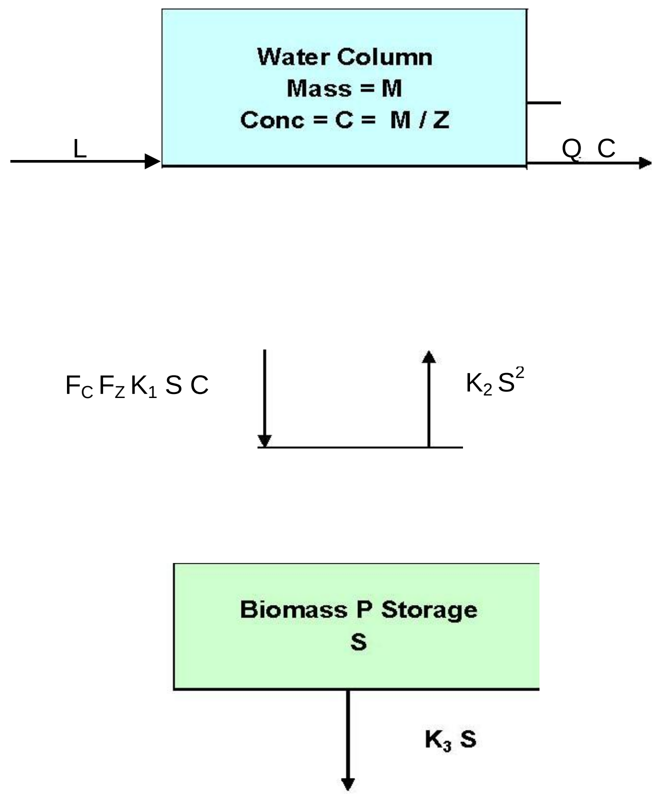
One CSTR at Steady-State

Unit Area Storage & Fluxes

Concs in mg/m^3

Fluxes in mg/m^2-yr

Storage in mg/m^2



F_Z = Depth Multiplier

F_C = Conc Multiplier

State Variables:

M	Water Column P Storage	mg/m^2
S	Temporary P Storage in Biota	mg/m^2
Z	Water Column Mean Depth	m

Driving Variables:

L	P Load, Including Atmos. Deposition	mg/m2-yr
Q	Outflow	m/yr

Parameter Values:

K1	Maximum Uptake Rate	m3/mg-yr
K2	Recycle Rate	m2/mg-yr
K3	Burial Rate	1/yr

Steady-State Mass Balances 1 CSTR, FZ = 1, & $C \ll C2$:

Storage:	$K1\ C = K2\ S + K3$
Overall:	$L - Q\ C = K3\ S$
Solution for C:	$C = (K2\ L + K3) / (K3\ K1 + Q\ K2)$
Solution for S:	$S = (K1\ C - K3) / K2$

For Parameter-Estimation Purposes, Model Coefficients Are Re-expressed as Follows:

K	Net Settling Rate at Steady State	m/yr	Fit to Concentration Time Series Data
C0	Water Column Conc at S = 0 mg/m2	ppb	Fit to Storage vs. Conc Correlations
C1	WC Conc at S = 1000 mg/m2	ppb	Fit to Storage vs. Conc Correlations

Transformation of Parameter Sets:

$K = K1\ K3 / K2$ $K3 = K\ (C1 - C0) / 1000$

$C0 = K3 / K1$ $K1 = K3 / C0$

$C1 = (1000\ K2 + K3) / K1$ $K2 = K3\ K1 / K$

Calibrations:

EMERG emergent marsh (cattail etc.) on previously farmed or otherwise disturbed soils

PEW preexistent wetlend; former wetland with vegetation established prior to construction; calcitic waters

SAV cell managed for SAV or other favorable community; calcitic waters

PSTA periphyton treatment area (peat removed or capped)

RESERV lake or reservoir, generally depths > 150 cm

Calibrations:

EMERG emergent marsh (cattail etc.) on previously farmed or otherwise disturbed soils

PEW preexistent wetlend; former wetland with vegetation established prior to construction; calcitic waters

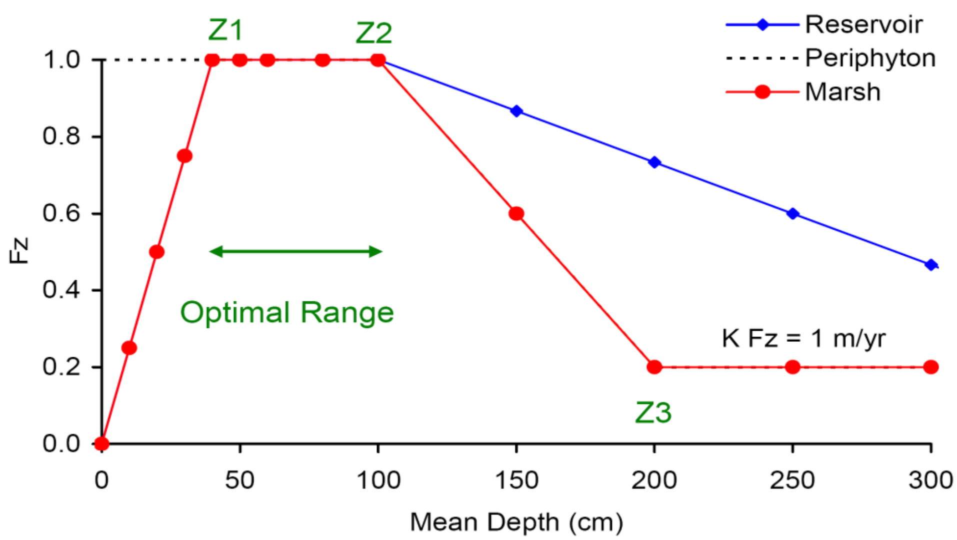
SAV cell managed for SAV or other favorable community; calcitic waters

PSTA periphyton treatment area (peat removed or capped)

RESERV lake or reservoir, generally depths > 150 cm

Parameter			EMG 3	PEW 3	SAV 3	PSTA 3
C0	WC Conc at 0 g/m2	ppb	3	3	3	3
C1	WC Conc at 1 g/m2	ppb	22	22	22	22
C2	Half-Saturation Conc	ppb	300	300	300	300
K	Net Settling Rate at	m/yr	16.8	34.9	52.5	23.6
Z1	Depth at Maximum	cm	40	40	40	0
Z2	Transition Depth	cm	100	100	100	100
Z3	Depth at Minimum	cm	200	200	200	200
FZ3	Relative Uptake Rate	-	0.2	0.2	0.2	0.2
K1	Uptake Rate	m^3/mg-	0.1064	0.2210	0.3325	0.1495
K2	Recycle Rate	m^2/mg-	0.0020	0.0042	0.0063	0.0028
K3	Burial Rate	1/yr	0.3192	0.6631	0.9975	0.4484

Depth Effects on Gross Uptake Rate:

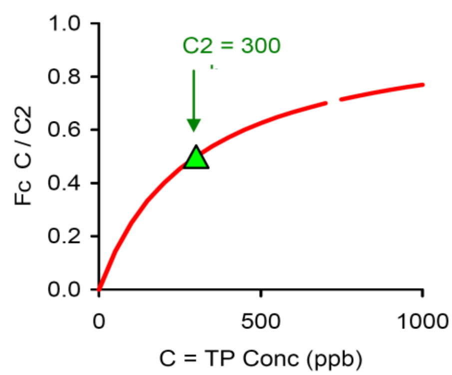


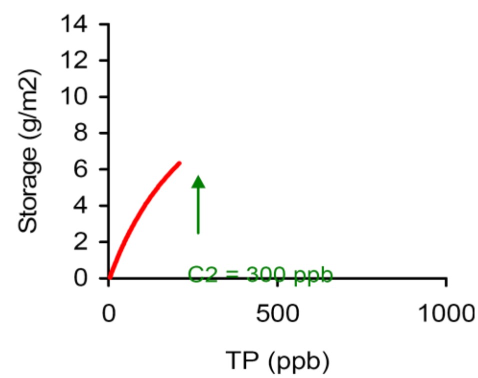
Depth		Marsh	PSTA	Reservoir	Time Scale
Z1	Lower End of Optimal Depth	40	0	40	Daily
Z2	Upper End of Optimal Depth	100	100	100	30-day
Z3	Depth at Minimum Uptake Rate	200	200	400	30-day

Values identical for each marsh calibration (EMG_3, PEW_3, SAV_3)
Parameters inferred from STA operating experience & calibration to time series.
Performance increases between 0 and Z1 (topographic effects, effective treatment area, short-circuiting)
Marsh performance starts to deteriorate at 30-day mean depth > Z2 (uprooting, light-limitation, short-circuiting, etc.)
Reservoir performance starts to deteriorate at depths > Z2 (stratification/anoxia, turbulence, light

limitation)
Between Z2 and Z3 all calibrations converge to K x Fz = 1 m/yr (K1, K2, K3 adjusted accordingly)
Above Z3, the product of K and Fz is constrained to 1 m/yr (typical of deep reservoirs)
Depth effects ignored if input Z1-Z3 values = 0

Concentration Effect on Gross Uptake Rate:





Fc = C2 / (C + C2)
Uptake = K1 S [C / (C + C2)] = K1 S [Fc C / C2]
C2 = half-saturation constant for P uptake = 300 ppb
= water column conc at 1/2 maximum storage, steady state, optimal depth
Reflects saturation of uptake rate at high concentrations
Transition from first-order to zero-order dependence on concentration
Calibrated to marsh datasets in high concentration range
Not applied to reservoirs (Fc = 1)

Info: http://www.wwwalker.net/bathtub

Appendix B-3

BATHTUB Trophic Response Models

Note: All of these models were calibrated to predict seasonal-average values (May-Sept); Daily values provided by WAM should be averaged over growing season for trophic state assessment.

Chlorophyll-a Models

			Applicability Constraints			
Option	**Description / Limiting Factors**	**Equations**	**a**	**(N150)/P**	**Ninorg/ Portho**	**Fs**
1	P, N, Light, Flushing	*Xpn = [P -2 + ((N-150)/12) -2] -0.5* *Bx = Xpn 1.33 / 4.31* *G = Zmix (0.14 + 0.0039 Fs)* *B = K Bx /[(1 + b Bx G) (1 + Ga)]*				
2	P, Light, Flushing [default]	*Bp = P 1.37 /4.88* *G = Zmix (0.19 + 0.0042 Fs)* *B = K Bp / [(1 + b Bp G) (1 + Ga)]*		*>12*	*>7*	17.0
3	P, N, Low Turbidity	*B = K 0.2 Xpn 1.25*	*<0.9*	18.0	19.0	*<25*
4	P, Linear	B = K 0.28 P	<0.9	>12	>7	<25
5	P, Exponential, Jones & Bachman (1976)	B = K 0.081 P 1.46	<.4	>12	>7	<25
6	P, Carlson TSI (1977), Lakes	B = K 0.087 P 1.45	<0.4	>12	>7	<25

Secchi Models

			Applicability Constraints	
Option	**Description**	**Equations**	**(N-150)/P**	**Ninorg/ Portho**
1	Secchi vs. Chl a and Turbidity [default]	*S = K / (a + b B)*		
2	Secchi vs. Composite Nutrient	*S = K 16.2 Xpn -0.79*		
3	Secchi vs. Total P, CE Reservoirs	*S = K 17.8 P -0.76*	>12	>7
4	Carlson TSI (1977) , Lakes	*S = K 48 / P*	*>12*	*>7*

Supplementary Response Models

Variable	**Equations**
Organic Nitrogen	***Norg = K (157 + 22.8 B + 75.3 a)***
Total P - Ortho P	***P - Portho = K Maximum [-4.1 + 1.78 B + 23.7 a , 1]***

Principal Components	$PC\text{-}1 = 1.47 + 0.949 \log(B) - 0.932 \log(S)$ $PC\text{-}2 = 0.13 + 0.673 \log(B) + 0.779 \log(S)$
Trophic State Indices (Carlson 1977)	$TSIp = 4.15 + 14.42 \ln(P)$ $TSIc = 30.6 + 9.84 \ln(B)$ $TSIs = 60.0 - 14.41 \ln(S)$
Algal Bloom Frequencies (Walker 1984) **Percent of time during growing season that Chl-a exceeds bloom criteria of 10, 20, 30, 40, 50, or 60 ppb.**	*Calculated from Mean Chl-a (B) assuming that temporal variations in chl-aare represented by a log-normal frequency distribution with a coefficient of variation = 0.62 (user-adjustable via the Model Coefficients< /A > screen)*
Non-Algal Turbidity (User Input)	*a = 1/S - b B (minimum value = 0.08 1/m)*
Mean Depth of Mixed Layer	*Applied to observed S and B values in each segment if non-algal turbidity values are not input directly (=0) on the Edit Segments screen. The parameter b (default = 0.025) is entered on the Model Coefficients screen.*
	$\log(Zmix) = -0.06 + 1.36 \log(Z) - 0.47 [\log(Z)]^2$ ($R^2 = 0.93$, $SE^2 = 0.0026$) *Constraint: Zmix <= Z Used to estimate Zmix value for each segment if not input directly*

Symbols

a	**Non-Algal Turbidity (m-1) = 1/S - b B , minimum value = 0.08 1/m]**
b	**Algal Light Extinction Coef = Slope of 1/Secchi vs. Chl-a [default = 0.025 1/m]**
B	**Chlorophyll a Concentration (mg/m3)**
Bp	**Phosphorus-Potential Chlorophyll a Concentration**
Bx	**Nutrient-Potential Chlorophyll a Concentration**
Fs	**Summer Flushing Rate = (Outflow /Volume (year-1))**
G	**Kinetic Factor Used in Chlorophyll a Model**
K	**User-Specified Calibration Factor (Normally = 1.0)**
N	**Reservoir Total Nitrogen Concentration (mg/m3)**
Norg	**Organic Nitrogen Concentration (mg/m3)**
P	**Total Phosphorus Concentration (mg/m3)**
PC-1	**First Principal Component of Trophic Response**
PC-2	**Second Principal Component of Trophic Response**
S	**Secchi Depth (m)**
T	**Hydraulic Residence Time (years)**
TSIp	**Carlson Trophic State Index (Phosphorus)**
TSIc	**Carlson Trophic State Index (Chlorophyll a)**
TSIs	**Carlson Trophic State Index (Transparency)**
Xpn	**Composite Nutrient Concentration (mg/m3)**
Z	**Total Depth (m)**
Zmix	**Mean Depth of Mixed Layer (m)**

Input Values for WAM Water Quality Simulation

Attachment 4

* BATHTUB tropic response models originally calibrated to seasonal averages; see BATHTUB_equations sheet
See Calibration Sheet for typical coefficient values.
See VBA Code for equations…

Variable	Units	Example Input	Comments	Suggested Mean	Default Values fo Florida Lakes Ra
Case Name					
POINSETT					
Initial Conditions			Results should be insensitive to these		
Initial Depth	m	1.00	supplied by WAM		
P Storage	mg/m2	0	for DMSTA P Model, if=0 will be estimated		
Initial TP Conc	mg/m3	50			
Initial TN Conc	mg/m3	1000			
Rate Coefficients for Nitrogen					
First-Order Settling Rate	m/yr	1.5		1.5	0.1 - 8
First-Order Volumetric Loss	1/yr				
Second-Order Loss	m3/mg-yr				
Sediment Release	mg/m2-day		Site-specific calibration		
Rate Coefficients for Phosphorus					
First-Order Settling Rate	m/yr				
First-Order Volumetric Loss	1/yr				
Second-Order Loss	m3/mg-yr				
Sediment Release	mg/m2-day		Site-specific calibration		
DMSTA Parameters for Phosphorus					
C0 = WC Conc at 0 g/m2 P Storage	ppb	3		3	
C1 = WC Conc at 1 g/m2 P storage	ppb	150		150	
C2 = WC Conc at Half-Max Uptake	ppb	0		0	
K = Net Settling Rate at Steady State	m/yr	5.0		5.0	3 - 9
Kmin = Settling Rate above Penalty Depth	m/yr	1		1	
Z1 = Lower Optimal Depth	m	40		40	
Z2 = Upper Optimal Depth	m	100		100	
Z3 = Upper Penalty Depth	m	400		400	
BATHTUB Trophic Response Parameters *			**S** BATHTUB Documentation		
Default Mixed Layer Depth		0	= 0, will be estimated from mean depth	0 <= Mean Depth	
Non-Algal Turbidity	1/m	0.7	from 1/Secchi vs. chla regression	0.7	2-1.2
Chla Light Extinction	m2/mg	0.02	from 1/Secchi vs. chla regression	0.02	.01-.03
Chla Coef of Variation		0.5	for computing bloom frequencies	0.5	.4 - .6
Chla Calibration Factor		1	modifies value predicted by BATHTUB equation	1	.5 - 2
Chla Flushing Term		1	modifies value predicted by BATHTUB equation	1	0-1
Secchi Calibration Factor		1	modifies value predicted by BATHTUB equation	1	.5 – 2
Organic N Calibration Factor		1	modifies value predicted by BATHTUB equation	1	.5 - 2
TP-OP Calibration Factor		1	modifies value predicted by BATHTUB equation	1	.5 – 2
Chla Model Number		2	See BATHTUB Documentation	2	1-6
Secchi Model Number		1	See BATHTUB Documentation	1	1-4
Growing Seas Start	month	5	for computation of seasonal-average results	5	1-12
Growing Seas Stop	month	9	for computation of seasonal-average results	9	1-12

Alternative Calibrations

Attachment 5

Number	Units	DEFAULT*	1	2	3	4	5	6	7	8
Water Body Type		Lake	Marsh	Lake	Lake	Lake	Lake	Lake	Lake	Lake
Calibration Source		2,8	DMSTA	DMSTA	DMSTA	DMSTA	Istokpoga	COE Res	COE Res	FL Lakes
Model Formulation			EMG_3	RES_3	1st Order	2nd Order	1st Order	1st Order	2nd Order	EPA/NES
Region		FL	FL	FL	FL	FL	FL	US	US	FL
Reference		B,E	A	A,B	B	B	C	D	D	E
Dynamic Simulation Tested *		P ONLY	YES	YES	YES	YES	YES	NO	NO	NO
Total Nitrogen Cycle										
Settling Rate	m/yr	1.5	N/A					12		1.5
Range		0.1 - 8.0	N/A					4 - 54		0.1 - 8
2nd Order	mg/m3-yr		N/A						0.0016	0.00100
Range **			N/A						.0006-.005	.0002 - .004
Total Phosphorus Cycle										
Settling Rate	m/yr		N/A		3.2		3.5	13		3
Range **			N/A		1 - 20			4 - 46		1 - 12
2nd Order	mg/m3-yr		N/A			0.024			0.040	0.025
Range **			N/A			.01-.15			.01-.5	.01 - .08
DMSTA P Cycle Parameters										
C0 = Conc at 0 g/m2 P Storage	ppb	3	3	3						
C1 = Conc at 1 g/m2 P storage	ppb	150	22	150						
C2 = Conc at Half-Max Uptake	ppb		300							
K = Net Settling Rate	m/yr	5.0	16.8	5.0						
Range **	m/yr	3 - 9	13 - 22	3 - 9						
Z1 = Saturated Uptake Depth	cm	40	40	40						
Z2 = Lower Penalty Depth	cm	100	100	100						
Z3 = Upper Penalty Depth	cm	400	200	400						
BATHTUB Light Extinction Coefs.										
Non-Algal Turbidity	1/m	0.7	N/A					0.6	0.6	0.7
Range **		0.2 - 1.2	N/A					.2 -2.0	.2 -2.0	0.2 - 1.2
Algal Light Extinction	m2/mg	0.02	N/A					0.025	0.025	0.02
Range **		.01 - .03	N/A					.01-.03	.01-.03	.01 -.03
Calibration Dataset Range**										
Min Depth	cm	90	35	90	90	90	170	150	150	90
Max Depth	cm	304	76	304	304	304	170	5900	5900	450
Min Hydraulic Load	m/yr	1.3	4	1.3	1.3	1.3	3.5	4	4	0.6
Max Hydraulic Load	m/yr	230	27	230	230	230	3.5	400	400	65
Min Outflow N Conc	ppb							240	240	530
Max INflow N Conc	ppb							8300	8300	1800
Min Outflow P Conc	ppb	50	20	50	50	50	60	10	10	17
Max Inflow P Conc	ppb	1165.0	800	1165.0	1165	1165	82	447	447	1900
Min Freq Z < 10 cm	%	0.00	0.00	0.00	0.0	0.0	0	0	0	0
Max Freq Z < 10 cm	%	0.00	0.09	0.00	0.0	0.0	0	0	0	0

* Recommended default values for WAM simulations of Florida Lakes
P Cycle parameters based upon DMSTA RES_3 calib. (Col 2); DMSTA First-Order Calibration (Col 3) could be used as an alternative; calibrated to dynamic simulations
N Cycle & Light Extinction parameters bBased EPA/NES Data (Col 8); calibrated to steady-state model only; not tested in dynamic simulation
All coefficients can be re-calibrated by user to site-specific data, if available.

** YES= Calibrated to time-variable simulation; NO = Calibrated to seasonal or annual averages only.

*** Ranges of Mean Values for Different Calibration Datasets (i.e. not dynamic range)

Ref	Model	Description	Link
A	DMSTA2	Florida Emergent Marsh	http://www.wwwalker.net/dmsta/calibration.htm#results
B	DMSTA2	Florida Shallow Lakes	http://www.wwwalker.net/dmsta/reservoirs/testing/ssmodel_nes.htm
B	DMSTA2	Florida Shallow Lakes	http://www.wwwalker.net/dmsta/reservoirs/index.htm
C	Walker & Havens, 2003	Lake Istokpoga	http://www.wwwalker.net/pdf/istokpoga_2003.pdf
D	BATHTUB	COE Reservoirs, Nationwide	http://www.wwwalker.net/bathtub/index.htm
E	EPA Database	EPA National Eutrophic Survey, Florida Lakes	http://www.wwwalker.net/dmsta/reservoirs/index.htm

APPENDIX C: Land Use, Soils, Drainage Basin, Topography and Model Reaches Maps

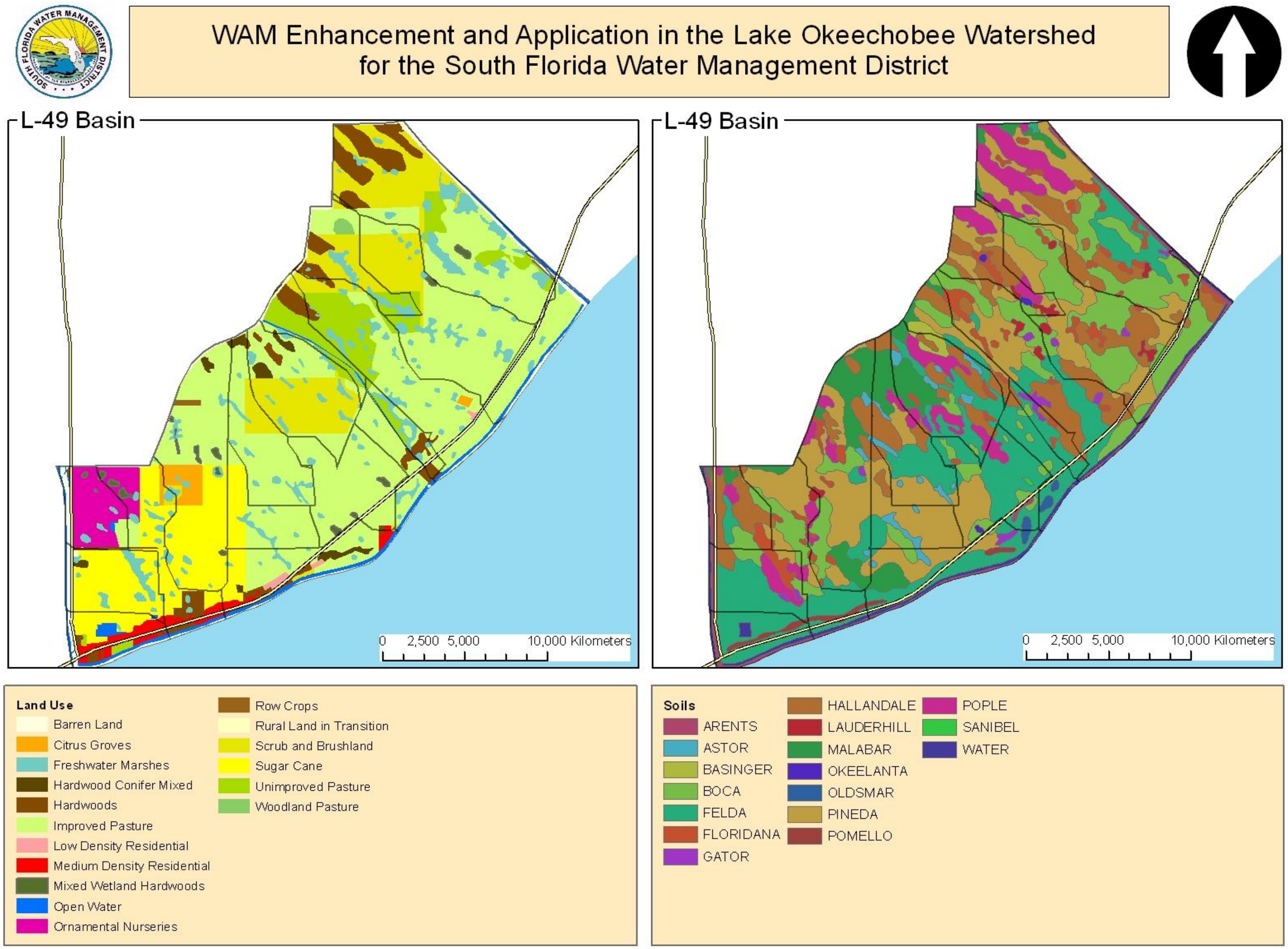


Figure C-1: Land Use and Soils in L-49 Basin

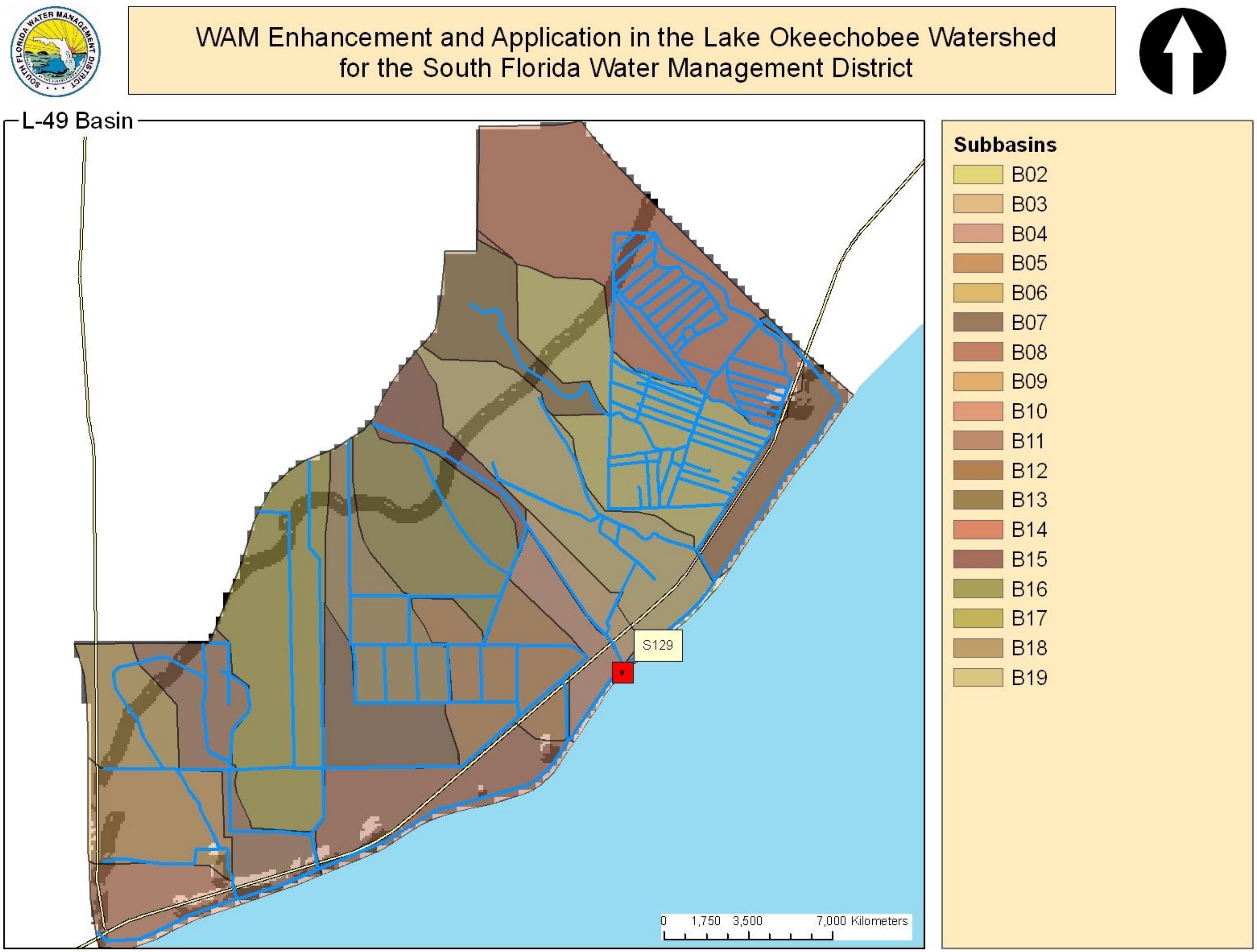


Figure C-2: Hydrologic Features in L-49 Basin

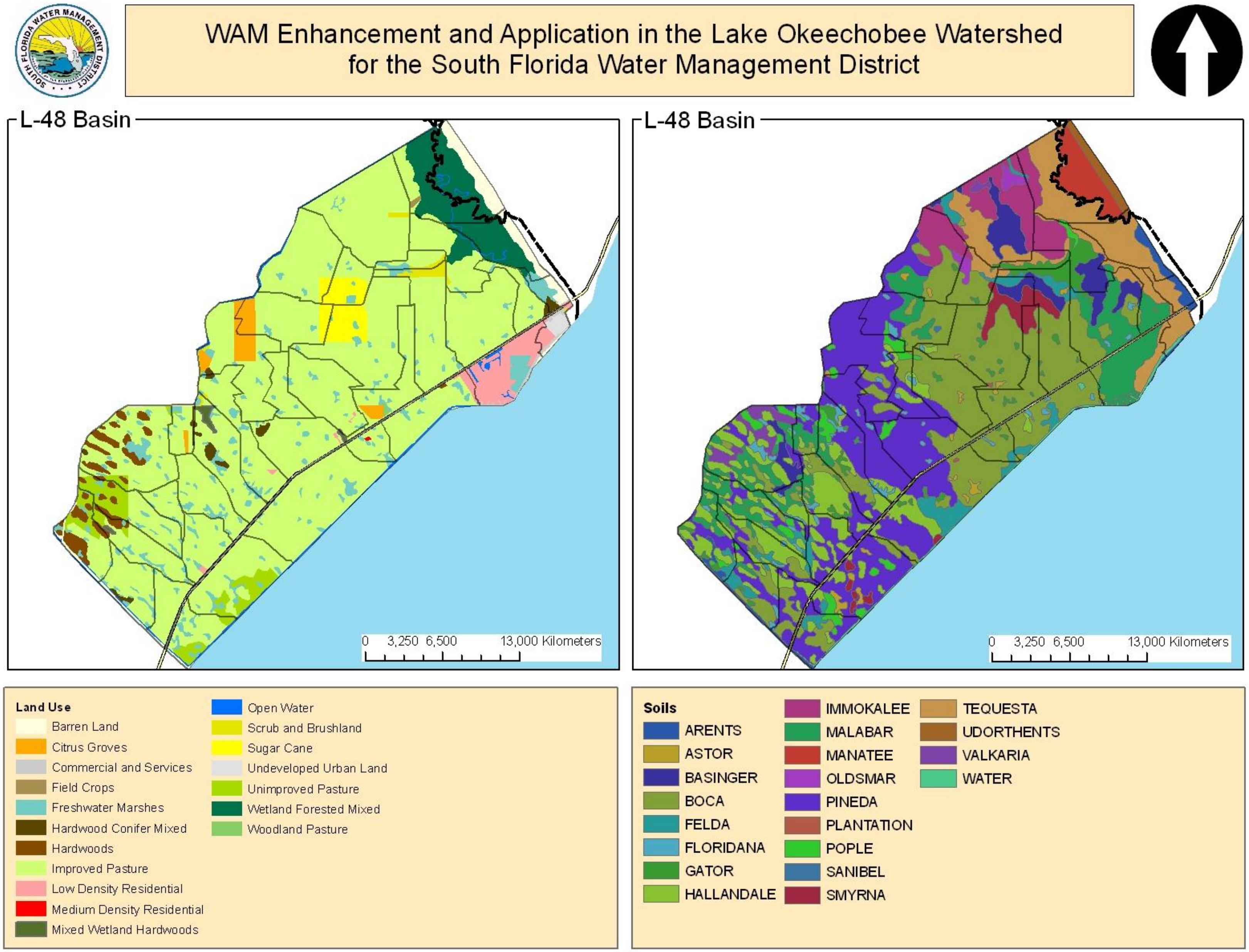


Figure C-3: Land Use and Soils in L-48 Basin

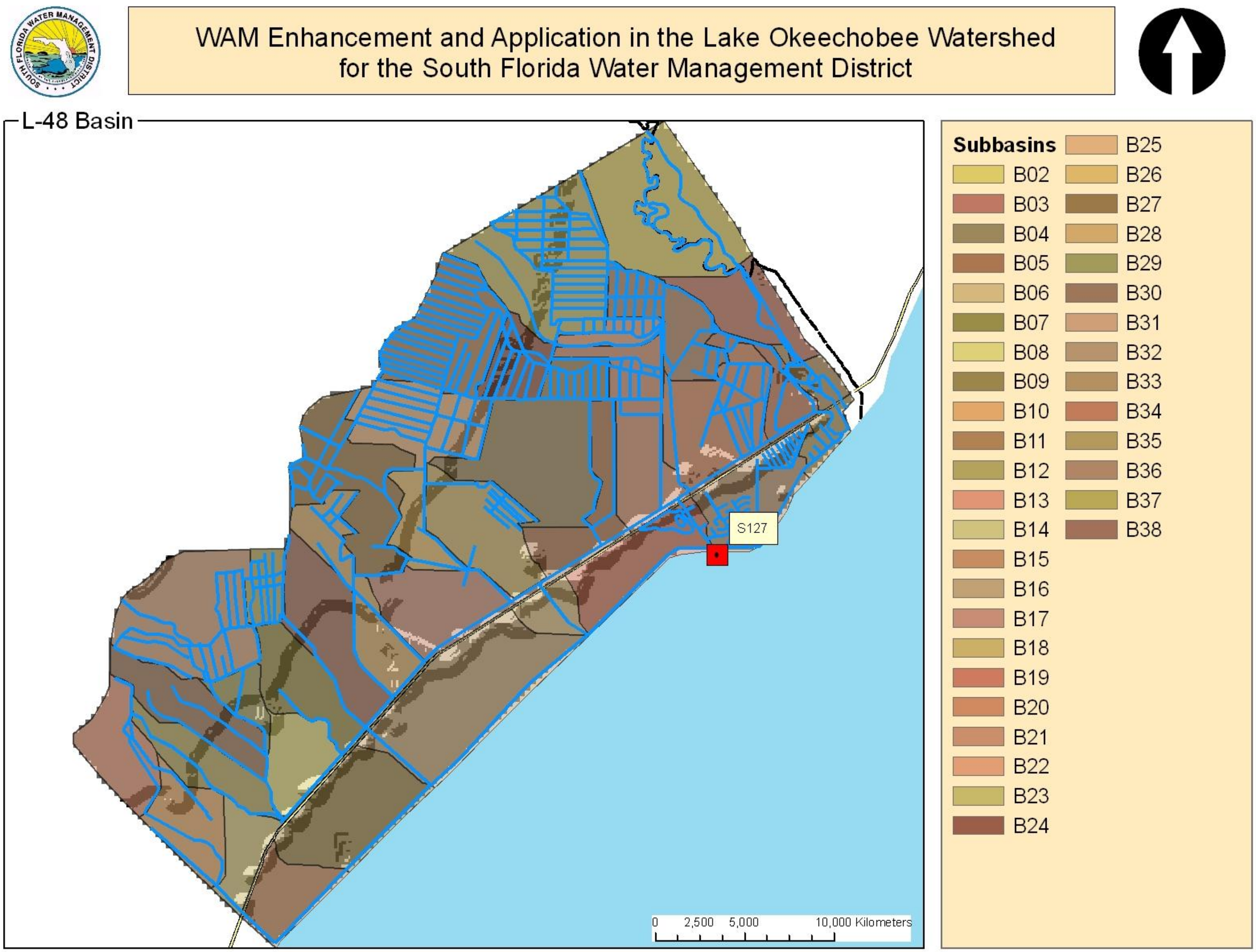


Figure C-4: Hydrologic Features in L-48 Basin

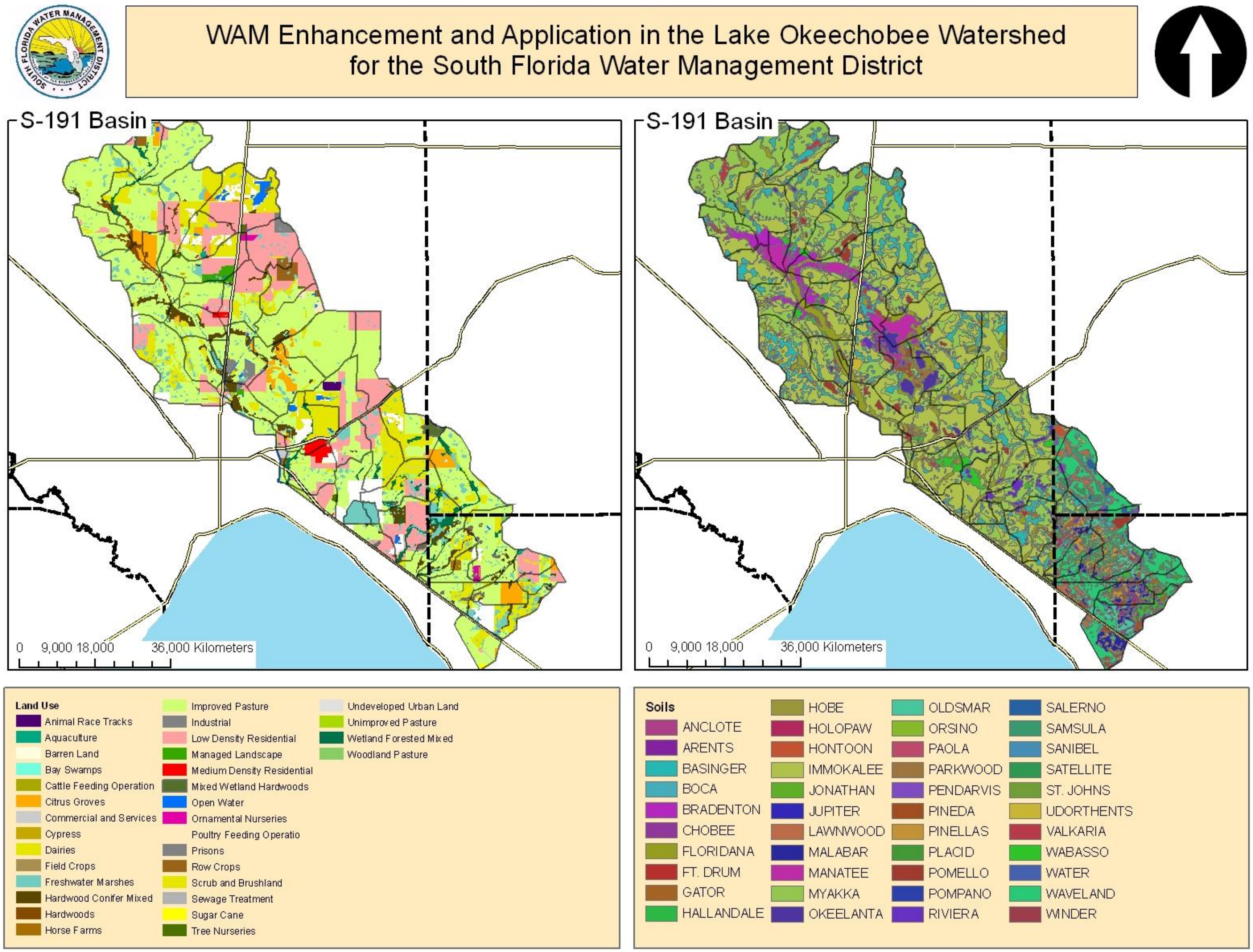


Figure C-5: Land Use and Soils in S-191 Basin

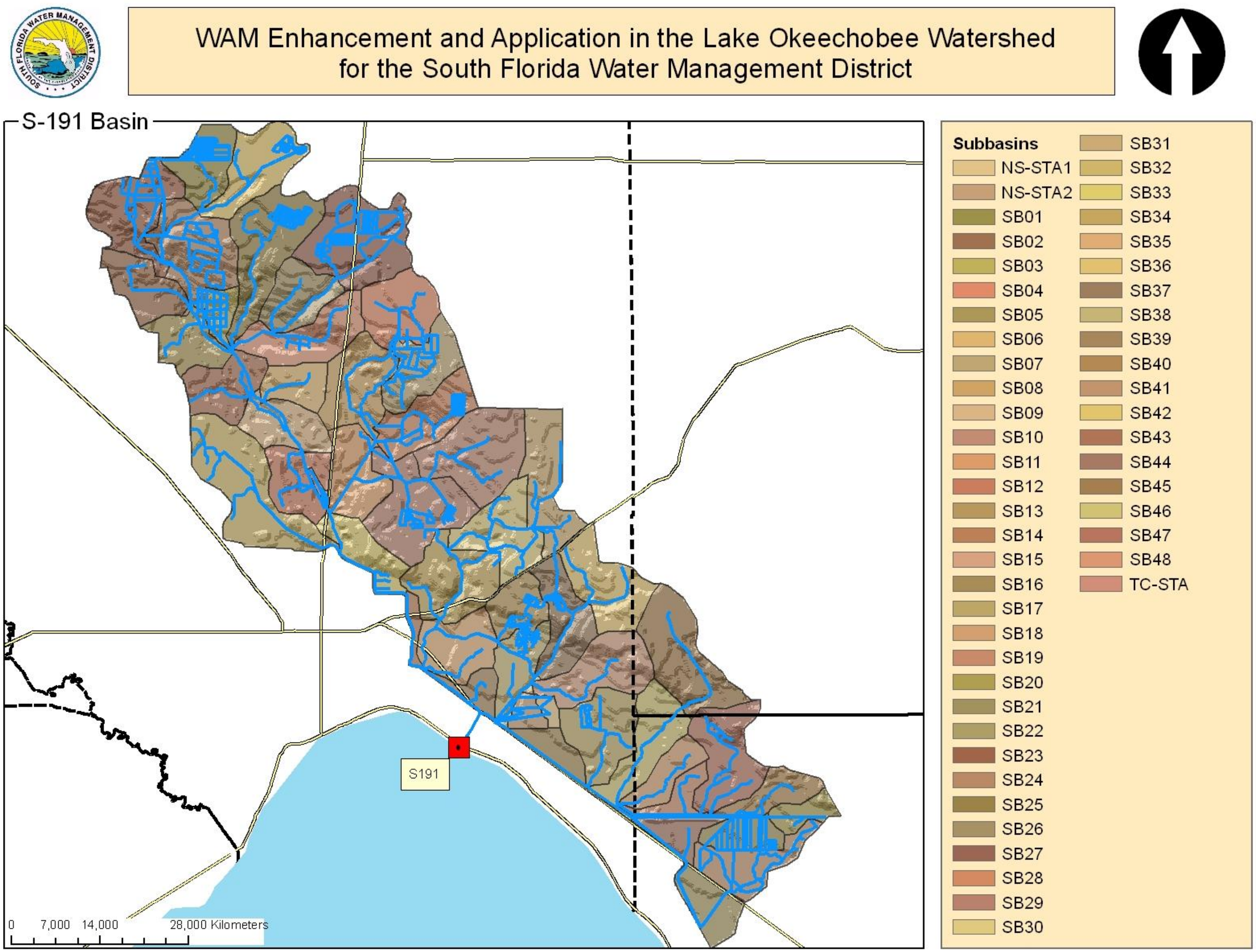


Figure C-6: Hydrologic Features in S-191 Basin

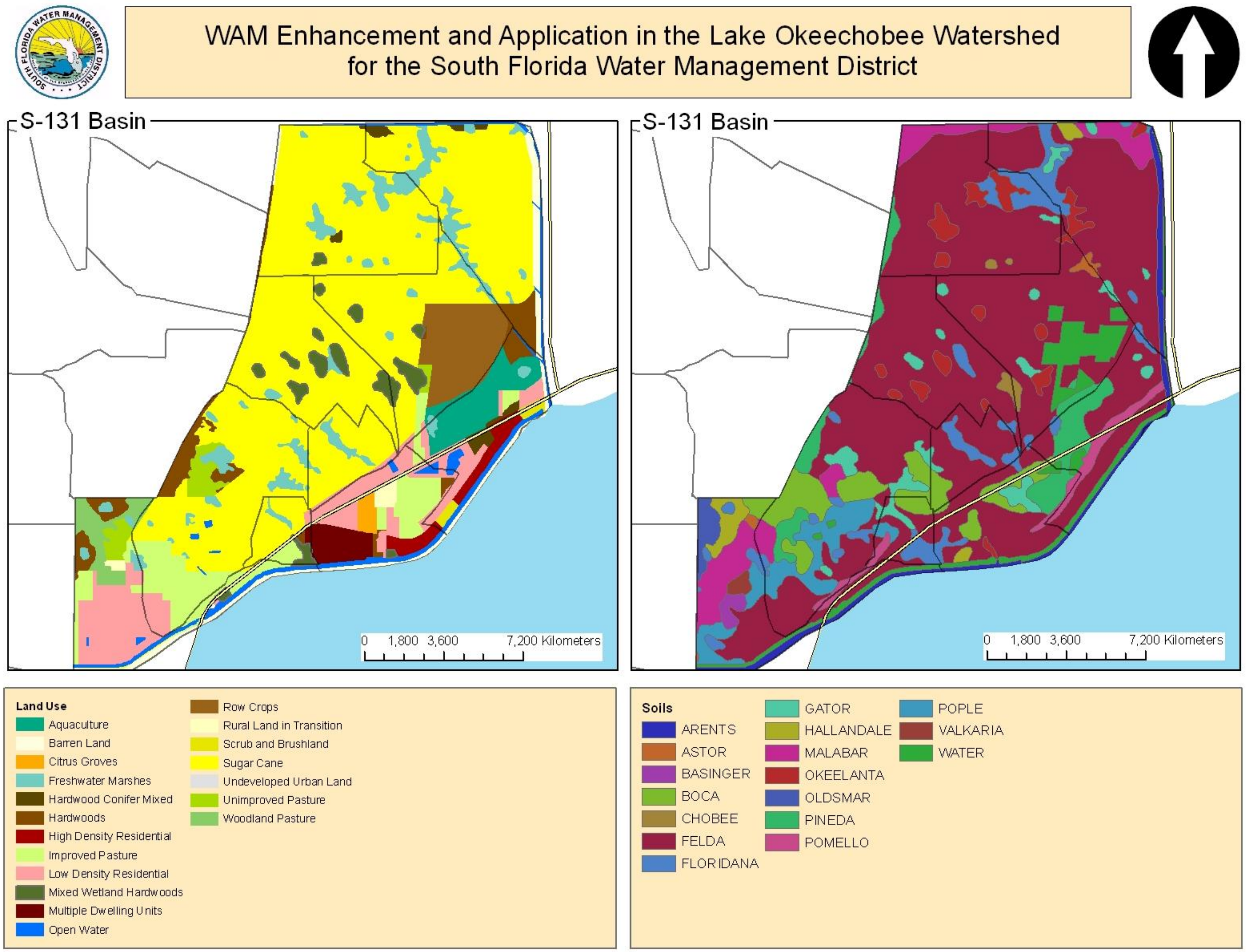


Figure C-7: Land Use and Soils in S-131 Basin

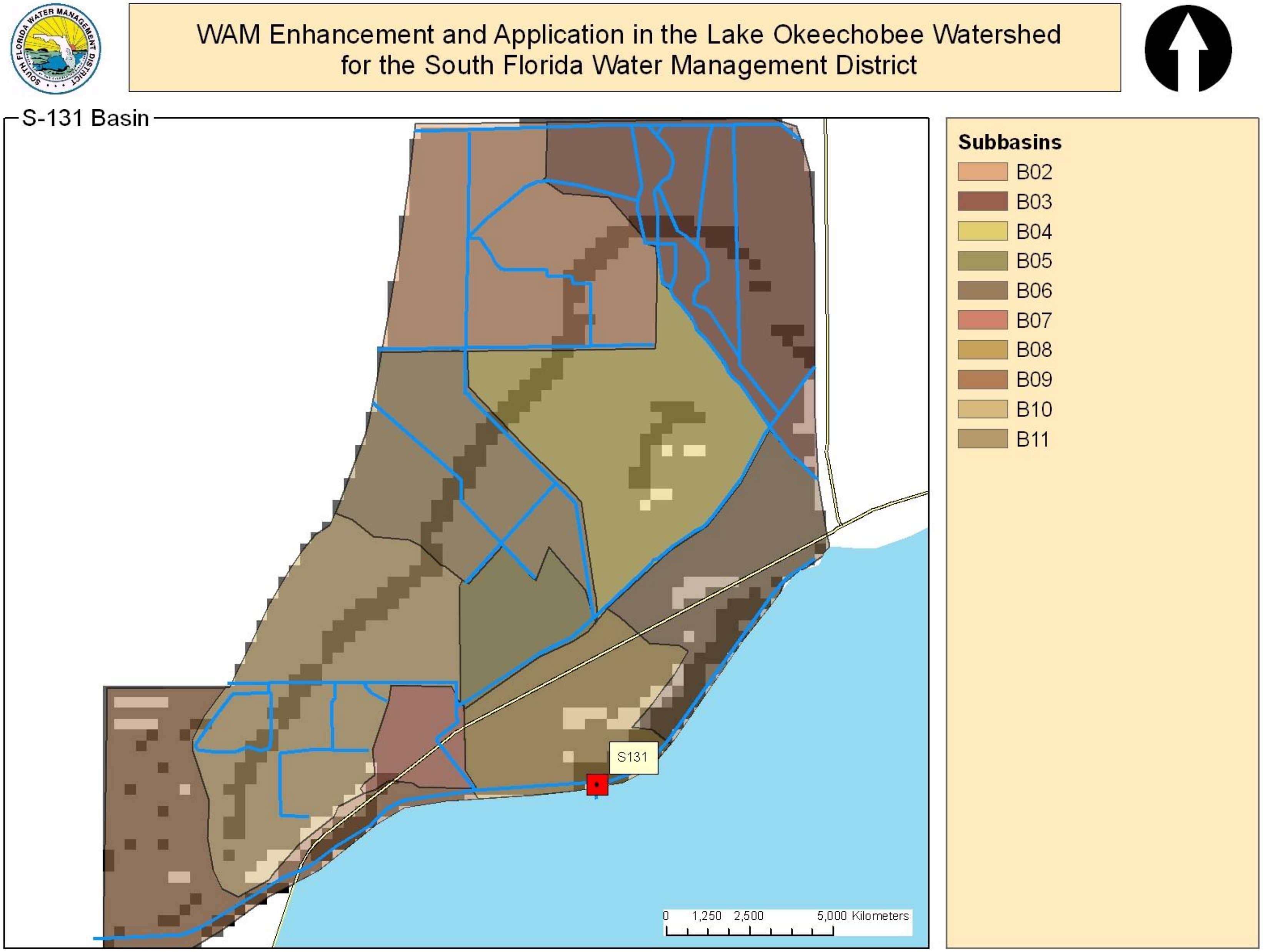


Figure C-8: Hydrologic Features in S-131 Basin

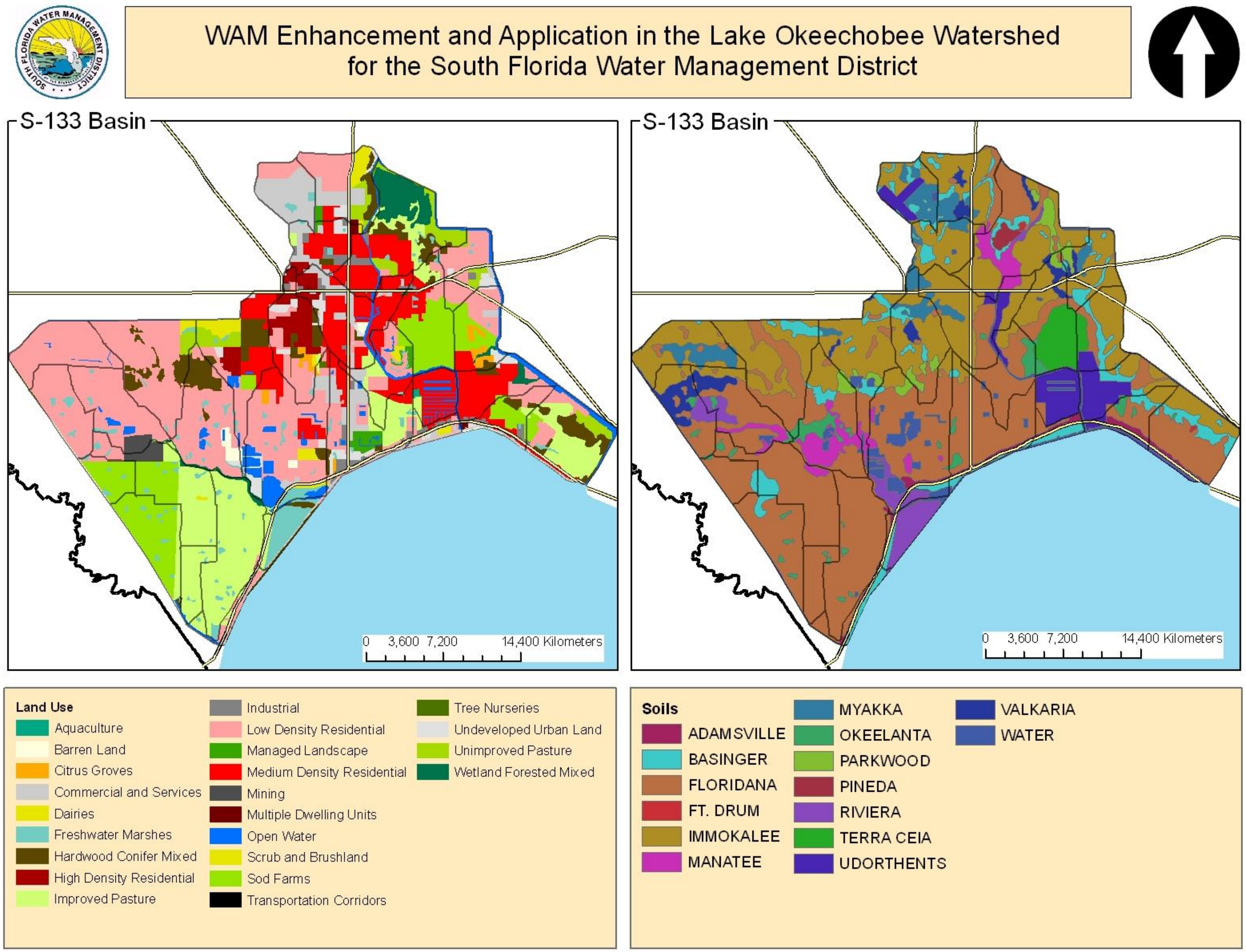


Figure C-9: Land Use and Soils in S-133 Basin

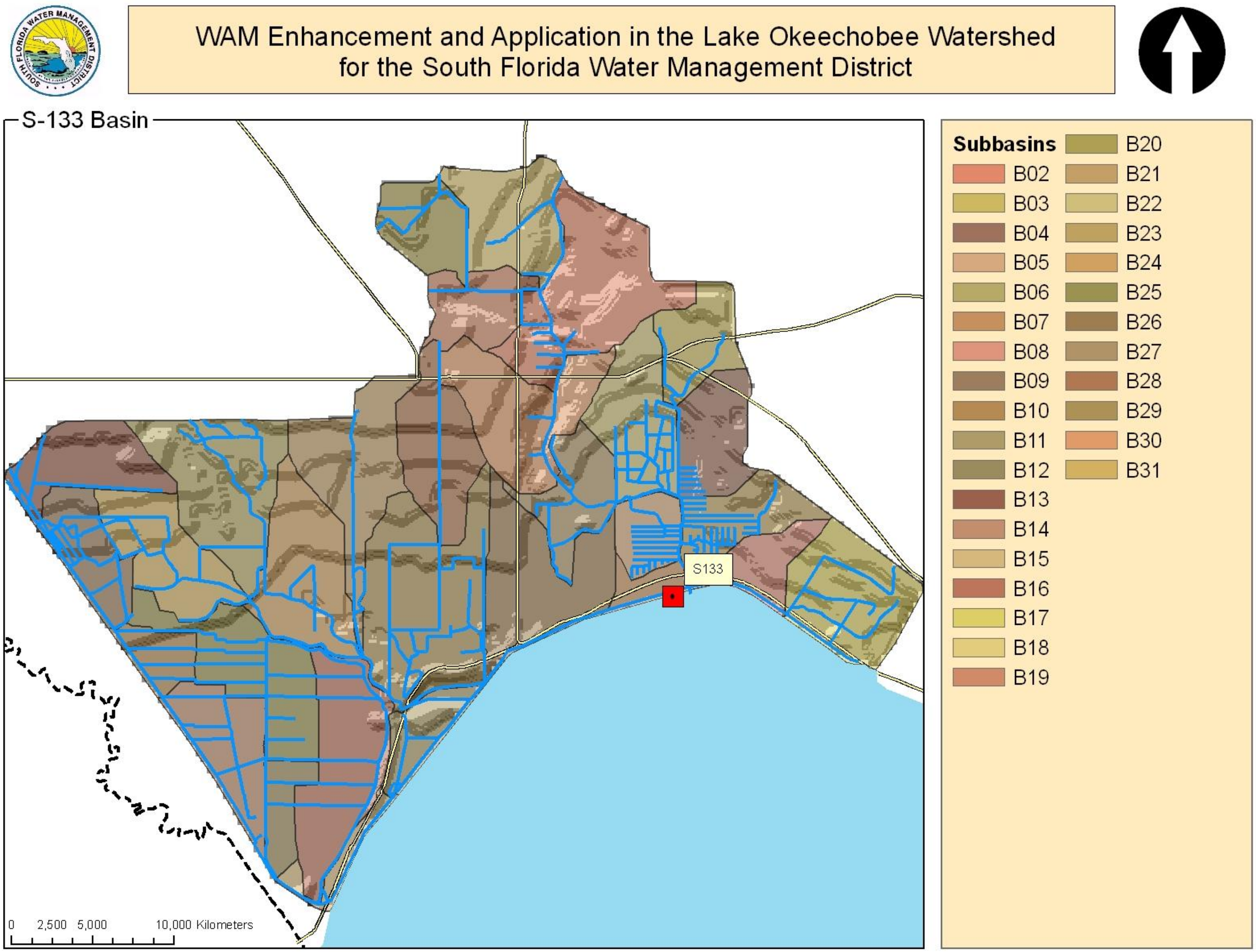


Figure C-10: Hydrologic Features in S-133 Basin

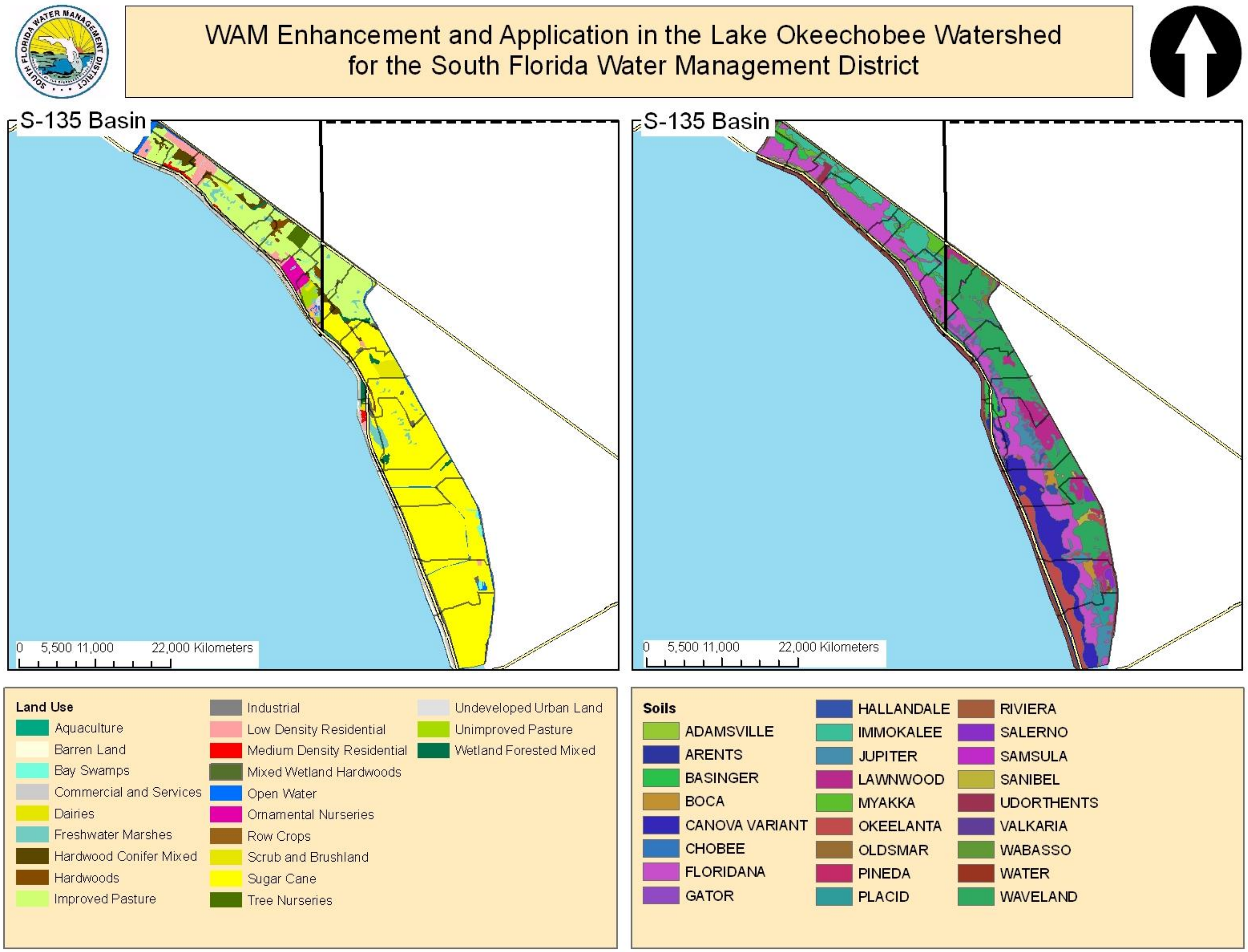


Figure C-11: Land Use and Soils in S-135 Basin

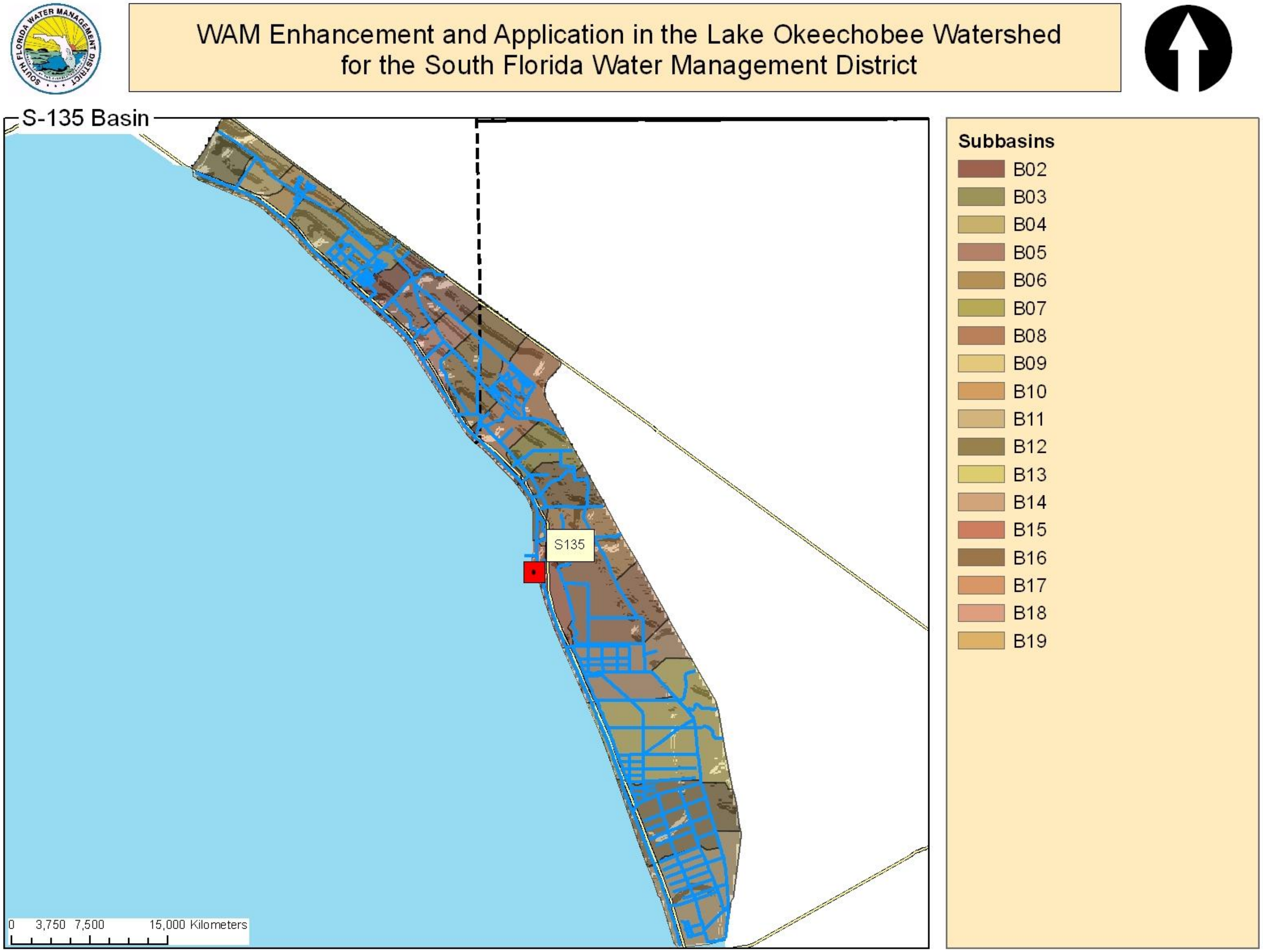


Figure C-12: Hydrologic Features in S-135 Basin

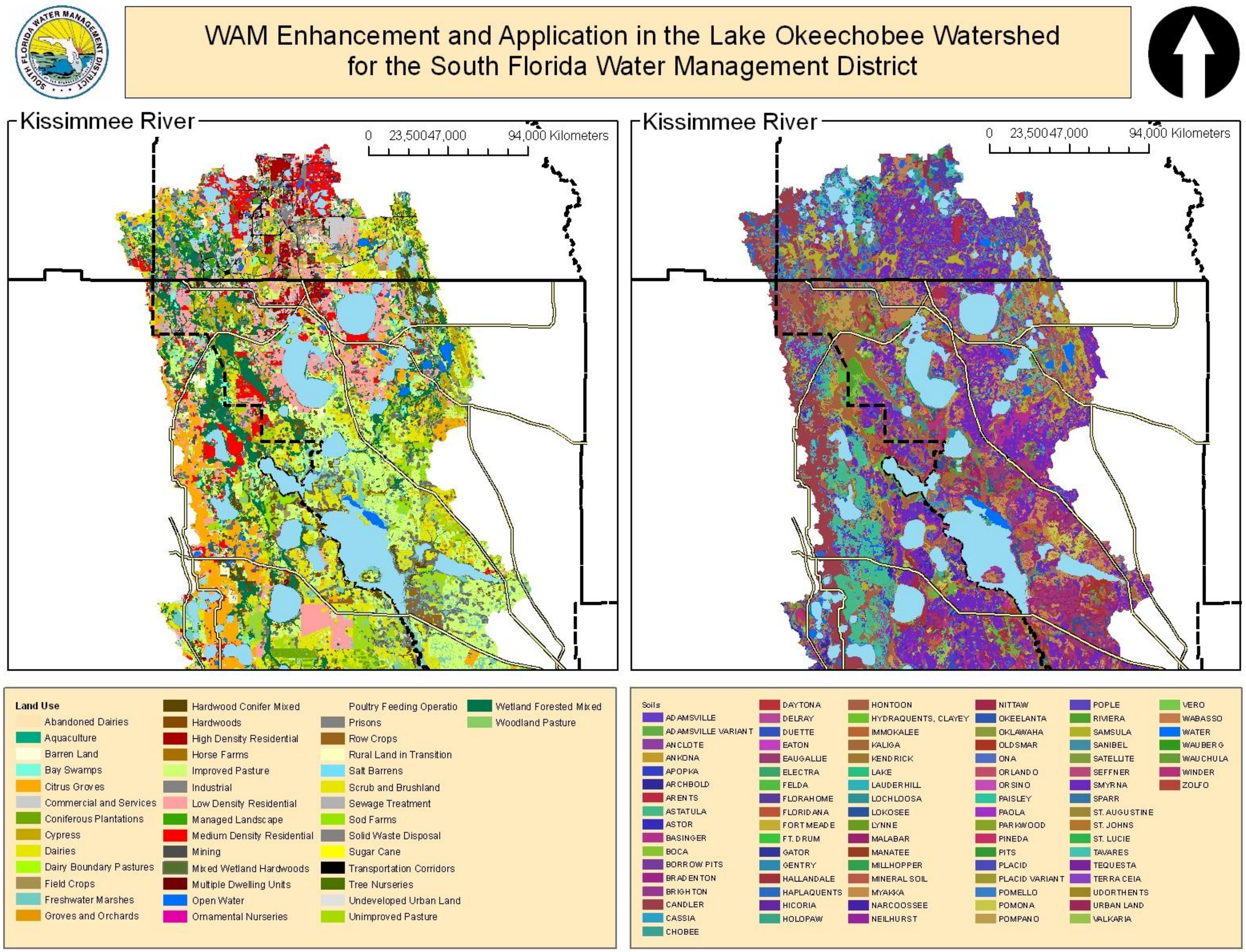


Figure C-13: Land Use and Soils in Northern Kissimmee River (C-38) Basin

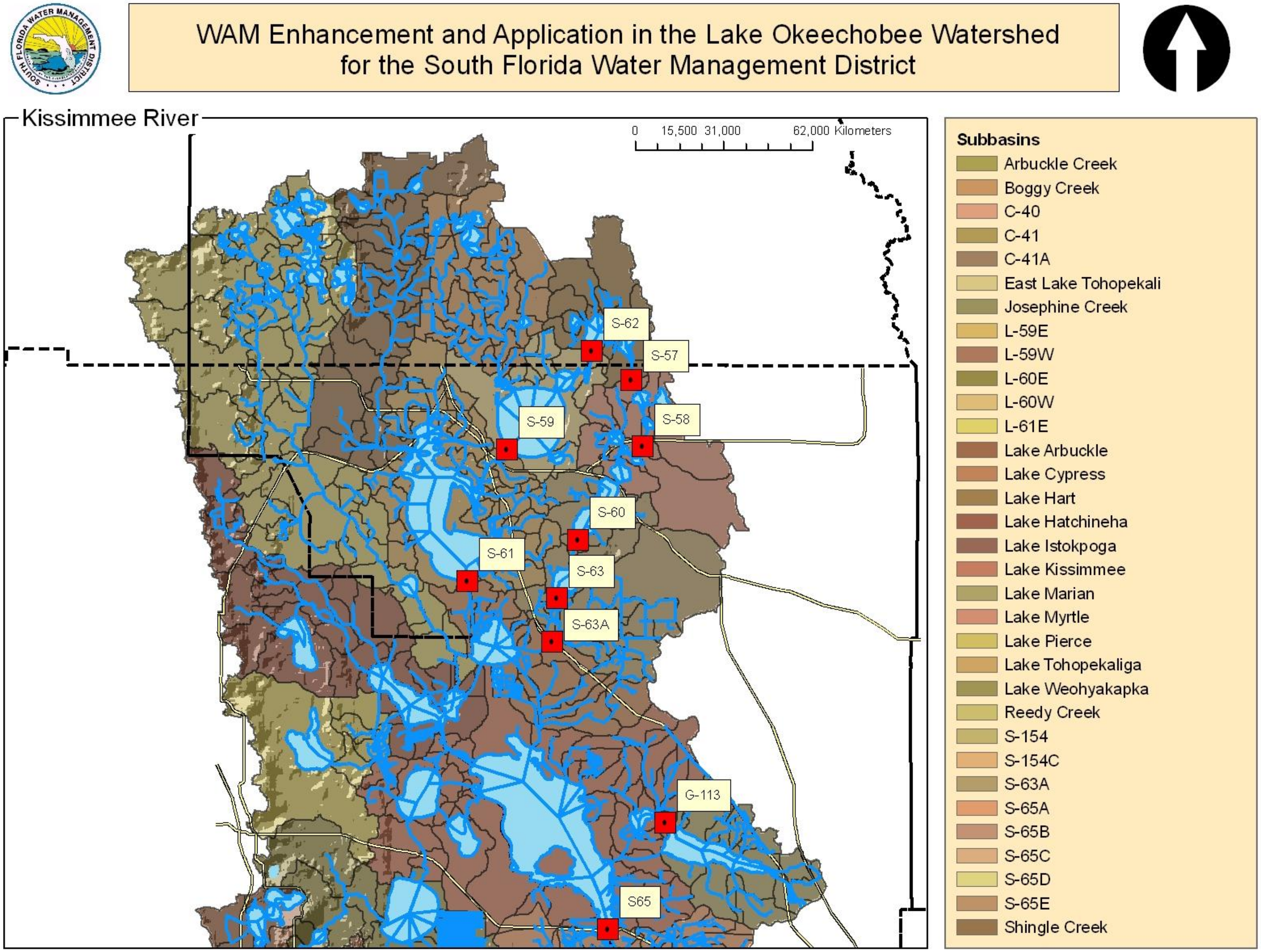


Figure C-14: Hydrologic Features in Northern Kissimmee River (C-38) Basin

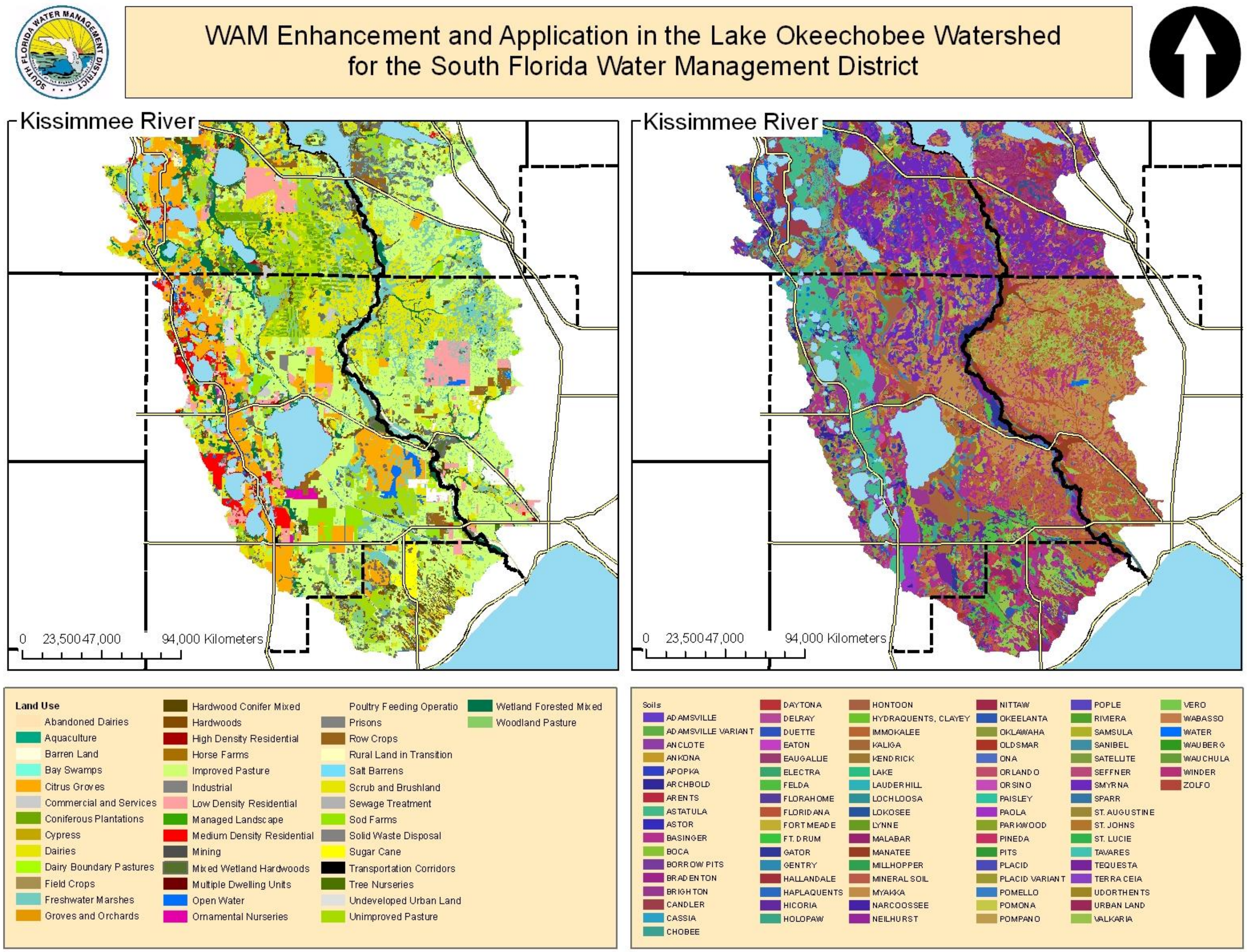


Figure C-15: Land Use and Soils in Southern Kissimmee River (C-38) Basin

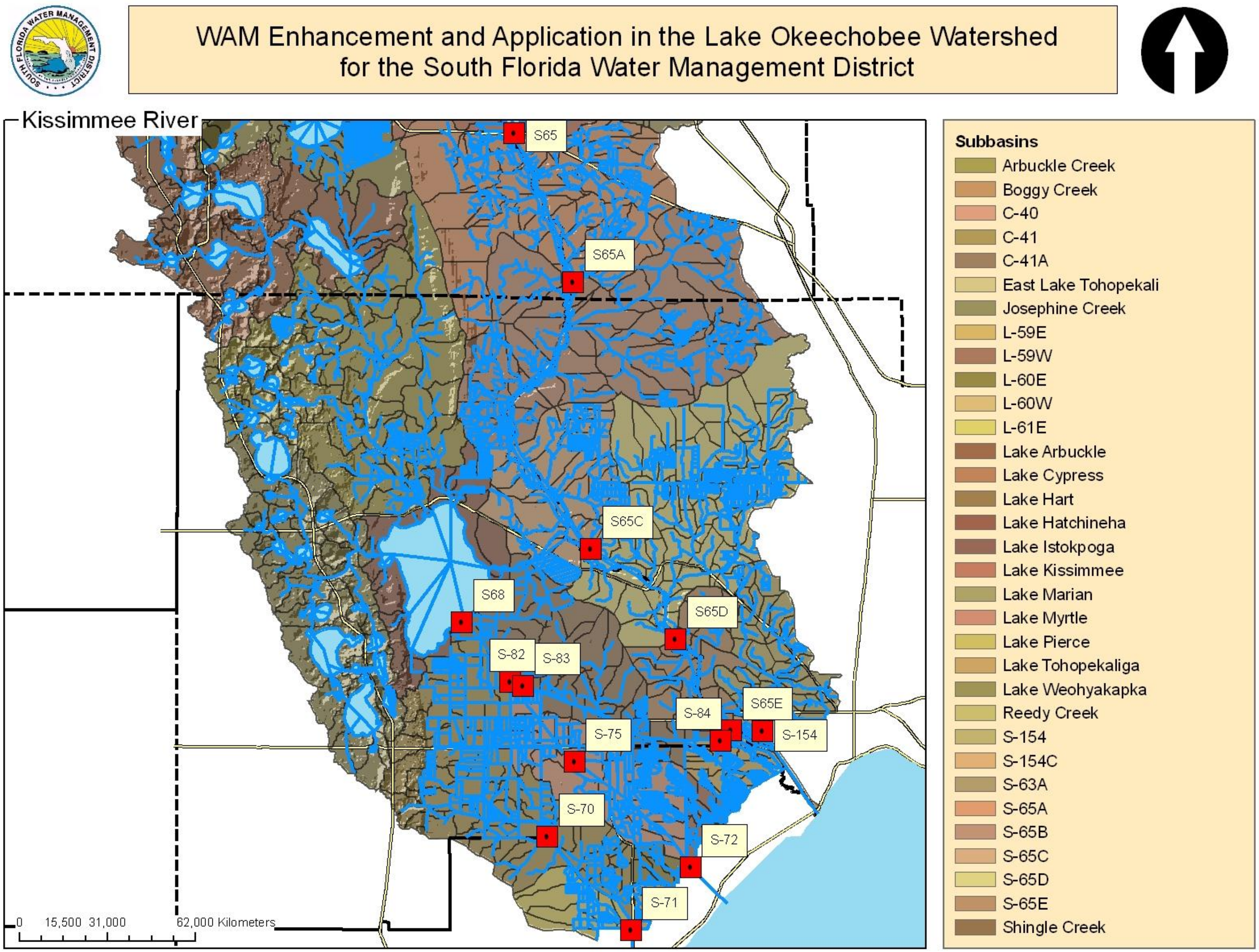


Figure C-16: Hydrologic Features in Southern Kissimmee River (C-38) Basin

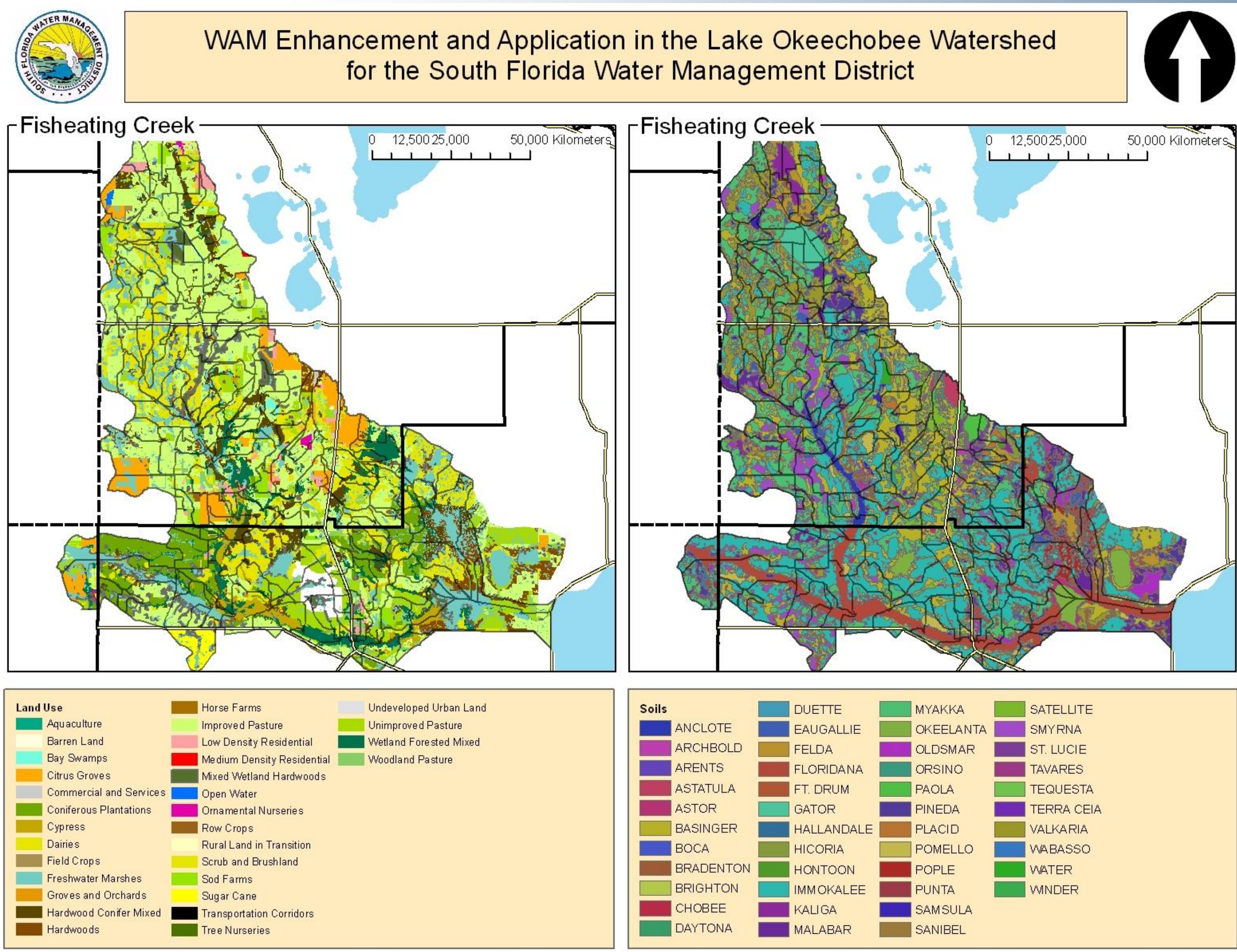


Figure C-17: Land Use and Soils in Fisheating Creek (FEC) Basin

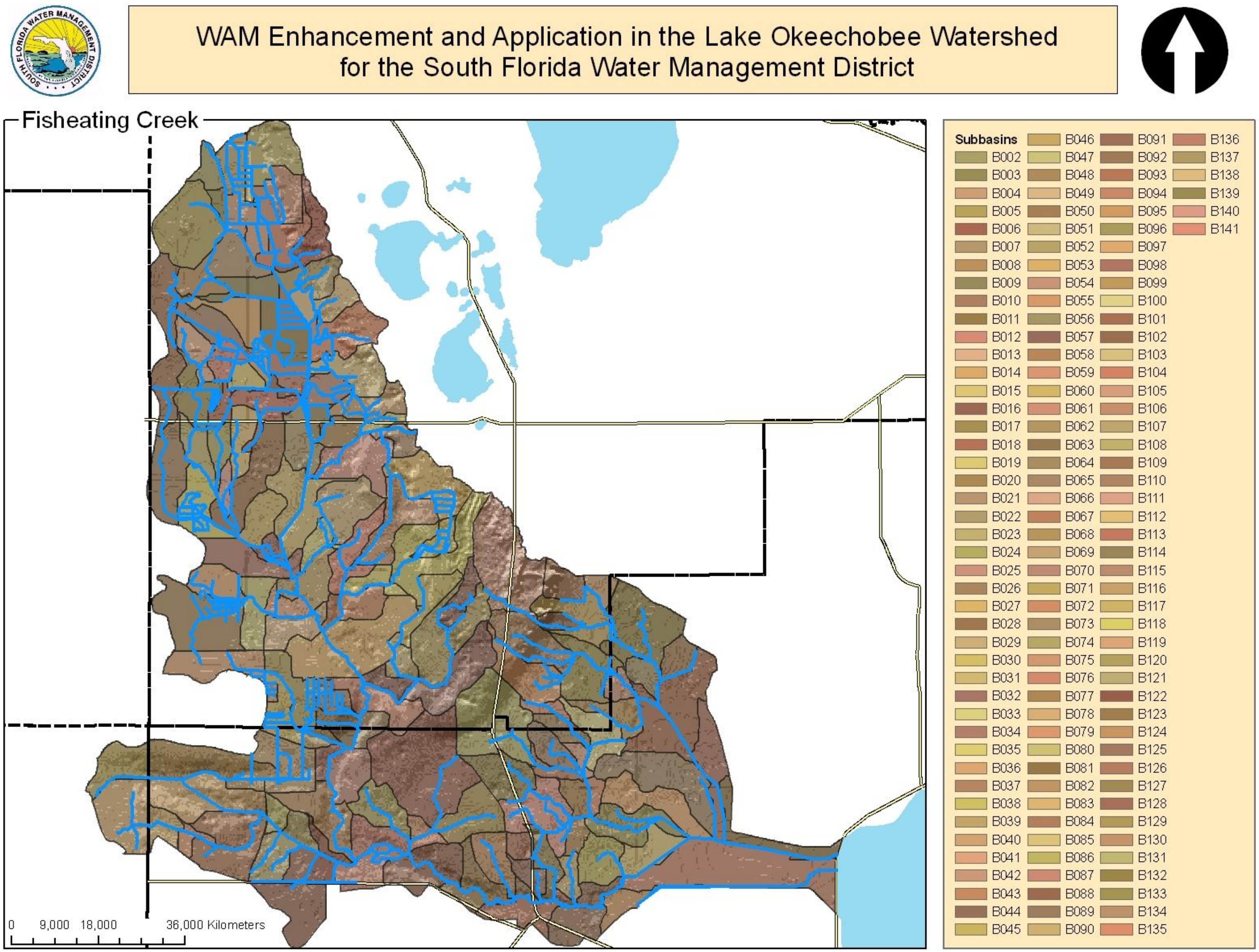


Figure C-18: Hydrologic Features in Fisheating Creek (FEC) Basin

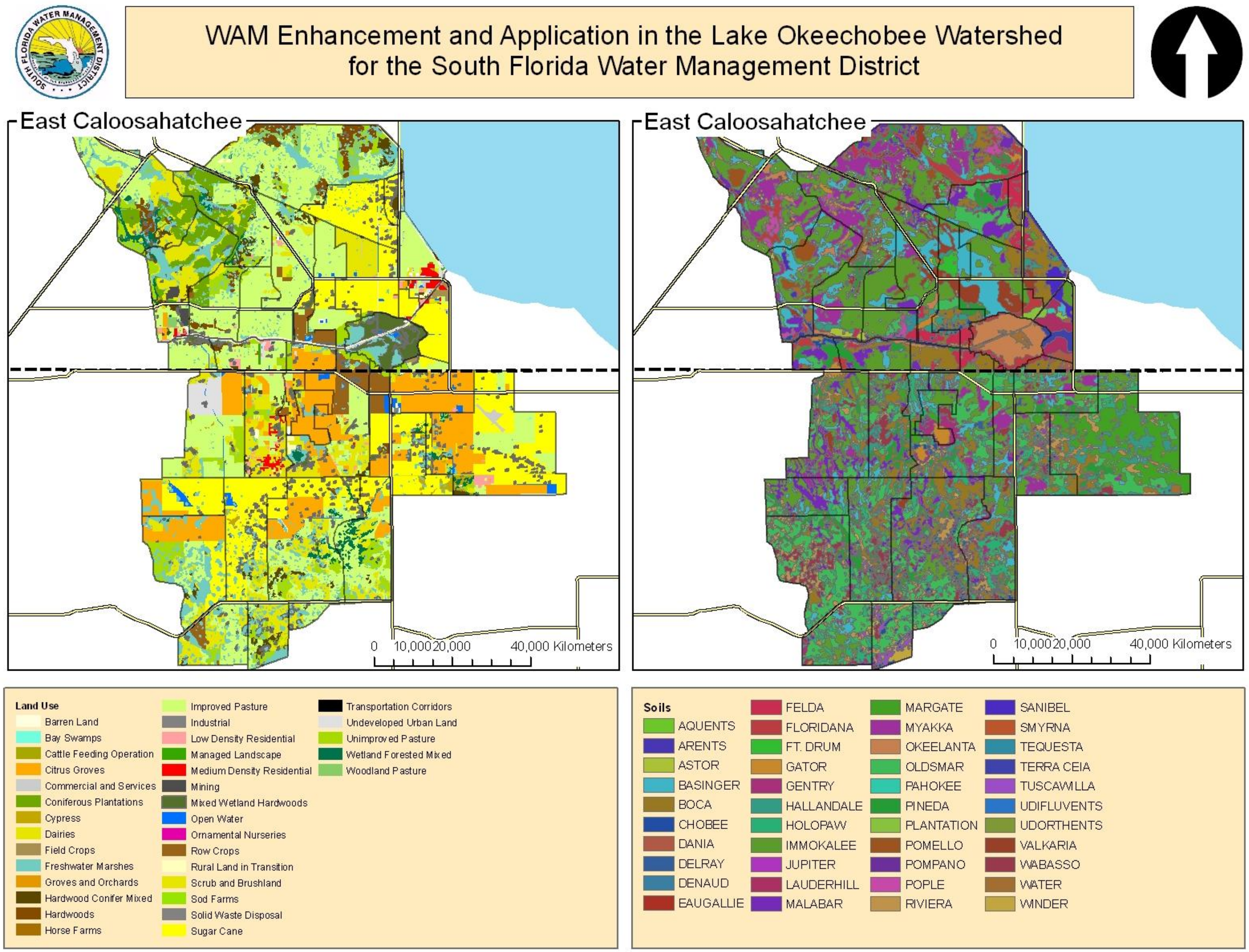


Figure C-19: Land Use and Soils in East Caloosahatchee River (C-43) Basin

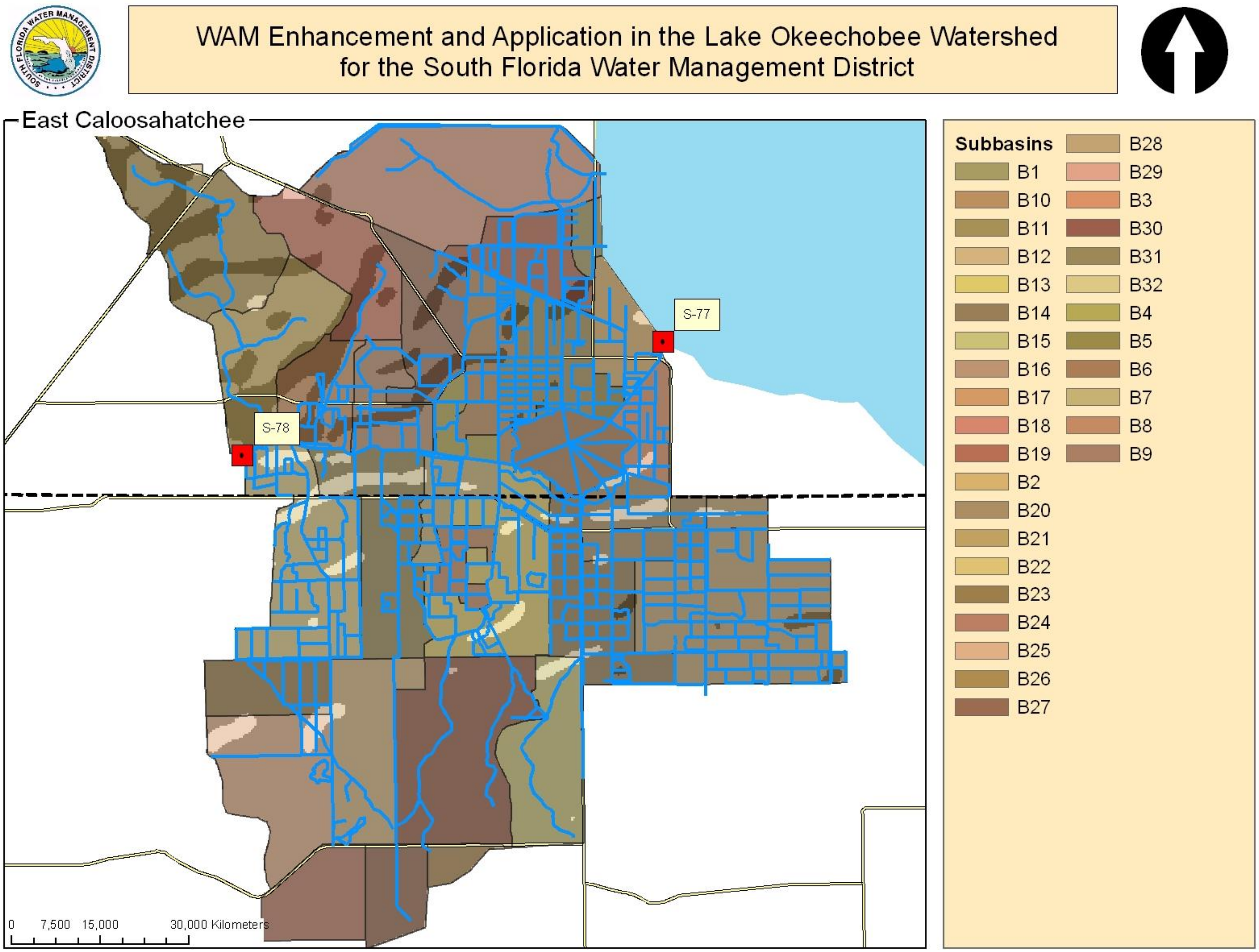


Figure C-20: Hydrologic Features in East Caloosahatchee River (C-43) Basin

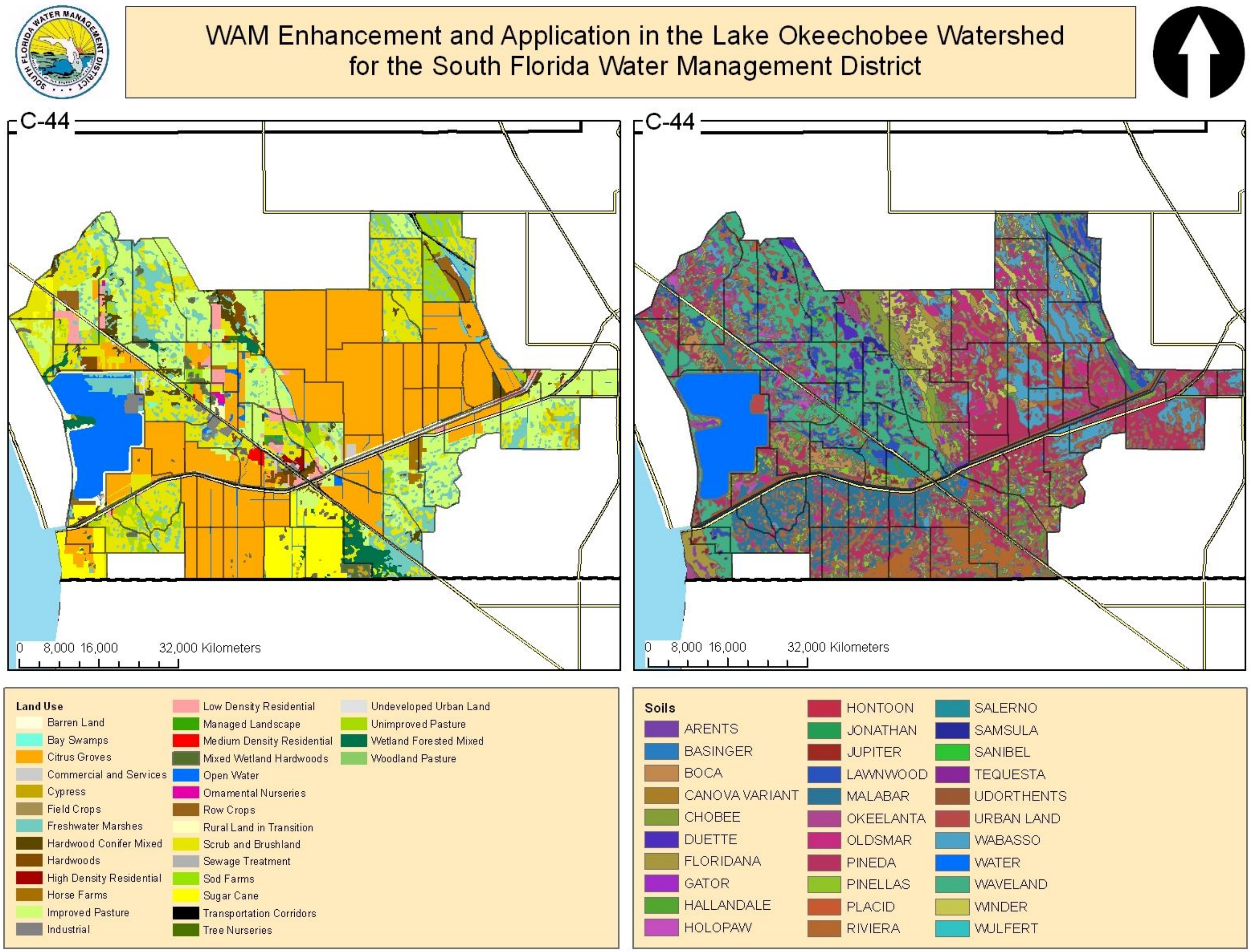


Figure C-21: Land Use and Soils in C-44 Basin

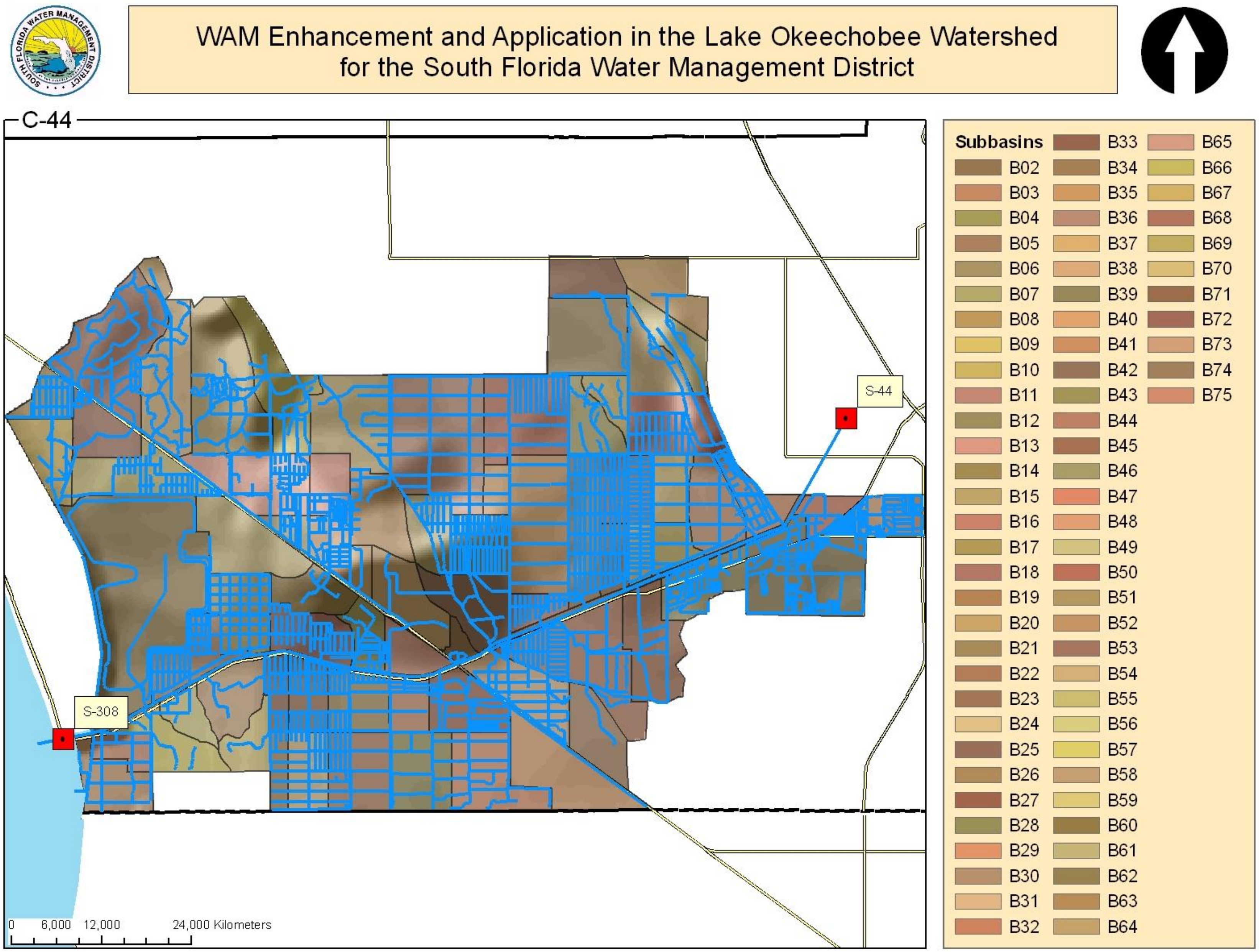


Figure C-22: Hydrologic Features in C-44 Basin

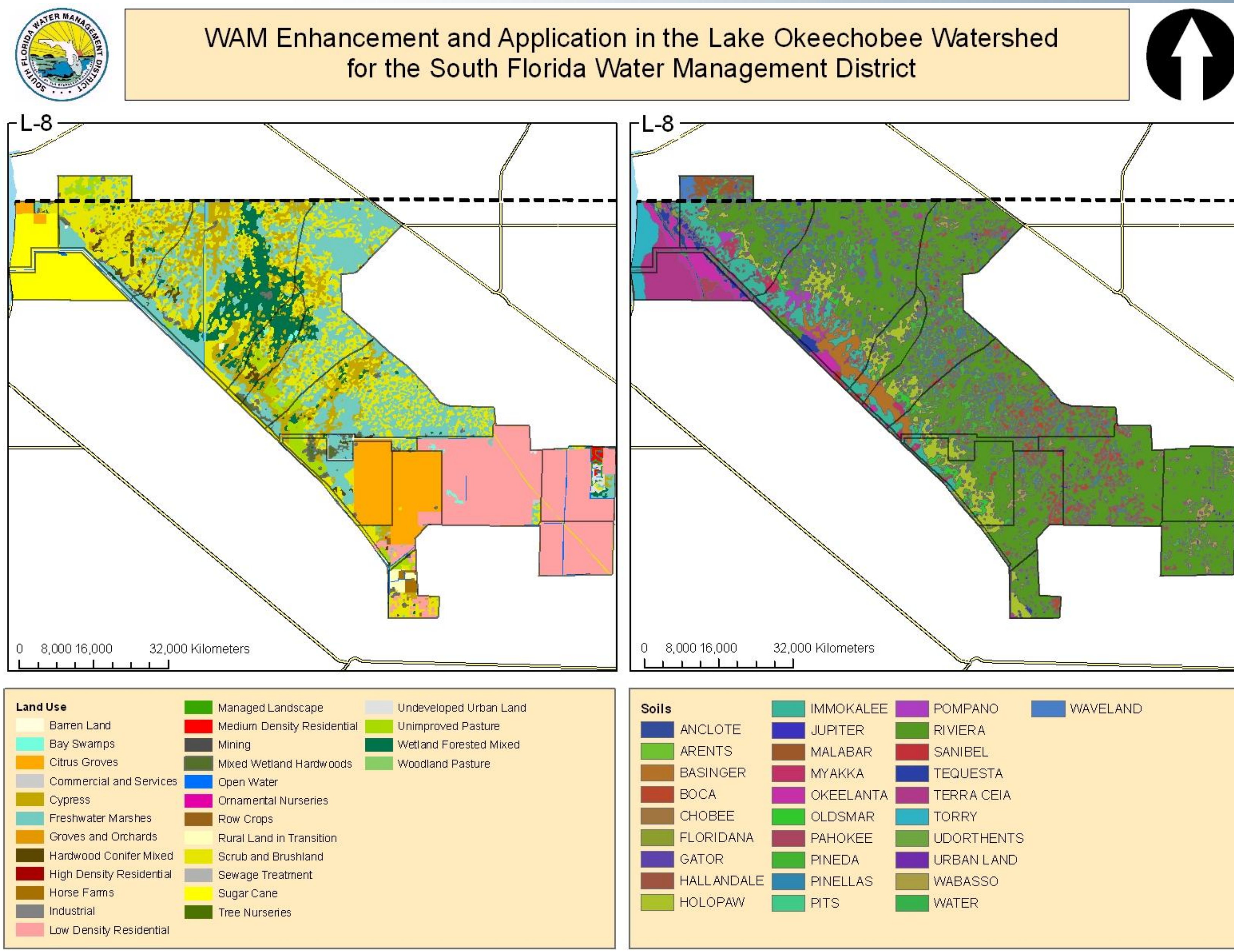


Figure C-23: Land Use and Soils in L-8 Basin

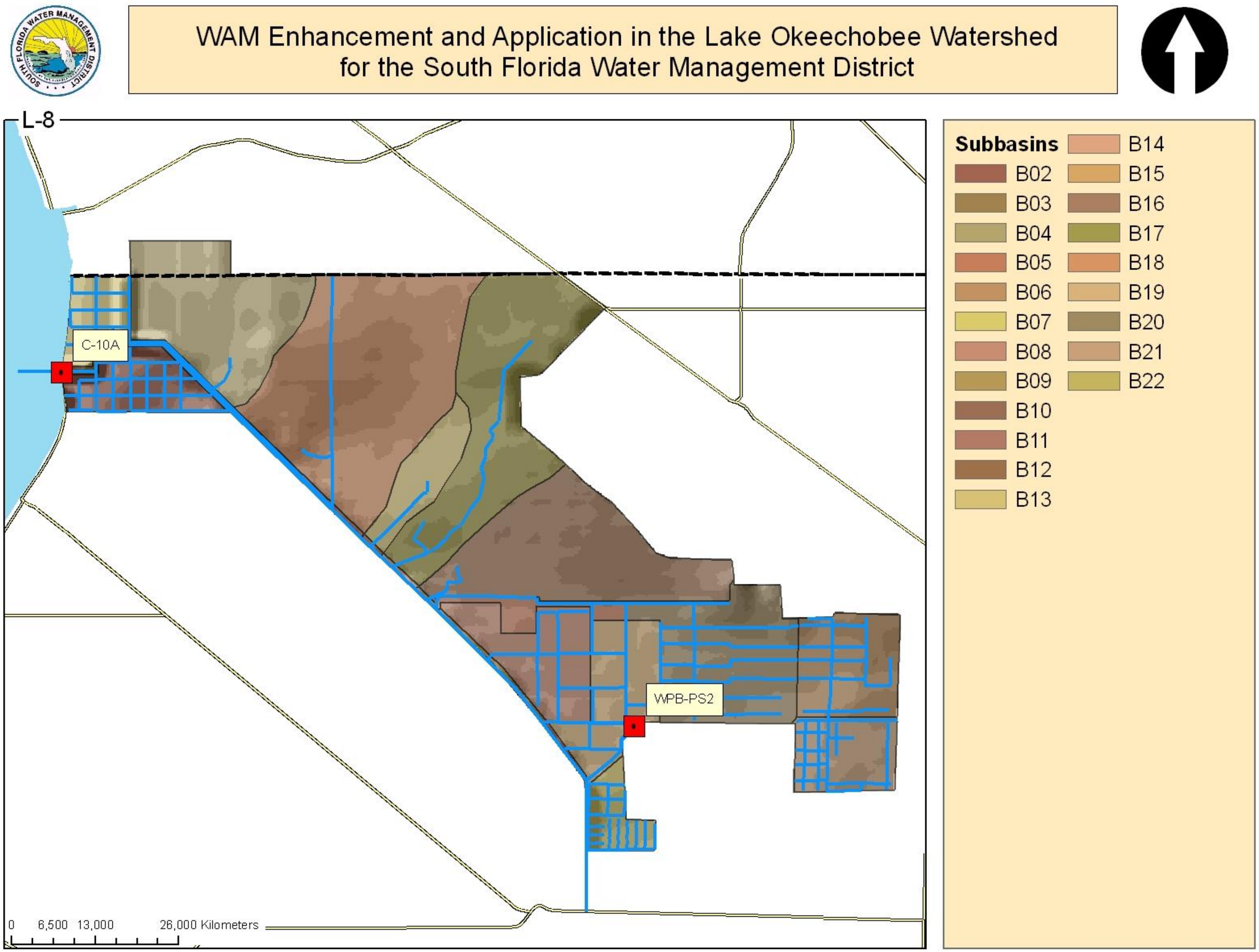


Figure C-24: Hydrologic Features in L-8 Bas