Final Report on the

S-4 Basin Diversion Study

Prepared for

Everglades Agricultural Area
Environmental Protection District

2006

Burns & McDonnell
SINCE 1898

S-4 BASIN DIVERSION STUDY

prepared for

Everglades Agricultural Area
Environmental Protection District
Palm Beach, Florida

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

Project 38554

January 2006

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Burns & McDonnell Engineering Company, Inc. (Burns & McDonnell) was retained by the Everglades Agricultural Area (EAA) Environmental Protection District (EPD) to evaluate the feasibility of diverting stormwater runoff from the S-4 Basin, which is currently discharged to Lake Okeechobee, to an alternate destination. This introduction presents a discussion of the project background, objectives, and study area.

1.1 PROJECT BACKGROUND

The South Florida Water Management District (SFWMD) has established a policy that seeks to limit the discharge of phosphorus contained in stormwater runoff to Lake Okeechobee. In Florida's Everglades Forever Act (373.4592, Florida Statutes), several of the Chapter 298 drainage districts that are located along the southern shore of Lake Okeechobee — East Beach Water Control District, South Shore Drainage District, South Florida Conservancy District, East Shore Water Control District, and Closter or 715 Farms (Agricultural Lease No. 3240) — are specifically required to install conveyance systems that would divert drainage away from the lake. The goal of these diversion systems is typically to divert 80 percent or more of this drainage into the SFWMD's primary conveyance canals so it can be delivered to one of the stormwater treatment areas (STA) for treatment prior to its discharge to the Everglades Protection Area (EPA). These diversion systems are currently operational or well along in their development. It is anticipated that at some point, as an element of the Lake Okeechobee Protection Project and in response to the establishment of Total Maximum Daily Load (TMDL) limitations on discharge to the lake, it will be necessary to reduce discharges to Lake Okeechobee from the S-4 Basin, particularly for total phosphorus (TP) loads. This reduction in allowable TP discharges to Lake Okeechobee may make full or partial diversion, or pretreatment of S-4 Basin discharges a necessity.

1.2 DIVERSION STUDY OBJECTIVES

The principle objectives of this study are as follows:

- Quantify the historic volumes, and TP concentrations and loads of stormwater that is discharged to Lake Okeechobee from the S-4 Basin
- Analyze alternatives for diversion of S-4 Basin stormwater drainage away from Lake Okeechobee
- Prepare a conceptual design of the recommended facilities required to affect this diversion

1.3 STUDY AREA

The study area for this diversion feasibility study includes the area of the S-4 Basin itself and that of the adjacent drainage basins that may receive the stormwater diverted from the S-4 Basin. These adjacent drainage basins are listed below along with their locations relative to the S-4 Basin:

- C-139 Basin – located immediately south
- C-43 Basin (Caloosahatchee River) – located immediately west
- S-3/S-8 Basin – located immediately southeast

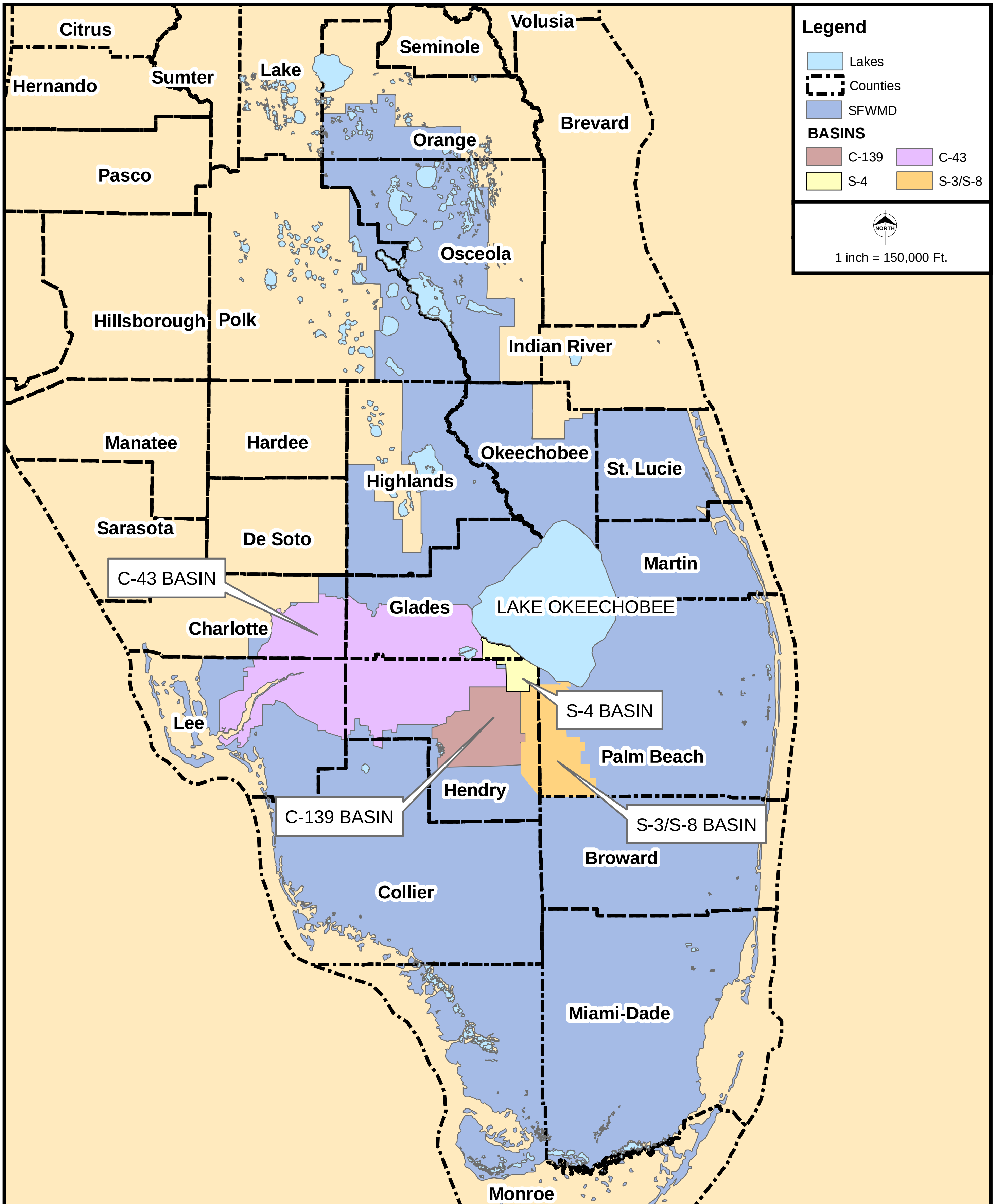
A map showing the locations of these drainage basins within south Florida is included as Figure 1-1.

The S-4 Basin is located on the southwestern shore of Lake Okeechobee in Glades and Hendry counties, between Clewiston and Moore Haven. This basin occupies an area of approximately 73.4 square miles (Cooper, 1989). The S-4 Basin includes all or portions of five special drainage districts:

- Clewiston Drainage District
- Disston Island Conservancy District
- East Hendry County Drainage District
- South Florida Conservancy District, Unit No. 5
- Sugarland Drainage District

Also included in the S-4 Basin, but not part of one the above drainage districts, is a large farming area owned by the United States Sugar Corporation (U.S. Sugar) that is known as the Townsite area.

* * * * *



Burns & McDonnell
SINCE 1898

Figure 1-1
S-4 BASIN DIVERSION
PROJECT STUDY AREA

2.0 HISTORIC HYDROLOGIC DATA

The first step in the diversion study was to collect historic hydrologic data on runoff volumes, TP concentrations and loads, and other relevant data for the S-4 and adjacent drainage basins. Figure 2-1 is a map of the project area that shows the locations of the individual drainage districts, and principal canals and control structures in the S-4 and adjacent drainage basins. A schematic of these basins, which more clearly shows the arrangement of control structures and their receiving canals, is included as Figure 2-2. The available hydrologic data for this basin, organized by drainage district, basin or area, are summarized in this report chapter.

2.1 DATA SOURCES

The hydrologic data utilized in this study were all obtained from the SFWMD. Those structures with the EPD prefix are monitored by the Environmental Protection District and these data are submitted to SFWMD on an annual basis. Therefore, all of the data received from SFWMD for the EPD-monitored structures is simply a compilation of the data provided by the EPD over the years. The period of record for these data starts 15 April 1992 and ends 15 February 2005 (SFWMD, 2005a). The provided EPD data includes estimates of daily flow, TP loads, TP concentrations and, at some locations, rainfall depths.

Most of the EPD-monitored structures are equipped with auto-samplers that collect composite samples. These composite samples are either flow-weighted (sampling rate proportional to pump discharge rate) or time-weighted (sampled at constant rate whenever pumps are operating). The composite samples are collected and analyzed at intervals ranging from about 14 to 30 days, with more frequent collections during periods of increased pump operation.

For certain of the control structures and other monitoring stations in the C-139 and S-3/S-8 drainage basins, the flow data and TP concentration and load estimates used in this study were provided directly by SFWMD staff as part of the concurrent EAA Regional Feasibility Study (RFS). The structures included in this category are G-136, G-342A – G-342D, G-406, L3DF, G-88, G-89, G-155, S-3/S-354, and S-8. In the C-139 Basin, the period of record for these RFS data is WY 1995–2005. These SFWMD-provided data are summarized in a report prepared by Burns & McDonnell (2005a).

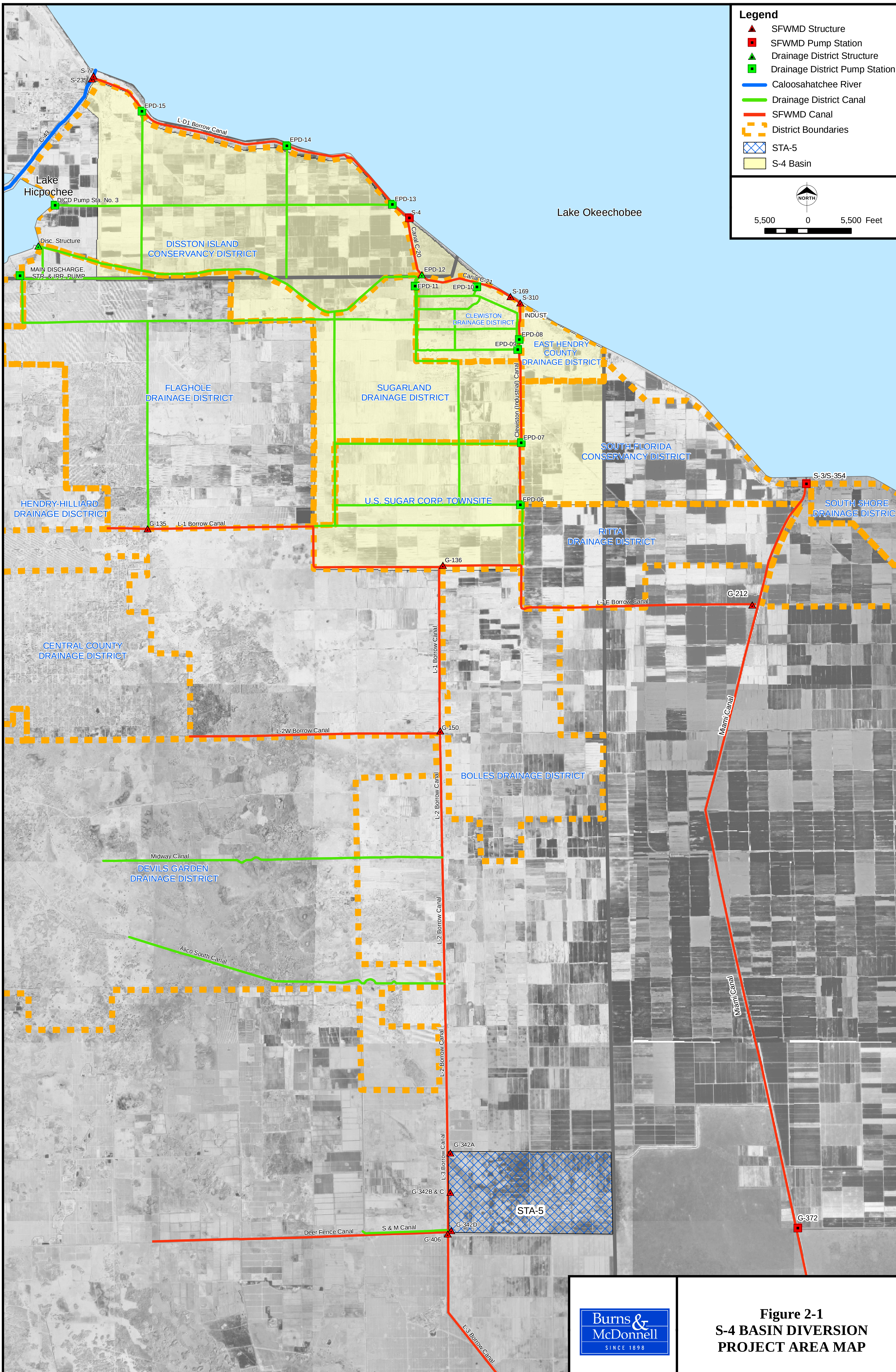
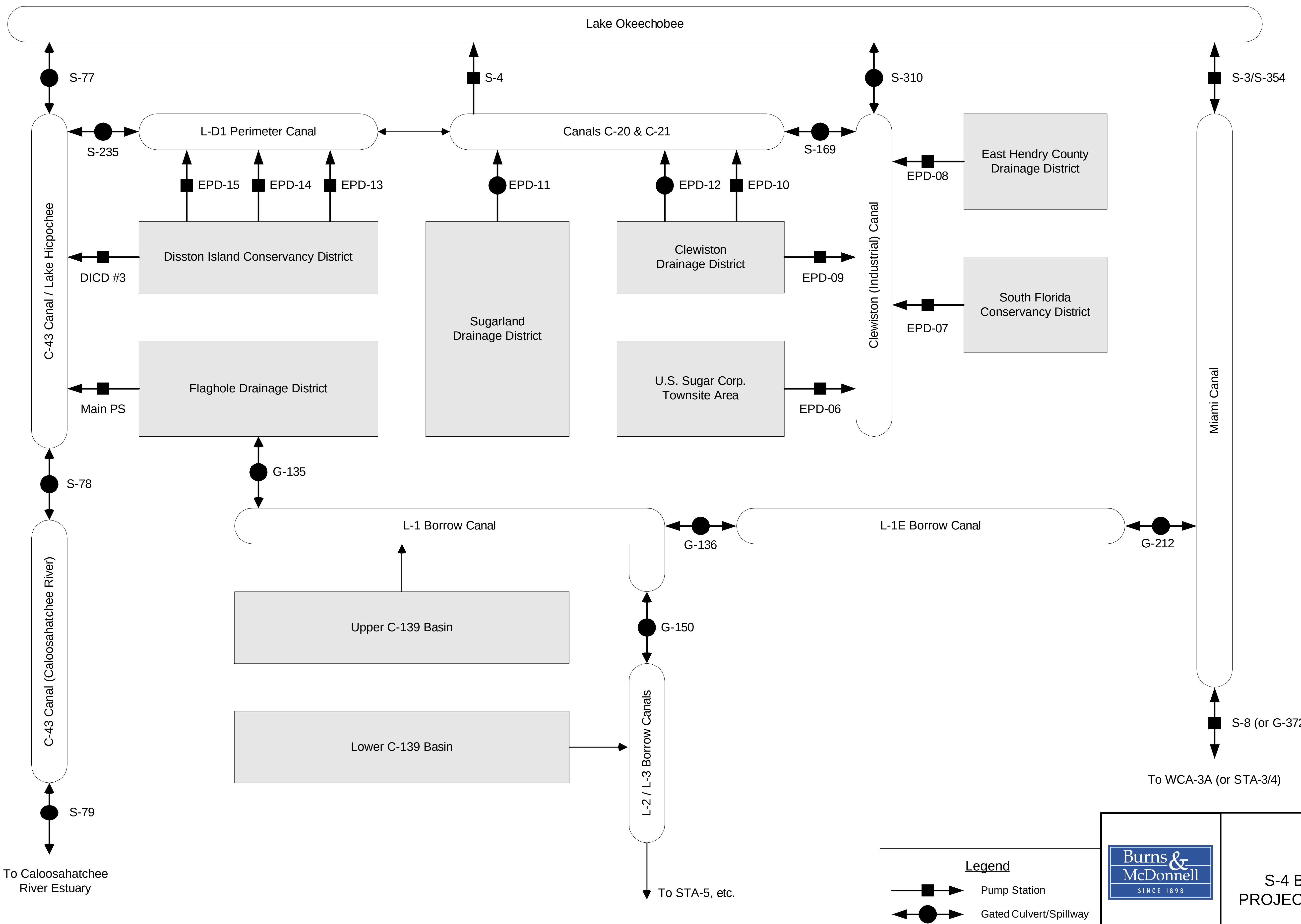


Figure 2-1
S-4 BASIN DIVERSION PROJECT AREA MAP



Burns & McDonnell SINCE 1898

Figure 2-2

S-4 BASIN DIVERSION PROJECT AREA SCHEMATIC

Except as noted above, the balance of the data used in this study was downloaded directly from SFWMD's environmental database, DBHYDRO. Data on daily mean flow rates, rainfall, and pan evaporation plus the results of TP sampling and analysis were obtained from DBHYDRO. The periods of record for these data varies by structure or monitoring station but are generally longer than for the EPD data, except for those structures that were placed into service more recently (SFWMD, no date).

TP concentrations and loads at structures or for time periods not provided directly by EPD or SFWMD were estimated by Burns & McDonnell from available sampling data. Where and when available, preference was given to concentration data from flow-weighted composite samples. For structures without composite sample data, grab sample data were used. The available grab sample data were screened to eliminate samples collected on days with no flow, or when water was flowing in the opposite direction. After screening, concentrations between the remaining grab samples were assumed to vary linearly with time.

The period of record selected for the analyses in this study is water years (WY) 1993–2004 (1 May 1992–30 April 2004). This 12-year period was selected based on the availability of the EPD monitoring data.

2.2 S-4 BASIN

There are a number of discharge structures — pump stations, culverts, spillways and locks — within the S-4 Basin where flow volumes and/or water quality are monitored. These structures are described briefly below, organized by drainage district.

2.2.1 Clewiston Drainage District

The Clewiston Drainage District is located in the northeast corner of the S-4 Basin in and around the City of Clewiston. This drainage district is bounded on the east by the Clewiston Canal (also known as the Industrial Canal) and on the north by Canal C-21. The Sugarland Drainage District abuts this district on the west and south.

Runoff from this district is discharged at the three primary structures listed below:

- Clewiston Pump Station No. 2 (EPD-10): Pump Station No. 2 is the largest capacity pump station in the Clewiston Drainage District and is located in the north-central part of the district. This station includes three pumps, each rated at 42,000 gallons per minute (gpm), that discharge to the C-21 Canal (Roberts, no date-a).

- Clewiston Pump Station No. 3 (EPD-09): This pump station is located in the southeastern part of this drainage district and discharges to the Clewiston Canal. There are two 36-inch pumps, both rated at 36,000 gpm, in this station (Roberts, no date-a).

- Clewiston C-21 Culvert (EPD-12): The discharge structure known as EPD-12 is a gated culvert that is located in the northwestern corner of this drainage district. This culvert discharges to the C-21 Canal but, according to the monitoring data provided by the EPD, there has been no flow through this culvert during the entire 12-year period of record.

Pump Station No. 1 is located in the northeast portion of the Clewiston Drainage District but is no longer in service.

2.2.2 Disston Island Conservancy District

The Disston Island Conservancy District (DICD) is located in the northwestern corner of the S-4 Basin. This district is bounded on the north by the L-D1 Borrow Canal and Lake Okeechobee; on the east by the C-20 Canal; on the south by the Nine Mile Canal, and Sugarland and Flaghole drainage districts; and on the west by the C-43 Canal and Lake Hicpochee. The part of this district that is generally west of U.S. Highway 27 is not considered to be part of the S-4 Basin but instead part of the C-43 Basin.

Drainage from this district is discharged at the four primary pump stations:

- DICD Pump Station No. 1 (EPD-15): Pump Station No. 1 is located in the northwestern portion of the DICD and discharges to the L-D1 Borrow Canal, which is also known as the Perimeter or Rim Canal. This pump station consists of two pumps and a gated culvert. One of the pumps is rated at 56,000 gpm and the other at 28,000 gpm (Roberts, no date-a). The available monitoring data for this pump station show it is operated only occasionally, with little or no discharge in some years.

- DICD Pump Station No. 2 (EPD-14): This pump station is located near the middle of the northern border of this drainage district and discharges to the L-D1 Borrow Canal. There are three pumps in this station. The nominal capacity of the first two pumps is 70,000 gpm but the capacity of the newer third pump is unknown (Roberts, no date-a).

- DICD Pump Station No. 3: Pump Station No. 3 is located at the western end of the DICD and discharges to Lake Hicpochee and the C-43 Basin. This pump station, which has a rated capacity of

80,000 gpm (DICD, no date), is not located within the S-4 Basin and is not monitored by the EPD. Therefore, no discharge records for this station are available in the EPD data obtained from SFWMD.

- DICD Pump Station No. 4 (EPD-13): Pump Station No. 4 is located in the eastern portion of the DICD, at the eastern end of DICD's Main Canal. This canal runs east-west through the district, with Pump Station No. 3 located at its western terminus. This pump station consists of three pumps, each rated at 30,000 gpm (Roberts, no date-a). The stormwater discharged at this pump station flows into the L-D1 Borrow Canal, just over a half mile west of the C-20 Canal and S-4 Pump Station.

2.2.3 East Hendry County Drainage District

The East Hendry County Drainage District is located on the shore of Lake Okeechobee, just east of Clewiston. This district lies between the Hendry-Palm Beach County line and the Clewiston Canal, and is bordered on the south by the South Florida Conservancy District.

There is a single discharge structure within this district, Pump Station No. 1 (EPD-08). This station consists of two pumps, an electric pump with a rated capacity of 12,000 gpm and a diesel pump of unknown capacity (Roberts, no date-a).[1]

2.2.4 South Florida Conservancy District

The South Florida Conservancy District, Unit No. 5 (SFCD) is located along of the shore of Lake Okeechobee, except for that portion that is within Hendry County and south of the East Hendry County Drainage District. It is this portion of the basin in Hendry County that is considered to be part of the S-4 Basin. The balance of the SFCD drains directly to Lake Okeechobee at Pump Station S-236 (P-5-N) or to the Miami Canal at Pump Station P-5-E.

There is a single SFCD pump station that discharges into the Clewiston Canal and the S-4 Basin. This pump station is known as P-5-W or EPD-07. This station contains four pumps, two with a nominal capacity of 48,000 gpm and two with a capacity of 38,000 gpm (Roberts, no date-a).

Similar to the diversion being studied for the S-4 Basin, there are plans to reduce discharges to Lake Okeechobee from the SFCD (S-236 Basin) by diverting drainage southward. These plans include canal improvements and the construction of a pump station at the eastern end of the district — an enlargement

[1] The pump equations used to estimate discharge from this pump station would seem to indicate that both pumps have a maximum capacity of 8,050 gpm (Roberts, no date-b).

or replacement for the existing Pump Station P-5-E. This new pump station would divert significant portions of the runoff from this basin into the Miami Canal for conveyance to STA-3/4 and the remaining two pump stations (S-236 and EPD-07) would be operated only in emergency situations.

The goal of this diversion project is to divert 80 percent of the runoff from the SFCD basin into the Miami Canal but, consistent with the operating experience for similar diversion systems in other drainage districts, actual diversion rates could be much higher than 80 percent. Historic discharge data for the three SFCD pump stations (August 1985 to February 1995), indicates approximately 56 percent of the total basin discharge occurred at EPD-07 (Searcy, 1997). Therefore, with diversion of 80 percent or more of the runoff from this basin, it is anticipated this diversion project will reduce future discharges at EPD-07 but the exact magnitude of these reductions is unknown. For subsequent analyses conducted for this study, base conditions assume discharges from EPD-07 will remain largely unchanged from historic operations but this assumption is considered to be conservative. To the extent that discharges from EPD-07 are reduced as a result of the current SFCD diversion project, the total diversion requirements from the S-4 Basin would be reduced as well. A sensitivity analysis was conducted to consider the possible impact of these anticipated discharge reductions at EPD-07.

2.2.5 Sugarland Drainage District

The Sugarland Drainage District is located in the center of the S-4 Basin. It shares boundaries with the Clewiston Drainage District, Disston Island Conservancy District, Flaghole Drainage District, and U.S. Sugar Townsite area. The eastern border of this district is formed by the Clewiston Canal.

The Sugarland Drainage District has only one primary discharge structure, the Sugarland Main Pump Station, or EPD-11. This pump station is located in the north-central part of this district and discharges to a short stub canal that connects with Canals C-20 and C-21 where these latter two canals intersect. At this structure, there is one pump and two gated weirs. The estimated TP concentrations in the discharge from this structure are based on grab samples (Roberts, no date-a).

2.2.6 U.S. Sugar Townsite Area

U.S. Sugar’s Townsite area is a large tract of farmland located in the southeastern corner of the S-4 Basin. This area, which covers approximately 14 square miles, abuts Levee 1 (L-1) and Levee 1 East (L-1E) along its southern border. Drainage from this area is discharged at U.S. Sugar’s Southline Pump Station (EPD-06). This pump station is located at the southern terminus of the Clewiston Canal and contains seven pumps: five rated at 22,000 gpm each and two rated at 45,000 gpm each.

2.2.7 SFWMD Structures

In addition to the EPD-monitored control structures described above, there are several structures within or adjacent to the S-4 Basin that are operated and monitored by SFWMD. Some of the structures included in this category are operated in cooperation with the U.S. Army Corps of Engineers (COE). Each of these structures is described below.

2.2.7.1 S-310 Lock

S-310 is a navigation lock structure located in L-D2, part of the Herbert Hoover Dike system that rings Lake Okeechobee. The lock chamber is 60 feet long by 50 feet wide. Under normal operation, this lock is left open to allow free passage of water and boats between Lake Okeechobee and the northern end of the Clewiston Canal. This lock is closed only when lake stages exceed 15.5 feet NGVD and during hurricane alerts to help prevent flooding within the S-4 Basin (Cooper, 1989).

When S-310 is open, drainage from the S-4 Basin is free to flow into Lake Okeechobee. The purpose of the proposed basin diversion project is to limit these flows to the extent practicable. The principal source of this drainage is discharge from one of the four primary pump stations located along the Clewiston Canal: EPD-06, EPD-07, EPD-08 and EPD-09. Though relatively uncommon, water can also flow into the Clewiston Canal and Lake Okeechobee through the S-169 culverts. Water also flows from the lake into the Clewiston Canal when necessary to meet water supply demands from this canal and the C-20 and C-21 canals via S-169.

Discharges through S-310 were estimated from data for the INDUST monitoring station (DBKEY 15628). In DBHYDRO, the location of this station is reported to be at the U.S. Highway 27 bridges over the Clewiston Canal, which are located about 2,000 feet south of S-310 and south of the canal that connects to S-169. However, comparison of the flow data for the INDUST station with that for the four EPD pump stations on the Clewiston Canal and S-169 indicates that the data for the INDUST station is actually a measure of flows between Lake Okeechobee and the Clewiston Canal at S-310. Positive flows at this station indicate releases from Lake Okeechobee to the canal and negative flows are discharges to the lake.

The TP concentrations in discharges to and from Lake Okeechobee at S-310 were estimated from sampling data retrieved from DBHYDRO for the INDUSCAN monitoring station. During the 12-year study period, data for 191 grab samples are available, which is an average collection interval of about once every 3.2 weeks. However, few of these samples were collected when flow was negative (from the

Clewiston Canal to Lake Okeechobee) so little credibility can be assigned to the corresponding TP load estimates.

2.2.7.2 S-169 Culverts

Structure S-169 is a series of gated culverts that connect the Clewiston Canal with the C-21 Canal. There are three 84-inch diameter by 60-foot long corrugated metal pipe (CMP) culverts in this structure with invert elevations of 6.0 feet. The gates for this culvert have three operating modes (Cooper, 1989):

- Auto: When stages in Lake Okeechobee are above 15.5 feet and the S-310 lock is closed, the gates at S-169 are adjusted automatically to maintain stages in the Clewiston Canal at about 15 feet (ranging from 14.7 to 15.2 feet). Any stormwater runoff discharged to the Clewiston Canal when S-169 is on auto is released to the C-21 Canal to keep canal stages within the target range.
- Closed: The gates at S-169 are kept closed when lake stages are between 13.0 and 15.5 feet. Under this operating mode, S-310 is open and any stormwater discharge to the Clewiston Canal would flow directly to Lake Okeechobee.
- Open: When lake stages are below 13.0 feet or during hurricane alerts, the gates at S-169 are left open to allow water to pass freely between the Clewiston and C-21 canals.

The historic flow data for S-169 was retrieved from DBHYDRO using two database keys: DBKEY 12774 through 3/10/1993 and 15590 starting on 3/11/1993. Sampling data for TP were also retrieved from DBHYDRO for station S169. During the study period, 173 grab samples were collected and analyzed at this structure. None of the available 173 grab samples were collected on days with negative flow at this structure so none are considered valid for estimating TP loads on negative flow days.

2.2.7.3 S-4 Pump Station

S-4 is a pump station in the alignment of the Hoover Dike (L-D1) at the northern end of the C-20 Canal, which pumps stormwater from the S-4 Basin to Lake Okeechobee. The purpose of this basin diversion study is to investigate ways to reduce or eliminate these lake discharges. This station contains three pumps, each rated at 935 cubic feet per second (cfs), for a total station capacity of 2,805 cfs. Under normal operations, pumping is started at this station whenever stages in the C-20 Canal exceed 14.0 feet NGVD and stopped when canal stages fall below 11.0 feet. During hurricane alerts, stages in the C-20 Canal are drawn down to and held at approximately 10.0 feet NGVD (Cooper, 1989).

The historic flow data for S-4 was retrieved from DBHYDRO using two database keys: DBKEY P1013 through 12/31/2002 and 15630 starting on 1/1/2003. Sampling data for TP were also retrieved from DBHYDRO for station S4. The TP sampling data for this station includes both flow-weighted composite samples and grab samples. In estimating daily TP concentrations in the discharge from this station, the composite samples were given precedence over the grab sample data.

2.2.7.4 S-235 Culverts

Structure S-235 is a series of gated culverts that connect the western end of the L-D1 Borrow Canal with the C-43 Canal (also know as the Caloosahatchee River). These culverts are located less than 400 feet downstream of the S-77 spillway, which controls discharge between Lake Okeechobee and the C-43 Canal. The S-235 structure consists of two 72-inch diameter by 70-foot long reinforced concrete pipe (RCP) culverts with invert elevations of 4.1 feet NGVD. The gates for these culverts are normally left open, and only closed when stages in Lake Okeechobee fall below 13.0 feet or during hurricane alerts (Cooper, 1989).

The majority of the flow through this structure is westward from the S-4 Basin to the C-43 Canal. Although there are rare instances when flow in the C-43 Canal reverses (that is, flows into Lake Okeechobee at S-77), the volume of water discharged at S-235 that may enter Lake Okeechobee is negligible. Therefore, virtually all of the discharge at S-235 flows down the C-43 Canal toward Lake Hicpochee, and not into Lake Okeechobee, so none of this discharge is considered to be a target for diversion.

The historic flow data for S-235 was retrieved from DBHYDRO using two database keys: DBKEY P094 through 12/31/2002 and 15590 starting on 1/1/2003. Although there is a water quality sampling station (S235) at this structure, it appears these samples are not tested for phosphorus because there is no TP concentration data available for this station in DBHYDRO. There is another water quality station located in the C-43 Canal in the vicinity of the S-235 tailwater (CR-00.2T) but, at best, the data at this station would be considered valid only during eastward (water supply) flows into the S-4 Basin.

2.2.8 S-4 Basin Discharge Summary

A discharge summary for each of the S-4 Basin structures discussed above is included in Table 2-1. This table lists average annual flow volumes in acre-feet (ac-ft), TP loads in kilograms (kg), and TP concentrations in part per billion (ppb).

Table 2-1: Discharge Summary for S-4 Basin Structures

Station No.	Description	Discharge Destination	Avg. Ann. Data, WY1993-2004		
			Flow (ac-ft)	TP Load (kg)	TP Conc. (ppb)
EPD-06	U.S. Sugar Southline Pump Sta.	Clewiston C.	21,556	5,403	203
EPD-07	SFCD P-5-W Pump Sta.	Clewiston C.	11,428	2,007	142
EPD-08	E. Hendry Co. Pump Sta. No. 1	Clewiston C.	1,415	553	317
EPD-09	Clewiston Pump Sta. No. 3	Clewiston C.	1,006	283	228
EPD-10	Clewiston Pump Sta. No. 2	C-21 Canal	2,336	643	223
EPD-11	Sugarland Main Pump Sta.	C-21 Canal	31,778	11,192	286
EPD-12	Clewiston C-21 Culvert	C-21 Canal	0	0	---
EPD-13	DICD Pump Sta. No. 4	L-D1 Canal	6,441	1,186	149
EPD-14	DICD Pump Sta. No. 2	L-D1 Canal	24,317	6,132	204
EPD-15	DICD Pump Sta. No. 1	L-D1 Canal	717	508	575
S-4	Pump Sta. S-4	L. Okeechobee	27,110	5,988	179
S-169	S-169 Culverts	C-21 Canal	39,401	4,235	87
		Clewiston C.	3,454	---	---
S-235	S-235 Culverts	C-43 Canal	65,650	---	---
		L-D1 Canal	10,048	1,644	133
S-310	S-310 Lock	L. Okeechobee	22,099	4,788	176
		Clewiston C.	42,162	4,755	91

2.3 C-43 BASIN

The C-43 Basin is located west of the S-4 Basin in Charlotte, Glades, Hendry and Lee counties. The principal conveyance facility in this basin is the C-43 Canal, or Caloosahatchee River, which connects Lake Okeechobee with the Gulf of Mexico. The western-most portion of the Disston Island Conservancy District and the entire Flaghole Drainage District drain directly to the C-43 Basin. Data for the three principal control structures on the C-43 Canal are summarized in the following sections.

2.3.1 S-77 Spillway

The S-77 spillway is located at the eastern terminus of the C-43 Canal and controls the discharge between this canal and Lake Okeechobee. The historic flow data for S-77 were downloaded from DBHYDRO for DBKEY P1022 through 12/31/2002 and 16535 starting 1/1/2003. Grab sample data collected at this location for water quality station S77 were also obtained from DBHYDRO. The available data for this structure show that reverse flows in the C-43 Canal (to Lake Okeechobee) are rare and were of significant volume in only 1 of the 12 years in the study period, WY 2002.

2.3.2 S-78 Spillway

The S-78 spillway is located about 15 miles downstream of Lake Okeechobee on the C-43 Canal. The historic flow data for S-78 were downloaded from DBHYDRO for DBKEY 00857 through 4/30/1996 and DJ236 starting 5/1/1996. Grab sample data collected at this location for water quality station S78 were also obtained from DBHYDRO.

2.3.3 S-79 Spillway

The last control structure on the C-43 Canal above the headwaters of the Caloosahatchee River estuary is the S-79 lock and spillway. This structure is located about 27 miles downstream of S-78. The historic flow data for S-79 were downloaded from DBHYDRO for DBKEY P1023 through 12/31/2003 and DJ237 starting 1/1/2004. Grab sample data collected at this location for water quality station S79 were also obtained from DBHYDRO.

2.3.4 C-43 Basin Discharge Summary

Table 2-2 includes a summary of the average annual discharge for each of primary structures in the C-43 Basin. Review of Table 2-2 shows the average annual discharge in the C-43 Canal at S-79 is over 1.5 million acre-feet. On average, nearly half (about 48 percent) of this discharge originates from Lake Okeechobee at S-77. As the various components of the Comprehensive Everglades Restoration Plan (CERP) are implemented in the next few years, it is anticipated that discharges from the lake at S-77 will decrease significantly. Therefore, discharges at S-78 and S-79 should decrease as well, with basin runoff constituting a larger portion of the remaining discharge.

Table 2-2: Discharge Summary for C-43 Basin Structures

Station No.	Description	Discharge Destination or Direction	Avg. Ann. Data, WY1993-2004		
			Flow (ac-ft)	TP Load (kg)	TP Conc. (ppb)
S-77	S-77 Lock and Spillway	C-43 Canal	751,539	63,421	68
		L. Okeechobee	7,294	1,219	135
S-78	S-78 Lock and Spillway	Westward	954,851	115,380	98
S-79	S-79 Lock and Spillway	Westward	1,569,213	249,860	129

2.4 C-139 BASIN

The C-139 drainage basin is classified as one of the Western Basins, those basins that drain into the Everglades Protection Area but are west of the EAA. This basin in located south of the S-4 Basin and covers approximately 243 square miles (Mock, Roos & Associates, 1993) (Figure 1-1). The C-139 Basin is bounded on the north and east by the L-1, L-2 and L-3 borrow canals and on the south by the Deer Fence Canal. On Figure 2-1, this map shows only about the eastern half of the C-139 Basin but it is the principal conveyance canals in this basin that are of primary interest in this study. The other large canals in the basin are the L-2W Borrow, Midway, Alico South and S&M canals.

The principal control structures and other flow monitoring stations in this basin are discussed in the following sections.

2.4.1 G-135 Culvert

Structure G-135 is a gated culvert that connects the upper reaches of the L-1 Borrow Canal with the Flaghole Drainage District. This culvert is intended to be opened only during emergency conditions to help alleviate flooding in the upper C-139 Basin. Although negative flows have been recorded at this structure (that is, flow into the C-139 Basin), these negative flows are relatively insignificant and most of the flow that passes through this structure enters the Flaghole Drainage District and C-43 Basin. These discharges from the C-139 Basin at G-135 are assumed to continue into the future and are not a target for redirection elsewhere.

2.4.2 G-136 Culverts

Structure G-136 is a series of gated culverts that connect the L-1 and L-1 East (L-1E) borrow canals. This structure, G-150 and the L-1E Borrow Canal were constructed in the early 1980s to help alleviate flooding problems in the upper C-139 Basin. The G-136 structure consists of three 84-inch diameter by 80-foot long CMP culverts with invert elevations of 8.0 feet NGVD. The flow in these culverts is controlled by stop logs in risers, with the stop log crest normally set at elevation 13.0 feet. These stop logs are raised to elevation 14.0 feet only when tailwater stages in the L-1E Canal exceed 15.5 feet, a very rare occurrence based on historic monitoring data.

During periods of higher runoff, G-150 may be closed to divert all of the drainage from the upper C-139 Basin — that portion of the basin above G-150 — eastward through G-136 into the L-1E Canal and S-3/S-8 Basin. Much of the discharge through G-136 will eventually pass through STA-3/4 for treatment.

The historic flow data for G-136 was retrieved from DBHYDRO using two database keys: DBKEY P1038 through 12/31/2002 and 15195 starting on 1/1/2003. The associated water quality monitoring station (G136) has data for both flow-weighted composite and grab samples. The flow and TP discharge data for G-136 were provided by SFWMD staff (Burns & McDonnell, 2005a).

2.4.3 G-150 Culverts

Structure G-150 is a series of gated culverts located at the intersection of the L-1 and L-2 borrow canals. The intersection of the L-2 and L-2W canals is immediately below (south) of G-150. G-150 consists of three 84-inch diameter by 40-foot long CMP culverts, with invert elevations of 8.5 feet. The flow through these culverts can be regulated by slide gates located on the south ends of these culverts.

During periods of higher runoff in the C-139 Basin, high stages in the L-2 Borrow Canal serve to restrict southward flow out of the upper basin through G-150, causing localized flooding in the upper basin. The critical flood stage in the L-1 Borrow Canal near G-136 is elevation 14 feet. When G-136 headwater elevations exceed 14 feet, the gates at G-150 are closed to prevent backflow into the upper basin and all drainage from the upper basin is routed eastward through G-136. There is no flow monitoring or regular water quality sampling at structure G-150.

2.4.4 L-3 Borrow Canal

All drainage from the lower C-139 Basin, plus any discharge from the upper basin through G-150, is conveyed southward via the L-2 and L-3 borrow canals. Prior to construction of STA-5 in 1999, this drainage continued south toward the corner between Broward, Hendry and Palm Beach counties. At this location, there are three control structures on the L-3 Borrow Canal:

- G-88 — Controls discharges eastward into the L-4 Borrow Canal
- G-89 — Controls discharges into the L-28 Borrow Canal
- G-155 — Controls discharges into the L-3 Canal Extension and Water Conservation Area 3A (WCA-3A)

With the construction of STA-5, most of the drainage from the C-139 Basin — the remaining portion that is not diverted eastward through G-136 — is now diverted into this stormwater treatment area via Structures G-342A through G-342D (Figure 2-1). Structure G-406 was constructed across the L-3 Borrow Canal, immediately south of its confluence with the Deer Fence Canal, to help force this drainage into STA-5. With the planned expansion of STA-5, there will likely be additional culverts similar to the G-342 culverts constructed along the L-3 canal and structure G-406 will either be relocated southward or eliminated.

The historic discharge in the L-3 Borrow Canal, at the current location of G-406, was estimated from the flow records for all of the above-mentioned structures, as described below:

- 5/1/1992 – 12/31/1995: Daily discharges in the L-3 Borrow Canal were calculated as the sum of the discharges at G-88, G-89 and G-155. There are no significant inflow sources between the location of G-406 and these three structures so the flow data for these structures are still valid even though they are located about 8.5 miles farther downstream. The discharge data for G-88, G-89 and G-155 were downloaded from DBHYDRO for DBKEYs P1052, P0153, and P1039, respectively. TP concentrations in these flows were estimated from sampling data for station L3. At times, there was negative flow at G-155 but these negative flows were ignored (assumed to be zero) for this analysis.
- 1/1/1996 – 6/25/2000: Flows at monitoring station L3DF (DBKEY 16243), plus flows for culverts G-342A through G-342D once they became operational in October 1999 (DBKEYs J6406, J6398, J6407 and J6405), were used. For L3DF, water quality data for station L3BRS (grab samples) and C139DFC (composite samples) were used to estimate TP concentrations. For the four G-342 culverts, both composite and grab sample data are available at water quality stations of the same name.
- 6/26/2000 – 4/30/2004: The sum of the discharges at structures G-406 (DBKEY JU789), G-342A, G-342B, G-342C and G-342D. Composite and grab sample data are also available at G-406.

The composite historic flows for these structures represent the potential or actual runoff from the C-139 Basin that would have been available for diversion into STA-5.

2.4.5 C-139 Basin Discharge Summary

Table 2-3 includes a summary of the average annual discharge for structure G-136 and the L3 Borrow Canal. There is only one sampling result for TP available during the first two years of the study period at G-136, an uncharacteristically low value of 22 ppb. After excluding these two years, the average TP concentration at this structure increases to 189 ppb.

Table 2-3: Discharge Summary for C-139 Basin Structures

Station No.	Description	Discharge Destination or Direction	Avg. Ann. Data, WY1993-2004		
			Flow (ac-ft)	TP Load (kg)	TP Conc. (ppb)
G-136	G-136 Culverts	S-3/S-8 Basin	17,479	3,522	163
L-3	L-3 Borrow Canal at G-406	Southward	167,291	44,034	213

2.5 S-3/S-8 BASIN

The S-3 and S-8 drainage basins are both drained by the Miami Canal so they are normally considered together. These two drainage basins are located respectively east and southeast of the S-4 Basin. There are dozens of water control structures in the S-3/S-8 Basin but the data for only two of these structures are summarized below. These two structures are S-3/S-354 and S-8.

2.5.1 S-3 Pump Station and S-354 Spillway

The S-3 pump station and S-354 spillway are two adjacent structures located on Lake Okeechobee at the head (northern end) of the Miami Canal. Bidirectional flow is possible at this location but current operating policies strive to minimize back pumping to Lake Okeechobee. Daily estimates for flow volumes and TP loads for these structures were provided by SFWMD staff (Burns & McDonnell, 2005a).

2.5.2 S-8 Pump Station

The S-8 pump station is located on the Miami Canal at the southern boundary of the S-3/S-8 Basin. Water Conservation Area 3A (WCA-3A) is located to the south of this pump station. Since construction of STA-3/4, much of the southward discharge at S-8 would now be diverted into this treatment area at Pump Station G-372. Therefore, the historic data for S-8 would also represent potential inflows to STA-3/4 at G-372. The discharge volumes and TP loads at S-8 were provided by SFWMD staff (Burns & McDonnell, 2005a).

2.5.3 S-3/S-8 Basin Discharge Summary

Table 2-4 includes a summary of the average annual discharge for structures S-3/S-354 and S-8. Historically, Table 2-4 shows most of the flow in this basin has been from north to south: from Lake Okeechobee to the S-3/S-8 Basin and from the S-3/S-8 Basin to WCA-3A.

Table 2-4: Discharge Summary for S-3/S-8 Basin Structures

Station No.	Description	Discharge Destination or Direction	Avg. Ann. Data, WY1993-2004		
			Flow (ac-ft)	TP Load (kg)	TP Conc. (ppb)
S-3/ S-354	Pump Sta. S-3 and S-354 Spillway	Miami Canal	139,958	13,824	80
		L. Okeechobee	19,001	3,068	282
S-8	S-8 Pump Sta. and Spillway	WCA-3A	360,064	44,166	99
		Miami Canal	687	103	121

2.6 METEOROLOGICAL DATA

Meteorological data on historic rainfall and evaporation were also collected for the study area. Five stations were selected from those available in DBHYDRO to characterize rainfall:

- SFWMD's Clewiston Field Station: Station CLEW.FS_R (DBKEY 16696)
- Devil's Garden Drainage District: Station DEVILS_R (DBKEY IV150)
- G-136: Station G136_R (DBKEY 16598)
- S-4: Station S4_R (DBKEY 16650)
- S-77: Station S77_R (DBKEY 16624)

The precipitation data for these five stations are summarized in Table 2-5.

Table 2-5: Summary of Study Area Rainfall

Water Year	Annual Rainfall (inches)				
	Clewiston FS	Devil's Garden	G-136*	S-4	S-77
1993	46.7	56.9	---	47.4	50.3
1994	45.9	61.1	---	33.7	39.0
1995	48.6	60.3	26.5	59.4	61.6
1996	54.4	60.9	55.2	46.9	56.0
1997	45.9	54.3	47.7	37.8	38.9
1998	50.1	58.2	58.2	47.6	54.3
1999	46.6	57.2	59.7	39.8	43.3
2000	60.3	55.9	81.9	32.1	44.9
2001	27.1	33.8	26.2	25.9	33.8
2002	49.9	62.0	41.2	15.7	44.2
2003	46.6	62.3	45.7	29.2	57.8
2004	47.9	54.3	52.2	22.7	43.6
Min. Ann.	27.1	33.8	26.2	15.7	33.8
Max. Ann.	60.3	62.3	81.9	59.4	61.6
Avg. Ann.	47.5	56.4	46.7	36.5	47.3

* Rainfall data for G-136 starts in Oct 1994 so the average annual rainfall is calculated from 10.58 years (10 years, 7 months) of data.

Evaporation data were also collected for the study vicinity. Unfortunately, there are no meteorological stations within the S-4 or C-139 basins with continuous evaporation data for the entire study period. The closest such station is located at Pump Station S-5A, which is approximately 34 miles east of the study area. Pan evaporation data for this station (DBKEY PN932) was obtained from DBHYDRO and is summarized by water year in Table 2-6. Lake evaporation estimates were calculated from the pan evaporation data using a pan coefficient of 76 percent.

Table 2-6: Evaporation Data Summary for Pump Station S-5A

Water Year	Pan Evaporation (inches	Lake Evaporation (inches)
1993	51.9	39.4
1994	55.7	42.3
1995	52.0	39.5
1996	50.3	38.2
1997	47.1	35.8
1998	48.9	37.2
1999	51.8	39.4
2000	48.8	37.1
2001	50.4	38.3
2002	53.3	40.5
2003	55.6	42.3
2004	54.1	41.1
Min. Ann.	47.1	35.8
Max. Ann.	55.7	42.3
Avg. Ann.	51.7	39.3

* * * * *

3.0 DIVERSION ALTERNATIVES

This report section presents estimates of the volumes and TP loads in drainage from the S-4 Basin that have historically been discharged to Lake Okeechobee and discusses alternatives for diversion of this drainage to an alternate destination.

3.1 DESIRED DIVERSION VOLUMES AND TP LOADS

The available historic data on runoff volumes and TP loads for the S-4 Basin are presented and summarized in Chapter 2. In this section, these base historic data are used to estimate the daily runoff volumes and associated TP loads that are now discharged to Lake Okeechobee and targeted for diversion elsewhere. The first step in this process was to divide the S-4 Basin into two subbasins, the eastern and western subbasins.

3.1.1 Eastern Subbasin

The eastern subbasin is composed of those areas that drain to the Clewiston (Industrial) Canal. Included in this subbasin are all or portions of five drainage districts:

- Clewiston Drainage District — portion drained by Pump Station No. 3 only (EPD-09)
- East Hendry County Drainage District (EPD-08)
- South Florida Conservancy District, Unit 5 — S-4 Basin portion that is drained by Pump Station P-5-W (EPD-07) only
- U.S. Sugar Corporation Townsite area (EPD-06)

There are four EPD pump stations that discharge to the Clewiston Canal: EPD-06, EPD-07, EPD-08 and EPD-09. The other relevant control structures in this subbasin are S-310 and S-169. Hydraulically, structure S-169 forms the dividing point between the eastern and western subbasins (Figure 2-2).

The total reported discharge from the four EPD monitoring stations in the eastern subbasin plus any inflow from the western subbasin at S-169 was compared on a daily basis with the discharge at structures S-310 and S-169. Theoretically, the total discharge at the four pump stations should equal the sum of the discharge to Lake Okeechobee at S-310 and the westward flow at S-169 but rarely do these two totals balance. There are a number of possible reasons for these imbalances:

- Concurrent Irrigation Withdrawals: There are no records of irrigation withdrawals from the Clewiston Canal or any of the other canals within the S-4 Basin. It is possible there are days when one district may be discharging water when another is withdrawing water for irrigation. Any such concurrent irrigation withdrawals would cause a flow imbalance.
- Changes in Canal Storage: Canal stages and storage will increase, at least locally, whenever water is discharged from one of the pump stations. These changes in canal storage are not monitored and would also contribute to an apparent water imbalance.
- Measurement Errors: Some error can be expected in all flow measurements. If these errors do not balance one another, they would contribute to an apparent flow imbalance.

To the extent possible, the total discharge from the four EPD pump stations in the eastern subbasin was allocated to either S-310 or S-169 each day there was some discharge at these pump stations and a net outflow from the subbasin as a whole. Pump discharges that occurred on days with no flow or a net flow into the eastern subbasin at S-310 and S-169 were assumed to be recaptured by concurrent irrigation withdrawals, or to contribute to rising canal stages. It was assumed these latter discharges, which were generally of small magnitude, would not contribute to S-4 Basin discharge.

A couple examples of this allocation process are listed below:

- On 20 July 1992, the total discharge to the Clewiston Canal from the four EPD monitoring points was 107.9 cfs (97.4 cfs from EPD-07 and 10.5 cfs from EPD-08). On this same day, the discharge to Lake Okeechobee at S-310 was 43.0 cfs and the westward flow through S-169 was 41.3 cfs. Therefore, 43.0 cfs of the EPD discharge was allocated to S-310 and another 41.3 cfs to S-169. The remainder (23.6 cfs) was assigned to an imbalance term. If the total discharge at S-310 and S-169 had exceeded that at the four EPD pump stations, the EPD-monitored discharge would have been allocated proportionately to S-310 and S-169.
- On 9 September 1992, there was an average inflow from Lake Okeechobee to the Clewiston Canal of 46 cfs at S-310 and no flow at S-169. On this same day, there was a mean discharge at EPD-08 of 17.9 cfs. For purposes of estimating S-4 Basin discharge, the EPD-08 discharge on this date was disregarded.

3.1.2 Western Subbasin

The western subbasin is composed of those portions of the S-4 Basin that drain to Canals C-20 or C-21, or the L-D1 Borrow Canal. The drainage districts included in this subbasin are listed below:

- Clewiston Drainage District — portion drained by Pump Station No. 2 (EPD-10)
- Disston Island Conservancy District — S-4 Basin portion only (EPD-13, EPD-14, and EPD-15)
- Sugarland Drainage District (EPD-11)

There are six EPD discharge points that drain to the canals in this subbasin: EPD-10, EPD-11, EPD-12, EPD-13, EPD-14, and EPD-15. The discharge from this subbasin to surrounding areas is controlled by Pump Station S-4, and structures S-169 and S-235.

A similar procedure was employed within the western subbasin to allocate the discharge from the six monitoring points to one of the three subbasin outlets — discharge to Lake Okeechobee at the S-4 pump station, discharge to C-43 Canal at S-235 and eastward flow at structure S-169 into the eastern subbasin — on days when a net outflow occurred from the subbasin. For the same reasons mentioned above, these canal inflows and outflows did not usually balance.

3.1.3 Adjusted Basin Discharge Allocation

The process described above allocated the combined discharge from the ten EPD monitoring points to one of the three basin discharge points (S-310, S-4 and S-235) or an imbalance term on each day during the 12-year period of record with a net basin outflow. These preliminary allocations are summarized in Table 3-1 along with the measured discharge at the three basin discharge points.

Table 3-1 shows that net annual basin discharges are estimated to average 94,396 acre-feet out of a total measured discharge at the ten EPD monitoring stations of 100,993 acre-feet. These average totals imply that approximately 6.5 percent of the total discharge at these stations is recaptured for basin irrigation (difference between total and net discharge), which appears to be a reasonable amount. Unfortunately, as also shown by review of this table, the unallocated portion of the net EPD discharge averaged about 21.5 percent of the net total discharge (20,300 out of 94,396 acre-feet per year). Comparing the total EPD discharge with the measured total basin discharge also shows that the measured S-4 Basin discharge is larger in most years, and on average, than the total EPD-measured discharge. Therefore, it was concluded that the unallocated imbalance flows should not be just assigned to measurement error and ignored. Instead, these imbalance flows were redistributed to one of the basin outlets using the calculated distribution of the allocated flows on the same day.

Table 3-1: Preliminary EPD Discharge Volume Allocation

Water Year	EPD (ac-ft)		Preliminary Allocation (ac-ft)				Measured Basin Discharge (ac-ft)			
	Total[1]	Net[2]	S-310	S-4	S-235	Imbal-ance[3]	S-310[4]	S-4	S-235[4]	Total
1993	114,181	112,823	14,836	24,243	49,977	23,766	16,991	25,645	107,985	150,621
1994	87,518	85,330	32,566	7,304	24,891	20,569	34,243	10,094	42,964	87,301
1995	114,753	110,145	11,527	38,282	42,368	17,967	12,352	54,158	63,971	130,480
1996	92,073	89,746	9,417	45,048	28,862	6,419	19,484	71,805	69,418	160,707
1997	77,569	75,831	24,136	9,714	29,636	12,344	35,119	12,074	74,921	122,114
1998	90,632	87,868	18,183	29,028	31,379	9,278	30,328	34,304	66,063	130,695
1999	90,092	78,508	4,775	26,396	30,618	16,720	6,036	30,985	63,871	100,891
2000	178,089	175,589	25,553	43,038	56,052	50,945	27,252	44,070	70,274	141,595
2001	94,566	67,371	11,429	186	13,164	42,592	14,250	649	28,571	43,469
2002	61,814	44,503	14,905	7,326	15,163	7,109	18,438	15,212	65,568	99,218
2003	110,404	106,796	34,951	5,677	44,658	21,510	36,152	6,870	68,499	111,520
2004	100,220	98,233	13,531	17,048	53,277	14,378	14,548	19,456	65,689	99,693
Min.	61,814	44,503	4,775	186	13,164	6,419	6,036	649	28,571	43,469
Max.	178,089	175,589	34,951	45,048	56,052	50,945	36,152	71,805	107,985	160,707
Avg.	100,993	94,395	17,984	21,107	35,004	20,300	22,099	27,110	65,650	114,859

1. Sum of the discharge from all ten EPD monitoring stations: EPD-06 through EPD-15.
2. Total net S-4 Basin discharge attributed to monitoring stations EPD-06 through EPD-15. Discharges occurring on days with net basin inflow are omitted from net totals.
3. EPD discharge that could not be allocated to one of the basin outlets.
4. Total S-4 Basin discharges only; basin inflows are omitted from totals.

After the flow imbalances were redistributed to one of the three basin outlets, the EPD-measured TP loads were distributed in a similar fashion. The total measured phosphorus load each day was allocated using the same ratios as the corresponding flow volumes. As discussed in Chapter 2, there are no sampling data for TP at S-235 and only limited grab sample data at S-310. The S-4 pump station is the only one of the basin outlets with a reasonably good record of TP discharges. Therefore, the TP concentration data and loads reported by the EPD are considered to be the best available measure of TP discharges from the S-4 Basin.

Tables 3-2 through 3-4 present annual summaries of these flow and TP discharge allocations for S-310, S-4 and S-235, respectively. In addition to annual flow volumes, TP loads, and TP concentrations, these tables also list the peak annual discharge rates. These peak flow rates are based on mean daily discharge data so instantaneous peak discharges were most likely higher. Table 3-5 is a summary of the total discharges to Lake Okeechobee at S-310 and S-4.

Table 3-2: Summary of S-4 Basin Discharge to Lake Okeechobee at S-310

Water Year	Flow Volume (ac-ft)	Flow Volume (hm^3)	Peak Flow (cfs)	TP Load (kg)	TP Conc. (ppb)
1993	18,223	22.48	669	5,914	263
1994	42,257	52.12	1,294	8,092	155
1995	15,932	19.65	933	3,162	161
1996	10,652	13.14	311	1,604	122
1997	28,333	34.95	613	6,590	189
1998	19,436	23.97	461	5,268	220
1999	7,454	9.19	379	2,073	225
2000	32,899	40.58	788	9,397	232
2001	35,383	43.64	1,869	8,208	188
2002	18,678	23.04	446	6,417	279
2003	47,285	58.32	1,062	11,987	206
2004	16,645	20.53	491	4,842	236
Min. Ann.	7,454	9.19	311	1,604	---
Max. Ann.	47,285	58.32	1,869	11,987	---
Avg. Ann.	24,431	30.14	---	6,130	203

Table 3-3: Summary of S-4 Basin Discharge to Lake Okeechobee at S-4

Water Year	Flow Volume (ac-ft)	Flow Volume (hm^3)	Peak Flow Rate (cfs)	TP Load (kg)	TP Conc. (ppb)
1993	31,424	38.76	1,356	9,700	250
1994	10,311	12.72	1,176	2,293	180
1995	41,826	51.59	1,116	10,344	201
1996	46,864	57.81	2,006	13,977	242
1997	11,078	13.66	554	3,012	220
1998	32,950	40.64	1,412	12,283	302
1999	31,099	38.36	1,708	8,949	233
2000	58,370	72.00	1,153	16,119	224
2001	303	0.37	140	24	64
2002	7,933	9.79	527	3,088	316
2003	7,042	8.69	754	2,377	274
2004	18,852	23.25	876	6,033	259
Min. Ann.	303	0.37	140	24	---
Max. Ann.	58,370	72.00	2,006	16,119	---
Avg. Ann.	24,838	30.64	---	7,350	240

Table 3-4: Summary of S-4 Basin Discharge to C-43 Canal at S-235

Water Year	Flow Volume (ac-ft)	Flow Volume (hm^3)	Peak Flow Rate (cfs)	TP Load (kg)	TP Conc. (ppb)
1993	63,176	77.93	886	18,793	241
1994	32,761	40.41	768	6,207	154
1995	52,299	64.51	666	10,389	161
1996	31,837	39.27	594	6,659	170
1997	36,419	44.92	652	7,988	178
1998	35,482	43.77	776	8,402	192
1999	39,917	49.24	839	11,421	232
2000	84,319	104.01	924	26,005	250
2001	31,684	39.08	1,345	9,835	252
2002	17,817	21.98	431	5,717	260
2003	52,359	64.58	565	14,000	217
2004	62,729	77.38	497	19,616	254
Min. Ann.	17,817	21.98	431	5,717	---
Max. Ann.	84,319	104.01	1,345	26,005	---
Avg. Ann.	45,067	55.59	---	12,086	217

Table 3-5: Summary of Total S-4 Basin Discharge to Lake Okeechobee*

Water Year	Flow Volume (ac-ft)	Flow Volume (hm^3)	Peak Flow Rate (cfs)	TP Load (kg)	TP Conc. (ppb)
1993	49,647	61.24	1,696	15,613	255
1994	52,569	64.84	2,019	10,384	160
1995	57,759	71.24	1,116	13,506	190
1996	57,516	70.94	2,006	15,581	220
1997	39,411	48.61	944	9,602	198
1998	52,386	64.62	1,412	17,552	272
1999	38,553	47.55	1,810	11,022	232
2000	91,270	112.58	1,491	25,516	227
2001	35,686	44.02	1,869	8,232	187
2002	26,611	32.82	851	9,505	290
2003	54,327	67.01	1,298	14,364	214
2004	35,498	43.79	876	10,876	248
Min. Ann.	26,611	32.82	851	8,232	---
Max. Ann.	91,270	112.58	2,019	25,516	---
Avg. Ann.	49,269	60.77	---	13,479	222

* Total EPD discharge to Lake Okeechobee from the S-4 Basin at structures S-310 and S-4.

The daily discharge estimates that are summarized in Table 3-5 are in fact the desired basin diversion amounts because the goal of this proposed diversion project is to limit discharges to Lake Okeechobee from the S-4 Basin. Review of this table shows that the available diversion volumes range from 26,611 to 91,270 acre-feet per year and average 49,269 acre-feet, which is an average rate of about 68 cfs. The average flow-weighted TP concentration in discharge to Lake Okeechobee is estimated to be 222 ppb.

The balance of the drainage from the EPD structures in the S-4 Basin is currently discharged to the C-43 Canal at S-235. These discharge volumes and TP loads average respectively 45,067 acre-feet and 12,086 kg per year (Table 3-4). Discharges to the C-43 Canal, which account for nearly half (47.7 percent) of the total basin discharge, are not targeted for diversion to any alternate destination.

3.1.4 Desired S-4 Basin Diversions after SFCD Diversions

As discussed in Section 2.2.4, there are current plans underway in the South Florida Conservancy District (SFCD) to divert at least 80 percent of its drainage away from Lake Okeechobee. These diversions are mandated under Florida's Everglades Forever Act. Historically, approximately half of the drainage from this district has been discharged to the Clewiston Canal and S-4 Basin at EPD-07. Once operational, the SFCD diversion system is expected to reduce the discharges at EPD-07 significantly; there will likely still be occasional discharges at this station during major storm events but on average, the discharge from this pump station should approach zero.

For the 12-year period of record for this study, the discharge at EPD-07 has averaged 11,428 acre-feet per year (Table 2-7), which is more than 20 percent of the total desired S-4 Basin diversions. Therefore, a significant reduction in the discharge at EPD-07 will have a similar effect on the quantities of water that would need to be diverted away from Lake Okeechobee from the S-4 Basin. To quantify these impacts on desired diversion quantities and TP loads, the allocation process described above was repeated with an adjusted series of EPD-07 discharges.

In the future, after completion of the SFCD diversion system, discharges at EPD-07 should become relatively rare. The most common discharges would likely occur during emergency situations when the necessary basin drainage exceeds the capacity of the proposed diversion system. Assuming this diversion system was operational during the available historic record at this station, one can assume these emergencies would probably coincide with periods when the discharge at this station was high historically. Therefore, it was assumed that the highest discharges would still occur at this station but all lesser discharge would become zero. The nominal discharge capacity of EPD-07 is 172,000 gpm, or about

383 cfs. A cutoff discharge rate of 250 cfs, which is about 65 percent of the nominal station capacity, was selected for use in screening the historic discharge record at EPD-07 (that is, all discharges above 250 cfs would still occur and all discharges of 250 cfs or less would be eliminated). An annual summary of the adjusted discharge at EPD-07 is shown in Table 3-6.

Table 3-6: Summary of Adjusted EPD-07 Discharge

Water Year	Flow		TP Load (kg)	TP Conc. (ppb)
	(ac-ft)	(hm^3)		
1993	574	0.71	198	280
1994	569	0.70	84	120
1995	1,159	1.43	286	200
1996	1,648	2.03	406	200
1997	0	0.00	0	---
1998	0	0.00	0	---
1999	1,960	2.42	851	352
2000	0	0.00	0	---
2001	0	0.00	0	---
2002	0	0.00	0	---
2003	0	0.00	0	---
2004	0	0.00	0	---
Min. Ann.	0	0.00	0	---
Max. Ann.	1,960	2.42	851	---
Avg. Ann.	493	0.61	152	250

Comparing the original and adjusted discharge records at this station (Tables 2-1 and 3-6, respectively) shows average annual discharges are predicted to decrease by over 95 percent, from 11,428 to 493 acre-feet. The average flow-weighted TP concentrations would almost double from 142 to 250 ppb. This latter phenomenon occurs because TP concentrations are typically higher when discharges are also high.

Using the adjusted EPD-07 discharges, the results of the flow and TP load allocation procedure are summarized in Tables 3-7 through 3-10. Note that because there is often not a clear, direct relationship between discharge at the various EPD pump stations and at the basin discharge points (S-310, S-4 and S-235), no attempt was made to adjust the discharge at these latter locations before re-applying the flow and load allocation procedure. This shortcoming probably results in a slight overestimation of S-4 Basin discharges (that is, the net impact of these EPD-07 discharge reductions could be larger than indicated, which would make these desired diversion estimates somewhat conservative).

Table 3-7: Summary of S-4 Basin Discharge at S-310 after SFCD Diversion

Water Year	Flow Volume (ac-ft)	Flow Volume (hm^3)	Peak Flow (cfs)	TP Load (kg)	TP Conc. (ppb)
1993	11,936	14.72	669	4,055	275
1994	27,476	33.89	949	5,610	166
1995	10,615	13.09	853	1,700	130
1996	3,464	4.27	270	780	183
1997	19,753	24.36	541	4,896	201
1998	16,154	19.93	389	4,835	243
1999	6,851	8.45	343	1,945	230
2000	28,978	35.74	756	8,217	230
2001	35,222	43.45	1,869	8,182	188
2002	16,729	20.64	415	6,133	297
2003	41,779	51.53	939	11,333	220
2004	13,987	17.25	444	4,327	251
Min. Ann.	3,464	4.27	270	780	---
Max. Ann.	41,779	51.53	1,869	11,333	---
Avg. Ann.	19,412	23.94	---	5,168	216

Table 3-8: Summary of S-4 Basin Discharge at S-4 after SFCD Diversion

Water Year	Flow Volume (ac-ft)	Flow Volume (hm^3)	Peak Flow Rate (cfs)	TP Load (kg)	TP Conc. (ppb)
1993	28,919	35.67	1,217	9,326	261
1994	10,429	12.86	1,292	2,329	181
1995	33,312	41.09	956	8,828	215
1996	40,636	50.12	2,006	12,893	257
1997	10,742	13.25	528	3,111	235
1998	31,025	38.27	1,301	12,039	315
1999	29,609	36.52	1,708	8,494	233
2000	56,824	70.09	1,089	16,024	229
2001	303	0.37	140	24	64
2002	7,828	9.66	527	3,274	339
2003	6,900	8.51	754	2,431	286
2004	16,963	20.92	713	5,812	278
Min. Ann.	303	0.37	140	24	---
Max. Ann.	56,824	70.09	2,006	16,024	---
Avg. Ann.	22,791	28.11	---	7,049	251

Table 3-9: Summary of S-4 Basin Discharge at S-235 after SFCD Diversion

Water Year	Flow Volume (ac-ft)	Flow Volume (hm^3)	Peak Flow Rate (cfs)	TP Load (kg)	TP Conc. (ppb)
1993	55,705	68.71	713	17,273	251
1994	31,918	39.37	844	6,203	158
1995	41,566	51.27	666	8,165	159
1996	26,391	32.55	594	5,893	181
1997	34,021	41.96	710	7,944	189
1998	33,313	41.09	776	8,242	201
1999	38,251	47.18	805	11,103	235
2000	83,179	102.60	924	25,988	253
2001	31,641	39.03	1,345	9,822	252
2002	17,515	21.60	431	5,651	262
2003	50,435	62.21	586	14,058	226
2004	58,467	72.12	465	19,464	270
Min. Ann.	17,515	21.60	431	5,651	---
Max. Ann.	83,179	102.60	1,345	25,988	---
Avg. Ann.	41,867	51.64	---	11,650	226

Table 3-10: Total S-4 Basin Discharge to Lake Okeechobee after SFCD Diversion*

Water Year	Flow Volume (ac-ft)	Flow Volume (hm^3)	Peak Flow Rate (cfs)	TP Load (kg)	TP Conc. (ppb)
1993	40,855	50.39	1,642	13,382	266
1994	37,905	46.75	1,791	7,938	170
1995	43,927	54.18	1,029	10,528	194
1996	44,100	54.40	2,006	13,673	251
1997	30,494	37.61	853	8,007	213
1998	47,178	58.19	1,301	16,874	290
1999	36,460	44.97	1,810	10,439	232
2000	85,802	105.83	1,421	24,240	229
2001	35,525	43.82	1,869	8,206	187
2002	24,557	30.29	742	9,407	311
2003	48,679	60.05	1,298	13,763	229
2004	30,950	38.18	792	10,139	266
Min. Ann.	24,557	30.29	742	7,938	---
Max. Ann.	85,802	105.83	2,006	24,240	---
Avg. Ann.	42,203	52.06	---	12,216	235

* Total EPD discharge to Lake Okeechobee from the S-4 Basin at structures S-310 and S-4.

With the assumed diversion of SFCD drainage, the biggest changes in flow allocation would occur at S-310, which is the basin outlet closest to EPD-07 hydraulically. The average annual discharge to Lake Okeechobee at this location decreases by over 5,000 acre-feet after SFCD diversion. Total discharges to Lake Okeechobee at structures S-310 and S-4 are predicted to decrease by a little more than 7,000 acre-feet per year. Similarly, TP loads would decrease by an average of 1,263 kg per year.

3.1.5 Partial Diversion Options

All of the alternatives described above assume all S-4 Basin drainage that is currently discharged to Lake Okeechobee at S-4 and S-310 would be diverted away from the lake. After this study was initiated, two partial diversion options were identified. These partial diversion options will be discussed in more detail later in Section 3.3 but the impact of these options on desired diversion quantities are described in this section.

3.1.5.1 Partial Diversion Option 1 – Exclusion of Clewiston Drainage District

The first of these partial diversion options would exclude drainage from the Clewiston Drainage District from potential S-4 Basin diversions. Under this option, it is assumed the drainage from the Clewiston Drainage District would be pretreated as necessary so it could still be discharged to Lake Okeechobee. As reported in Table 2-1, the annual discharge volume and TP load from this drainage district (EPD-09, EPD-10 and EPD-12) averages 3,342 acre-feet and 926 kg, respectively. The average flow-weighted TP concentration in these discharges is 224 ppb.

The flow allocation procedure described above in Section 3.1.4 was repeated, this time excluding discharges from the Clewiston Drainage District. These flow allocation estimates used the adjusted EPD-07 discharges as well. The resulting potential S-4 Basin diversions away from Lake Okeechobee are summarized in Table 3-11. The quantities listed in this table exclude the drainage from the Clewiston Drainage District that would still be discharged to Lake Okeechobee after treatment. Assuming these discharges would be undiminished in volume and limited to a flow-weighted mean TP concentration of 40 ppb, these direct discharges to Lake Okeechobee from the Clewiston Drainage District would average 3,342 acre-feet and 160 kg per year.

Table 3-11: Potential Diversions from S-4 Basin–Partial Diversion Option 1*

Water Year	Flow Volume (ac-ft)	Flow Volume (hm^3)	Peak Flow Rate (cfs)	TP Load (kg)	TP Conc. (ppb)
1993	39,468	48.68	1,546	12,713	261
1994	37,295	46.00	1,787	7,810	170
1995	42,500	52.42	1,029	10,166	194
1996	41,769	51.52	1,861	12,931	251
1997	29,928	36.92	834	7,872	213
1998	46,137	56.91	1,268	16,468	289
1999	35,400	43.67	1,689	10,100	231
2000	82,279	101.49	1,334	23,103	228
2001	34,835	42.97	1,859	8,047	187
2002	23,199	28.62	692	8,999	314
2003	47,532	58.63	1,289	13,528	231
2004	30,127	37.16	770	9,871	266
Min. Ann.	23,199	28.62	692	7,810	---
Max. Ann.	82,279	101.49	1,861	23,103	---
Avg. Ann.	40,872	50.42	---	11,801	234

* Total EPD discharge to Lake Okeechobee from the S-4 Basin at structures S-310 and S-4 after prior SFCD diversion and exclusion of drainage from the Clewiston Drainage District.

Predictably, because the Clewiston Drainage District discharges are relatively small, exclusion of these discharges does not have a significant impact on total desired diversions. Comparing Tables 3-10 and 3-11 show that total desired basin diversions decrease by an average of 1,331 acre-feet and 415 kg per year under this partial diversion option. Again, the impact of these Clewiston Drainage District discharge reductions on total desired diversions is probably somewhat underestimated.

3.1.5.2 Partial Diversion Option 2 – Exclusion of Clewiston and Sugarland Drainage Districts

The second partial diversion option considers exclusion of the drainage from both the Clewiston and Sugarland drainage districts. Under this option, it is assumed the drainage from the Clewiston and Sugarland drainage districts would be pretreated as necessary so it could still be discharged to Lake Okeechobee. As reported in Table 2-1, the annual discharge volume and TP load from these two drainage districts (EPD-09, EPD-10, EPD-11 and EPD-12) averages 35,120 acre-feet and 12,118 kg, respectively. The average flow-weighted TP concentration in these discharges is 288 ppb.

Historic drainage from the Sugarland Drainage District is nearly ten times larger than that from the Clewiston Drainage District so exclusion of this drainage has a significant impact on total desired S-4 Basin diversions. The resulting net annual S-4 Basin discharges to Lake Okeechobee (desired diversions) are listed in Table 3-12. Comparing the average annual discharge volumes and TP loads from this option (Table 3-12) with the base estimates in Table 3-5-indicate net reductions of about 44 and 46 percent, respectively, in desired diversions. The quantities listed in Table 3-12 exclude the drainage from the Clewiston and Sugarland drainage districts that would still be discharged to Lake Okeechobee after treatment. Assuming these discharges would be undiminished in volume and limited to a flow-weighted mean TP concentration of 40 ppb, these direct discharges to Lake Okeechobee from these two drainage districts would average 35,120 acre-feet and 1,849 kg per year.

Table 3-12: Potential Diversions from S-4 Basin–Partial Diversion Option 2*

Water Year	Flow Volume		Peak Flow Rate (cfs)	TP Load (kg)	TP Conc. (ppb)
	(ac-ft)	(hm^3)			
1993	23,558	29.06	925	8,271	285
1994	25,855	31.89	635	4,858	152
1995	34,179	42.16	552	6,819	162
1996	35,899	44.28	1,095	11,883	268
1997	21,260	26.22	511	5,118	195
1998	35,446	43.72	799	9,570	219
1999	24,527	30.25	1,171	8,330	275
2000	43,672	53.87	625	14,840	275
2001	11,243	13.87	617	1,529	110
2002	17,789	21.94	502	4,787	218
2003	35,069	43.26	743	5,635	130
2004	24,838	30.64	672	5,253	171
Min. Ann.	11,243	13.87	502	1,529	---
Max. Ann.	43,672	53.87	1,171	14,840	---
Avg. Ann.	27,778	34.26	---	7,241	211

* Total EPD discharge to Lake Okeechobee from the S-4 Basin at structures S-310 and S-4 after prior SFCD diversion and exclusion of drainage from the Clewiston and Sugarland drainage districts.

3.1.6 Diversion Rates

During the 12-year study period, the highest mean daily discharge rates to Lake Okeechobee (that is, desired diversions) are estimated to be as follows:

- 2,019 cfs under current conditions
- 2,006 cfs after SFCD diversion
- 1,861 cfs after SFCD diversion and exclusion of drainage from the Clewiston Drainage District (Partial Diversion Option 1)
- 1,171 cfs after SFCD diversion and exclusion of the drainage from the Clewiston and Sugarland drainage districts (Partial Diversion Option 2)

For the two partial diversion options, these peak flow rates are peak diversion rates as it is assumed that the excluded drainage from the Clewiston and Sugarland drainage districts would still be discharged to Lake Okeechobee after treatment.

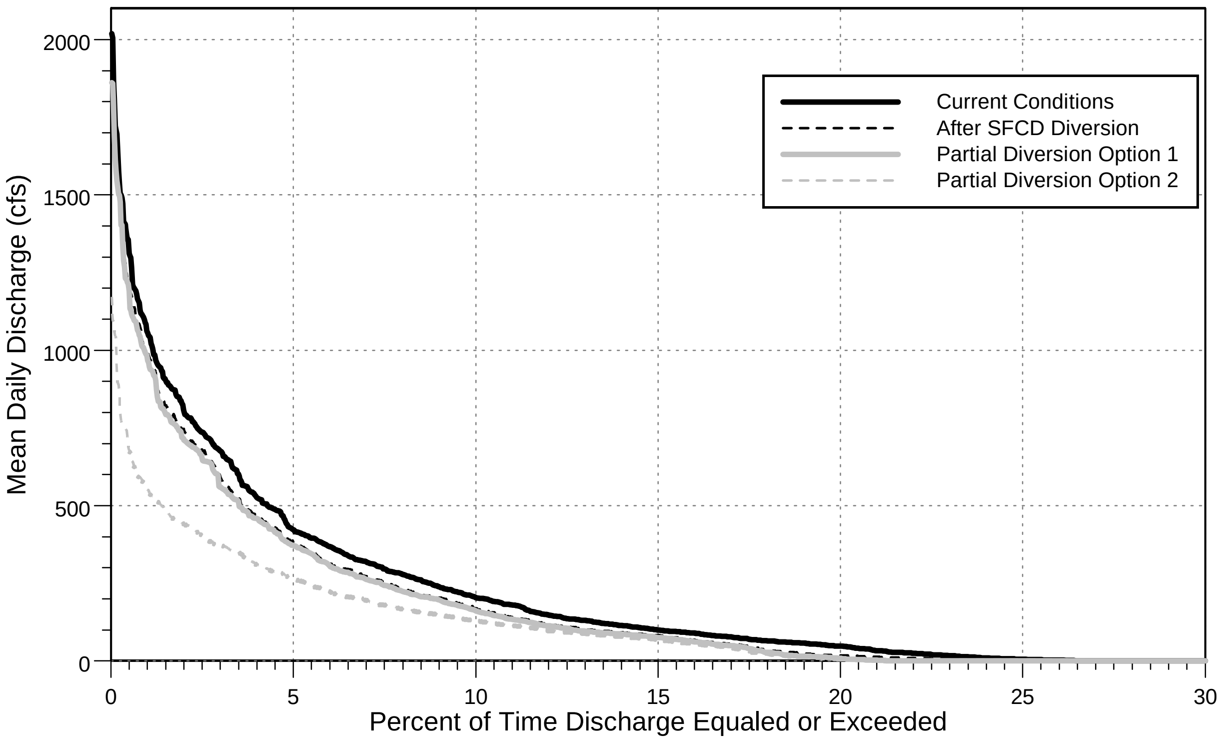
Figure 3-1 shows discharge durations for all four cases. As this graph shows, desired diversions are zero about 73 percent of the time under current conditions; this rate increases slightly for the other three cases. The duration graphs for the After SFCD Diversion and Partial Diversion Option 1 cases are virtually identical, which is expected because the discharge from the Clewiston Drainage District is relatively small.

3.2 DIVERSION SYSTEM CAPACITY

Once a daily series of historic discharges to Lake Okeechobee (desired diversions) had been developed for the four cases considered, the next step was to determine the recommended diversion system capacity. This value is defined as the maximum rate at which stormwater could be diverted, or captured, by the proposed system. This initial analysis did not consider a specific destination for the diverted stormwater from the S-4 Basin nor if there are any constraints as to when or how much water can be exported to these adjacent basins. This analysis also did not consider any internal hydraulic constraints within the S-4 Basin that could limit the feasibility of delivering these diversions to an adjacent basin, in whole or in part.

As stated above, the highest desired diversion rates during WY 1993-2004 were estimated to be just over 2,000 cfs. With Partial Diversion Option 2, this peak discharge decreases to slightly less than 1,200 cfs. Therefore, depending on the option under consideration a diversion system with a capacity ranging between 1,200 and 2,000 would be able to capture 100 percent of the desired diversions away from Lake

Figure 3-1: Desired Diversion Durations from S-4 Basin



Okeechobee. However, it may be impracticable for technical and economic reasons to develop a diversion system with such high capacities so an analysis was completed to determine the relationship between diversion system capacity and diversion efficiency. Diversion efficiency is defined as the ratio between the total amount of discharge that is diverted away from Lake Okeechobee and the total desired diversion amount. For the two partial diversion options, the diversion efficiency calculations include consideration of the excluded drainage from the Clewiston and Sugarland drainage districts. It was assumed the drainage from these two districts would be discharged directly to Lake Okeechobee, undiminished in volume but treated so that flow-weighted mean TP concentrations would be 40 ppb or less.

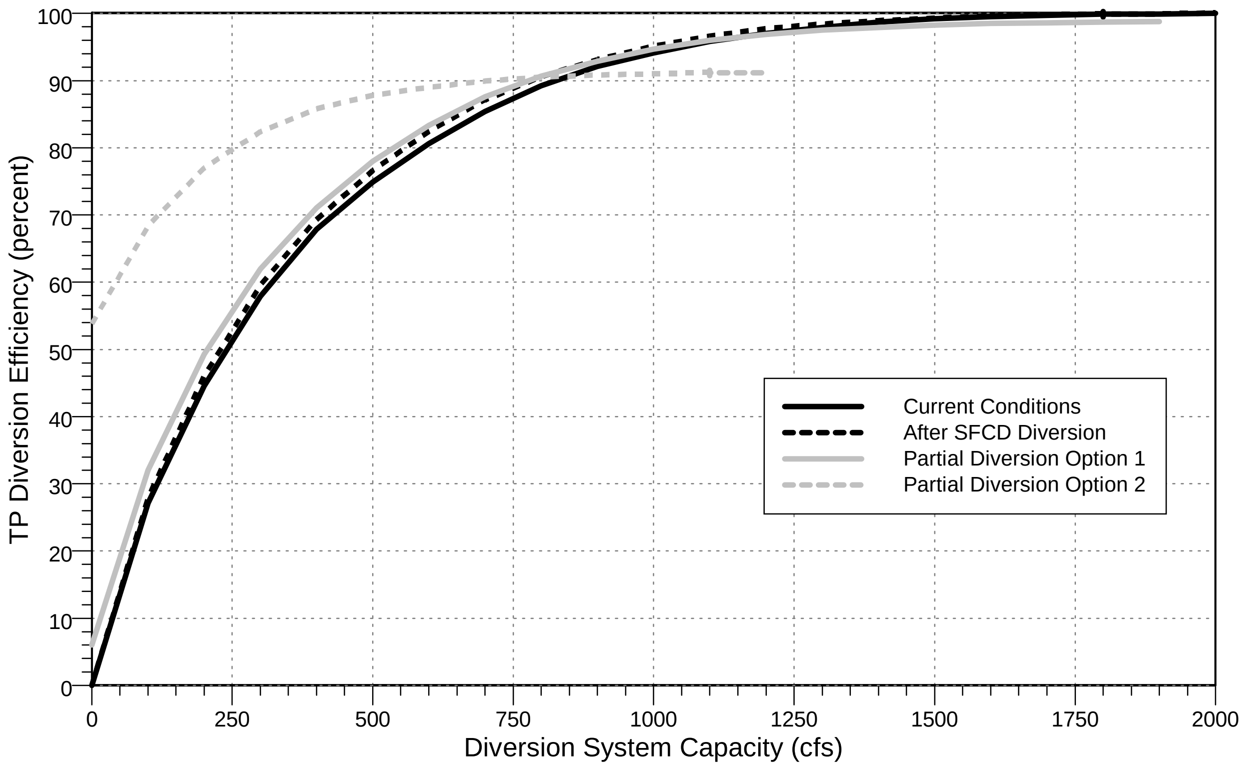
Table 3-13 shows how diversion system capacity is related to volumetric and TP load diversion efficiency. TP diversion efficiency is plotted against system capacity in Figure 3-2. For this table and graph, TP diversion efficiency includes not only consideration for the phosphorus diverted away from Lake Okeechobee but also that which would be removed by the treatment systems that would be required under the two partial diversion options. This is the reason that TP diversion efficiency for the two partial diversion options is greater than zero even with no diversion system (diversion capacity of zero). These data indicate that approximately 6 percent of the TP discharged to Lake Okeechobee would be removed by treating Clewiston Drainage District runoff alone to 40 ppb. This value increases to over 53 percent by treating the runoff from both the Clewiston and Sugarland drainage district to 40 ppb prior to its discharge to Lake Okeechobee. Also, some runoff volume and TP load (the volume and TP loading of treatment system effluent) would still be discharged to Lake Okeechobee under the two partial diversion options. Therefore, both the volumetric and TP load diversion efficiency for these cases will never reach 100 percent, regardless of diversion system capacity.

Table 3-13: Diversion Efficiency (percent) vs. System Capacity

Maximum Diversion Capacity (cfs)	Current Conditions[1]		After SFCD Diversion[2]		Partial Diversion Option 1[2,3]		Partial Diversion Option 2[2,3,4]	
	Volume	TP Load	Volume	TP Load	Volume	TP Load	Volume	TP Load
0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	53.8
100	29.1	27.1	29.4	27.8	27.4	32.0	18.7	68.4
200	47.0	44.6	47.8	46.0	44.7	49.3	29.1	77.0
300	59.8	57.9	60.7	59.5	56.7	62.0	35.3	82.4
400	69.2	67.9	70.1	69.3	65.5	71.1	39.2	85.8
500	76.2	74.9	77.3	76.6	72.2	78.0	41.4	87.8
600	81.8	80.6	82.9	82.4	77.3	83.3	42.5	89.0
700	86.5	85.4	87.5	87.1	81.5	87.6	43.2	89.9
800	90.0	89.2	90.8	90.6	84.4	90.7	43.6	90.5
900	92.6	92.1	93.1	93.1	86.5	92.9	43.9	90.8
1,000	94.6	94.1	95.1	95.1	88.3	94.7	44.0	91.0
1,100	96.1	95.8	96.5	96.6	89.5	96.0	44.1	91.2
1,200	97.2	97.0	97.5	97.7	90.4	96.9	44.2	91.2
1,300	98.0	97.9	98.2	98.4	91.0	97.5	44.2	91.2
1,400	98.7	98.7	98.8	98.9	91.5	97.9	44.2	91.2
1,500	99.1	99.2	99.2	99.3	91.9	98.3	44.2	91.2
1,600	99.4	99.5	99.5	99.6	92.1	98.5	44.2	91.2
1,700	99.7	99.7	99.7	99.8	92.3	98.6	44.2	91.2
1,800	99.8	99.9	99.9	99.9	92.4	98.7	44.2	91.2
1,900	99.9	99.9	99.9	99.9	92.4	98.8	44.2	91.2
2,000	100.0	100.0	100.0	100.0	92.4	98.8	44.2	91.2

1. Discharges to Clewiston Canal at EPD-07 assumed to continue at historic levels.
2. All discharges of 250 cfs or less at EPD-07 assumed diverted away from S-4 Basin.
3. Discharge from Clewiston Drainage District excluded from potential diversion amounts and discharged directly to Lake Okeechobee after pretreatment to FWM TP concentration of 40 ppb.
4. Discharge from Sugarland Drainage District excluded from potential diversion amounts and discharged directly to Lake Okeechobee after pretreatment to FWM TP concentration of 40 ppb.

Figure 3-2: TP Diversion Efficiency vs. Diversion System Capacity



Although total discharges to Lake Okeechobee are reduced substantially after SFCD diversion and with exclusion of Clewiston Drainage District discharge, Figure 3-2 shows there is little difference in diversion efficiency between the first three cases. The last case, Partial Diversion Option 2, is however significantly different than the other three — TP diversion efficiency ranges from a minimum of about 53 percent to a high of 91 percent and the maximum useful diversion system capacity is only 1,200 cfs.

A diversion system, or combination partial diversion/partial treatment system, with even a modest capacity would be capable of reducing a large percentage of historic TP discharge to Lake Okeechobee. For example, TP efficiencies would range from 74.9 to 87.8 percent with a 500-cfs system. However, larger and larger capacity additions are necessary to obtain increasing efficiency gains.

Several of the nearby Chapter 298 districts along the south shore of Lake Okeechobee are required under the Everglades Forever Act to divert at least 80 percent of their drainage away from Lake Okeechobee. Therefore, 80 percent diversion efficiency — or more specifically an 80 percent reduction in phosphorus loading — is considered to be realistic lower limit. For the S-4 Basin, achieving 80 percent TP reduction efficiency would require the following diversion capacities:

- Current Conditions – 588 cfs
- After SFCD Diversion – 556 cfs
- Partial Diversion Option 1 – 536 cfs
- Partial Diversion Option 2 – 250 cfs

Although 80 percent diversion efficiency is a likely minimum requirement, much higher efficiencies are desirable. Those Chapter 298 districts that have operating diversion systems are actually diverting well over 90 percent of their total drainage. For example, the East Beach Water Control District diverted approximately 97.8 percent of its total runoff volume away from Lake Okeechobee in WY 2003 and 2004. For these same two water years, the East Shore Water Control District and 715 Farms area diverted 99.1 percent of their runoff (Burns & McDonnell, 2005a).

For the S-4 Basin, obtaining TP reductions of 98 percent would require diversion capacities of approximately 1,300 cfs for the first three cases. For Partial Diversion Option 2, a TP reduction of 98 percent is not possible, unless the remaining runoff discharged to Lake Okeechobee is treated to a concentration much less than 40 ppb. With a 1,300-cfs diversion system discussed above, the maximum TP reduction under this last case is 91.2 percent but a system with a capacity of only 900 cfs would be almost as efficient with a TP reduction of 90.8 percent.

3.3 REVIEW OF DIVERSION ALTERNATIVES

Drainage from the S-4 Basin that is diverted away from Lake Okeechobee will have to be exported to one of the adjacent drainage basins. There are three adjacent basins that are reasonable candidates to receive these diversions, the C-139, C-43 and S-3/S-8 basins. Each of these alternative destinations is discussed below.

3.3.1 C-139 Basin

One alternative destination for diversions from the S-4 Basin is the C-139 Basin. This basin is located immediately south of the S-4 Basin and has an effective drainage area of approximately 168,437 acres, or 263.2 square miles (Mock/Roos, 1993). Levee 1 forms the common boundary between the S-4 and C-139 basins over a distance of about four miles. The primary canals within the C-139 Basin are the L-1, L-2 and L-3 borrow canals. These canals were constructed in the 1950s primarily to provide the fill material necessary to construct Levees 1, 2 and 3, which form the northern and eastern boundaries of the C-139 Basin.

The drainage from this basin flows generally east until it is intercepted by one of these primary canals. Once in the primary canal system, this drainage is directed to the south. Historically, most of this drainage was discharged directly to WCA-3A; however with construction of STA-5, the majority of this drainage is now diverted to STA-5 for treatment. The initial operation of STA-5 commenced in 1999. With limited exception, all of the drainage within the C-139 Basin, including diversions into STA-5, flows by gravity alone. There is one pump station however that drains an area of approximately 1,240 acres and discharges to the L-2 Borrow Canal.

Currently, STA-5 has an effective treatment area of 4,110 acres (Burns & McDonnell, 2005c) but there are ongoing plans to expand this treatment area in the near future. By 2006, a third flow way will be added to STA-5, increasing its treatment area to approximately 6,165 acres. A further expansion by 2010 will increase STA-5 by another 4,916 acres, bringing its total effective area to 11,081 acres (SFWMD, 2005b).

3.3.1.1 Potential STA-5 Impacts

The performance of STA-5 to date has been somewhat disappointing compared to the other STAs. Effluent TP concentrations from STA-5 have been near 100 ppb while the other STAs have been able to achieve discharge concentrations of near 30 ppb or less. Part of this difference in performance is attributed to higher TP concentrations in runoff from the C-139 Basin as compared to that from the primary EAA basins (216 ppb verses 104 ppb) (Burns & McDonnell, 2005a). With the ongoing implementation of best management practices (BMP) to reduce TP concentrations in C-139 Basin runoff and expansion of STA-5, the performance of this treatment area should improve.

In a parallel effort being conducted under the EAA Regional Feasibility Study (RFS), Burns & McDonnell has completed analyses to estimate the future performance of STA-5 (Burns & McDonnell, 2005f). As mentioned above, the full build out of STA-5 within Compartment C should be complete by 2010. As proposed, this treatment area will then consist of six parallel flow-ways of two cells each. Emergent vegetation is planned in the upstream cells and submerged aquatic vegetation (SAV) in the downstream cells. Using the Dynamic Model for Stormwater Treatment Areas–Version 2 (DMSTA2) developed by Walker & Kadlec (2005), the performance of the expanded STA-5 was estimated for this base case (Base SAV) and an alternate case that assumes development of emergent vegetation in the downstream cells (Base Emergent). This alternate case was included because the performance of STA-5 to date has more closely matched that expected with emergent vegetation in both the upstream and downstream cells. Until such time as the performance of STA-5 has been shown to improve to more expected levels, it is considered prudent to consider the full range in possible performance.

For this S-4 Diversion study, 12 additional cases were analyzed. For these new cases, it was assumed that 100 percent of the desired S-4 Basin diversions could be diverted southward and delivered to STA-5. In all likelihood, actual diversions would be less than 100 percent of the desired amount; therefore, loadings to STA-5 would be somewhat less and treatment performance slightly better than indicated below. The 12 new DMSTA2 cases for STA-5 are described below:

- S4cc SAV: STA-5 with SAV in downstream cells treating runoff from C-139 Basin (including runoff currently discharged through G-136) plus desired diversions from S-4 Basin under Current Conditions.
- S4cc Emergent: Same as S4cc SAV except with emergent vegetation assumed in downstream cells
- S4sf SAV: STA-5 with SAV in downstream cells treating all runoff from C-139 Basin plus desired diversions from S-4 Basin. Desired S-4 Basin diversions are adjusted to reflect prior diversion of SFCD drainage.
- S4sf Emergent: Same as S4sf SAV except with emergent vegetation assumed in downstream cells
- S4p1 SAV: STA-5 with SAV in downstream cells treating all runoff from C-139 Basin plus desired diversions from S-4 Basin under Partial Diversion Option 1.
- S4p1 Emergent: Same as S4p1 SAV except with emergent vegetation assumed in downstream cells
- S4p2 SAV: STA-5 with SAV in downstream cells treating all runoff from C-139 Basin plus desired diversions from S-4 Basin under Partial Diversion Option 2.
- S4p2 Emergent: Same as S4p2 SAV except with emergent vegetation assumed in downstream cells
- Alternative No. 3 + S4cc: Alternative No. 3 from the EAA RFS evaluated a partial transfer of inflow from STA-3/4 to STA-5. These additional diversions are additive to those considered in case S4cc SAV.
- Alternative No. 3 + S4sf: Same as Alternative No. 3 + S4cc case except desired S-4 Basin diversions are from case S4sf.
- Alternative No. 3 + S4p1: Same as Alternative No. 3 + S4cc case except desired S-4 Basin diversions are from case S4p1.
- Alternative No. 3 + S4p2: Same as Alternative No. 3 + S4cc case except desired S-4 Basin diversions are from case S4p2.

The modeling results for the base and S-4 Basin-specific cases are summarized in Table 3-14.

Table 3-14: DMSTA2 Modeling Summary for STA-5

Parameter	Units	Base[1]		S4cc[2]		S4sf[3]	
		SAV	Emer-gent	SAV	Emer-gent	SAV	Emer-gent
Average Annual Inflow (WY 1995-2004)							
Volume	1000 ac-ft	160.0	160.0	226.8	226.8	220.7	220.7
TP Load	1000 kg	39.85	39.85	57.16	57.16	56.11	56.11
FWM TP Concentration[4]	ppb	201.8	201.8	204.3	204.3	206.2	206.2
Average Annual Outflow (WY 1995-2004)							
Volume	1000 ac-ft	162.3	162.3	229.0	229.0	222.9	222.9
TP Load[5]	1000 kg	1.96	4.33	4.00	10.20	3.80	9.65
FWM TP Concentration[4]							
Median	ppb	9.8	21.6	14.2	36.1	13.8	35.1
10-90% Conf. Limits[6]	ppb	8.3-12.0	15.1-31.6	11.3-18.5	24.8-51.0	11.1-18.0	24.1-49.8
Geometric Mean TP Conc							
Median	ppb	6.3	18.1	9.9	31.8	9.5	30.8
10-90% Conf. Limits[6]	ppb	5.1-8.4	11.7-27.9	7.1-14.2	20.7-46.4	6.9-13.7	20.0-45.2
Parameter	Units	S4p1[7]		S4p2[7]			
		SAV	Emer-gent	SAV	Emer-gent		
Average Annual Inflow (WY 1995-2004)							
Volume	1000 ac-ft	219.2	219.2	206.2	206.2		
TP Load	1000 kg	55.69	55.69	50.96	50.96		
FWM TP Concentration[4]	ppb	205.9	205.9	200.3	200.3		
Average Annual Outflow (WY 1995-2004)							
Volume	1000 ac-ft	221.5	221.5	208.5	208.5		
TP Load[5]	1000 kg	3.74	9.48	3.20	7.92		
FWM TP Concentration[4]							
Median	ppb	13.7	34.7	12.4	30.8		
10-90% Conf. Limits[6]	ppb	11.0-17.8	23.8-49.3	10.1-16.0	21.1-44.1		
Geometric Mean TP Conc							
Median	ppb	9.4	30.4	8.4	26.7		
10-90% Conf. Limits[6]	ppb	6.8-13.5	19.7-44.8	6.2-11.8	17.2-39.8		

1. Base cases assume treatment of runoff from C-139 Basin only, excluding current discharge through G-136.
2. S4cc cases assume treatment of all C-139 Basin runoff (including discharge through G-136) plus desired S-4 Basin diversions under current conditions.
3. S4sf cases assume treatment of C-139 Basin runoff (including discharge through G-136) plus desired S-4 Basin diversions after diversion of SFCD drainage.
4. Flow-weighted mean (FWM) TP concentration.
5. Outflow TP load based on median FWM TP concentration.
6. Mean TP concentrations for 10-90% confidence limits based on simulations using 10th and 90th percentile settling rate (K) estimates. Base (median) concentration estimates are based on simulations with median K values.
7. S4p1 and S4p2 cases are with desired S-4 Basin diversions under Partial Diversion Options 1 and 2, respectively.

Table 3-14: DMSTA2 Modeling Summary for STA-5 (cont.)

Parameter	Units	Alternative No. 3 Cases					
		Base[8]	Alt. 3 only[9]	Alt. 3+ S4cc[10]	Alt. 3+ S4sf[11]	Alt. 3+ S4p1[12]	Alt. 3+ A4p2[13]
Average Annual Inflow (WY 1995-2000)							
Volume	1000 ac-ft	160.7	266.9	344.6	336.4	334.8	321.0
TP Load	1000 kg	34.33	47.61	67.37	65.87	65.35	61.33
FWM TP Concentration[4]	ppb	173.2	144.6	158.7	158.2	154.9	
Average Annual Outflow (WY 1995-2004)							
Volume	1000 ac-ft	161.7	267.8	345.5	337.3	335.7	321.9
TP Load[5]	1000 kg	1.68	3.93	7.81	7.39	7.27	6.40
FWM TP Concentration[4]							
Median	ppb	8.4	11.9	18.3	17.8	17.6	16.1
10-90% Conf. Limits[6]	ppb	7.3-10.2	9.4-15.5	13.9-24.4	13.5-23.6	13.4-23.4	12.4-21.4
Geometric Mean TP Conc							
Median	ppb	58.	8.9	14.4	13.8	13.7	12.5
10-90% Conf. Limits[6]	ppb	4.8-7.4	6.6-12.5	10.1-20.3	9.7-19.6	9.6-19.4	8.9-17.7

8. This base case is identical to the above Base case except the results are for a shorter, 6-year modeling period.
9. All C-139 Basin runoff (including discharge through G-136) plus additional Alternative No. 3 inflow only.
10. All C-139 Basin runoff (including discharge through G-136) plus additional Alternative No. 3 inflow and desired S-4 Basin diversions under current conditions.
11. All C-139 Basin runoff (including discharge through G-136) plus additional Alternative No. 3 inflow and desired S-4 Basin diversions after SFCD diversion.
12. All C-139 Basin runoff (including discharge through G-136) plus additional Alternative No. 3 inflow and desired S-4 Basin diversions for Partial Diversion Option 1.
13. All C-139 Basin runoff (including discharge through G-136) plus additional Alternative No. 3 inflow and desired S-4 Basin diversions for Partial Diversion Option 2.

3.3.1.2 Full Diversion Options

Diverted drainage from the S-4 Basin would need to be delivered into the primary canal system of the C-139 Basin (that is, the L-1, L-2 or L-3 borrow canals). Although these two basins abut one another, the drainage system in the S-4 Basin is currently configured to convey water northward to Lake Okeechobee (that is, away from the C-139 Basin). Therefore, the existing canal system would need to be reconfigured to deliver drainage southward into the C-139 Basin.

Much of the drainage targeted for diversion away from Lake Okeechobee originates in the eastern portion of the S-4 Basin. The drainage districts in this part of the basin include the Clewiston Drainage District, Sugarland Drainage District, East Hendry County Drainage District, South Florida Conservancy District, and U.S. Sugar Townsite area. The total historic drainage discharged from these districts (EPD-06 through EPD-11) averages 69,519 acre-feet per year, or about 141 percent of the desired diversion amount. About half of this drainage (35,405 acre-feet per year) is discharged to the Clewiston (Industrial) Canal at EPD-06, EPD-07, EPD-08 and EPD-09 so one obvious diversion option would be to extend the Clewiston Canal southward to intersect one of the C-139 Basin primary canals. The balance of the drainage from the eastern districts is discharged to the C-21 Canal at EPD-10 and EPD-11. There is an existing connection between the C-21 and Clewiston canals at structure S-169 so it may also be possible to divert this drainage to the C-139 Basin by routing it through S-169 into the Clewiston Canal; however, stages in the Clewiston Canal are typically higher than those in the C-21 Canal under current operating policies. Also, routing drainage eastward through S-169 and then southward in the Clewiston Canal would require the S-310 lock to remain closed; under current operating policies this lock is left open much of the time. An alternative of this latter routing would be to improve and extend one of the existing Sugarland Drainage District canals southward to meet the Clewiston Canal south of Clewiston or the L-1 Borrow Canal.

As discussed in the previous chapter, there are existing flooding problems in the upper C-139 Basin. During higher runoff events, backwater from the L-2 Borrow Canal causes localized flooding along the L-1 Borrow Canal near G-136. Structures G-136, G-150 and the L-1E Borrow Canal were constructed in the early 1980s to provide an alternate outlet from the upper C-139 Basin and help alleviate these flooding problems. Because of this situation, it may be impracticable to deliver diversions from the S-4 Basin directly into the L-1 Borrow Canal without improvements to this canal. An alternative destination for these diversions may be the L-2 Borrow Canal below G-150. Except with the lowest flows in the L-2/L-3 canal system, stages in the L-2 Borrow Canal are generally higher than those in the S-4 Basin (Clewiston Canal) so a pump station would in all probability be required to lift S-4 Basin diversions into the C-139 Basin canal system.

3.3.1.3 Partial Diversion Options

As described previously, the two partial diversion options would exclude drainage from the Clewiston Drainage District (Option 1) or Clewiston and Sugarland drainage districts (Option 2) from diversion to another drainage basin. The impetus behind development of these two partial diversion options is concern over possible recreational impacts in Clewiston. The nature of these potential impacts and the required improvements necessary for implementation of these partial diversion options are discussed below.

The northern end of the Clewiston Canal (that part between S-310 and U.S. Highway 27) and the canal west of S-310 to S-169 is lined with marinas and boat docks. Boaters moor their boats along these canals and then enter Lake Okeechobee through the S-310 lock structure. Under most conditions — Lake Okeechobee stages less than 15.5 feet — the S-310 lock gates are left in the open position so boaters can pass freely between Lake Okeechobee and the Clewiston Canal. If drainage from the Clewiston Drainage District (that portion currently discharged at EPD-10) and the Sugarland Drainage District were to be routed eastward through S-169 and then southward in the Clewiston Canal to the C-139 Basin, the S-310 lock would have to remain closed at all times to prevent this drainage from entering Lake Okeechobee. Requiring boaters to always "lock through" S-310 would introduce significant delays and inconvenience. Also, canal stages in the Clewiston Canal would have to be lowered (approximately two feet from current normal levels) to allow potential diversions to flow southward by gravity through S-169. Lower canal stages could also negatively impact boating activities.

Elimination of periods with free passage through S-310 and lower canal stages would inconvenience or otherwise impact boaters under current conditions but there has also been discussion about expanding the marina facilities in Clewiston. This expansion would be accomplished by relocating S-169 farther west, opening up additional canal frontage for development of marina/dock facilities and corresponding commercial and residential property development. Local civic and business leaders in Clewiston can be expected to view the potential closure of the S-310 lock and lowering of Clewiston Canal stages as a detriment to their economic development efforts. By excluding drainage from the Clewiston and Sugarland drainage districts from possible diversion southward, as proposed with the two partial diversion options, operational changes for the S-310 lock and northern Clewiston Canal could be avoided.

With the first option, Clewiston Drainage District runoff would be passed through a new STA located within or adjacent to the district for treatment and then delivered directly to Lake Okeechobee. Implementation of this option would require development of the STA itself plus conveyance and pumping facilities to deliver drainage to the STA and then discharge its effluent to Lake Okeechobee. Under this option, runoff from the Sugarland Drainage District would have to be routed directly southward from this district to the C-139 Basin. This could be accomplished by improving and extending one or more of the existing district canals and laterals to connect with the Clewiston Canal south of Clewiston or directly to the L-1 Borrow Canal. One possible option to convey this drainage southward would be to extend Canal 4, one of the main north-south canals within this district. Canal 4 currently terminates only one mile north of the L-1 Borrow Canal.

Runoff from both the Clewiston and Sugarland drainage districts would be excluded from diversion southward under Option 2. Similar to the first option, all of the runoff from these two districts would have to be routed through a new STA prior to discharging it directly to Lake Okeechobee. The treatment facilities required under this option would be significantly larger than for the first option because the combined runoff volume from these two drainage districts averages 10.5 times that of the Clewiston Drainage District alone. Also, there would be no requirement to extend and improve any Sugarland Drainage District canals to deliver this district's drainage to the C-139 Basin under Option 2.

Based on the best estimates now available, discharges to Lake Okeechobee are likely to be limited to a flow-weighted mean TP concentration of 40 ppb in the near future. Preliminary DMSTA2 modeling was completed to estimate the gross size of the required STAs under these two partial diversion options. No attempt has yet been made to find an actual location for these potential treatment areas so these estimates are based on the following assumed STA characteristics:

- Length is twice the width
- Each flow path will consist of two cells in series. The length of the upstream cell will be 40 percent of the total STA length and the downstream cell will occupy the remaining 60 percent.
- Both cells will be planted with emergent vegetation.
- Exterior and interior levees average 40 feet wide

To simplify the modeling, these potential STAs were modeled as a single flow way; however, it may be desirable to split these treatment areas into two or more flow ways for operational flexibility. The only impact of this change would be the slight decrease in effective treatment area caused by construction of the longitudinal dividing levees between flow ways. With these assumptions, the required size of each STA was determined by trial and error. The modeling results for these STAs are summarized in Table 3-15. The required STA sizes listed in this table are based on achieving FWM TP concentrations below 40 ppb. For Option 1 and 2, the estimated STA sizes are 240 and 3,360 acres, respectively.

3.3.2 C-43 Basin

Another alternative destination for S-4 Basin diversions is the C-43 Basin. The C-43 Basin is located immediately west of the S-4 Basin and its primary conveyance facility is the C-43 Canal, or Caloosahatchee River. The C-43 and S-4 basins share a common boundary for a distance of about 16 miles. The western portion of the Disston Island Conservancy District, and all of the Flaghole and Hendry-Hilliard drainage districts are assigned to the C-43 Basin (Figure 2-1).

Table 3-15: DMSTA2 Modeling Summary for Partial Diversion Options

Parameter	Units	Option 1[1]	Option 2[2]
Overall STA Footprint	acres	240	3,360
Average Annual Inflow (WY 1993-2004)			
Volume	1000 ac-ft	3.32	35.18
TP Load	1000 kg	0.93	12.13
FWM TP Concentration[4]	ppb	224.6	279.7
Average Annual Outflow (WY 1993-2004)			
Volume	1000 ac-ft	3.57	38.67
TP Load[4]	1000 kg	0.16	1.85
FWM TP Concentration[3]			
Median	ppb	36.1	38.7
10-90% Conf. Limits[5]	ppb	27.4-47.1	31.0-48.8
Geometric Mean TP Conc			
Median	ppb	27.4	20.3
10-90% Conf. Limits[5]	ppb	19.0-37.8	13.7-29.2

1. Option 1 considers treatment of all runoff from the Clewiston Drainage District.
2. Option 2 considers treatment of all runoff from the Clewiston and Sugarland drainage districts.
3. Flow-weighted mean (FWM) TP concentration.
4. Outflow TP load based on median FWM TP concentration.
5. Mean TP concentrations for 10-90% confidence limits based on simulations using 10th and 90th percentile settling rate (K) estimates. Base (median) concentration estimates are based on simulations with median K values.

The C-43 Canal connects Lake Okeechobee at structure S-77 with the Caloosahatchee River estuary and Gulf of Mexico. The flow in this canal is predominately from east to west although there are infrequent occasions when water is discharged back to Lake Okeechobee at S-77. Farther downstream at S-79, discharges to the Caloosahatchee River estuary averaged over 1.5 million acre-feet during the 12-year study period. Nearly half of these discharges, on average, resulted from Lake Okeechobee releases at S-77.

These large historic discharges to tide through the C-43 Canal have caused unintended environmental impacts in the estuary. During periods of high discharge, salinity levels in the estuary fall dramatically and during low flows, salinity concentrations can rise to levels that may be toxic to aquatic species in the estuary. One of the authorized CERP projects, the C-43 Basin Storage Project, is intended to improve the timing, quantity and quality of freshwater flows to the Caloosahatchee River estuary by ensuring a more natural, consistent flow of freshwater into the estuary. The principal component of this project is a reservoir that will provide at least 160,000 acre-feet of storage. This reservoir will provide temporary storage to attenuate high flows and provide a supplemental supply for environmental releases to the estuary and basin irrigation during droughts (Corps of Engineers, 2003).

One of the design goals for the C-43 reservoir is to eliminate discharges under 300 cfs or over 4,500 cfs at S-79 to the extent practicable. For the period WY 1993-2004, the minimum flow at S-79 was zero and flows less than 300 cfs occurred 31.5 percent of the time. During this same period, the highest mean daily flow was 15,500 cfs and flows above 4,500 cfs occurred 17.8 percent of the time. As currently planned, the C-43 reservoir will have a storage capacity of 170,000 acre-feet and an inflow pump station with a capacity of 1,500 cfs (Stanley Consultants, 2005).

Given the existing frequency of high flows and the limited capacity of the reservoir's planned inflow pump station, diverting additional drainage from the S-4 Basin to the C-43 Canal could be problematic. The maximum diversion rate from the S-4 Basin would likely be in the range of 565 to 1,300 cfs (80 to 98 percent diversion efficiency). The highest diversion rates would most likely occur when runoff from the C-43 Basin is already high so these additional diversions could easily overwhelm the planned C-43 diversion and storage facilities. These additional diversions from the S-4 Basin could be accommodated by an expansion of the proposed facilities for the C-43 Basin storage project (that is, increasing the storage capacity of the proposed reservoir and pumping capacity of the inflow pump station). However, the Basis of Design Report and 30 percent design for this reservoir project are essentially complete (scheduled for completion in October 2005). Therefore, these facilities would have to be redesigned which could impact the development schedule for this project. The C-43 reservoir is one of the Acceler8 projects and is targeted for early completion in 2010.

On average, nearly half (47.8 percent) of the total drainage from the S-4 Basin is already delivered to the C-43 Canal at S-235. However, the additional diversions necessary to reduce Lake Okeechobee discharges would more than double the volume and peak rate of deliveries to the C-43 Canal. Therefore, certain canal and control structure improvements would be necessary to divert these additional drainage amounts to the C-43 Canal. In a study conducted in the late 1980s, Briley, Wild and Associates (1990) considered various alternatives to accomplish these diversions. They concluded that diversion of S-4 Basin discharge to the C-43 Canal could be accomplished by improvements to the existing conveyance system as listed below:

- Increase capacity of S-169 (add fourth culvert)

- Increase cross section of C-21 Canal immediately east and west of S-169
- Increase cross section in eastern portion of L-D1 Borrow Canal
- Increase capacity of S-235 (add third culvert)

For this earlier study, the increased diversions to the C-43 Canal (18,000 acre-feet per year) averaged only about one third of the amounts now contemplated so more extensive conveyance improvements than those listed above may be required.

Existing discharge from the S-4 Basin to the C-43 Canal flows by gravity through S-235. Stages in the C-43 Canal below S-235 are low enough that gravity flow should be possible at this location even with significantly higher discharges. There are no known capacity issues with the C-43 Canal that would limit additional diversions from the S-4 Basin.

3.3.3 S-3/S-8 Basin

The S-3/S-8 drainage basin is the final alternative destination for S-4 Basin diversions considered in this study. The combined S-3/S-8 drainage basin is located southeast of the S-4 Basin in Hendry and Palm Beach counties. This basin covers a total area of approximately 302.4 square miles with approximately 72 percent of this area located in Palm Beach County and 28 percent in Hendry County (Cooper, 1989). The S-4 and S-3/S-8 basins share a common boundary over a distance of about 5.5 miles, with approximately 2 miles of this common boundary formed by Levee 1 East (L-1E).

The principal canal in the S-3/S-8 Basin is the Miami Canal (L-23, L-24 and L-25 borrow canals), which connects Lake Okeechobee at S-3/S-354 to WCA-3A at S-8. Flow in this canal is generally north to south but there are infrequent periods when water is back pumped to Lake Okeechobee at S-3. With completion of STA-3/4 in 2004, much of the flow in this canal that was historically discharged to WCA-3A at S-8 is now diverted to STA-3/4 via pump station G-372.

STA-3/4 has an effective treatment area of 16,543 acres (Burns & McDonnell, 2005c) and there are no current plans for its expansion. However, the EAA Storage Reservoir Project will be built on lands immediately north of STA-3/4, with phase 1 (A-1 Reservoir) scheduled for completion by 2010 and phase 2 (A-2 Reservoir) by 2015. This reservoir project will have a significant impact on the operation of STA-3/4. Based on SFWMD simulation models, average deliveries to this treatment area are projected to be approximately 643,000 acre-feet per year before reservoir construction (2006); decrease slightly to about 587,000 acre-feet per year after completion of the A-1 Reservoir (2010); and then potentially increase substantially to approximately 842,000 acre-feet per year after completion of the A-2 reservoirs (2015) (Burns & McDonnell, 2005d, 2005e). One of the primary goals of the ongoing EAA RFS is to optimize the loadings to the various STAs so the projected inflow volumes listed above may be altered in the future.

For 2010 conditions after construction of the A-1 Reservoir, Burns & McDonnell has previously analyzed two possible alternatives (Alternative Nos. 1 and 2) for reallocation of STA inflows. Both of these alternatives involve diverting more drainage from the eastern portions of the EAA to the west, effectively increasing the inflow to STA-3/4. Table 3-16 presents a summary of the DMSTA2 modeling completed for these two alternatives.

Table 3-16: DMSTA2 Modeling Summary for STA-3/4

Parameter	Units	Alternative No. 1[1]	Alternative No. 2[2]
Average Annual Inflow (WY 1966-2000)			
Volume	1000 acre-feet	585.7	617.4
TP Load	1000 kg	65.86	63.07
FWM TP Concentration[3]	ppb	91	83
Average Annual Outflow (WY 1966-2000)			
Volume	1000 acre-feet	566.8	598.4
TP Load[4]	1000 kg	12.99	13.49
FWM TP Concentration[3]			
Median	ppb	18.6	18.3
10-90% Conf. Limits[5]	ppb	15.3-23.2	15.0-22.6
Geometric Mean TP Conc			
Median	ppb	14.6	14.2
10-90% Conf. Limits[5]	ppb	11.5-18.9	11.3-18.3

1. Table 8.2 (Burns & McDonnell, 2005f).
2. Table 7.2 (Burns & McDonnell, 2005g).
3. Flow-weighted mean (FWM) TP concentration.
4. Outflow TP load based on median FWM TP concentration.
5. Mean TP concentrations for 10-90% confidence limits based on simulations using 10th and 90th percentile settling rate (K) estimates. Base (median) concentration estimates are based on simulations with median K values.

While no specific DMSTA2 modeling was completed to show the impact of delivering S-4 Basin diversions to STA-3/4, these diversions could increase the average TP loading to this STA by up to 20 percent (13,479 kg per year). An increase of this magnitude in TP loading would have a detrimental impact on STA-3/4 outflow TP concentrations.

Diverted drainage from the S-4 Basin would need to be delivered to the L-1E Borrow Canal. This canal connects the L-1 Borrow Canal at G-136 with the Miami Canal at G-212. Discharges to the L-1E Borrow Canal would flow to the Miami Canal and subsequently be diverted to STA-3/4. Much of the above discussion about potential diversions to the C-139 Basin would apply to diversions into the L-1E Borrow Canal and S-3/S-8 Basin also. Much of the drainage targeted for diversion away from Lake Okeechobee would come from the eastern portion of the S-4 Basin and could be diverted into the L-1E Borrow Canal by extending the Clewiston Canal southward to meet this canal in the extreme southeast corner of the S-4 Basin.

Historic stages in the L-1E Borrow Canal below G-136 are generally lower than typical stages in the Clewiston Canal. Therefore, diversions from the S-4 Basin to this canal may flow by gravity. It is anticipated that limited conveyance improvements would be necessary in the L-1E Borrow Canal to accommodate the desired diversions from the S-4 Basin.

3.3.4 Summary

This section presents a summary and comparison of the three potential destinations for diversions from the S-4 Basin and other diversion options. Table 3-17 summarized the relative advantages and disadvantages of each destination alternative.

Based primarily on concerns about overloading the planned C-43 Reservoir project or STA-3/4, diversions of additional S-4 Basin drainage to respectively the C-43 or S-3/S-8 basins are not considered to be the best options at this time. However, the potential for diversion to the S-3/S-8 Basin should be considered in detailed planning and analyses for Compartment A-2 of the EAA Storage Reservoir. If STA inflows could be redistributed or additional treatment area developed to accommodate these diversions from the S-4 Basin, the S-3/S-8 Basin could become a more attractive destination for these diversions. Subsequent analyses conducted in this study evaluated diversion of S-4 Basin drainage to the C-139 Basin as the preferred option.

With the C-139 Basin selected as the preferred destination for S-4 Basin diversions, there is still another question to answer: Which of the four diversion cases should be used as the basis for subsequent planning studies? As discussed above, potential S-4 Basin diversions have been estimated under four scenarios:

Table 3-17: Summary of Alternative Destinations for S-4 Basin Diversions

Destination for S-4 Basin Diversions	Advantages	Disadvantages
C-139 Basin	• Moderate canal improvements may be required within S-4 Basin • After its expansion, STA-5 may be capable of treating both C-139 Basin runoff and S-4 Basin diversions	• Major canal improvements may be required for C-139 Basin canals • Pump station may be required to lift S-4 Basin diversions into C-139 Basin canals
C-43 Basin	• Moderate canal improvements may be required within S-4 Basin • Diversions may flow by gravity between S-4 and C-43 basins	• C-43 Reservoir project not designed to accommodate additional diversions from S-4 Basin. Redesign of this Acceler8 project may cause unacceptable delays.
S-3/S-8 Basin	• Moderate canal improvements may be required within the S-4 Basin • Diversions may flow by gravity between S-4 and S-3/S-8 basins	• STA-3/4 inflows projected to increase significantly by 2015. Additional S-4 Basin diversions may overload this treatment area.

- Current Conditions: Desired S-4 Basin diversions are based on historic Lake Okeechobee discharges.
- After SFCD Diversion: Desired S-4 Basin diversions assume prior diversion of SFCD drainage.
- Partial Diversion Option 1: Clewiston Drainage District runoff is excluded from potential diversion amounts along with prior diversion of SFCD drainage.
- Partial Diversion Option 2: Drainage from the Clewiston and Sugarland drainage districts excluded from potential diversion amounts along with prior diversion of SFCD drainage.

Diversion of SFCD drainage away from Lake Okeechobee (into the Miami Canal) is a requirement of the Everglades Forever Act so there is little doubt that this diversion system will be developed. Therefore, it would seem logical to assume prior diversion of SFCD drainage when estimating potential S-4 Basin diversion amounts. This assumption would eliminate the "Current Conditions" scenario from active consideration.

The two partial diversion options were developed to address concerns over recreational impacts in Clewiston. For Option 2, runoff from both the Clewiston and Sugarland drainage districts would be treated and discharged directly to Lake Okeechobee, excluding this drainage from potential diversion to an adjacent drainage basin. The STA required for treatment of this drainage is conservatively estimated to be 3,360 acres (5.25 square miles) in size (Table 3-13). A STA of this size would occupy the equivalent of roughly a quarter of the total land area within these two drainage districts. Partial Diversion Option 2 is considered unattractive for a number of reasons, which are listed below, and is not further considered herein:

- Anticipated high capital cost relative to that for redirection of Sugarland DD discharges, particularly with respect to the cost of land acquisition;
- Impact on local government tax bases;
- Reduced impact on total phosphorus load discharged to Lake Okeechobee, as compared to all other alternatives considered;
- Uncertain effect of future regulatory actions on permittable discharges to Lake Okeechobee.

Partial Diversion Option 1 considers exclusion of Clewiston Drainage District runoff only from potential S-4 Basin diversions. The STA required to treat this drainage prior to its discharge to Lake Okeechobee would be of modest size (240 acres) so it should be practicable to find a location for this STA. However, the principal goal of this partial diversion option is to avoid potential recreational impacts in Clewiston. To accomplish this goal, drainage from the Sugarland Drainage District would have to be routed directly southward to the C-139 Basin and not pass through S-169 into the Clewiston Canal. This drainage routing would require extension of one of the existing Sugarland Drainage District canals to connect with the Clewiston Canal south of Clewiston or the L-1 Borrow Canal. While this direct southward routing would be practicable, it could also be included in any of the non-partial diversion alternatives to minimize recreational impacts in Clewiston. Therefore, if drainage from the Sugarland and Clewiston drainage districts that is currently discharged to Canals C-20 or C-21 were routed directly southward, there is really little difference between the “After SFCD Diversion” and “Partial Diversion Option 1” cases because Clewiston Drainage District runoff is relatively small anyway.

For the reasons stated above, subsequent evaluations in this study are based on full or partial diversion of all S-4 Basin discharge to Lake Okeechobee (after prior SFCD diversion) southward into the C-139 Basin.

* * * * *

4.0 HYDRAULIC ANALYSIS OF C-139 BASIN CANALS

After diversion of S-4 Basin drainage to the C-139 Basin was identified as an option warranting further exploration, a hydraulic analysis was conducted to determine the hydraulic capacity of the canals in the C-139 Basin. Initially, this analysis focused on determining the existing capacity of the primary conveyance canals in this basin and later investigated the improvements necessary to increase these capacities, where warranted.

Little current information on the geometry of the canals within the S-4 Basin was available for use in this study so no hydraulic analyses of these canals were performed. In subsequent studies concerning this proposed basin diversion project, additional information on these canals should be collected and hydraulic analyses completed to determine the exact nature of any required intrabasin conveyance improvements.

4.1 EXISTING CAPACITY OF C-139 BASIN CANALS

The primary conveyance canals in the C-139 Basin are the L-1, L-2 and L-3 borrow canals. Currently, these canals transport most of the runoff from the C-139 Basin to STA-5. Any practicable scheme for diverting drainage from the S-4 Basin to STA-5 will necessarily require delivering this drainage to one or more of these same canals.

4.1.1 Hydraulic Modeling Assumptions

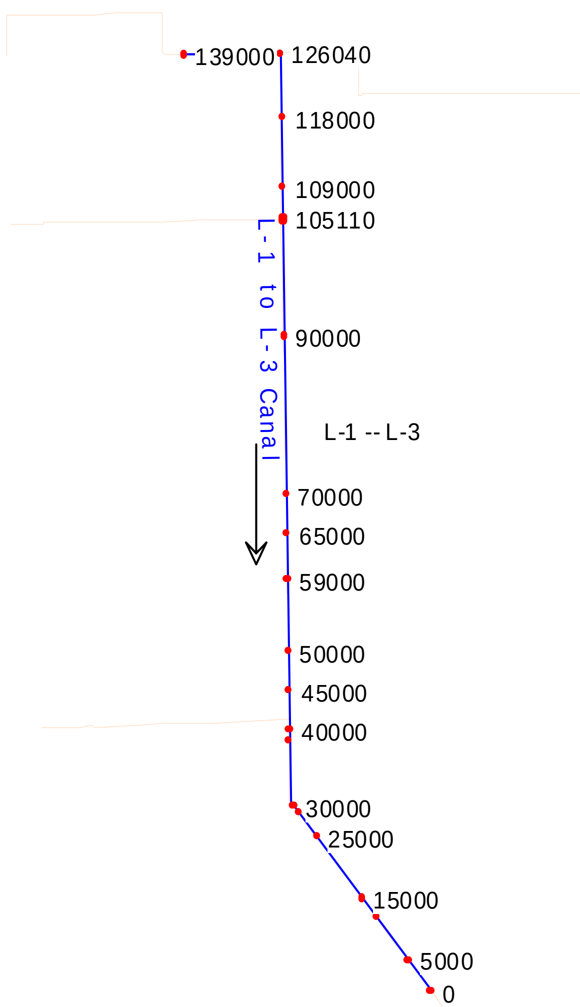
A hydraulic model of the combined L-1/L-2/L-3 borrow canal system was built using the *River Analysis System* computer model (HEC-RAS) developed at the Corps of Engineers, Hydrologic Engineering Center (2002). This model uses information on channel geometry, flow resistance factors and discharge rates to predict water surface profiles within the streams being modeled. The principal data sources or assumptions used in the hydraulic model for the L-1/L-2/L-3 canal system are discussed below.

4.1.1.1 Channel Geometry

The geometry of these canals was obtained from drawings prepared by the COE (1954, 1958). These record plan, profile and cross section drawings show the condition of these canals shortly after they were constructed in the 1950s. As these canals have now been in service for about 50 years, some deposition, dredging and other maintenance activities have occurred over the years but no recent, comprehensive resurvey of these canals has been completed. Therefore, the geometry of these canals was assumed to be reasonable similar to that shown in these original drawings.

Figure 4-1 is a map showing the locations of the cross sections used in the HEC-RAS model relative to the major SFWMD canals in the C-139 Basin. The cross section station numbers shown on this map are based on the distance, in feet, of these cross sections upstream of the southern end of the model.

Figure 4-1: Cross Section Location Map



4.1.1.2 Flow Resistance Factors

Flow resistance in HEC-RAS is modeled using Manning's *n* resistance factors. From guidance provided in the HEC-RAS model, two different *n* values were used for this hydraulic model:

- Channels: Manning's *n* = 0.027 (straight and uniform earthen channels with short grass and few weeds)

- Overbank Areas: Manning's n = 0.035 (flood plains with high grass)

4.1.1.3 Canal Discharge

The allowable discharge in these canals is the principal variable to be determined in this hydraulic analysis. However, this discharge will not be constant along the entire length of these canals if some or all of it is a result of C-139 Basin runoff. Therefore, the results of prior hydrologic modeling were reviewed to help apportion this discharge appropriately.

In their *Western Basins Environmental Assessment,* Mock, Roos & Associates (Mock/Roos, 1993) developed flow estimates for a 3-year, 24-hour flood in the C-139 Basin. These flood discharge estimates were used to determine peak flow rates at several locations along the L-1/L-2/L-3 canal system for two different scenarios:

- <u>L-2 Alternative</u>: Mock/Roos built its hydrologic model based on the current operating policies in this basin. During flood conditions, these policies dictate that structure G-150 should be closed to prevent backwater from entering the upper basin and all drainage from the upper C-139 Basin is diverted eastward through G-136 into the L-1E Borrow Canal. For this alternative, the hydraulic model described in this chapter includes only the L-2 and L-3 borrow canals below G-150. These conditions would apply if diversions from the S-4 Basin are delivered to the L-2 Borrow Canal just below G-150.
- <u>L-1 Alternative</u>: This alternate model scenario looks at the entire L-1/L-2/L-3 canal system under the assumption that all C-139 Basin drainage has to flow southward. To accomplish this goal, G-150 must remain open and G-136 must be closed. This scenario was not modeled specifically by Mock/Roos so discharge estimates south of G-150 were taken as the sum of the modeled discharges in this reach plus any discharge from the upper basin at G-136. This flow scenario was investigated to look at the feasibility of diverting drainage from the S-4 Basin into the L-1 Borrow Canal at or above G-136.

Table 4-1 is a summary of the estimated 3-year, 24-hour flood discharges at various points along this canal system for both flow scenarios. For any discharges other than the 3-year, 24-hour values shown in Table 4-1, the accompanying percentages were used to estimate discharges at points above the Deer Fence Canal.

Table 4-1: Estimated 3-year, 24-hour Flood Discharges*

Model Station	Description	L-2 Scenario (L-2/L-3 only)		L-1 Scenario (entire L-1/L-2/L-3 system)	
		Peak Discharge (cfs)	Percent of Total at Sta. 40000	Peak Discharge (cfs)	Percent of Total at Sta. 40000
139000	Upstream end of HEC-RAS model	---	---	391	33.7
105100	Immediately upstream of G-150	---	---	448	38.6
104500	Downstream of G-150 & L-2W Canal	169	23.7	617	53.1
90000	Near confluence of Midway Canal	253	35.5	701	60.4
70000	Below Alico South Canal	429	60.2	877	75.5
40000	Below Deer Fence Canal	713	100.0	1,161	100.0

* Derived from Mock, Roos and Associates (1993).

While the discharge estimates listed in Table 4-1 are based on hydrologic modeling completed by Mock/Roos for a 3-year, 24-hour storm, actual historic monitoring data for the L-3 Borrow Canal were used to develop reference discharge rates for this canal system. These historic mean daily flow rates are discussed in Chapter 2. For the 12-year study period, the highest mean daily discharge rate was recorded for each water year. These peak annual flow rates varied from 701 cfs to 1,919 cfs, with an arithmetic mean of 1,227 cfs and a geometric mean of 1,179 cfs.

The Mock/Roos estimate of the 3-year, 24-hour peak discharge appears to be incongruent with the historic flow monitoring data. The Mock/Roos estimate of 713 cfs for the 3-year flood in the L-3 Borrow Canal reach immediately below the Deer Fence Canal confluence is only slightly higher than the lowest recorded peak discharge for the 12-year study period, a mean daily discharge of 701 cfs. By definition, one would expect the 3-year discharge to be exceeded on average only once every 3 years, not in 11 of 12 years. Also, the Mock/Roos estimate is an instantaneous peak discharge, which would always be higher than the mean discharge on the same day, making the disagreement between these two data sources even more striking.

Although there is no readily apparent explanation for the disagreement between these various flow estimates, the actual flow monitoring data were used to develop a reference discharge rate. Assuming a log-normal distribution, the geometric mean flow (1,179 cfs) is an estimate of the 2-year peak, mean daily flow in the L-3 Borrow Canal below the Deer Fence Canal. Hydrologic events with a 2-year recurrence interval are considered to be routine because they have a 50 percent annual probability, or occur every other year on average.

4.1.1.4 Initial Water Surface Elevation

The last key modeling assumption required in the hydraulic model is the initial water surface elevation at the downstream end of the HEC-RAS model (Station 0). This initial model cross section is located only about 3,500 feet upstream of the G-88/G-89/G-155 gate complex so water levels at this location are impacted by water management decisions.

A relationship between canal stages and discharges in the lower reaches of the L-3 Borrow Canal was developed using monitoring data for the L3BRS monitoring station. This monitoring station is located about 830 feet upstream of the end of the L-3 Borrow Canal, or approximately a half mile downstream of the last hydraulic model cross section. The historic flow and stage data for the L3BRS station were downloaded from DBHYDRO (DBKEYs 16245 and 16244, respectively) and cover the period June 1995 through March 2005, nearly 10 years. A scatter plot of these data is shown in Figure 4-2.

Review of Figure 4-2 shows that stages in the L-3 Borrow Canal have varied over a wide range at low flows, which are sometimes negative. However, a definite stage-discharge relationship is evident for flows above about 150 cfs. A linear regression analysis of stage vs. the common logarithm of flow, for flows greater than 150 cfs only, yields an equation with a coefficient of determination (r^2) of 0.63. This regression equation, with S equal to stage (feet NGVD) and Q equal to discharge (cfs), is shown below:

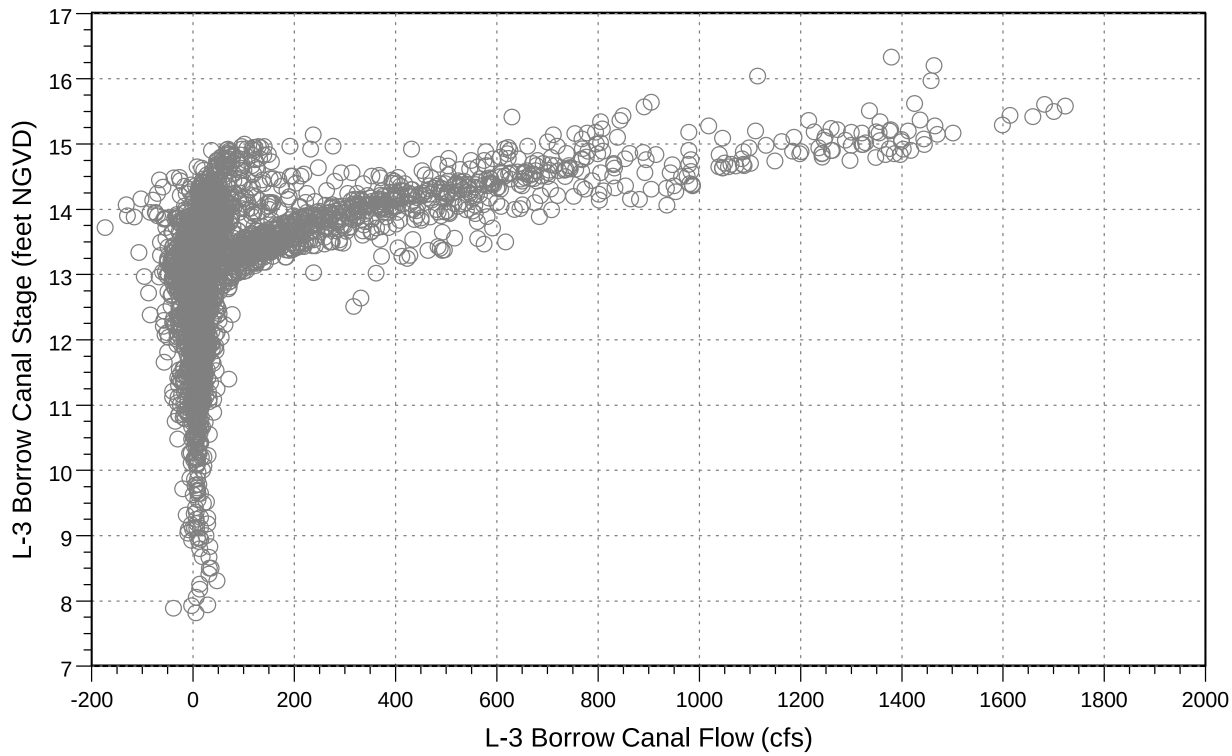
$$S = 10.029 + 1.587 \log Q$$

The above regression equation was used to estimate the starting water surface elevation at the downstream end of the HEC-RAS hydraulic model for all discharges.

4.1.2 Hydraulic Modeling Results

After the hydraulic model for the C-139 Basin canals was constructed, it was used to estimate water surface elevations for various scenarios and discharge rates.

Figure 4-2: L-3 Borrow Canal Stage vs. Flow Data at Station L3BRS



4.1.2.1 L-2 Alternative (L2)

As described above, current operating protocols for the C-139 Basin require that G-150 be closed during significant runoff events. This requirement would apply also if significant volumes of drainage from the S-4 Basin were diverted to the south. Therefore, under current operating policies diversions from the S-4 Basin would have to be delivered to the L-2 Borrow Canal below G-150 in order to be conveyed to STA-5. If one were to divert water into the L-1 Borrow Canal above G-150, with G-150 closed and G-136 open as currently prescribed, all of these diversions would pass through G-136 into the L-1E Borrow Canal and S-3/S-8 drainage basin. Eventually, these diversions would have to be treated in STA-3/4 and not STA-5 as contemplated under this diversion option.

As discussed above in Section 4.1.1.3, the 2-year reference discharge in the L-3 Borrow is estimated to be 1,179 cfs. For this reference discharge, the flow into the L-2 Borrow Canal from the L-2W Borrow Canal is estimated to be 279 cfs (23.7 percent from Table 4-1). With this range of discharges, which result from local runoff only, the hydraulic model estimates water surface elevations in this canal system will range from 14.92 feet in the lower reaches of the L-3 Borrow Canal (Station 0) to 17.46 feet in the L-2 Borrow Canal just below G-150. These water levels approximate bank full conditions along much of this canal reach except in a few localized areas. In the canal reach below the confluence of the Alico South Canal but above STA-5, water levels are estimated to exceed bank full conditions by about a foot; however, these canal flows would still be contained within the canal right of way by the main levee on the east side of the canal and the low water control berm along the west side of the canal.

The range in canal water levels discussed in the previous paragraph will occur, on average, about once every two years. These same water levels were used to determine the maximum allowable diversion rates from the S-4 Basin. That is, diversion rates that will not cause water levels to exceed the estimated values causes by a 2-year discharge. With no local runoff from the C-139 Basin, the maximum allowable diversion into the L-2/L-3 canal system below G-150 was determined to be 657 cfs. With a mixture of local runoff and S-4 Basin diversions, the maximum diversion rate will vary from a maximum of 657 cfs down to zero, as shown in Table 4-2.

Table 4-2: Allowable Diversion Rate into L-2 Borrow Canal (Existing Conditions)

Local Runoff Discharge[1,2] (cfs)	Allowable Diversion Rate from S-4 Basin[3] (cfs)	Total Discharge[1] (cfs)
0	657	657
100	608	708
200	555	755
300	500	800
400	447	847
500	392	892
600	337	937
700	281	981
800	224	1024
900	166	1066
1000	107	1107
1179	0	1179

1. Discharge in L-3 Borrow Canal below Deer Fence Canal confluence.
2. Local runoff includes drainage from lower C-139 basin below G-150 only.
3. Diversions delivered to L-2 Borrow Canal immediately below G-150.

4.1.2.2 L-1 Alternative (L1)

All of the modeling results described in the previous section assume that diversions from the S-4 Basin will be delivered to the L-2 Borrow Canal below G-150. However, with a change in operating policies, it might be possible to divert water directly into the L-1 Borrow Canal. This is an attractive alternative because the S-4 and C-139 basins share a common border for a length of about four miles. This common border is formed by Levee 1 and its adjacent borrow canal so diversions into this borrow canal would take less effort than the L-2 alternative.

There is a long history of flooding problems in the L-1 Borrow Canal in the vicinity of the bend in this canal, near G-136. It was these problems that led to the construction of structures G-136 and G-150, and the L-1E Borrow Canal. In order to help prevent flooding impacts to adjacent lands, the desired maximum stage in the L-1 Borrow Canal at G-136 has been established as 14 feet NGVD.

The first goal of the hydraulic modeling for the L-1 scenario was to estimate the maximum canal system discharge that would not violate this target maximum stage value. By trial and error, this discharge was determined to be 192 cfs. This reference discharge is for the L-3 Borrow Canal between the Deer Fence Canal and the G-88/G-89/G-155 gate complex. This discharge is assumed to be entirely from basin runoff so the flow in this canal system increases in a downstream direction. For this reference discharge of 192 cfs, the discharge in the L-1 Borrow Canal above G-150 is only 74 cfs (38.6 percent from Table 4-1).

A second case was investigated with no local basin runoff and all of the canal discharge resulting from a diversion from the S-4 Basin. It was assumed this drainage from the S-4 Basin would be delivered to the L-1 Borrow Canal above G-136. For this case, the maximum allowable diversion rate was estimated to be 148 cfs. With simultaneous runoff from the C-139 Basin, the maximum allowable import rate from the S-4 Basin would vary from 0 to 148 cfs for this scenario as indicated in Table 4-3.

4.2 ENHANCED CAPACITY OF C-139 BASIN CANALS

As shown above, potential diversions into the existing C-139 Basin canals are highly restricted, especially during periods when there is simultaneous local runoff in the C-139 Basin. In order to enhance the import capacity of these canals, an analysis was conducted to determine the hydraulic capacity of these same canals after certain improvements.

The hydraulic model described above was modified to evaluate possible conveyance enhancements in the L-1/L-2/L-3 canal system. All of the assumptions and conditions utilized for the original hydraulic model were retained except for those described below. Five different alternatives were evaluated:

Table 4-3: Allowable Diversion Rate into L-1 Borrow Canal (Existing Conditions)

Local Runoff Discharge[1,2] (cfs)	Allowable Diversion Rate from S-4 Basin[3] (cfs)	Total Discharge[1] (cfs)
0	148	148
25	129	154
50	110	160
75	91	166
100	72	172
125	53	178
150	33	183
175	14	189
192	0	192

1. Discharge in L-3 Borrow Canal below Deer Fence Canal confluence.
2. Local runoff includes drainage from entire C-139 Basin, including runoff that would currently be discharged into L-1E Borrow Canal at G-136.
3. Diversions delivered to L-1 Borrow Canal above G-136.

- L-2 Enhanced Version 1 (L2-1) — The L2-1 alternative considers an enlargement of the L-2 and L-3 borrow canals below G-150. For this alternative, the right (west) bank of the L-2 and L-3 borrow canals was moved back 15 to 20 feet while maintaining the existing invert profile. This assumed enlargement of these canals would increase their cross sectional area by nearly one quarter (24.2 percent on a reach length weighted basis).
- L-2 Enhanced Version 2 (L2-2) – The L2-2 alternative also considers an enlargement of the L-2 and L-3 borrow canals below G-150 but for this alternative, the right bank of the L-2 and L-3 borrow canals was moved back 35 to 40 feet. The result of this assumed excavation was to increase the size of these canals by a little more than half (54.2 percent).
- L-1 Enhanced Version P0 (L1-P0) – Because stages in the L-2/L-3 canal system are typically higher than in the existing S-4 Basin canals, it appears likely a pump station would be required to lift S-4 Basin diversions into the L-2 Borrow Canal. The L1-P0 alternative considers locating this pump station at G-150 between the L-1 and L-2 borrow canals. This new pump station could either replace or supplement the existing gated culverts at G-150. A pump station at this location could help alleviate some of the existing flooding problems in the L-1 Borrow Canal, and also significantly increase allowable diversions into this same canal from the S-4 Basin. This alternative assumes no enlargement of the L-1 Borrow Canal or the L-2/L-3 canal system below G-150. Therefore, the hydraulic characteristics of the L-2/L-3 canal reach are identical to those of the original L-2

alternative. Because the maximum import capacity of the L-2/L-3 canal system was determined to be 657 cfs under existing conditions with no local inflow, this pump station should have at a minimum the same nominal capacity. Larger capacities may be warranted if this pump station is also utilized to convey diversion to a detention storage reservoir.

- L-1 Enhanced Version P1 (L1-P1) – The L1-P1 alternative again assumes installation of a pumping station at G-150 but the nominal capacity of this station would be increased to match the maximum allowable import capacity for the L-2 Borrow Canal determined under alternative L2-1. Also, enlargement of the L-1 Borrow Canal between G-136 and G-150, similar to those incorporated into the L2-1 alternative, are included in this alternative.
- L-1 Enhanced Version P2 (L1-P2) – This last alternative is similar to the L1-P1 alternative but assumes canal enlargements in the L-1/L-2/L-3 canal system between G-136 and the Deer Fence Canal similar to those included in the L2-2 alternative.

4.2.1 Enhanced L-2 Alternatives

The results of the hydraulic analyses for the two L-2 enhancement alternatives are summarized in Tables 4-4 and 4-5. Review of these tables shows the maximum import rate to the L-2 Borrow Canal (with no local runoff) is increased from 657 cfs under existing conditions (L-2 alternative) to 855 and 1,076 cfs for enhanced conditions (alternatives L2-1 and L2-2, respectively).

Table 4-4
Allowable Diversion Rate into L-2 Borrow Canal (Enhanced Conditions–Version 1)

Local Runoff Discharge[1,2] (cfs)	Allowable Diversion Rate from S-4 Basin[3] (cfs)	Total Discharge[1] (cfs)
0	855	855
100	798	898
200	741	941
300	682	982
400	623	1023
500	564	1064
600	503	1103
700	444	1144
800	383	1183
900	320	1220
1000	257	1257
1100	194	1294
1200	130	1330
1300	65	1365
1400	0	1398

1. Discharge in L-3 Borrow Canal below Deer Fence Canal confluence.
2. Local runoff includes drainage from lower C-139 basin below G-150 only.
3. Diversions delivered to L-2 Borrow Canal immediately below G-150.

Table 4-5
Allowable Diversion Rate into L-2 Borrow Canal (Enhanced Conditions–Version 2)

Local Runoff Discharge[1,2] (cfs)	Allowable Diversion Rate from S-4 Basin[3] (cfs)	Total Discharge[1] (cfs)
0	1076	1076
100	1016	1116
200	956	1156
300	896	1196
400	835	1235
500	774	1274
600	712	1312
700	649	1349
800	586	1386
900	523	1423
1000	458	1458
1100	394	1494
1200	328	1528
1300	262	1562
1400	195	1595
1500	127	1627
1600	59	1659
1686	0	1686

1. Discharge in L-3 Borrow Canal below Deer Fence Canal confluence.
2. Local runoff includes drainage from lower C-139 basin below G-150 only.
3. Diversions delivered to L-2 Borrow Canal immediately below G-150.

4.2.2 Enhanced L-1 Alternatives

The three L-1 enhancement alternatives are designed to mesh with the corresponding L-2 alternatives: L1-P0 with L-2; L1-P1 with L2-1; and L1-P2 with L2-2. Hydraulic analyses were performed for each of these L-1 alternatives. These analyses confirmed that, as long as the included pump station at G-150 is sized to equal or exceed the maximum import capacity of the applicable L-2 alternative, the import capacities for these alternatives are still controlled by conditions in the L-2/L-3 canal system.

The most likely scenario for these L-1 alternatives would be for S-4 Basin drainage to be diverted into the L-1E Borrow Canal and then routed westward through G-136 into the L-1 Borrow Canal. Therefore, target operating stages in the L-1 Borrow Canal near G-136 would need to match or be less than those in the L-1E Borrow Canal, a reversal of current conditions. To achieve these target stages near G-136, hydraulic modeling indicates headwater stages at G-150 will need to be held down to 9 to 10 feet. Given these conditions, a design head of at least 9 feet would be required for the proposed pump station.

4.3 SUMMARY OF HYDRAULIC ANALYSES

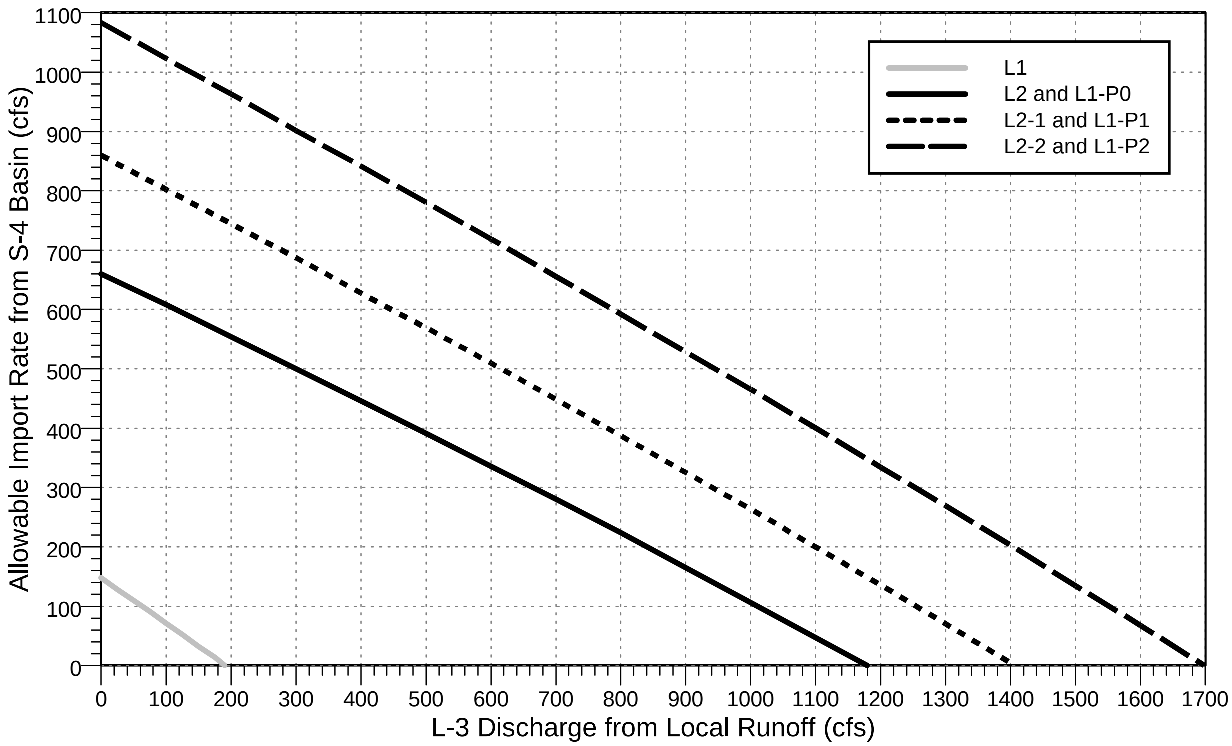
Table 4-6 presents a summary of the hydraulic analyses. Figure 4-3 shows how the maximum import capacity of the L-1/L-2/L-3 canal system varies with different amount of local runoff.

Table 4-6: Summary of Hydraulic Analyses

Alternative	Delivery Point for S-4 Basin Diversions	Import Capacity[1] (cfs)	Required Improvements[2]
L1	L-1 Canal at G-136	0-148	None, existing conditions
L1-P0	L-1 Canal at G-136	0-657	Pump station at G-150 with capacity ≥ 657 cfs
L1-P1	L-1 Canal at G-136	0-855	New pump station with capacity ≥ 855 cfs and 25% enlargement of L-1, L-2 and L-3 canals
L1-P2	L-1 Canal at G-136	0-1076	New pump station with capacity ≥ 1076 cfs and 50% enlargement of L-1, L-2 and L-3 canals
L2	L-2 Canal below G-150	0-657	None, existing conditions
L2-1	L-2 Canal below G-150	0-855	25% enlargement of L-2 and L-3 canals
L2-2	L-2 Canal below G-150	0-1076	50% enlargement of L-2 and L-3 canals

1. Import capacity varies based on quantity of local runoff from C-139 Basin. Maximum import capacity possible only during periods with no local runoff.
2. Implicit in the required improvements for all of the L-2 alternatives is construction of a new connector canal, at least four miles long, from the S-4 Basin to the L-2 Borrow Canal below G-150 and a suitably-sized pump station to lift diversions into the L-2 Borrow Canal. This connector canal would not be required for the L-1 alternatives as S-4 Basin diversions could be delivered directly into the L-1 Borrow Canal or indirectly via L-1E Borrow Canal.

Figure 4-3: Allowable Import Rates to C-139 Basin



* * * * *

5.0 ANALYSIS OF POTENTIAL DIVERSION SYSTEM

The performance of a potential S-4 Basin diversion system is analyzed in this report chapter. This analysis is accomplished by testing the efficiency of the proposed diversion system with different capacity assumptions.

5.1 DIVERSION SYSTEM SIMULATION MODEL

A simple computer model of the proposed S-4 Basin diversion system was developed to estimate overall performance given different diversion capacities and amounts of temporary detention storage. For each day during the 12-year study period, this model makes the following comparisons or calculations.

1. Compare total desired diversions with capacity of diversion system. Total desired diversions are the sum of S-4 Basin drainage that is currently discharged to Lake Okeechobee (after prior SFCD diversion) and runoff from the upper C-139 Basin that is currently discharged to the L-1E Borrow Canal at G-136. The lesser of total desired diversions and diversion system capacity is the potential diversion rate.
2. Estimate direct import capacity to L-1 or L-2 borrow canal, as appropriate. Direct import capacity is a function of the local C-139 Basin runoff as determined by the hydraulic analyses in Chapter 4 (Tables 4-2 through 4-5).
3. Determine direct import rate to L-1 or L-2 borrow canal on this date, which is the lesser of the rates calculated in Steps 1 and 2 above.

The next few steps apply only to a diversion system with temporary detention storage. For a system without temporary detention storage, skip to Step 8.

4. Estimate net changes in start-of-day detention storage due to direct rainfall and evaporation. For purposes of calculating direct rainfall and evaporation, the detention reservoir is assumed to have a working depth of 10 feet so the net effective reservoir area (acres) is one tenth its storage capacity (acre-feet). The difference between this adjusted storage volume and the maximum reservoir capacity is the available detention storage volume.
5. Estimate diversions to the reservoir. Available reservoir diversion is the difference between potential diversions (Step 1) and direct discharges to the receiving canal (Step 3).

6. If reservoir is not empty, calculate allowable reservoir releases. Reservoir releases are the lesser of the current day's storage volume and the excess import capacity of the receiving canal (Step 2 less Step 3). One of the goals built into the simulation model is to empty the detention reservoir as quickly as possible.
7. Calculate end-of day reservoir storage and spills. Reservoir spills occur only because of direct rainfall on a reservoir that is full or nearly full. It was assumed that reservoir spills would be discharged to the L-1E Borrow Canal or other receiving canal within the S-3/S-8 drainage basin.

Finally, estimate bypass amounts and sources of diversions to STA-5 and bypass.

8. Calculate bypass amounts to Lake Okeechobee and S-3/S-8 Basin. Bypass to Lake Okeechobee is the difference between desired S-4 Basin diversions (historic discharge to lake) and actual diversions to south. Bypass amounts to the S-3/S-8 Basin are the difference between total diversions each day (Step 1) and the sum of direct exports to L-1 or L-2 borrow canal (Step 2) and diversions to detention reservoir, if applicable (Step 5).

The eight steps described above are repeated for each day during the 12-year study period. Phosphorus loads in each of the flow streams described above are calculated from the associated concentrations. No atmospheric deposition of phosphorus to the detention reservoir or treatment (phosphorus removal) within the reservoir is accounted for in the simulation model. The overall diversion efficiencies for flow volume and TP loads are calculated as total diversions divided by total desired diversions.

5.2 SYSTEM SIMULATION FOR L-2 ALTERNATIVE

The L-2 alternative (L2) assumes diversions from the S-4 Basin and runoff from the upper C-139 Basin will both be delivered to the upper reaches of the L-1E Borrow Canal. This mixture is then delivered to the L-2 Borrow Canal below G-150 through a new connector canal and pump station. These simulation results are also applicable to the L-1 Enhanced Version P0 (L1-P0) alternative. For this latter alternative, S-4 Basin diversions and upper C-139 Basin runoff are routed southward in the L-1 Borrow Canal to a new pump station located at G-150. If required, it is assumed a detention storage reservoir would be located to the east of L-1 or L-2 in the vicinity of G-150.

The L2 and L1-P0 alternatives do not include any conveyance improvements in the L-2/L-3 canal system. The simulation model was executed for these alternatives with different assumptions for maximum diversion capacity and available detention storage to determine values that would meet the following criteria on an average annual basis:

- Divert 98 percent of historic S-4 Basin discharge to Lake Okeechobee to an alternate destination
- Limit bypass amounts (both bypass volumes and TP loads, whichever is more restrictive) into the S-3/S-8 Basin to historic values of C-139 Basin runoff discharged to L-1E Borrow Canal at G-136.

By trial and error, the maximum diversion capacity and required detention storage needed to meet these criteria were determined to by 1,410 cfs and 5,100 acre-feet, respectively. The results of this simulation run are summarized in Table 5-1.

Table 5-1: Simulation Summary for L2 and L1-P0 Alternatives

Source	Destination	Avg. Ann. Volume[3]		Avg. Ann. TP Load[3]	
		(acre-feet)	(% of total)	(kg)	(% of total)
S-4 Diversions[1]	Total	42,205	100.0	12,216	100.0
	To STA-5	33,531	79.4	9,353	76.6
	To S-3/S-8 Basin	7,825	18.5	2,621	21.5
	To L. Okeechobee	849	2.0	242	2.0
Upper C-139 Runoff[2]	Total	17,479	100.0	3,522	100.0
	To STA-5	13,726	78.5	2,635	74.8
	To S-3/S-8 Basin	3,753	21.5	887	25.2
Lower C-139 Runoff	Total (to STA-5)	184,770	100.0	44,034	100.0
All Sources	Total	244,454	100.0	59,772	100.0
	To STA-5	232,027	94.9	56,021	93.7
	To S-3/S-8 Basin	11,578	4.7	3,509	5.9
	To L. Okeechobee	849	0.3	242	0.4

1. Desired S-4 Basin diversions (historic discharge to Lake Okeechobee).
2. Runoff from upper C-139 Basin currently discharged to S-3/S-8 Basin at G-136.
3. Based on simulation for WY 1993–2004.

5.3 SYSTEM SIMULATION FOR L-2 ENHANCED ALTERNATIVES

Like the base L-2 alternative, the enhanced scenarios assume the diversions from the S-4 Basin will be delivered to the L-2 Borrow Canal below G-150; however, these scenarios evaluate the impact of conveyance enhancements in the L-2/L-3 canal system. The simulation model results for these two enhancement versions are discussed below.

5.3.1 L-2 Enhanced Version 1

The L-2 Enhanced Version 1 (L2-1) alternative assumes an enlargement of the L-2/L-3 canal system below G-150. This enlargement would increase canal cross sections by an average of about 25 percent. The simulation results for the L2-1 alternative are also applicable to the corresponding L-1 Enhanced Version P1 (L1-P1) alternative.

In order to meet the same criteria described in Section 5.2, the maximum diversion capacity and required detention storage for these alternatives were determined to by 1,410 cfs and 2,500 acre-feet, respectively. The results of this simulation run are summarized in Table 5-2.

Table 5-2: Simulation Summary for L2-1 and L1-P1 Alternatives

Source	Destination	Avg. Ann. Volume[3]		Avg. Ann. TP Load[3]	
		(acre-feet)	(% of total)	(kg)	(% of total)
S-4 Diversions[1]	Total	42,205	100.0	12,216	100.0
	To STA-5	33,713	79.9	9,375	76.7
	To S-3/S-8 Basin	7,643	18.1	2,599	21.3
	To L. Okeechobee	849	2.0	242	2.0
Upper C-139 Runoff[2]	Total	17,479	100.0	3,522	100.0
	To STA-5	13,839	79.2	2,632	74.7
	To S-3/S-8 Basin	3,640	20.8	890	25.3
Lower C-139 Runoff	Total (to STA-5)	184,770	100.0	44,034	100.0
All Sources	Total	244,454	100.0	59,772	100.0
	To STA-5	232,322	95.0	56,041	93.8
	To S-3/S-8 Basin	11,283	4.6	3,489	5.8
	To L. Okeechobee	849	0.3	242	0.4

1. Desired S-4 Basin diversions (historic discharge to Lake Okeechobee).
2. Runoff from upper C-139 Basin currently discharged to S-3/S-8 Basin at G-136.
3. Based on simulation for WY 1993–2004.

5.3.2 L-2 Enhanced Version 2

The L-2 Enhanced Version 2 (L2-2) alternative also assumes an enlargement of the L-2/L-3 canal system below G-150. This enlargement would increase canal cross sections by an average of about 50 percent. The simulation results for the L2-2 alternative are also applicable to the corresponding L-1 Enhanced Version P2 (L1-P2) alternative.

In order to meet the same criteria described in Section 5.2, the maximum diversion capacity is still 1,410 cfs but no detention storage would be required. The results of this simulation run are summarized in Table 5-3. Review of this table shows average annual TP loads delivered to the S-3/S-8 Basin would increase slightly from 3,522 to 3,556 kg but correcting this small discrepancy would require a detention reservoir too small (about 30 acre-feet) to be practicable.

Table 5-3: Simulation Summary for L2-2 and L1-P2 Alternatives

Source	Destination	Avg. Ann. Volume[3]		Avg. Ann. TP Load[3]	
		(acre-feet)	(% of total)	(kg)	(% of total)
S-4 Diversions[1]	Total	42,205	100.0	12,216	100.0
	To STA-5	33,807	80.1	9,330	76.4
	To S-3/S-8 Basin	7,549	17.9	2,644	21.6
	To L. Okeechobee	849	2.0	242	2.0
Upper C-139 Runoff[2]	Total	17,479	100.0	3,522	100.0
	To STA-5	13,577	77.7	2,609	74.1
	To S-3/S-8 Basin	3,903	22.3	913	25.9
Lower C-139 Runoff	Total (to STA-5)	184,770	100.0	44,034	100.0
All Sources	Total	244,454	100.0	59,772	100.0
	To STA-5	232,154	95.0	55,973	93.6
	To S-3/S-8 Basin	11,452	4.7	3,556	6.0
	To L. Okeechobee	849	0.3	242	0.4

1. Desired S-4 Basin diversions (historic discharge to Lake Okeechobee).
2. Runoff from upper C-139 Basin currently discharged to S-3/S-8 Basin at G-136.
3. Based on simulation for WY 1993–2004

* * * * *

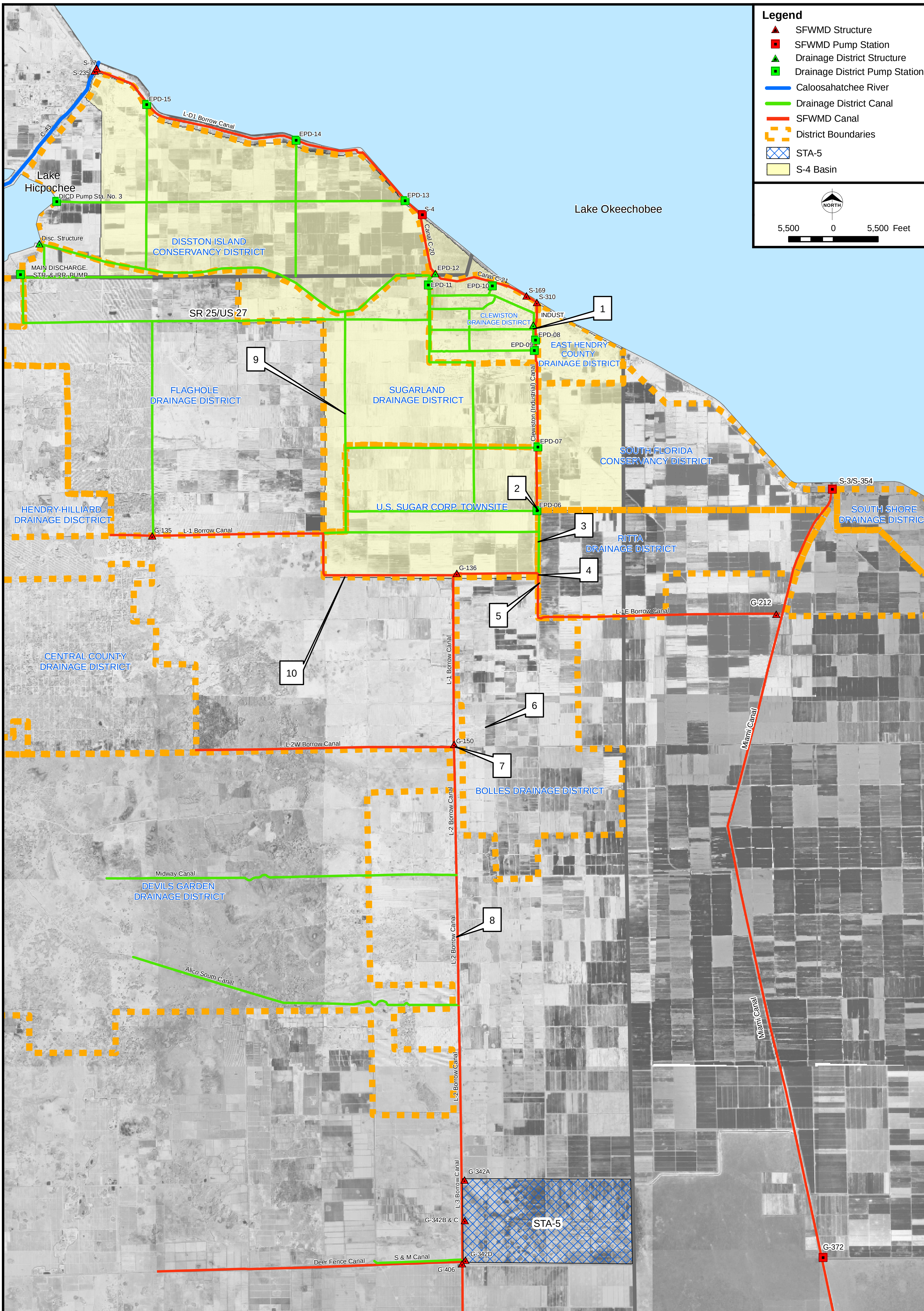
6.0 CONCEPTUAL DIVERSION SYSTEM DESIGN

A conceptual design for the proposed S-4 Basin diversion system is presented in this chapter. The previous analyses presented in this report have concentrated on where to deliver diversions from the S-4 Basin and on the required diversion system capacity and detention storage. For these prior analyses, it was assumed that these diversions could be collected and delivered to the appropriate destination without significant limitation. With the C-139 Basin now identified as the primary destination for these diversions, this chapter presents a conceptual design of the required diversion facilities and other improvements required within and external to the S-4 Basin. Because of a lack of recent geometric data, no hydraulic analyses have been completed for some of the canals potentially impacted by development of this diversion system. Therefore, subsequent analyses may require adjustment of some of the assumptions utilized in this conceptual design.

In the following sections, a brief overview of the entire system is presented first followed by more detailed discussions of the necessary improvements and management changes. Figure 6-1 contains a map that shows the locations of the more significant improvements.

6.1 SYSTEM OVERVIEW

All of the S-4 Basin discharge targeted for diversion is currently discharged to Lake Okeechobee at S-4 and S-310. For the most part, these discharges originate in the eastern portion of the basin at EPD monitoring stations EPD-06 through EPD-12. Pump stations at EPD-06, EPD-07, EPD-08 and EPD-09 discharge directly to the Clewiston (Industrial) Canal and the three other structures discharge to the C-21 Canal. Flow between the C-21 and Clewiston canal is regulated at S-169. All targeted diversions that are currently discharged to the Clewiston Canal (EPD-06 through EPD-09) will be conveyed southward by an extension of the Clewiston Canal that connects with the L-1E Borrow Canal at the southern basin boundary. Clewiston Drainage District discharge at EPD-10 and EPD-12, and Sugarland Drainage District runoff will be conveyed southward by extension of Canal 4, one of the existing main canals within the Sugarland Drainage District, to connect with the L-1 Borrow Canal.



Notes
1. Install new control structure in Clewiston Canal South of U.S 27
2. Relocate U.S. Sugar pump station (EPD-06) to west of Clewiston Canal
3. Extend Clewiston Canal south to meet L-1E by enlarging existing U.S Sugar canal
4. Install new gate structure between Clewiston Canal and L-1E Canal
5. Install new gate structure in L-1E Canal downstream of new connection to Clewiston Canal
6. Detention reservoir (if required)
7. Install new pump station between L-1 and L-2 borrow canals at G-150
8. Enlarge L-1, L-2 and L-3 canals between G-136 and Deer Fence Canal
9. Enlarge and extend Sugarland Canal 4 to meet L-1 Canal
10. Install new gate structure between Canal 4 extension and L-1 Canal

Burns & McDonnell
SINCE 1898

Figure 6-1
S-4 BASIN DIVERSION PROBABLE IMPROVEMENTS REQUIRED

Once delivered to the L-1E Borrow Canal, S-4 Basin diversions conveyed by the Clewiston Canal will flow westward through structure G-136 into the L-1 Borrow Canal where they will mix with any local runoff from the upper C-139 Basin and the balance of the S-4 Basin diversions delivered via Canal 4. This combined flow will be conveyed southward in the L-1 Borrow Canal to a new pump station located at G-150. Any portion of this combined flow that exceeds the capacity of this new pump station will flow back eastward via the L-1E Borrow Canal into the S-3/S-8 Basin.

The new pump station at G-150 will discharge S-4 Basin diversions and upper C-139 Basin runoff into the L-2 Borrow Canal or, if applicable, into an adjacent detention storage reservoir. This pump discharge plus any reservoir releases will then be conveyed to STA-5 via the L-2 and L-3 borrow canals.

6.2 INTERNAL S-4 BASIN IMPROVEMENTS

The anticipated internal improvements and management changes needed within the S-4 Basin are described in the following sections.

6.2.1 Canals C-20 and C-21

Much of the basin drainage currently discharged to the C-20 and C-21 Canals will be diverted southward through the Sugarland Drainage District; however, some portion of this discharge will continue to flow westward into the C-43 Basin via the L-D1 Borrow Canal and S-235. A new control structure at the junction between the C-20 Canal and L-D1 Borrow Canal (immediately west of S-4) may be required to prevent increased westward flow.

By volume, most of the current discharge to the C-21 Canal originates from the Sugarland Drainage District (31,778 acre-feet per year average). Under normal conditions, this drainage flows northward by gravity from this drainage district into Canal C-21. As proposed, this drainage would be routed southward in the future by improvement and extension of the existing main Sugarland DD canals. Canal 4 would be extended to meet the L-1 Borrow Canal. The southern terminus of Canal 4 is located approximately one mile north of the L-1 Borrow Canal. This canal would have to be extended across or around land that is part of the U.S. Sugar Townsite area.

The Clewiston Drainage District also has a pump station that discharges to the C-21 Canal (Pump Station No. 2 or EPD-10). The average annual volumes discharged at this pump station (2,336 acre-feet) are small compared to those from the Sugarland Drainage District. Currently, the primary discharge point from the Sugarland DD to the C-21 Canal is a weir so routing of EPD-10 discharge back through the

Sugarland DD would require removal of this weir or possibly construction of a new pump station to handle these flows. A less invasive approach would be to redirect much of the EPD-10 discharge to the Clewiston Canal via the district's other operational pump station (Pump Station No. 3 or EPD-09). EPD-09 discharges to the Clewiston Canal. With development of this diversion system, it is recommended that future district drainage be discharged through EPD-09 to the extent practicable.

At the eastern end of the C-21 Canal, structure S-169 controls flows between the C-21 and Clewiston Canals. Its primary purpose is to limit westward flow from the Clewiston Canal, which is generally maintained at higher stages than the C-21 Canal. The operation of this control structure would remain largely unchanged with development of this proposed diversion system.

6.2.2 Clewiston Canal

As contemplated herein, the Clewiston Canal would become one of the primary conveyance facilities for basin diversions. In order to prevent the water in this canal from flowing northward into Lake Okeechobee, a new control structure in the Clewiston Canal would be required. This control structure would be located at or south of the U.S. Highway 27 bridges but north of the discharge point for EPD-08. This control structure would remain closed under normal operation and opened only during high rainfall events when bypass to Lake Okeechobee may still be necessary. With construction of this new control structure, no changes in the operation of the S-310 lock would be required; therefore, little if any recreational impacts should occur within Clewiston.

The southern terminus of the Clewiston Canal is presently located at U.S. Sugar's Southline Pump Station (EPD-06). This canal would have to be extended southward, approximately 1.5 miles, to meet Levee 1 East at the extreme southeast corner of the S-4 Basin. A new control structure would be required at this location to control flow between the Clewiston and L-1E canals. There is an existing U.S. Sugar canal along the alignment of this possible canal extension that could potentially be enlarged and used for this purpose. Subsequent hydraulic analyses would also be necessary to determine the need for additional improvements in the Clewiston Canal north of EPD-06.

The EPD-06 pump station currently sits at the end of the Clewiston Canal and discharges northward into this canal. To allow this canal to be extended southward, this pump station would have to be relocated. The most likely spot for its relocation would be immediately west of its current location. With the new control structure described above near U.S. Highway 27, operating stages in the Clewiston Canal could be lowered to near 13 feet, or even less, which could make it possible to drain much of U.S. Sugar's

Townsite area by gravity to this canal. Under these conditions, it may be possible to eliminate the EPD-06 pump station entirely. However, eliminating this pump station would make it impossible to drain this area northward under emergency conditions when it may still be necessary to discharge basin drainage to Lake Okeechobee.

6.2.3 Sugarland Drainage District Canals

Diversion of S-4 Basin drainage that is now discharged to Canals C-20 and C-21 would occur through the Sugarland DD by extension of Canal 4 to meet the L-1 Borrow Canal. In addition to this canal extension, certain hydraulic improvements would be necessary in this and other Sugarland DD canals in order to change the predominant flow direction from northward to southward.

A new control structure will likely be required at the junction between the Canal 4 extension and the L-1 Borrow Canal. This structure would likely remain open under normal conditions but could be closed to prevent backflow from the L-1 Borrow Canal into the Sugarland DD.

6.3 L-1E BORROW CANAL

Diversions from the S-4 Basin that are delivered to the L-1E Borrow Canal would pass through a potential new control structure through Levee L-1E. Historically, stages in this canal have ranged from about 9 to 13.2 feet (WY 1993-2004) but the median stage is about 11.1 feet. With Clewiston Canal stages typically maintained near 15 feet, these L-1E Canal stages should allow diversions from the S-4 Basin to flow by gravity into the L-1E Borrow Canal.

The intent of this diversion plan is to direct S-4 Basin diversions westward through G-136 into the L-1 Borrow Canal. To prevent uncontrolled eastward discharges, a new control structure in the L-1E Borrow Canal may be required. This control structure would be located immediately downstream of the new connection between the Clewiston and L-1E canals. This structure would be operated to prevent unintended eastward flow but still allow bypasses when necessary to maintain desired stages in the L-1E Borrow Canal.

At the western end of the L-1E Borrow Canal, structure G-136 controls flow between this canal and the L-1 Borrow Canal. Currently, essentially all flow through this structure is from west to east and is controlled by flashboard risers normally set at an elevation of 13 feet. To facilitate bidirectional flow through this structure, the flashboards in G-136 would have to be removed.

It is not anticipated that any conveyance improvements would be necessary in this two-mile section of the L-1E Borrow Canal or for structure G-136 but subsequent hydraulic analyses would be needed to verify these assumptions.

6.4 L-1 BORROW CANAL

S-4 Basin diversions and runoff from the upper C-139 Basin will mix in the L-1 Borrow Canal and be conveyed southward to a new pump station at G-150. To limit hydraulic gradients and flow velocities in the L-1 Borrow Canal between G-136 and G-150, an enlargement of this four-mile canal section would be necessary. An enlargement of the L-1 Borrow Canal upstream of G-136, between this structure and the proposed Canal 4 extension, may also be required. Additional analyses would be required to determine an optimum plan these canal improvements but an enlargement of approximately 50 percent is considered representative.

It is intended that diversions would flow by gravity from the L-1E Borrow Canal to the L-1 Borrow Canal through G-136 so stages in the L-1 Borrow Canal would have to be maintained lower than those in the L-1E Borrow Canal. Stages in the range of 9 to 11 feet are recommended.

Stages in the L-2 Borrow Canal downstream of G-150 can easily exceed 17 feet. In Chapter 4, it was estimated that a 2-year flood would cause tailwater stages at G-150 to rise to about 17.5 feet. Therefore, a pump station is needed at G-150 to lift water from the L-1 Borrow Canal (at stages between 9 and 11 feet) to the L-2 Borrow Canal (at stages of near 17.5 feet). With an enlargement of the L-2 and L-3 borrow canals, the maximum import capacity of these canals is estimated to be 1,076 cfs (Table 4-5). For the purposes of this diversion project, the nominal capacity of this new pump station should be specified as the same unless a larger capacity pump station is warranted to serve some additional flood control purpose.

Inflow to the L-1 Borrow Canal would consist of S-4 Basin diversions and local runoff from the upper C-139 Basin under this potential diversion project. If these inflows should exceed the capacity of the new pump station at G-150, water would back up in the L-1 and L-1E borrow canals. If stages get high enough, water would pass through the potential new L-1E control structure into the S-3/S-8 Basin. One suggested goal of this diversion project is to limit average bypasses to no more than historic flow volumes and TP loads through G-136 into the S-3/S-8 Basin.

6.5 L-2 AND L-3 BORROW CANALS

From the new G-150 pump station, diversions will be discharged to the L-2 Borrow Canal. It would be necessary to enlarge the L-2 and L-3 borrow canals from G-150 south to below the Deer Fence Canal to increase the capacity of this canal system without causing canal stages to rise to levels where they may adversely impact adjacent landowners. With the planned future expansion of STA-5, it may be necessary to extend these improvements to below the most southerly inflow structure to STA-5. For these analyses, it is assumed these canals will be increased in size by approximately 50 percent.

* * * * *

7.0 CONCLUSIONS

This chapter presents the conclusions reached as a result of the investigations and evaluations conducted during this study.

- Over the 12-year analyses period (WY 1993–2004) employed in this study, discharges from the S-4 Basin have averaged 94,336 acre-feet per year at a flow-weighted mean TP concentration of 220 ppb. By volume, approximately 52 percent of these discharges have been delivered to Lake Okeechobee and 48 percent to the C-43 Basin.

- After the planned diversion system in the South Florida Conservancy District (Unit 5) becomes operational, average S-4 Basin discharges to Lake Okeechobee are estimated to decline by over 7,000 acre-feet per year, a decrease of approximately 14 percent.

- The two partial diversion options would exclude drainage from the Clewiston Drainage District, or Clewiston and Sugarland drainage districts from potential S-4 Basin diversions (Options 1 and 2, respectively). Under these options, desired S-4 Basin diversions would be approximately 40,900 and 27,800 acre-feet per year.

- Peak discharge rates from the S-4 Basin (on a mean daily basis) are estimated to be about 2,000 cfs. In order to divert approximately 98 percent of historic discharges to Lake Okeechobee, a diversion capacity of at least 1,300 cfs would be required.

- Potential destinations for S-4 Basin diversions include the C-139, C-43 and S-3/S-8 basins.

- Possible diversions from the S-4 Basin have not been included in the planning and preliminary design studies for the C-43 Reservoir project. Accommodating these diversions would in all probability require revisions to these existing studies and potentially delay this reservoir project. As a result, diversion of S-4 Basin discharge to the C-43 Basin is not considered to be an attractive option at this time.

- Discharge of S-4 Basin diversions to the S-3/S-8 Basin would have to be treated in STA-3/4. The ongoing EAA Regional Feasibility Study is designed to optimize the loading of the various STAs but no potential S-4 Basin diversions have been included in evaluations for STA-3/4 to date. Diversions from the S-4 Basin could increase the TP loading to STA-3/4 by up to 20 percent, which is likely to have a detrimental impact on the performance of this treatment area. For this reason, it was concluded that the S-3/S-8 Basin may not be the most viable destination for S-4 Basin diversions at this time. If potential S-4 Basin diversions are incorporated into the planning process for Compartment A-2 of the EAA Reservoir Storage project, this option could become more attractive in the future.

- The potential performance of STA-5, after its expansion to occupy the remainder of Compartment C, was evaluated with addition of potential S-4 Basin diversions using the Dynamic Model for Stormwater Treatment Areas–Version 2. These analyses indicate this expanded STA could have median flow-weighted mean outflow TP concentrations ranging from 13.8 to 35.1 ppb (after planned SFCD diversions). The corresponding geometric mean TP concentrations are predicted to range between 9.5 and 30.8 ppb. At the lower end of these ranges, this performance may be acceptable so the C-139 Basin was identified as the preferred destination for S-4 Basin diversions.

- The import capacity of the L-1 and L-2/L-3 borrow canals is a measure of their ability to accept potential diversions from the S-4 Basin. The existing import capacities of these canals are respectively 148 and 657 cfs. With enlargements of approximately 25 or 50 percent, the import capacity of the L-2/L-3 canal system could be increased by about 200 or 400 cfs, respectively.

- With a system designed to divert both S-4 Basin diversions and runoff from the upper C-139 Basin to STA-5, a peak diversion rate of 1,410 cfs would be necessary to divert 98 percent of the historic discharges from the S-4 Basin to Lake Okeechobee.

- Without any improvements in the L-2/L-3 canal system, a diversion system with approximately 5,100 acre-feet of detention storage would be required. With an assumed enlargement in this canal system of 25 percent, the required amount of detention storage falls to 2,500 acre-feet. The need for detention storage could be eliminated by enlarging the L-2 and L-3 borrow canals by approximately 50 percent.

* * * * *

8.0 REFERENCES

This chapter lists complete citations for the references cited in this report.

Briley, Wild and Associates. (1990, January). *S-4 Nutrient Reduction Plan* (Project SF 86124-3R). Prepared for South Florida Water Management District. Ormond Beach, FL: Author.

Burns & McDonnell Engineering Co. (1994, February 14). *Everglades Protection Project: Conceptual Design* (Project 92-166-1-002). Prepared for South Florida Water Management District. Kansas City, MO: Author.

Burns & McDonnell Engineering Co. (2005a, June 27). *Deliverable 1.3.2 – Historic Inflow Volumes and Total Phosphorus Concentrations by Source (Final Report)* (Burns & McDonnell Project 38318). Prepared under subcontract to ADA Engineering for South Florida Water Management District. Kansas City, MO: Author.

Burns & McDonnell Engineering Co. (2005b, August 9). *Deliverable 1.5.2 – Inflow Data Sets for the Period 2006-2009 (Final Report)* (Burns & McDonnell Project 38318). Prepared under subcontract to ADA Engineering for South Florida Water Management District. Kansas City, MO: Author.

Burns & McDonnell Engineering Co. (2005c, September 7). *Deliverable 2.2 – Optimum Allocation of Loads to the STAs for the Period 2006-2009 (Final Report)* (Burns & McDonnell Project 38318). Prepared under subcontract to ADA Engineering for South Florida Water Management District. Kansas City, MO: Author.

Burns & McDonnell Engineering Co. (2005d, September 29). *Deliverable 1.2A.1 – Inflow Data Sets for the Period after 2014 (Final Report)* (Burns & McDonnell Project 38318). Prepared under subcontract to ADA Engineering for South Florida Water Management District. Kansas City, MO: Author.

Burns & McDonnell Engineering Co. (2005e, September 29). *Deliverable 1.2B.1 – Inflow Data Sets for the Period after 2014 (Final Report)* (Burns & McDonnell Project 38318). Prepared under subcontract to ADA Engineering for South Florida Water Management District. Kansas City, MO: Author.

Burns & McDonnell Engineering Co. (2005f, October 3). *Optimum Allocation of Loads to the STAs for the Period 2010-2014, Alternative No. 1 (Final Report)* (Burns & McDonnell Project 38318). Prepared under subcontract to ADA Engineering for South Florida Water Management District. Kansas City, MO: Author.

Burns & McDonnell Engineering Co. (2005g, October 3). *Optimum Allocation of Loads to the STAs for the Period 2010-2014, Alternative No. 2 (Final Report)* (Burns & McDonnell Project 38318). Prepared under subcontract to ADA Engineering for South Florida Water Management District. Kansas City, MO: Author.

Burns & McDonnell Engineering Co. (2005h, October 3). *Optimum Allocation of Loads to the STAs for the Period 2010-2014, Alternative No. 3 (Final Report)* (Burns & McDonnell Project 38318). Prepared under subcontract to ADA Engineering for South Florida Water Management District. Kansas City, MO: Author.

Cooper, R. M. (1989, September). *An atlas of the Everglades Agricultural Area surface water management basins*. West Palm Beach, FL: Water Resources Division, South Florida Water Management District.

Corps of Engineers. (1954, April). *Central and Southern Florida Project, Levee 1 (East 10 Miles): Plan, Profile and Sections, Record Drawing.* Jacksonville, FL: Author.

Corps of Engineers. (1958, December). *Central and Southern Florida Project, Levee-2 & 3: Plan, Profile and Sections, Record Drawing.* Jacksonville, FL: Author.

Corps of Engineers. (2003, February). *CERP fact sheet: C-43 Basin Storage Project – Part 1*. Retrieved 15 August 2005 from http://www.evergladesplan.org/docs/fs_c43.pdf.

Disston Island Conservancy District. (no date). *Disston Island Conservancy District: Glades & Hendry Counties, Florida* [Map]. AutoCAD drawing of district in file "disston.dwg" with unknown author.

Hydrologic Engineering Center. (2002, November). *HEC-RAS: River Analysis System, User's Manual, Version 3.1* [CPD-68]. Davis, CA: U.S. Army Corps of Engineers.

Mock, Roos & Associates, Inc. (1993, January). *Western Basins Environmental Assessment.* Prepared for South Florida Water Management District. West Palm Beach, FL: Author.

Roberts, R. (no date-a). *Pumps Summary Table*. Retrieved 28 June 2005 from http://epd.rayrob.com/INFORMATION/PUMP_INFORMATION/Summary_Table/Summary_Table_Pumps.html.

Roberts, R. (no date-b). *Pump information: Pump equations*. Retrieved 27 July 2005 from http://epd.rayrob.com/INFORMATION/PUMP_INFORMATION/Pump_Equations/Pump_Equations.html.

Searcy, Howard L., Engineers. (1997, August). *South Florida Conservancy District, Unit No. 5: Everglades Construction Project, Diversion Plan, Preliminary Engineering Report (SFWMD ECP Project No. 10).* Prepared for South Florida Conservancy District. West Palm Beach, FL: Howard L. Searcy Engineers, a division of Lindahl, Browning, Ferrari & Hellstrom, Inc.

South Florida Water Management District (2002, October 8). *Everglades Construction Project Schedule*. Retrieved 24 August 2005 from http://www.sfwmd.gov/org/erd/ecp/sched1.pdf.

South Florida Water Management District. (2005, May 23). *EAA-EPD historic and recent data files* [CD-ROM]. Data compilation for EPD-provided monitoring data. West Palm Beach, FL: Author.

South Florida Water Management District. (2005b, July 5). *Everglades Construction Project: SFWMM Model Assumptions* (Draft). West Palm Beach, FL: Author.

South Florida Water Management District (no date). *DBHYDRO* [Database]. Data retrieved on various dates from http://www.sfwmd.gov/org/ema/dbhydro/index.html.

Stanley Consultants. (2005, January). *C-43 West Storage Reservoir: Basis of Design Report (Pre-final version).* Prepared for South Florida Water Management District. West Palm Beach, FL: Author.

Walker, W. & Kadlec, R. (2005, July 1). *Dynamic Model for Stormwater Treatment Areas-Version 2* [Computer Model]. Developed for U.S. Department of Interior and U.S. Army Corps of Engineers. Retrieved from www.wwwalker.net/dmsta.

* * * * *