



# EVALUATING AND IMPROVING FLOW DATA QUALITY USING STRIVE DATA AT WATER CONTROL STRUCTURES

Volume I



By

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**TECHNICAL PUBLICATION**  
**ERA REPORT # 428**

**July 2005**

**OPERATIONS AND HYDRO DATA MANAGEMENT DIVISION**  
**SCADA AND HYDRO DATA MANAGEMENT DEPARTMENT**  
**SOUTH FLORIDA WATER MANAGEMENT DISTRICT**



## EXECUTIVE SUMMARY

The South Florida Water Management District (District) is responsible for managing water resources in 16 counties within South Florida. The District operates 1,800 miles of canals and more than 400 water control structures. The agency is also responsible for collecting, validating, and archiving hydrological data including water level, water control structure operations, and flow.

As of March 2005, flow is computed by the District at 423 water control structures. These structures are comprised of culverts (58 percent), spillways (25 percent), pump stations (13 percent), and weirs (4 percent). In order to compute flow, the District determines static structure information from the “as-built” drawings of structures. The flow data are stored in DBHYDRO, the District’s hydrometeorologic database. However, this static structure information is often not of sufficient quality to compute flow accurately in certain hydraulic conditions and, in some cases, the information is erroneous or not up to date.

In 1999, the Structure Information Verification (STRIVE) project was initiated to evaluate and improve the quality of existing flow data at each water control structure. This project was established to verify static structure information (dimensions, elevations, entrance and outlet conditions, sedimentation, and other maintenance effects) collected from recent field topographic and geometric surveys. To date, the District has completed field surveys for 367 water control structures. The flow data for 168 of these structures have been computed and archived in DBHYDRO.

This study provides details of the methodology and principles of hydraulics used in computing, comparing, and analyzing the flow data at the water control structures. Among the surveyed structures, 83 culverts, 65 spillways, 16 pump stations, and 4 weirs are registered in DBHYDRO and flow data have been computed. For each structure, a new flow time series was computed from recently acquired static structure data under the STRIVE project. The new and existing flow datasets were compared and analyzed for each structure. Average monthly differences in new and existing flow data were greater than  $\pm 5$  percent for 47 structures and the differences were less than  $\pm 5$  percent for 121 structures. Data change procedures will be used prior to revising the historical flow data series in DBHYDRO if the new flow data are significantly different. The improved flow datasets for the historical period of record from this project will be stored in DBHYDRO, where appropriate.

The District has completed field surveys for 78 additional water control structures where flow data analysis using STRIVE data are needed. In addition, 177 structures will need to be surveyed in the next four to five years, and these structures will also require flow data analysis.



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## **ACKNOWLEDGEMENTS**

The authors are very thankful to Mr. Howard Ehmke for providing continuing support on field survey data for water control structures during the period of this study. In addition, the authors would like to thank the following for their assistance in preparation of this report: Mr. Tarek Salaheldin and Mr. Efrain Giron of PHS Engineering, Inc. for the hydraulic data analyses; Lokendra Matoli for writing computer scripts for data extraction from the database and modification of the FLOW program; Ashie Akpoji, Matahel Ansar, Scott Huebner, Sashi Nair and Taiye Sangoyomi for reviewing drafts and providing valuable comments; and Stacey Efron for technical editing of this report.



## INTRODUCTION

### Background

The South Florida Water Management District (District) is responsible for protecting regional water supply resources and for alleviating flooding in 16 counties within South Florida. Within the Central and South Florida (C&SF) drainage system, the District manages about 1,800 miles of canals and levees and more than 400 water control structures. Extensive hydrological and structure operational data (e.g., water level and gate openings) are collected, validated, analyzed, and archived by the District to support its water management efforts.

In 1999, the Structure Information Verification (STRIVE) project was initiated to improve the quality of existing structure data and computed flow data at each water control structure. Because flow computations are based on both static and dynamic data available for each structure, the District has historically determined static structure information from the “as-built” drawings of structures. The flow data are stored in DBHYDRO, the District’s hydrometeorologic database. However, these “as-built” drawings do not often meet accuracy and precision needed for flow computation purposes due to many site conditions, such as uneven weir perimeters, weed clogging, weed barriers, rebuilt and new constructions, and structure failures.

The STRIVE project was established to verify static structure information collected from field topographic and geometric surveys. The information is composed of dimensions, elevations, entrance and outlet conditions, sedimentation, and other maintenance effects. These structures consist of culverts, spillways, pump stations, and weirs. The District completed the topographic surveys for 367 water control structures over the last six years.

This report details the methodology and principles of hydraulics used in computation, comparison, and analysis of the flow data at 168 water control structures. For each structure, a new flow time series was computed from recently obtained static structure data under the STRIVE project. Differences in new and existing flow data were compared for the structures. The revised flow datasets for the historical period of record from this project will be stored in DBHYDRO, where appropriate. This project is important because it will substantially improve the accuracy and precision of flow data necessary for water budgets and water quality analyses that are used in various water resources projects at the District.

### Project Objectives

The goals and objectives of this project are to:

- verify the information relevant to the physical characteristics of the District’s hydraulic structures.
- use the structure static data that are obtained from field surveys to improve computed flow data.
- systematically review and verify structure information.



## **Scope of the Project**

The scope of this project is to:

- compare STRIVE data with data in DBHYDRO currently used in computing flow.
- verify all inconsistencies at the structures using standard survey forms.
- assess the impact of the newly computed flow data on historical flows obtained from DBHYDRO using the FLOW computer program.
- revise static structure data in DBHYDRO, where warranted.
- use data change procedures (Akpoji et al., 2003) prior to revising the historical flow data series in DBHYDRO if the new flow data are significantly different.



## DATA COLLECTION

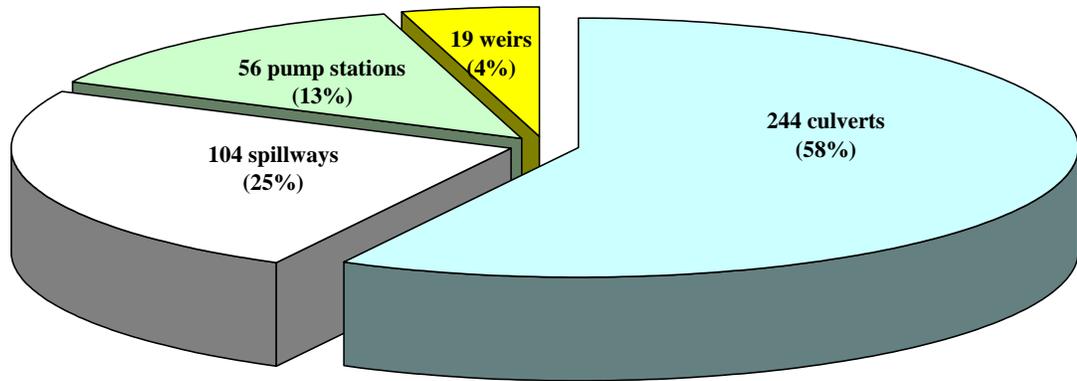
The STRIVE project is concerned with structure static data and has revealed inconsistencies between water control structure data in DBHYDRO and field measured topographic and geometric data. Site visits to structures have identified static data discrepancies that could lead to inaccurate flow computations. The structure data that were field verified include the descriptive parameters of structures: sill and invert elevations, gate types, gate shapes, gate dimensions, culvert types, culvert materials, etc. These parameters constitute the static structure data and are used in the District's FLOW computer program.

As of March 2005, the District computed flow at 423 water control structures registered in DBHYDRO. It should be noted that several water control structures are added every week at the District. Several structures that are under construction at Stormwater Treatment Areas 1 East and 3/4 (STA-1E and STA-3/4) are not included in this study. The 423 structures are grouped into culverts (58 percent), spillways (25 percent), pump stations (13 percent), and weirs (4 percent) (**Figure 1**). Approximately 45 percent of the water control structures are located in the STAs and 55 percent of these structures are located within the C&SF system (**Figure 2**). Only 56 percent of the structures have stream gauging data (**Figure 3**) that is used in calibrating and validating flow rating equations. Currently, the STRIVE project has completed surveying and flow data analysis for 168 water control structures (40 percent). Of the remaining structures, 78 (18 percent) have been surveyed but still require flow data analysis and 177 (42 percent) require surveying and flow data analysis (**Figure 4**).

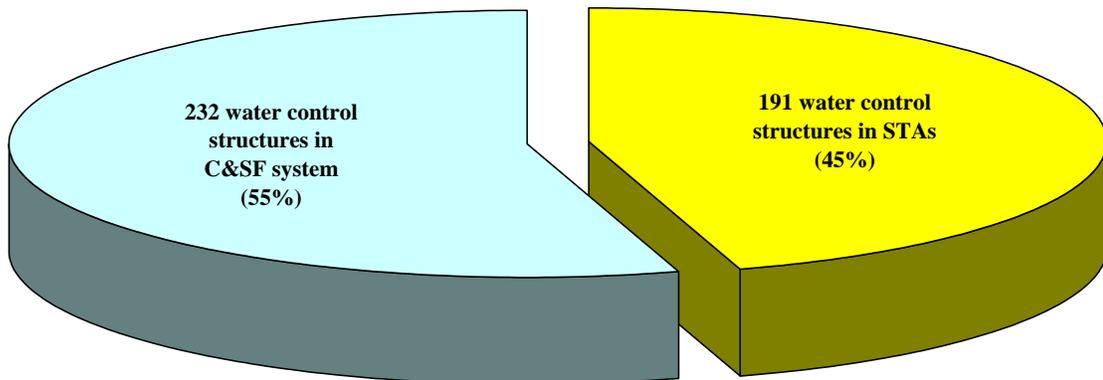
After collecting the field data, the District's professional surveyors record the data on a standard survey data sheet (see Appendix A). The survey data sheets are signed, sealed, and submitted to the STRIVE project manager, Mr. Howard Ehmke.

The topographic surveys were performed to National Geodetic Survey's (NGS) third order closure standard [defined as  $(0.05 \text{ ft}) * \sqrt{(\text{Distance in Miles})}$  for elevation data]. All elevations measured at the water control structures are provided in North American Vertical Datum (NAVD) 1988 and National Geodetic Vertical Datum (NGVD) 1929.

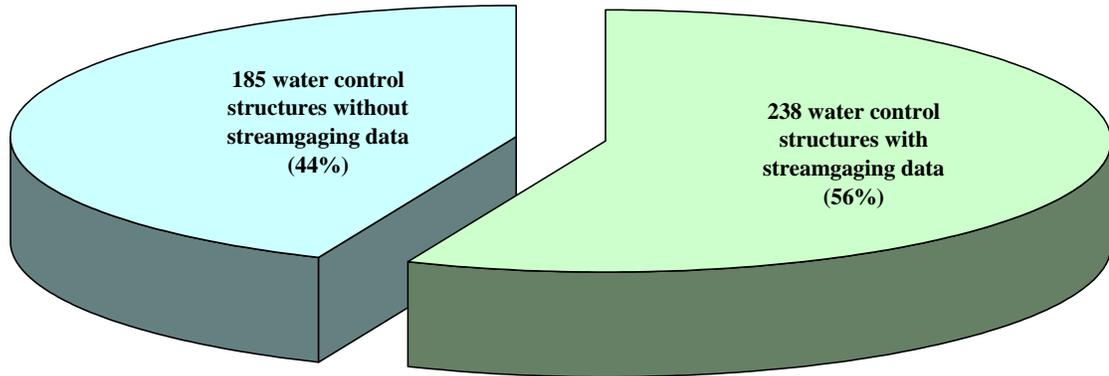
Prior to performing the field surveys, the surveyors compared the data values from "as-built" drawings, structure books, and design drawings. After proper examination for consistency and errors, the surveyed data for all structure parameters was entered into STRIVE tables using Microsoft Excel. All data for a given structure were reviewed and revised by the responsible engineer for consistency and accuracy.



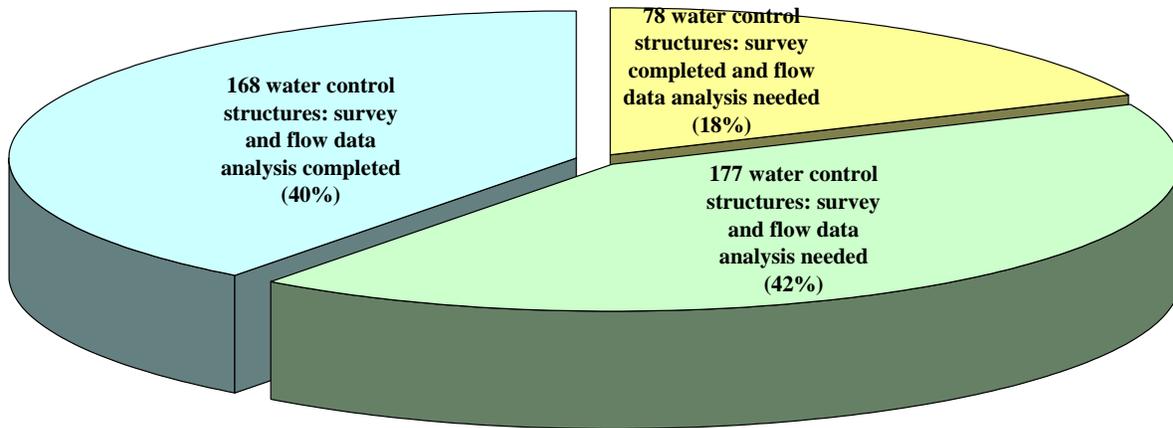
**Figure 1.** Flow data computations at the 423 District water control structures, as of March 2005.



**Figure 2.** Water control structures in the STAs and C&SF system, as of March 2005.



**Figure 3.** Stream gauging data availability for water control structures, as of March 2005.



**Figure 4.** Current status and future work effort for the STRIVE project, as of March 2005.



## FLOW COMPUTATIONS AND DATA ANALYSES

### Flow Computations

Flow data computations at the water control structures require a. static structure data; b. three dynamic data sets that include upstream stage, downstream stage and structure operation data and c. hydraulic flow equations. Errors in these three areas result in errors in computed flow values. This study focused on use of the improved static structure information in estimating flow data. The two other data groups, as noted above, are not evaluated in the study. However, they remain critical in improving the accuracy of the flow data as well.

The static structure data are determined, in the majority of the cases, from the “as-built” drawings of the structure. Three dynamic data that include upstream stage, downstream stage and structure operation data are obtained from sensor instruments in the field located within the vicinity of the structure.

Flow equations used in the District are assembled from various sources based on the structure type (culvert, spillway, pump station, weir) and flow regime (Ansar and Alexis, 2003). These equations are used in the FLOW computer program that was written in FORTRAN.

Culvert flow computations are based on three types of flow conditions: full-pipe flow, orifice flow, and open channel flow. Full-conduit flow is subdivided into two subtypes of flow conditions depending on whether the inlet is submerged or free. Orifice flow is similarly subdivided into two subtypes depending on whether the barrel is partially filled or completely full. Open channel flow is subdivided into three subtypes depending on whether critical flow occurs at the inlet or at the outlet, or whether subcritical flow occurs throughout the barrel under tailwater control. Culvert flow equations were developed from hydraulic principles by Fan (1985).

The U.S. Army Corps of Engineers derived the flow equations from small-scale model testing model of C & SF spillways (Ansar and Alexis, 2003). Spillway flow is classified into five types: controlled free, controlled submerged, uncontrolled free, uncontrolled submerged and over-the-top flows.

The District subdivides spillways into three cases for flow computations:

- Case 1: The flow rate is obtained from a standard spillway equation with the discharge coefficient set equal to a constant for each flow condition.
- Case 2: The flow rate is computed from a standard spillway equation with a variable discharge coefficient at each flow condition.
- Case 3: The flow rate is obtained from a non-standardized equation derived mostly from regression analysis of the flow measurements.



Flows at pump stations are modeled based on pump curves, which define the flow rate as a polynomial function of the head difference. There are eight cases for flow computations. Cases 1 and 5 are used at constant speed pumps, where flow is computed using a third order polynomial fitting of the head difference (pump head) between upstream and downstream stages. Cases 2 and 4 are used at highly variable speed pumps, where flow is computed using a two-variable polynomial fitting of the pumping head and the engine speed of the pump. Case 3 is used at variable speed pumps, where flow is obtained from an interpolation between an upper and lower discharge curves that are given by third order polynomials of the pumping head, as in Cases 1 and 5. Case 6 is developed for the variable speed pumps, where the flow is computed as a function of the pumping head and the pump engine speed. In Case 7, pump affinity laws are used to predict the discharge. Case 8 is used to generalize variable and constant speed pumps in order to simplify computations.

Weirs are classified into three major categories: ogee, trapezoidal, and variable weirs for flow computations. A free weir equation is used to compute free flows; however, Villemonte's equation is used to compute submerged flows. For trapezoidal weirs, combinations of V-notch and rectangular weir flows are used to compute the discharge. For variable weirs, a distinction is made between sharp-crested and broad-crested weir flows based on the ratio of the headwater depth above sill, and the crest width in the direction of the flow.

## **Data Analyses**

In this study, flow data were computed using the FLOW computer program for two sets of structure static data that were obtained from DBHYDRO and the STRIVE project. Subsequently, the two sets of flow data were compared and analyzed.

Data analysis was performed on the calculated historical flow data at each of the 168 water control structures. Mean daily flow data were computed for each water control structure using static structure data from DBHYDRO and STRIVE. The period of record for the flow data varied up to 10 years depending upon availability of historical data for each structure. The daily difference in mean daily flow data between DBHYDRO and STRIVE were computed for each structure and for the period of record. Subsequently, average monthly differences were computed from daily differences.

In addition, for each structure, the percent of records where the flow differences were greater than  $\pm 5$  percent was computed. This percentage was obtained by dividing the number of flow days when flow differences were greater than  $\pm 5$  percent by the total number of flow days.



## RESULTS

A total of 367 water control structures (225 culverts, 90 spillways, 30 pump stations, and 22 weirs) were surveyed under the STRIVE project. Among these structures, 83 culverts, 65 spillways, 16 pump stations, and 4 weirs are registered in DBHYDRO and had flow data computed by the District. However, 15 culverts and 10 spillways were registered in DBHYDRO but flow data were not computed. Of these structures, 62 culverts, 63 spillways, 15 pump stations, and 3 weirs had stream gauging data.

Analysis was performed on the calculated historical flow data to determine impacts to the 168 water control structures. The average, maximum and minimum monthly differences in percent were computed for each structure and are presented in **Tables 1** through **7**. These tables were grouped based on structure type and percent of average monthly differences that are less than or greater than  $\pm 5$  percent. The static structure information for each water control structure is presented in Appendices B through D. Appendix E summarizes structure information and computed flow differences between DBHYDRO and STRIVE.

Average monthly differences in new and existing flow data were less than  $\pm 5$  percent for 121 water control structures and the differences were greater than  $\pm 5$  percent for 47 water control structures. Average monthly differences in new and existing flow data were less than and greater than  $\pm 5$  percent for 56 and 27 culverts, respectively. For spillways, average monthly differences were less than and greater than  $\pm 5$  percent for 47 and 18 spillways, respectively. Whereas, average monthly differences were less than  $\pm 5$  percent for all 16 pump stations; and the differences were less than and greater than  $\pm 5$  percent for 2 weirs. For four culverts, three spillways and one pump station, average monthly flow differences were less than  $\pm 5$  percent and percent records were greater than 20 percent.

Flow data for 168 structures was computed and compared. Field surveying for 78 structures was completed but flow data analysis is needed for these structures. Currently, 177 structures will need to be surveyed. Thirty-five of these structures have stream gauging data. These structures are identified in **Tables 8, 9A, and 9B**.

**Figures 5** through **8** show the current status of work completed and work remaining for culverts, spillways, pump stations, and weirs, respectively. The surveyed structures static data are presented in Appendix F. Appendix G contains a list of structures that require surveying. Appendix H includes all water control structures that were surveyed but they are not listed in DBHYDRO database.

In next four to five years, surveying will be needed on the remaining 177 structures. The structure static data in DBHYDRO will be revised, as appropriate, and then the new flow data and historical flow data will be compared. If new flow data is significantly different, then data change procedures (Akpoji et al., 2003) will be used prior to revising the historical flow data series in DBHYDRO.

**Table 1.** Percent flow difference between STRIVE and DBHYDRO data for culverts: average monthly difference less than 5%.

Station Name	Monthly Difference			% of Records have difference > 5 %
	Ave %	Max %	Min %	
S143_C	0.01	0.09	0.00	0.00
S197_C	0.02	1.20	0.00	0.05
G344B_C	0.02	0.79	0.00	0.05
S30_C	0.04	7.61	0.00	0.20
S343A_C	0.04	1.30	0.00	0.15
S344_C	0.04	0.91	0.00	0.00
G344C_C	0.04	1.00	0.00	0.10
G344D_C	0.04	1.33	0.00	0.20
G34_C	0.06	2.85	0.00	0.51
S121_C	0.07	5.55	0.00	0.46
S337_C	0.07	9.94	0.00	0.34
S336_C	0.08	1.85	0.00	0.00
S151_C	0.09	11.80	0.00	0.49
G119_C	0.11	1.54	0.00	0.00
S10E_C	0.22	6.39	0.00	2.18
S175_C	0.24	3.58	0.00	1.20
S343B_C	0.36	30.39	0.00	0.36
G94C_C	0.38	0.91	0.00	0.00
G204_C	0.40	16.43	0.00	5.06
G72_C	0.43	14.85	0.00	1.77
G58_C	0.52	19.39	0.00	1.46
S169_C	0.59	12.26	0.00	1.00
G327A	0.61	4.15	0.00	3.93
S58_C	0.71	31.01	0.00	2.28
S142_C	0.73	13.36	0.00	2.40
G304J_C	0.74	9.00	0.00	1.85
G206_C	0.84	10.53	0.00	7.32
S195_C	1.03	13.10	0.00	8.54
S338_C	1.11	3.21	0.00	0.52
S154_C	1.48	36.44	0.00	2.26
S178_C	1.56	29.35	0.00	7.64

\*: % of Records that are greater than 20 percent.



**Table 1. Continued.**

Station Name	Monthly Difference			% of Records have difference > 5 %
	Ave %	Max %	Min %	
G108_C	1.68	26.31	0.00	1.63
G96_C	1.77	18.90	0.00	3.15
S146_C	1.80	14.32	0.00	17.41
S120_C	1.82	33.80	0.00	2.60
S150_C	1.86	47.20	0.00	5.66
S144_C	1.98	43.00	0.00	11.50
G69_C	1.98	58.56	0.00	6.87
G607	2.13	11.97	0.16	11.71
G88_C	2.25	12.02	0.00	19.63
G304I_C	2.62	15.49	0.00	8.37
S173_C	2.79	50.49	0.00	14.06
S13A_C	2.85	64.18	0.00	12.08
S145_C	2.87	11.08	0.00	24.51*
G304D_C	2.87	18.50	0.00	9.33
G304G_C	2.90	19.20	0.00	7.23
G304A_C	3.03	20.23	0.00	7.46
G304C_C	3.17	25.13	0.00	11.80
G211_C	3.34	99.69	0.00	5.05
G136_C	3.77	7.69	0.00	51.46*
G150_C	3.94	32.36	0.00	15.94
G304F_C	3.99	22.30	0.00	8.41
G304E_C	4.06	39.37	0.00	11.55
G135_C	4.53	85.68	0.00	40.92*
G304H_C	4.65	33.27	0.00	9.00
S38C_C	4.75	8.08	0.00	66.60*

\*: % of Records that are greater than 20 percent.



**Table 2.** Percent flow difference between STRIVE and DBHYDRO data for culverts: average monthly difference greater than 5%.

Station Name	Monthly Difference			% of Records have difference > 5 %
	Ave %	Max %	Min %	
S34_C	6.68	56.17	0.00	24.39*
G134_C	6.84	24.82	0.00	51.29*
G306E	6.98	22.18	0.00	34.91*
G306J	7.03	20.21	0.00	38.51*
G306D	7.09	23.78	0.00	35.00*
S194_C	7.53	51.16	0.00	31.10*
G306B	7.62	22.21	0.00	37.28*
G306A	7.67	22.20	0.00	37.54*
G306H	7.74	22.15	0.00	37.98*
G304B	7.93	44.37	0.00	7.26
G306G	8.10	22.12	0.00	39.04*
G306I	8.18	22.15	0.00	39.39*
G306C	8.36	26.50	0.00	35.44*
G354A_C	9.44	100.00	0.00	39.90*
G354B_C	9.44	100.00	0.00	39.90*
S124_C	9.69	81.51	0.00	34.66*
S57_C	9.76	57.70	0.00	31.13*
S196_C	9.83	54.93	0.00	30.78*
G354C_C	11.14	99.51	0.00	40.88*
S31_C	11.38	88.27	0.00	20.51*
G306F	11.87	36.21	0.00	37.19*
G151_C	13.11	50.01	0.00	65.90*
S32_C	15.75	96.14	0.00	34.09*
S47B_C	17.79	32.97	0.00	98.18*
G92_C	18.65	45.48	0.00	80.83*
S25_C	19.42	86.95	0.00	42.01*
S38_C	26.03	89.16	0.00	48.35*

\*: % of Records that are greater than 20 percent.

**Table 3.** Percent flow difference between STRIVE and DBHYDRO data for spillways:  
average monthly difference less than 5%.

Station Name	Monthly Difference			% of Records have difference > 5 %
	Ave. %	Max. %	Min. %	
S118_S	0.03	0.99	0.00	0.05
S166_S	0.04	0.81	0.00	0.03
S29_S	0.06	3.65	0.00	0.23
S68_S	0.07	1.57	0.00	0.09
G338_C	0.07	0.33	0.00	0.00
S179_S	0.09	1.80	0.00	0.38
S191_S	0.10	3.22	0.00	0.79
S82_S	0.12	0.21	0.00	0.00
S33_S	0.15	13.35	0.00	0.28
S177_S	0.16	3.72	0.00	0.21
S119_S	0.17	7.94	0.00	0.16
S22_S	0.17	3.67	0.00	0.49
S28_S	0.18	5.22	0.00	0.62
G339_S	0.21	3.33	0.00	0.23
S167_S	0.28	2.34	0.00	0.69
S11A_C	0.28	2.34	0.00	0.30
S165_S	0.31	2.84	0.00	0.41
G301_S	0.47	1.94	0.00	0.20
S20_S	0.48	38.67	0.00	2.48
S334_S	0.52	2.76	0.00	0.07
S27_S	0.58	0.73	0.00	0.00
S190_S	0.64	6.77	0.00	2.84
S123_S	0.70	3.00	0.00	0.12
S174_S	0.81	3.94	0.00	0.28
S155_S	0.93	1.97	0.00	0.05
S21_S	1.14	80.10	0.00	2.08
G93	1.29	26.46	0.00	1.00
S40_S	1.35	32.39	0.00	1.78
S21A_S	1.41	31.97	0.00	5.79
S72_S	1.44	11.49	0.00	3.99

\*: % of Records that are greater than 20 percent..



**Table 3. Continued.**

Station Name	Monthly Difference			% of Records have difference > 5 %
	Ave. %	Max. %	Min. %	
S75_S	1.69	2.15	0.00	0.00
S70_S	1.84	6.37	0.00	1.06
S41_S	1.93	39.69	0.00	2.99
S20G_S	1.94	30.46	0.00	6.64
S26_S	2.34	8.92	0.00	0.13
S335_S	2.73	33.75	0.00	0.97
S25B_S	2.77	6.40	0.00	1.99
G57_S	2.96	23.80	0.00	0.78
S97_S	3.09	20.07	0.00	3.14
G302_S	3.22	10.15	0.00	23.46*
G54_S	3.44	5.71	0.00	30.81*
S71_S	3.71	83.82	0.00	4.48
S148_S	3.82	27.91	0.00	9.68
S37A_S	4.14	93.59	0.00	3.92
S333_S	4.24	70.03	0.00	3.62
S59_S	4.35	59.65	0.00	11.23
S36_S	4.51	33.20	0.00	50.82*

\*: % of Records that are greater than 20 percent.



**Table 4.** Percent flow difference between STRIVE and DBHYDRO data for spillways: average monthly difference greater than 5%.

Station Name	Monthly Difference			% of Records have difference > 5 %
	Ave. %	Max. %	Min. %	
S155A_S	5.86	20.87	0.00	83.57*
G303_S	6.01	11.50	0.00	54.08*
S20F_S	6.51	10.26	0.00	79.28*
S49_S	7.16	55.11	0.00	7.43
S83_S	8.28	49.55	0.00	9.81
G56_S	8.68	18.98	0.00	72.38*
S176_S	9.62	27.40	0.00	43.11*
S18C_S	9.79	24.65	0.00	38.83*
S46_S	9.95	76.45	0.00	33.18*
S47D_S	15.29	100.00	0.00	24.43*
S99_S	16.22	76.64	0.00	21.00*
S84_S	31.81	93.92	0.00	54.55*
S44_S	48.67	100.00	3.82	88.05*
S37B_S	53.20	100.00	0.00	75.76*
S354_S	641.92	17439.00	0.00	18.55
S351_S	1042.11	24212.98	0.00	29.05*
S352_S	2605.18	173010.72	0.00	44.62*
S39_S	4494.81	96404.53	0.00	55.78*

\*: % of Records that are greater than 20 percent.



**Table 5.** Percent flow difference between STRIVE and DBHYDRO data for pump stations: average monthly difference less than 5%.

Station Name	Monthly Difference			% of Records have difference > 5 %
	Ave. %	Max. %	Min. %	
S332D_P	0.00	0.00	0.00	0.00
S127_P	0.00	0.00	0.00	0.00
S2_P	0.00	0.00	0.00	0.00
S3_P	0.00	0.03	0.00	0.00
S4_P	0.00	0.00	0.00	0.00
S135_P	0.00	0.08	0.00	0.03
G-600_P	0.01	0.34	0.00	0.04
S6_P	0.02	3.00	0.00	0.03
S131_P	0.05	3.65	0.00	0.48
S129_P	0.06	4.02	0.00	0.75
S140_P	0.63	54.33	0.00	1.77
G409_P	0.65	6.93	0.00	1.98
S332_P	1.53	9.68	0.00	13.30
S133_P	3.46	59.89	0.00	4.24
S331_P	4.68	10.74	0.00	45.32*
G123_P	4.76	99.99	0.00	16.35

**Table 6.** Percent flow difference between STRIVE and DBHYDRO data for weirs: average monthly difference less than 5%.

Station Name	Monthly Difference			% of Records have difference > 5 %
	Ave. %	Max. %	Min. %	
S50_S	0.41	4.73	0.00	1.08
S141_W	2.77	21.45	0.00	20.87*

**Table 7.** Percent flow difference between STRIVE and DBHYDRO data for weirs: average monthly difference greater than 5%.

Station Name	Monthly Difference			% of Records have difference > 5 %
	Ave. %	Max. %	Min. %	
G155_W	7.46	15.18	0.00	65.78*
S48_S	27.27	79.42	0.00	80.13*

\*: % of Records that are greater than 20 percent.



**Table 8.** Water control structures: survey completed and flow data analysis using STRIVE data is needed.

Station Name	Structure Type	STA Site	Stream Gauging Data
CV5	Culvert	No	No
G205_C	Culvert	No	No
S380_C	Culvert	No	No
S38A_C	Culvert	No	No
S12A_S	Spillway	No	No
S12B_S	Spillway	No	No
S12C_S	Spillway	No	No
S12D_S	Spillway	No	No
S5AS_S	Spillway	No	No
G258_C	Culvert	Yes	No
G259_C	Culvert	Yes	No
G305G_C	Culvert	Yes	No
G305N_C	Culvert	Yes	No
G331G_C	Culvert	Yes	No
G393A_C	Culvert	Yes	No
G393C_C	Culvert	Yes	No
G349B_P	Pump	Yes	No
G350B_P	Pump	Yes	No
CULV5A_C	Culvert	No	Yes
PC17A_C	Culvert	No	Yes
G357_C	Culvert	No	Yes
S5AE_C	Culvert	No	Yes
S5AW_C	Culvert	No	Yes
G404_P	Pump	No	Yes
S13_P	Pump	No	Yes
S236_P	Pump	No	Yes
GORDY_S	Spillway	No	Yes
S13_S	Spillway	No	Yes
S339_S	Spillway	No	Yes
S61_S	Spillway	No	Yes
S63_S	Spillway	No	Yes
S63A_S	Spillway	No	Yes



**Table 8.** Continued.

Station Name	Structure Type	STA Site	Stream Gauging Data
S65E_S	Spillway	No	Yes
C18W_W	Weir	No	Yes
G329A_C	Culvert	Yes	Yes
G329B_C	Culvert	Yes	Yes
G329C_C	Culvert	Yes	Yes
G329D_C	Culvert	Yes	Yes
G330A_C	Culvert	Yes	Yes
G330B_C	Culvert	Yes	Yes
G330C_C	Culvert	Yes	Yes
G330D_C	Culvert	Yes	Yes
G330E_C	Culvert	Yes	Yes
G331A_C	Culvert	Yes	Yes
G331B_C	Culvert	Yes	Yes
G331C_C	Culvert	Yes	Yes
G331D_C	Culvert	Yes	Yes
G331E_C	Culvert	Yes	Yes
G331F_C	Culvert	Yes	Yes
G333A_C	Culvert	Yes	Yes
G333B_C	Culvert	Yes	Yes
G333C_C	Culvert	Yes	Yes
G333D_C	Culvert	Yes	Yes
G333E_C	Culvert	Yes	Yes
G342A_C	Culvert	Yes	Yes
G342B_C	Culvert	Yes	Yes
G342C_C	Culvert	Yes	Yes
G342D_C	Culvert	Yes	Yes
G344A_C	Culvert	Yes	Yes
G393B_C	Culvert	Yes	Yes
G406_C	Culvert	Yes	Yes
G251_P	Pump	Yes	Yes
G310_P	Pump	Yes	Yes
G328_P	Pump	Yes	Yes



**Table 8.** Continued.

Station Name	Structure Type	STA Site	Stream Gauging Data
G335_P	Pump	Yes	Yes
G337_P	Pump	Yes	Yes
G349A_P	Pump	Yes	Yes
G350A_P	Pump	Yes	Yes
S8_P	Pump	Yes	Yes
G300_S	Spillway	Yes	Yes
G308_S	Spillway	Yes	Yes
G309_S	Spillway	Yes	Yes
G332_S	Spillway	Yes	Yes
G334_S	Spillway	Yes	Yes
S8_S	Spillway	Yes	Yes
G601	Weir	Yes	Yes
G602	Weir	Yes	Yes
G603	Weir	Yes	Yes



**Table 9A.** Water control structures: survey and flow data analysis are needed where stream gauging data are available.

Station Name	Structure Type	STA Site
S129_C	Culvert	No
S5AX_C	Culvert	No
G200A_P	Pump	No
G200B_P	Pump	No
G201_P	Pump	No
G207	Pump	No
G208	Pump	No
S9_P	Pump	No
S9A_P	Pump	No
COCO1_S	Spillway	No
S140_S	Spillway	No
S308_S	Spillway	No
S340_S	Spillway	No
S60_S	Spillway	No
S62_S	Spillway	No
S65_S	Spillway	No
S65A_S	Spillway	No
S65B_S	Spillway	No
S65C_S	Spillway	No
S65D_S	Spillway	No
S65NEW_S	Spillway	No
S77_S	Spillway	No
S78_S	Spillway	No
S79_S	Spillway	No
S80_S	Spillway	No
FAKA	Weir	No
LNHRT_W	Weir	No
WEIR1_W	Weir	No
WFEED_W	Weir	No



**Table 9A.** Continued.

Station Name	Structure Type	STA Site
G250_P	Pump	Yes
G370_P	Pump	Yes
G410_P	Pump	Yes
S5A_P	Pump	Yes
S7_P	Pump	Yes
S7_S	Spillway	Yes



**Table 9B.** Water control structures: survey and flow data analysis are needed where stream gauging data are not available.

Station Name	Structure Type	STA Site
BONEY.SC_C	Culvert	No
G402A_C	Culvert	No
G402B_C	Culvert	No
G402C_C	Culvert	No
G402D_C	Culvert	No
G74_C	Culvert	No
G75_C	Culvert	No
G76_C	Culvert	No
G86N_C	Culvert	No
G86S_C	Culvert	No
LETTC_C	Culvert	No
NUBBC_C	Culvert	No
S127_C	Culvert	No
S135_C	Culvert	No
S235_C	Culvert	No
S342_C	Culvert	No
S65AX_C	Culvert	No
S65BX1_C	Culvert	No
S65BX2_C	Culvert	No
S65CX_C	Culvert	No
S65DX_C	Culvert	No
S9XN_C	Culvert	No
S9XS_C	Culvert	No
SHING.PE	Culvert	No
SHING.PN	Culvert	No
SHING.SS	Culvert	No
ACME1	Pump	No
ACME2	Pump	No
EBPS3_P	Pump	No
ESPS2_P	Pump	No
G210_P	Pump	No
S25B_P	Pump	No



**Table 9B.** Continued.

Station Name	Structure Type	STA Site
S332B_P	Pump	No
S332B1_P	Pump	No
S332B2_P	Pump	No
COCO2_S	Spillway	No
COCO3_S	Spillway	No
G160_S	Spillway	No
S178_S	Spillway	No
BONEY.SW_W	Weir	No
COCO1_W	Weir	No
COCO3_W	Weir	No
S178_W	Weir	No
S59WEIR_W	Weir	No
WEIR2_W	Weir	No
WEIR3_W	Weir	No
G255A_C	Culvert	Yes
G255B_C	Culvert	Yes
G256_C	Culvert	Yes
G345_C	Culvert	Yes
G354_C	Culvert	Yes
G374A_C	Culvert	Yes
G374B_C	Culvert	Yes
G374C_C	Culvert	Yes
G374D_C	Culvert	Yes
G374E_C	Culvert	Yes
G374F_C	Culvert	Yes
G375A_C	Culvert	Yes
G375B_C	Culvert	Yes
G375C_C	Culvert	Yes
G375D_C	Culvert	Yes
G375E_C	Culvert	Yes
G375F_C	Culvert	Yes
G376A_C	Culvert	Yes



**Table 9B.** Continued.

Station Name	Structure Type	STA Site
G376B_C	Culvert	Yes
G376C_C	Culvert	Yes
G376D_C	Culvert	Yes
G376E_C	Culvert	Yes
G376F_C	Culvert	Yes
G377A_C	Culvert	Yes
G377B_C	Culvert	Yes
G377C_C	Culvert	Yes
G377D_C	Culvert	Yes
G377E_C	Culvert	Yes
G378A_C	Culvert	Yes
G378B_C	Culvert	Yes
G378C_C	Culvert	Yes
G378D_C	Culvert	Yes
G378E_C	Culvert	Yes
G379A_C	Culvert	Yes
G379B_C	Culvert	Yes
G379C_C	Culvert	Yes
G379D_C	Culvert	Yes
G379E_C	Culvert	Yes
G380A_C	Culvert	Yes
G380B_C	Culvert	Yes
G380C_C	Culvert	Yes
G380D_C	Culvert	Yes
G380E_C	Culvert	Yes
G380F_C	Culvert	Yes
G381A_C	Culvert	Yes
G381B_C	Culvert	Yes
G381C_C	Culvert	Yes
G381D_C	Culvert	Yes
G381E_C	Culvert	Yes
G381F_C	Culvert	Yes



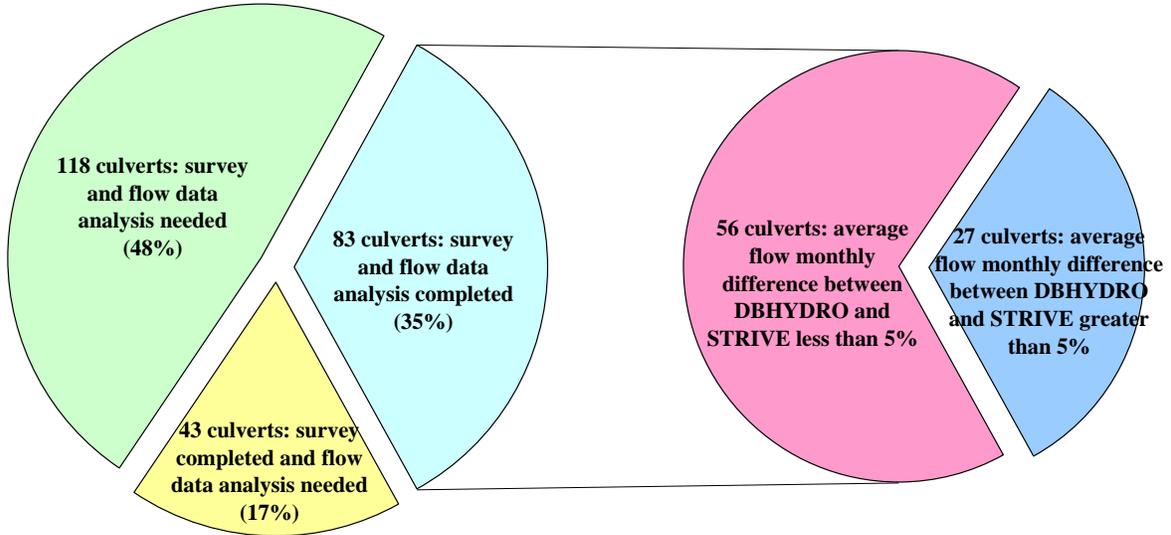
**Table 9B.** Continued.

Station Name	Structure Type	STA Site
G382A_C	Culvert	Yes
G382B_C	Culvert	Yes
G383_C	Culvert	Yes
G393_C	Culvert	Yes
G600C_C	Culvert	Yes
S363A_C	Culvert	Yes
S363B_C	Culvert	Yes
S363C_C	Culvert	Yes
S364A_C	Culvert	Yes
S364B_C	Culvert	Yes
S364C_C	Culvert	Yes
S365A_C	Culvert	Yes
S365B_C	Culvert	Yes
S366A_C	Culvert	Yes
S366B_C	Culvert	Yes
S366C_C	Culvert	Yes
S366D_C	Culvert	Yes
S366E_C	Culvert	Yes
S367A_C	Culvert	Yes
S367B_C	Culvert	Yes
S367C_C	Culvert	Yes
S367D_C	Culvert	Yes
S367E_C	Culvert	Yes
S368A_C	Culvert	Yes
S368B_C	Culvert	Yes
S368C_C	Culvert	Yes
S368D_C	Culvert	Yes
S368E_C	Culvert	Yes
S369A_C	Culvert	Yes
S369B_C	Culvert	Yes
S369C_C	Culvert	Yes
S369D_C	Culvert	Yes

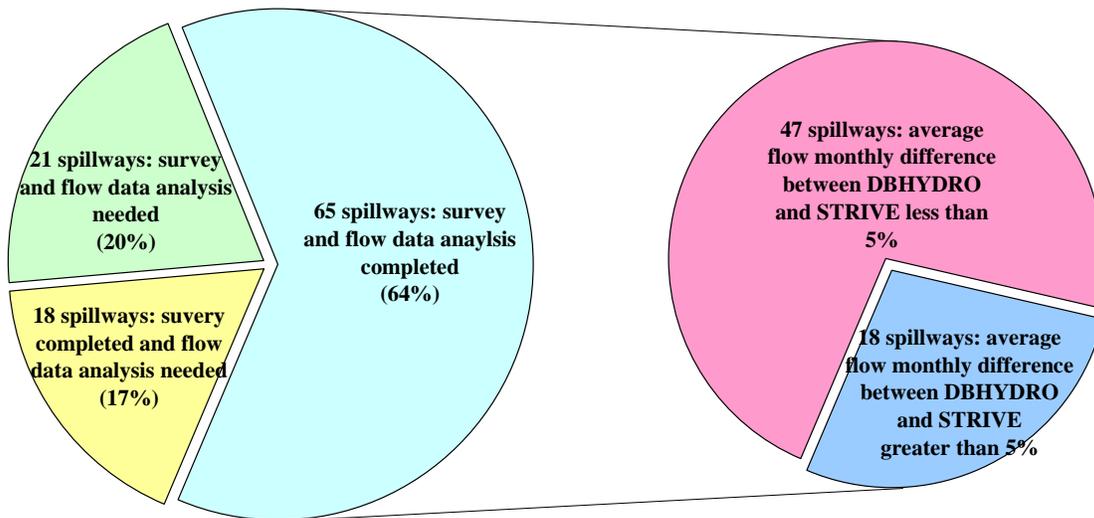


**Table 9B.** Continued.

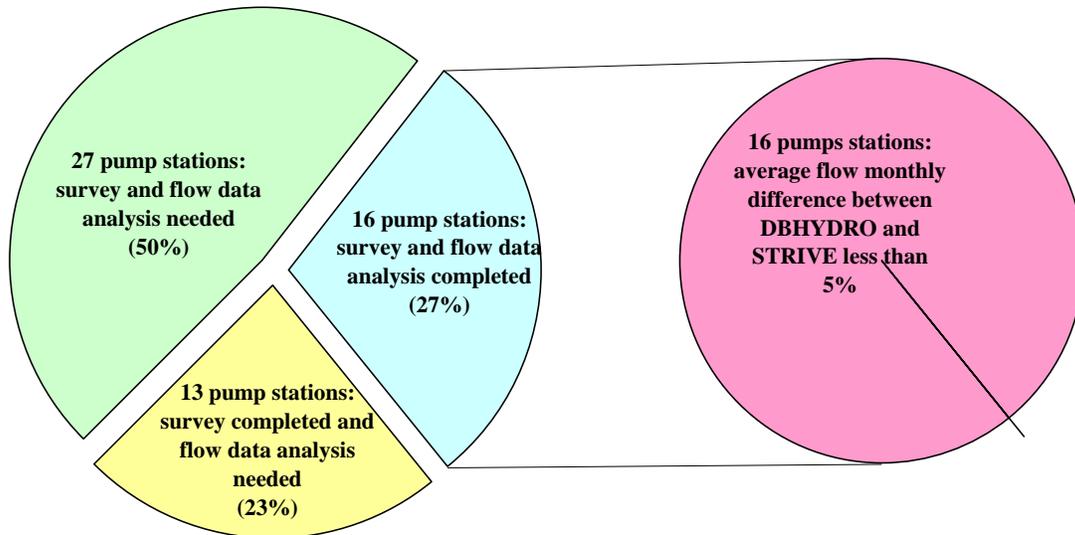
Station Name	Structure Type	STA Site
S370A_C	Culvert	Yes
S370B_C	Culvert	Yes
S370C_C	Culvert	Yes
S371B_C	Culvert	Yes
S372C_C	Culvert	Yes
S373A_C	Culvert	Yes
S373B_C	Culvert	Yes
S374B_C	Culvert	Yes
G250S_P	Pump	Yes
G372_P	Pump	Yes
G600I_P	Pump	Yes
S319_P	Pump	Yes
S361_P	Pump	Yes
S362_P	Pump	Yes



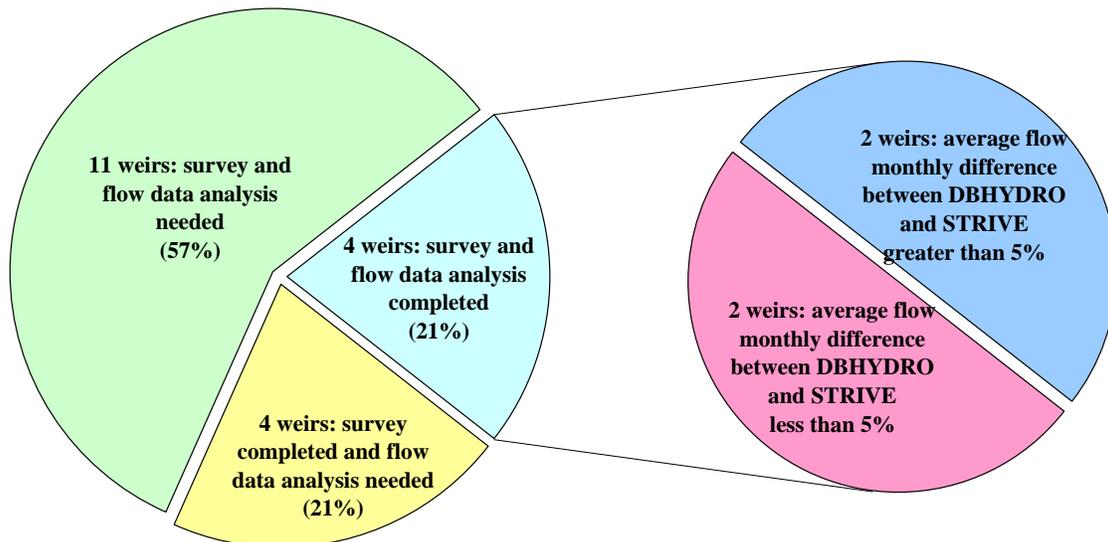
**Figure 5:** Status of survey and flow data analysis for culverts, as of March 2005.



**Figure 6:** Status of survey and flow data analysis for spillways, as of March 2005.



**Figure 7:** Status of survey and flow data analysis for pump stations, as of March 2005.



**Figure 8:** Status of survey and flow data analysis for weirs, as of March 2005.



## CONCLUSIONS

A total of 367 water control structures were field surveyed by the District during the last six years. Among these structures, 83 culverts, 65 spillways, 16 pump stations, and 4 weirs are registered in DBHYDRO database and flow data have been computed. Of these 168 structures, the structure data was compared with existing static data in DBHYDRO. New flow data was computed using new static data from the STRIVE project and were compared with historical flow data series from DBHYDRO. The work performed in this study evaluated the impacts of static data on historical flow data at each structure. Flow data for 168 structures was computed and compared. Field surveying for 78 structures was completed but flow data analysis is needed for these structures. Currently, 177 structures will need to be surveyed. Thirty-five of these structures have stream gauging data.

Average monthly differences in new and existing flow data were less than  $\pm 5$  percent for 121 structures and the differences were greater than  $\pm 5$  percent for 47 structures.

The structure static data in DBHYDRO will be revised, as appropriate, when the flow differences are greater than  $\pm 5$  percent different, then data change procedures (Akpoji et al., 2003) will be used prior to revising the historical flow data series in DBHYDRO.

The STRIVE project is a critical effort in improving flow data that will benefit the District's various water resources projects. A significant effort is required to complete and continuously update the water control structures information and, therefore, several District staff has been dedicated to support this project.



## RECOMMENDATIONS

The following six recommendations are provided as a result of this study.

1. The STRIVE project should continue until all of the water control structures are field surveyed. This project has been worthwhile and resources expended for this purpose have been useful.
2. Upon completion of the STRIVE project, a new project should be initiated where only primary and secondary benchmarks of each water control structure are field surveyed every five years on cyclic basis. If benchmark elevations are changed beyond the specific limits (e.g.,  $\pm 0.02$  ft), then the entire water control structure should be surveyed during the benchmark surveys.
3. Distribution of the flow errors should be investigated. Specifically, the errors due to static information; errors due to dynamic information and errors due to rating equations should be determined.
4. Change in the static information of the pump structures did not produce any noticeable flow differences. Therefore, it is not necessary to perform flow data analyses for pump structures based on the STRIVE data unless significant differences are observed between physical parameters in the field and those in DBHYDRO.
5. For 27 culverts, 18 spillways and 2 weirs, where average monthly flow differences were greater than  $\pm 5$  percent, present flow rating equations should be reexamined and revised where necessary.
6. For four culverts, three spillways and one pump station, where average monthly flow differences were less than  $\pm 5$  percent and percent records that were greater than 20 percent, should be further analyzed.



## REFERENCES

- Akpoji, G. A., E. Damisse, M. Imru, C. James and N. D. Mtundu. 2003. Standard Operating Procedures for Flow Data Management in the District's Hydrologic Database. Hydrology and Hydraulics Division. Environmental Monitoring and Assessment Department, South Florida Water Management District, West Palm Beach, FL.
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