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Water Budget Analysis for Stormwater Treatment Area 5

(May 1, 2000 to April 30, 2003)

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EXECUTIVE SUMMARY

This report presents a water budget for Stormwater Treatment Area (STA) 5. It covers a three-year period of operation from May 1, 2000 to April 30, 2003. South Florida experienced a severe drought during this period until September 2001. The report augments the previous water budget report for STA-5 published in February 2002. Improvements in the rating curves for the G342 and G344 structures were made in June 2003 and were used for this analysis. In this report, the water year runs from May to April to coincide with periods used in the *Everglades Consolidated Report* published annually by the South Florida Water Management District.

STA-5 treats runoff from the C-139 basin in northeastern Hendry County. The STA is located along the western boundary of the Everglades Agricultural Area (EAA) adjacent to the L-2 canal, west of the northwestern corner of the Rotenberger Wildlife Management Area. It has a total effective treatment area of 4,118 acres. Construction of STA-5 was completed in December 1998 at a cost of $10.6 million. The STA was in a startup phase of operations from initial flooding in January 1999 through October 1999. The Florida Department of Environmental Protection (FDEP) issued an emergency order to the South Florida Water Management District (SFWMD) authorizing discharges from STA-5 for a 14-day period in October 1999 in response to flood flows caused by Hurricane Irene. STA-5 began routine flow-through operations in June 2000.

In water year 2001 (May 2000 to April 2001), a total of 50,111 ac-ft of water entered STA-5 through the gated culverts at G342A-D. It constituted 51.9 percent of the total inflow to the STA's treatment cells and was 64.0 percent of the expected annual inflow volume at G342A-D (78,340 ac-ft). The lower flow volume was a direct result of the drought. During the same period, rainfall accounted for 13,178 ac-ft or 13.6 percent of the total inflow. Flow from seepage canal pumps at G349A and G350A contributed 31,495 ac-ft of flow, which was 32.6 percent of the total inflow that year. This included 4,503 ac-ft of water that came from the Miami Canal using pumps at G349B and G350B. A temporary pump provided 1,772 ac-ft from the Miami canal to Cell 1B. This cell needed to remain hydrated because it uses submerged aquatic vegetation for phosphorus uptake. During this period, 39,976 ac-ft of water were discharged from the STA at G344A–D (40.3 percent of the total outflow). Evapotranspiration accounted for an additional 19,230 ac-ft of water leaving the STA (19.4 percent of the total outflow). Estimated seepage out of STA-5 accounted for 41.6 percent of the total outflow from the STA or 41,243 ac-ft. Water budget errors other than those inherent in the above estimates were less than 2.0 percent for water year 2001.

A total of 158,673 ac-ft of water entered STA-5 through the gated culverts at G342A-D in water year 2002 (WY02), twice the expected annual inflow volume. This volume constituted 77.6 percent of the total inflow to the STA's treatment cells for that year. Rainfall accounted for 12,176 ac-ft or 6.0 percent of the total inflow. Flow from seepage canal pumps at G349A and G350A contributed 15.8 percent of the total inflow or 32,368 ac-ft of water. The temporary pump at Cell 1B provided 1,389 ac-ft of water from the Miami Canal. Outflow at gated culverts at G344A-D discharged 126,181 ac-ft of water (63.6 percent of the total outflow). Evapotranspiration was 18,104 ac-ft or 9.1 percent of total outflow. Estimated seepage out of STA-5 accounted for 44,050 ac-ft, which was 22.2 percent of total outflow. Water budget errors were 5.0 percent for this year.

Operation of the G342A-D culverts in WY03 resulted in an inflow of 170,177 ac-ft of water entering STA-5 or 78.5 percent of total inflow. This was more than twice the expected annual

inflow. During the same period, STA-5 received 16,339 ac-ft of rainfall which was 7.5 percent of the total inflow. Seepage canal pumps at G349A and G350A contributed 30,272 ac-ft of flow or 14.0 percent of the total inflow that year. The G345 culverts were installed between Cells 1B and 2B in December 2002, but stop logs prevented flow between the cells in WY03. Gated culverts G344A-D discharged 160,519 ac-ft of water from the STA (73.9 percent of the total outflow). Evapotranspiration accounted for 17,515 ac-ft of water leaving the STA (8.1 percent of total outflow). Estimated seepage for WY03 was 47,260 ac-ft, 21.8 percent of total outflow. WY03 water budget error was 3.7 percent.

Potential sources of error in the water budget were also examined using the daily water budget data and a subset of 15-minute data. The use of 15-minute data was intended to capture relatively rapid changes in flow and storage. The analysis demonstrated the sensitivity of water budget error to estimates of storage, storage change and the precision of mean stage data. The results suggest that stage gages used to compute flow at structures may not provide information representative of mean stage in the STA's cells during operation of the structures.

This water budget analysis covers the first three full water years of operation at STA-5. The report provides a look at the hydraulic performance of the STA and the cells in its two treatment flow ways. A better understanding of specific hydrologic components at STA-5 and accompanying error terms will improve future analyses.

ACKNOWLEDGMENTS

The following people helped in preparing and reviewing the drafts of this document: Ron Bearzotti drafted the permit history of the STA-5; Sashi Nair suggested the 15-minute analysis that appears in Appendix E and reviewed the report; Hedy Marshall, Wossenu Abtew, Julia LaRock, Guy Germain and Martha Nungesser reviewed the report and provided valuable feedback with respect to content.

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INTRODUCTION

This report presents a three-year water budget for Stormwater Treatment Area (STA) 5. It covers the period of operation from May 1, 2000 through April 30, 2003. During the period, South Florida experienced a severe drought from November 1999 through September 2001. The report is based upon daily water budgets for the treatment cells in STA-5. Daily results were aggregated to develop monthly and annual water budgets for water years 2001, 2002 and 2003 (WY01, WY02 and WY03). In this report, a water year runs from May 1st to April 30th; WY03 ends in 2003. This coincides with the period used in the Everglades Consolidated Report (SFWMD, 2003). The daily water budget accounted for inflow, outflow, rainfall, evapotranspiration, seepage and error.

STA-5 is located along the western boundary of the Everglades Agricultural Area (EAA), adjacent to the L-2 canal, west of the northwestern corner of the Rotenberger Wildlife Management Area. STA-5 and its location relative to major canals and roadways are shown in **Figure 1**.

This section of the report presents background information about STA-5 and hydro-meteorological monitoring at STA-5. It is followed by sections describing the operation of STA-5 and the sources of data used for the report. The actual water budget analyses are presented, followed by a summary, recommendations and conclusions.

Background

STA-5's principal purpose is to reduce phosphorous concentrations in runoff from the C-139 basin to the north and west of STA-5. Prior to construction, the land now occupied by the stormwater treatment area was used for agricultural purposes.

Construction of STA-5 was completed in December 1998 at a cost of $10.6 million. The STA was in its startup phase of operations from initial flooding in January 1999 through October 1999. On October 15, 1999, due to conditions caused by Hurricane Irene, the Florida Department of Environmental Protection issued an emergency order to the South Florida Water Management District authorizing discharges from STA-5 for a 14-day period until October 29, 1999.

The Florida Department of Environmental Protection (FDEP) issued the Everglades Forever Act (EFA) permit for STA-5 on February 29, 2000. The issuance of the National Pollution Discharge Elimination System (NPDES) permit was delayed due to objections by the Friends of the Everglades, an environmental interest group. However, authorization for interim operations of STA-5 under the terms and conditions of the NPDES permit was recommended by the Division of Administrative Hearings and granted by FDEP on March 20, 2000. After satisfying the Friends of the Everglades' concerns, the NPDES permit was issued on May 24, 2001.

The southern flow-way of STA-5 (Cells 2A and 2B) began routine flow-through operations in June 2000. The northern flow-way of STA-5 (Cells 1A and 1B) began routine flow-through operations in August 2000.

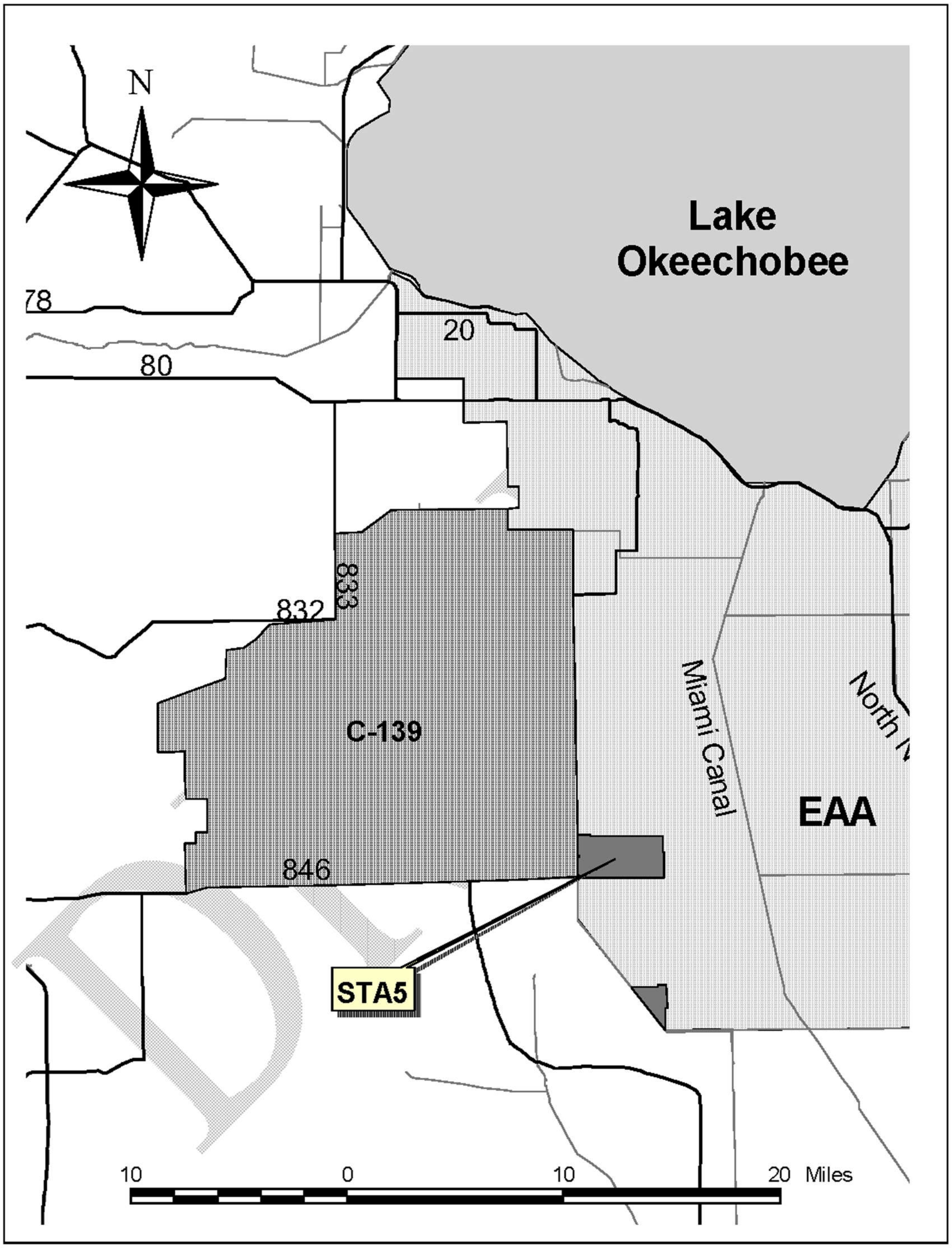

Figure 1. STA-5 location map.

The water budgets completed for the Everglades Nutrient Removal project (ENR) and STA-1W (SFWMD, 1996; Abtew and Mullen, 1997; Abtew and Downey, 1998; Guardo, 1999; Abtew et al., 2000; Abtew and Bechtel, 2001; Abtew et al., 2001) and presentation of the results influenced the methods used in this study. A water budget for the first two years of operation at STA-6 was published in February 2001 (Huebner). Techniques used in this analysis closely parallel those in the STA-6 study. Results from the ENR and STA-6 water budget studies were also used to evaluate and compare water budget errors in the analysis for STA-5.

The water budget at STA-5 is comprised of the following hydrologic/hydraulic components:

- Inflow through pumps and gated structures
- Outflow through gated structures
- Rainfall
- Evapotranspiration
- Seepage
- Change in storage
- Water budget error

Each component makes up an important part of the water budget for STA-5. The budget is developed for varying time periods ranging from 1 day to 12 months using the following equation:

$$\frac{\Delta S}{\Delta t} = I - O + R - ET \pm G + \varepsilon \qquad (1)$$

where ΔS = change in storage over the time period
Δt = time period
I = average inflow over the time period
O = average outflow over the time period
R = rainfall over the time period
ET = evapotranspiration over the time period
G = levee and deep seepage over the time period
ε = water budget error over the time period

In Equation 1, all terms have the same units, acre-feet per unit time (day, month or year). Rainfall and evapotranspiration values (in inches or millimeters) have been converted to feet and multiplied by the effective surface area in acres, (e.g., 839 acres for Cell 1A) to get a volume of rainfall or evapotranspiration for a selected time period.

Three water years of daily average stage, flow, rainfall and evapotranspiration data were used in this report. The data were analyzed using Equation 1 on a daily, monthly and annual basis. Each of the terms in Equation 1 was quantified for each time period.

Site Description

STA-5 is comprised of four treatment cells that have a total effective treatment area of 4118 acres. The cells are divided into two flow ways running from west to east. The northern flow way consists of Cells 1A and 1B; the southern flow way, Cells 2A and 2B. The cells are bermed wetlands with gated culverts and weir structures that control inflow, outflow and stage (water level) within the cells. Vegetation in the cells varies. It includes primrose willow, cattail, smartweed, mixed grasses and submerged aquatic vegetation (Environmental Research Institute, 2001). **Figure 2** shows a schematic of the cells and control structures. **Table A-1** in Appendix A contains a summary of site properties used in the water budget calculations for STA-5.

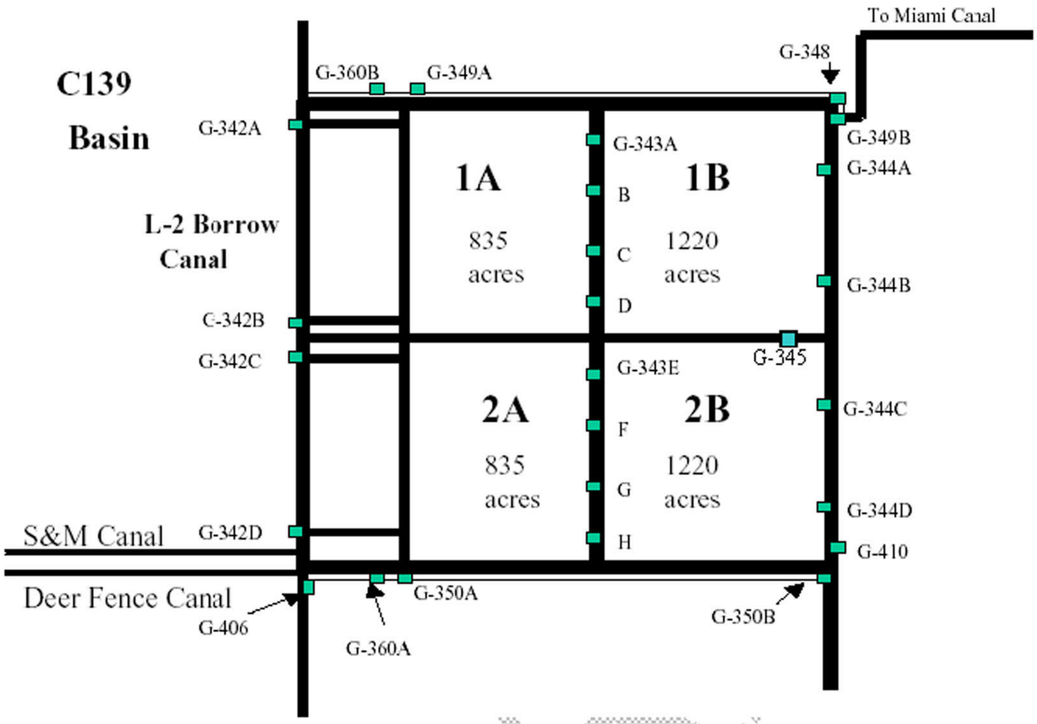

Figure 2. Schematic diagram of STA-5 (not to scale).

STA OPERATION

The STA's treatment cells receive runoff from the C-139 basin via the L-2 canal north of the Deer Fence Canal. Under normal operating conditions, the G406 structure is closed blocking flow to the south in the L-3 canal. The gates at G406 are opened only when the water level in the L-2 canal exceeds 16.0 ft NGVD allowing water to bypass the STA.

Water flows west to east by gravity in the STA initially into distribution ditches located east of the G342A, B, C and D gated culverts in Cells 1A and 2A. Cells 1A and 2 A slope west to east at a rate of 0.0003 ft/ft. Cells 1B and 2B have an west-to-east slope of 0.00014 ft/ft. There is also a gradual slope from north to south of approximately 0.00015 ft/ft at the western end of the STA. Two pumps at G349A and two at G350A re-circulate water from the seepage canals located along the northern and southern borders of the STA into Cells 1A and 2A, respectively. Eight intermediate combination weir/culvert structures, G343A through H, pass flow from Cells 1A and 2A to Cells 1B and 2B. Culverts at G345 located near G344B and G344C between Cells 1B and 2B, installed in December 2002, provide the ability to transfer water between the northern and southern flow ways in the eastern treatment cells.

Water is discharged to the east through structures G344A, B, C and D. Water from the STA flows in a canal to the Miami Canal, five miles to the east. Water discharged from STA-5 is also used to restore hydropatterns in the Rotenberger Wildlife Management Area using pumps located at structure G410 near the southeastern corner of STA-5. During the last months of the drought in 2001, water was pumped through a temporary pump, located near G344A and G349B in the northeast corner of the STA, into Cell 1B effectively using water from the Miami Canal to keep the cell from drying out and prpeserving the submerged aquatic vegetation used for treatment. Pumps at G349B and G350B provide water originating from the Miami Canal to the G349A and G350A pumps during dry periods to keep Cells 1A and 2A hydrated.

STA-5 is currently operated under an interim operations plan (SFWMD, 2000). The interim plan accommodates additional flow to STA-5 that will eventually be directed to STA-6, Section 2 once that section of STA-6 is constructed. A full description of STA-5, its design and operation are provided in the revised STA-5 Operation Plan (SFWMD, 2000).

Monitoring

Three hydrometeorologic parameters were monitored at STA-5: rainfall, stage (water surface elevation) and flow. The station locations are shown in **Figure 2**. Flow is computed using calibrated rating equations. The calibration is based on in-channel flow measurements using acoustic Doppler devices. Evapotranspiration was estimated for STA-5 based on data from nearby monitoring stations using an empirically based energy equation (Abtew, 1996). **Tables A-2** through **A-5** in Appendix A list the stations where daily average stage, flow, rainfall and evapotranspiration data were recorded together with database (DB) key numbers and station descriptions. Seepage in each cell was estimated using an equation that relates differences in water surface elevations along a length of levee to the amount of water gained or lost due to seepage. Estimated seepage is not recorded in DBHYDRO, the South Florida Water Management District's corporate database.

The following sections describe the data that were used for the water budget computations and any special considerations concerning the data. Monitored data came from DBHYDRO.

Rainfall

Daily rainfall data for STA-5 was collected at G343B_R, located near the center of the STA. The data were compared to rainfall values at seven nearby rain gage locations to check for data errors. Missing values were filled based upon the best available information, usually from nearby rain gages. The data were loaded into a preferred DB key every month. A preferred DB key contains data that has been reviewed by an engineer and, if possible, has no missing values. A final QA/QC check of the data was completed on a quarterly basis. The preferred DB key provided a high-quality, continuous record of daily rainfall amounts. **Tables B-1, B-2** and **B-3** in Appendix B list the daily rainfall amounts recorded at G343B_R.

Stage and Gate Openings

Stage and gate opening data were monitored on an instantaneous basis. Both were recorded using two methods. Data were stored on-site in solid-state data loggers called CR10s and transmitted periodically to a District database. Stage and gate opening data were also telemetered to a District database. Daily mean stage values and gate openings used in this study were based on telemetered data.

The stage data were averaged and recorded as daily average stage in DBHYDRO. The instantaneous stage data were also used to compute flows at the inlet and outlet structures at STA-5. A headwater stage, a tailwater stage and a gate opening are needed to compute flow at each of the structures. Each treatment cell has several structures associated with it. As a result, more than one stage value was available to report average daily stage within each of the treatment cells.

The daily stage at each of the recording gages within a cell was arithmetically averaged to generate a daily mean stage for the entire cell.

When the recorded stage in a treatment cell fell below the average ground elevation, a function was used to estimate the volume of water that was available for release or necessary to fill voids in the soils beneath the cells. Equations were developed for a falling and a rising water table and are presented in **Figure D-1** in Appendix D. They are the same equations used for this purpose in the water budget analysis for STA-6 (Huebner, 2001) based on work done by Abtew, et al. (1998).

Flow

Daily average flow rates were determined using two methods, culvert equations and pump performance curves. At pump stations G349A, G350A, G349B and G350B, average daily flow was computed instantaneously using motor speed and headwater and tailwater elevation data. The daily average flow at these stations was recorded in DBHYDRO and reviewed on a monthly basis for accuracy and missing data.

Daily average flow at the gated culverts in STA5, G342A, B, C and D, G344A, B, C and D and G406 were based on instantaneous flow values that were calculated using instantaneous headwater stage, tailwater stage and gate openings. A complete record of daily average flow was loaded monthly to a preferred DB key in DBHYDRO. A final QA/QC check of the flow data in the preferred DB keys was performed on a quarterly basis.

Evapotranspiration

Evapotranspiration (ET) is the loss of water to the atmosphere by vaporization (evaporation) at the surface of a water body and/or by respiration of living organisms including vegetation (transpiration). The evapotranspiration data used in this report were derived from ET data maintained in a preferred DB key for STA-1W. STA-1W is located on the eastern side of the Everglades Agricultural Area, approximately 33 miles from STA-5. These data for ET were considered to be of the highest quality available. **Tables C-1, C-2** and **C-3** in Appendix C list the daily ET values used.

Seepage

No direct measurement of seepage was made at STA-5 during the period of this study. A number of attempts to quantify seepage at STA sites have been made. The most recent, detailed studies have been associated with the ENR project which is now part of STA-1W (Choi and Harvey, 2000) and those discussed in the 1998-99 water budget analysis for STA-6 (Huebner, 2001).

In this analysis, seepage was computed as:

$$G = 1.983 K_{sp} L \Delta H \quad (2)$$

where G = seepage, levee and deep (ac-ft/d)

K_{sp} = coefficient of seepage (cfs/mi/ft)

L = length along the seepage boundary (mi)

ΔH = hydraulic head difference between the cell stage and the water level along the cell's boundary (ft)

1.938 = constant to convert from cfs to ac-ft/d

The value of K_{sp} was adjusted to minimize the sum of the squared daily water budget error in the three-year period of study. The results from previous studies were used to compare values of the seepage coefficient. The values compared favorably with the range of values presented in previous studies (Huebner, 2001).

In general, there is a net loss of water from the STA due to higher water surface elevations maintained in the treatment cells as compared to the L-2 canal, the discharge canal and the seepage canals located along the northern and southern boundaries of the STA.

WATER BUDGET

Methodology

In this analysis, STA-5 was divided into two hydrologic units: 1) the northern flow way consisting of Cells 1A and 1B; and 2) the southern flow way consisting of Cells 2A and 2B. A water budget analysis was performed on each of the units on a daily, monthly and annual basis using Equation 1. A daily, monthly and annual water budget was also completed for the entire STA using data from both flow ways. Terms in equation 1 were converted to acre-feet (ac-ft) per unit time (day, month or year, depending upon the period being used for the water budget calculations). The discussion of the results in the following section of the report focuses on the annual water budgets.

Results

Rainfall and Evapotranspiration

Rainfall data for STA-5 are presented in Appendix B. Evapotranspiration (ET) data can be found in Appendix C. **Table 1** presents the annual rainfall summary for the three water years analyzed in this report. **Figure 3** shows the monthly rainfall surplus or deficit based on the sum of rainfall less estimated ET at STA-5. In 24 of 36 months (eight months out of each water year), ET exceeded rainfall. The rainfall surplus in October 2000 was due to an unnamed tropical wave. November 1999 was the beginning of an extended drought in South Florida that continued until the beginning of the wet season in WY02. During WY01, WY02 and WY03, ET exceeded rainfall by a total of 17.46, 17.28 and 3.42 in., respectively. The 40.26 in. of rainfall received at STA-5 during calendar year 2000 represented 75 percent of the expected or long-term average rainfall for the East EAA rain area for that period, 53.46 in. The amounts of rainfall for calendar years 2001 and 2002 were 37.62 (70 percent of expected rainfall) and 45.39 in. (85 percent of expected rainfall).

Table 1. Rainfall amounts WY01-WY03 (in.).

Water Year	Rainfall Amount (in.)	Percent of Expected Rainfall
WY01	38.4	72
WY02	35.5	66
WY03	47.6	89

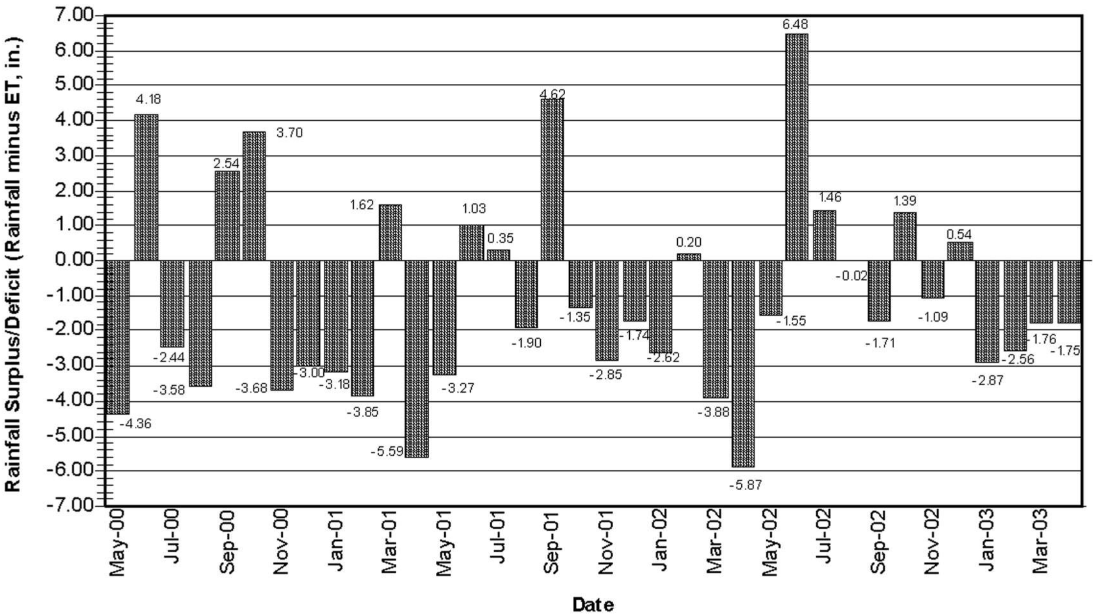

Figure 3. Monthly rainfall less estimated evapotranspiration at STA-5.

Northern Flow Way – Cells 1A and 1B

Table 2 presents the annual water budgets for the northern flow way at STA-5. The properties (width, length and surface area) of the elements that make up the northern flow way, i.e. Cells 1A and 1B, are listed in **Table A-1** in Appendix A. **Table 2** also shows summary information for the daily water budget analysis. A similar table is shown in the corresponding section for the other hydrologic units at STA-5. Inflow was measured at G342A and B, G349A and STA5TP_P; outflow at G344A and B.

In **Table 2**, error in the water budget ranged from about -14 to -20 percent. Water budget error is computed on a daily basis using equation (1) and summed for the month or water year. These errors are greater than that of the previous report due in part to the coefficient of seepage, which was adjusted to minimize the sum of the squared daily error (SSE) for the entire STA over the three- year period of record examined. Monthly water budget residuals were used as a check on using adjustments to the seepage coefficient to minimize SSE. The percentage of days where the daily water budget did not balance within a 0.25 ft (3 in.) depth was less than 2.5 percent for the WY02 budget and even smaller—less than one-half percent—for the WY01 and WY03 budgets, where there was only a single day for each WY where the budget did not balance within 0.25 ft. This implies that daily values in the budget were adequately quantified. For the northern flow way, daily residuals were less than 1.0 in. for 81 percent of the daily values for WY02 and WY03, while they were less than 1.0 in. for 92 percent of the daily values for WY01. Daily water budget residuals are shown in **Figure 4**.

Table 2. Water budget summary for Cells 1A and 1B.

WY 2001	STA-5 - Cell 1 Water Budget						
	INFLOW	ac-ft	Percent	OUTFLOW	ac-ft	Percent	
	G342A-B	18,113	41.68%	G344A-B	20,566	45.29%	
	G349A_P	16,982	39.08%	ET	9,615	21.17%	
	STA5TP_P	1,772	4.08%	Seepage	23,011	50.68%	
	Rain	6,589	15.16%	Error	-7,785	-17.14%	
	Total	43,455	100.00%	Total	45,408	100.00%	
	Storage Chg.	-1,953					
	Residuals Analysis				1" error	2" error	3" error
Sum=	-7,784.78	Avg. Err.	-21.33	# of Days	26	10	1
Max=	379.73	St. Dev.	108.63	Percent	7.12	2.74	0.27
Min=	-593.51						

WY 2002	STA-5 - Cell 1 Water Budget						
	INFLOW	ac-ft	Percent	OUTFLOW	ac-ft	Percent	
	G342A-B	81,487	77.20%	G344A-B	83,779	81.05%	
	G349A_P	16,590	15.72%	ET	9,052	8.76%	
	STA5TP_P	1,389	1.32%	Seepage	24,949	24.14%	
	Rain	6,088	5.77%	Error	-14,416	-13.95%	
	Total	105,553	100.00%	Total	103,364	100.00%	
	Storage Chg.	2,189					
	Residuals Analysis				1" error	2" error	3" error
Sum=	-14,415.93	Avg. Err.	-39.50	# of Days	65	17	9
Max=	876.25	St. Dev.	176.00	Percent	17.81	4.66	2.47
Min=	-1,326.29						

WY 2003	STA-5 - Cell 1 Water Budget						
	INFLOW	ac-ft	Percent	OUTFLOW	ac-ft	Percent	
	G342A-B	88,105	78.91%	G344A-B	100,939	90.39%	
	G349A_P	15,375	13.77%	ET	8,757	7.84%	
	Rain	8,170	7.32%	Seepage	24,209	21.68%	
				Error	-22,236	-19.91%	
	Total	111,650	100.00%	Total	111,669	100.00%	
	Storage Chg.	-19					
	Residuals Analysis				1" error	2" error	3" error
Sum=	-22,236.49	Avg. Err.	-60.92	# of Days	69	10	1
Max=	418.32	St. Dev.	122.70	Percent	18.90	2.74	0.27
Min=	-725.14						

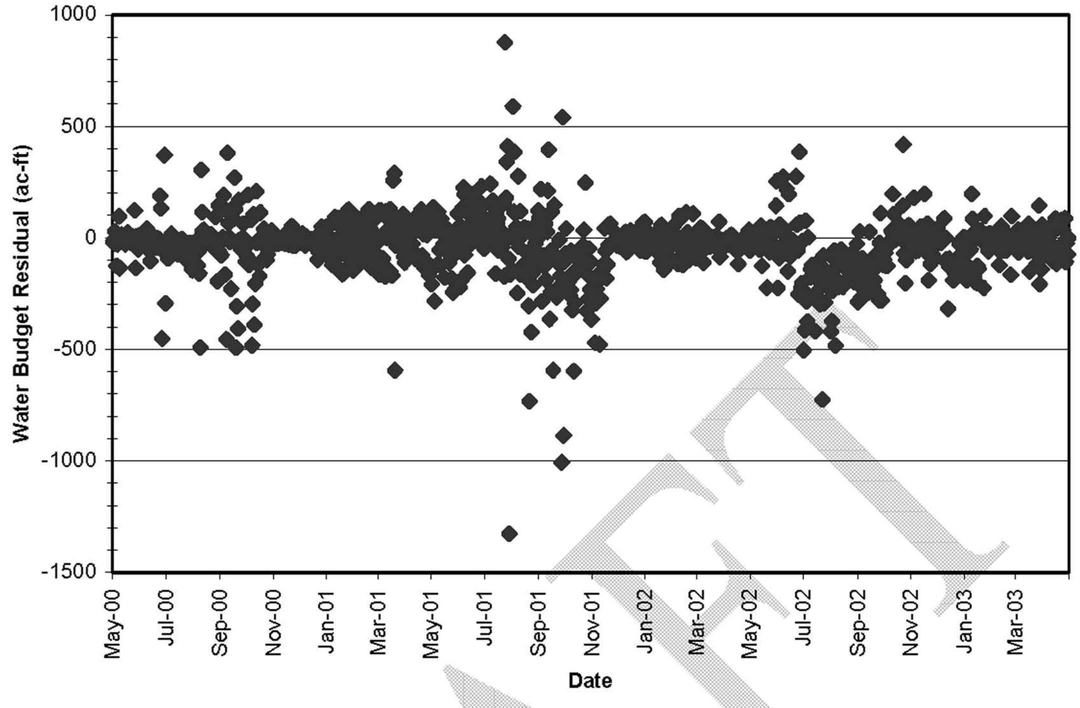

Figure 4. Water budget residuals for Cells 1A and 1B.

The seepage coefficient was 2.20 cfs/mi/ft, well within the values reported in other studies (Brown and Caldwell, 1996; Guardo and Rohrer, 2000). The previous report (Huebner, 2002) used a seepage coefficient of 1.61 cfs/mi/ft. Seepage constituted 51, 24 and 22 percent of the water budget for WY01, 02 and 03, respectively. The value for WY01 is high due largely to the effects of the drought (i.e., significantly lower inflow and outflow). **Figure 5** shows the estimated seepage for Cells 1A and 1B over the period of the study. **Table 3** summarizes inflow and outflow at culverts and pumps in the northern flow way for WY01-WY03. **Figure 6** displays the water levels in the northern flow way cells versus surrounding canals and cells. For the three-year period examined, seepage out of the northern flow way was greater than seepage into Cells 1A and 1B. In general, the direction of seepage flow was into the treatment cells from the L-2 canal and Cells 2A and 2B and out of the treatment cells toward the seepage canal along the STA's northern boundary and the discharge canal along the eastern boundary. Inflow, outflow and stage for Cells 1A and 1B are shown in **Figure 7**. Approximately 88 percent of the flow leaving the northern flow way at G344A and B entered the STA at G342A and B for WY01 (the percentages for WY02 and 03 are 97 and 87). This apparent reversal (outflow greater than inflow) was due to the lower inflow values caused by the drought and seepage pumping at G349A that was counted as inflow to the STA in this study. **Table 4** presents the results of the monthly water budget analysis for Cells 1A and 1B.

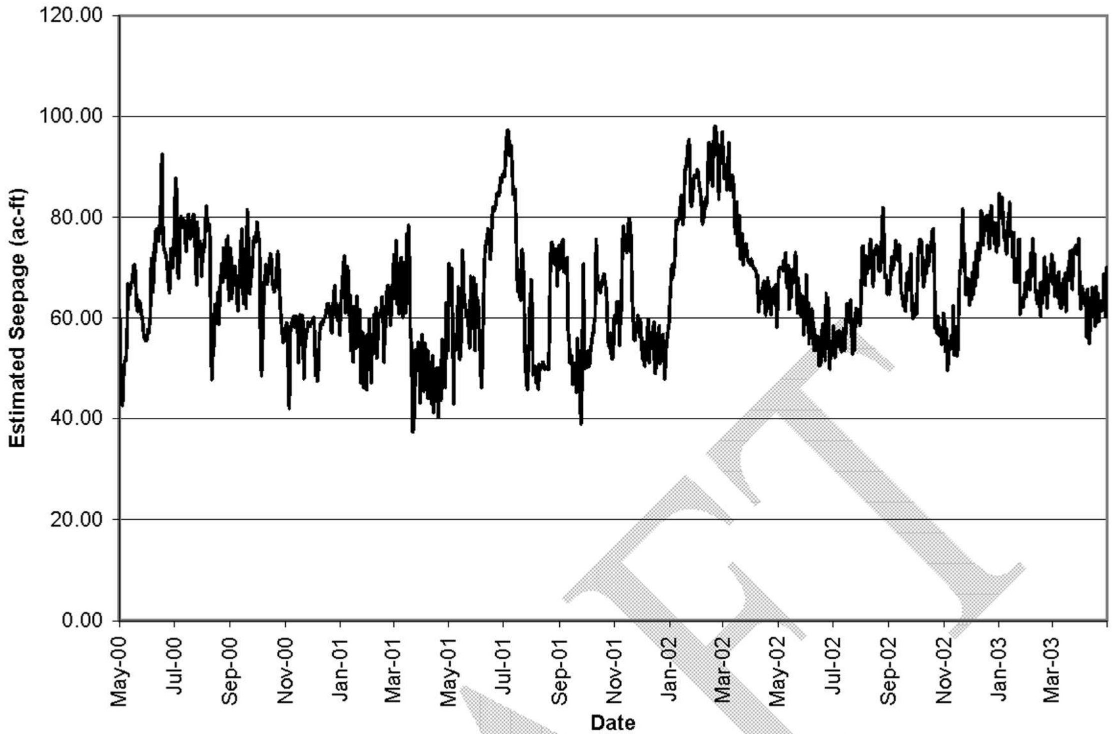

Figure 5. Estimated seepage for Cells 1A and 1B.

Table 3. Inflow and Outflow at Structures - Northern Flow Way WY01-WY-03.

Water Year	Inflow (ac-ft)	Outflow (ac-ft)	Percent of Inflow
WY01	36,867	20,566	56
WY02	99,466	83,779	84
WY03	111,650	100,939	90

Note: Inflow calculated at G342A, G342B, G349A and STA5TP_P. Outflow calculated at G344A and G344B
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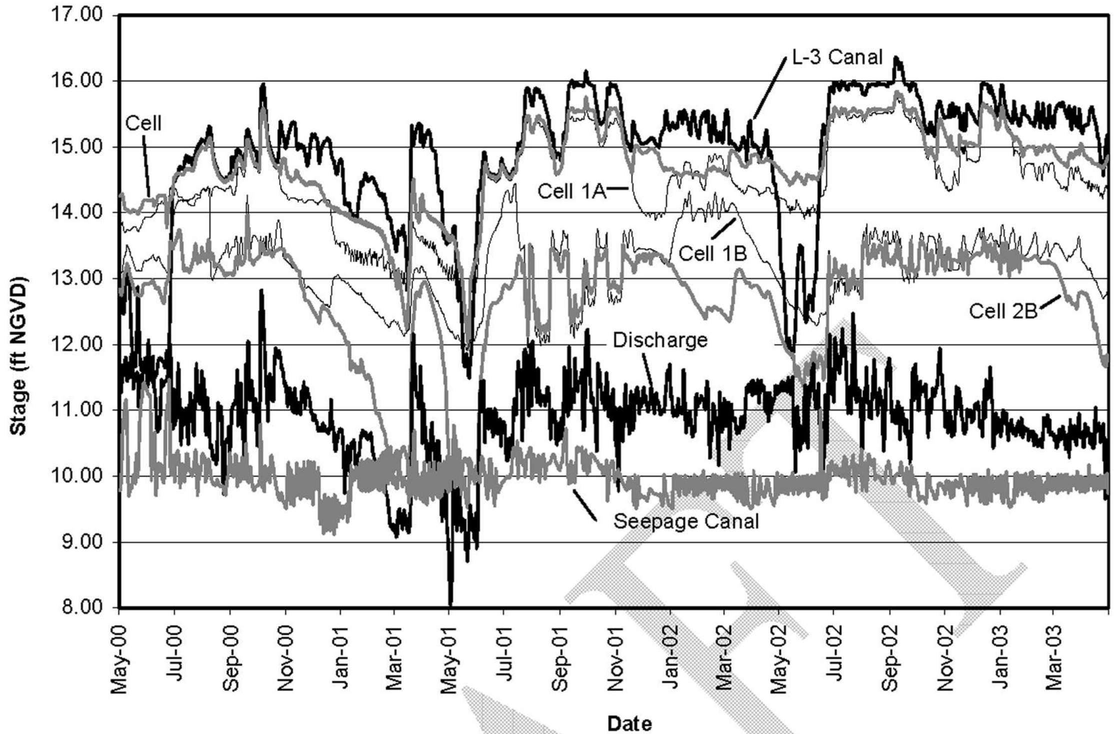

Figure 6. Cells 1A and 1B stage versus surrounding areas.

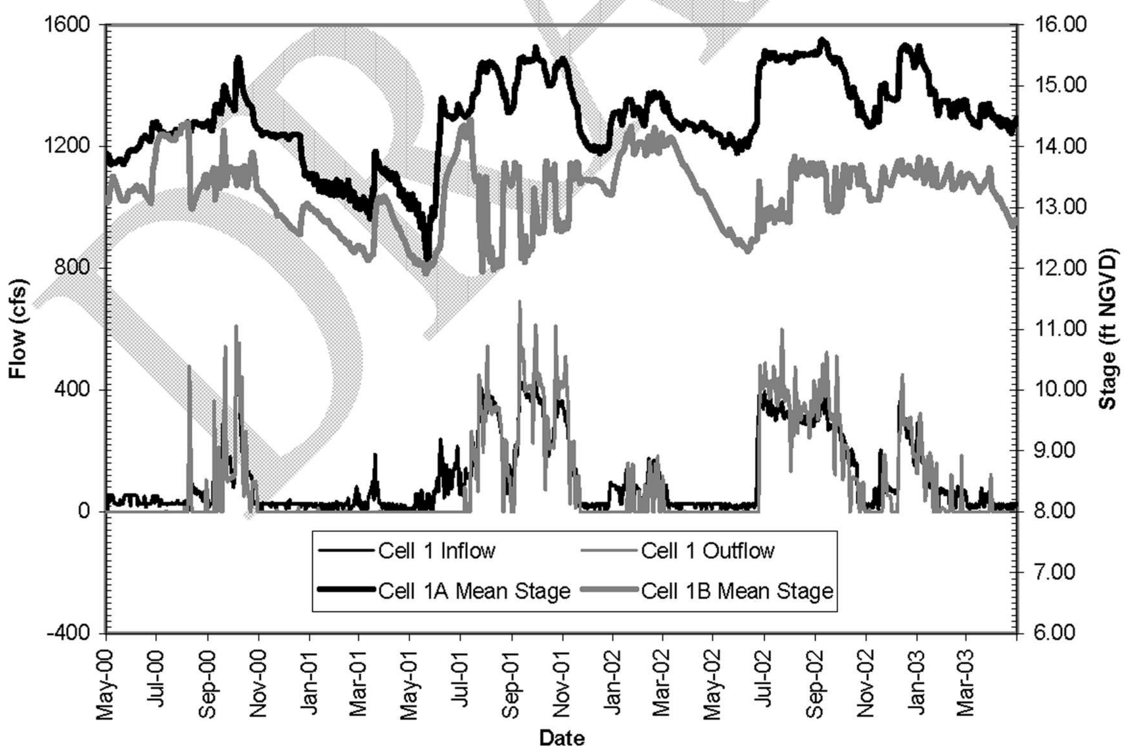

Figure 7. Inflow, outflow and stage for Cells 1A and 1B.

Table 4. Monthly Water Budget for Cells 1A and 1B.

Water Year	Month	Inflow (ac-ft)	Outflow (ac-ft)	ΔStorage (ac-ft)	Rain (ac-ft)	ET (ac-ft)	Seepage (ac-ft)	Error (ac-ft)	Daily Avg. Error (in)
2001	May-00	2,275	0	111	745	2,240	1,845	-1,175	0.22
	Jun-00	2,193	0	1,244	3,322	1,889	2,160	223	0.04
	Jul-00	1,781	4	410	944	1,780	2,370	-1,839	0.35
	Aug-00	3,171	2,330	-1,120	515	1,743	2,116	-1,383	0.26
	Sep-00	8,122	6,773	503	2,392	1,520	2,108	-390	0.08
	Oct-00	10,415	11,388	-714	2,735	1,465	2,031	-1,019	0.19
	Nov-00	1,426	11	-661	3	1,268	1,706	-894	0.17
	Dec-00	1,443	27	-366	58	1,088	1,827	-1,075	0.20
	Jan-01	1,057	23	-566	196	1,285	1,838	-1,327	0.25
	Feb-01	1,477	8	-530	0	1,321	1,663	-985	0.21
	Mar-01	2,805	4	1,447	2,237	1,682	1,870	39	0.01
	Apr-01	700	0	-1,709	31	1,949	1,477	-986	0.19
2002	May-01	1,457	0	200	861	1,985	1,871	-1,737	0.33
	Jun-01	7,557	0	3,838	2,165	1,811	2,220	1,854	0.36
	Jul-01	12,649	9,660	-330	1,932	1,813	2,318	1,120	0.21
	Aug-01	16,213	16,118	-669	1,129	1,780	1,804	-1,691	0.32
	Sep-01	19,890	22,000	220	2,941	1,356	1,723	-2,468	0.48
	Oct-01	18,533	21,425	-380	813	1,276	1,862	-4,836	0.91
	Nov-01	7,989	9,642	-241	182	1,159	1,966	-4,354	0.85
	Dec-01	1,934	0	203	422	1,018	1,688	-553	0.10
	Jan-02	4,862	1,537	1,055	271	1,170	2,540	-1,170	0.22
	Feb-02	5,180	3,056	325	940	871	2,494	-626	0.13
	Mar-02	1,775	336	-1,093	501	1,834	2,495	-1,295	0.24
	Apr-02	1,425	4	-939	17	2,032	1,969	-1,624	0.32
2003	May-02	1,189	2	-855	1,681	2,214	2,070	-560	0.11
	Jun-02	6,641	4,734	1,426	3,664	1,439	1,710	997	0.19
	Jul-02	20,456	25,645	264	2,223	1,721	1,784	-6,735	1.27
	Aug-02	17,982	19,769	1,001	1,623	1,628	2,210	-5,004	0.94
	Sep-02	18,617	21,554	-778	926	1,512	2,026	-4,771	0.93
	Oct-02	8,344	6,556	-360	1,873	1,396	2,080	545	0.10
	Nov-02	4,041	1,945	294	731	1,103	1,844	-415	0.08
	Dec-02	12,723	12,134	670	1,125	941	2,326	-2,223	0.42
	Jan-03	7,761	7,135	-698	175	1,159	2,262	-1,922	0.36
	Feb-03	2,907	988	122	336	1,214	1,885	-966	0.20
	Mar-03	1,823	458	-337	906	1,510	2,122	-1,024	0.19
	Apr-03	998	17	-766	1,077	1,676	1,892	-744	0.14

Note: Negative storage values indicate decreasing stage over the month. No signs are shown for other values, except error. To compute the water budget error, flow into the cell was taken as positive and flow out of a cell was taken as negative.

Southern Flow Way – Cells 2A and 2B

Table 5 shows the period of study water budget for the southern flow way, comprised of Cells 2A and 2B. Inflow was measured at G342C and D and G350A; outflow at G344C and D.

As a percentage of the budget, error is about 12 percent for WY01 and less than 26 and 14 percent for WY02 and 03. For WY02, less than 4 percent of the days have errors that are greater than 0.25 ft (3 in.) in depth, while for WY01 and 03, less than 1 percent of the days have errors greater than 0.25 ft. Seventy-five percent of the days have a budget error less than 1.0 in. in depth for WY02, while water budget errors were less than 1.0 in. 88 and 80 percent of the days

Table 5. Water Budget Summary Cells 2A and 2B.

WY 2001 — STA-5 - Cell 2 Water Budget

INFLOW	ac-ft	Percent	OUTFLOW	ac-ft	Percent
G342C-D	31,999	60.26%	G344C-D	19,410	36.13%
+ G350A_P	14,513	27.33%	ET	9,615	17.90%
Rain	6,589	12.41%	Seepage	18,231	33.94%
			Error	6,466	12.04%
Total	53,101	100.00%	Total	53,722	100.00%
Storage Chg.	-621				

Residuals Analysis					1" error	2" error	3" error
Sum=	6,466.04	Avg. Err.	17.72	# of Days	45	11	2
Max=	497.96	St. Dev.	147.75	Percent	12.33	3.01	0.55
Min=	-1,743.51						

WY 2002 — STA-5 - Cell 2 Water Budget

INFLOW	ac-ft	Percent	OUTFLOW		INFLOW	ac-ft
G342C-D	77,186	77.92%	G344C-D	42,402	44.65%	
+ G350A_P	15,778	15.93%	ET	9,052	9.53%	
Rain	6,088	6.15%	Seepage	19,100	20.11%	
			Error	24,405	25.70%	
Total	99,052	100.00%	Total	94,959	100.00%	
Storage Chg.	4,093					

Residuals Analysis					1" error	2" error	3" error
Sum=	24,372.88	Avg. Err.	67.14	# of Days	90	26	14
Max=	1,011.42	St. Dev.	198.35	Percent	24.66	7.12	3.84
Min=	-1,327.96						

WY 2003 — STA-5 - Cell 2 Water Budget

INFLOW	ac-ft	Percent	OUTFLOW		INFLOW	ac-ft
G342C-D	82,072	78.06%	G344C-D	59,580	56.40%	
+ G350A_P	14,897	14.17%	ET	8,757	8.29%	
Rain	8,170	7.77%	Seepage	23,081	21.85%	
			Error	14,221	13.46%	
Total	105,139	100.00%	Total	105,639	100.00%	
Storage Chg.	-501					

Residuals Analysis					1" error	2" error	3" error
Sum=	14,221.23	Avg. Err.	38.96	# of Days	73	12	2
Max=	487.70	St. Dev.	141.61	Percent	20.00	3.29	0.55
Min=	-873.45						

for WY01 and WY03. **Figure 8** shows the daily residual error plot for the three-year water budget. The seepage coefficient for the Cells 2A and 2B was 2.20 cfs/mi/ft. **Table 6** shows the annual inflow and outflow at culverts and pumps for the southern flow way for WY01-WY03.

Seepage constitutes 34, 20 and 22 percent of the water budget for WY01, 02 and 03, respectively. Seepage out of the southern flow way is depicted in **Figure 9**. In general, seepage from the southern flow way flows into the northern flow way, the seepage canal along the southern boundary of the cells and the discharge canal along the eastern boundary of the STA. Based on water elevation differences, it appears that some water seeped into the southern flow way from the L-2 canal (typical for the period, except for late spring 2002 and a brief period in late April 2003) and the northern flow way (stage in Cell 1B was typically greater than in Cell 2B, except during the summer of 2002; stage in Cell 1A was only occasionally greater than that of Cell 2A). Stage in the cells and in surrounding areas is presented in **Figure 10**. An amount equal to 61 percent of the water flowing into Cell 2A at G342C and D flowed out of the STA at G344C and D during WY01 (the percentages for WY02 and WY03 are 55 and 73). **Figure 11** shows the inflow, outflow and stage in Cells 2A and 2B for study period.

The monthly water budget is shown in **Table 7**. The monthly error in ac-ft/month and the daily average error in inches are given in the right two columns of the table. All average daily errors based on the monthly water budget are less than 1.0 in., except for July and August of 2002, which are 1.19 and 1.45 in.

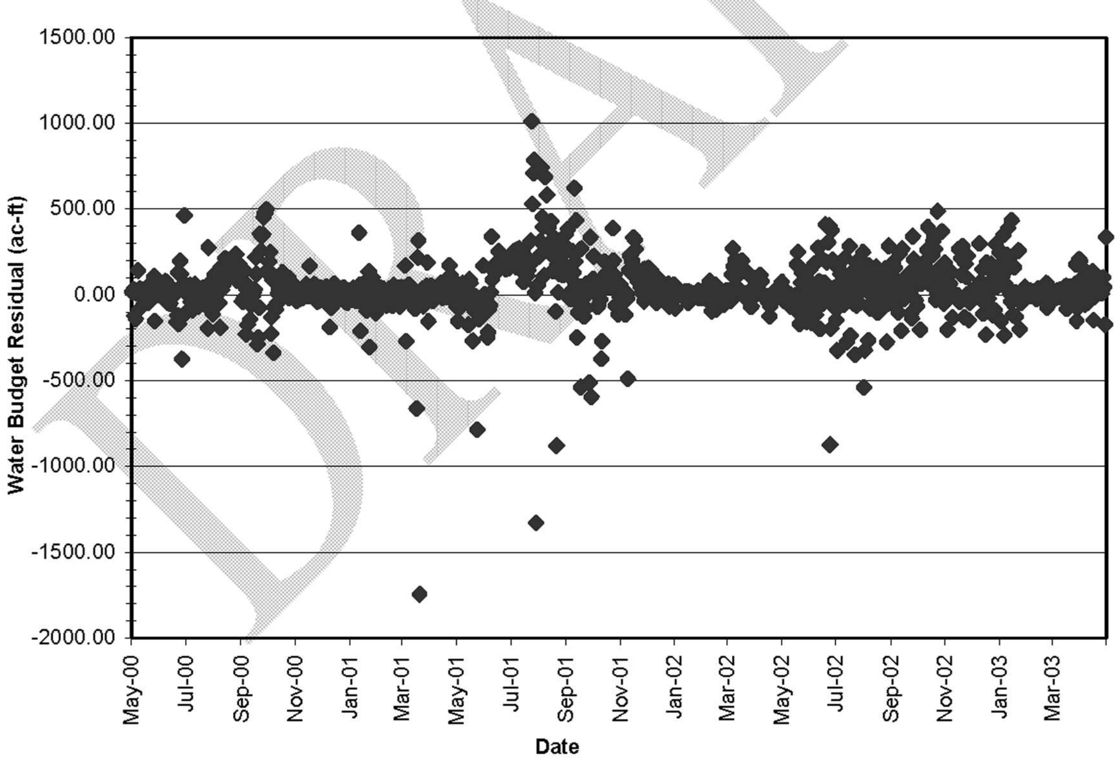

Figure 8. Water budget residuals for Cells 2A and 2B.

Table 6. Inflow and Outflow at Structures - Southern Flow Way WY01-WY03.

Water Year	Inflow (ac-ft)	Outflow (ac-ft)	Percent of Inflow
WY01	49,512	19,410	42
WY02	92,694	42,402	46
WY03	96,969	59,580	61

Note: Inflow calculated at G342C, G342D and G350A. Outflow calculated at G344C and G344D.

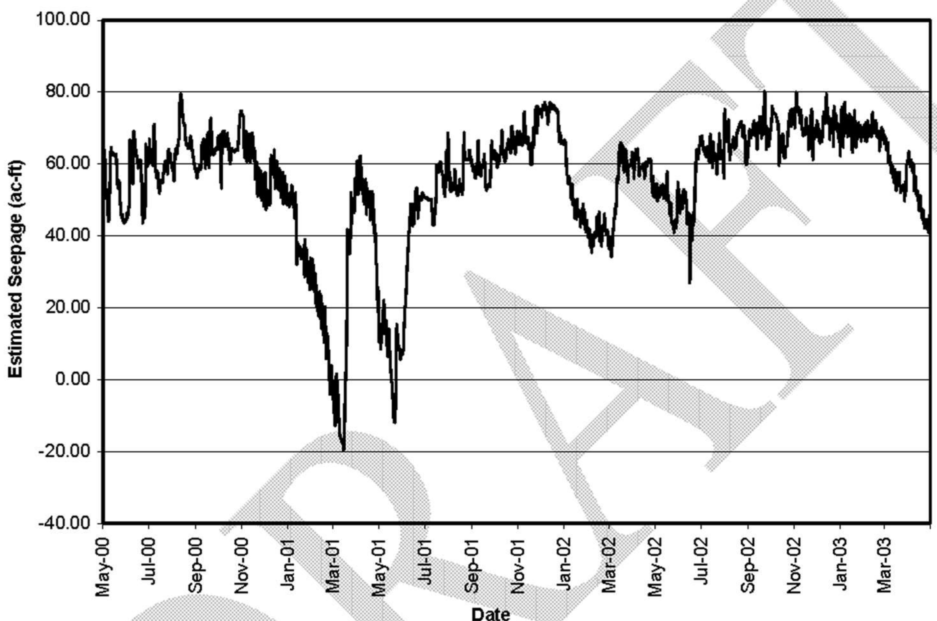

Figure 9. Estimated seepage Cells 2A and 2B.

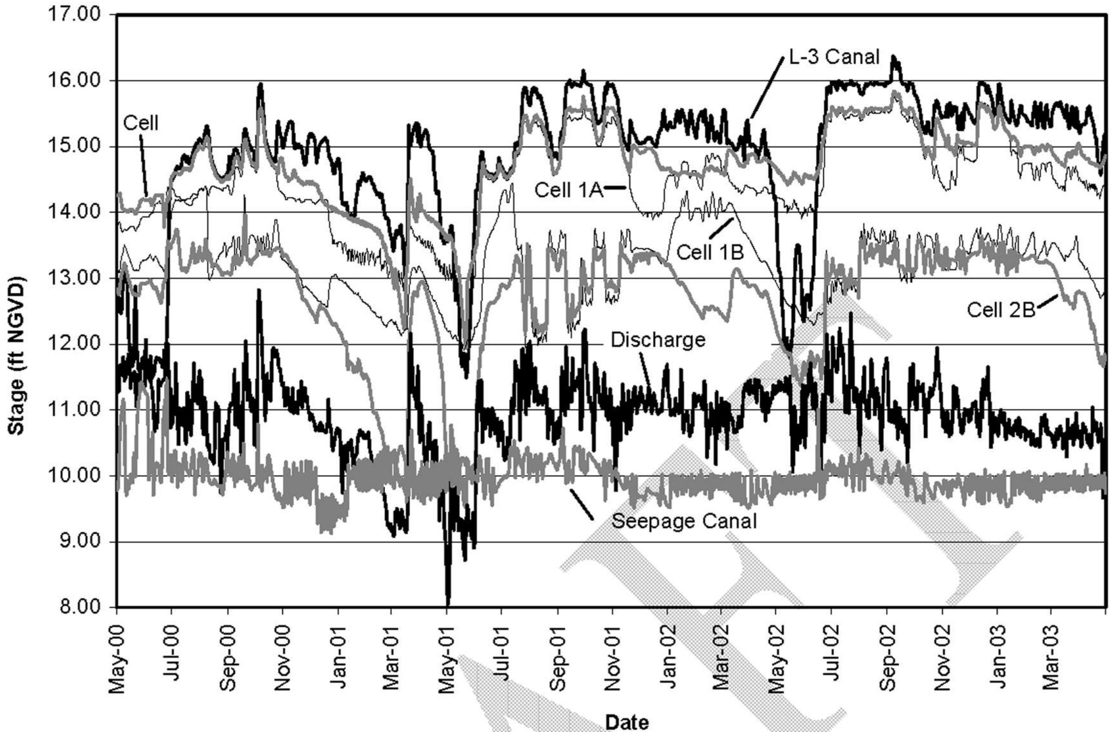

Figure 10. Stage in Cells 2A and 2B and surrounding areas.

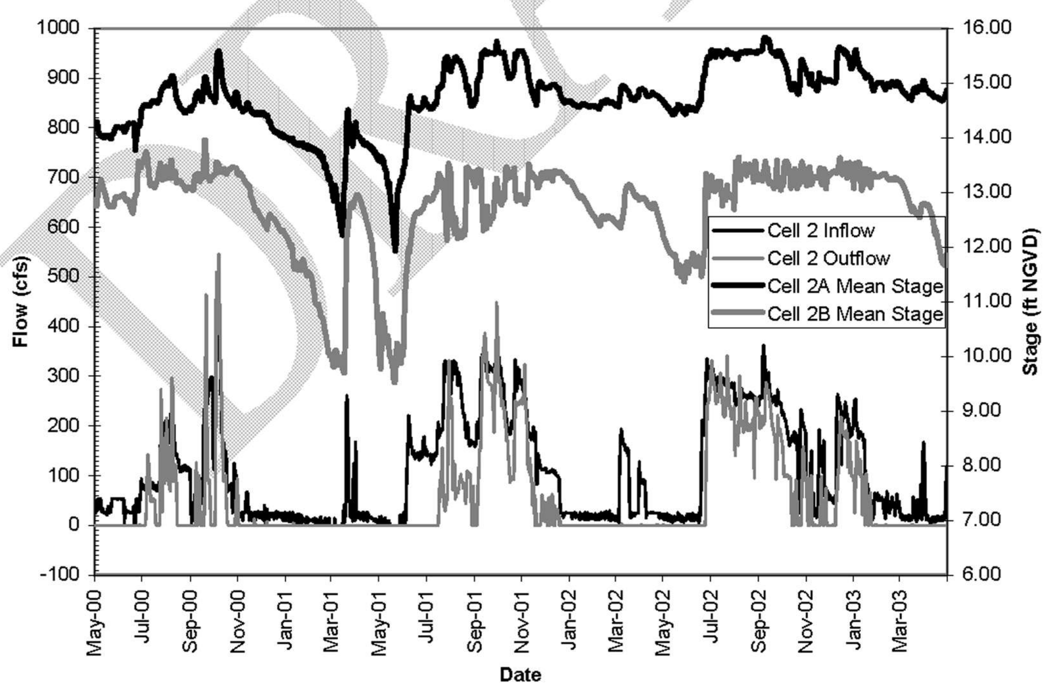

Figure 11. Cells 2A and 2B inflow, outflow and stage.

Table 7. Monthly Water Budget for Cells 2A and 2B.

Water Year	Month	Inflow (ac-ft)	Outflow (ac-ft)	ΔStorage (ac-ft)	Rain (ac-ft)	ET (ac-ft)	Seepage (ac-ft)	Error (ac-ft)	Daily Avg. Error (in)
2001	May-00	2,431	0	-26	745	2,240	1,674	-711	0.13
	Jun-00	2,345	2	1,005	3,322	1,889	1,715	1,056	0.21
	Jul-00	6,380	3,695	353	944	1,780	1,851	-356	0.07
	Aug-00	9,187	3,907	-842	515	1,743	2,046	2,847	0.54
	Sep-00	8,345	3,703	408	2,392	1,520	1,901	3,205	0.62
	Oct-00	10,164	7,989	119	2,735	1,465	2,041	1,285	0.24
	Nov-00	1,521	91	-1,262	3	1,268	1,832	-404	0.08
	Dec-00	1,275	15	-742	58	1,088	1,694	-722	0.14
	Jan-01	796	8	-1,040	196	1,285	1,206	-468	0.09
	Feb-01	386	-1	-651	0	1,321	444	-728	0.15
	Mar-01	2,381	0	4,153	2,237	1,682	376	-1,592	0.30
	Apr-01	1,301	0	-2,096	31	1,949	1,452	27	0.01
2002	May-01	250	0	1,355	861	1,985	221	-2,450	0.46
	Jun-01	7,807	0	3,431	2,165	1,811	1,234	3,496	0.68
	Jul-01	12,398	3,355	1,166	1,932	1,813	1,657	6,339	1.19
	Aug-01	14,842	5,563	-841	1,129	1,780	1,771	7,698	1.45
	Sep-01	17,331	14,323	819	2,941	1,356	1,759	2,015	0.39
	Oct-01	16,009	12,563	-316	813	1,276	1,991	1,309	0.25
	Nov-01	10,277	5,654	-90	182	1,159	2,047	1,689	0.33
	Dec-01	4,492	933	-348	422	1,018	2,270	1,042	0.20
	Jan-02	1,143	0	-807	271	1,170	1,560	-510	0.10
	Feb-02	987	0	-133	940	871	1,145	45	0.01
	Mar-02	5,013	5	722	501	1,834	1,666	1,288	0.24
	Apr-02	2,414	6	-866	17	2,032	1,780	-521	0.10
2003	May-02	917	4	-809	1,681	2,214	1,535	-346	0.07
	Jun-02	6,642	2,746	2,408	3,664	1,439	1,527	2,186	0.42
	Jul-02	17,724	16,068	-385	2,223	1,721	1,953	590	0.11
	Aug-02	15,707	12,792	779	1,623	1,628	2,088	42	0.01
	Sep-02	16,135	12,453	-256	926	1,512	2,084	1,268	0.25
	Oct-02	11,209	4,316	-53	1,873	1,396	2,158	5,265	0.99
	Nov-02	4,675	1,268	-121	731	1,103	2,128	1,027	0.20
	Dec-02	10,404	6,731	37	1,125	941	2,193	1,627	0.31
	Jan-03	7,461	3,190	-110	175	1,159	2,173	1,225	0.23
	Feb-03	2,404	4	-82	336	1,214	1,931	-326	0.07
	Mar-03	2,078	4	-497	906	1,510	1,786	181	0.03
	Apr-03	1,611	4	-1,412	1,077	1,676	1,525	896	0.17

Note: Negative storage values indicate decreasing stage over the month. No signs are shown for other values, except error. To compute the water budget error, flow into the cell was taken as positive and flow out of a cell was taken as negative.

STA-5

Table 8 summarizes the annual inflow and outflow volumes at culverts and pumps at STA-5 for WY01-WY03. **Table 9** contains the summary of the water budget for the entire STA, which includes both flow ways, discussed above. Using a seepage coefficient of 2.20 cfs/mi/ft, error for the WY02 budget was slightly greater than 5 percent of the budget—for WY01 and 03, the errors were less than 2 percent and less than 4 percent. Seepage was about 22 percent of the water budget for WY02 and WY03 and about 42 percent for WY01. Less than 3 percent of the days during WY02 had errors that were greater than 0.25 ft (3.0 in), while less than 1 percent of the days during WY01 and WY03 had errors greater than 0.25 ft.

Figure 12 shows the residual in the daily water budgets. The peaks in the residual plot occur during periods of high inflow, indicating that the daily water budget under these conditions does not accurately quantify the hydrologic processes occurring in the STA. **Figure 13** presents the estimated seepage out of STA-5. It shows that there is a persistent net loss of water from the treatment cells. However, the pumps at G349A and G350A return a substantial fraction of this seepage volume (shown in **Table 9**) to Cells 1A and 2A—76, 73 and 64 percent for WY01, 02 and 03, respectively. Inflow, outflow and stage are shown in **Figure 14**.

Table 10 shows the monthly water budget summary. The daily average errors are less than 1.0 in. The two highest values are for July and August 2001 and July 2002. **Figure 15** summarizes the inflows and outflows to STA-5 for the period May 2000 through April 2003. The outflow volume during this 3-year period at G344A through D was 86 percent of the inflow volume at G342A though D.

Table 8. Annual Inflow and Outflow at Culverts and Pumps - STA5 WY01-WY03.

Water Year	Inflow (ac-ft)	Outflow (ac-ft)	Percent of Inflow
WY01	83,378	39,975	48
WY02	192,430	126,181	66
WY03	200,449	160,519	80

Note: Inflow calculated at G342A, B, C and D, G349A, G350A and STA5TP_P. Outflow calculated at G344A, B, C and D.

Table 9. Water Budget Summary for STA-5.

WY 2001			STA-5 Water Budget				
	INFLOW	ac-ft	Percent	OUTFLOW	ac-ft		
	G342A-D	50,111	51.9%	**G344A-D**	39,976	40.3%	
	+ G349A_P	16,982	17.6%	**ET**	19,230	19.4%	
	+ G350A_P	14,513	15.0%	**Seepage**	41,243	41.6%	
	+ STA5TP_P	1,772	1.8%	**Error**	-1,319	-1.3%	
	Rain	13,178	13.6%				
	Total	96,556	100.0%	**Total**	99,130	100.0%	
	Storage Chg.	-2,574					
	Residuals Analysis				1" error	2" error	3" error
Sum=	-1,318.74	**Avg. Err.**	-3.61	**# of Days**	27	6	1
Max=	833.56	**St. Dev.**	221.79	**Percent**	7.40	1.64	0.27
Min=	-2,337.02						

WY 2002		STA-5 Water Budget					
	INFLOW	ac-ft	Percent	OUTFLOW	ac-ft	Percent	
	G342A-D	158,673	77.55%	**G344A-D**	126,181	63.62%	
	+ G349A_P	16,590	8.11%	**ET**	18,104	9.13%	
	+ G350A_P	15,778	7.71%	**Seepage**	44,050	22.21%	
	+ STA5TP_P	1,389	0.68%	**Error**	9,989	5.04%	
	Rain	12,176	5.95%				
	Total	204,605	100.00%	**Total**	198,323	100.00%	
	Storage Chg.	6,282					
	Residuals Analysis				1" error	2" error	3" error
Sum=	9,988.58	**Avg. Err.**	27.37	**# of Days**	54	18	10
Max=	1,887.67	**St. Dev.**	343.32	**Percent**	14.79	4.93	2.74
Min=	-2,654.25						

WY 2003		STA-5 Water Budget					
	INFLOW	ac-ft	Percent	OUTFLOW	ac-ft	Percent	
	G342A-D	170,177	78.50%	**G344A-D**	160,519	73.87%	
	+ G349A_P	15,375	7.09%	**ET**	17,515	8.06%	
	+ G350A_P	14,897	6.87%	**Seepage**	47,290	21.76%	
	Rain	16,339	7.54%	**Error**	-8,015	-3.69%	
	Total	216,789	100.00%	**Total**	217,308	100.00%	
	Storage Chg.	-519					
	Residuals Analysis				1" error	2" error	3" error
Sum=	-8,015.26	**Avg. Err.**	-21.96	**# of Days**	40	8	1
Max=	906.02	**St. Dev.**	220.09	**Percent**	10.96	2.19	0.27
Min=	-1,074.94						

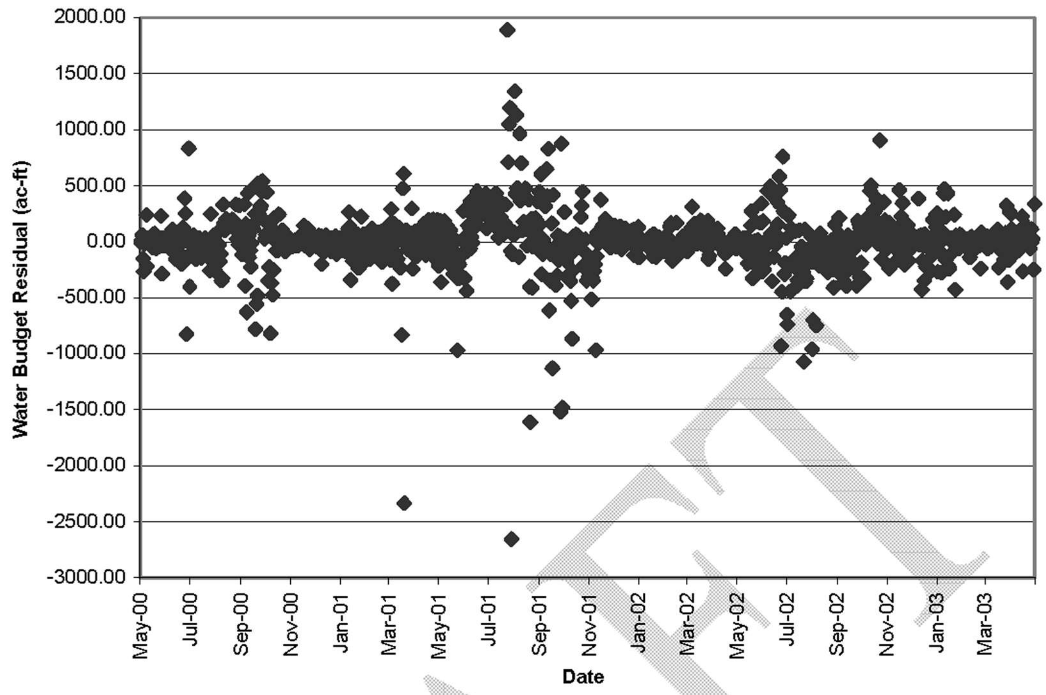

Figure 12. Water budget residuals for STA-5.

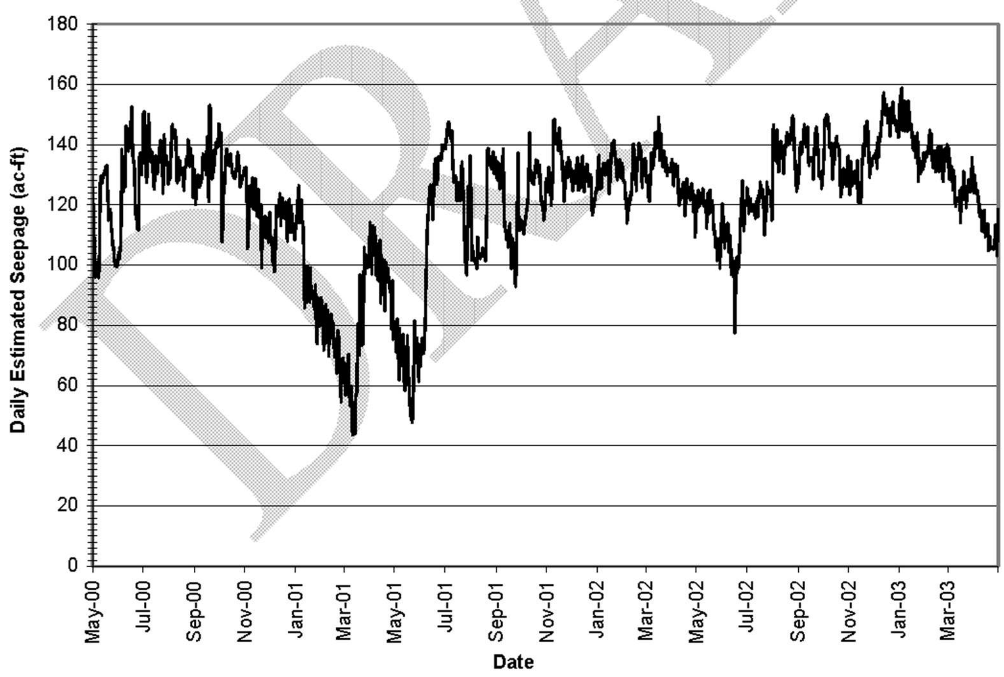

Figure 13. STA-5 estimated seepage.

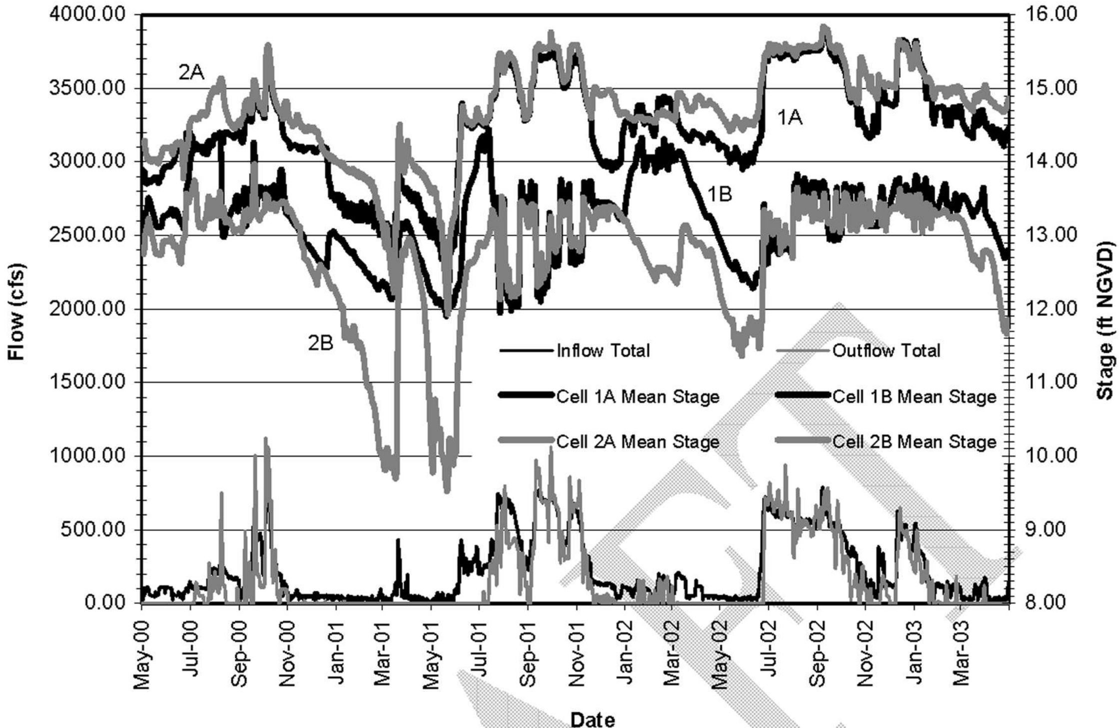

Figure 14. STA-5 inflow, outflow and stage.

Table 10. Monthly Water Budget for STA-5.

Water Year	Month	Inflow (ac-ft)	Outflow (ac-ft)	Δ Storage (ac-ft)	Rain (ac-ft)	ET (ac-ft)	Seepage (ac-ft)	Error (ac-ft)	Daily Avg. Error (in.)
2001	May-00	4,706	0	85	745	2,240	3,519	-392	0.04
	Jun-00	4,538	2	2,249	3,322	1,889	3,874	-155	0.02
	Jul-00	8,161	3,699	763	944	1,780	4,221	-1,358	0.13
	Aug-00	12,358	6,237	-1,962	515	1,743	4,162	2,693	0.25
	Sep-00	16,467	10,476	911	2,392	1,520	4,008	1,944	0.19
	Oct-00	20,580	19,377	-595	2,735	1,465	4,072	-1,004	0.09
	Nov-00	2,947	102	-1,923	3	1,268	3,538	-34	0.00
	Dec-00	2,717	42	-1,108	58	1,088	3,521	-767	0.07
	Jan-01	1,854	31	-1,607	196	1,285	3,044	-704	0.07
	Feb-01	1,863	7	-1,181	0	1,321	2,107	-392	0.04
	Mar-01	5,186	4	5,599	2,237	1,682	2,246	-2,108	0.20
	Apr-01	2,001	0	-3,805	31	1,949	2,929	959	0.09
2002	May-01	1,707	0	1,556	861	1,985	2,092	-3,063	0.29
	Jun-01	15,364	0	7,269	2,165	1,811	3,454	4,995	0.49
	Jul-01	25,047	13,015	836	1,932	1,813	3,974	7,341	0.69
	Aug-01	31,055	21,681	-1,509	1,129	1,780	3,575	6,657	0.63
	Sep-01	37,221	36,323	1,039	2,941	1,356	3,481	-2,038	0.20
	Oct-01	34,542	33,988	-696	813	1,276	3,853	-3,065	0.29
	Nov-01	18,267	15,296	-331	182	1,159	4,013	-1,688	0.16
	Dec-01	6,427	933	-145	422	1,018	3,958	1,085	0.10
	Jan-02	6,005	1,537	249	271	1,170	4,100	-780	0.07
	Feb-02	6,168	3,056	192	940	871	3,638	-651	0.07
	Mar-02	6,788	341	-371	501	1,834	4,161	1,326	0.12
	Apr-02	3,839	10	-1,806	17	2,032	3,750	-130	0.01
2003	May-02	2,106	7	-1,664	1,681	2,214	3,605	-374	0.04
	Jun-02	13,283	7,480	3,834	3,664	1,439	3,236	958	0.09
	Jul-02	38,180	41,713	-122	2,223	1,721	3,737	-6,647	0.62
	Aug-02	33,689	32,561	1,780	1,623	1,628	4,298	-4,956	0.47
	Sep-02	34,752	34,007	-1,034	926	1,512	4,110	-2,917	0.28
	Oct-02	19,553	10,872	-413	1,873	1,396	4,238	5,333	0.50
	Nov-02	8,716	3,213	174	731	1,103	3,972	985	0.10
	Dec-02	23,127	18,865	707	1,125	941	4,520	-781	0.07
	Jan-03	15,222	10,325	-808	175	1,159	4,435	286	0.03
	Feb-03	5,311	992	40	336	1,214	3,815	-414	0.04
	Mar-03	3,901	462	-835	906	1,510	3,908	-239	0.02
	Apr-03	2,609	20	-2,178	1,077	1,676	3,416	751	0.07

Note: Negative storage values indicate decreasing stage over the month. No signs are shown for other values, except error. To compute the water budget error, flow into the cell was taken as positive and flow out of a cell was taken as negative.

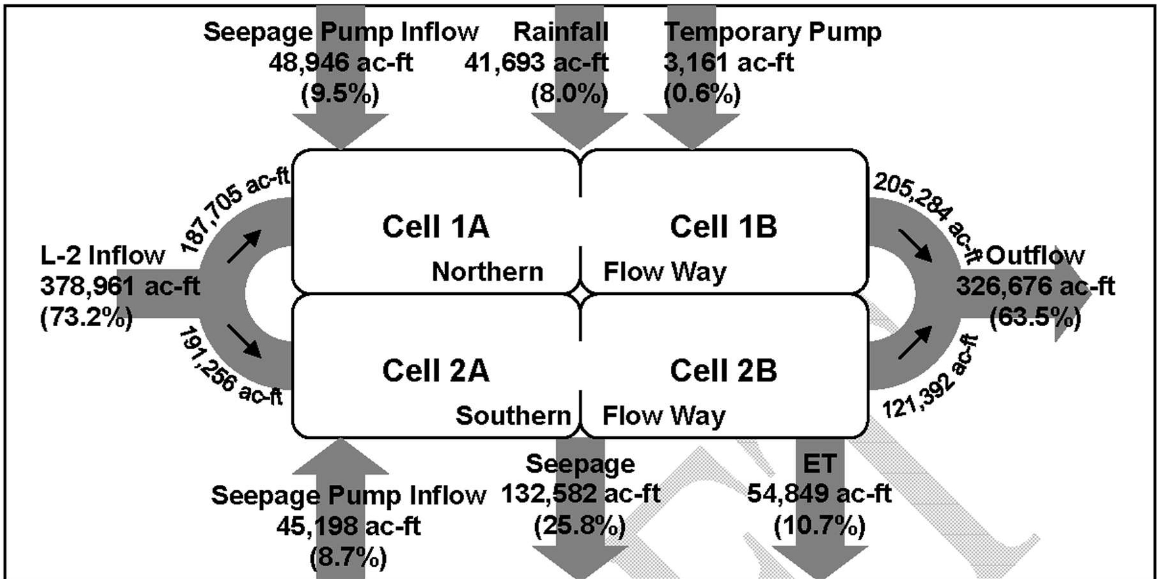

Figure 15. STA-5 water budget volumes WY 01-03.

Mean Hydraulic Retention Time

Mean hydraulic retention time (MHRT) is a measure of how long water remains in each cell and estimates the treatment time. Over this period, physical, chemical and biological processes remove particulate and soluble phosphorous and other contaminants. The mean hydraulic retention time (also referred to as mean cell residence time) was determined using equation 3:

$$t = \frac{V}{Q} \qquad (3)$$

where t = mean hydraulic retention time (d)
V = cell volume (ac-ft)
Q = flow rate (ac-ft/d)

MHRT was based upon the average stage during the study period and the average volume of total inflow and total outflow including rainfall, evapotranspiration and seepage which are large percentages of the water budget. **Table 11** shows the MHRT in days for the northern flow way (Cells 1A and 1B) and the southern flow way (Cells 2A and 2B) for wet and dry seasons. The retention times for each flow way (14.2 to 25.9 days on an annual basis for the northern flow way and 16.8 to 21.0 days for the southern flow way) are comparable with those reported for the ENR (17 days in 1994-96, 24.5 days in 1996-97 and 25.4 days in 1997-98, Abtew, et al., 1997, 1998, 2000). MHRT was 7.2 days for the northern flow way and 7.9 days for the southern flow way during the wet season in WY02 (May 2001 to October 2001).

Table 11. Mean Hydraulic Retention Time (MHRT).

Water Year	Season	Cell	Mean Stage (ft)	Mean Depth (ft)	Volume (ac-ft)	Average Flow (ac-ft/d)	MHRT (days)
2001	**Wet**	Cell 1A	14.32	1.57	1319	195	6.8
	(May-Oct)	Cell 1B	13.57	2.07	2531	195	13.0
		Northern					19.8
		Cell 2A	14.57	1.82	1531	217	7.0
		Cell 2B	13.20	1.70	2075	217	9.5
		Southern					16.5
	Dry	Cell 1A	13.59	0.84	703	69	10.2
	(Nov-Apr)	Cell 1B	12.73	1.23	1500	69	21.8
		Northern					32.0
		Cell 2A	13.91	1.16	970	56	17.3
		Cell 2B	11.88	0.38	460	56	8.2
		Southern					25.5
2002	**Wet**	Cell 1A	14.61	1.86	1559	454	3.4
	(May-Oct)	Cell 1B	12.93	1.43	1747	454	3.8
		Northern					7.2
		Cell 2A	14.71	1.96	1646	334	4.9
		Cell 2B	12.32	0.82	1001	334	3.0
		Southern					7.9
	Dry	Cell 1A	14.46	1.71	1439	155	9.3
	(Nov-Apr)	Cell 1B	13.64	2.14	2612	155	16.8
		Northern					26.1
		Cell 2A	14.78	2.03	1701	129	13.2
		Cell 2B	12.91	1.41	1722	129	13.4
		Southern					26.6
2003	**Wet**	Cell 1A	14.99	2.24	1876	474	4.0
	(May-Oct)	Cell 1B	13.08	1.58	1929	474	4.0
		Northern					8.0
		Cell 2A	15.20	2.45	2058	378	5.4
		Cell 2B	12.80	1.30	1590	378	4.2
		Southern					9.6
	Dry	Cell 1A	14.77	2.02	1697	197	8.6
	(Nov-Apr)	Cell 1B	13.39	1.89	2300	197	11.7
		Northern					20.3
		Cell 2A	15.04	2.29	1918	159	12.0
		Cell 2B	13.06	1.56	1908	159	12.0
		Southern					24.0

Note: Average flow is the average of total inputs and outputs and is calculated by:
$Q = \frac{1}{2}\,[(R + I) + (ET + G + O)] / D$
Where D is the number of days in the season (184 for the wet season and 181 for the dry season) and R, I, ET, G and O are seasonal total volumes of rainfall, inflow, evapotranspiration, seepage and outflow, respectively.

SUMMARY AND DISCUSSION

A total of 378,961 ac-ft of water entered STA-5 from the gated culverts at G342A – D from May 1, 2000 to April 30, 2003. This flow constituted 73 percent of the total inflow to the STA. Rainfall accounted for 41,693 ac-ft or 8 percent of the total inflow. Flow from seepage canal pumps at G349A and G350A contributed 48,946 ac-ft and 45,189 ac-ft of flow which was 10 and 9 percent, respectively, of the total inflow to the treatment area during the period of the study. During WY01, 2,194 ac-ft of water came from the Miami Canal due to pumping at G349B and 2,308 ac-ft due to pumping at G350B (only a negligible amount was pumped from these in WY02 and 03). Due to the drought, a temporary pump was located at the northeast corner of STA-5 in February 2001. It supplied 3,161 ac-ft of water to Cell 1B from the Miami Canal. The area around STA-5 received about 76 percent of its expected annual rainfall. The Pollution Prevention Plan (SFWMD, 2000) cites expected flows into the STA through the G342A – D culverts of 78,340 ac-ft per year or 215 ac-ft per day. During the study period, STA-5 received flow through these structures equaling a mean value of 346 ac-ft per day or 61 percent more than the expected annual volume.

During the same period, 326,676 ac-ft of water was discharged from the STA at G344A – D (86 percent of the total outflow). Evapotranspiration accounted for an additional 54,849 ac-ft of water leaving the STA (11 percent of the total outflow). Estimated seepage out of STA-5 accounted for 26 percent of the total outflow from the STA or 132,582 ac-ft. The volume of seepage was based upon head differences between the treatment cells and the water levels in the areas surrounding the STA and an estimated seepage coefficient of 2.20 cfs/ft/mi. This coefficient was well within the values found in literature concerning the design of STAs and other analyses of seepage potential. Water budget error was about one-tenth of one percent for the period covering the three water years.

The greatest monthly errors in the water budget for the STA occurred in July and August 2001. Rainfall and inflow to the STA during these months represented the end of the drought in South Florida. STA-5 effectively rehydrated during these months. Nevertheless, the daily average error in the monthly water budgets for STA-5 was less than 1.0 in.

Cells 1A and 1B, constituting the northern flow way, received 187,705 ac-ft of water from May 2000 to April 2003 through structures G342A and B. The pumps at G349A provided an additional 48,946 ac-ft of water during the same period. Rain into these cells accounted for 20,846 ac-ft of inflow. The volume of water stored in the cells increased by 218 ac-ft over this period. G344A and B discharged 205,284 ac-ft of water. ET accounted for another 27,424 ac-ft. Seepage out of Cells 1A and 1B was estimated at 72,170 ac-ft using an estimated seepage coefficient of 2.20 cfs/ft/mi. Water budget error was about 17 percent.

The southern flow way, Cells 2A and 2B, received 191,256 ac-ft of water during the study period through culverts G342C and D. The pumps at G350A discharged 45,188 ac-ft of water into Cell 2A. Rainfall contributed 20,846 ac-ft of water to these cells. Storage in Cells 2A and 2B decreased by 2,971 ac-ft. G344C and D released 121,392 ac-ft of water during the study period. ET accounted for a loss of 27,424 ac-ft and seepage losses were estimated at 60,412 ac-ft using an estimated seepage coefficient of 2.20 cfs/ft/mi. Seepage was out of the southern flow way and into the cells of the northern flow way, the seepage canal and discharge canal. Water budget error was about 18 percent.

Mean hydraulic residence times during this period were 7.2 (wet season WY02) to 32.0 (dry season WY01) days for the northern flow way, Cells 1A and 1B and 7.9 (wet season WY02) to

26.6 (dry season WY02) days for the southern flow way, Cells 2A and 2B. These values compare favorably with the MHRT's observed for STA-1W and the ENR project.

There were a number of problems associated with calculating the water budget for STA-5. The largest source of error may be the values computed for seepage. The seepage and budget residual combined constitute up to 43 percent of the water budget (**Table 9**, WY01). The seepage coefficients used in this study were calibrated based on minimizing the sum of the squared daily net water budget error for the entire STA. Other errors, such as those associated with flow calculations, may also be incorporated in the seepage estimates. However, implementation of new rating curves for the inflow and outflow structures reduced this error. Appendix E discusses seepage and analysis of error in greater detail.

The daily water budget residuals or error for STA-5 shown in **Figures 4**, **8** and **12** (residuals for Cells 1A and 1B, Cells 2A and 2B and STA-5 as a whole) are not random. The residuals increase when flow increases. This situation occurs in all three wet seasons of WY's 2001 to 2003, beginning in June and lasting until October or even until January; and in March of each year. **Figure 16** shows the residuals for STA-5 plotted with inflow data and seepage data. The largest residuals are observed during each period of significantly higher inflow. Although seepage also increases during these periods (in response to increased stages), the volume of outflow from STA-5 plus the increased seepage and the increase in storage do not equal the volume of water entering STA-5 on a daily basis. This is expected since the mean residence time or time to flow through the treatment cells is greater than a day. The same type of response has been observed at STA-6 (Huebner, 2001) and STA-1W (Abtew et al., 2001). This response to large flows and rapidly changing water levels is not adequately represented by the traditional equations for daily storage and levee seepage used in this and other studies.

Other possible sources of error in the budget include use of ET values from the ENR located approximately 33 miles to the northeast of STA-5, using average ground elevations for the bottom of the treatment cells and assuming a constant surface area independent of water depth in the cells. These weaknesses had a minor impact on the water budget.

Appendix E contains the results of a water budget analysis of 15-minute data for the period from July 18, 2001 to July 31, 2001. The work was done in order to identify errors introduced by using daily data that miss transients involving flow and stage that occur more frequently. Although error was reduced, the level of effort involved with increasing stage measurement precision and analyzing 15-minute data for this period does not justify changing the water budget time step from one day to 15 minutes.

RECOMMENDATIONS

Seepage was the largest single quantifiable unknown at the site. Although the percentage of the water budget attributed to seepage fell within the range of values presented in the literature, it is greater than values reported for the ENR and STA-1W. Additional study of the groundwater flow regime and the impact of seepage on treatment performance is warranted at this site. Piezometers with water level recorders located outside the boundary of STA-5 would have aided the analysis of seepage for this study especially along the northern and southern boundaries. The ability to calculate seepage into and out of an STA should be a design criterion. Location and installation of observation wells for this purpose should be a design/construction requirement for all STAs.

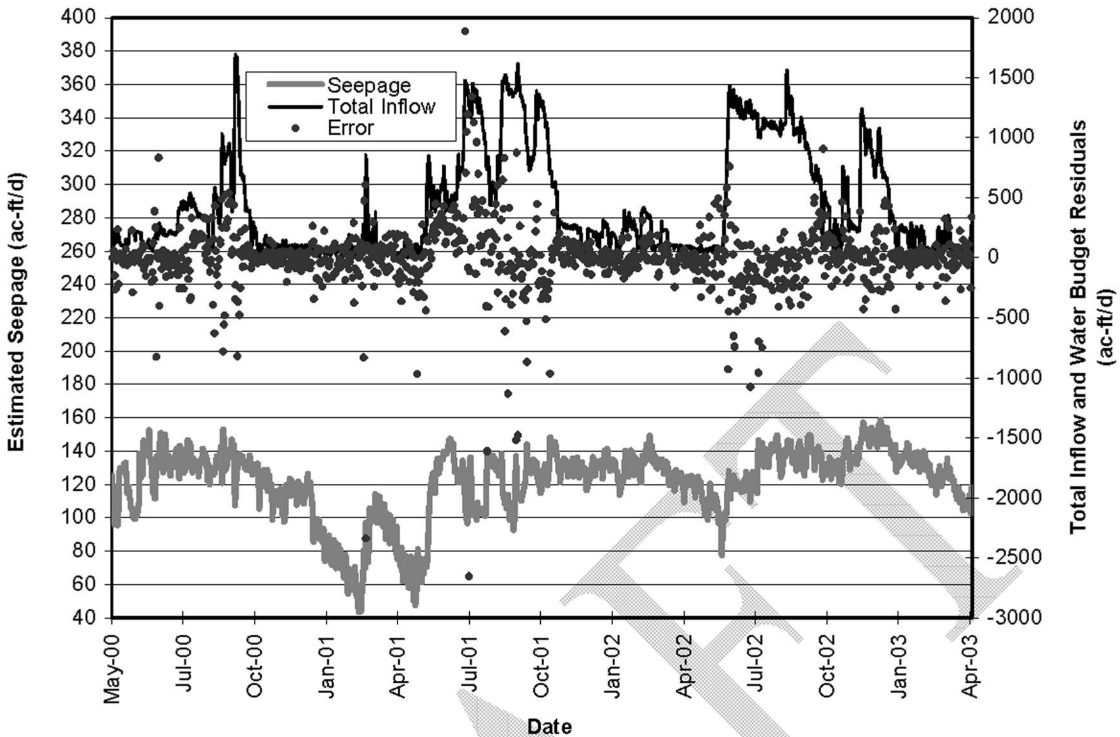

Figure 16. STA-5 inflow, seepage and water budget residuals.

The design of the gated culverts at STA-5 is susceptible to backflow or reverse flow under certain operating conditions. Although the magnitude of these flows is small relative to flow during major runoff events, backflow into or out of the STA is contrary to the design principles of STAs in general. Back-flow at the G344A through D structures introduces untreated water from the Miami Canal into the finishing Cells 1B and 2B. Likewise, backflow from Cells 1A and 2A at structures G342A through D mixes treated water with untreated water in the L-2 canal. Automating the operation of the gates would minimize the volume of backflow.

CONCLUSIONS

This water budget is the second for STA-5. This report provides another look at the hydraulic performance of the STA and its two treatment flow ways over three water years. Improvements to the water budget and a better understanding of the hydrologic components at STA-5 will come with additional years of data.

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APPENDICES

Appendix A – Site Properties and Monitoring Stations

Table A-1. STA-5 Site Properties

Surface Area

Cell 1A (Northwest)	**839 ac**
Cell 1B (Northeast)	**1220 ac**
Cell 2A (Southwest)	**839 ac**
Cell 2B (Southeast)	**1220 ac**
Total	**4118 ac**

Cells 1A and 2A Bottom Elevation **~12.75 ft NGVD**

(Cells 1A and 2A vary in elevation from G342 to G360 from 14.5 to 13.0 ft.; Cells 1A and 2A slope west to east from 13.50 to 11.25 ft.)

Cells 1B and 2B Bottom Elevation **~11.50 ft NGVD**

(Cells 1B and 2B slope west to east from 12.25 to 10.75 ft.)

Inflow

Flow at G342A-D, G349A_P, G350A_P and STA5TP_P

Outflow

Flow at G344A-D

Levee Length		Aspect Ratio
Along Northern Boundary		
Cell 1A	**~ 7,140 ft**	**1.39**
Cell 1B	**~10,380 ft**	**2.03**
Along Southern Boundary		
Cell 2A	**~ 7,140 ft**	**1.39**
Cell 2B	**~10,380 ft**	**2.03**
Along Eastern Boundary		
Cell 1A	**~ 5,120 ft**	
Cell 2A	**~ 5,120 ft**	
Along Western Boundary		
Cell 1B	**~ 5,120 ft**	
Cell 2B	**~ 5,120 ft**	

Table A-2. Stage Monitoring Stations.

STATION	STATION DESCRIPTION	DBKEY
G342A_H	G342A STA5 INFLOW STRUCTURE CELL 1A (HEADWATER)	JJ109
G342A_T	G342A STA5 INFLOW STRUCTURE CELL 1A (TAILWATER)	JJ110
G342B_H	G342B STA5 INFLOW STRUCTURE CELL 1A (HEADWATER)	JJ114
G342B_T	G342B STA5 INFLOW STRUCTURE CELL 1A (TAILWATER)	JJ115
G342C_H	G342C STA5 INFLOW STRUCTURE CELL 2A (HEADWATER)	JJ121
G342C_T	G342C STA5 INFLOW STRUCTURE CELL 2A (TAILWATER)	JJ123
G342D_H	G342D STA5 INFLOW STRUCTURE CELL 2A (HEADWATER)	JJ127
G342D_T	G342D STA5 INFLOW STRUCTURE CELL 2A (TAILWATER)	JJ128
G343B_H	G343B STA5 INTERIOR STRUCTURE BETWEEN CELL 1A AND 1B (HEADWATER)	JJ812
G343B_T	G343B STA5 INTERIOR STRUCTURE BETWEEN CELL 1A AND 1B (TAILWATER)	JJ813
G343F_H	G343F STA5 INTERIOR STRUCTURE BETWEEN CELL 2A AND 2B (HEADWATER)	JJ815
G343F_T	G343F STA5 INTERIOR STRUCTURE BETWEEN CELL 2A AND 2B (TAILWATER)	JJ816
G344A_H	G344A STA5 CELL 1B OUTFLOW STRUCTURE (HEADWATER)	JJ133
G344A_T	G344A STA5 CELL 1B OUTFLOW STRUCTURE (TAILWATER)	JJ135
G344B_H	G344B STA5 CELL 1B OUTFLOW (HEADWATER)	JJ138
G344B_T	G344B STA5 CELL 1B OUTFLOW (TAILWATER)	JJ140
G344C_H	G344C STA5 CELL 2B OUTFLOW (HEADWATER)	JJ143
G344C_T	G344C STA5 CELL 2B OUTFLOW (TAILWATER)	JJ145
G344D_H	G344D STA5 CELL 2B OUTFLOW (HEADWATER)	JJ148
G344D_T	G344D STA5 CELL 2B OUTFLOW (TAILWATER)	JJ150
G349A_H	G349A PUMP AT STA5 INFLOW (HEADWATER)	JJ156
G349A_T	G349A PUMP AT STA5 INFLOW (TAILWATER)	JJ157
G350A_H	G350 PUMPS AT STA5 INFLOW (HEADWATER)	JJ160
G350A_T	G350 PUMPS AT STA5 INFLOW (TAILWATER)	JJ161
G349B_H	STORMWATER TREATMENT AREA 5, G349B (HEADWATER)	JJ802
G349B_T	STORMWATER TREATMENT AREA 5, G349B (TAILWATER)	JJ803
G350B_H	G350B STA5 SOUTH SEEPAGE CANAL PUMP STATION (HEADWATER)	JJ810
G350B_T	G350B STA5 SOUTH SEEPAGE CANAL PUMP STATION (TAILWATER)	JJ811
G406_T	G406 STA5 INFLOW STRUCTURE (TAILWATER)	JJ155

Table A-3. Flow Monitoring Stations.

STATION	STATION DESCRIPTION	DBKEY
G342A_C	G342A STA5 INFLOW STRUCTURE CELL 1A	J6406
G342B_C	G342B STA5 INFLOW STRUCTURE CELL 1A	J6398
G342C_C	G342C STA5 INFLOW STRUCTURE CELL 2A	J6407
G342D_C	G342D STA5 INFLOW STRUCTURE CELL 2A	J6405
G344A_C	STORMWATER TREATMENT AREA 5 CELL 1B	J0719
G344B_C	STORMWATER TREATMENT AREA 5 CELL 1B	J0720
G344C_C	STORMWATER TREATMENT AREA 5 CELL 2B	J0721
G344D_C	STORMWATER TREATMENT AREA 5 CELL 2B	J0722
G345_C	CULVERT CONNECTING CELLS 1B AND 2B IN STA-5	P4547
G349A_P	STORMWATER TREATMENT AREA 5, G349A INFLOW PUMP	JJ838
G349B_P	STORMWATER TREATMENT AREA 5, G349B INFLOW PUMP	JA353
G350A_P	STORMWATER TREATMENT AREA 5, G350A INFLOW PUMP	JJ839
G350B_P	G350B STA5 SOUTH SEEPAGE CANAL PUMP STATION	JA352
G406_C	G406 STA5 INFLOW STRUCTURE	JU789
STA5TP_P	TEMP PUMP AT STA5 (BETWEEN G349B AND G344A) FOR CELL 1B	N2481

Note: Station STA5TP_P was renamed to G507_P in WY04 when the temporary pump was installed permanently.

Table A-4. Rainfall Monitoring Sites.

STATION	STATION DESCRIPTION	DBKEY
G343B_R	G343B STA5 INTERIOR STRUCTURE BETWEEN CELL 1A AND 1B	JJ837

Table A-5. Evapotranspiration Stations.

STATION	STATION DESCRIPTION	DBKEY
STA1W	AREAL COMPUTED PARAMETER FOR STA1W PROJECT	KN810

Appendix B – Rainfall Data

Table B-1. Rainfall at G343B_R (in.) for water year 2001.

Day	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	0.00	0.00	0.05	0.09	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.09
2	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.05	0.00	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.09	0.00	0.13	5.10	0.00	0.00	0.01	0.00	0.68	0.00
5	0.00	0.04	0.38	0.02	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.35	0.06	0.02	0.27	1.50	0.00	0.03	0.00	0.00	0.00	0.00
7	0.00	0.01	0.46	0.00	0.71	0.00	0.00	0.01	0.00	0.00	0.00	0.00
8	0.88	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.19	0.00	0.01	0.02	0.00	0.00	0.00	0.00
11	0.00	0.63	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.02	0.10	0.00	1.94	0.00	0.00	0.00	0.00	0.00	0.01	0.00
18	0.00	0.05	0.00	0.00	1.34	0.00	0.00	0.00	0.00	0.00	0.93	0.00
19	0.00	0.12	0.16	0.00	0.26	0.00	0.00	0.00	0.00	0.00	4.07	0.00
20	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.12	0.00	0.01	0.00
21	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00
23	0.00	0.00	0.07	0.00	0.00	0.12	0.00	0.00	0.01	0.00	0.00	0.00
24	0.04	1.40	0.18	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	3.33	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
26	1.01	0.00	0.00	0.51	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.00
27	0.00	0.05	0.00	0.28	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.18	0.03	0.01	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
29	0.00	2.77	0.23	0.01	0.00	0.00	0.00	0.00	0.00		0.78	0.00
30	0.00	0.00	0.16	0.32	0.00	0.00	0.00	0.00	0.00		0.01	0.00
31	0.00		0.01	0.22		0.00		0.00	0.00		0.00	
MAX	1.01	3.33	0.46	0.51	1.94	5.10	0.01	0.10	0.25	0.00	4.07	0.09
MEAN	0.07	0.32	0.09	0.05	0.23	0.26	0.00	0.01	0.02	0.00	0.21	0.00
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUM	2.17	9.68	2.75	1.50	6.97	7.97	0.01	0.17	0.57	0.00	6.52	0.09

Table B-2. Rainfall at G343B_R (in.) for water year 2002.

Day	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	0.08	0.61	0.00	0.84	0.50	0.00	0.00	0.00	0.01	0.00	0.00	0.00
2	0.00	0.01	0.00	0.43	0.00	0.04	0.17	0.00	0.10	0.00	0.00	0.00
3	0.78	1.21	0.00	0.35	1.21	0.00	0.00	0.00	0.00	0.00	0.00	0.03
4	0.05	0.00	0.03	0.24	0.32	0.00	0.19	0.00	0.00	0.00	0.09	0.00
5	0.00	0.71	0.00	0.01	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00
6	0.00	0.76	0.00	0.36	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.83	0.09	0.10	0.21	0.00	0.00	0.23	0.00	0.00	0.50	0.00
8	0.00	0.00	0.00	0.02	0.98	0.04	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.38	0.37	0.00	0.98	0.00	0.00	0.02	0.00	0.85	0.00	0.00
10	0.00	0.00	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.00
11	0.00	0.00	0.08	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.42	0.23	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.02
13	0.00	0.25	0.02	0.00	0.56	0.00	0.00	0.00	0.03	0.00	0.00	0.00
14	0.00	0.00	0.90	0.00	0.56	0.00	0.00	0.00	0.12	0.00	0.00	0.00
15	0.00	0.00	0.24	0.08	0.01	0.00	0.00	0.00	0.47	0.00	0.00	0.00
16	0.00	0.00	0.00	0.44	0.00	0.11	0.00	0.00	0.00	0.56	0.00	0.00
17	0.00	0.51	0.00	0.00	0.00	0.01	0.00	0.01	0.03	0.00	0.00	0.00
18	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.01	0.09	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.10	0.30	0.05	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.02	0.03	0.37	0.00	1.21	0.00	0.00	0.00	0.03	0.00	0.00
23	0.00	0.07	1.86	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00
24	0.00	0.17	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.04	0.04	0.00	0.00	0.36	0.00	0.26	0.00	0.00	0.00	0.00
26	0.00	0.03	0.04	0.00	0.02	0.18	0.00	0.19	0.00	0.00	0.66	0.00
27	0.00	0.15	0.04	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.21	0.00
28	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.01	0.00	1.21	0.00	0.00	0.03	0.00		0.00	0.00
30	0.00	0.04	0.00	0.00	0.00	0.09	0.00	0.00	0.00		0.00	0.00
31	1.60		0.20	0.00		0.00		0.49	0.00		0.00	0.00
MAX	1.60	1.21	1.86	0.84	1.21	1.21	0.19	0.49	0.47	0.99	0.66	0.03
MEAN	0.08	0.21	0.18	0.11	0.29	0.08	0.02	0.04	0.03	0.10	0.05	0.00
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUM	2.51	6.31	5.63	3.29	8.57	2.37	0.53	1.23	0.79	2.74	1.46	0.05

Table B-3. Rainfall at G343B_R (in.) for water year 2003.

Day	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	0.00	0.00	0.72	0.00	0.00	0.32	0.01	0.00	0.39	0.00	0.09	0.00
2	0.00	0.00	0.27	0.00	0.00	0.01	0.00	0.01	0.03	0.00	0.00	0.00
3	0.00	0.00	0.50	0.00	0.95	0.00	0.00	0.00	0.08	0.00	0.04	0.00
4	0.03	0.00	0.02	0.00	0.29	0.20	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.07	0.06	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.06
6	0.00	0.00	0.14	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00
7	0.00	1.82	0.53	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.09	0.36	0.00	0.08	0.00	0.00	0.01	0.00	0.00	0.00	0.00
9	0.00	0.03	0.48	0.01	0.06	0.00	0.00	2.20	0.00	0.00	0.01	0.62
10	0.00	0.04	0.21	0.00	0.01	0.00	0.00	0.31	0.00	0.00	0.01	0.00
11	0.00	1.09	0.30	0.35	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.39	1.13	0.01	0.02	0.21	0.00	0.15	0.00	0.00	0.00	0.00
13	0.01	0.00	0.00	0.69	0.00	0.02	0.07	0.25	0.00	0.00	0.00	0.00
14	0.03	1.52	0.00	0.72	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.72	0.02	0.00	0.01	0.19	0.00	0.00	0.01	0.00	0.00	0.36
16	0.41	0.21	0.21	0.25	0.00	0.00	1.59	0.00	0.00	0.10	0.09	0.00
17	0.00	0.09	0.02	0.17	0.38	0.00	0.16	0.00	0.00	0.39	0.84	0.00
18	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	0.93	0.09	0.04	0.08	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.37	0.00	0.01	0.03	0.00	0.00	0.35	0.00	0.01	0.00	0.00
21	0.00	0.02	1.17	0.04	0.00	0.00	0.07	0.00	0.00	0.00	0.01	0.00
22	0.00	0.96	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.47	0.01	0.00
23	0.00	1.40	0.00	0.00	0.00	2.88	0.00	0.00	0.00	0.01	0.42	0.00
24	0.00	0.36	0.29	0.00	0.00	1.55	0.00	0.00	0.00	0.00	0.10	0.00
25	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.02	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.23
27	0.00	0.04	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
28	0.00	0.05	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.42
29	0.00	0.47	0.00	0.52	0.00	0.00	0.00	0.00	0.00		0.00	0.00
30	1.63	0.41	0.00	0.53	0.00	0.00	0.00	0.00	0.00		0.00	0.45
31	1.86		0.00	1.02		0.00		0.00	0.00		0.00	
MAX	1.86	1.82	1.17	1.02	0.95	2.88	1.59	2.20	0.39	0.47	1.00	1.23
MEAN	0.16	0.36	0.21	0.15	0.09	0.18	0.07	0.11	0.02	0.03	0.09	0.10
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUM	4.90	10.68	6.48	4.73	2.70	5.46	2.13	3.28	0.51	0.98	2.64	3.14

Appendix C – Evapotranspiration Data

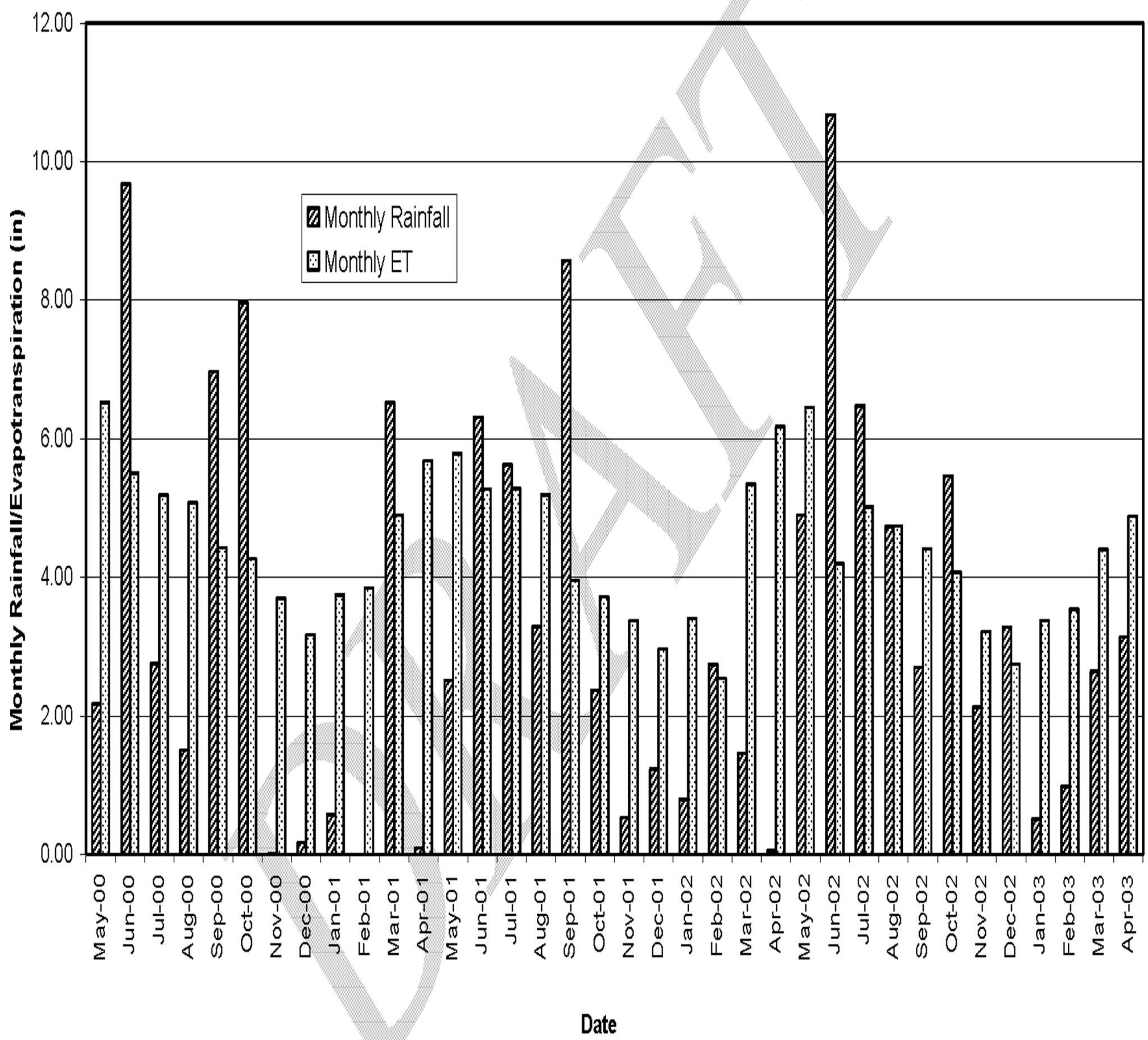

Figure C-1. STA-5 monthly rainfall and evapotranspiration (in.).

Table C-1. Evapotranspiration at STA-5 (in.) for water year 2001.

Day	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	0.23	0.22	0.10	0.18	0.21	0.15	0.16	0.12	0.14	0.15	0.16	0.23
2	0.21	0.24	0.18	0.08	0.21	0.07	0.14	0.09	0.13	0.13	0.14	0.24
3	0.11	0.23	0.13	0.13	0.15	0.03	0.15	0.11	0.13	0.10	0.15	0.24
4	0.22	0.18	0.10	0.21	0.17	0.06	0.13	0.11	0.15	0.12	0.14	0.20
5	0.24	0.24	0.21	0.13	0.12	0.15	0.15	0.09	0.13	0.09	0.18	0.18
6	0.21	0.21	0.24	0.13	0.11	0.13	0.14	0.10	0.14	0.15	0.21	0.17
7	0.21	0.19	0.21	0.18	0.10	0.17	0.15	0.12	0.14	0.15	0.21	0.16
8	0.13	0.08	0.13	0.21	0.14	0.15	0.15	0.13	0.13	0.15	0.20	0.21
9	0.23	0.18	0.19	0.18	0.12	0.07	0.14	0.11	0.14	0.13	0.20	0.21
10	0.24	0.21	0.17	0.22	0.16	0.15	0.10	0.06	0.14	0.14	0.08	0.21
11	0.23	0.12	0.17	0.20	0.18	0.15	0.15	0.09	0.12	0.10	0.15	0.18
12	0.24	0.23	0.15	0.15	0.19	0.16	0.14	0.10	0.10	0.15	0.17	0.19
13	0.20	0.18	0.18	0.15	0.19	0.18	0.14	0.10	0.13	0.14	0.18	0.18
14	0.24	0.20	0.22	0.18	0.20	0.14	0.10	0.11	0.10	0.15	0.14	0.23
15	0.21	0.21	0.21	0.19	0.14	0.16	0.15	0.10	0.11	0.15	0.13	0.18
16	0.23	0.25	0.23	0.21	0.07	0.17	0.15	0.09	0.14	0.14	0.13	0.21
17	0.15	0.23	0.17	0.18	0.05	0.18	0.14	0.10	0.12	0.13	0.11	0.23
18	0.22	0.21	0.18	0.15	0.14	0.16	0.12	0.11	0.11	0.13	0.09	0.23
19	0.21	0.15	0.19	0.17	0.16	0.16	0.13	0.11	0.14	0.14	0.02	0.19
20	0.25	0.23	0.23	0.15	0.16	0.14	0.04	0.14	0.04	0.12	0.21	0.19
21	0.25	0.15	0.20	0.14	0.15	0.10	0.14	0.11	0.15	0.15	0.15	0.18
22	0.21	0.19	0.16	0.15	0.14	0.15	0.15	0.13	0.01	0.15	0.21	0.20
23	0.19	0.22	0.10	0.16	0.16	0.12	0.12	0.09	0.13	0.13	0.22	0.18
24	0.20	0.16	0.13	0.18	0.18	0.12	0.10	0.04	0.15	0.16	0.21	0.21
25	0.23	0.07	0.13	0.18	0.20	0.18	0.04	0.08	0.15	0.14	0.21	0.20
26	0.23	0.18	0.10	0.15	0.16	0.16	0.07	0.09	0.13	0.15	0.19	0.17
27	0.17	0.09	0.15	0.16	0.15	0.15	0.10	0.10	0.10	0.16	0.16	0.21
28	0.22	0.15	0.16	0.16	0.09	0.15	0.13	0.09	0.13	0.15	0.16	0.16
29	0.24	0.12	0.17	0.16	0.10	0.14	0.07	0.08	0.14		0.15	0.05
30	0.19	0.18	0.10	0.13	0.14	0.13	0.14	0.13	0.07		0.07	0.07
31	0.21		0.22	0.10		0.13		0.14	0.15		0.18	
MAX	0.25	0.25	0.24	0.22	0.21	0.18	0.16	0.14	0.15	0.16	0.22	0.24
MEAN	0.21	0.18	0.17	0.16	0.15	0.14	0.12	0.10	0.12	0.14	0.16	0.19
MIN	0.11	0.07	0.10	0.08	0.05	0.03	0.04	0.04	0.01	0.09	0.02	0.05
SUM	6.53	5.50	5.19	5.08	4.43	4.27	3.69	3.17	3.75	3.85	4.90	5.68

Table C-2. Evapotranspiration at STA-5 (in.) for water year 2002.

Day	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	0.15	0.18	0.21	0.07	0.15	0.16	0.12	0.09	0.13	0.10	0.10	0.14
2	0.20	0.17	0.23	0.05	0.15	0.16	0.10	0.10	0.02	0.10	0.18	0.15
3	0.15	0.14	0.21	0.07	0.18	0.11	0.12	0.12	0.06	0.08	0.13	0.15
4	0.16	0.18	0.10	0.17	0.11	0.17	0.04	0.10	0.15	0.07	0.07	0.23
5	0.24	0.15	0.25	0.18	0.09	0.14	0.04	0.10	0.08	0.06	0.16	0.21
6	0.23	0.14	0.19	0.19	0.12	0.18	0.16	0.10	0.07	0.06	0.07	0.20
7	0.21	0.09	0.18	0.17	0.15	0.15	0.10	0.10	0.09	0.05	0.07	0.18
8	0.18	0.23	0.21	0.17	0.11	0.15	0.11	0.10	0.15	0.08	0.19	0.20
9	0.23	0.21	0.10	0.17	0.07	0.10	0.14	0.08	0.14	0.09	0.20	0.23
10	0.19	0.24	0.16	0.14	0.09	0.15	0.14	0.11	0.15	0.10	0.22	0.21
11	0.24	0.24	0.16	0.11	0.13	0.18	0.13	0.11	0.13	0.07	0.16	0.16
12	0.24	0.24	0.15	0.20	0.08	0.16	0.07	0.12	0.12	0.10	0.14	0.21
13	0.24	0.20	0.16	0.15	0.08	0.17	0.14	0.12	0.10	0.11	0.18	0.20
14	0.23	0.17	0.12	0.23	0.12	0.10	0.12	0.07	0.04	0.07	0.18	0.10
15	0.22	0.18	0.15	0.21	0.16	0.11	0.04	0.10	0.04	0.07	0.19	0.11
16	0.23	0.22	0.18	0.23	0.18	0.07	0.11	0.11	0.09	0.01	0.18	0.14
17	0.24	0.18	0.15	0.17	0.18	0.13	0.14	0.10	0.11	0.14	0.22	0.17
18	0.24	0.18	0.20	0.21	0.19	0.09	0.11	0.10	0.10	0.13	0.17	0.24
19	0.24	0.21	0.18	0.18	0.18	0.11	0.10	0.08	0.13	0.10	0.20	0.19
20	0.18	0.13	0.19	0.17	0.16	0.07	0.12	0.13	0.15	0.10	0.20	0.21
21	0.18	0.15	0.13	0.12	0.19	0.06	0.13	0.13	0.12	0.09	0.18	0.24
22	0.14	0.13	0.13	0.16	0.15	0.05	0.11	0.09	0.13	0.09	0.15	0.24
23	0.07	0.13	0.02	0.23	0.14	0.14	0.13	0.09	0.14	0.03	0.18	0.21
24	0.21	0.20	0.22	0.21	0.18	0.11	0.12	0.10	0.13	0.15	0.22	0.23
25	0.10	0.17	0.23	0.23	0.18	0.09	0.13	0.07	0.13	0.12	0.21	0.23
26	0.12	0.18	0.20	0.22	0.11	0.07	0.13	0.10	0.13	0.15	0.15	0.24
27	0.11	0.08	0.13	0.11	0.04	0.15	0.10	0.07	0.10	0.14	0.21	0.24
28	0.10	0.13	0.21	0.18	0.04	0.13	0.14	0.13	0.12	0.10	0.21	0.23
29	0.15	0.23	0.14	0.15	0.05	0.08	0.13	0.07	0.15		0.19	0.23
30	0.18	0.21	0.23	0.18	0.17	0.07	0.14	0.07	0.10		0.21	0.24
31	0.18		0.18	0.18		0.10		0.02	0.11		0.21	0.25
MAX	0.24	0.24	0.25	0.23	0.19	0.18	0.16	0.13	0.15	0.15	0.22	0.25
MEAN	0.19	0.18	0.17	0.17	0.13	0.12	0.11	0.10	0.11	0.09	0.17	0.20
MIN	0.07	0.08	0.02	0.05	0.04	0.05	0.04	0.02	0.02	0.01	0.07	0.10
SUM	5.78	5.28	5.28	5.19	3.95	3.72	3.38	2.97	3.41	2.54	5.34	6.17

Table C-3. Evapotranspiration at STA-5 (in.) for water year 2003.

Day	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	0.25	0.23	0.04	0.24	0.13	0.13	0.09	0.05	0.06	0.14	0.13	0.18
2	0.22	0.23	0.17	0.18	0.18	0.16	0.12	0.07	0.08	0.15	0.14	0.14
3	0.24	0.20	0.17	0.15	0.15	0.15	0.11	0.10	0.04	0.15	0.13	0.17
4	0.24	0.16	0.21	0.15	0.18	0.13	0.13	0.07	0.12	0.12	0.12	0.18
5	0.23	0.15	0.16	0.13	0.10	0.18	0.10	0.10	0.11	0.04	0.13	0.13
6	0.25	0.21	0.15	0.20	0.15	0.17	0.10	0.03	0.12	0.11	0.14	0.21
7	0.20	0.19	0.14	0.07	0.15	0.19	0.15	0.07	0.12	0.12	0.14	0.18
8	0.24	0.08	0.09	0.22	0.19	0.16	0.10	0.07	0.13	0.06	0.13	0.18
9	0.25	0.19	0.09	0.15	0.14	0.13	0.13	0.02	0.13	0.13	0.15	0.10
10	0.22	0.22	0.12	0.16	0.19	0.16	0.12	0.07	0.10	0.13	0.10	0.16
11	0.22	0.12	0.12	0.07	0.06	0.14	0.14	0.08	0.06	0.15	0.13	0.12
12	0.24	0.11	0.17	0.16	0.07	0.10	0.12	0.07	0.11	0.16	0.11	0.21
13	0.22	0.12	0.20	0.15	0.14	0.12	0.10	0.05	0.07	0.16	0.14	0.22
14	0.24	0.15	0.23	0.13	0.18	0.11	0.10	0.11	0.07	0.13	0.15	0.17
15	0.14	0.04	0.18	0.21	0.15	0.13	0.10	0.07	0.14	0.13	0.13	0.17
16	0.12	0.14	0.23	0.16	0.16	0.14	0.03	0.14	0.12	0.14	0.12	0.18
17	0.21	0.18	0.15	0.21	0.15	0.14	0.06	0.13	0.10	0.07	0.16	0.17
18	0.22	0.15	0.12	0.17	0.17	0.16	0.15	0.07	0.09	0.17	0.16	0.18
19	0.05	0.16	0.22	0.13	0.18	0.14	0.10	0.08	0.15	0.12	0.15	0.14
20	0.22	0.13	0.17	0.10	0.15	0.10	0.09	0.04	0.14	0.11	0.18	0.20
21	0.18	0.07	0.16	0.13	0.16	0.12	0.07	0.14	0.14	0.13	0.16	0.19
22	0.23	0.07	0.16	0.13	0.18	0.15	0.09	0.10	0.13	0.14	0.13	0.21
23	0.21	0.09	0.16	0.13	0.11	0.10	0.15	0.12	0.10	0.16	0.07	0.21
24	0.22	0.12	0.17	0.16	0.10	0.14	0.13	0.10	0.11	0.13	0.19	0.19
25	0.19	0.05	0.19	0.22	0.13	0.10	0.10	0.09	0.13	0.11	0.19	0.16
26	0.17	0.17	0.17	0.21	0.15	0.11	0.09	0.13	0.12	0.10	0.12	0.01
27	0.18	0.11	0.20	0.15	0.13	0.10	0.10	0.11	0.13	0.13	0.10	0.17
28	0.24	0.10	0.16	0.12	0.14	0.08	0.10	0.12	0.12	0.15	0.18	0.13
29	0.26	0.15	0.18	0.10	0.15	0.10	0.14	0.14	0.13		0.21	0.21
30	0.18	0.10	0.13	0.15	0.20	0.11	0.13	0.12	0.10		0.12	0.04
31	0.17		0.21	0.13		0.13		0.11	0.14		0.22	
MAX	0.26	0.23	0.23	0.24	0.20	0.19	0.15	0.14	0.15	0.17	0.22	0.22
MEAN	0.21	0.14	0.16	0.15	0.15	0.13	0.11	0.09	0.11	0.13	0.14	0.16
MIN	0.05	0.04	0.04	0.07	0.06	0.08	0.03	0.02	0.04	0.04	0.07	0.01
SUM	6.45	4.19	5.02	4.74	4.41	4.07	3.22	2.74	3.38	3.54	4.40	4.88

Appendix D – Soil Moisture Equations

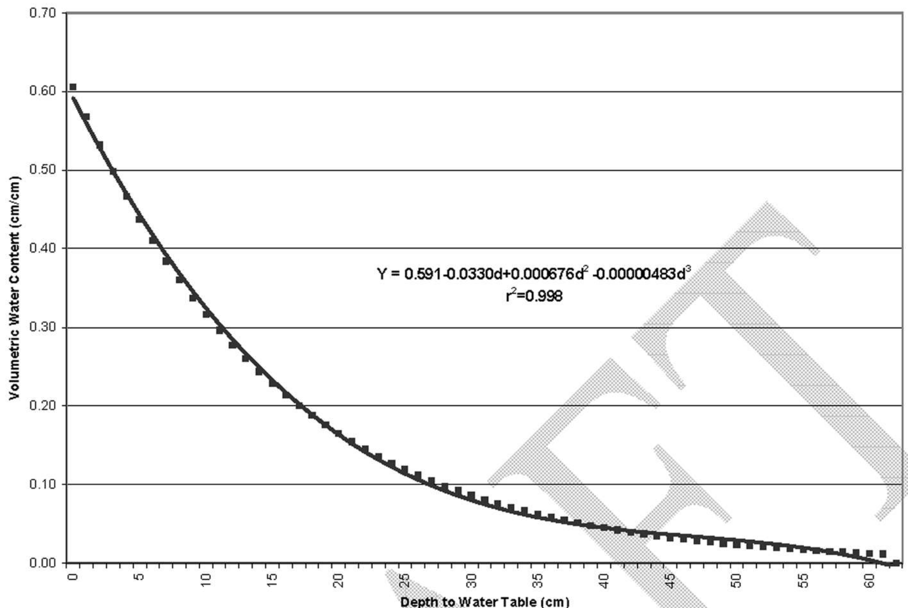

Figure D-1. Falling water table (drying front) equation.

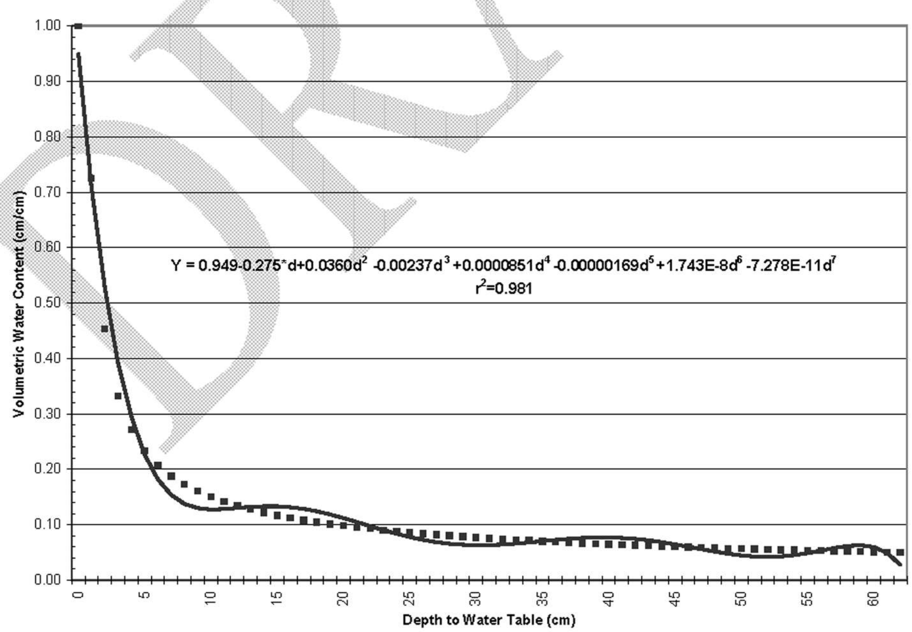

Figure D-2. Rising water table (wetting front) equation.

Appendix E – Analysis of Seepage and Water Budget Error

Introduction

The inflow, outflow, rainfall, potential evaporation and change in storage terms in the water budget equation, equation E-1 below, are either recorded or calculated using equations that are based on observed values and independently calibrated parameters and coefficients. As such, errors in their daily values should be minimal in the long term (i.e., random error will be negated and systematic error will be minimal because of the scrutiny that these values receive through data processing and validation). The errors in these values that do occur are captured in the error term in the equation. It is not unusual to lump the remaining parameter, seepage, in with the error term in water budget calculations because seepage is not as accurately quantified as the other terms in the equation. In other words, there is significantly more uncertainty associated with seepage estimates than there is for the other calculated values in the equation (other than the error term, which is an unknown). Ideally, an estimate of seepage would reduce water budget error without eliminating the inherent error in the other parameters or terms.

Huebner (2003) used correlation analysis to examine the relationship between the terms in the water budget equation for STA 6 and the error term. This was done to identify which of the terms might be the source of the error in the water budget. The results were inconclusive. Since that time, additional stream gauging has been undertaken at all of the STAs and improved flow values have been placed in DBHYDRO. This should have resulted in a reduction in overall error in the water budget equation. However, error in the annual water budget remained relatively large, especially if seepage was not estimated and included in the water budget.

Changes in flow, stage, storage, rainfall, evapotranspiration and seepage are instantaneous, transient phenomena. Likewise, limiting the number of significant digits in a calculation introduces another source of error. This appendix discusses the effects on water budget error of time step length, seepage coefficient, data precision and round-off, data smoothing, rainfall, basin geometry and storage. The discussion is followed by conclusions and recommendations.

In an effort to explore and isolate the effect of the time step on error, 15-minute data were used and analyzed for relationships between error and other quantities that are part of the water budget. In previous budget reports (Huebner 2002), daily water budget quantities were aggregated into monthly and annual values but still showed systematic errors. The use of 15-minute data was intended to capture relatively rapid changes in flow, stage and storage and to examine those as sources of water budget error.

The data span several days in July 2001, beginning at midnight on the 18th and ending at midnight on August 1st. Quantities represented by the data include flow through the four inflow structures (G342A, B, C and D) and the four outflow structures (G344A, B, C and D); headwater and tailwater data for the G342A, B, C and D, G343A, B, C, D, E, F, G and H, G344A, B, C and D, G349A and B and G350A and B structures; rainfall data from G343B_R; and potential ET, calculated from measurements at STA-1W.

A water budget describes relationships among the various hydraulic/hydrologic parameters of STA-5:

$$\Delta S = I - O + R - ET - G - \varepsilon \qquad \text{(E-1)}$$

where I and O are inflow and outflow through structures, R is rainfall, ET is potential evapotranspiration, G is seepage from STA-5 or the part of STA-5 under consideration (e.g., Cell 1A) and ε is the error term.

In the daily budget, it appears that there is some relationship between error and inflow when examining a graph of these quantities versus time (**Figure E-1**). However, there seems to be almost no linear correlation between these two parameters (**Figure E-2**). Examining the data at 15-minute intervals, rather than at daily intervals shows a much stronger relationship between the error and inflow (described below).

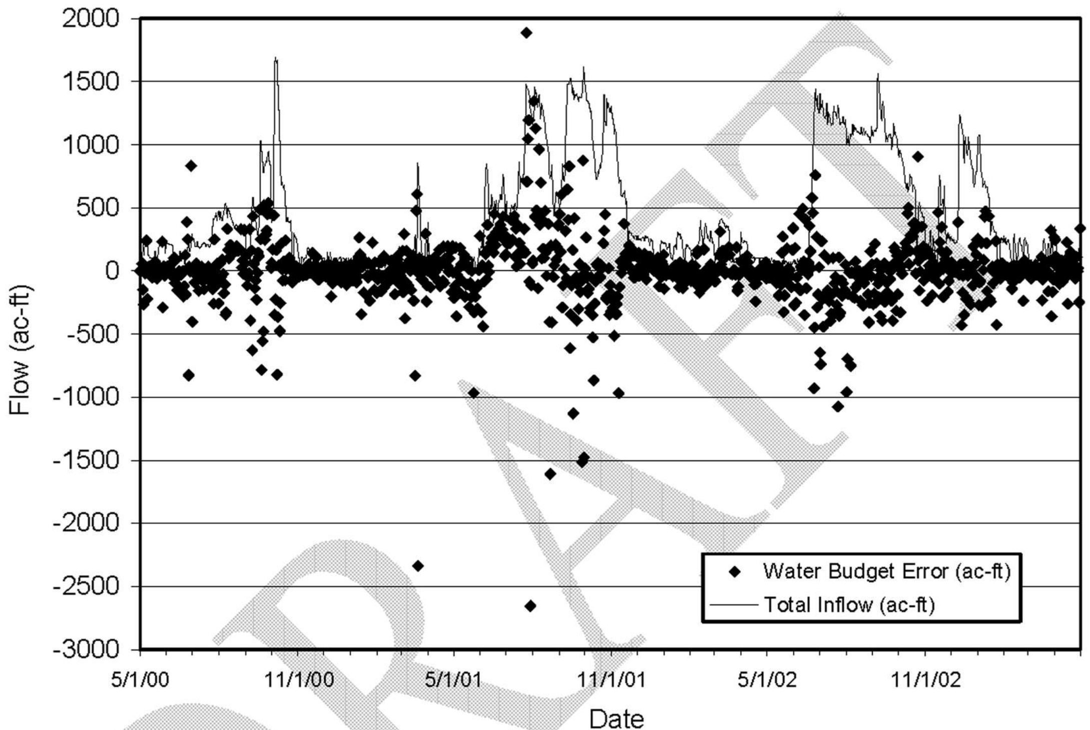

Figure E-1. Daily water budget error and total inflow for STA5.

Background

Uram and Maristany (1997) estimated seepage from STA-5 using the SEEP2D finite element model and data that was available before the construction of STA-5 (geologic information and design parameters). They report a seepage coefficient of up to about 7.5 cubic feet per day, per foot of levee, per foot of head difference, or about 0.46 cfs/mi/ft.

Huebner (2001) discusses the results of several other studies in which seepage coefficients were estimated for other levees in South Florida not associated with STA-5. The seepage coefficients reported in those studies are typically between 0 and 10 cfs/mi/ft (cubic feet per second, per mile of levee, per foot of head difference).

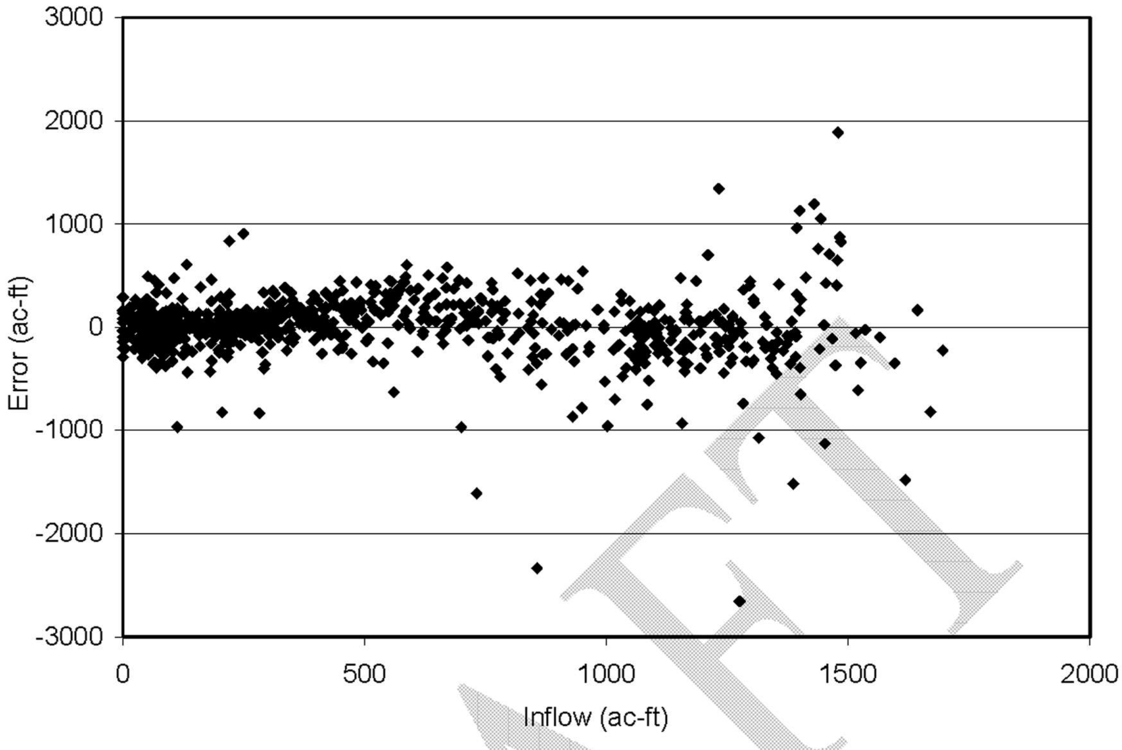

Figure E-2. Daily water budget error versus inflow for STA-5.

Data Description—Apparent Lag in Storage with Respect to Flow

A plot of the storage in Cell 1 along with all the other water budget parameters at first seems to indicate that there is a lag in storage with respect to the other parameters (**Figure E-3**). For example, on July 23rd, the peak in storage follows a peak in rainfall and occurs during a peak in outflow. Examination of separate plots of storage curves for Cell 1A and Cell 1B show that there is little or no lag at the 15-minute level. For example, the increase in the steepness of the inflow curve corresponds directly with the increase in the steepness of the Cell 1A storage curve.

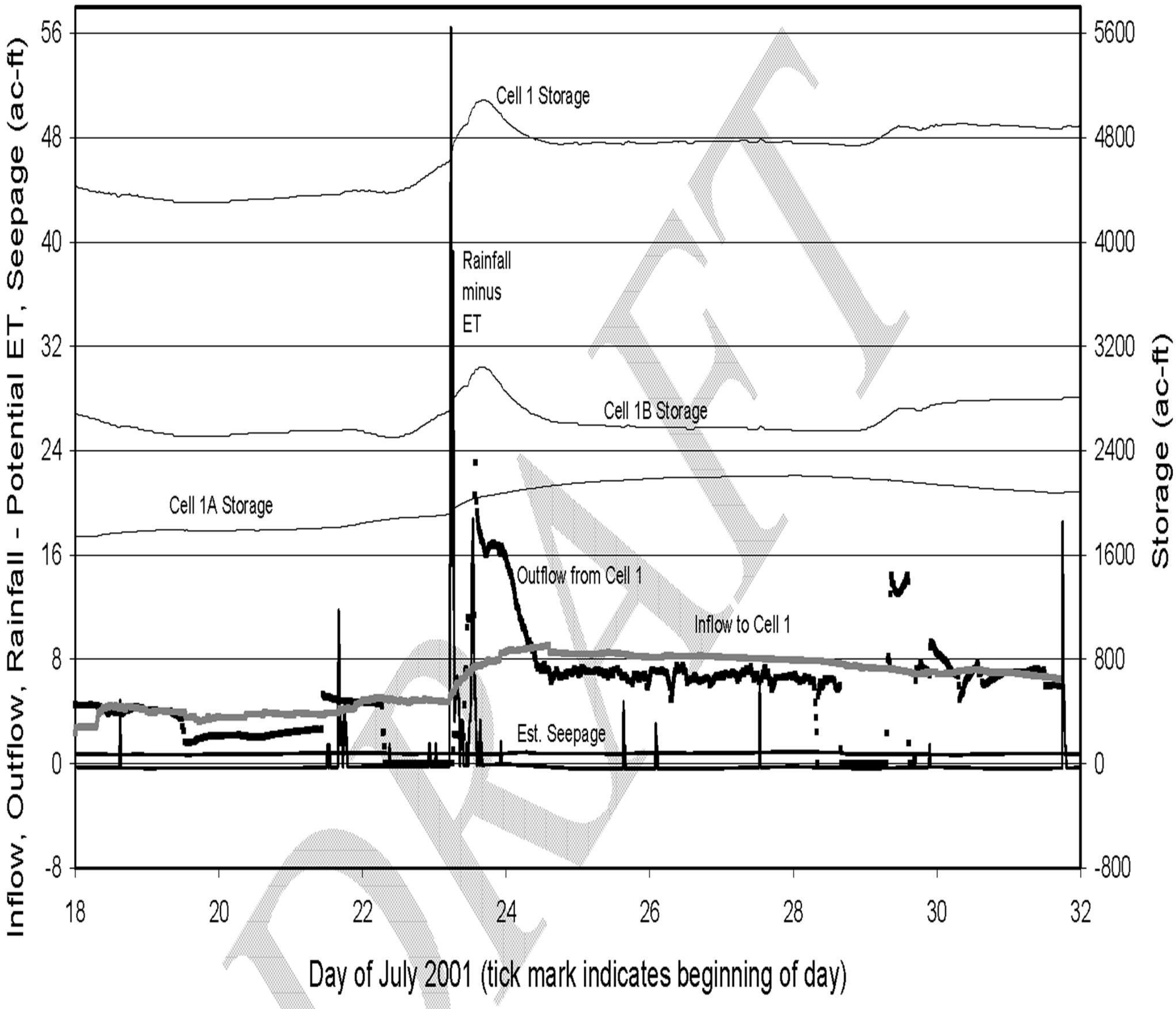

Figure E-3. Water budget terms for Cell 1.

Seepage Coefficient Estimation for Cell 1A

Seepage for Cell 1A was estimated by

$$G = K\,\Sigma_{i=1,2,3}(L\Delta H)_i \qquad \text{(E-2)}$$

Where K is the seepage coefficient, L is the length of levee i (the west perimeter levee, the north perimeter levee, or the east-west interior levee) and ΔH is the difference in head across the levee. $\Delta H_i > 0$ indicates that the water surface within Cell 1A is higher than that found on the other side of the levee. Error (ε) is calculated by rearrangement of the water budget:

$$\varepsilon = I - O + R - ET - G - \Delta S \qquad \text{(E-3)}$$

Three distinct measures of ΔS were used to determine the best value for K. In the first two cases, the storage was calculated from the 15-minute mean stages for the stage stations within Cell 1A. In the first case, these storage values were used directly in calculating change in storage. In the second case, the mean storage values were smoothed in an attempt to add more precision (though not necessarily more accuracy[*]) to the data by artificial means (details below, at "Smoothing"). In the third and final case, instantaneous values of stage were used to calculate the instantaneous storage. Change in storage was calculated using forward differencing (future value minus current value).

In order to determine an estimated value for K, the error for each time step was squared, then the square errors for each time step in the data set were added together (this sum is called the sum of square errors, SSE) and the SSE was noted, along with an estimated value for K. This process was repeated for several values of K. A plot of SSE versus K for each pair of values is presented in **Figure E-4**. As would be expected, the smoothed values of storage produced an SSE lower than the "noisy" values. While one may expect the instantaneous values of storage to produce less error than the mean values (since calculating ΔS from instantaneous values of stage is more correct, conceptually), this was not the case, perhaps because mean values are smoother than instantaneous values to begin with. More importantly, however, is the fact that the e versus K curves are shaped alike for all three cases and have the minimum at the same value of K, 4.3. We note that this value is different from the value of 2.2 obtained for the entire STA-5, with daily data. This difference suggests that the seepage coefficient is spatially variable (e.g., each cell could have a unique seepage coefficient). Increasing the time step to 30 minutes, one hour, two hours, four hours and eight hours does not change the seepage coefficient.

[*] Flow ratings for the G342 structures "were calibrated from 32 stream flow measurements collected using an Acoustic Doppler Current Profiler (ADCP) [measured at the inlet, under pipe flow conditions]... The overall mean absolute error [between measured and calculated flows]... is around 5%, with the maximum error for a single measurement around 11%." Flow ratings for the G344 structures "were calibrated from 43 stream flow measurements collected using an Acoustic Doppler Flow Meter (ADFM) [measured at the outlet, under pipe flow conditions—data was averaged for 15 to 20 minutes].... The overall mean absolute error [is about] 4% and the largest error for a single measurement is [about] 10%" (Nair 2003).

Choi and Harvey (2000) used a water mass balance and a solute mass balance in order to estimate groundwater discharge and recharge for ENR. They report, "uncertainty in estimated [net ground water flux for ENR] increases with higher surface water inflow rate and higher change in surface-water storage" (p. 507). They estimate the uncertainty of surface water inflow and outflow, recycled seepage inflow and outflow and levee seepage at 10%, precipitation at 8.5%, evapotranspiration at 20% and storage volume and change in storage volume at 15% (p. 505, Table 2). "All components of input and output... were averaged over two-week periods in order to consider both the hydrologic residence time of approximately 20 days in surface water (Guardo 1999) and time interval of chemical monitoring by [SFWMD] (14 days)" (pp. 502-503).

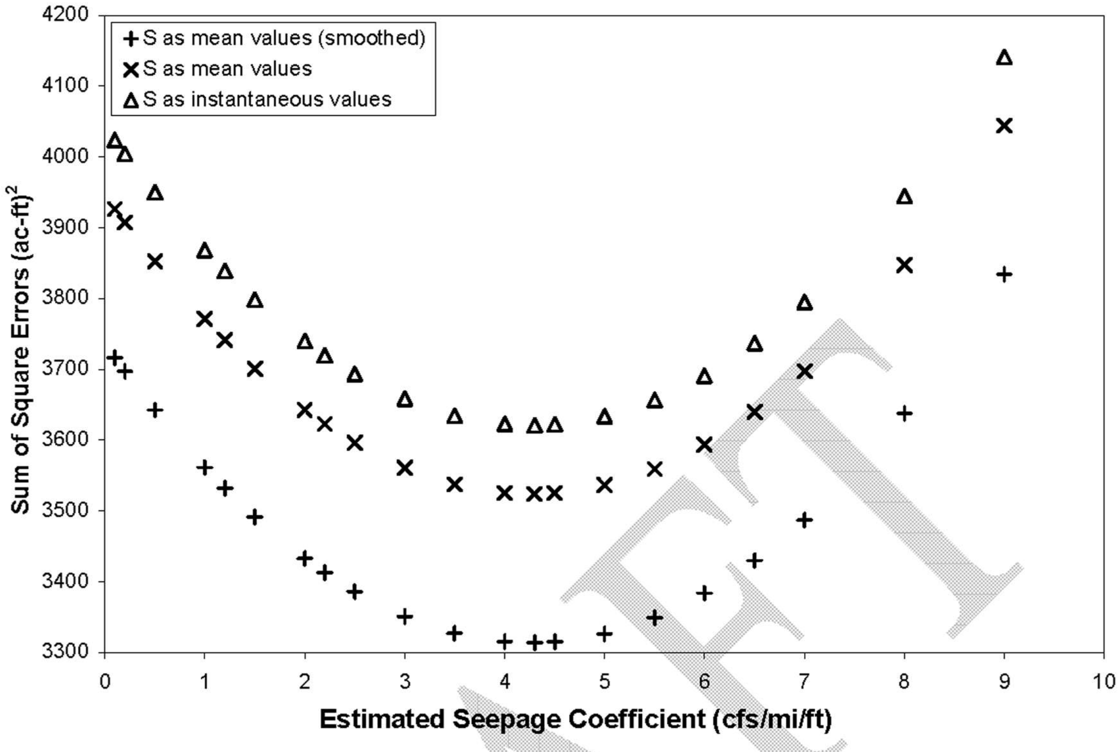

Figure E-4. Sum of square errors (SSE) versus estimated seepage coefficient.

Precision of Stage Records and Storage Calculation

If the stage data are used directly to compute storage and change in storage, it becomes apparent that the stage data are quite noisy. In fact, the noise associated with ΔS is as large as most of the values of ΔS. Since the seepage plus error (G + e) group is directly related to ΔS through the water budget equation, the noisiness of ΔS affects G + e as well (**Figures E-5 and E-6**). One way to eliminate the noise is to smooth the values of S and use the smoothed values of S to calculate ΔS.

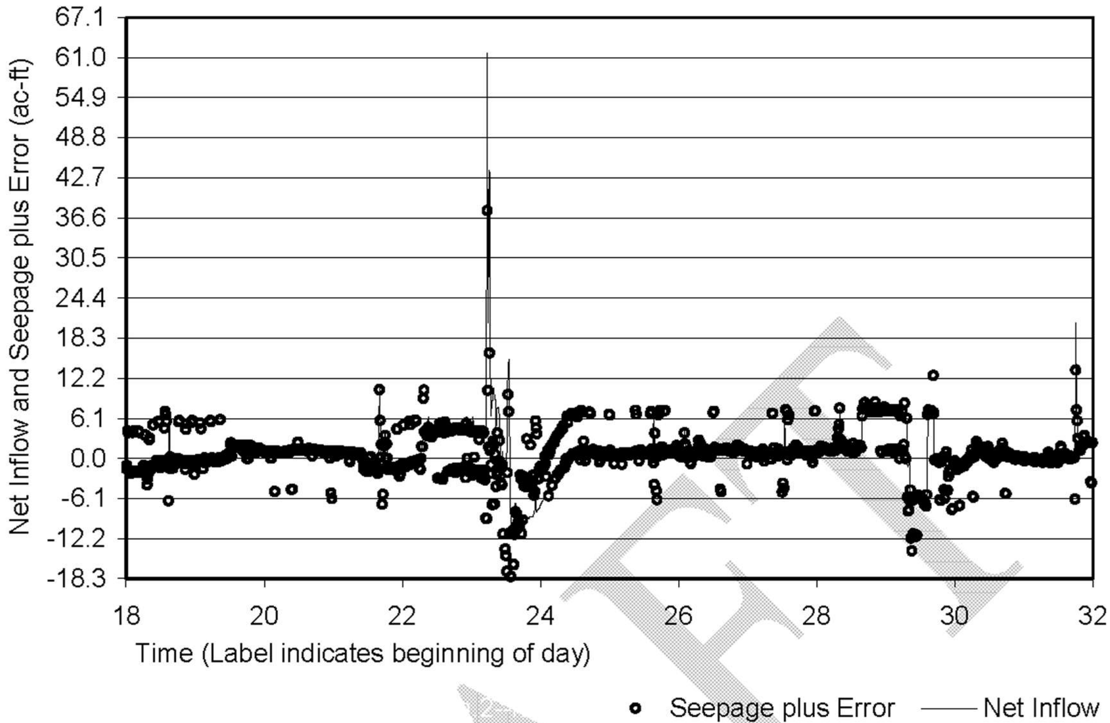

Figure E-5. Net inflow and seepage plus error for Cell 1.

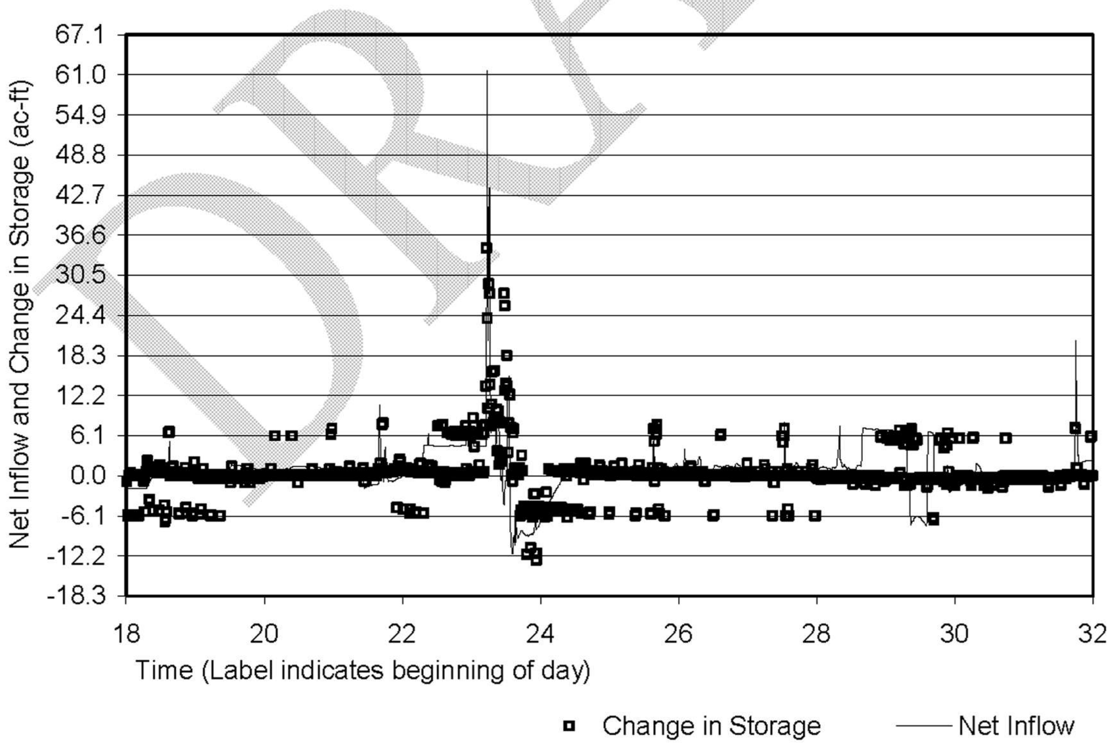

Figure E-6. Net inflow and change in storage for Cell 1.

Effects of Record Precision

Two types of stage-measuring recorders are used at STA-5: CR10s and RACUs (Remote Access Control Unit). A CR10 takes a reading every 5 minutes. It averages the data over a 15-minute period and records these averages. RACU data is monitored continuously, but only changes in state are recorded. Each instrument gathers/records data at 0.01 ft increments. **Table E-1** shows a list of stations and the respective instrumentation (Wilkins).

Table E-1. Instrumentation of select stations at STA-5.

Site(s)	RACU	CR10
G342A, B, C and D	✓	✓
G343B, C, F and G		✓
G344A, B, C and D	✓	✓
G349A	✓	
G449B		✓
G350A	✓	
G350B		✓

A rain gage is located at G343B. It is a tipping bucket rain gage that tips each time the bucket fills with 0.01 in. of water. Note that a single tip of the bucket does not indicate the rainfall intensity, as the time required to fill the bucket is unknown. Additionally, beyond a rainfall intensity of about three inches per hour (0.75 in. / 15-min.) the rain gage is less and less accurate due to splashing, i.e., as the drops of rain fall into the bucket, they may come with such force so as to cause some water to be lost from the bucket, or they may contact and bounce off the sides of the bucket as it tips (Wilkins).

The precision of the measured parameters has a marked effect on the noise associated with the ΔS and the $G + \varepsilon$ group. The following discussion elaborates on some of the effects of the limitations on precision. **Table E-2** gives the precision (in the familiar units of the data source) of each parameter that contributes to the water budget equation. For example, when the records give the value 16.67 for a stage reading that has a precision of two decimals, it indicates that the actual value is somewhere between 16.665 and 16.675, assuming that the record is as accurate as it is precise (which is unlikely, but at least the precision is an upper bound on accuracy for single measurements, i.e., a single measurement cannot be more accurate than it is precise).

In **Table E-2**, the precision values have been converted into precisions in ac-ft. There are four columns; which column applies depends upon the situation. For example, if the water budget is being applied to the entire STA-5, the column at the extreme right would apply, thus the precision of change in stage yields a precision in ΔS for STA-5 of 41.18 ac-ft.

Table E-2. Effect of precision of measured parameters on water volumes (rounded to 4 decimals).

Parameter	Units	Typical Value	Number of Decimals	Precision bound in Given units	Cell 1A or 2A (839 acres) (ac-ft)	Cell 1B or 2B (1220 acres) (ac-ft)	Cell 1 or Cell 2 (2059 acres) (ac-ft)	STA-5 (4118 acres) (ac-ft)
Stage	ft	16.67	2	± 0.005	4.1950	6.1000	10.2950	20.5900
Change in Stage	ft	0.00	2	± 0.01	8.3900	12.2000	20.5900	41.1800
Rainfall	in	0.01	2	± 0.005	0.3496	0.5083	0.8579	1.7158
Potential ET*	mm	3.748	3	± 0.005	0.0138	0.0200	0.0338	0.0676
Inflow	cfs	114.822	3	± 0.0005	<0.0001	<0.0001	<0.0001	<0.0001
Outflow	cfs	219.201	3	± 0.0005	<0.0001	<0.0001	<0.0001	<0.0001

* Although the records have three decimal places, the precision for potential ET is at best ± 0.005, since the coefficient used in the formula that estimates potential ET has three significant figures.

Round-off Errors for Storage

The spatial mean stage in Cell 1A is estimated by the arithmetic mean of the four data points available for Cell 1A, for each 15-minute increment. The precision of the stage data is ±0.005 ft. These precisions in stage yield precisions in storage of ±4.195 ac-ft for Cells 1A and 2A and ±6.1 ac-ft for Cells 2A and 2B. Since change in storage is the difference between two storage values, the precision for the change in storage is twice that of a single storage value, or ±8.39 and ±12.2 ac-ft.

Drawdown Effect in Cell 1B

When the gates of G344A and/or G344B are opened, the headwaters of the structures experience significant—and sudden—drops compared with water levels downstream of the G343 structures (**Figure E-7**). The headwater gages of G344A and G344B may be located too close to the structures to be used for calculating the storage in Cell 1B, as long as the gates are open. Note how sudden changes in outflow are reflected by sudden changes in stage at G344A and G344B, particularly around noon on July 23rd and in the afternoon of the 28th (**Figure E-7**). Using G344A and G344B stage gage data in order to calculate storage in Cell 1B would be the cause of a great deal of error in the storage calculation.

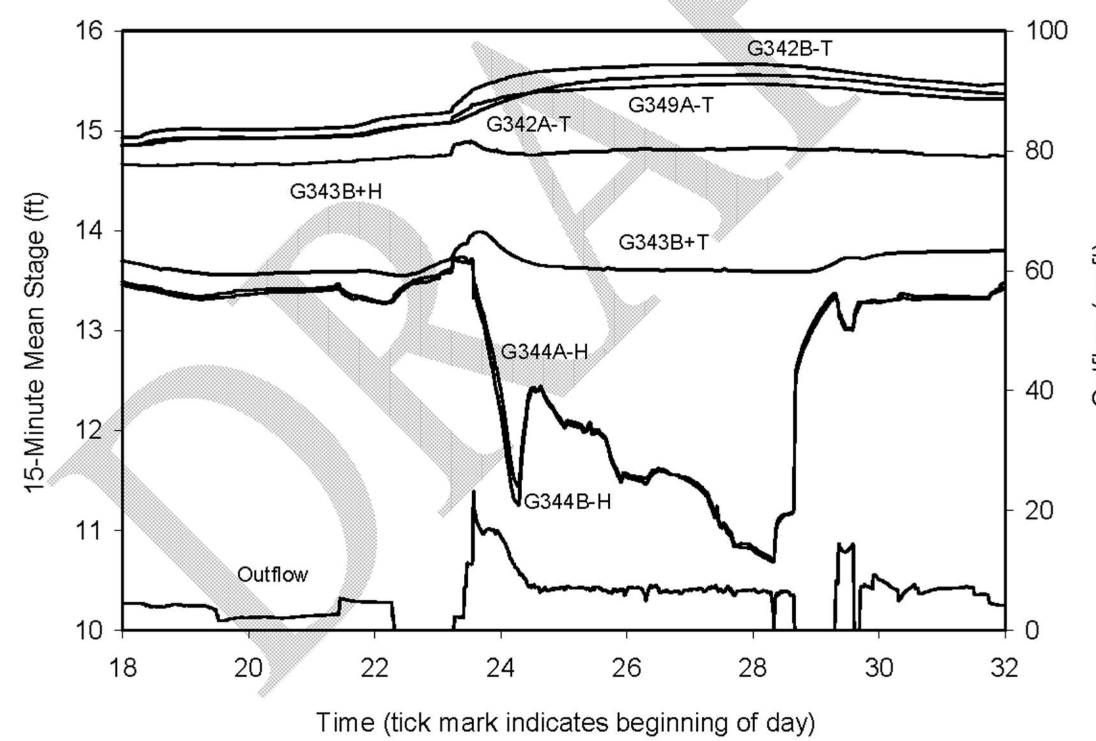

Figure E-7. Data for stage gages in Cell 1A and Cell 1B, with Outflow.

Smoothing (ΔS, Cell 1A)

In order to better comprehend the nature of the error term in relation to the other parameters of the water budget, the ΔS term was computed from smoothed values of S by forward differencing (future – current). The smoothed values of S were obtained from best-fit polynomials which covered sub-intervals of the total time span of the data set (**Figure E-8**). Locations of interval endpoints were placed near the times of rapid changes in stage (which usually correspond with rainfall events).

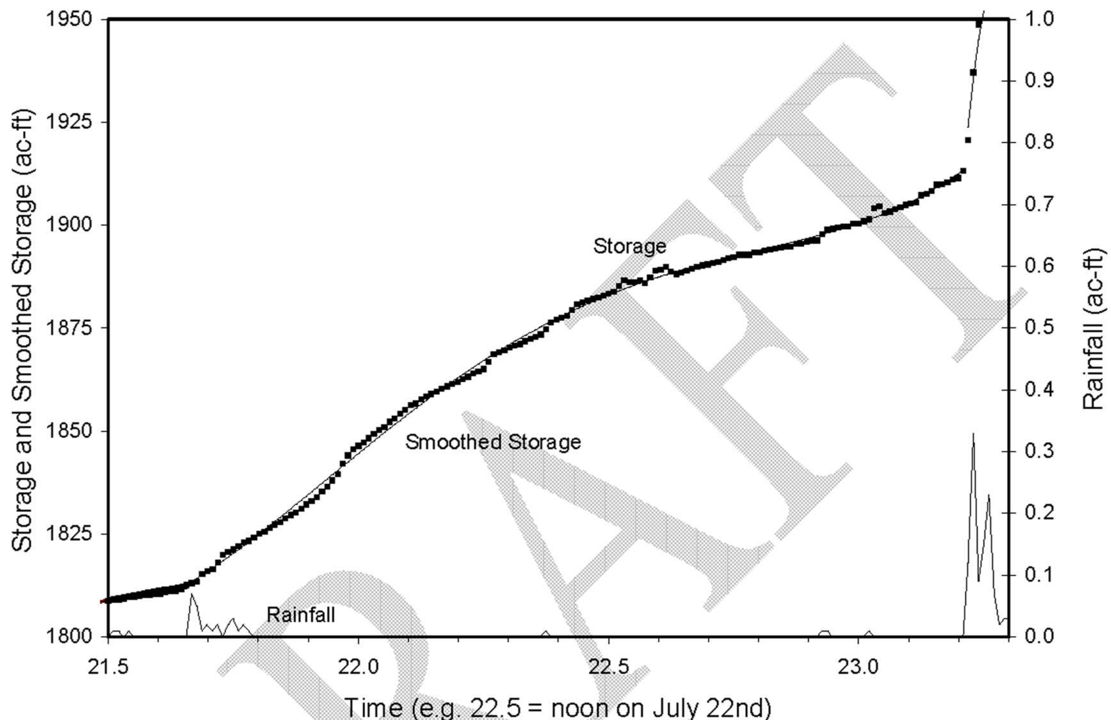

Figure E-8. Example of smoothing of stage data for Cell 1A. Two partial segments and one full segment are shown (the full segment is between the rainfall peaks).

Some Observations and Interpretations of the Water Budget during Rainfall Events

All spikes in the error term of the water budget occur during rainfall events. Some observations and interpretations of the values that some of the water budget terms take during these events are presented below. (Note: In this section, six digit numbers represent the day and time: e.g., 222215 is 10:15pm on July 22nd.) **Tables E-3A** to **E-3K** present stage data and water budget terms for the time steps surrounding the rainfall events described in this section. The tables are presented in chronological order.

Low-intensity Rainfall Events (0.01 in / 15 min.)

In response to the spikes in rainfall at 222215 and 222230 (**Table E-3D**, highlighted rows), there may be a change in storage, as evinced by the higher ΔS's, in the noisy mean data as well as in the instantaneous data. Note the increase in G343B+H from 17.40 to 17.45, then to 17.50 in the next time step. In this instance, change in storage leads rainfall.

There may or may not be a response in stage for the events at 220900 (**Table E-3C**) and 292130 (**Table E-3J**), as the ΔS's are within the precision for ΔS. An even more curious observation is that the data near 222130 actually show a drop in S at that time! Observe particularly the stage at G343B+H.

At 230030 (**Table E-3D**), positive ΔS lags (instantaneous data) the rainfall by one step. However, this is negated in the next step by a negative ΔS, which cannot be explained by the small changes in inflow, outflow, potential ET, or seepage.

For the rainfall event at 232215 (**Table E-3F**), the instantaneous and noisy data seem to increase at the time of the rainfall event, but decrease again in the next time step.

Higher-intensity Rainfall Events (> 0.01 in / 15 min.)

The rainfall event at 181500 (**Table E-3A**) does not seem to show up in any storage calculation (note that the other terms of the water budget are relatively constant).

A rainfall event beginning at 211600 (**Table E-3B**) with 4.894 ac-ft in the first 15 minutes and continuing for at least three hours seems to show up in each of the three storage records in a subdued form. It is as if the rain is more intense over the gage and less intense over Cell 1A. A similar situation seems to be occurring at the beginning of the storm that peaks at 230530 (**Table E-3D**), during which there is the only negative spike in the data set; it seems to occur because of a lead in ΔS with respect to rainfall.

Changes in stage about the event that peaks at 231300 (**Table E-3E**) are more spread out and less erratic than the gage data. This would be consistent with the general nature of a single point measure (at the gage) as compared to the mean of several point measures (ΔS may be thought to be comprised of a mean of an infinite number of rain gage data points within Cell 1A—multiplied by the area of Cell 1A).

The rainfall event at 251515 (**Table E-3G**) seems to show only at G343B+H, which recovers in about two time steps.

The event at 260200 (**Table E-3H**) seems not to show up in stage records.

The event at 271245 (**Table E-3I**) probably shows in G343B+H because of its proximity to the rain gage, since the other stage gages do not show a response to the 2.797 ac-ft of rainfall at the gage.

Stage at G343B+H responds to the event at 311800 (**Table E-3K**), however, the other stage gages do not.

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Table E-3A. Water budget data for the periods before, during and after the rainfall event at 181500.

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.												
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107181230	14.881	14.993	14.906	14.650	14.85750	1768.193	0.419	1767.997	0.649	14.881	14.992	14.905	14.650	14.857	1767.773	0.629	4.396	4.419	0.000	0.127	0.538	-1.338
200107181245	14.882	14.994	14.906	14.650	14.85800	1768.612	0.629	1768.646	0.628	14.882	14.993	14.906	14.650	14.858	1768.402	0.420	4.382	4.419	0.000	0.127	0.538	-1.331
200107181300	14.883	14.995	14.907	14.650	14.85875	1769.241	1.259	1769.274	0.609	14.882	14.994	14.907	14.650	14.858	1768.822	0.419	4.370	4.419	0.000	0.128	0.538	-1.325
200107181315	14.883	14.995	14.908	14.655	14.86025	1770.500	1.678	1769.883	0.590	14.883	14.995	14.907	14.650	14.859	1769.241	2.727	4.409	4.470	0.000	0.128	0.538	-1.318
200107181330	14.884	14.996	14.909	14.660	14.86225	1772.178	-0.839	1770.474	0.573	14.884	14.996	14.908	14.660	14.862	1771.968	0.419	4.472	4.522	0.000	0.129	0.538	-1.289
200107181345	14.884	14.997	14.909	14.655	14.86125	1771.339	-0.420	1771.047	0.557	14.884	14.997	14.909	14.660	14.863	1772.388	-1.468	4.401	4.470	0.000	0.129	0.538	-1.294
200107181400	14.885	14.998	14.910	14.650	14.86075	1770.919	0.629	1771.604	0.542	14.885	14.998	14.910	14.650	14.861	1770.919	0.210	4.370	4.419	0.000	0.129	0.538	-1.259
200107181415	14.886	14.999	14.911	14.650	14.86150	1771.549	0.420	1772.147	0.529	14.885	14.999	14.910	14.650	14.861	1771.129	0.420	4.375	4.419	0.000	0.130	0.538	-1.241
200107181430	14.886	15.000	14.912	14.650	14.86200	1771.968	0.419	1772.675	0.516	14.886	14.999	14.911	14.650	14.862	1771.549	0.420	4.283	4.419	0.000	0.130	0.539	-1.321
200107181445	14.887	15.001	14.912	14.650	14.86250	1772.388	0.420	1773.191	0.504	14.886	15.000	14.912	14.650	14.862	1771.968	0.629	4.271	4.419	0.000	0.131	0.538	-1.321
200107181500	14.887	15.002	14.913	14.650	14.86300	1772.807	0.629	1773.695	0.493	14.887	15.001	14.913	14.650	14.863	1772.597	0.419	4.312	4.419	2.098	0.131	0.538	0.829
200107181515	14.888	15.003	14.914	14.650	14.86375	1773.436	0.000	1774.187	0.483	14.888	15.002	14.913	14.650	14.863	1773.017	0.420	4.377	4.419	0.000	0.131	0.537	-1.194
200107181530	14.888	15.003	14.914	14.650	14.86375	1773.436	0.629	1774.670	0.473	14.888	15.003	14.914	14.650	14.864	1773.436	0.629	4.365	4.419	0.000	0.132	0.537	-1.196
200107181545	14.889	15.004	14.915	14.650	14.86450	1774.066	0.629	1775.143	0.464	14.889	15.004	14.915	14.650	14.865	1774.066	0.420	4.351	4.419	0.000	0.132	0.537	-1.201
200107181600	14.890	15.005	14.916	14.650	14.86525	1774.695	1.259	1775.608	0.457	14.889	15.005	14.916	14.650	14.865	1774.485	0.419	4.339	4.419	0.000	0.132	0.537	-1.206
200107181615	14.894	15.006	14.917	14.650	14.86675	1775.953	1.468	1776.064	0.449	14.890	15.006	14.916	14.650	14.866	1774.905	2.517	4.268	4.419	0.000	0.133	0.537	-1.270
200107181630	14.900	15.007	14.917	14.650	14.86850	1777.422	0.629	1776.513	0.443	14.900	15.007	14.917	14.650	14.869	1777.422	0.210	4.177	4.419	0.000	0.133	0.538	-1.356
200107181645	14.901	15.008	14.918	14.650	14.86925	1778.051	0.420	1776.956	0.436	14.900	15.007	14.918	14.650	14.869	1777.631	0.629	4.164	4.419	0.000	0.134	0.538	-1.363
200107181700	14.901	15.009	14.919	14.650	14.86975	1778.470	0.419	1777.392	0.431	14.901	15.008	14.919	14.650	14.870	1778.261	0.210	4.230	4.419	0.000	0.134	0.537	-1.291
200107181715	14.901	15.010	14.920	14.650	14.87025	1778.890	0.210	1777.823	0.426	14.901	15.009	14.919	14.650	14.870	1778.470	0.629	4.416	4.419	0.000	0.134	0.537	-1.100
200107181730	14.902	15.010	14.920	14.650	14.87050	1779.100	0.000	1778.248	0.421	14.902	15.010	14.920	14.650	14.871	1779.100	0.000	4.407	4.419	0.000	0.135	0.536	-1.104

Table E-3B. Water budget data for the periods before, during and after the rainfall event at 211600.

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.												
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107211330	14.945	15.037	14.957	14.690	14.90725	1809.933	0.420	1810.383	0.233	14.945	15.037	14.957	14.690	14.907	1809.933	0.000	3.916	4.833	0.000	0.115	0.580	-1.844
200107211345	14.946	15.038	14.957	14.690	14.90775	1810.352	0.000	1810.616	0.231	14.945	15.037	14.957	14.690	14.907	1809.933	0.420	3.917	4.833	0.000	0.114	0.580	-1.841
200107211400	14.946	15.038	14.957	14.690	14.90775	1810.352	0.210	1810.846	0.229	14.946	15.038	14.957	14.690	14.908	1810.352	0.000	3.909	4.833	0.000	0.114	0.579	-1.846
200107211415	14.946	15.038	14.958	14.690	14.90800	1810.562	0.000	1811.075	0.226	14.946	15.038	14.957	14.690	14.908	1810.352	0.210	3.914	4.833	0.000	0.114	0.580	-1.839
200107211430	14.946	15.038	14.958	14.690	14.90800	1810.562	0.420	1811.301	0.224	14.946	15.038	14.958	14.690	14.908	1810.562	0.419	3.915	4.833	0.000	0.113	0.580	-1.836
200107211445	14.947	15.039	14.958	14.690	14.90850	1810.982	0.210	1811.525	0.221	14.947	15.039	14.958	14.690	14.909	1810.982	0.000	3.907	4.833	0.000	0.113	0.580	-1.840
200107211500	14.947	15.039	14.959	14.690	14.90875	1811.191	0.000	1811.747	0.219	14.947	15.039	14.958	14.690	14.909	1810.982	0.210	3.912	4.833	0.000	0.112	0.580	-1.832
200107211515	14.947	15.039	14.959	14.690	14.90875	1811.191	0.420	1811.965	0.216	14.947	15.039	14.959	14.690	14.909	1811.191	0.210	3.917	4.833	0.000	0.112	0.580	-1.824
200107211530	14.948	15.040	14.959	14.690	14.90925	1811.611	1.049	1812.181	0.213	14.947	15.040	14.959	14.690	14.909	1811.401	0.210	3.918	4.833	0.000	0.111	0.580	-1.820
200107211545	14.948	15.040	14.959	14.695	14.91050	1812.660	0.419	1812.394	1.014	14.948	15.040	14.959	14.690	14.909	1811.611	2.307	3.913	4.886	0.000	0.111	0.580	-2.678
200107211600	14.948	15.041	14.960	14.695	14.91100	1813.079	0.420	1813.409	0.792	14.948	15.040	14.960	14.700	14.912	1813.918	-1.678	3.970	4.886	4.894	0.110	0.579	2.498
200107211615	14.948	15.043	14.960	14.695	14.91150	1813.499	1.888	1814.201	0.813	14.948	15.042	14.960	14.690	14.910	1812.240	2.727	4.182	4.886	3.496	0.110	0.578	1.291
200107211630	14.949	15.045	14.961	14.700	14.91375	1815.386	0.629	1815.013	0.832	14.949	15.044	14.960	14.700	14.913	1814.967	0.629	4.176	4.939	0.699	0.110	0.579	-1.584
200107211645	14.949	15.047	14.962	14.700	14.91450	1816.016	0.419	1815.845	0.851	14.949	15.046	14.961	14.700	14.914	1815.596	0.420	4.163	4.939	1.398	0.109	0.579	-0.915
200107211700	14.949	15.048	14.963	14.700	14.91500	1816.435	1.678	1816.696	0.868	14.949	15.047	14.962	14.700	14.915	1816.016	0.629	4.152	4.939	0.699	0.109	0.578	-1.643
200107211715	14.949	15.050	14.964	14.705	14.91700	1818.113	1.888	1817.564	0.885	14.949	15.049	14.963	14.700	14.915	1816.645	2.936	4.136	4.992	1.398	0.108	0.578	-1.029
200107211730	14.950	15.052	14.965	14.710	14.91925	1820.001	0.629	1818.449	0.900	14.950	15.051	14.964	14.710	14.919	1819.581	0.839	4.113	5.045	0.000	0.108	0.579	-2.519
200107211745	14.950	15.054	14.966	14.710	14.92000	1820.630	0.629	1819.349	0.915	14.950	15.053	14.966	14.710	14.920	1820.420	0.629	4.145	5.045	1.398	0.107	0.579	-1.103
200107211800	14.950	15.056	14.967	14.710	14.92075	1821.259	0.839	1820.264	0.929	14.950	15.055	14.967	14.710	14.921	1821.050	0.839	4.240	5.045	2.098	0.107	0.578	-0.321
200107211815	14.951	15.058	14.968	14.710	14.92175	1822.098	0.839	1821.193	0.942	14.951	15.057	14.968	14.710	14.922	1821.889	0.839	4.220	5.045	0.699	0.106	0.578	-1.752
200107211830	14.952	15.060	14.969	14.710	14.92275	1822.937	0.420	1822.135	0.954	14.952	15.059	14.969	14.710	14.923	1822.728	0.629	4.193	5.045	1.398	0.106	0.578	-1.091

Table E-3C. Water balance data for the periods before, during and after the rainfall event at 220900.

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.															
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107220630	15.016	15.134	15.029	14.730	14.97725	1868.663	0.419	1868.679	0.788	15.015	15.133	15.028	14.730	14.977	1868.034	0.629	5.054	5.260	0.000	0.095	0.576	-1.665
200107220645	15.017	15.135	15.029	14.730	14.97775	1869.082	0.629	1869.467	0.776	15.016	15.134	15.029	14.730	14.977	1868.663	0.839	5.029	5.260	0.000	0.095	0.576	-1.678
200107220700	15.018	15.136	15.030	14.730	14.97850	1869.712	0.629	1870.242	0.763	15.018	15.135	15.030	14.730	14.978	1869.502	0.629	5.002	5.260	0.000	0.095	0.576	-1.692
200107220715	15.019	15.137	15.031	14.730	14.97925	1870.341	0.419	1871.005	0.750	15.019	15.136	15.031	14.730	14.979	1870.131	0.420	4.981	5.260	0.000	0.095	0.576	-1.699
200107220730	15.020	15.137	15.032	14.730	14.97975	1870.760	0.420	1871.755	0.737	15.020	15.137	15.031	14.730	14.980	1870.551	0.419	4.966	5.260	0.000	0.095	0.576	-1.701
200107220745	15.021	15.138	15.032	14.730	14.98025	1871.180	0.629	1872.492	0.724	15.020	15.138	15.032	14.730	14.980	1870.970	0.629	4.952	5.260	0.000	0.095	0.576	-1.702
200107220800	15.022	15.139	15.033	14.730	14.98100	1871.809	0.629	1873.215	0.710	15.021	15.139	15.033	14.730	14.981	1871.599	0.629	4.932	5.260	0.000	0.095	0.577	-1.710
200107220815	15.023	15.140	15.034	14.730	14.98175	1872.438	0.419	1873.926	0.697	15.022	15.140	15.034	14.730	14.982	1872.229	0.210	4.912	5.260	0.000	0.095	0.577	-1.716
200107220830	15.024	15.140	15.035	14.730	14.98225	1872.858	0.629	1874.623	0.684	15.023	15.140	15.034	14.730	14.982	1872.438	0.629	4.899	5.260	0.000	0.094	0.577	-1.715
200107220845	15.025	15.141	15.036	14.730	14.98300	1873.487	1.258	1875.307	0.671	15.024	15.141	15.035	14.730	14.983	1873.068	0.629	4.883	5.260	0.000	0.094	0.577	-1.719
200107220900	15.026	15.141	15.036	14.735	14.98450	1874.746	1.678	1875.978	0.658	15.026	15.141	15.036	14.730	14.983	1873.697	2.727	4.918	5.314	0.699	0.094	0.577	-1.026
200107220915	15.027	15.142	15.037	14.740	14.98650	1876.424	0.629	1876.635	0.644	15.027	15.142	15.037	14.740	14.987	1876.424	0.210	4.968	5.368	0.000	0.094	0.577	-1.716
200107220930	15.028	15.143	15.038	14.740	14.98725	1877.053	0.419	1877.280	0.631	15.028	15.142	15.037	14.740	14.987	1876.633	0.629	4.952	5.368	0.000	0.094	0.577	-1.719
200107220945	15.029	15.143	15.039	14.740	14.98775	1877.472	0.420	1877.911	0.618	15.029	15.143	15.038	14.740	14.988	1877.263	0.420	4.936	5.368	0.000	0.094	0.577	-1.722
200107221000	15.030	15.144	15.039	14.740	14.98825	1877.892	1.468	1878.529	0.605	15.030	15.143	15.039	14.740	14.988	1877.682	0.629	4.920	5.368	0.000	0.094	0.577	-1.725
200107221015	15.031	15.144	15.045	14.740	14.99000	1879.360	1.468	1879.133	0.592	15.031	15.144	15.040	14.740	14.989	1878.311	2.517	4.903	5.368	0.000	0.094	0.578	-1.728
200107221030	15.032	15.145	15.050	14.740	14.99175	1880.828	0.419	1879.725	0.579	15.032	15.145	15.050	14.740	14.992	1880.828	0.210	4.887	5.368	0.000	0.094	0.579	-1.733
200107221045	15.033	15.145	15.051	14.740	14.99225	1881.248	0.420	1880.304	0.566	15.033	15.145	15.050	14.740	14.992	1881.038	0.629	4.871	5.368	0.000	0.094	0.579	-1.736
200107221100	15.034	15.146	15.051	14.740	14.99275	1881.667	0.419	1880.870	0.553	15.034	15.146	15.051	14.740	14.993	1881.667	0.210	4.854	5.368	0.000	0.094	0.579	-1.740
200107221115	15.035	15.147	15.051	14.740	14.99325	1882.087	0.420	1881.423	0.541	15.035	15.146	15.051	14.740	14.993	1881.877	0.629	4.838	5.368	0.000	0.094	0.579	-1.743
200107221130	15.036	15.147	15.052	14.740	14.99375	1882.506	0.419	1881.964	0.528	15.036	15.147	15.052	14.740	14.994	1882.506	0.420	4.821	5.368	0.000	0.094	0.579	-1.748

Table E-3D. Water balance data for the periods before, during and after the rainfall events at 222215, 230030 and 230530.

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.														
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107221945	15.062	15.164	15.064	14.740	15.00750	1894.043	0.210	1894.540	0.303	15.062	15.164	15.064	14.740	15.008	1894.043	0.210	4.837	5.368	0.000	0.092	0.579	-1.505
200107222000	15.063	15.164	15.064	14.740	15.00775	1894.252	0.419	1894.843	0.305	15.063	15.164	15.064	14.740	15.008	1894.252	0.000	4.833	5.368	0.000	0.092	0.579	-1.511
200107222015	15.063	15.165	15.065	14.740	15.00825	1894.672	0.210	1895.148	0.307	15.063	15.164	15.064	14.740	15.008	1894.252	0.420	4.836	5.368	0.000	0.092	0.579	-1.510
200107222030	15.064	15.165	15.065	14.740	15.00850	1894.882	0.000	1895.455	0.311	15.063	15.165	15.065	14.740	15.008	1894.672	0.210	4.888	5.368	0.000	0.092	0.579	-1.462
200107222045	15.064	15.165	15.065	14.740	15.00850	1894.882	0.629	1895.766	0.314	15.064	15.165	15.065	14.740	15.009	1894.882	0.420	4.947	5.368	0.000	0.092	0.579	-1.406
200107222100	15.065	15.166	15.066	14.740	15.00925	1895.511	0.000	1896.080	0.319	15.064	15.166	15.066	14.740	15.009	1895.301	0.210	4.937	5.368	0.000	0.092	0.579	-1.421
200107222115	15.065	15.166	15.066	14.740	15.00925	1895.511	0.420	1896.399	0.324	15.065	15.166	15.066	14.740	15.009	1895.511	0.000	4.927	5.368	0.000	0.092	0.579	-1.437
200107222130	15.066	15.166	15.067	14.740	15.00975	1895.930	0.210	1896.724	0.331	15.065	15.166	15.066	14.740	15.009	1895.511	0.629	4.916	5.368	0.000	0.092	0.579	-1.453
200107222145	15.066	15.167	15.067	14.740	15.01000	1896.140	0.210	1897.054	0.338	15.066	15.167	15.067	14.740	15.010	1896.140	0.000	4.906	5.368	0.000	0.092	0.579	-1.470
200107222200	15.067	15.167	15.067	14.740	15.01025	1896.350	1.468	1897.392	0.345	15.066	15.167	15.067	14.740	15.010	1896.140	0.210	4.896	5.368	0.000	0.092	0.579	-1.488
200107222215	15.067	15.168	15.068	14.745	15.01200	1897.818	1.049	1897.737	0.354	15.067	15.167	15.067	14.740	15.010	1896.350	2.517	4.886	5.423	0.699	0.092	0.579	-0.862
200107222230	15.067	15.168	15.068	14.750	15.01325	1898.867	0.210	1898.091	0.363	15.067	15.168	15.068	14.750	15.013	1898.867	0.210	4.876	5.477	0.699	0.091	0.580	-0.937
200107222245	15.068	15.168	15.068	14.750	15.01350	1899.077	0.419	1898.454	0.373	15.068	15.168	15.068	14.750	15.014	1899.077	0.420	4.865	5.477	0.000	0.091	0.580	-1.657
200107222300	15.068	15.169	15.069	14.750	15.01400	1899.496	0.210	1898.827	0.384	15.068	15.169	15.069	14.750	15.014	1899.496	0.210	4.855	5.477	0.000	0.091	0.580	-1.678
200107222315	15.069	15.169	15.069	14.750	15.01425	1899.706	0.000	1899.212	0.396	15.069	15.169	15.069	14.750	15.014	1899.706	0.000	4.845	5.477	0.000	0.091	0.580	-1.700
200107222330	15.069	15.169	15.069	14.750	15.01425	1899.706	0.629	1899.608	0.409	15.069	15.169	15.069	14.750	15.014	1899.706	0.629	4.835	5.477	0.000	0.091	0.579	-1.722
200107222345	15.070	15.170	15.070	14.750	15.01500	1900.335	0.000	1900.017	0.423	15.070	15.170	15.070	14.750	15.015	1900.335	0.000	4.825	5.477	0.000	0.091	0.580	-1.746
200107230000	15.070	15.170	15.070	14.750	15.01500	1900.335	0.629	1900.440	0.437	15.070	15.170	15.070	14.750	15.015	1900.335	0.419	4.843	5.477	0.000	0.091	0.580	-1.742
200107230015	15.071	15.171	15.071	14.750	15.01575	1900.964	0.419	1900.877	0.453	15.071	15.171	15.070	14.750	15.016	1900.755	0.629	4.837	5.477	0.000	0.090	0.580	-1.763
200107230030	15.072	15.172	15.071	14.750	15.01625	1901.384	2.727	1901.330	0.469	15.072	15.172	15.071	14.750	15.016	1901.384	0.210	4.831	5.477	0.699	0.089	0.580	-1.086
200107230045	15.073	15.173	15.072	14.760	15.01950	1904.111	0.420	1901.799	0.487	15.072	15.173	15.071	14.750	15.017	1901.594	4.824	4.825	5.587	0.000	0.088	0.580	-1.918
200107230100	15.074	15.174	15.072	14.760	15.02000	1904.530	-1.678	1902.286	0.505	15.073	15.174	15.072	14.770	15.022	1906.418	-3.775	4.819	5.587	0.000	0.088	0.580	-1.942
200107230115	15.074	15.175	15.073	14.750	15.01800	1902.852	0.419	1902.791	0.525	15.074	15.175	15.072	14.750	15.018	1902.642	0.629	4.813	5.477	0.000	0.087	0.580	-1.856
200107230130	15.075	15.176	15.073	14.750	15.01850	1903.272	0.629	1903.316	0.545	15.075	15.176	15.073	14.750	15.019	1903.272	0.420	4.806	5.477	0.000	0.086	0.580	-1.882
200107230145	15.076	15.177	15.074	14.750	15.01925	1903.901	0.420	1903.861	0.567	15.076	15.177	15.073	14.750	15.019	1903.691	0.210	4.800	5.477	0.000	0.085	0.580	-1.909

Table E-3D. Water balance data for the periods before, during and after the rainfall events at 222215, 230030 and 230530 (cont'd).

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.												
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107230200	15.077	15.178	15.074	14.750	15.01975	1904.320	0.629	1904.428	0.589	15.076	15.177	15.074	14.750	15.019	1903.901	0.420	4.794	5.477	0.000	0.084	0.580	-1.937
200107230215	15.078	15.179	15.075	14.750	15.02050	1904.950	0.420	1905.017	0.613	15.077	15.178	15.074	14.750	15.020	1904.320	0.629	4.788	5.477	0.000	0.084	0.581	-1.966
200107230230	15.079	15.180	15.075	14.750	15.02100	1905.369	0.210	1905.629	0.637	15.078	15.179	15.075	14.750	15.021	1904.950	0.420	4.782	5.477	0.000	0.083	0.581	-1.996
200107230245	15.079	15.181	15.075	14.750	15.02125	1905.579	1.678	1906.266	0.663	15.079	15.180	15.075	14.750	15.021	1905.369	0.629	4.776	5.477	0.000	0.082	0.581	-2.026
200107230300	15.080	15.182	15.076	14.755	15.02325	1907.257	0.420	1906.929	0.690	15.080	15.181	15.076	14.750	15.022	1905.998	2.517	4.770	5.532	0.000	0.081	0.581	-2.114
200107230315	15.081	15.183	15.076	14.755	15.02375	1907.676	0.629	1907.619	0.717	15.081	15.182	15.076	14.760	15.025	1908.515	-1.678	4.764	5.532	0.000	0.081	0.581	-2.147
200107230330	15.082	15.184	15.077	14.755	15.02450	1908.306	1.468	1908.336	0.746	15.081	15.183	15.077	14.750	15.023	1906.837	2.517	4.758	5.532	0.000	0.080	0.581	-2.181
200107230345	15.083	15.185	15.077	14.760	15.02625	1909.774	0.210	1909.083	0.777	15.082	15.184	15.077	14.760	15.026	1909.354	0.629	4.752	5.587	0.000	0.079	0.582	-2.272
200107230400	15.083	15.185	15.078	14.760	15.02650	1909.984	0.419	1909.859	0.808	15.083	15.185	15.078	14.760	15.027	1909.984	0.419	4.746	5.587	0.000	0.078	0.582	-2.309
200107230415	15.084	15.186	15.078	14.760	15.02700	1910.403	0.629	1910.667	0.840	15.084	15.186	15.078	14.760	15.027	1910.403	0.629	4.740	5.587	0.000	0.077	0.582	-2.347
200107230430	15.085	15.187	15.079	14.760	15.02775	1911.032	0.420	1911.508	0.874	15.085	15.187	15.079	14.760	15.028	1911.032	0.210	4.734	5.587	0.000	0.077	0.582	-2.386
200107230445	15.086	15.188	15.079	14.760	15.02825	1911.452	1.678	1912.382	0.909	15.085	15.188	15.079	14.760	15.028	1911.242	0.629	4.728	5.587	0.000	0.076	0.582	-2.426
200107230500	15.087	15.189	15.080	14.765	15.03025	1913.130	7.551	1913.291	10.529	15.086	15.189	15.080	14.760	15.029	1911.871	2.517	4.752	5.642	0.000	0.075	0.582	-12.077
200107230515	15.087	15.197	15.093	14.780	15.03925	1920.681	16.361	1923.820	11.908	15.087	15.190	15.080	14.770	15.032	1914.388	13.424	5.080	5.809	8.390	0.074	0.583	-4.905
200107230530	15.088	15.218	15.119	14.810	15.05875	1937.041	11.746	1935.728	9.152	15.088	15.210	15.103	14.790	15.048	1927.812	18.668	5.256	6.147	23.073	0.074	0.583	12.373
200107230545	15.089	15.239	15.133	14.830	15.07275	1948.787	4.195	1944.880	6.992	15.089	15.230	15.131	14.830	15.070	1946.480	3.566	5.397	6.377	6.293	0.073	0.581	-2.333
200107230600	15.090	15.245	15.136	14.840	15.07775	1952.982	4.824	1951.873	5.354	15.089	15.243	15.135	14.830	15.074	1950.046	5.873	5.470	6.492	10.488	0.072	0.580	3.460
200107230615	15.090	15.249	15.140	14.855	15.08350	1957.807	3.356	1957.226	4.146	15.090	15.247	15.138	14.850	15.081	1955.919	3.985	5.495	6.667	16.081	0.071	0.578	10.114
200107230630	15.092	15.254	15.144	14.860	15.08750	1961.163	1.678	1961.373	3.305	15.091	15.251	15.142	14.860	15.086	1959.904	1.888	5.512	6.725	4.894	0.070	0.575	-0.270
200107230645	15.093	15.258	15.147	14.860	15.08950	1962.841	1.468	1964.677	2.775	15.092	15.256	15.145	14.860	15.088	1961.792	2.098	5.515	6.725	1.398	0.070	0.573	-3.230
200107230700	15.094	15.261	15.150	14.860	15.09125	1964.309	4.824	1967.453	2.473	15.094	15.260	15.149	14.860	15.091	1963.889	1.678	5.794	6.725	2.098	0.069	0.570	-1.945
200107230715	15.096	15.273	15.154	14.865	15.09700	1969.133	3.566	1969.925	2.355	15.095	15.265	15.151	14.860	15.093	1965.567	6.502	5.976	6.784	2.098	0.068	0.569	-1.703
200107230730	15.097	15.280	15.158	14.870	15.10125	1972.699	1.888	1972.281	2.371	15.096	15.280	15.156	14.870	15.101	1972.070	1.678	6.121	6.843	2.797	0.067	0.567	-0.931
200107230745	15.098	15.284	15.162	14.870	15.10350	1974.587	2.517	1974.652	2.482	15.098	15.282	15.160	14.870	15.103	1973.748	2.097	6.204	6.843	2.797	0.066	0.566	-0.957
200107230800	15.101	15.289	15.166	14.870	15.10650	1977.104	3.775	1977.134	2.639	15.099	15.287	15.164	14.870	15.105	1975.845	3.356	6.224	6.843	2.098	0.066	0.564	-1.790

Table E-3E. Water balance data for the periods before, during and after the rainfall event at 231300.

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.												
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107231030	15.134	15.340	15.202	14.890	15.14150	2006.469	3.356	2007.212	2.592	15.132	15.338	15.200	14.890	15.140	2005.210	2.727	6.767	7.080	0.000	0.058	0.558	-3.521
200107231045	15.137	15.350	15.205	14.890	15.14550	2009.825	2.097	2009.804	2.387	15.135	15.345	15.203	14.890	15.143	2007.937	2.937	6.774	7.080	0.699	0.057	0.557	-2.607
200107231100	15.140	15.354	15.208	14.890	15.14800	2011.922	1.888	2012.191	2.215	15.138	15.352	15.207	14.890	15.147	2010.873	2.097	7.044	7.080	0.000	0.056	0.556	-2.863
200107231115	15.142	15.358	15.211	14.890	15.15025	2013.810	3.356	2014.406	2.107	15.141	15.356	15.210	14.890	15.149	2012.971	2.097	7.063	7.080	0.000	0.056	0.556	-2.736
200107231130	15.145	15.367	15.215	14.890	15.15425	2017.166	1.468	2016.513	2.104	15.144	15.360	15.213	14.890	15.152	2015.068	3.776	7.009	7.080	0.699	0.055	0.556	-2.086
200107231145	15.148	15.372	15.219	14.885	15.15600	2018.634	0.839	2018.617	2.252	15.147	15.371	15.217	14.890	15.156	2018.844	-0.210	6.987	7.021	1.398	0.054	0.555	-1.497
200107231200	15.150	15.375	15.223	14.880	15.15700	2019.473	1.888	2020.869	2.615	15.150	15.373	15.221	14.880	15.156	2018.634	1.678	7.008	6.961	1.398	0.053	0.555	-1.779
200107231215	15.153	15.377	15.227	14.880	15.15925	2021.361	6.083	2023.484	3.230	15.151	15.376	15.225	14.880	15.158	2020.312	1.888	7.090	6.961	2.098	0.052	0.554	-1.611
200107231230	15.156	15.380	15.235	14.895	15.16650	2027.444	7.551	2026.714	4.176	15.154	15.378	15.229	14.880	15.160	2022.200	11.746	7.179	7.140	6.293	0.052	0.554	1.550
200107231245	15.159	15.393	15.250	14.900	15.17550	2034.995	3.566	2030.890	5.512	15.158	15.385	15.244	14.910	15.174	2033.946	2.097	7.316	7.200	6.992	0.051	0.553	0.992
200107231300	15.163	15.407	15.259	14.890	15.17975	2038.560	1.888	2036.402	3.059	15.161	15.400	15.256	14.890	15.177	2036.043	3.566	7.362	7.080	7.691	0.050	0.549	4.314
200107231315	15.166	15.411	15.261	14.890	15.18200	2040.448	0.210	2039.461	0.454	15.164	15.410	15.260	14.890	15.181	2039.609	1.468	7.413	7.080	2.098	0.049	0.548	1.379
200107231330	15.169	15.413	15.262	14.885	15.18225	2040.658	0.000	2039.915	0.494	15.168	15.412	15.261	14.890	15.183	2041.077	-0.629	7.428	7.021	2.797	0.048	0.546	2.115
200107231345	15.170	15.416	15.263	14.880	15.18225	2040.658	1.259	2040.410	0.532	15.170	15.415	15.263	14.880	15.182	2040.448	0.839	7.451	6.961	2.098	0.048	0.544	1.463
200107231400	15.172	15.419	15.264	14.880	15.18375	2041.916	0.210	2040.942	0.569	15.171	15.417	15.264	14.880	15.183	2041.287	1.468	7.471	6.961	0.699	0.047	0.542	0.052
200107231415	15.175	15.421	15.265	14.875	15.18400	2042.126	-0.839	2041.511	0.603	15.174	15.420	15.265	14.880	15.185	2042.755	-0.839	7.535	6.902	0.000	0.046	0.540	-0.557
200107231430	15.177	15.424	15.266	14.865	15.18300	2041.287	0.420	2042.114	0.636	15.176	15.423	15.266	14.870	15.184	2041.916	-1.049	7.546	6.784	0.699	0.045	0.539	0.240
200107231445	15.179	15.427	15.268	14.860	15.18350	2041.707	1.049	2042.750	0.668	15.178	15.425	15.267	14.860	15.183	2040.868	1.259	7.540	6.725	0.699	0.045	0.539	0.263
200107231500	15.186	15.429	15.269	14.855	15.18475	2042.755	1.049	2043.418	0.697	15.180	15.428	15.268	14.860	15.184	2042.126	0.839	7.513	6.667	0.000	0.044	0.537	-0.432
200107231515	15.193	15.431	15.270	14.850	15.18600	2043.804	1.259	2044.115	0.726	15.191	15.430	15.269	14.850	15.185	2042.965	1.259	7.516	6.608	1.398	0.043	0.536	1.001
200107231530	15.196	15.433	15.271	14.850	15.18750	2045.063	0.419	2044.841	0.752	15.194	15.432	15.270	14.850	15.187	2044.224	1.468	7.530	6.608	0.000	0.042	0.534	-0.407

Table E-3F. Water balance data for the periods before, during and after the rainfall event at 232215.

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.												
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107231945	15.244	15.476	15.300	14.800	15.20500	2059.745	1.049	2060.207	1.018	15.242	15.475	15.299	14.800	15.204	2058.906	1.678	7.839	6.034	0.000	0.029	0.521	0.237
200107232000	15.247	15.477	15.301	14.800	15.20625	2060.794	1.259	2061.225	1.024	15.246	15.477	15.301	14.800	15.206	2060.584	1.049	7.826	6.034	0.000	0.028	0.521	0.218
200107232015	15.250	15.479	15.302	14.800	15.20775	2062.052	1.049	2062.249	1.030	15.249	15.478	15.302	14.800	15.207	2061.633	0.839	7.847	6.034	0.000	0.027	0.521	0.235
200107232030	15.251	15.481	15.304	14.800	15.20900	2063.101	1.259	2063.279	1.035	15.250	15.480	15.303	14.800	15.208	2062.472	1.258	7.908	6.034	0.000	0.027	0.521	0.291
200107232045	15.254	15.483	15.305	14.800	15.21050	2064.360	1.049	2064.315	1.040	15.253	15.482	15.304	14.800	15.210	2063.730	0.839	7.922	6.034	0.000	0.026	0.521	0.302
200107232100	15.257	15.484	15.306	14.800	15.21175	2065.408	1.259	2065.354	1.043	15.255	15.483	15.305	14.800	15.211	2064.569	1.258	7.941	6.034	0.000	0.025	0.521	0.318
200107232115	15.260	15.486	15.307	14.800	15.21325	2066.667	-0.210	2066.397	1.046	15.258	15.485	15.306	14.800	15.212	2065.828	1.468	7.960	6.034	0.000	0.024	0.521	0.335
200107232130	15.262	15.487	15.308	14.795	15.21300	2066.457	0.210	2067.443	1.048	15.261	15.487	15.308	14.800	15.214	2067.296	-1.049	7.979	5.977	0.000	0.023	0.521	0.409
200107232145	15.265	15.489	15.309	14.790	15.21325	2066.667	3.356	2068.492	1.050	15.264	15.488	15.309	14.790	15.213	2066.247	1.049	7.998	5.921	0.000	0.023	0.521	0.484
200107232200	15.268	15.490	15.311	14.800	15.21725	2070.023	3.356	2069.542	1.051	15.266	15.490	15.310	14.790	15.214	2067.296	5.453	8.310	6.034	0.000	0.022	0.521	0.682
200107232215	15.270	15.492	15.313	14.810	15.22125	2073.379	0.419	2070.593	1.052	15.269	15.491	15.312	14.810	15.221	2072.750	1.259	8.526	6.147	0.699	0.021	0.524	1.481
200107232230	15.271	15.495	15.316	14.805	15.22175	2073.798	-0.629	2071.645	1.052	15.270	15.494	15.314	14.810	15.222	2074.008	-0.629	8.528	6.091	0.000	0.020	0.527	0.838
200107232245	15.273	15.498	15.318	14.795	15.22100	2073.169	0.419	2072.697	1.051	15.272	15.496	15.317	14.800	15.221	2073.379	-0.629	8.526	5.977	0.000	0.020	0.528	0.949
200107232300	15.274	15.501	15.321	14.790	15.22150	2073.589	1.468	2073.748	1.050	15.273	15.499	15.320	14.790	15.221	2072.750	1.468	8.524	5.921	0.000	0.019	0.530	1.004
200107232315	15.276	15.503	15.324	14.790	15.22325	2075.057	1.468	2074.798	1.049	15.275	15.502	15.322	14.790	15.222	2074.218	1.678	8.522	5.921	0.000	0.018	0.532	1.003
200107232330	15.278	15.506	15.326	14.790	15.22500	2076.525	1.468	2075.847	1.047	15.277	15.505	15.325	14.790	15.224	2075.896	1.258	8.528	5.921	0.000	0.017	0.533	1.009
200107232345	15.279	15.509	15.329	14.790	15.22675	2077.993	0.210	2076.894	1.044	15.278	15.507	15.328	14.790	15.226	2077.154	1.468	8.594	5.921	0.000	0.016	0.535	1.076
200107240000	15.281	15.511	15.331	14.785	15.22700	2078.203	0.210	2077.938	1.042	15.280	15.510	15.330	14.790	15.228	2078.623	-1.049	8.605	5.865	0.000	0.017	0.536	1.145
200107240015	15.285	15.512	15.332	14.780	15.22725	2078.413	1.049	2078.980	1.039	15.283	15.511	15.331	14.780	15.226	2077.574	1.259	8.629	5.809	0.000	0.018	0.537	1.226
200107240030	15.288	15.513	15.333	14.780	15.22850	2079.462	1.259	2080.019	1.035	15.286	15.512	15.333	14.780	15.228	2078.832	1.049	8.653	5.809	0.000	0.020	0.539	1.250
200107240045	15.291	15.514	15.335	14.780	15.23000	2080.720	1.049	2081.054	1.031	15.289	15.513	15.334	14.780	15.229	2079.881	1.468	8.677	5.809	0.000	0.021	0.541	1.275

Table E-3G. Water balance data for the periods before, during and after the rainfall event at 251515.

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.												
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107251245	15.504	15.632	15.422	14.790	15.33700	2170.493	0.210	2170.495	0.225	15.504	15.632	15.422	14.790	15.337	2170.493	0.000	8.483	5.921	0.000	0.164	0.562	1.612
200107251300	15.504	15.632	15.423	14.790	15.33725	2170.703	0.210	2170.721	0.218	15.504	15.632	15.422	14.790	15.337	2170.493	0.210	8.476	5.921	0.000	0.164	0.561	1.612
200107251315	15.505	15.632	15.423	14.790	15.33750	2170.913	0.210	2170.938	0.210	15.504	15.632	15.423	14.790	15.337	2170.703	0.420	8.469	5.921	0.000	0.164	0.561	1.614
200107251330	15.505	15.633	15.423	14.790	15.33775	2171.122	0.000	2171.148	0.202	15.505	15.633	15.423	14.790	15.338	2171.122	0.000	8.463	5.921	0.000	0.164	0.561	1.614
200107251345	15.505	15.633	15.423	14.790	15.33775	2171.122	0.210	2171.351	0.195	15.505	15.633	15.423	14.790	15.338	2171.122	0.210	8.456	5.921	0.000	0.164	0.561	1.615
200107251400	15.506	15.633	15.423	14.790	15.33800	2171.332	0.000	2171.546	0.187	15.506	15.633	15.423	14.790	15.338	2171.332	0.000	8.449	5.921	0.000	0.164	0.561	1.616
200107251415	15.506	15.633	15.423	14.790	15.33800	2171.332	0.419	2171.733	0.179	15.506	15.633	15.423	14.790	15.338	2171.332	0.000	8.442	5.921	0.000	0.164	0.561	1.617
200107252000	15.507	15.633	15.424	14.790	15.33850	2171.752	0.210	2171.912	0.044	15.506	15.633	15.423	14.790	15.338	2171.332	0.420	8.248	6.147	0.000	0.165	0.561	1.330
200107251445	15.507	15.634	15.424	14.790	15.33875	2171.961	0.000	2172.084	0.164	15.507	15.633	15.424	14.790	15.339	2171.752	0.210	8.428	5.921	0.000	0.164	0.561	1.618
200107251500	15.507	15.634	15.424	14.790	15.33875	2171.961	1.259	2172.248	0.157	15.507	15.634	15.424	14.790	15.339	2171.961	0.210	8.421	5.921	0.000	0.164	0.561	1.618
200107251515	15.508	15.634	15.424	14.795	15.34025	2173.220	1.049	2172.404	0.149	15.508	15.634	15.424	14.790	15.339	2172.171	2.097	8.414	5.977	2.098	0.164	0.561	3.660
200107251530	15.508	15.634	15.424	14.800	15.34150	2174.269	-0.839	2172.553	0.141	15.508	15.634	15.424	14.800	15.342	2174.269	0.210	8.407	6.034	0.000	0.164	0.560	1.507
200107251545	15.509	15.634	15.424	14.795	15.34050	2173.430	-0.839	2172.695	0.858	15.509	15.634	15.424	14.800	15.342	2174.478	-1.888	8.400	5.977	0.699	0.164	0.560	1.540
200107251600	15.509	15.634	15.425	14.790	15.33950	2172.591	0.420	2173.553	1.032	15.509	15.634	15.425	14.790	15.340	2172.591	0.210	8.394	5.921	0.000	0.164	0.559	0.717
200107251615	15.510	15.635	15.425	14.790	15.34000	2173.010	0.210	2174.585	0.919	15.509	15.635	15.425	14.790	15.340	2172.800	0.210	8.387	5.921	0.000	0.164	0.559	0.823
200107251630	15.511	15.635	15.425	14.790	15.34025	2173.220	1.678	2175.505	0.814	15.510	15.635	15.425	14.790	15.340	2173.010	1.049	8.374	5.921	0.000	0.164	0.559	0.916
200107251645	15.519	15.635	15.425	14.790	15.34225	2174.898	1.259	2176.319	0.714	15.515	15.635	15.425	14.790	15.341	2174.059	1.049	8.309	5.921	0.000	0.164	0.559	0.950
200107251700	15.520	15.635	15.425	14.795	15.34375	2176.156	1.049	2177.033	0.625	15.520	15.635	15.425	14.790	15.343	2175.108	2.097	8.299	5.977	0.000	0.165	0.559	0.972
200107251715	15.520	15.635	15.425	14.800	15.34500	2177.205	0.419	2177.658	0.540	15.520	15.635	15.425	14.800	15.345	2177.205	0.210	8.294	6.034	0.000	0.165	0.560	0.996
200107251730	15.520	15.636	15.426	14.800	15.34550	2177.625	0.000	2178.198	0.464	15.520	15.635	15.426	14.800	15.345	2177.415	0.210	8.290	6.034	0.000	0.165	0.560	1.067
200107251745	15.520	15.636	15.426	14.800	15.34550	2177.625	1.049	2178.662	0.393	15.520	15.636	15.426	14.800	15.346	2177.625	0.000	8.286	6.034	0.000	0.165	0.561	1.133

Table E-3H. Water balance data for the periods before, during and after the rainfall event at 260200.

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.												
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107252330	15.520	15.640	15.430	14.810	15.35000	2181.400	0.000	2181.291	0.170	15.520	15.640	15.430	14.810	15.350	2181.400	0.000	8.189	6.147	0.000	0.166	0.561	1.144
200107252345	15.520	15.640	15.430	14.810	15.35000	2181.400	0.000	2181.461	0.195	15.520	15.640	15.430	14.810	15.350	2181.400	0.000	8.185	6.147	0.000	0.166	0.561	1.115
200107260000	15.520	15.640	15.430	14.810	15.35000	2181.400	0.629	2181.656	0.218	15.520	15.640	15.430	14.810	15.350	2181.400	0.419	8.183	6.147	0.000	0.166	0.561	1.091
200107260015	15.521	15.641	15.431	14.810	15.35075	2182.029	0.000	2181.874	0.242	15.520	15.641	15.431	14.810	15.351	2181.820	0.210	8.183	6.147	0.000	0.166	0.562	1.066
200107260030	15.521	15.641	15.431	14.810	15.35075	2182.029	0.420	2182.116	0.266	15.521	15.641	15.431	14.810	15.351	2182.029	0.420	8.184	6.147	0.000	0.165	0.562	1.043
200107260045	15.521	15.642	15.432	14.810	15.35125	2182.449	0.420	2182.383	0.289	15.521	15.642	15.432	14.810	15.351	2182.449	0.210	8.184	6.147	0.000	0.165	0.561	1.021
200107260100	15.522	15.643	15.432	14.810	15.35175	2182.868	0.210	2182.671	0.313	15.522	15.642	15.432	14.810	15.352	2182.659	0.419	8.184	6.147	0.000	0.165	0.561	0.997
200107260115	15.522	15.643	15.433	14.810	15.35200	2183.078	0.420	2182.985	0.335	15.522	15.643	15.433	14.810	15.352	2183.078	0.210	8.185	6.147	0.000	0.165	0.561	0.976
200107260130	15.523	15.644	15.433	14.810	15.35250	2183.498	0.210	2183.319	0.357	15.523	15.643	15.433	14.810	15.352	2183.288	0.419	8.185	6.147	0.000	0.165	0.562	0.955
200107260145	15.523	15.644	15.434	14.810	15.35275	2183.707	0.419	2183.676	0.375	15.523	15.644	15.434	14.810	15.353	2183.707	0.210	8.185	6.147	0.000	0.164	0.561	0.937
200107260200	15.524	15.645	15.434	14.810	15.35325	2184.127	0.210	2184.051	0.395	15.523	15.645	15.434	14.810	15.353	2183.917	0.420	8.186	6.147	1.398	0.164	0.561	2.316
200107260215	15.524	15.645	15.435	14.810	15.35350	2184.337	0.210	2184.446	0.411	15.524	15.645	15.435	14.810	15.354	2184.337	0.210	8.186	6.147	0.699	0.164	0.561	1.601
200107260230	15.524	15.646	15.435	14.810	15.35375	2184.546	0.629	2184.858	0.426	15.524	15.646	15.435	14.810	15.354	2184.546	0.419	8.186	6.147	0.699	0.164	0.561	1.588
200107260245	15.525	15.647	15.436	14.810	15.35450	2185.176	0.000	2185.283	0.440	15.525	15.646	15.436	14.810	15.354	2184.966	0.210	8.187	6.147	0.000	0.163	0.561	0.875
200107260300	15.525	15.647	15.436	14.810	15.35450	2185.176	0.629	2185.723	0.450	15.525	15.647	15.436	14.810	15.355	2185.176	0.210	8.187	6.147	0.000	0.163	0.561	0.865
200107260315	15.526	15.648	15.437	14.810	15.35525	2185.805	0.000	2186.173	0.459	15.525	15.647	15.437	14.810	15.355	2185.385	0.419	8.187	6.147	0.000	0.163	0.561	0.857
200107260330	15.526	15.648	15.437	14.810	15.35525	2185.805	0.629	2186.632	0.466	15.526	15.648	15.437	14.810	15.355	2185.805	0.210	8.188	6.147	0.000	0.163	0.561	0.851
200107260345	15.527	15.649	15.438	14.810	15.35600	2186.434	0.210	2187.098	0.469	15.526	15.648	15.438	14.810	15.356	2186.015	0.419	8.188	6.147	0.000	0.163	0.561	0.847
200107260400	15.527	15.649	15.439	14.810	15.35625	2186.644	1.258	2187.567	0.470	15.527	15.649	15.438	14.810	15.356	2186.434	0.420	8.188	6.147	0.000	0.162	0.561	0.847
200107260415	15.527	15.650	15.439	14.815	15.35775	2187.902	1.468	2188.038	0.470	15.527	15.650	15.439	14.810	15.357	2186.854	2.307	8.189	6.204	0.000	0.162	0.562	0.791
200107260430	15.528	15.650	15.440	14.820	15.35950	2189.371	0.210	2188.507	0.466	15.528	15.650	15.439	14.820	15.359	2189.161	0.419	8.234	6.262	0.000	0.162	0.562	0.782

Table E-3I. Water balance data for the periods before, during and after the rainfall event at 271245.

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.												
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107271015	15.554	15.664	15.464	14.810	15.37300	2200.697	0.000	2201.399	-0.032	15.554	15.664	15.464	14.810	15.373	2200.697	0.000	8.089	6.147	0.000	0.122	0.570	1.282
200107271030	15.554	15.664	15.464	14.810	15.37300	2200.697	0.629	2201.367	-0.031	15.554	15.664	15.464	14.810	15.373	2200.697	0.000	8.087	6.147	0.000	0.121	0.570	1.279
200107271045	15.555	15.665	15.465	14.810	15.37375	2201.326	0.000	2201.336	-0.026	15.554	15.664	15.464	14.810	15.373	2200.697	0.629	8.084	6.147	0.000	0.120	0.571	1.272
200107271100	15.555	15.665	15.465	14.810	15.37375	2201.326	0.000	2201.310	-0.019	15.555	15.665	15.465	14.810	15.374	2201.326	0.000	8.082	6.147	0.000	0.120	0.571	1.263
200107271115	15.555	15.665	15.465	14.810	15.37375	2201.326	0.000	2201.291	-0.009	15.555	15.665	15.465	14.810	15.374	2201.326	0.000	8.080	6.147	0.000	0.119	0.571	1.251
200107271130	15.555	15.665	15.465	14.810	15.37375	2201.326	0.000	2201.282	0.004	15.555	15.665	15.465	14.810	15.374	2201.326	0.000	8.077	6.147	0.000	0.119	0.571	1.237
200107271145	15.555	15.665	15.465	14.810	15.37375	2201.326	0.000	2201.286	0.022	15.555	15.665	15.465	14.810	15.374	2201.326	0.000	8.075	6.147	0.000	0.118	0.571	1.216
200107271200	15.555	15.665	15.465	14.810	15.37375	2201.326	0.000	2201.308	0.043	15.555	15.665	15.465	14.810	15.374	2201.326	0.000	8.073	6.147	0.000	0.118	0.571	1.194
200107271215	15.555	15.665	15.465	14.810	15.37375	2201.326	-1.049	2201.351	0.069	15.555	15.665	15.465	14.810	15.374	2201.326	0.000	8.070	6.147	0.000	0.117	0.571	1.166
200107271230	15.555	15.665	15.465	14.805	15.37250	2200.278	0.000	2201.420	0.099	15.555	15.665	15.465	14.810	15.374	2201.326	-2.098	8.068	6.091	0.000	0.117	0.571	1.190
200107271245	15.555	15.665	15.465	14.805	15.37250	2200.278	1.049	2201.519	0.136	15.555	15.665	15.465	14.800	15.371	2199.229	2.098	8.066	6.091	2.797	0.116	0.571	3.949
200107271300	15.555	15.665	15.465	14.810	15.37375	2201.326	0.629	2201.654	0.177	15.555	15.665	15.465	14.810	15.374	2201.326	0.629	8.063	6.147	0.000	0.115	0.570	1.053
200107271315	15.556	15.666	15.466	14.810	15.37450	2201.956	0.000	2201.831	0.224	15.556	15.666	15.466	14.810	15.375	2201.956	0.000	8.061	6.147	0.000	0.115	0.571	1.003
200107271330	15.556	15.666	15.466	14.810	15.37450	2201.956	0.000	2202.056	0.278	15.556	15.666	15.466	14.810	15.375	2201.956	0.000	8.058	6.147	0.000	0.114	0.571	0.947
200107271345	15.556	15.666	15.466	14.810	15.37450	2201.956	1.049	2202.334	0.340	15.556	15.666	15.466	14.810	15.375	2201.956	0.000	8.056	6.147	0.000	0.114	0.571	0.884
200107271400	15.556	15.666	15.466	14.815	15.37575	2203.004	1.049	2202.674	0.350	15.556	15.666	15.466	14.810	15.375	2201.956	2.097	8.053	6.204	0.000	0.113	0.571	0.814
200107271415	15.556	15.666	15.466	14.820	15.37700	2204.053	0.000	2201.546	0.389	15.556	15.666	15.466	14.820	15.377	2204.053	0.000	8.051	6.262	0.000	0.113	0.572	0.715
200107271430	15.556	15.666	15.466	14.820	15.37700	2204.053	0.000	2201.935	0.373	15.556	15.666	15.466	14.820	15.377	2204.053	0.000	8.049	6.262	0.000	0.112	0.573	0.729
200107271445	15.556	15.666	15.466	14.820	15.37700	2204.053	0.000	2202.308	0.357	15.556	15.666	15.466	14.820	15.377	2204.053	0.000	8.046	6.262	0.000	0.112	0.573	0.744
200107271500	15.556	15.666	15.466	14.820	15.37700	2204.053	0.000	2202.665	0.341	15.556	15.666	15.466	14.820	15.377	2204.053	0.000	8.044	6.262	0.000	0.111	0.573	0.758
200107271515	15.556	15.666	15.466	14.820	15.37700	2204.053	0.629	2203.006	0.325	15.556	15.666	15.466	14.820	15.377	2204.053	0.000	8.041	6.262	0.000	0.110	0.573	0.771

Table E-3J. Water balance data for the periods before, during and after the rainfall event at 292130.

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.														
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107291900	15.492	15.562	15.397	14.800	15.31275	2150.147	-0.420	2150.397	-0.502	15.493	15.562	15.398	14.800	15.313	2150.567	-0.419	6.915	6.034	0.000	0.113	0.575	0.694
200107291915	15.492	15.561	15.396	14.800	15.31225	2149.728	-0.419	2149.895	-0.502	15.492	15.562	15.397	14.800	15.313	2150.147	-0.420	6.919	6.034	0.000	0.112	0.575	0.701
200107291930	15.491	15.560	15.396	14.800	15.31175	2149.308	-0.210	2149.393	-0.503	15.492	15.561	15.396	14.800	15.312	2149.728	-0.629	6.924	6.034	0.000	0.112	0.575	0.707
200107291945	15.491	15.560	15.395	14.800	15.31150	2149.099	-0.419	2148.890	-0.504	15.491	15.560	15.395	14.800	15.312	2149.099	0.000	6.922	6.034	0.000	0.111	0.575	0.705
200107292000	15.491	15.559	15.394	14.800	15.31100	2148.679	-0.839	2148.386	-0.504	15.491	15.560	15.395	14.800	15.312	2149.099	-0.629	6.921	6.034	0.000	0.110	0.575	0.706
200107292015	15.488	15.559	15.393	14.800	15.31000	2147.840	-1.888	2147.882	-0.505	15.490	15.559	15.394	14.800	15.311	2148.469	-1.888	6.937	6.034	0.000	0.110	0.574	0.724
200107292030	15.480	15.558	15.393	14.800	15.30775	2145.952	-0.419	2147.377	-0.505	15.483	15.558	15.393	14.800	15.309	2146.582	-1.049	7.012	6.034	0.000	0.109	0.573	0.800
200107292045	15.479	15.558	15.392	14.800	15.30725	2145.533	-0.629	2146.872	-0.506	15.479	15.558	15.392	14.800	15.307	2145.533	-0.210	7.017	6.034	0.000	0.109	0.573	0.807
200107292100	15.478	15.557	15.391	14.800	15.30650	2144.904	-1.259	2146.366	-0.506	15.479	15.557	15.392	14.800	15.307	2145.323	-0.419	7.020	6.034	0.000	0.108	0.573	0.812
200107292115	15.478	15.556	15.391	14.795	15.30500	2143.645	-1.468	2145.860	-0.507	15.478	15.557	15.391	14.800	15.307	2144.904	-2.727	7.023	5.977	0.000	0.108	0.572	0.873
200107292130	15.477	15.556	15.390	14.790	15.30325	2142.177	0.420	2145.353	-0.507	15.477	15.556	15.390	14.790	15.303	2142.177	-0.210	7.027	5.921	0.699	0.107	0.571	1.633
200107292145	15.476	15.555	15.389	14.795	15.30375	2142.596	0.629	2144.846	-0.507	15.477	15.555	15.390	14.790	15.303	2141.967	1.468	7.029	5.977	0.000	0.106	0.571	0.882
200107292200	15.475	15.555	15.388	14.800	15.30450	2143.226	-0.419	2144.339	-0.508	15.476	15.555	15.388	14.800	15.305	2143.435	-0.629	7.032	6.034	0.000	0.106	0.571	0.829
200107292215	15.475	15.554	15.387	14.800	15.30400	2142.806	-0.629	2143.831	-0.508	15.475	15.554	15.387	14.800	15.304	2142.806	-0.419	7.035	6.034	0.000	0.105	0.571	0.833
200107292230	15.474	15.553	15.386	14.800	15.30325	2142.177	-0.419	2143.324	-0.508	15.474	15.554	15.386	14.800	15.304	2142.387	-0.419	7.038	6.034	0.000	0.105	0.570	0.837
200107292245	15.473	15.553	15.385	14.800	15.30275	2141.757	-0.629	2142.816	-0.508	15.474	15.553	15.385	14.800	15.303	2141.967	-0.629	7.042	6.034	0.000	0.104	0.570	0.841
200107292300	15.472	15.552	15.384	14.800	15.30200	2141.128	-0.419	2142.308	-0.508	15.473	15.552	15.384	14.800	15.302	2141.338	-0.420	7.045	6.034	0.000	0.104	0.570	0.845
200107292315	15.472	15.551	15.383	14.800	15.30150	2140.709	-0.419	2141.799	-0.508	15.472	15.552	15.383	14.800	15.302	2140.918	-0.629	7.048	6.034	0.000	0.103	0.570	0.849
200107292330	15.471	15.551	15.382	14.800	15.30100	2140.289	-0.839	2141.291	-0.508	15.471	15.551	15.382	14.800	15.301	2140.289	-0.210	7.051	6.034	0.000	0.103	0.570	0.852
200107292345	15.470	15.550	15.380	14.800	15.30000	2139.450	-1.049	2140.783	-0.508	15.471	15.551	15.381	14.800	15.301	2140.079	-0.629	7.047	6.034	0.000	0.102	0.569	0.850
200107300000	15.470	15.550	15.380	14.795	15.29875	2138.401	-1.468	2140.274	-0.508	15.470	15.550	15.380	14.800	15.300	2139.450	-2.307	6.872	5.977	0.000	0.102	0.569	0.732

Table E-3K. Water balance data for the periods before, during and after the rainfall event at 311800.

	Data and Calculations based upon 15-minute mean stage.									Data and Calculations based upon instantaneous stage.												
Date and Time	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S) (noisy)	(ΔS) (noisy)	Storage (S) (smooth)	(ΔS) (smth)	G342A-T	G342B-T	G349A-T	G343B+H	Spatial Mean Stage	Storage (S)	(ΔS) (noisy)	Inflow	Outflow	Rainfall	Potential ET	Est. Seep-age	Est. Error
(yr.mo.da.time)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
200107311530	15.381	15.452	15.320	14.740	15.22325	2075.057	0.210	2074.784	-0.026	15.382	15.451	15.320	14.740	15.223	2075.057	0.000	6.550	5.368	0.000	0.142	0.570	0.496
200107311545	15.381	15.453	15.320	14.740	15.22350	2075.267	-0.210	2074.758	0.059	15.381	15.452	15.320	14.740	15.223	2075.057	0.000	6.530	5.368	0.000	0.141	0.571	0.391
200107311600	15.380	15.453	15.320	14.740	15.22325	2075.057	0.210	2074.816	0.147	15.380	15.453	15.320	14.740	15.223	2075.057	0.210	6.517	5.368	0.000	0.141	0.571	0.289
200107311615	15.380	15.454	15.320	14.740	15.22350	2075.267	0.210	2074.964	0.233	15.380	15.454	15.320	14.740	15.224	2075.267	0.210	6.504	5.368	0.000	0.141	0.571	0.191
200107311630	15.380	15.455	15.320	14.740	15.22375	2075.476	0.000	2075.197	0.316	15.380	15.455	15.320	14.740	15.224	2075.476	0.000	6.508	5.368	0.000	0.140	0.571	0.112
200107311645	15.379	15.456	15.320	14.740	15.22375	2075.476	0.210	2075.513	0.389	15.379	15.456	15.320	14.740	15.224	2075.476	0.210	6.520	5.368	0.000	0.140	0.571	0.052
200107311700	15.379	15.457	15.320	14.740	15.22400	2075.686	0.210	2075.902	0.452	15.379	15.457	15.320	14.740	15.224	2075.686	0.210	6.531	5.368	0.000	0.139	0.571	0.000
200107311715	15.379	15.458	15.320	14.740	15.22425	2075.896	0.000	2076.354	0.501	15.379	15.458	15.320	14.740	15.224	2075.896	-0.210	6.543	5.368	0.000	0.139	0.572	-0.036
200107311730	15.378	15.459	15.320	14.740	15.22425	2075.896	0.210	2076.855	0.539	15.378	15.458	15.320	14.740	15.224	2075.686	0.210	6.555	5.368	0.000	0.139	0.571	-0.062
200107311745	15.378	15.460	15.320	14.740	15.22450	2076.106	1.258	2077.394	0.558	15.378	15.459	15.320	14.740	15.224	2075.896	0.210	6.567	5.368	0.000	0.138	0.571	-0.067
200107311800	15.378	15.461	15.320	14.745	15.22600	2077.364	1.049	2077.952	0.563	15.378	15.460	15.320	14.740	15.225	2076.106	2.097	6.579	5.423	7.691	0.138	0.570	7.577
200107311815	15.377	15.462	15.320	14.750	15.22725	2078.413	1.259	2078.514	0.550	15.377	15.461	15.320	14.750	15.227	2078.203	0.210	6.591	5.477	2.797	0.137	0.569	2.655
200107311830	15.377	15.463	15.320	14.755	15.22875	2079.671	1.049	2079.064	0.521	15.377	15.462	15.320	14.750	15.227	2078.413	2.307	6.449	5.532	2.098	0.137	0.568	1.789
200107311845	15.377	15.463	15.320	14.760	15.23000	2080.720	0.000	2079.585	0.475	15.377	15.463	15.320	14.760	15.230	2080.720	0.210	6.154	5.587	0.699	0.137	0.567	0.087
200107311900	15.376	15.464	15.320	14.760	15.23000	2080.720	0.210	2080.059	0.417	15.377	15.464	15.320	14.760	15.230	2080.930	0.000	6.162	5.587	0.699	0.136	0.565	0.155
200107311915	15.376	15.465	15.320	14.760	15.23025	2080.930	0.210	2080.476	0.341	15.376	15.465	15.320	14.760	15.230	2080.930	0.210	6.161	5.587	0.000	0.136	0.563	-0.466
200107311930	15.376	15.466	15.320	14.760	15.23050	2081.140	0.000	2080.817	0.262	15.376	15.466	15.320	14.760	15.231	2081.140	0.210	6.161	5.587	0.000	0.136	0.561	-0.385
200107311945	15.375	15.467	15.320	14.760	15.23050	2081.140	0.210	2081.079	0.162	15.376	15.467	15.320	14.760	15.231	2081.349	0.000	6.161	5.587	0.000	0.135	0.560	-0.283
200107312000	15.375	15.468	15.320	14.760	15.23075	2081.349	0.210	2081.241	0.067	15.375	15.468	15.320	14.760	15.231	2081.349	0.000	6.635	5.587	0.000	0.135	0.558	0.288
200107312015	15.375	15.469	15.320	14.760	15.23100	2081.559	0.000	2081.308	-0.034	15.375	15.468	15.320	14.760	15.231	2081.349	0.210	6.787	5.587	0.000	0.134	0.558	0.542
200107312030	15.374	15.470	15.320	14.760	15.23100	2081.559	0.000	2081.274	-0.150	15.375	15.469	15.320	14.760	15.231	2081.559	0.000	6.781	5.587	0.000	0.134	0.559	0.651

General Interpretation of the Relationship between Rainfall and Error

Based upon the limited data analyzed here, it would seem that rainfall recorded at the single gage in the center of STA-5 does not adequately reflect the volume of rainfall that falls on Cell 1A, the farther parts of which are over one mile from the gage. However, there are no spikes in error that occur apart from gage-recorded rainfall events, i.e., spikes we would expect to see if there were rainfall over Cell 1A and not over the gage.

Although there are breaks in the smooth curve that is used in an attempt to obtain better estimates of ΔS between 180615-180630, 190515-190530, 211545-211600*, 230500-230515*, 231300-231315*, 251545-251600*, 261215-261230, 271400-271415*, 311345-311400, 312030-312045 (times marked with an asterisk (*) are at or near spikes in estimated error), these do not seem to be the source of the spikes, as they would still be present if estimated error were calculated using only the unsmoothed mean or instantaneous stage (or storage) data.

Leading and/or lagging of ΔS with respect to rainfall may be due to the inherent, erratic nature of rainstorms, in both the spatial and temporal dimensions. Also, the lack of response by recorded stage (or calculated storage) to the minimal rainfall amounts could be a result of the nature of the storm. For instance, it may drizzle all day, taking that amount of time to fill up the bucket of the tipping-bucket gage, but the bucket tips in what appears as an instant in the data records, creating the illusion of a much more intense rainfall event than actually occurs.

Correlation of Error with Inflow and Net Inflow

Graphs of estimated error (ε) versus inflow (I) and net inflow (I – O + R – ET) show linear relationships of some strength (**Figures E-9 and E-10**). Removal of data points corresponding to time intervals near (0, 1, or 2 time steps away from) rainfall events as well as those that correspond to high changes in inflow (magnitude of change > 0.069 ac-ft; about 5.5% of the data)—as has been done for the construction of **Figures E-9** and **E-10**—makes for a stronger relationship. In each figure, the data appear to be clustered into two groups, because there are no data points in the low positive range for net inflow and none in the medium range for inflow. Note that calculated flows were within about 10% of measured flows in the calibration study for inflow from the G342 structures (Nair 2003a). This 10% implies that the estimated mean accuracy for inflow is about 28 cfs (0.56 ac-ft / 15-min.) and for the highest flow, 39 cfs (0.81 ac-ft). Taking the same 10% figure for outflow accuracy (which could be worse than 10%, since the weir equation for the G343 structures has yet to be calibrated), yields an estimated accuracy of 0.55 ac-ft for the mean flow and 0.72 ac-ft for the maximum flow.

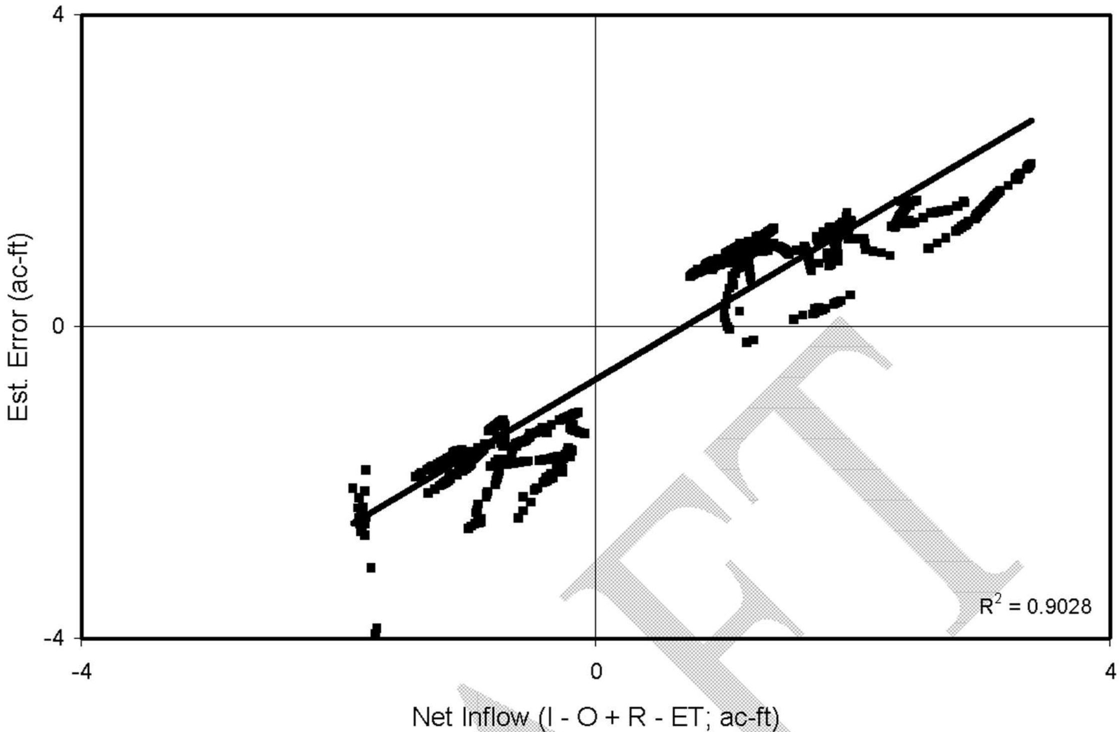

Figure E-9. Correlation of e and net inflow in Cell 1A (cumulative volumes over 15-minute intervals), after removal of select data points. Calculation of error is based on smoothed values of ΔS.

Correlation of Error with Rainfall

A plot of estimated error together with net inflow (I – O + R – ET; **Figure E-11**) seems to indicate that spikes in error are associated with spikes in rainfall (rainfall events are the cause of the spikes in net inflow). However, the values of estimated error are only weakly correlated with values of rainfall.

Spikes in error in the same time-frame as rainfall events may be due to the spatial variability of rainfall patterns, thus the amount of rainfall recorded by the rain gage at the center of STA-5 may not accurately reflect the total volume of water received by STA-5 in a 15-minute interval (recall the large size of STA-5: 4118 ac or 6.43 sq. mi. and over 3 miles long).

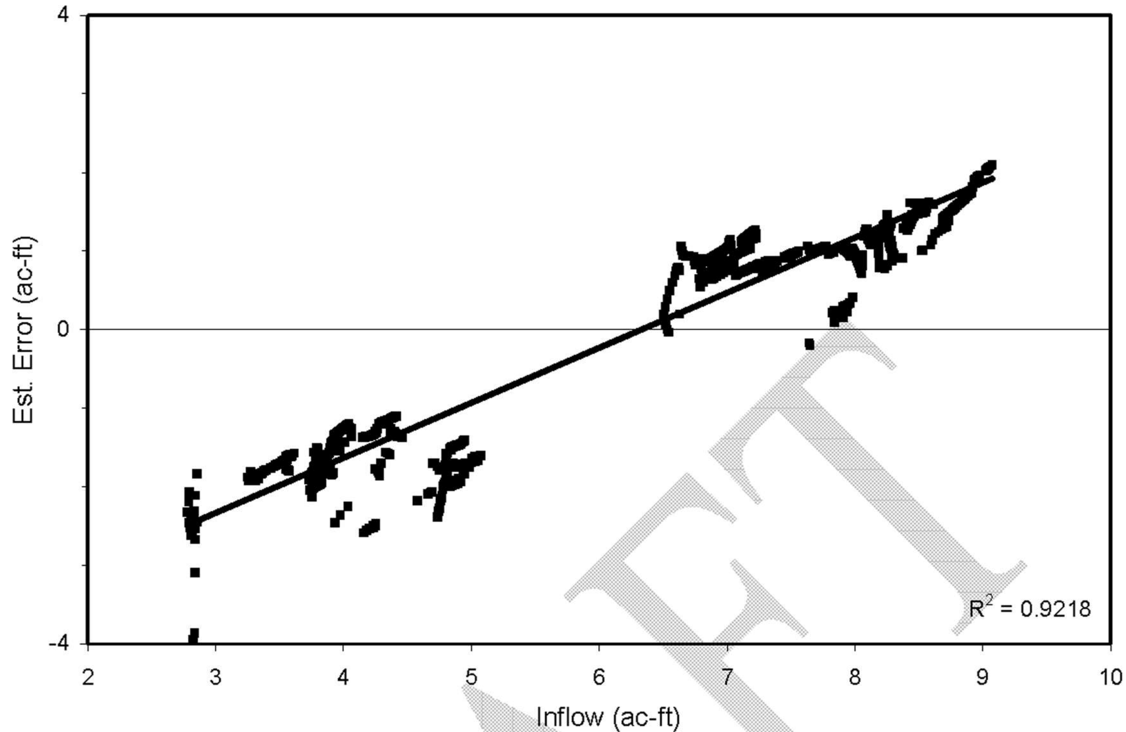

Figure E-10. Correlation of ε and inflow (cumulative volumes over 15-minute intervals) in Cell 1A, after removal of select data points. Calculation of error is based on smoothed values of ΔS.

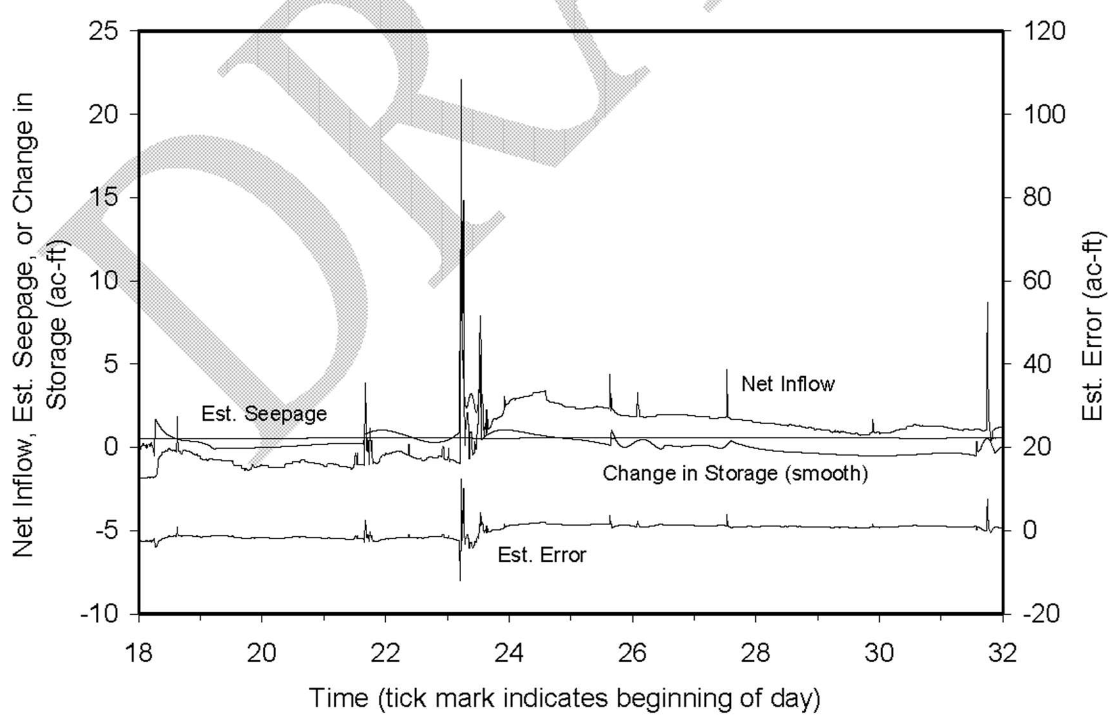

Figure E-11. Incremental (15-min.) water budget for Cell 1A. Net inflow is I – O + R – ET.

Effect of slight variation in ΔH for weirs G343

Differences between measured and actual headwaters at the G343 structures contribute to error at a level between that of rainfall and potential ET. Flow at the G343 structures for each flow way was estimated using the weir equation:

$$Q = NCKL\,(H - H_W)^{1.5} \qquad \text{(E-4)}$$

where N = 4 = number of weirs in each flow way, C = 2.2 = weir coefficient, K = 1.546 = a conversion factor, L = 30 ft = approximate length of one weir when the low level outlet weirs are closed, H_w = 14 ft = weir invert (NGVD), H = water stage upstream of weir (ft NGVD). According to this equation, a measured upstream stage of 14.9 ft (the maximum value in data analyzed here) yields a flow of 348.480 cfs. Supposing the actual upstream stage to be 14.905 (being the greatest possible value within the precision bound), the actual flow would be 351.387 cfs using the same equation; this yields a difference of 2.907 cfs or 0.060 ac-ft over a 15-minute period. Clearly, the limitation on weir head precision, as far as it affects the calculation of flow in one of the regions of STA-5, is far less important than the limitation on the precision of stage and change in storage (cf. **Table E-2**). Note that equation (E-4) is provisional, as the relationship between head and flow is not precisely known, although equation (E-4) is based upon the rating curve for a geometrically similar weir. Nair (2003b) is presently developing a weir equation for the G343 structures.

Effect of Approximating Geometry on Storage Accuracy

The calculations of storage presented here assume that each half of each cell is shaped like a rectangular box. Because of the great horizontal extent of STA-5, the slope of the levees was found to be of minimal significance. For example, the storage change for July 27th, from 10:30 PM to 10:45 PM is 2.0975 ac-ft assuming rectangular geometry (measured stage increases from a spatial average of 15.37925 to 15.38175 ft. and the area is 839 ac), while the storage change under the assumption of sloped (3:1) sides is 2.1092 ac-ft, for a difference of .0117 ac-ft. This is below the limitation on storage precision of ET (cf. **Table 2**).

Storage Calculation and Error (Daily Budget)

The error term (calculated using the smoothed values of ΔS) for the 15-minute data ranges from about -4 to 2 ac-ft, which is about the same as the range for round off error—the best situation possible, given the precision of the data. Additionally, 15-minute error may be related to inflow as discussed above.

The daily budget was examined in light of the analysis performed on the 15-minute data. The error term for the daily analysis is typically well outside of the range that could be attributed to round off error; also, error spikes occurred at times other than at times of rainfall. However, if different interpretations of the stage data are allowed when computing storage—in Cell 2 over WY03 (May 1, 2002 to April 30, 2003), for example—then we may compute a difference between two values of ΔS. Two methods for calculating storage in Cell 2B are:

$$S = \tfrac{1}{3} \Sigma_{i=1,2,3} H_i - H_0 \qquad \text{(E-5a)}$$

and

$$S' = 0.85\,H_1 + 0.15\,(H_2 + H_3)/2 - H_0 \qquad \text{(E-5b)}$$

where H_1 is the tailwater stage at G343F, H_2 and H_3 are the headwater stages at G344C and G344D and H_0 = 11.50 ft is the mean ground surface elevation. The coefficients 0.85 and 0.15 were chosen so as to minimize the sum of error magnitudes of water budget error that would result if equation (E-5b) were used in order to compute stage—and change in stage—of Cell 2B. There are many ways in which storage could be computed; the difference between ΔS and $\Delta(S')$ is an estimate of the range of values that could be computed for the change in storage in Cell 2, i.e., an estimate of the accuracy of the calculation of ΔS. **Figure E-12** presents a plot of the water budget error versus $\Delta(S') - \Delta S$ (Note that data points falling on days with rainfall have been removed). Note that while the linear relationship between the two quantities is not of overwhelming strength, the best-fit line, having a slope very near to one, suggests that the error term has a component that is in direct proportion to $\Delta(S') - \Delta S$. Additionally, deviation of the error term from the trend line can be appreciated by considering the possible contributions of the errors in individual water budget terms. Inflow and outflow are accurate to within about ten percent (mean $\approx$ 22 ac-ft, max $\approx$ 64 ac-ft) of the calculated flow. ΔS has a round off error of up to 20.59 ac-ft. The difference between two ways to calculate change in storage for Cell 2A (equally weighted versus area-weighted) has a mean of about 8.5 ac-ft and a maximum of 66 ac-ft. Again, $\Delta(S') - \Delta S$ is only an estimate of the accuracy of ΔS and the actual value of ΔS could be further from the actual value than $\Delta(S') - \Delta S$ suggests.

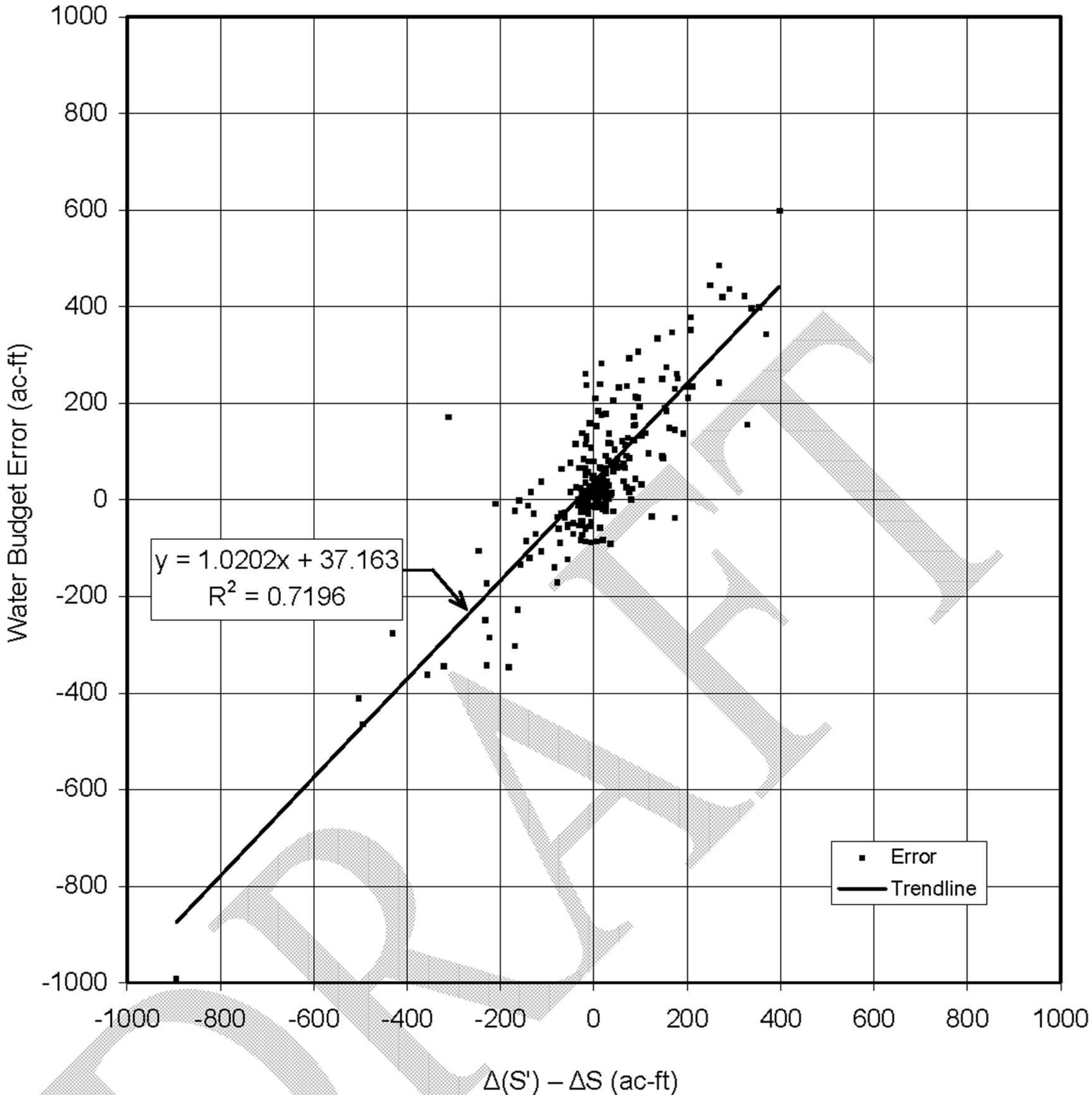

Figure E-12. Water budget error versus Δ(S') – ΔS.

Comparison of Daily and 15-Minute Errors

In order to compare the performance of the 15-minute budget against the daily budget, a daily budget for Cell 1A was produced using the same formulae as the 15-minute budget, with the exception of the time step; also, no smoothing was attempted, since it is not expected that change in stage should be smooth at increments of one day. The errors of the 15-minute budget are aggregated so that the daily and 15-minute errors can be compared (**Table E-4**). The 15-minute budget has errors of lesser magnitude than the daily budget for each day in the interval (14 days). Additionally, the accumulated daily budget error over the interval, produces a cumulative error many times greater than that for the 15-minute budget. Although this information, taken alone, would suggest a preference for analyzing the water budget on a 15-minute basis, a longer time-period should be analyzed in order to determine whether this is generally the case.

Table E-4. Comparison of errors for 15-minute and daily budgets.

Day in July 2001	15-Minute Budget Error (ac-ft)	(inches)	Daily Budget Error (ac-ft)	(inches)
18	-171.5	-2.45	-356.40	-5.10
19	-144.3	-2.06	-345.81	-4.95
20	-159.0	-2.27	-377.91	-5.41
21	-176.6	-2.53	-406.40	-5.81
22	-159.2	-2.28	-489.00	-6.99
23	-68.6	-0.98	-346.77	-4.96
24	151.4	2.16	-288.58	-4.13
25	133.3	1.91	-290.31	-4.15
26	117.3	1.68	-292.02	-4.18
27	103.8	1.49	-292.35	-4.18
28	94.5	1.35	-288.75	-4.13
29	75.9	1.09	-288.89	-4.13
30	98.9	1.42	-278.80	-3.99
31	79.4	1.14	-273.69	-3.91

Future Work

Surveys of the STA-5 structures have been budgeted for FY 2003-2004 and are planned for FY 2004-2005 (Pathak, 2003). At the present time, the elevations for the stage gages of STA-5 are based upon as-built drawings. The accuracy of the elevations is uncertain. The surveys should provide more accurate elevations and also provide information on the accuracy of those measurements. This new information may prompt revision of the coefficient of discharge for the inflow and outflow culverts, since the rating curve is dependent upon the gate opening and head difference across the culvert (comprised of two head measurements), where each is measured relative to a different datum (Pathak, 2003) and the datums may or may not be of the same numerical value. Available data on the accuracy of the flow through the G342 or G344 structures indicate that actual flow is typically within about 10 cfs of the calculated flow (Nair 2003a); this error produces a water budget error of within 0.2 ac-ft in 15 minutes, significantly less than the error in ΔS. Information from the planned survey should not produce changes in ΔS: consider each measurement of stage to consist of two addends, a datum and an offset from that datum. The differences between datums at different locations will not affect the calculated values of ΔS, since the differencing of two measurements taken at the same location will cancel the addends attributed to the datum.

This has been a first, cursory study of the water budget of STA-5 that focuses on the seepage and error terms; it encompasses a limited amount of data. Future studies may accommodate more data and may more closely examine the water budget over the other cells (1B, 2A, and 2B), flow ways (Cell 1, Cell 2) and/or the entire STA at the 15-minute level or at other time steps. They may make use of data from gages that began measuring head- and tailwaters at G343C and G343G in June of 2002. A more comprehensive study would take into account the nature of the statistical distribution of the round off error and would distinguish it from other components of the error term. It might also incorporate consideration of spatial variation of seepage potential.

Conclusion

Smoothing of storage data may not be necessary for calculating a seepage coefficient for STA-5; however, smoothing is an aid in shedding light on the nature of the error term, ε. Major sources of error are the method of calculating storage and change in storage, data precision of stage records and the ability (or inability) of a single rain gage to represent the volume of rain that falls over the 4,118 acres (more than 6 sq. mi.) STA-5. All spikes in error are due to rainfall events. Of the parameters considered in the water budget, error seems to be most strongly correlated with inflow.

Calculated values of changes in stage for Cells 1B and 2B seem to be the quantities most adversely affected by round off error, which, in turn, affect water budget error. Additional precision for ΔS could be obtained by ±0.0005 ft. precision stage gages at the G343 structures. Additional accuracy in ΔS could be accomplished by the addition of gages toward the down stream end of the B cells, but outside the influence of the gated outflow culverts, as well as at other locations that would be determined through future research.

Recommendations

Fifteen-minute records that correspond to times more than 30 minutes away from rainfall events show estimated errors with a mean magnitude of about 1.32 ac-ft and a range of -3.94 to 2.09 ac-ft. This, taken together with the fact that the precision of the ΔS term is ±8.39 ac-ft for Cell 1A (or 2A), suggests that increasing the precision of the ΔS term would improve the error term. The ΔS term may be improved to ±0.839 ac-ft precision by determining stage with ±0.0005 ft precision. The ΔS for Cell 1B (or 2B) may be improved from ±12.2 to ±1.22 ac-ft. However, this may be impractical considering site conditions like the effect of wind-driven stage fluctuations in larger treatment cells.

During and within 30 minutes of rainfall events, reduction of error may be achieved by a more accurate determination of the volume of rainfall over the cells of STA-5. A single gage appears to be inadequate for making this determination accurately enough to avoid the spikes in error that occur during and near rainfall events.

Rainfall events aside, if the error term is allowed to be composed of a systematic part and a random part, then the information presented above suggests that there may be a systematic error associated with the inflow equation and a random error associated with the precision of the stage data. Therefore, we suggest that the inflow equation be re-evaluated (thus treating the largest systematic error), and that an additional digit of precision be added to the stage data (thus treating the greatest contributor to random error).

More important for error reduction in the daily budget than improving the precision of the stage gages is determining an optimal formula for the computation of storage within STA-5 (or any of its cells) given the stage records. It may be desirable to add more gages in order to better account for the variation in stage across thousands of acres.

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