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Water Budget Analysis for Stormwater Treatment Area 6, Section 1

(Water Years 2003 and 2004; May 1, 2002 to April 30, 2004)

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By

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EXECUTIVE SUMMARY

This report presents a water budget for Stormwater Treatment Area (STA) 6, Section 1 for Water Year 2003 (May 1, 2002 through April 30, 2003) (WY2003) and Water Year 2004 (May 1, 2003 to April 30 2004) (WY2004). It follows the first two water budgets for STA-6 that covered calendar years 1998 and 1999 (Huebner, 2001), and WY1999 to WY2002 (Huebner, 2003). STA-6, Section 1, was the first of six stormwater treatment areas to be built as part of the Everglades Construction Project (ECP). It became fully operational on December 9, 1997, and is used to reduce the phosphorous concentration in runoff from approximately 10,400 acres of agricultural land north of STA-6. This study covers the fifth and sixth Water Years of STA operation.

STA-6, Section 1 is comprised of two bermed wetland treatment cells, Cell 3 and Cell 5, with a total effective treatment area of 870 acres (245 acres and 625 acres, respectively). Under typical operating conditions, the cells are designed to have water depths of 0.5 to 4.5 feet (ft), with a long-term design operating water depth of 2.0 ft. Water flows from west to east across the cells, then north to south in the discharge canal, and eventually discharges to the L4 canal through G607.

In WY2003 and WY2004, STA-6 received 108,925 ac-ft of water from pumping operations at G600_P. Of this amount, 92,195 ac-ft entered treatment Cells 3 and 5 at G601, G602, and G603. An additional 6,945 ac-ft were input to STA-6 from rainfall; 7,412 ac-ft were lost through evapotranspiration (ET). Estimated seepage was 24 percent of the water budget during this period, with a loss of 28,553 ac-ft to surrounding water bodies and the surficial aquifer. Outflow from STA-6 at G354 and G393 was 74 percent of the flow entering STA-6 at G601, G602, and G603, or 68,256 ac-ft. The amount of water stored in STA-6 increased by 512 ac-ft in two years. The error in the water budget was 11,753 ac-ft, or 10.7 percent of the budget. Water entering Cell 3 was retained for an average of 7 days in WY2003 and WY2004. The average retention time in Cell 5 was 18 days.

Estimated seepage constituted a large percentage of the water budget but was consistent with previous budget analysis. Mean hydraulic residence times continued to be lower than those observed at other STAs, yet the removal efficiencies remained high. Hurricane Kyle and Tropical Storm Edouard each came within three to four hundred kilometers of STA-6 during WY2003. These storms did not seem to affect rainfall at STA-6.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Stormwater Treatment Areas (STAs) are the cornerstone of Everglades restoration. Hydrologic analysis of STAs is vital to ongoing research and evaluation efforts to optimize their performance. The information provides a better understanding of the physical processes that are occurring, and ultimately offers a perspective on where water in the system is coming from, where it is going, and in what quantities.

This report presents a water budget for STA-6, Section 1 covering Water Year 2003 (May 1, 2002 through April 30, 2003) (WY2003) and Water Year 2004 (May 1, 2003 through April 30, 2004) (WY2004). When comparing the water budget for these water years to that of other water years, the following facts should be considered: from the beginning of WY1999, South and Central Florida experienced the end of a La Niña-influenced weather pattern. Hurricane Irene affected the area from October 14 through 17, 1999 (Abtew and Huebner, 2000), resulting in an average of 6.84 inches (in.) of rain over the South Florida Water Management District (SFWMD or District). One of the most severe long-term droughts ever to impact the area began in November 1999, and ended in September 2001. Rainfall during calendar years 1998, 1999, 2000, and 2001 was 55.94 in., 55.62 in., 39.46 in., and 53.25 in., respectively, compared with a historical average of 52.75 in.

This analysis is based upon a daily water budget for hydrologic units in STA-6. Daily results were aggregated in order to develop monthly and annual water budgets. The daily water budget accounted for inflow, outflow, rainfall, ET, seepage, storage, and error. This section of the report presents background information about STA-6, water budget analyses, and monitoring at STA-6. Sections describing the operation of STA-6 and the sources of data used for the report follow. The actual water budget analysis is presented after that, followed by a summary, conclusions, and recommendations.

Background

STA-6, Section 1 was the first of six STAs to be built and operated following the success of the prototype Everglades Nutrient Removal project begun in August 1994. Construction of STA-6 was substantially completed October 31, 1997. It was funded as part of the ECP, an element of the Everglades Program established by the Everglades Forever Act (§373.4592, Florida Statute). STA-6 received a discharge permit from the Florida Department of Environmental Protection, and became fully operational on December 9, 1997. Its principal purpose is to reduce phosphorous concentrations in runoff from U.S. Sugar Corporation's (USSC's) Unit 2 development (approximately 10,400 acres) north of STA-6. Prior to construction of STA-6, the area was a runoff detention area belonging to USSC. The Unit 2 development is now owned by the District. USSC continued to farm this area until the Spring 2005 harvest. Design of STA-6, Section 2 is in progress.

The water budget at STA-6 involves the following hydrologic/hydraulic components:

- Inflow by pump and over weirs
- Outflow over weirs
- Rainfall
- ET
- Seepage
- Change in storage
- Water budget error

Each component makes up an important part of the water budget for STA-6. The budget is developed for varying time periods ranging from one day to two years, using the following equation:

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

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	=	ET 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, volume per unit time. In the report, units of acre-feet (ac-ft) per unit time (day, month, year) are used. All of the terms can be determined from observation or estimated. The error term is determined by solving Equation 1 for the error term. In order to establish values for rainfall and ET, units (in inches or millimeters) are converted to feet, and multiplied by the effective surface area in acres (e.g., 245 acres for Cell 3) to get a volume of rainfall or ET for a selected time period. Change in storage is calculated by multiplying the effective surface area of each cell by the change in water surface elevation over time.

Two years' worth of daily mean stage, flow, rainfall, and ET data were used in this report. The data were analyzed using Equation 1 on daily, monthly, and annual and two-year (period of study) basis.

Site Description

STA-6 is in the southwestern corner of the Everglades Agricultural Area, adjacent to the Rotenberger Wildlife Management Area (RWMA). STA-6 and its location relative to major canals and roadways are shown in **Figure 1**. It is comprised of two treatment cells, Cell 3 and Cell 5, with a total effective treatment area of 870 acres (245 acres and 625 acres, respectively). The cells are bermed wetlands with structures that control inflow, outflow, and stage within the cells. Vegetation is described by Huebner (2001), based on a study by Geonex (1999). In general, vegetation consists of mixed wetland varieties for both cells. Cell 3 has 3 percent open water, whereas Cell 5 has nearly 15 percent open water. **Table A-1** in Appendix A contains a summary of site properties used in the water budget calculations for STA-6.

The treatment cells receive water via a supply canal west of the cells and east of the L-3 borrow canal (**Figure 2**). Under normal operating conditions, water enters the supply canal from the north through pump station G600_P. It can also enter the supply canal through G604 at the southern end of the supply canal, consisting of a set of five culverts with upstream flap gates. Water entering the supply canal through G604 is used to irrigate USSC's Unit 2 development to the north of STA-6. This water rarely enters the treatment cells because the stage in the canal is typically below the crest of the inlet weirs under the conditions prevalent during the dry season, when irrigation occurs.

There is one inflow weir (G603) for Cell 3, and two inflow weirs (G601 and G602) for Cell 5. Each treatment cell has a series of three outlet weir structures (Cell 3: G393A, B, and C; Cell 5: G354A, B, and C), through which water exits the cell. Under the current operation plan for STA-6, only one gate (G393B) is open for Cell 3 discharges, but all three gates (G354A, B, and C) are open in Cell 5. Treated water from each cell then enters a discharge canal that connects to the L4 canal (the canal runs east to west along the southern boundary of the EAA). It then flows east during the wet season, either to the District's S8 pump station and the Miami canal, or through a breech in the L4 levee to the northwest corner of Water Conservation Area 3A.

A full description of STA-6, its design and operation are provided in the Operation Plan Stormwater Treatment Area 6 (SFWMD, 2002b).

Monitoring

Two hydrologic parameters, stage and rainfall, were monitored at STA-6. Pump speed was also monitored. The depth of rainfall in inches was recorded at G600_R, located near pump station G600_P, and at a weather station (ROTNWX) located in the RWMA. The rainfall data were compared to rainfall amounts at nearby rainfall recording locations to check for potential data errors before they were uploaded to DBHYDRO. The station names, database (DB) keys, and station descriptions are shown in **Tables A-2** through **A-5** in Appendix A.

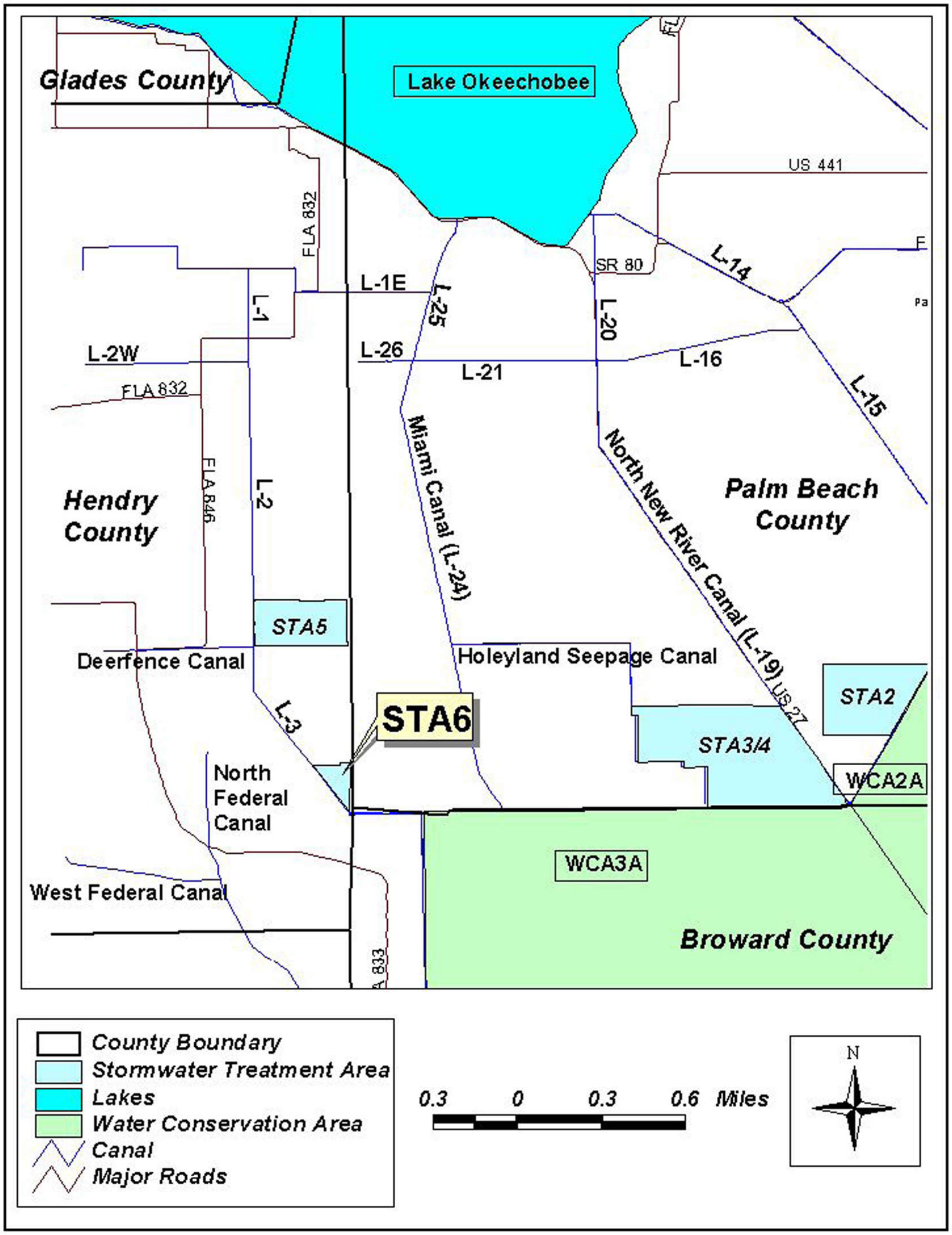

Figure 1. STA-6 Site map.

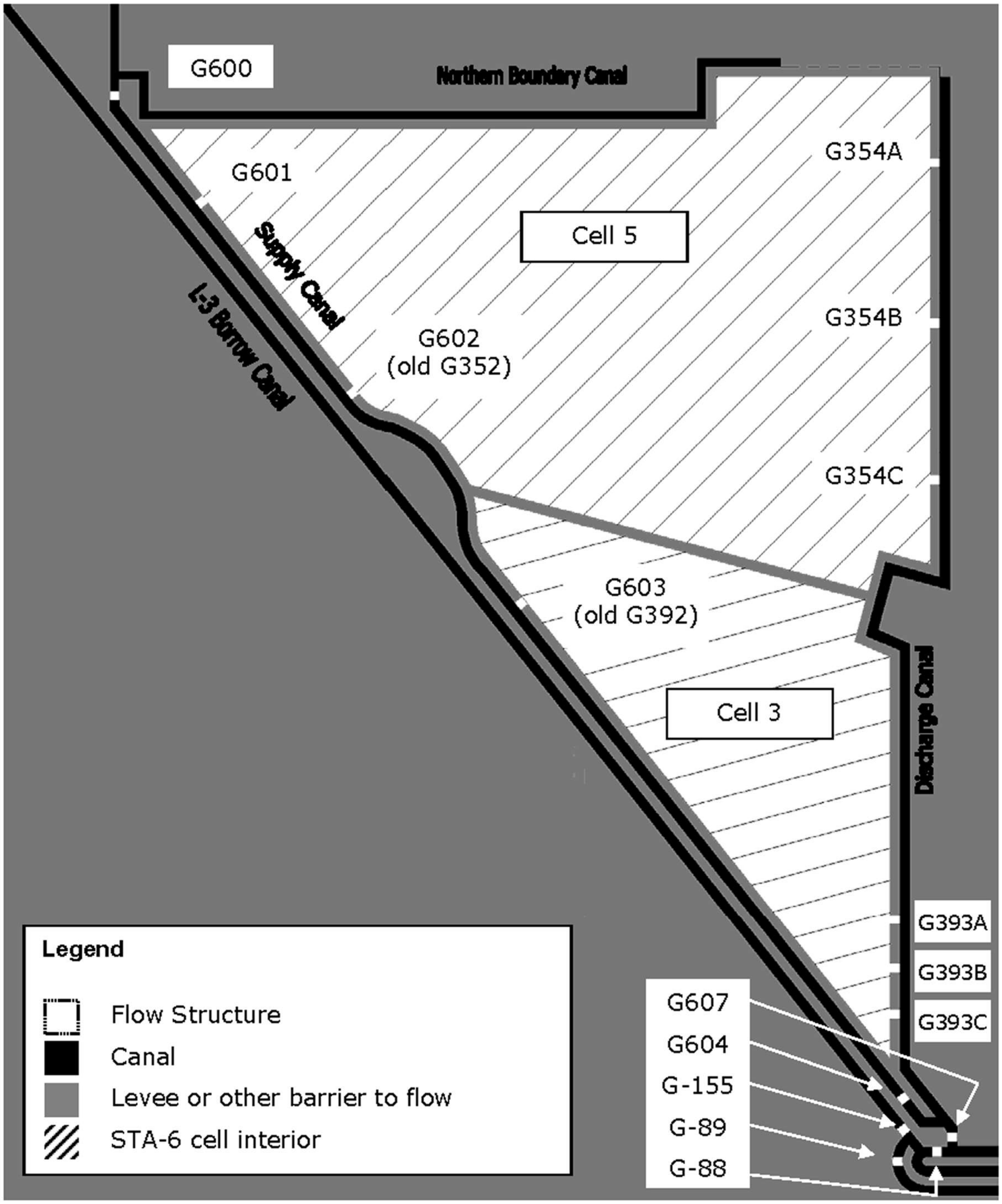

Figure 2. STA-6, Section 1 structure and monitoring locations. Not to scale.

See also
http://terraserver.microsoft.com/image.aspx?t=1&s=13&x=319&y=1821&z=17&w=1.

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 ET data used in this water budget analysis were derived from ET data for STA-1W. The station information for the ET data that was used in this study is listed in **Table A-5**.

STA OPERATION

The five pumps at station G600_P typically run during the wet season in order to drain agricultural fields to the north of STA-6. Each pump has a capacity of 100 cfs. The pumps are cycled on and off depending upon the amount of water to be withdrawn from the fields. This water discharges into the STA-6 supply canal and creates a hydraulic head on the inlet weirs, G601, G602, and G603 to Cells 3 and 5. The only inflow control for the treatment cells is accomplished by controlling the stage in the supply canal by varying the amount of water pumped at G600_P. Since Cell 3 has a surface area that is 28 percent of the total effective treatment area of STA-6 (245 acres vs. 870 acres), it was designed to treat 28 percent of the total inflow. The design of the inlet weirs was based upon this distribution of flow (SFWMD, 1997). The inlet weir crests for G601 and G602 (Cell 5) are set at 14.1 ft NGVD (National Geodetic Vertical Datum). The crest of the weir at G603 (Cell 3) is set at 14.2 ft NGVD. The maximum total design inflow for both cells together is 500 cfs. This value has never been exceeded. The maximum inflow since the start-up of STA-6 was 456.7 cfs, recorded at G600_P on October 18, 1999, and attributed to runoff caused by Hurricane Irene.

The cells are designed to have water depths of 0.5 to 4.5 ft under typical operating conditions. The average ground elevation of each cell is 12.4 ft NGVD. The long-term design operating depth is 2.0 ft (14.4 ft NGVD). The outlet weir boxes at G354A through C and G393A through C control the water-surface elevations in each of the treatment cells. The outlet weir crest elevations were originally set at 13.6 ft NGVD. During the first two years of operation, the outlet weir boxes at G354 (Cell 5) and G393 (Cell 3) were not level. In April 2000, weir plates were installed to correct this problem, leveling the weir crest. The crests of the weir plates are now set at 14.0 ft NGVD in Cell 3, and 14.1 ft NGVD in Cell 5. Each of the six outlet weir boxes is connected to gated culverts that allow water to flow into the STA-6 discharge canal. Normally, all three gates in Cell 5 (G354A through C) are open. In Cell 3, only one gate is usually open, G393B. Because of this, the maximum flow rate under normal operating conditions in Cell 3 is 140 cfs, which is 28 percent of the total design inflow of 500 cfs. Flow in the discharge canal goes to G607, a set of six culverts that connect the discharge canal to the L4 canal.

During extreme storm conditions all the outlet structures for Cells 3 and 5 are opened, and are operated at maximum capacity. Under drought conditions, minimum water levels in the cells should, to the greatest extent practicable, be maintained at 12.4 ft NGVD. This would maintain static water levels above the average ground surface elevation for approximately 50 percent of the treatment area.

HYDROLOGIC AND HYDRAULIC DATA

The following sections describe the data that were used for the water budget computations, and any special considerations for using the data. The source for the data was DBHYDRO, the District's corporate database (SFWMD, 2000a). The corresponding DB keys and station names are presented in Appendix A.

Rainfall

Daily rainfall data for STA-6 is collected at G600_R (near the inflow pumping station, G600_P). Missing values are filled based upon the best available information, usually from nearby rain gauges. The data are also compared to rainfall values at seven other nearby rain gauges in order to check for data errors. The data for G600_R are loaded into a preferred DB key every month; a final Quality Assurance/Quality Check (QA/QC) check is completed on a quarterly basis. This preferred DB key provides a high-quality continuous record of daily rainfall amounts.

G600_R, along with G600_P, are located at the northwest corner of the STA. The rain gauge at ROTNWX is located near the southeast corner of the STA in the RWMA. Data from the RWMA rain gauge was averaged with values from the G600_R gauge, and used for the mean daily rainfall at STA-6 for this report. **Tables B-1, B-2, Figures B-1** and **B-2** in Appendix B list the daily rainfall amounts recorded at G600_R, and ROTNWX for WY2003 and WY2004.

Hurricane Kyle and Tropical Storm Edouard each came within approximately 200 miles of STA-6 during WY2003 (NHC, 2004). Neither of these storms seemed to affect rainfall at STA-6.

Evapotranspiration

Daily ET data was taken from preferred DB keys for STA-1W. The data for ET in these DB keys were considered to be of the highest quality available. The DB key is populated with data using Equation 2, daily air temperature, and total solar radiation. **Tables C-1**, **C-2** and **Figure C-1** in Appendix C list the daily ET values used in this study.

$$ET = K_1 \frac{R_s}{\lambda} \quad (2)$$

where ET = ET

K_1 = empirical constant (= 0.53)

R_s = total solar radiation

λ = latent heat of vaporization (varies with air temperature)

Stage

Stage data are collected on an instantaneous basis, averaged, and recorded as daily mean stage in DBHYDRO. A headwater stage and a tailwater stage are needed in order to compute flow at each of the structures. As a result, more than one stage value was available for and used in computing average daily stage within each of the treatment cells. **Tables D-1, D-2, D-3,** and **D-4** show the mean daily stage values for Cell 3 and Cell 5, respectively.

Stage data was also used to estimate seepage to and from treatment cells and the STA. The equation used for seepage estimation is described below (Equation. 3). Seepage was driven by stage differences between each treatment cell and surrounding water bodies. Details are provided in Appendix E.

When the recorded stage in a treatment cell fell below the average ground elevation, a function was used to estimate the volume of water available for release or that was necessary to fill voids in the soils beneath the cells. Equations were developed for a falling and a rising water table from cumulative water gain and water release equations (Abtew et al., 1998), and are discussed in detail (Huebner, 2000).

Flow

Daily mean flow rates were determined using weir equations and pump performance curves. In this study, the daily mean inflow at G601, G602, and G603 was used for the cell water budgets. Inflow at G600_P was used for the STA-6 water budget. Since flow at G600_P is not equal to the sum of flows at G601, G602, and G603, there are discrepancies between cell water budgets and the STA water budget. Daily mean flows at G601, G602, G603 (inlet weirs), G354A through C, and G393A through C were computed using weir equations for each structure, and were recorded in DBHYDRO. Negative flow values were retained in the analysis. Daily mean flow that was negative had a relatively small value. Because these flows were based primarily on changes in stage data and the fact that stage data records have relatively few missing values, the daily average flow records at these stations were complete for the period of the study.

At G600_P, average daily flow is computed instantaneously using pump motor speed and headwater and tailwater elevation data. The daily average flow at G600_P is recorded in DBHYDRO, and reviewed monthly for accuracy and missing data. A complete record of daily average flow is loaded monthly into a preferred DB key in DBHYDRO. A final QA/QC check of the flow data in the preferred DB key is conducted quarterly.

In this study, the flows recorded for G601, G602, and G603 were considered to be less accurate than flow calculated at a pump, especially since the calibration of the weir coefficient has not been completed for G601, G602, and G603. On certain days in WY1999, WY2000, and WY2001, the sum of the flows at these weirs was greater than the inflow at G660_P. In this study, the flow was adjusted and as a result the sum of G601, G602, G603 was always equal to or less than the flow at G600.

Inflow values for Cell 3 and Cell 5 are nearly equal in both WY2003 and WY2004. Since though Cell 5 has two inflow weirs, normally Cell 5 inflow should be about twice as Cell 3 inflow values.

Outflow in this report was computed at weirs G354A, B, and C, and G393A, B, and C. Calibration work at these weirs has been completed for both years. The level of the weir box was corrected by adding plates to the weir box at these stations in April 2000.

Flow at stations G606 was not considered in this analysis, but the sum of the flow through the G354 and G393 structures was taken as the outflow of the entire STA-6.

Seepage

No direct measurement of seepage was made at the STA. A number of attempts to quantify seepage at wetland treatment sites like STA-6 have been made. They are discussed extensively in Huebner (2001). In general, seepage losses have been reported on the order of 2.0 to 5.6 cubic ft per second per mile of levee per foot of head difference (cfs/mi/ft). Huebner (2001) also shows the groundwater flow regimen around STA-6 for dry and wet periods, with and without the STA. In general, the regional groundwater table gradient is from north to south. Because of the impounding of water within the STA, the local gradients carry water out of the STA to the surrounding shallow aquifer and nearby canals.

In this analysis, seepage was computed as:

$$G = 1.983 * K_{sp} * L * \Delta H \quad (3)$$

where

G	=	levee (horizontal) and deep (vertical) seepage (ac-ft/d)
K_{sp}	=	coefficient of seepage (cfs/mi./ft)
L	=	length along the seepage boundary (mi.)
ΔH	=	hydraulic head difference between the unit and the boundary (ft)
1.938	=	constant to convert from cubic ft per second (cfs) to ac-ft/d

The value of K_{sp} was optimized by minimizing the sum of the squared daily error in the water budget for the six-year period from WY1999 to WY2004, even though the study is for WY2003 and WY2004 water budget. This report differs from previous reports in as much as a different seepage coefficient was used for each treatment cell.

WATER BUDGET

Methodology

Three sets of water budgets were produced; one for each treatment cell, and one for the entire STA. Water budgets were computed on a daily, monthly, annual and biannual basis using Equation 1. Terms in Equation 1 were converted to ac-ft per unit time (day, month, or year, depending on the period being used for the water budget calculations). The Water Year used in this report extends from May to April, and was used for the annual and biannual periods. Wet season months are June through October, and the dry season extends from November to May.

Results

Cell 3

Table 1 and **Figure 3** show the biannual and annual water budgets for Cell 3 for WY2003 and WY2004. Cell 3 is south of Cell 5. It is the smaller of the treatment cells at STA-6, covering 245 acres. Inflow was measured at G603; outflow was recorded at weir boxes G393A, B, and C. Error in the biannual water budget was 12.5 percent. Seepage was 16 percent of the biannual water budget. Outflow through weir boxes G393A through C was 70 percent of the inflow to Cell 3, measured at G603.

Table 2 contains the monthly water budget for Cell 3. The mean daily error in the monthly water budget analysis shown in **Table 2** is less than 2.0 in. for 23 months, and less than 1.0 in. for 13 of the 24 months in the period. The seepage coefficient used for the water budget for Cell 3 was 5.05 cfs/mi/ft, which is within the values found in the literature.

Figure 3 presents the components of the water budget for each water year. **Figure 4** shows the daily errors or residuals in the Cell 3 water budget for WY2003 and WY2004. Cell 3 displayed the lower amount of variation in the water budget residuals. **Figure 5** depicts the estimated seepage into and out of Cell 3. The variation in Cell 3 inflow, outflow, and stage is depicted in **Figure 6. Figure** 7 shows the stage in Cells 3 and 5, versus that in the supply and discharge canals and in Cell 5.

Table 1. Cell 3 Annual Water Budget Summary (ac-ft), WY2003 to WY2004.

Cell 3	Inflows				Outflows				ΔS	r	ε
	Is	Ig	P	Σinflow	Os	Og	ET	Σoutflow			
WY2003	25,077	508	952	**26,536**	14,376	3,277	1,043	**18,695**	687	7,154	31.6%
WY2004	19,528	67	1,004	**20,599**	16,861	4,677	1,045	**22,582**	-344	-1,639	-7.6%
TOTAL	44,605	575	1,956	**47,135**	31,237	7,953	2,087	**41,277**	343	5,515	12.5%
% inflow	95%	1%	4%	**% outflow**	76%	19%	5%				

Notes:

1. All values in ac-ft
2. I_s measured at G603
3. P is average of values at G600_R and ROTNWX
4. O_s measured at G393B
5. ET data is from STA-1W
6. Ig and Og estimated based on head differences between cell water levels and surrounding water levels using a seepage coefficient of: Cell 3=5.05 cfs/mi/ft, Cell 5=2.36 cfs/mi/ft
7. ΔS for water levels below average ground level estimated using equations developed by Huebner (2001), based on data available in Abtew et al. (1998)

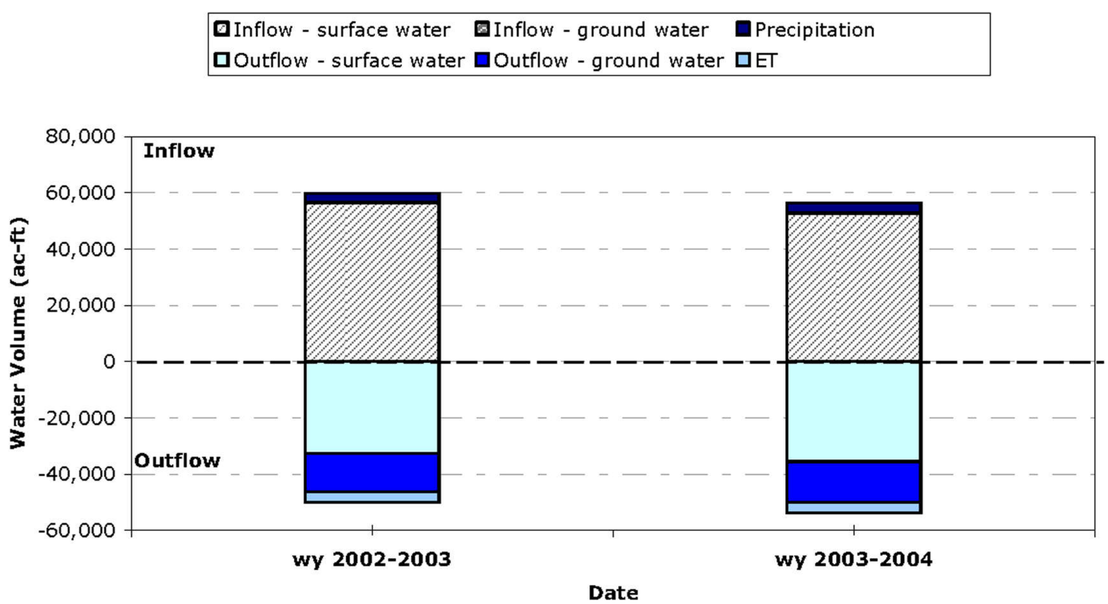

Figure 3. Cell 3 Annual Water Budget Summary, WY2003 to WY2004.

Table 2. Cell 3 Monthly Water Budget, WY2003 to WY2004.

Month-Year	Inflow surface water	Outflow surface water	Change in storage	Rain	ET	Seepage	Error	Daily Average Error
	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	in
May 2002	0.000	0.000	194.831	78.125	131.792	498.406	-746.904	-1.180
Jun 2002	2264.659	1073.267	670.432	198.219	85.681	-172.999	806.497	1.317
Jul 2002	4733.204	4184.114	30.376	226.309	102.527	17.170	625.326	0.988
Aug 2002	3677.447	2080.878	-0.965	112.036	96.941	-47.506	1660.135	2.623
Sep 2002	2414.546	1330.699	-37.624	27.887	90.034	-114.768	1174.092	1.917
Oct 2002	1368.055	614.033	-65.795	46.882	83.127	451.751	331.819	0.524
Nov 2002	1602.041	693.277	75.839	46.476	65.698	379.350	434.354	0.709
Dec 2002	2704.599	1538.476	-56.942	62.106	56.059	70.699	1158.413	1.830
Jan 2003	1603.801	709.337	31.479	8.374	68.989	153.729	648.641	1.025
Feb 2003	998.093	344.985	-23.023	17.259	72.288	668.746	-47.644	-0.083
Mar 2003	2533.334	1135.382	106.564	73.553	89.888	137.799	1137.254	1.797
Apr 2003	1176.872	671.121	-238.275	54.940	99.811	726.896	-27.741	-0.045
May 2003	1008.186	237.124	207.623	111.331	103.735	972.978	-401.943	-0.635
Jun 2003	2219.634	1829.762	-24.264	159.112	98.279	82.738	392.231	0.640
Jul 2003	1888.349	1605.852	-13.709	94.363	108.939	251.124	30.506	0.048
Aug 2003	3159.001	3978.096	71.161	137.751	87.205	77.177	-916.887	-1.449
Sep 2003	3786.208	4454.565	176.153	240.496	83.565	115.684	-803.262	-1.311
Oct 2003	1961.627	2415.843	-336.027	14.511	87.805	218.065	-409.547	-0.647
Nov 2003	978.920	548.847	-70.805	31.357	64.919	501.624	-34.308	-0.056
Dec 2003	1298.531	447.309	62.220	32.987	62.066	246.082	513.841	0.812
Jan 2004	271.821	9.574	20.462	59.228	68.851	636.732	-404.570	-0.639
Feb 2004	2078.348	958.078	95.903	70.067	73.342	61.847	959.245	1.678
Mar 2004	877.496	375.993	-248.692	1.946	99.924	536.986	115.230	0.182
Apr 2004	0.000	0.000	-283.908	50.554	105.915	908.578	-680.031	-1.110

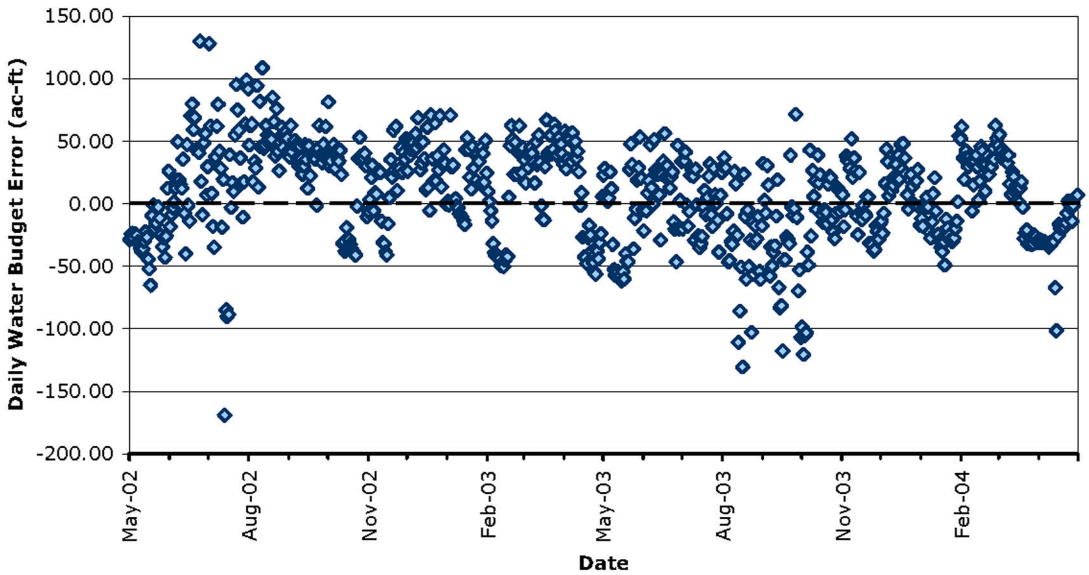

Figure 4. Cell 3 Daily Water Budget Error, WY2003 to WY2004.

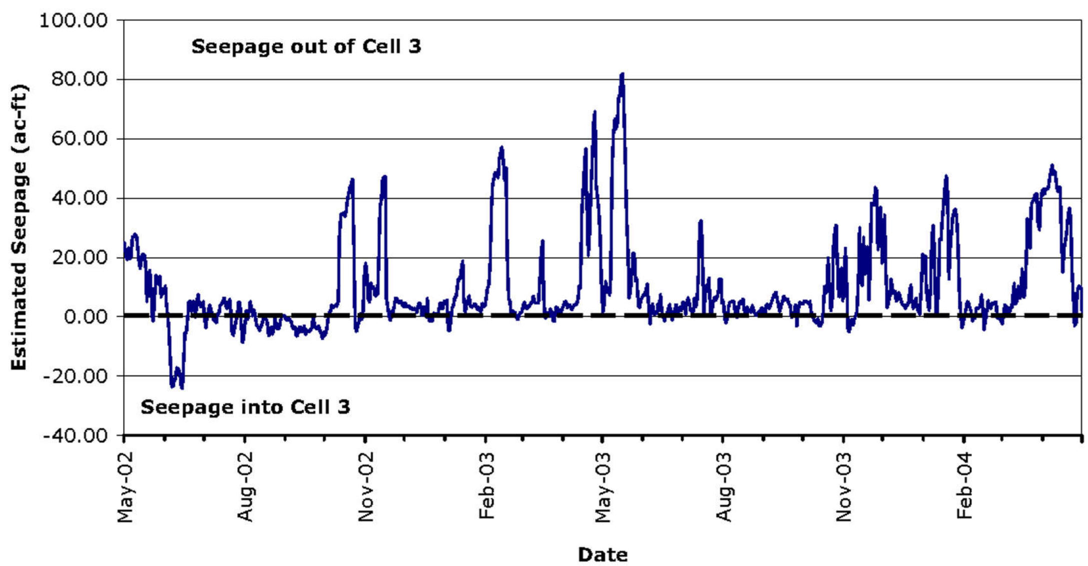

Figure 5. Cell 3 Estimated Seepage, WY2003 to WY2004.

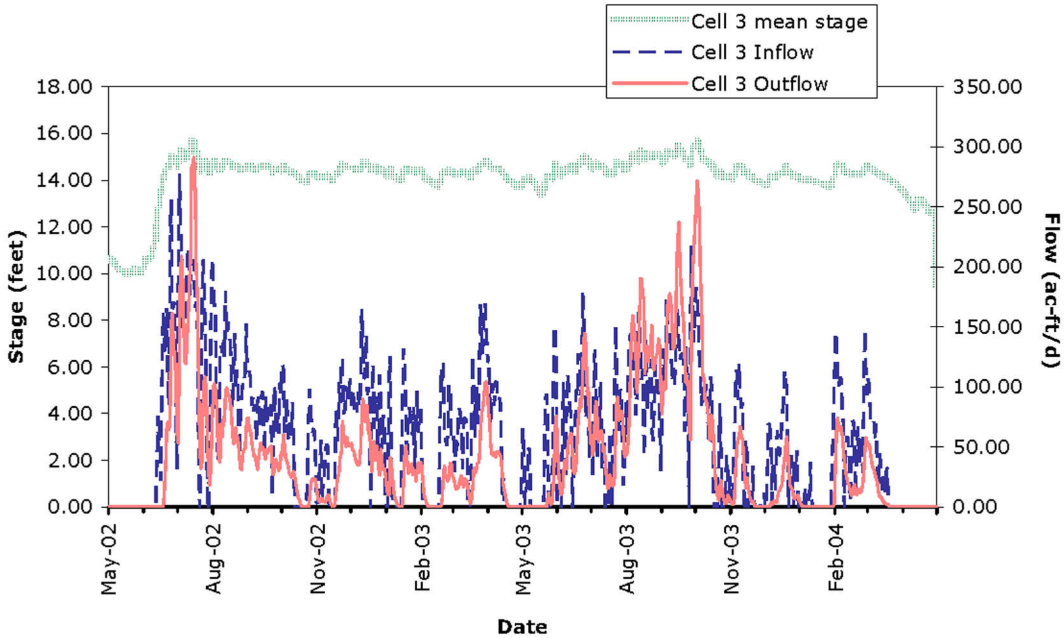

Figure 6. Cell 3 Inflow, Outflow, and Stage, WY2003 to WY2004.

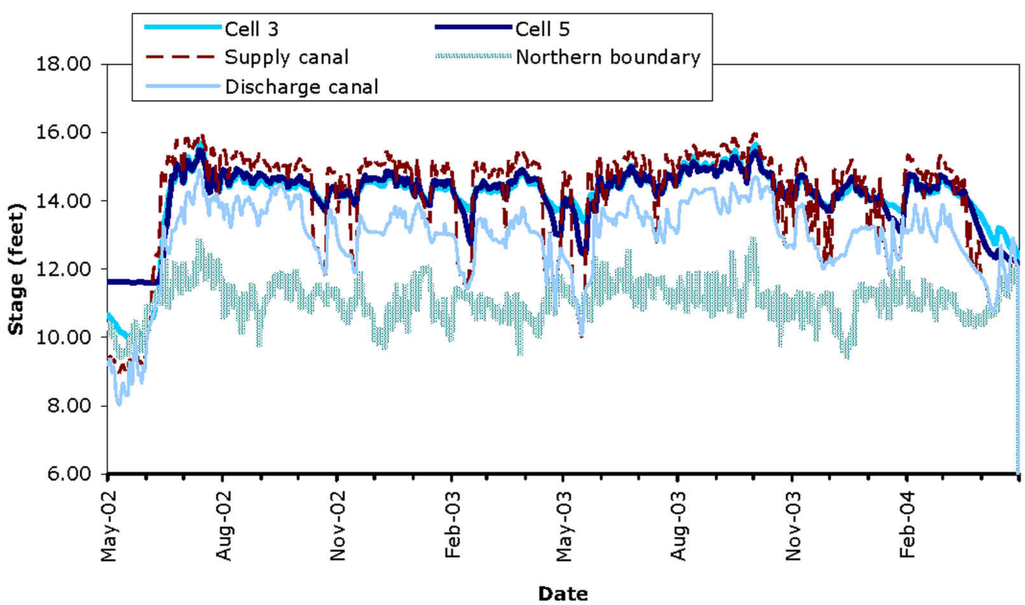

Figure 7. Stage in Cells 3, 5, and surrounding water bodies, WY2003 to WY2004.

Cell 5

Table 3 and **Figure 8** shows the annual water budget for Cell 5. Cell 5 is the northern cell of the two treatment cells in STA-6. Inflow was measured at G601 and G602; outflow was recorded at G354A, B, and C.

As a percentage of the water budget, error for Cell 5 was -18.2 percent over the two years. **Figure 9** shows the residual error plot for the Cell 5 water budget. The seepage coefficient used for the Cell 5 water budget was 2.36 cfs/mi/ft, which agrees with values from the literature. Seepage constitutes 28 percent of the water budget. Proportionally, the water budget residuals for Cell 5 were on the same order as those for Cell 3.

Seepage into and out of Cell 5 is depicted in **Figure 10.** Stage in Cells 3 and 5 and in surrounding water bodies has been presented in **Figure** 7. 78 percent of the inflow to the cell at G601 and G602 left the cell at G354A, B, and C. **Figure 11** shows the inflow, outflow, and stage in Cell 5 for WY2003 to WY2004.

The monthly water budgets for WY2003 are shown in **Table 4**. The two columns on the right in the table show the monthly error in ac-ft/month, and the daily average error in inches. The average daily errors are less than 1.0 in for 21 months. The sum of the mean daily error was lower for Cell 5 than Cell 3, partially because the budget is being applied to a unit that has a much larger area (625 ac versus 245 ac for Cell 3)

Table 3. Cell 5 Annual Water Budget Summary (ac-ft), WY2003 to WY2004.

Cell 5	Inflows				Outflows				ΔS	r	ε
	Is	Ig	P	Σinflow	Os	Og	ET	Σoutflow			
WY2003	28,133	31	2,429	**30,593**	18,331	10,709	2,660	**31,700**	877	-1,984	-6.4%
WY2004	19,457	11	2,560	**22,028**	18,688	9,891	2,665	**31,244**	-707	-8,509	-31.9%
TOTAL	47,590	42	4,989	**52,621**	37,019	20,600	5,325	**62,944**	169	-10,493	-18.2%
% inflow	90%	0%	9%	**% outflow**	59%	33%	8%				

Notes:

1. All values in ac-ft
2. I_s measured at G601 and G602
3. P is average of values at G600_R and ROTNWX
4. O_s measured at G354 A, B, and C
5. Data from STA1W is used for ET.
6. Ig and Og estimated based on head differences between cell water levels and surrounding water Levels using a seepage coefficient of: Cell 3 = 5.05 cfs/mi/ft, Cell 5 = 2.36 cfs/mi/ft
7. ΔS for water levels below average ground level estimated using equations developed by Huebner (2001), based on data available in Abtew et al. (1998)

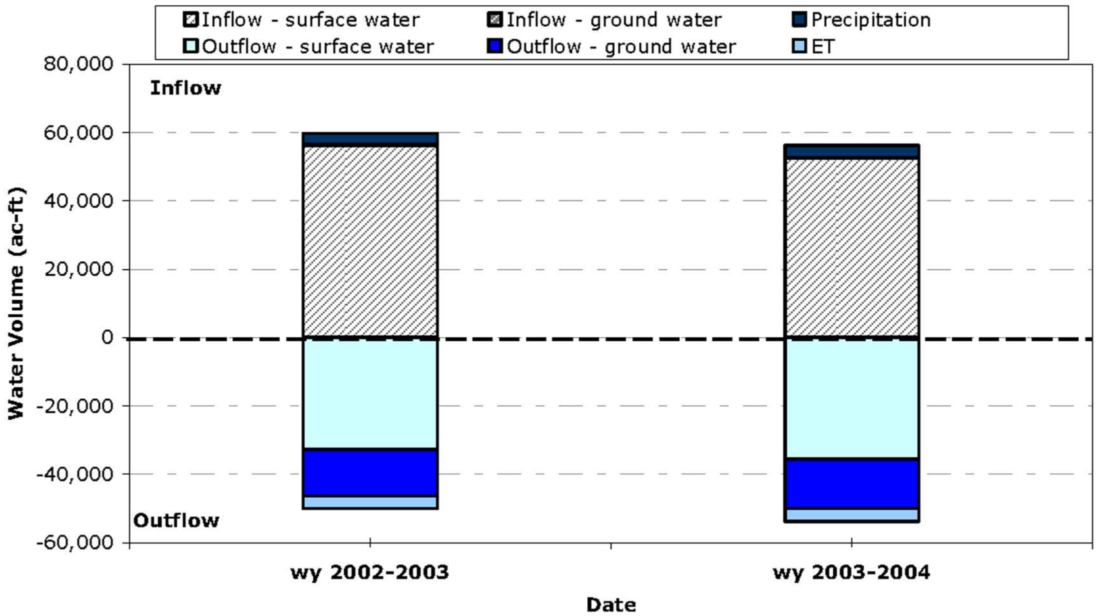

Figure 8. Cell 5 Annual Water Budget Summary, WY2003 to WY2004.

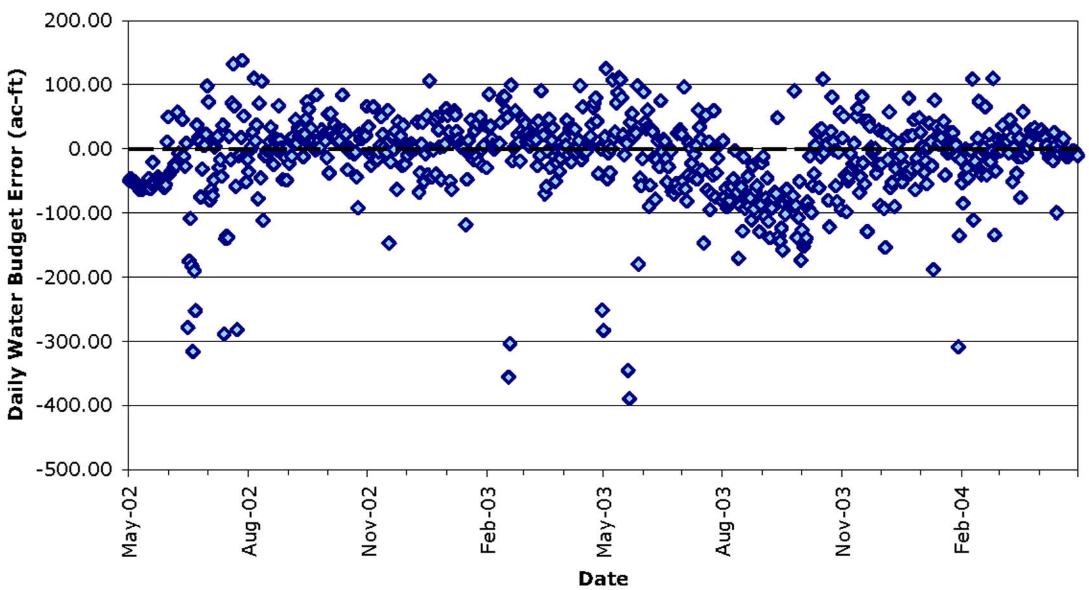

Figure 9. Cell 5 Daily Water Budget Error, WY2003 to WY2004.

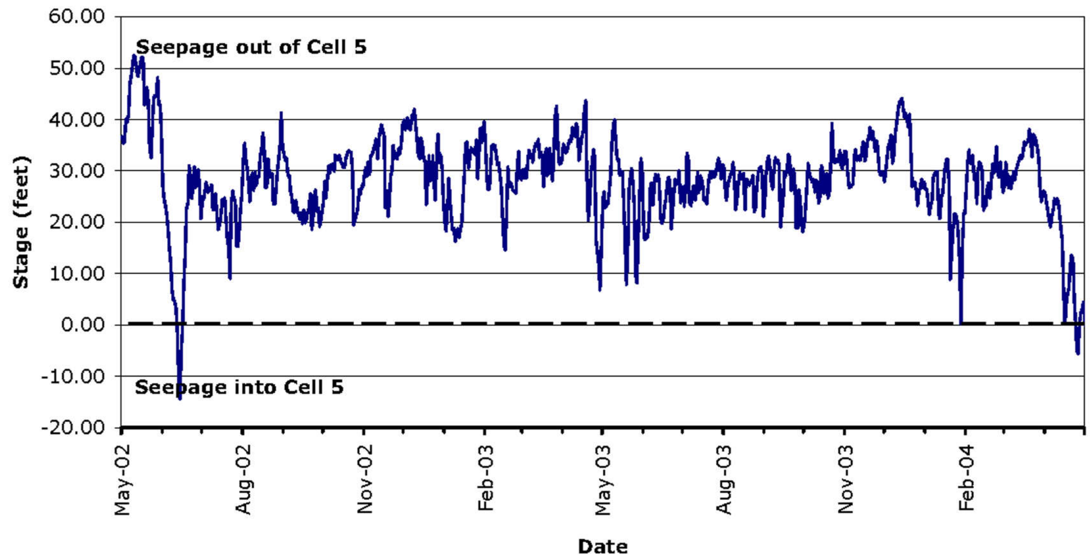

Figure 10. Cell 5 Estimated Seepage, WY2003 to WY2004.

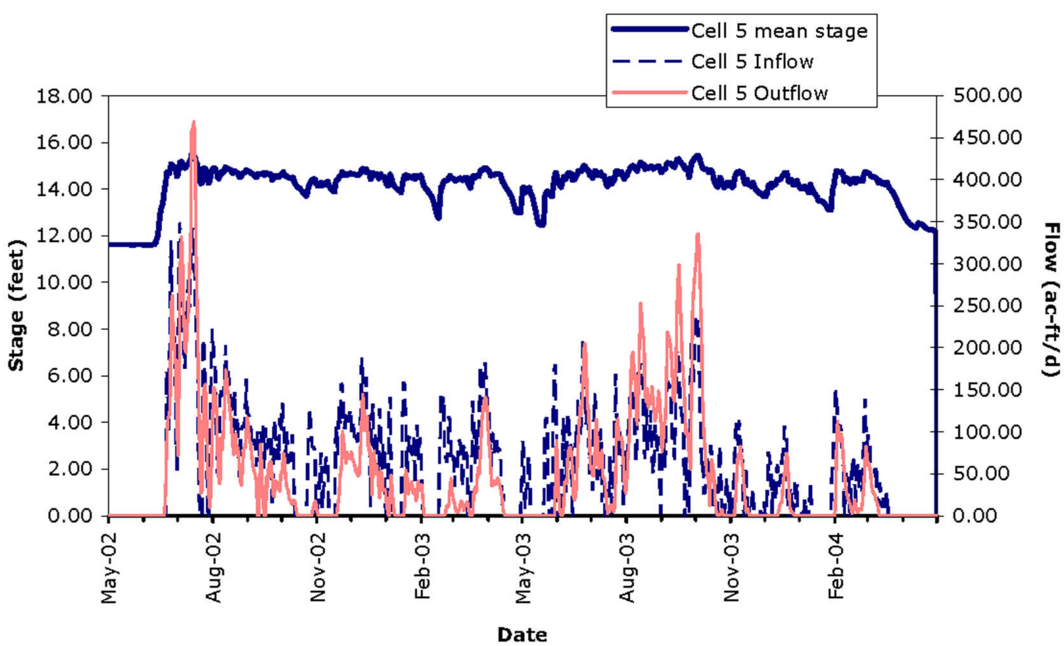

Figure 11. Cell 5 Inflow, Outflow, and Stage, WY2003 to WY2004.

Table 4. Cell 5 Monthly Water Budget, WY2003 to WY2004.

Month-Year	Inflow surface water	Outflow surface water	Change in storage	Rain	ET	Seepage	Error	Daily Average Error
	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	in
May 2002	0.000	0.000	-0.332	199.298	336.270	1367.058	-1503.698	-0.931
Jun 2002	1838.152	1679.599	1539.376	505.654	218.551	472.351	-1566.072	-1.002
Jul 2002	6018.586	6331.200	187.818	577.310	261.469	689.548	-874.140	-0.541
Aug 2002	4002.805	3056.264	-32.500	285.789	247.290	939.335	78.206	0.048
Sep 2002	2653.226	1301.798	-94.387	71.105	229.690	710.707	576.523	0.369
Oct 2002	1600.412	465.906	-244.347	119.567	212.066	899.166	387.189	0.240
Nov 2002	2073.914	748.752	269.997	118.521	167.616	968.260	37.810	0.024
Dec 2002	3062.052	2061.008	-204.056	158.391	142.980	1050.066	170.445	0.106
Jan 2003	1890.457	622.335	148.436	21.370	176.015	851.676	113.365	0.070
Feb 2003	1209.251	202.759	-84.684	44.020	184.373	788.929	161.893	0.111
Mar 2003	2690.906	1264.458	229.382	187.559	229.333	1015.774	139.518	0.086
Apr 2003	1093.170	597.131	-838.130	140.150	254.570	924.735	295.015	0.189
May 2003	1297.850	134.776	741.245	283.949	264.549	798.698	-357.469	-0.221
Jun 2003	2586.750	2300.710	-50.635	405.875	250.711	728.169	-236.329	-0.151
Jul 2003	1953.714	1665.250	0.024	240.691	277.958	861.112	-609.939	-0.378
Aug 2003	3238.731	4567.614	92.199	351.438	222.418	850.266	-2142.327	-1.327
Sep 2003	3420.251	5132.002	385.300	613.515	213.209	820.554	-2517.299	-1.611
Oct 2003	1835.534	2484.207	-662.471	36.991	223.934	900.601	-1073.746	-0.665
Nov 2003	911.026	518.422	-295.955	79.974	165.679	977.867	-375.012	-0.240
Dec 2003	1173.224	399.868	194.377	84.157	158.342	1055.319	-550.525	-0.341
Jan 2004	324.548	0.000	69.978	151.095	175.642	701.417	-471.394	-0.292
Feb 2004	1973.868	1158.510	275.939	178.714	187.097	839.329	-308.293	-0.211
Mar 2004	741.326	326.923	-1033.131	4.945	254.910	975.102	222.467	0.138
Apr 2004	0.000	0.000	-424.269	128.963	270.216	372.135	-89.118	-0.057

STA 6

Tables 5 and **Figure 12** contain the summary of the WY2003 and WY2004 water budget for the entire STA-6, which includes Cells 3 and 5, as discussed previously. Water budget error constituted 10.7 percent of the budget. Seepage was 24 percent of the water budget.

Table 6 shows the monthly water budget summary. The daily average errors are less than 1.0 in, except in May 2002. **Figure 13** shows the residual in the daily water budgets. The peaks in the residual plot occur during periods of high inflow, showing that the daily water budget under these conditions does not accurately quantify all of the hydrologic processes occurring in STA-6. Work recently completed for STA-5 indicates that this may be due to transient flow and stage conditions that take place in less than one day (Parrish and Huebner, 2004.). **Figure 14** presents the estimated seepage into and out of STA-6. It shows that there is a net loss of water seeping from STA-6 into the surrounding area. This is consistent with groundwater gradients depicted in **Figure 7**.

Figure 15 shows the daily inflow and outflow volumes for STA-6 for WY2003 and WY2004. **Figures 12** through **15** summarize the two-year and annual water budgets. Outflow from Cells 3 and 5 was 74 percent of the inflow recorded at G601, G602, and G603 during WY2003 and WY2004. **Figure 16** depicts the two-year water budget values for STA-6 for WY2003 and WY2004.

Table 5. STA6 Annual Water Budget Summary (ac-ft), WY2003 to WY2004.

STA 6	Inflows				Outflows				ΔS	r	ε
	Is	Ig	P	Σinflow	Os	Og	ET	Σoutflow			
WY2003	56,252	196	3,381	**59,829**	32,707	13,643	3,703	**50,052**	1,563	8,213	14.9%
WY2004	52,673	16	3,564	**56,254**	35,549	14,506	3,709	**53,764**	-1,051	3,540	6.4%
TOTAL	108,925	212	6,945	**116,082**	68,256	28,149	7,412	**103,817**	512	11,753	10.7%
% inflow	94%	0%	6%	**% outflow**	66%	27%	7%				

Notes:
1. All values in ac-ft
2. I_s measured at G600.
3. P is average of values at G600_R and ROTNWX
4. O_s measured at G354 and G393
5. ET data is from STA1W
6. Ig and Og estimated based on head differences between cell water levels and surrounding water levels using a seepage coefficient of: Cell 3 = 5.05 cfs/mi/ft, Cell 5 = 2.36 cfs/mi/ft
7. ΔS for water levels below average ground level estimated using equations developed by Huebner (2001), based on data available in Abtew et al. (1998)

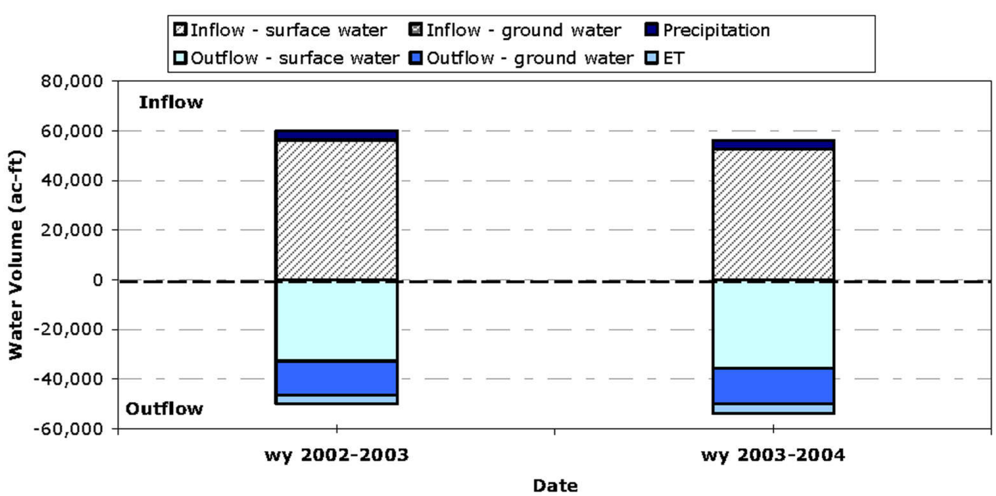

Figure 12. STA-6 Annual Water Budget Summary, WY2003 to WY2004.

Table 6. STA-6 Monthly Water Budget, WY2003 to WY2004.

Month-Year	Inflow surface water	Outflow surface water	Change in storage	Rain	ET	Seepage	Error	Daily Average Error
	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	ac-ft	in
May 2002	0.000	0.000	194.498	277.431	468.054	1865.480	-2250.602	-1.001
Jun 2002	5378.627	2752.842	2209.792	703.889	304.208	299.352	516.322	0.237
Jul 2002	11939.387	10515.314	218.203	803.619	363.979	706.718	938.792	0.418
Aug 2002	7730.401	5137.158	-33.481	397.809	344.231	891.837	1788.465	0.796
Sep 2002	4680.291	2632.505	-131.979	98.984	319.716	595.971	1363.061	0.627
Oct 2002	2684.097	1079.923	-310.158	166.449	295.160	1350.925	434.695	0.193
Nov 2002	4284.095	1442.029	345.836	165.006	233.273	1347.585	1080.377	0.497
Dec 2002	5857.050	3599.508	-261.023	220.489	199.014	1120.725	1419.314	0.632
Jan 2003	3666.535	1331.647	179.906	29.736	244.931	1005.373	934.414	0.416
Feb 2003	2242.949	547.752	-107.715	61.279	256.605	1457.676	149.911	0.074
Mar 2003	5457.360	2399.815	335.962	261.096	319.181	1153.573	1509.924	0.672
Apr 2003	2331.127	1268.236	-1076.380	195.106	354.364	1651.615	328.398	0.151
May 2003	3054.010	371.908	948.877	395.279	368.284	1771.676	-11.455	-0.005
Jun 2003	5878.289	4130.512	-74.866	564.995	348.982	810.899	1227.759	0.564
Jul 2003	4881.712	3271.086	-13.717	335.078	386.873	1112.253	460.296	0.205
Aug 2003	8374.649	8545.710	163.376	489.213	309.574	927.467	-1082.266	-0.482
Sep 2003	10645.436	9586.559	561.461	854.035	296.733	936.254	118.465	0.054
Oct 2003	5758.195	4900.050	-998.506	51.503	311.698	1118.674	477.782	0.213
Nov 2003	3237.378	1067.268	-366.744	111.331	230.582	1479.475	938.127	0.431
Dec 2003	3553.210	847.185	256.613	117.135	220.327	1301.401	1044.821	0.465
Jan 2004	1033.293	9.574	90.456	210.331	244.477	1338.173	-439.056	-0.195
Feb 2004	4398.190	2116.613	371.867	248.781	260.415	901.119	996.958	0.491
Mar 2004	1859.132	702.900	-1281.807	6.891	354.843	1512.080	578.007	0.257
Apr 2004	0.000	0.000	-708.145	179.501	376.099	1280.712	-769.165	-0.354

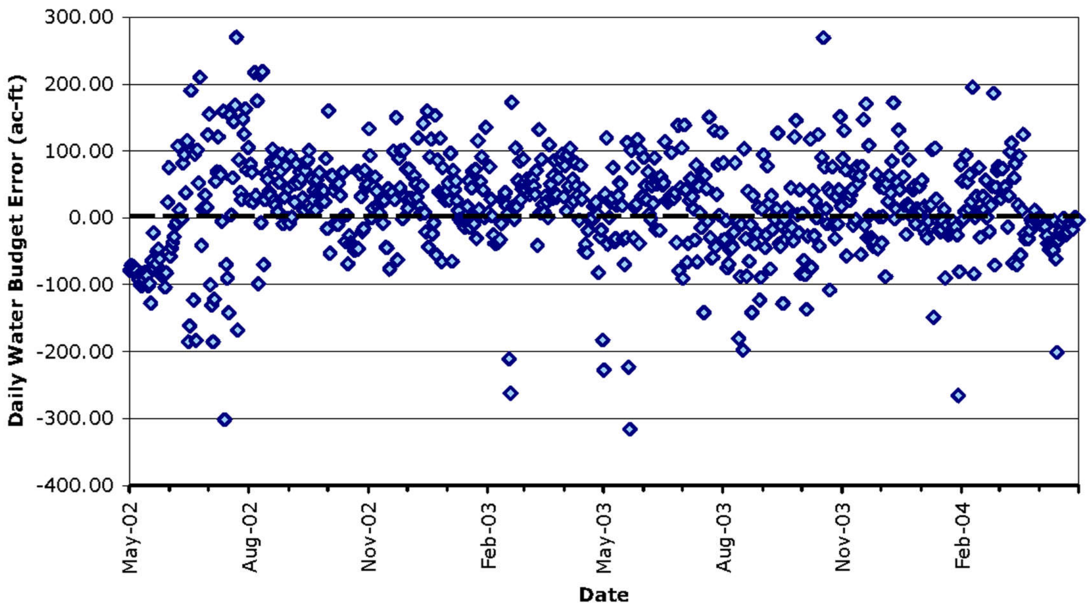

Figure 13. STA-6 Daily Water Budget Error, WY2003 to WY2004.

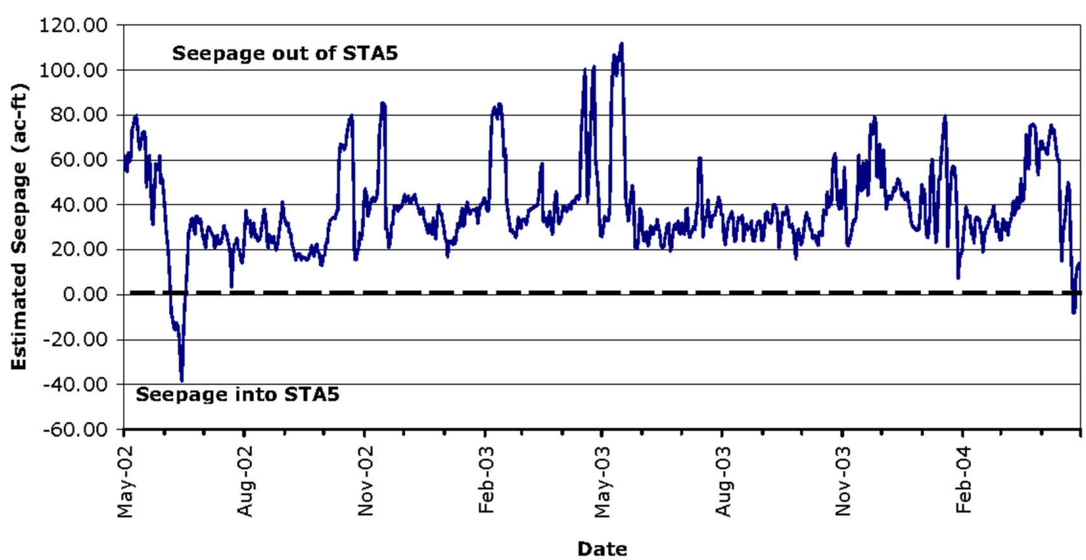

Figure 14. STA-6 Estimated Seepage, WY2003 to WY2004.

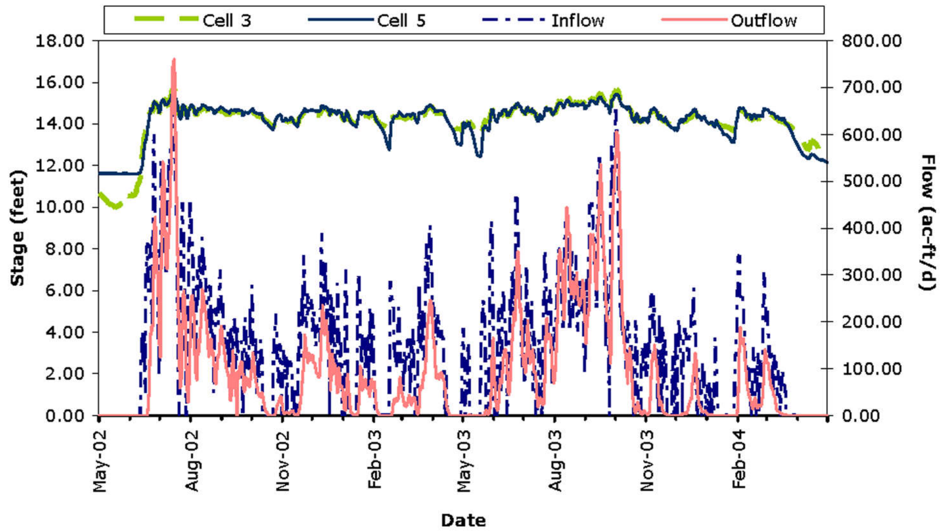

Figure 15. STA-6 Inflow, Outflow, and Stage, WY2003 to WY2004.

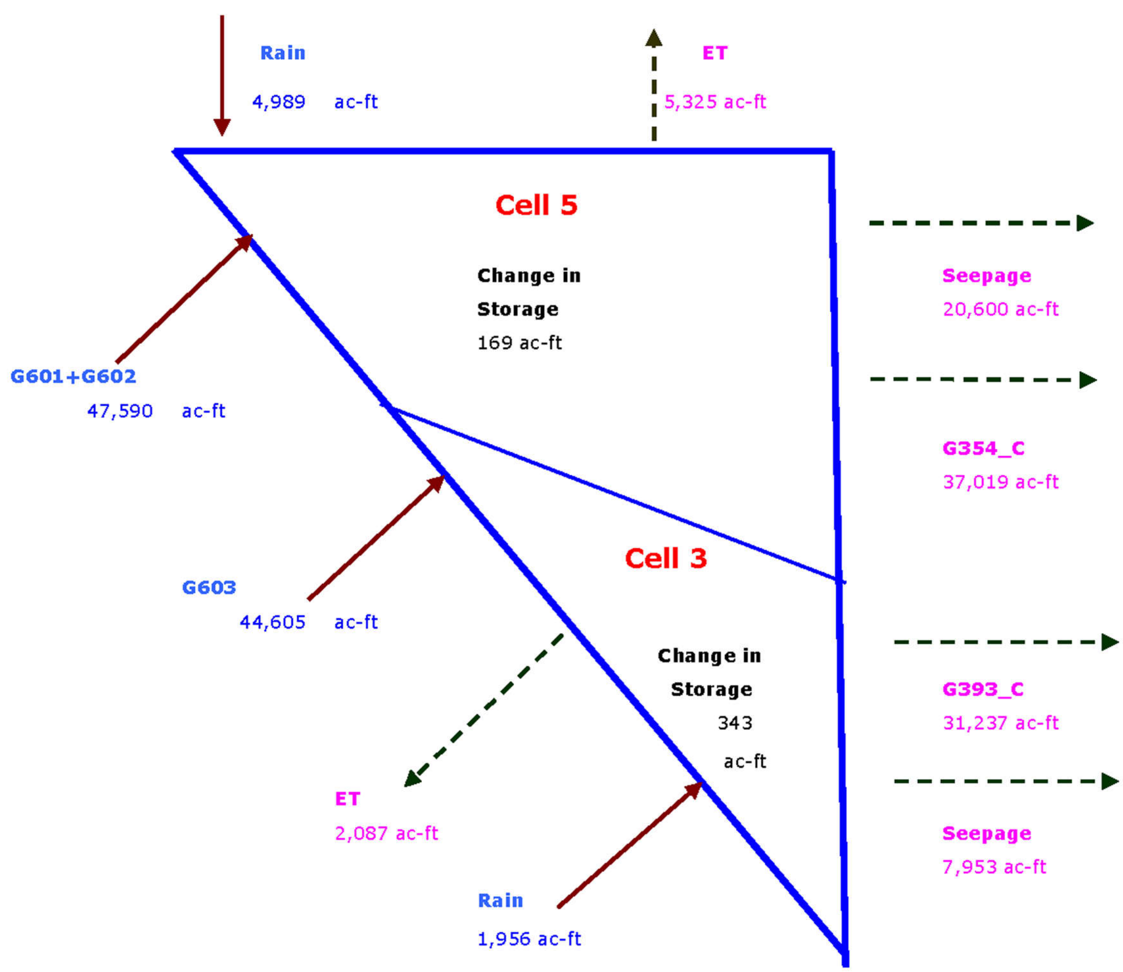

Figure 16. STA-6 Water Budget Volumes, WY2003 to WY2004.

Mean Hydraulic Retention Time

Hydraulic retention time is an estimate of how long water remains in each cell. During that time, physical, chemical, and biological processes remove particulate and soluble phosphorous and other contaminants. The mean hydraulic retention time (MHRT, also referred to as mean cell residence time) was determined using Equation 5:

$$t = \frac{V}{Q} \tag{5}$$

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

Table 7 shows the mean hydraulic retention time in days for Cells 3 and 5. The annual mean was based on the average stage during the water year or season, and the average rate of inflow and outflow, including rainfall, ET, and seepage. Wet-season MHRT is based on data spanning June to October, and dry-season MHRT is based on data spanning November to May.

Table 7. Mean Hydraulic Retention Time (days).

	Annual		Wet Season		Dry season	
Cell 3	Average depth (feet)	MHRT (days)	Average depth (feet)	MHRT (days)	Average depth (feet)	MHRT (days)
WY2003	1.53	6.19	1.85	5.56	1.30	7.02
WY2004	1.89	7.89	2.36	6.07	1.56	11.71
2-yr. Mean	1.71	7.04	2.10	5.81	1.43	9.36
Cell 5						
WY2003	1.69	17.39	1.93	10.42	1.51	14.91
WY2004	1.81	19.26	2.34	12.35	1.43	22.38
2-yr. Mean	1.75	18.32	2.13	11.39	1.47	18.65

During the wet season, MHRTs ranged from 5.56 to 6.07 days for Cell 3, and from 10.42 to 12.35 days for Cell 5. Dry-season MHRTs ranged from 7.02 to 11.71 days for Cell 3 and from 14.91 to 22.38 days for Cell 5. At maximum normal flow conditions in the STA, described in the STAs Operation Plan (SFWMD 1997), Cell 3 has a MHRT of 4.0 days, based on a flow of 140 cfs and a depth of 4.5 ft. Cell 5 has a MHRT of 3.9 days, based on a flow of 360 cfs and a depth of 4.5 ft.

Hydraulic Loading Rate

Hydraulic loading rate (HLR) is the rate at which water flows into a system. This was calculated by dividing the inflow (ac-ft/day) at the control structures by the treatment area. For this analysis, the entire STA6 was considered and therefore inflow was divided by 870 ac (the area of STA-6). **Table 8** presents the average hydraulic loading rate for each month for WY2003 and WY2004. The highest hydraulic loading rate occurred in July 2002, which was 0.44 ac-ft/day/ac. The hydraulic loading rate was zero in May 2002 and April 2004, since inflow was zero. **Figure 17** shows the hydraulic loading rate based on the wet and dry seasons of the water years. During the dry season in WY2003, STA-6 had a mean hydraulic loading rate of 0.13 ac-ft/day/ac, with a rate of 0.09 ac-ft/day/ac in WY2004. The WY2003 wet season hydraulic loading rate of STA-6 was 0.24 ac-ft/day/ac, with a rate of 0.27 ac-ft/day/ac in WY2004. The mean hydraulic loading rate of the entire WY2003 was 0.185 ac-ft/day/ac, and the entire rate in WY2004 was 0.18 ac-ft/day/ac.

Table 8. Hydraulic Loading Rate (ac-ft/day/ac) in WY2003 and WY2004.

WY2003		WY2004	
Month	Hydraulic loading (ac-ft/day/ac)	Month	Hydraulic loading (ac-ft/day/ac)
May 2002	0.00	May 2003	0.11
Jun 2002	0.21	Jun 2003	0.23
Jul 2002	0.44	Jul 2003	0.18
Aug 2002	0.29	Aug 2003	0.31
Sep 2002	0.18	Sep 2003	0.41
Oct 2002	0.10	Oct 2003	0.21
Nov 2002	0.16	Nov 2003	0.12
Dec 2002	0.22	Dec 2003	0.13
Jan 2003	0.14	Jan 2004	0.04
Feb 2003	0.09	Feb 2004	0.17
Mar 2003	0.20	Mar 2004	0.07
Apr 2003	0.09	Apr 2004	0.00

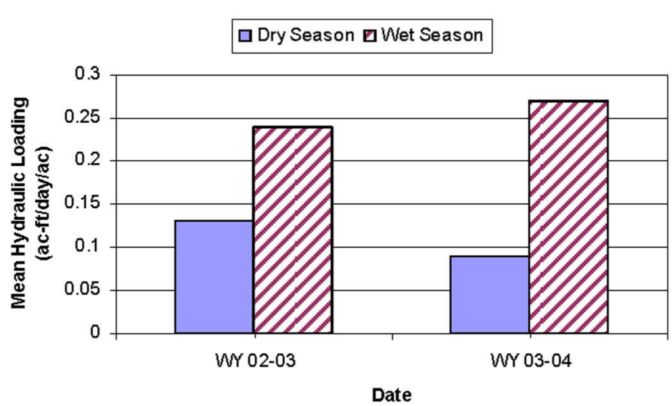

Figure 17. Hydraulic Loading based on the Season, WY2003 to WY2004.

SUMMARY AND DISCUSSION

Over the two-year period of WY2003 and WY2004, STA-6 received 108,925 ac-ft of water from pumping operations at G600_P. Of this amount, 92,195 ac-ft entered treatment Cells 3 and 5 at G601, G602, and G603. An additional 6,945 ac-ft were input to STA-6 via rainfall; 7,412 ac-ft were lost through ET. Estimated seepage was 24 percent of the water budget during this period, losing 27,796 ac-ft to surrounding water bodies and the surficial aquifer. Outflow from STA-6 at G354 and G393 was 74.03 percent of the flow entering STA-6 at G601, G602, and G603, or 68,256 ac-ft. This volume was released into the discharge canal at STA-6, and was eventually discharged at G607 to the L-4 canal. The amount of water stored in STA-6 increased by 512 ac-ft in two years. The error in the water budget was 11,753 ac-ft or 10.7 percent of the budget. Cell 3 retained water an average of 7.04 days in WY2003 and WY2004. The average retention time in Cell 5 was 18.32 days

Determining the seepage coefficient for each treatment cell was the biggest challenge in this water budget analysis. This was the first time that unique seepage coefficient for each treatment cell was used. Even though this study includes WY2003 and WY2004, the seepage coefficients were calibrated by minimizing the six-year sum of the squared daily water budget error. The seepage coefficient for Cell 3 was 5.05 cfs/mi/ft, and 2.36 cfs/mi/ft for Cell 5.

An anomaly was observed in inflow data for the treatment cells in WY2004. Cell 5 contains two inflow weirs (G601 and G602), and Cell 3 only has one inflow weir structure (G603). This should result the total inflow in Cell 5 being close to double the inflow to Cell 3. In WY2003, Cell 5 inflow is a little bit higher than Cell 3, but in WY2004, Cell 5 inflow was lower than Cell 3 inflow. This can be attributed to the fact that the weir at G603 (Cell 3) is larger than either of the weirs at G601 and G602 (Cell 5). Also, the elevation of the weir crest at G603 is 14.2 ft. NGVD; the crest elevation of weirs at G601 and G602 is 14.1 ft. NGVD.

There are two other structures, an irrigation pump at station G600I_P, and a gated culvert at station G600_C at STA-6, that were instrumented in 2004. The culverts and irrigation pumps typically do not affect the STA water budget, and were not used in this analysis.

The water budget residual for STA-6 shown in **Figures 4**, **9**, and **13** (residuals for Cell 3, Cell 5, and STA-6 as a whole) are not random. In general, the residuals increase when flow increases, as shown in **Figure 17**, which shows daily inflow, seepage, and budget error for the four-year period. Although seepage also increases during these periods (in response to increased stage in STA-6), the volume of outflow from STA-6, plus the increased seepage and the increase in storage, do not equal the daily volume of water entering STA-6. Flow measurement error may account for this. The algorithm for inflow is based on a uniform trapezoidal shape. The construction drawings show that inflow weirs have sloped sides approximating a trapezoid but the crest elevation (bottom of the trapezoid) is irregular. Likewise, the outflow structures are a combination of gated culvert and weir. Flow equations for these structures are being revised to account for the complex nature of flow through these structures and flow values used for this study represent best estimates at the time flow values were entered into DBHYDRO. Error in the budget may also indicate a systemic response to flow that is not adequately represented by daily mean values used in water budget calculations.

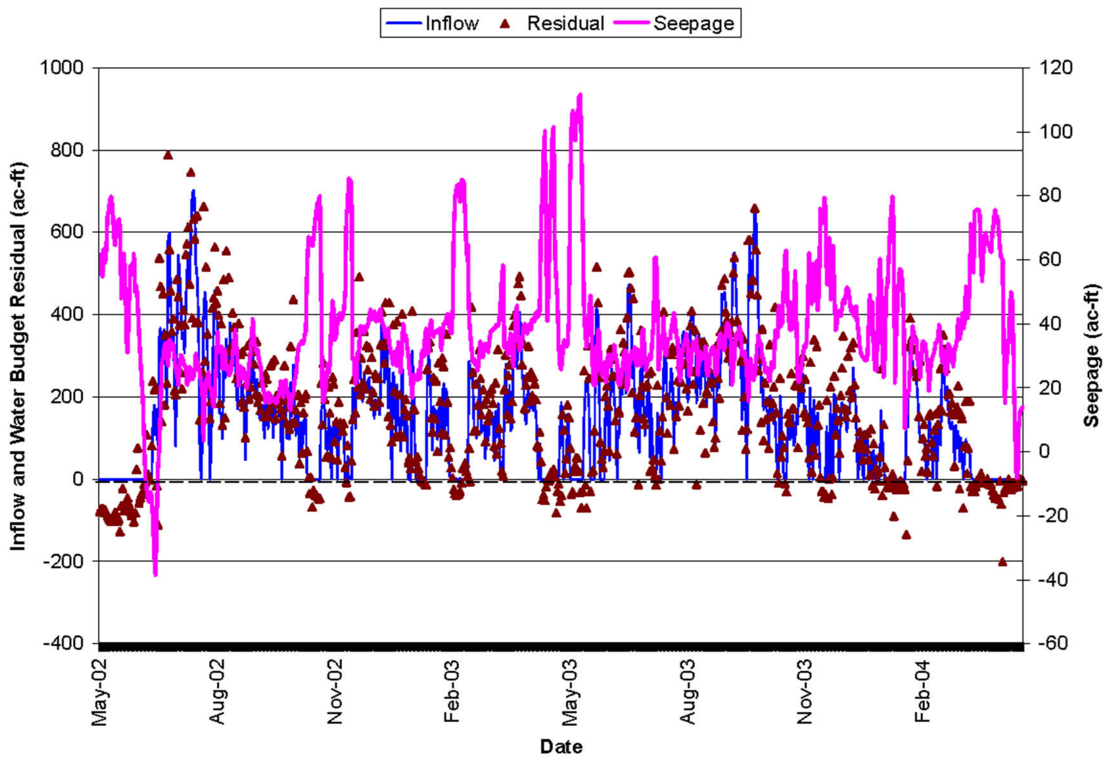

Figure 18 . STA-6 Inflow, Estimated Seepage, and Water Budget Residuals, WY2003 to WY2004.

RECOMMENDATIONS

The geology and the seepage characteristics of the area warrant additional study. Overall seepage constituted the largest single quantifiable unknown at the site. The quantity of water lost through seepage has implications for STA design and water quality management in the basin. Further investigation of this aspect of treatment cell dynamics, especially with respect to long-term aquifer and downstream impacts, remains a research need.

Installation of ground water observation wells with stage recorders located outside the boundary of STA-6 would aid the analysis of seepage, especially along the northern and eastern boundaries. Location and installation of observation wells for this purpose should be a design/construction requirement for all STAs.

Since the retention time of the cells is significantly lower than that reported for STA-1W, short circuiting is likely to have a more pronounced impact on the removal efficiency of the treatment cells.

CONCLUSIONS

Estimated seepage continued to constitute a large portion of the water budget. Flow measurement errors at the inflow and outflow weirs were apparent in preparing data for the analysis and were corrected. Mean hydraulic residence times continued to be lower than those observed at other STAs, yet the removal efficiencies remained high.

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APPENDICES

Appendix A. Site Properties and Monitoring Stations

Table A- 1. STA-6 Site properties.

Surface Area		
Cell 5	625	ac
Cell 3	245	ac
Cell 5 Ground Elevation	~ 12.4	ft
Cell 3 Ground Elevation	~ 12.4	ft
Levee Length		
Along Northern Boundary	7785	ft
Supply Canal		
Along Cell 5	4412	ft
Along Cell 3	7136	ft
Discharge Canal		
Along Cell 5	6012	ft
Along Cell 3	4584	ft
Between Cells 3 and 5	4195	ft

Table A- 2. Stage monitoring stations.

DBKEY	Structure	STA	COUNTY
G6559	G352S_H	STA-6 Section 1 (in supply canal across from Cell 5)	HENDRY
G6560	G352S_T	STA-6 Section 1 (in Cell 5 across from supply canal)	HENDRY
G6563	G354C_H	STA-6 Section 1 in Cell 5 near Outflow C	HENDRY
G6564	G354C_T	STA-6 Section 1 in discharge canal near Outflow C	HENDRY
G6561	G392S_H	STA-6 Section 1 (in supply canal across from Cell 3)	HENDRY
G6562	G392S_T	STA-6 Section 1 (in Cell 3 across from supply canal)	HENDRY
G6565	G393B_H	STA-6 Section 1 in Cell 3 at Weir-culvert B	HENDRY
G6566	G393B_T	STA-6 Section 1 in discharge canal at Weir-culvert B	HENDRY
G6528	G600_H	STA-6 Section 1, Inflow pump station, headwater	HENDRY
G6529	G600_T	STA-6 Section 1, Inflow pump station, tailwater	HENDRY

Table A- 3. Flow monitoring stations.

DBKEY	Structure	STA	COUNTY
MC958	G354_C	STA-6 Section 1 discharge canal, combined flow for G354A, B, C	HENDRY
MC959	G393_C	STA-6 Section 1 Cell 3 combined Outflow for G393A, B, C	HENDRY
GG955	G600_P	STA-6 Section 1 Inflow pump station	HENDRY
J5566	G601	STA-6 Section 1 Cell 5 Inflow WeiR 1	HENDRY
J5567	G602	STA-6 Section 1 Cell 5 Inflow WeiR 2	HENDRY
J5568	G603	STA-6 Section 1 Cell 3 Inflow WeiR 3	HENDRY

Table A- 4. Rainfall monitoring sites.

DBKEY	Structure	STA	COUNTY
JJ025	G600_R	STA6 Section 1 Inflow pump station at rain gauge	HENDRY
GE354	ROTNWX	STA6 Rotenberger tract weather station, located by G606 at STA-6	BROWARD

Table A- 5. Evapotranspiration monitoring sites.

DBKEY	Structure	STA	COUNTY
KN810	STA1W	Areal computed parameter for STA-1W project	PALM BEACH

Appendix B. Rainfall Data

Table B- 1. Daily average rainfall at G600_R and ROTNWX (inches), WY2003.

Day	2002-05	2002-06	2002-07	2002-08	2002-09	2002-10	2002-11	2002-12	2003-01	2003-02	2003-03	2003-04
1	0.00	0.00	0.80	0.00	0.01	0.18	0.00	0.03	0.14	0.00	0.00	0.01
2	0.00	0.00	0.57	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.21	0.03	0.01	0.00	0.00	0.00	0.13	0.00	0.01	0.00
4	0.00	0.00	0.06	0.01	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.05	0.01	0.48	0.05	0.00	0.07	0.01	0.00	0.01	0.00	0.02
6	0.00	0.00	0.00	0.06	0.11	0.00	0.09	0.01	0.00	0.00	0.00	0.00
7	0.00	1.53	0.66	0.95	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.08	1.07	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.01	0.42	0.00	0.07	0.00	0.00	2.04	0.00	0.00	0.00	0.61
10	0.00	0.03	0.45	0.00	0.01	0.00	0.00	0.21	0.00	0.00	0.05	0.01
11	0.00	1.17	1.11	2.28	0.32	0.00	0.00	0.01	0.00	0.00	0.01	0.00
12	0.00	0.23	3.41	0.00	0.01	0.29	0.00	0.08	0.00	0.00	0.00	0.00
13	0.03	0.01	0.00	0.05	0.01	0.66	0.05	0.18	0.02	0.00	0.01	0.00
14	0.04	2.01	0.00	0.01	0.01	0.00	0.00	0.00	0.12	0.00	0.03	0.00
15	0.00	0.85	0.29	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.01	0.35
16	0.23	0.19	0.00	0.02	0.00	0.00	1.75	0.01	0.00	0.07	0.18	0.01
17	0.00	0.05	0.00	0.10	0.00	0.00	0.19	0.00	0.00	0.20	0.85	0.00
18	0.00	0.01	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
19	0.48	0.18	0.00	0.25	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.01	0.23	0.00	0.01	0.03	0.01	0.00	0.46	0.00	0.05	0.04	0.00
21	0.00	0.02	0.69	0.02	0.00	0.00	0.04	0.00	0.00	0.01	0.04	0.00
22	0.00	0.78	0.01	0.01	0.00	0.00	0.07	0.00	0.00	0.45	0.55	0.00
23	0.00	0.87	0.00	0.00	0.10	0.48	0.00	0.00	0.01	0.05	0.68	0.00
24	0.00	0.35	0.23	0.07	0.33	0.01	0.00	0.00	0.00	0.00	0.01	0.00
25	0.00	0.38	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95
27	0.00	0.01	0.00	0.22	0.03	0.00	0.00	0.00	0.00	0.00	0.80	0.08
28	0.00	0.02	0.38	0.39	0.01	0.00	0.00	0.00	0.00	0.00	0.25	0.07
29	0.00	0.45	0.27	0.02	0.01	0.01	0.00	0.00	0.00		0.00	0.00
30	1.21	0.18	0.43	0.05	0.01	0.01	0.00	0.00	0.00		0.01	0.60
31	1.83		0.00	0.38		0.00		0.01	0.00		0.01	
MAX	*1.83*	*2.01*	*3.41*	*2.28*	*0.33*	*0.66*	*1.75*	*2.04*	*0.14*	*0.45*	*0.85*	*0.95*
MEAN	*0.12*	*0.32*	*0.36*	*0.18*	*0.05*	*0.07*	*0.08*	*0.10*	*0.01*	*0.03*	*0.12*	*0.09*
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	*3.83*	*9.70*	*11.08*	*5.48*	*1.36*	*2.29*	*2.28*	*3.04*	*0.41*	*0.84*	*3.60*	*2.69*

Table B- 2. Daily Average Rainfall at G600_R and ROTNWX (inches), WY2004.

Day	2003-05	2003-06	2003-07	2003-08	2003-09	2003-10	2003-11	2003-12	2004-01	2004-02	2004-03	2004-04
1	0.15	0.31	0.00	0.52	0.38	0.00	0.00	0.00	0.00	1.08	0.00	0.00
2	0.01	0.05	1.41	0.29	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.00
3	0.07	0.00	0.00	0.01	0.31	0.00	0.34	0.13	0.00	0.00	0.00	0.00
4	0.00	0.95	0.00	0.07	0.84	0.00	0.78	0.03	0.00	0.01	0.00	0.00
5	0.00	0.01	0.05	0.76	0.63	0.00	0.31	0.18	0.01	0.00	0.00	0.00
6	0.00	0.26	0.00	0.20	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00
7	0.00	0.50	0.12	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
8	0.00	0.44	0.52	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.66	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.01	0.00	0.12	0.00	0.00	0.03	0.10	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.69	0.00	1.05	2.87	0.00	0.00	0.00	0.00	0.00	0.00	0.91
13	0.00	0.01	0.01	0.03	0.59	0.00	0.00	0.00	0.00	0.09	0.00	1.54
14	0.01	0.01	0.04	0.14	0.37	0.14	0.00	0.80	0.00	0.00	0.00	0.00
15	0.01	0.00	0.10	0.16	0.00	0.00	0.00	0.00	0.00	0.16	0.01	0.00
16	0.41	0.57	0.42	0.03	0.01	0.00	0.00	0.27	0.00	0.00	0.08	0.00
17	0.14	0.76	0.00	0.03	0.14	0.00	0.00	0.10	0.00	0.03	0.00	0.00
18	0.48	0.55	0.00	0.05	0.00	0.00	0.00	0.00	0.97	0.00	0.01	0.00
19	0.56	0.20	0.38	0.03	0.15	0.00	0.02	0.00	0.01	0.00	0.00	0.00
20	0.22	0.16	0.00	0.12	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.01	1.24	0.15	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.05	0.15	0.31	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.74	0.16	0.03	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.18	0.01	0.01	0.64	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.01	0.00	1.02	0.00	1.02	0.05	0.00	0.00	0.00	1.86	0.00	0.00
26	0.03	0.00	0.01	0.05	0.27	0.03	0.00	0.00	0.00	0.19	0.00	0.00
27	1.99	0.00	0.01	0.07	0.70	0.00	0.00	0.00	0.29	0.02	0.00	0.02
28	0.15	0.10	0.00	1.32	1.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00
29	0.21	0.00	0.00	0.00	2.23	0.48	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.00	1.25		0.00	0.00
31	0.01		0.01	0.00		0.00		0.00	0.37		0.00	
MAX	*1.99*	*1.24*	*1.41*	*1.32*	*2.87*	*0.48*	*0.78*	*0.80*	*1.25*	*1.86*	*0.08*	*1.54*
MEAN	*0.18*	*0.26*	*0.15*	*0.22*	*0.39*	*0.02*	*0.05*	*0.05*	*0.09*	*0.12*	*0.00*	*0.08*
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	*5.45*	*7.79*	*4.62*	*6.75*	*11.78*	*0.71*	*1.53*	*1.62*	*2.90*	*3.43*	*0.10*	*2.47*

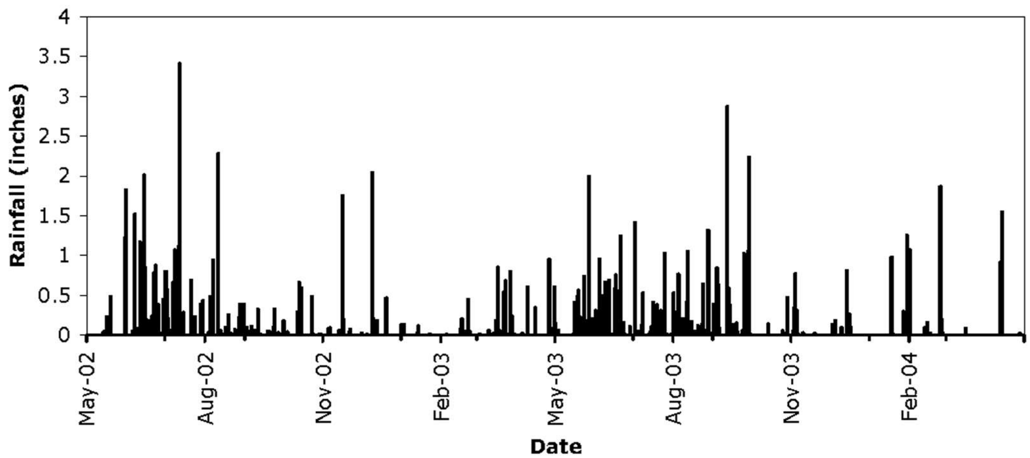

Figure B- 1. Rainfall in inches at G600_R and ROTNWX, WY2003 to WY2004.

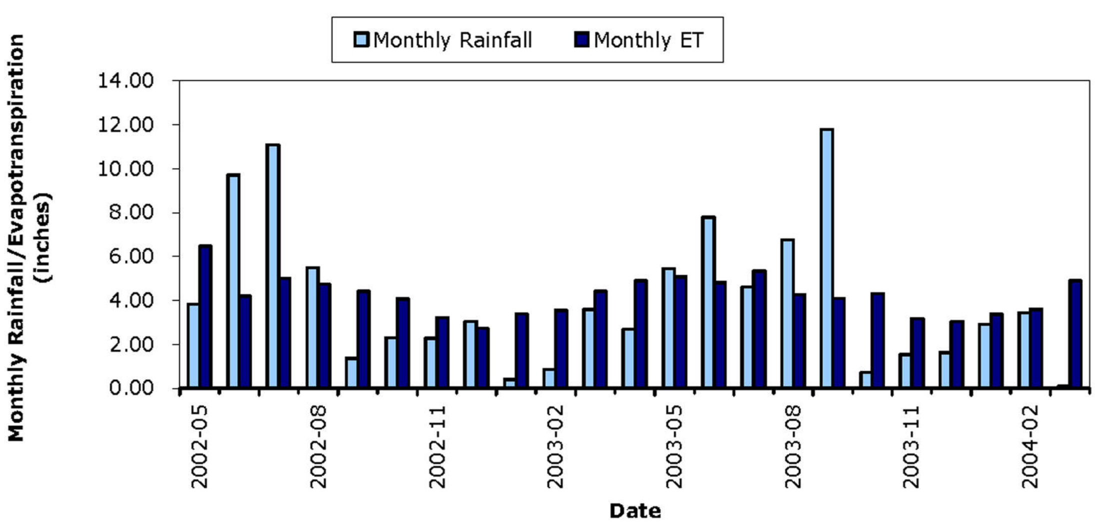

Figure B- 2. Daily rainfall and ET in inches, WY2003 to WY2004.

Appendix C. Evapotranspiration Data

Table C- 1. STA 1W ET (inches), WY2003.

Day	2002–05	2002–06	2002–07	2002–08	2002–09	2002–10	2002–11	2002–12	2003–01	2003–02	2003–03	2003–04
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*	*4.75*	*4.41*	*4.07*	*3.22*	*2.74*	*3.38*	*3.54*	*4.40*	*4.89*

Table C- 2. STA 1W ET (inches), WY2004.

Day	2003-05	2003-06	2003-07	2003-08	2003-09	2003-10	2003-11	2003-12	2004-01	2004-02	2004-03	2004-04
1	0.16	0.16	0.16	0.11	0.11	0.13	0.13	0.11	0.13	0.10	0.13	0.21
2	0.21	0.23	0.16	0.07	0.16	0.13	0.13	0.12	0.10	0.13	0.15	0.22
3	0.20	0.09	0.18	0.14	0.14	0.14	0.13	0.11	0.09	0.15	0.13	0.23
4	0.21	0.14	0.18	0.20	0.13	0.12	0.04	0.10	0.10	0.13	0.16	0.21
5	0.21	0.16	0.12	0.17	0.10	0.18	0.06	0.06	0.10	0.12	0.15	0.22
6	0.13	0.15	0.19	0.14	0.09	0.15	0.07	0.07	0.13	0.13	0.18	0.17
7	0.16	0.14	0.20	0.19	0.15	0.15	0.10	0.13	0.05	0.10	0.16	0.18
8	0.14	0.16	0.18	0.11	0.18	0.13	0.10	0.10	0.12	0.14	0.19	0.20
9	0.17	0.18	0.22	0.15	0.18	0.15	0.10	0.10	0.13	0.13	0.14	0.13
10	0.18	0.24	0.21	0.13	0.17	0.13	0.13	0.04	0.04	0.14	0.19	0.14
11	0.16	0.17	0.23	0.15	0.20	0.12	0.15	0.13	0.13	0.10	0.18	0.18
12	0.18	0.18	0.19	0.18	0.18	0.17	0.11	0.11	0.08	0.15	0.15	0.06
13	0.17	0.23	0.21	0.20	0.12	0.15	0.15	0.11	0.15	0.12	0.17	0.09
14	0.16	0.21	0.18	0.10	0.11	0.11	0.14	0.01	0.15	0.14	0.09	0.21
15	0.19	0.15	0.14	0.15	0.19	0.14	0.13	0.13	0.15	0.06	0.15	0.24
16	0.17	0.15	0.13	0.15	0.18	0.15	0.10	0.07	0.16	0.16	0.08	0.17
17	0.10	0.17	0.16	0.12	0.18	0.09	0.09	0.04	0.10	0.08	0.16	0.17
18	0.13	0.10	0.15	0.12	0.14	0.17	0.14	0.13	0.06	0.18	0.21	0.18
19	0.09	0.13	0.18	0.11	0.14	0.12	0.04	0.12	0.09	0.15	0.19	0.20
20	0.21	0.11	0.21	0.04	0.08	0.14	0.14	0.13	0.14	0.07	0.19	0.21
21	0.19	0.09	0.21	0.12	0.17	0.15	0.10	0.09	0.09	0.13	0.20	0.15
22	0.08	0.13	0.13	0.11	0.15	0.17	0.10	0.07	0.13	0.16	0.19	0.16
23	0.14	0.09	0.18	0.15	0.13	0.16	0.10	0.10	0.15	0.15	0.16	0.19
24	0.17	0.16	0.09	0.12	0.14	0.17	0.12	0.10	0.15	0.15	0.09	0.18
25	0.17	0.22	0.13	0.15	0.11	0.11	0.07	0.10	0.14	0.07	0.12	0.19
26	0.19	0.18	0.12	0.13	0.13	0.15	0.10	0.10	0.10	0.16	0.16	0.14
27	0.12	0.16	0.18	0.14	0.11	0.14	0.10	0.11	0.07	0.09	0.18	0.12
28	0.10	0.13	0.12	0.08	0.11	0.10	0.11	0.11	0.15	0.13	0.21	0.12
29	0.14	0.20	0.22	0.15	0.03	0.16	0.13	0.10	0.13	0.11	0.08	0.14
30	0.22	0.21	0.19	0.18	0.10	0.10	0.09	0.12	0.05		0.16	0.18
31	0.21		0.19	0.21		0.13		0.11	0.01		0.18	
MAX	*0.22*	*0.24*	*0.23*	*0.21*	*0.20*	*0.18*	*0.15*	*0.13*	*0.16*	*0.18*	*0.21*	*0.24*
MEAN	*0.16*	*0.16*	*0.17*	*0.14*	*0.14*	*0.14*	*0.11*	*0.10*	*0.11*	*0.12*	*0.16*	*0.17*
MIN	*0.08*	*0.09*	*0.09*	*0.04*	*0.03*	*0.09*	*0.04*	*0.01*	*0.01*	*0.06*	*0.08*	*0.06*
SUM	*5.08*	*4.81*	*5.33*	*4.27*	*4.09*	*4.30*	*3.18*	*3.04*	*3.37*	*3.59*	*4.89*	*5.19*

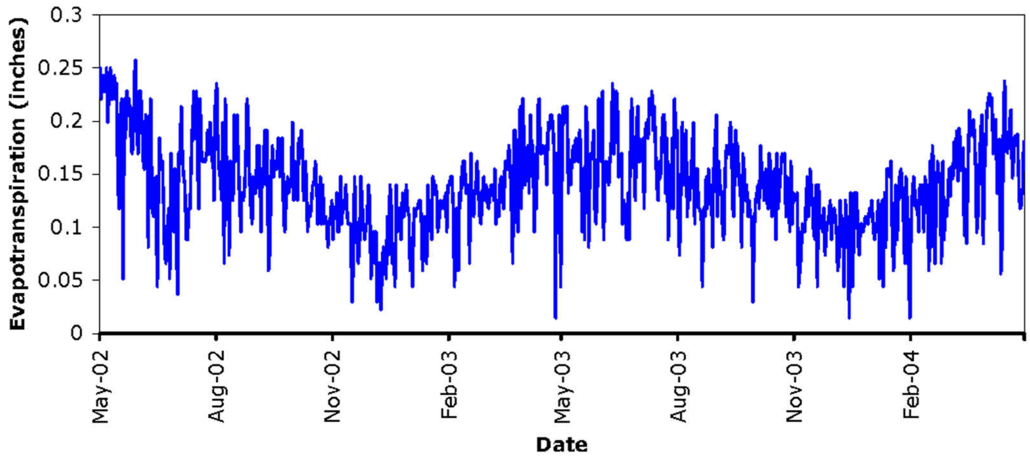

Figure C- 1. Daily ET in inches, WY2003 to WY2004.

Appendix D. Stage Data and Soil Moisture Equations

Table D- 1. Cell 3 daily average stage (feet), WY2003.

Day	2002–05	2002–06	2002–07	2002–08	2002–09	2002–10	2002–11	2002–12	2003–01	2003–02	2003–03	2003–04
1	10.66	10.63	14.55	14.80	14.66	14.51	14.15	14.54	14.22	14.38	14.33	14.70
2	10.60	10.60	14.95	14.80	14.60	14.62	14.11	14.51	14.16	14.25	14.26	14.66
3	10.55	10.56	15.18	14.78	14.59	14.52	14.12	14.51	14.28	14.17	14.26	14.52
4	10.51	10.55	15.28	14.69	14.52	14.45	14.17	14.47	14.52	14.11	14.25	14.50
5	10.46	10.57	15.20	14.50	14.49	14.45	14.13	14.45	14.44	14.07	14.26	14.50
6	10.42	10.60	15.00	14.40	14.46	14.39	14.12	14.43	14.32	14.04	14.31	14.49
7	10.37	10.73	14.87	14.45	14.46	14.36	14.11	14.43	14.22	14.00	14.34	14.49
8	10.31	11.00	14.88	14.64	14.41	14.35	14.14	14.43	14.15	13.97	14.34	14.51
9	10.26	11.13	14.99	14.58	14.46	14.33	14.18	14.50	14.10	13.94	14.27	14.50
10	10.20	11.20	15.14	14.66	14.54	14.37	14.20	14.69	14.07	13.92	14.29	14.50
11	10.16	11.38	15.24	14.64	14.56	14.37	14.15	14.77	14.05	13.89	14.33	14.50
12	10.13	12.08	15.37	14.80	14.55	14.29	14.10	14.72	14.03	13.85	14.30	14.47
13	10.12	12.64	15.68	14.80	14.56	14.24	14.05	14.67	14.01	13.81	14.32	14.33
14	10.11	12.90	15.67	14.78	14.61	14.19	14.01	14.75	14.00	13.77	14.21	14.27
15	10.07	13.34	15.66	14.76	14.55	14.13	13.98	14.72	14.13	13.74	14.13	14.19
16	10.02	13.52	15.54	14.73	14.59	14.10	13.99	14.62	14.36	13.70	14.07	14.14
17	9.97	13.73	15.23	14.67	14.60	14.05	14.20	14.65	14.49	13.86	14.17	14.08
18	9.98	14.05	15.14	14.55	14.57	14.01	14.30	14.45	14.51	14.10	14.34	14.02
19	10.04	14.26	14.79	14.54	14.56	13.98	14.33	14.42	14.41	14.21	14.42	13.98
20	10.07	14.40	14.48	14.62	14.54	13.95	14.40	14.58	14.36	14.37	14.36	13.95
21	10.09	14.61	14.35	14.60	14.54	13.92	14.47	14.54	14.42	14.38	14.41	13.92
22	10.12	14.59	14.47	14.55	14.41	13.88	14.52	14.47	14.40	14.33	14.43	13.89
23	10.18	14.55	14.70	14.55	14.35	13.90	14.66	14.55	14.41	14.32	14.43	13.84
24	10.19	14.68	14.82	14.43	14.41	14.04	14.59	14.45	14.35	14.30	14.50	13.78
25	10.15	15.04	14.82	14.39	14.46	14.21	14.55	14.37	14.40	14.36	14.67	13.71
26	10.10	15.05	14.74	14.39	14.42	14.31	14.54	14.41	14.33	14.43	14.71	13.77
27	10.07	14.94	14.49	14.47	14.41	14.32	14.58	14.53	14.33	14.40	14.72	13.78
28	10.03	14.89	14.31	14.50	14.39	14.32	14.54	14.42	14.41	14.34	14.80	13.75
29	10.01	14.79	14.26	14.51	14.45	14.32	14.55	14.41	14.42		14.85	13.73
30	10.02	14.54	14.46	14.64	14.50	14.31	14.54	14.40	14.38		14.84	13.81
31	10.18		14.66	14.66		14.23		14.31	14.44		14.78	
MAX	*10.66*	*15.05*	*15.68*	*14.80*	*14.66*	*14.62*	*14.66*	*14.77*	*14.52*	*14.43*	*14.85*	*14.70*
MEAN	*10.20*	*12.92*	*14.93*	*14.61*	*14.51*	*14.24*	*14.28*	*14.52*	*14.29*	*14.11*	*14.41*	*14.18*
MIN	*9.97*	*10.55*	*14.26*	*14.39*	*14.35*	*13.88*	*13.98*	*14.31*	*14.00*	*13.70*	*14.07*	*13.71*

Table D- 2. Cell 3 daily average stage (feet), WY2004.

Day	2003-05	2003-06	2003-07	2003-08	2003-09	2003-10	2003-11	2003-12	2004-01	2004-02	2004-03	2004-04
1	13.97	14.47	14.58	14.48	14.71	15.59	14.08	13.81	14.07	14.46	14.58	13.49
2	14.06	14.31	14.46	14.58	14.83	15.65	14.05	13.76	14.04	14.63	14.58	13.43
3	13.98	14.22	14.57	14.70	14.87	15.61	14.09	13.83	14.02	14.66	14.51	13.36
4	13.99	14.17	14.74	14.87	14.85	15.52	14.24	14.03	14.01	14.61	14.47	13.29
5	13.97	14.24	14.75	15.05	15.02	15.30	14.44	14.12	14.04	14.61	14.44	13.21
6	14.04	14.38	14.63	15.11	15.20	15.13	14.57	14.17	14.01	14.64	14.43	13.14
7	14.11	14.43	14.56	15.08	15.21	14.89	14.58	14.08	13.99	14.58	14.39	13.06
8	14.02	14.39	14.58	15.03	15.23	14.91	14.63	14.12	13.96	14.51	14.38	12.98
9	13.97	14.42	14.63	14.92	15.19	14.82	14.64	14.13	13.96	14.37	14.29	12.89
10	13.92	14.54	14.58	14.80	15.09	14.85	14.58	14.08	14.07	14.35	14.22	12.82
11	13.87	14.57	14.51	14.95	15.03	14.81	14.58	14.16	14.00	14.34	14.23	12.74
12	13.81	14.58	14.52	15.11	15.03	14.74	14.45	14.23	13.98	14.31	14.22	12.76
13	13.73	14.59	14.39	15.28	15.22	14.67	14.30	14.23	13.96	14.29	14.15	12.98
14	13.65	14.45	14.29	15.27	15.40	14.76	14.30	14.23	13.94	14.19	14.14	13.20
15	13.55	14.37	14.22	15.22	15.45	14.75	14.36	14.28	13.92	14.20	14.13	13.18
16	13.46	14.35	14.24	15.18	15.47	14.66	14.22	14.32	13.89	14.27	14.10	13.17
17	13.41	14.44	14.38	14.90	15.31	14.43	14.16	14.42	13.86	14.31	14.13	13.15
18	13.38	14.55	14.30	15.00	15.24	14.29	14.14	14.51	13.87	14.30	14.13	13.09
19	13.47	14.66	14.24	15.01	15.17	14.20	14.09	14.56	13.89	14.21	14.05	13.03
20	13.62	14.72	14.30	14.96	15.12	14.14	14.15	14.59	13.88	14.25	14.01	12.95
21	13.83	14.76	14.34	15.00	14.96	14.18	14.07	14.49	13.86	14.29	13.98	12.85
22	13.98	14.73	14.62	15.06	14.91	14.36	14.03	14.33	13.83	14.25	13.96	12.74
23	14.16	14.91	14.75	15.10	14.89	14.33	14.00	14.28	13.80	14.26	13.92	12.64
24	14.19	15.03	14.76	14.94	14.82	14.21	13.97	14.27	13.77	14.27	13.88	12.60
25	14.11	15.04	14.65	14.94	14.59	14.14	13.94	14.21	13.73	14.27	13.83	12.61
26	14.06	14.96	14.68	14.99	14.69	14.09	13.91	14.15	13.70	14.45	13.79	12.67
27	14.07	14.79	14.71	15.01	15.12	14.09	13.88	14.19	13.69	14.60	13.73	12.63
28	14.30	14.81	14.67	15.01	15.30	14.16	13.86	14.17	13.71	14.61	13.69	12.56
29	14.50	14.64	14.58	15.07	15.38	14.20	13.82	14.21	13.85	14.58	13.67	12.49
30	14.68	14.56	14.45	15.02	15.51	14.13	13.85	14.15	13.98		13.62	12.40
31	14.65		14.50	14.79		14.14		14.10	14.19		13.56	
MAX	*14.68*	*15.04*	*14.76*	*15.28*	*15.51*	*15.65*	*14.64*	*14.59*	*14.19*	*14.66*	*14.58*	*13.49*
MEAN	*13.95*	*14.57*	*14.52*	*14.98*	*15.09*	*14.64*	*14.20*	*14.20*	*13.92*	*14.40*	*14.10*	*12.94*
MIN	*13.38*	*14.17*	*14.22*	*14.48*	*14.59*	*14.09*	*13.82*	*13.76*	*13.69*	*14.19*	*13.56*	*12.40*

Table D- 3. Cell 5 daily average stage (feet), WY2003.

Day	2002–05	2002–06	2002–07	2002–08	2002–09	2002–10	2002–11	2002–12	2003–01	2003–02	2003–03	2003–04
1	11.62	11.61	14.66	14.90	14.78	14.65	14.14	14.66	14.22	14.47	14.44	14.77
2	11.62	11.61	15.03	14.89	14.74	14.73	14.14	14.65	14.13	14.26	14.35	14.71
3	11.62	11.61	15.14	14.87	14.73	14.59	14.20	14.65	14.39	14.15	14.38	14.58
4	11.62	11.61	15.18	14.72	14.66	14.55	14.28	14.61	14.63	14.07	14.36	14.62
5	11.62	11.61	15.08	14.50	14.64	14.56	14.14	14.61	14.51	14.01	14.40	14.60
6	11.62	11.61	14.96	14.45	14.58	14.49	14.17	14.60	14.34	13.94	14.45	14.61
7	11.62	11.61	14.90	14.59	14.58	14.49	14.17	14.62	14.20	13.87	14.46	14.64
8	11.62	11.61	14.95	14.73	14.51	14.48	14.24	14.61	14.11	13.80	14.46	14.65
9	11.62	11.63	15.02	14.68	14.59	14.45	14.29	14.68	14.05	13.73	14.37	14.64
10	11.62	11.62	15.11	14.77	14.66	14.50	14.32	14.86	14.01	13.66	14.41	14.63
11	11.62	11.68	15.15	14.77	14.66	14.47	14.18	14.88	13.97	13.53	14.49	14.63
12	11.62	11.85	15.26	14.94	14.64	14.25	14.08	14.80	13.93	13.35	14.45	14.57
13	11.62	12.02	15.49	14.89	14.66	14.18	14.01	14.74	13.89	13.16	14.48	14.33
14	11.62	12.33	15.47	14.88	14.68	14.11	13.95	14.84	13.86	12.98	14.25	14.31
15	11.62	12.85	15.45	14.86	14.60	14.06	13.89	14.77	14.16	12.85	14.13	14.16
16	11.62	13.14	15.35	14.83	14.69	14.05	13.88	14.69	14.43	12.75	14.05	14.09
17	11.62	13.29	15.13	14.77	14.68	13.99	14.23	14.71	14.57	13.43	14.27	14.01
18	11.62	13.55	15.04	14.67	14.66	13.93	14.38	14.42	14.60	14.08	14.52	13.93
19	11.61	14.01	14.73	14.73	14.66	13.87	14.40	14.52	14.47	14.08	14.57	13.86
20	11.61	14.24	14.37	14.80	14.63	13.82	14.50	14.70	14.50	14.29	14.48	13.78
21	11.61	14.72	14.24	14.73	14.63	13.77	14.56	14.63	14.56	14.36	14.58	13.70
22	11.61	14.69	14.26	14.72	14.39	13.71	14.62	14.59	14.53	14.36	14.58	13.57
23	11.61	14.66	14.84	14.69	14.43	13.81	14.74	14.65	14.54	14.38	14.55	13.40
24	11.62	14.86	14.91	14.51	14.54	14.08	14.64	14.54	14.48	14.39	14.63	13.22
25	11.62	15.08	14.87	14.51	14.57	14.20	14.61	14.46	14.56	14.49	14.80	13.03
26	11.62	15.01	14.75	14.56	14.52	14.30	14.62	14.56	14.43	14.58	14.81	13.01
27	11.62	14.95	14.38	14.66	14.53	14.36	14.67	14.65	14.48	14.51	14.82	13.04
28	11.62	14.92	14.26	14.69	14.51	14.40	14.62	14.51	14.59	14.45	14.89	13.01
29	11.62	14.79	14.36	14.71	14.59	14.43	14.67	14.53	14.55		14.91	12.99
30	11.61	14.54	14.67	14.81	14.63	14.42	14.67	14.53	14.52		14.87	13.48
31	11.61		14.84	14.78		14.24		14.35	14.59		14.82	
MAX	*11.62*	*15.08*	*15.49*	*14.94*	*14.78*	*14.73*	*14.74*	*14.88*	*14.63*	*14.58*	*14.91*	*14.77*
MEAN	*11.62*	*13.11*	*14.90*	*14.73*	*14.61*	*14.26*	*14.33*	*14.63*	*14.35*	*13.93*	*14.52*	*14.02*
MIN	*11.61*	*11.61*	*14.24*	*14.45*	*14.39*	*13.71*	*13.88*	*14.35*	*13.86*	*12.75*	*14.05*	*12.99*

Table D- 4. Cell 5 daily average stage (feet), WY2004.

Day	2003–05	2003–06	2003–07	2003–08	2003–09	2003–10	2003–11	2003–12	2004–01	2004–02	2004–03	2004–04
1	14.03	14.38	14.58	14.56	14.72	15.40	14.21	13.80	14.07	14.58	14.69	12.93
2	14.07	14.23	14.47	14.71	14.86	15.45	14.06	13.70	14.01	14.77	14.67	12.83
3	13.83	14.14	14.65	14.80	14.86	15.43	14.14	13.85	14.04	14.77	14.57	12.74
4	13.90	14.08	14.80	14.90	14.87	15.35	14.42	14.16	14.03	14.72	14.54	12.67
5	13.91	14.28	14.76	14.98	15.04	15.18	14.61	14.18	14.11	14.74	14.53	12.59
6	14.03	14.52	14.62	15.00	15.12	15.03	14.72	14.23	14.06	14.76	14.52	12.53
7	14.06	14.50	14.59	14.98	15.11	14.88	14.69	14.08	13.94	14.69	14.48	12.49
8	13.82	14.42	14.66	14.93	15.11	14.87	14.76	14.18	13.87	14.63	14.50	12.45
9	13.72	14.53	14.72	14.84	15.07	14.82	14.74	14.25	13.88	14.33	14.36	12.42
10	13.60	14.68	14.58	14.78	14.99	14.85	14.68	14.20	14.19	14.46	14.28	12.39
11	13.41	14.69	14.55	14.93	14.96	14.82	14.68	14.35	14.04	14.47	14.36	12.35
12	13.20	14.67	14.57	15.04	14.95	14.73	14.47	14.42	13.95	14.46	14.33	12.34
13	12.96	14.66	14.34	15.14	15.12	14.72	14.25	14.39	13.86	14.42	14.23	12.43
14	12.73	14.39	14.20	15.11	15.25	14.83	14.38	14.42	13.80	14.23	14.27	12.54
15	12.54	14.39	14.12	15.07	15.28	14.80	14.42	14.47	13.73	14.29	14.25	12.52
16	12.48	14.43	14.18	15.01	15.28	14.64	14.20	14.53	13.63	14.41	14.18	12.52
17	12.46	14.55	14.45	14.86	15.17	14.32	14.20	14.60	13.52	14.46	14.28	12.50
18	12.45	14.63	14.34	14.96	15.12	14.24	14.23	14.68	13.48	14.44	14.27	12.46
19	12.46	14.76	14.22	14.91	15.06	14.15	14.11	14.70	13.49	14.27	14.10	12.41
20	13.03	14.79	14.34	14.90	15.02	14.09	14.30	14.71	13.47	14.37	14.03	12.36
21	13.77	14.79	14.38	14.91	14.87	14.24	14.17	14.55	13.45	14.43	13.97	12.33
22	13.84	14.76	14.71	14.97	14.90	14.49	14.05	14.30	13.41	14.37	13.91	12.29
23	13.92	14.94	14.79	14.96	14.87	14.42	13.98	14.35	13.34	14.41	13.84	12.27
24	13.86	15.00	14.75	14.87	14.78	14.20	13.92	14.39	13.26	14.41	13.75	12.27
25	13.76	14.98	14.66	14.89	14.52	14.13	13.87	14.31	13.17	14.34	13.64	12.27
26	13.70	14.89	14.73	14.94	14.76	14.07	13.81	14.19	13.12	14.62	13.53	12.27
27	13.68	14.80	14.74	14.93	15.09	14.13	13.82	14.30	13.11	14.74	13.41	12.26
28	14.14	14.80	14.67	14.93	15.18	14.27	13.80	14.31	13.12	14.73	13.30	12.22
29	14.46	14.63	14.51	14.99	15.24	14.30	13.70	14.36	13.66	14.68	13.22	12.19
30	14.70	14.58	14.43	14.92	15.35	14.15	13.81	14.22	14.05		13.12	12.16
31	14.66		14.58	14.73		14.29		14.12	14.23		13.02	
MAX	*14.70*	*15.00*	*14.80*	*15.14*	*15.35*	*15.45*	*14.76*	*14.71*	*14.23*	*14.77*	*14.69*	*12.93*
MEAN	*13.59*	*14.60*	*14.54*	*14.92*	*15.02*	*14.62*	*14.24*	*14.30*	*13.71*	*14.52*	*14.07*	*12.43*
MIN	*12.45*	*14.08*	*14.12*	*14.56*	*14.52*	*14.07*	*13.70*	*13.70*	*13.11*	*14.23*	*13.02*	*12.16*

Appendix E. Seepage Calculation

There are three boundaries around STA-6; the northern boundary, the western boundary, and the eastern boundary. To calculate the seepage of Cell 5, there are four boundaries that should be taken into account. They are the northern boundary, the western boundary of Cell 5, the eastern boundary of Cell 5, and the boundary between Cell 3 and Cell 5. Cell 3 has three boundaries; the western boundary of Cell 3, the eastern boundary of Cell 3, and the boundary between Cell 3 and Cell 5. Lengths along these seepage boundaries (L) are included in the **Figure E-1**.

In this analysis, seepage was computed as:

$$G = 1.983 * K_{sp} * L * \Delta H$$

Where	G	=	levee (horizontal) and deep (vertical) seepage (ac-ft/d)
	K_{sp}	=	coefficient of seepage (cfs/mi./ft)
	L	=	length along the seepage boundary (mi.)
	ΔH	=	hydraulic head difference between the unit and the boundary (ft)
	1.938	=	constant to convert from cfs to ac-ft/d

To calculate hydraulic head difference between the unit and the boundary (ΔH), it is necessary to know the average stage values at each location. Units are Cell 3, Cell 5, or the entire STA-6.

Average stage east of STA-6 (stage discharge canal)
= Avg. (G354C_T, G393B_T, G607_H)
Average stage west of STA-6 (stage supply canal)
= Avg. (G352S_H, G392S_H, G600_T, G604_H)
Average stage north boundary = Avg. (G393B_T, G600_H)
Average stage Cell 3 = Avg. (G392S_T, G393B_H)
Average stage Cell 5 = Avg. (G352S_T, G354C_H)

Example of a seepage calculation equation:

STA-6 Seepage (ha-m) = [(24 * (3600/43560) / 5280) / 8.1068) * (K_{C5} * L_{N_C5} * (S_{C5} - S_N) + K_{C5} * L_{E_C5} * (S_{C5} - S_E) + K_{C3} * L_{E_C3} * (S_{C3} - S_E) + K_{C3} * L_{W_C3} * (S_{C3} -S_E) + K_{C5} * L_{W_C5} * (S_{C5} - S_W)]

KC5 = seepage coefficient of Cell 5
KC3 = seepage coefficient of Cell 3
S_N = average stage north of STA6
S_E = average stage east of STA-6
S_W = average stage west of STA-6
S_{C5} = average stage of Cell 5
S_{C3} = average stage of Cell 3

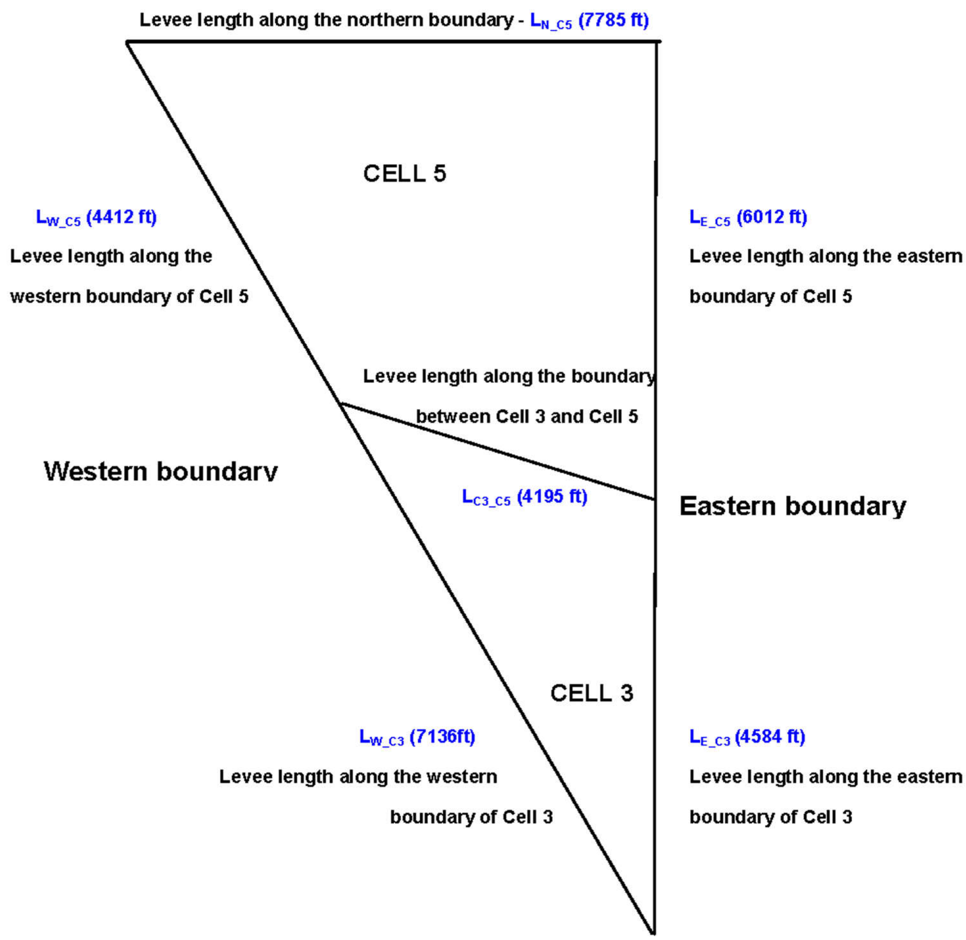

Figure E -1. STA-6 sketch map showing boundaries.