Technical Memorandum

To: **Mac Hatcher, PM Collier County**

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Date: **April 11, 2011**

Re: **Watershed Model Update and Plan Development**
Contract 08-5122, PO 4500106318
Element 1, Task 1.1: Surface Water Quantity

1.0 Objective

The purpose of this Technical Memorandum is to present the water quantity results of the Collier County MIKE SHE/MIKE11 Existing Conditions Model (ECM). This Technical Memorandum summarizes the predicted water budgets simulated by the ECM and discusses potential issues identified through the water budgeting process. It addresses the following items:

- **Water Budget Components.** This section describes the components used to define the water budget in MIKE SHE.

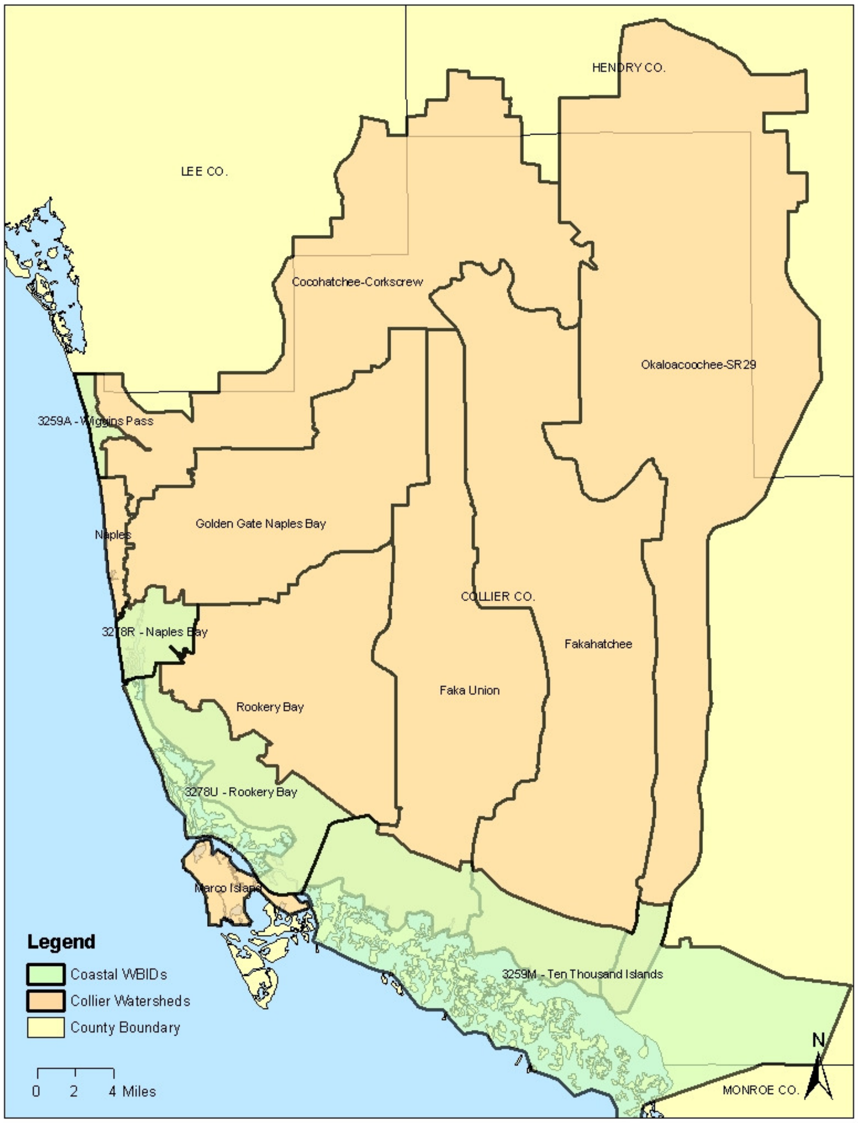
- **Surface Water and Groundwater Budgets.** This section describes the overall surface water and groundwater budgets, and the water budgets developed for each watershed (**Figure 2-1**).

- **Baseflow and Structure Operations.** This section focuses on the distribution of baseflow contributions within the Golden Gate – Naples Bay watershed. The section will also evaluate the potential effect of changes in structure operations.

- **Canal Capacity.** This section will identify locations water elevations in the canal are predicted to exceed the top of bank elevation during storm events. This is another factor that could help define potential changes in structure operations.

- **Conclusions.** This section presents the conclusions of these analyses.

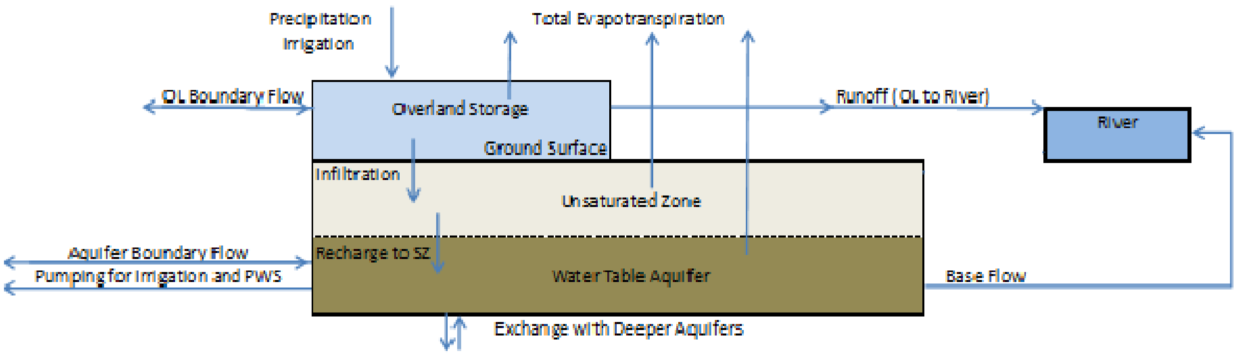
Figure 2-1. Collier County Watersheds and Coastal WBIDs



2.0 Water Budget Components

A water budget analysis was conducted to understand the distribution of watershed inflows and outflows. **Figure 2.1** is a schematic of the water budget components. As shown, the primary sources of inflow to a watershed are precipitation and applied irrigation. This water accumulates on the ground surface as basin storage, runs off as overland flow or infiltrates into the ground. Overland flow can be evaporated, discharged into the canal, or flow across watershed boundaries. Water that infiltrates into the soils can be taken up by plants or percolate into the water table (Surficial) aquifer. This water can then be removed from the Surficial Aquifer by plant uptake, by moving laterally across the watershed boundary, by pumping to meet potable water and irrigation needs, or by percolation to underlying aquifers. Any residual water is stored in the aquifer. Similar processes occur in each of the deeper aquifers.

Figure 2.1. Schematic of MIKE SHE Water Budget



The components of the water budget are described in further detail below:

Inflows:

- **Precipitation:** This is water entering the watershed as rainfall. Some portion of precipitation is intercepted by the vegetative canopy. The rest is applied to the ground surface.
- **Irrigation:** This is the sum of all model predicted irrigation applied to the ground surface in the watershed. This consists of water pumped from the Water Table (Surficial) and Lower Tamiami aquifers and water applied from external sources such as reuse water provided by Collier County or the City of Naples.
- **Overland Boundary Inflow:** This is water that enters a watershed as sheet flow from adjacent watersheds. This typically occurs during large storm events in the wet season when water ponded on the ground surface crosses a watershed boundary.
- **Aquifer Boundary Inflow:** This is groundwater that enters a watershed via subsurface flow from adjacent watersheds. There are four aquifers in the model, so this component can be broken in inflows per aquifer layer.

Outflows:

- **Evapotranspiration (ET):** The ET represents the combined total of direct evaporation of water ponded on the ground surface or captured in the vegetative canopy and water transpired from the soils and water table aquifer by plant uptake.
- **Runoff:** This represents the model predicted amount of overland flow that discharges into the river and canal network. This component also includes stormwater runoff from secondary and tertiary urban and agricultural drainage networks that are not explicitly represented in the model.
- **Baseflow:** This component of the model represents groundwater inflows to the canal network.

- **Pumping for irrigation and potable water supply:** This item represents the total volume of water pumped out of the aquifer system. Some portion of this water is applied to the ground surface as irrigation. Water pumped for potable water supply is used as reuse irrigation water or is injected into deep aquifers.
- **Overland Boundary Outflow:** This is water that leaves a watershed as overland flow into adjacent watersheds or across the model boundary and typically occurs during large storm events.
- **Aquifer Boundary Inflow:** This is groundwater that exits a watershed or the model via subsurface flow. There are four aquifers in the model, so this component can be broken in outflows per aquifer layer.

Storage Change:

- This component represents the total change in watershed storage. This includes overland storage, storage in the unsaturated zone and storage in groundwater.

3.0 Surface Water and Groundwater Budgets

For the water budget analyses, data was extracted from the MIKE SHE/MIKE11 model results files using a pre-defined Total Water Budget tool in the program. The model results were then post processed to create water budgets for the entire model study area as well as for each of the watersheds, Cocohatchee-Corkscrew (CC), Golden Gate Naples Bay (GGNB), Rookery Bay (RB), and the combined Faka Union, Fakahatchee, and Okaloacoochee-SR29 (FUFHOK) watersheds. These watersheds are comprised of aggregated WBID areas.

Water budgets were generated for the model simulation period of January 1, 2002 through October 31, 2007. Budgets were developed for different time periods based on model simulation data availability. The time periods include:

- **Annual:** The water budget represents average conditions during the water year. The budget represents the period from November 1 – October 31. For example, the 2003 water year is the period from November 1, 2002 – October 31, 2003. Water year budgets were calculated for 2003 through 2007.

- **Wet Season:** The wet season is defined as July 1 – October 31. Wet season water budgets were developed for the years 2002 – 2007. This period includes all the wet seasons incorporated in the model simulation period.

- **Dry Season:** The dry season is defined as the period from November 1 – June 30. The 2003 dry season represents November 2002 – June 2003. Dry season water budgets were developed for the years 2003 – 2007.

3.1. Water Budget Results

This section describes the results of the water budget analysis in terms of annual average, wet season and dry season. In addition, water budgets were prepared for a wet year and a dry year relative to the average annual conditions. Finally, seasonal water budgets were developed for each watershed.

3.1.1 Water Budget Results for the Study Area

Table 3.1 shows the annual water year and seasonal water budget components for the study area. **Figure 3.1** shows the average water year budget for the entire study area. **Figure 3.2 and Figure 3.3** show the corresponding average wet season and dry season water budgets. The data indicate that rainfall during the four (4) month wet season represents about 54 percent of the total annual amount and that most is lost through ET.

Table 3.1. Annual Water Year and Seasonal Water Budgets for Study Area

Period	Inflows (inches)		Outflows (inches)				Change in Storage
	Precipitation	Irrigation	Evapo Transpiration	Runoff	Baseflow to River	Pumping	
Dry Season Average							
2003	31.10	1.57	24.45	1.65	1.93	2.17	3.15
2004	24.72	1.81	25.55	1.26	2.28	2.44	-4.45
2005	35.79	1.81	25.08	3.31	2.24	2.44	4.41
2006	19.45	2.60	25.47	1.22	2.13	3.27	-9.57
2007	17.17	3.50	24.69	0.16	1.06	4.21	-7.99
Average	25.65	2.26	25.05	1.52	1.93	2.91	-2.89
Wet Season Average							
2002	21.14	0.31	16.22	1.38	1.85	0.63	1.14
2003	29.65	0.12	15.67	8.86	3.11	0.39	-0.35
2004	34.72	0.08	16.26	8.70	2.87	0.39	4.53
2005	33.86	0.08	17.36	10.16	3.50	0.39	-0.51
2006	30.59	0.43	17.17	5.31	2.80	0.71	3.62
2007	26.38	0.39	17.44	0.83	1.61	0.71	6.26
Average	29.39	0.24	16.69	5.87	2.62	0.54	2.45
Annual Average							
2003	60.75	1.69	40.12	10.51	5.04	2.56	2.80
2004	59.45	1.89	41.81	9.96	5.16	2.83	0.08
2005	69.65	1.89	42.44	13.46	5.75	2.83	3.90
2006	50.04	3.03	42.64	6.54	4.92	3.98	-5.94
2007	43.54	3.90	42.13	0.98	2.68	4.92	-1.73
Average	56.69	2.48	41.83	8.29	4.71	3.43	-0.18

Runoff and baseflow are important components of the water budget as they represent about 15 and eight (8) percent of annual rainfall (8.3 and 4.7 inches, respectively). In other words, the volume of groundwater that enters the canal network as baseflow is approximately 36 percent of the total fresh water discharged into the canal network. It is important to point out that baseflow discharges are the result of the construction of the drainage canals that cut into the water table aquifer.

During the wet period, runoff is about 70 percent of the total contributions to the canal network. However, in the dry season, the runoff volume decreases to about 44 percent of the total contribution the canal network. Therefore, the majority of the dry season canal flow is baseflow. This is because runoff is highly sensitive to varying meteorological conditions, whereas baseflow is relatively stable. The ratio of average runoff to average rainfall ranges from 20 percent in the wet season to 6 percent in the dry season. On the other hand, baseflow (wet season = 2.62 inches and dry season = 1.93 inches) remains at about 8 percent of rainfall.

Figures 3.2 and 3.3 also illustrate the seasonal variations in pumping and irrigation. As expected, pumping and irrigation demand during the dry season represents about 85 percent of the annual water budget for these two items.

Finally, the water budget also includes watershed storage. As shown in **Figures 3.1**, change in storage as an annual average is negligible. **Figures 3.2 and 3.3** show that about 2.5 inches of storage is lost in the dry season, but that volume is recovered in the wet season. This indicates that, at least during the simulation period 2002 – 2007, hydrologic characteristics of the study area did not worsen, although no recovery is apparent.

Figure 3.1. Average Water Year (2003 – 2007) Water Budget

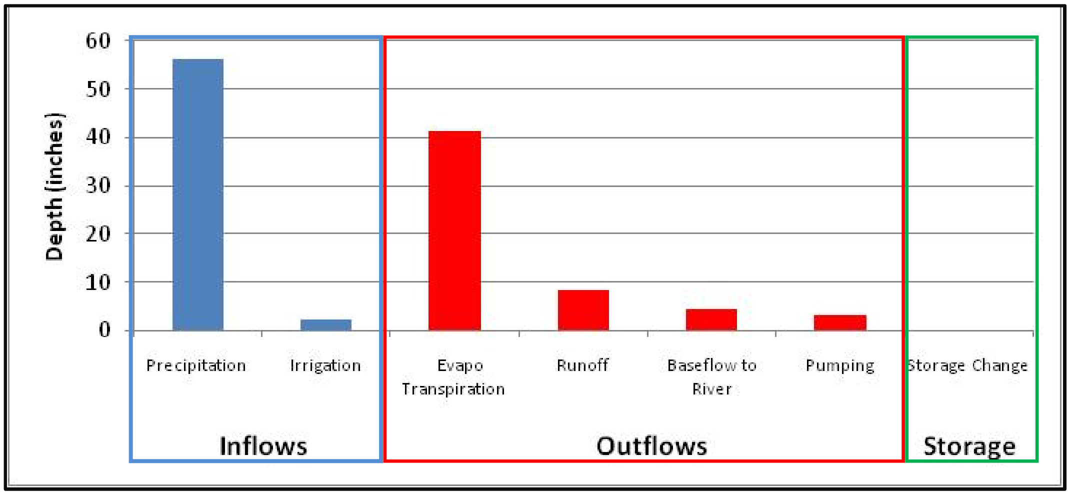


Figure 3.2. Average Wet Season (2002 – 2007) Water Budget

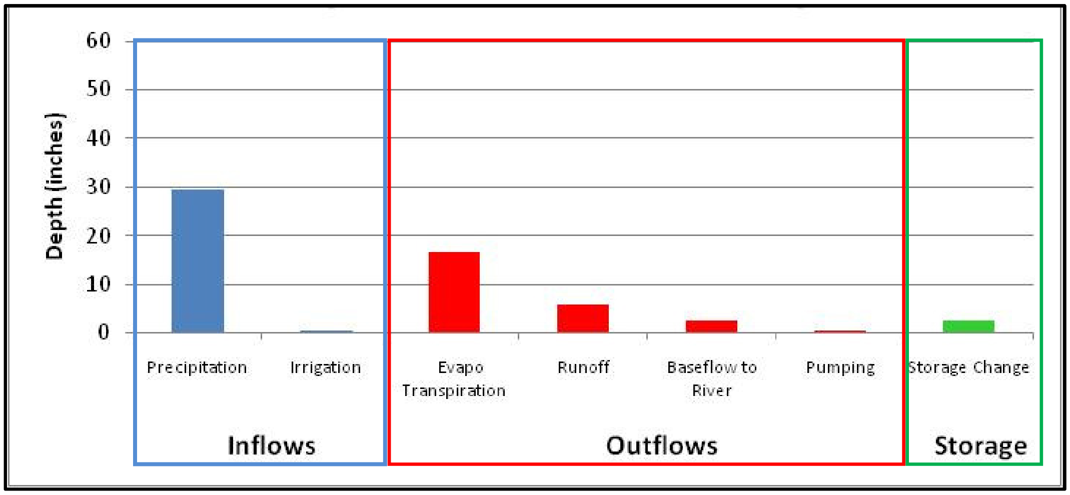
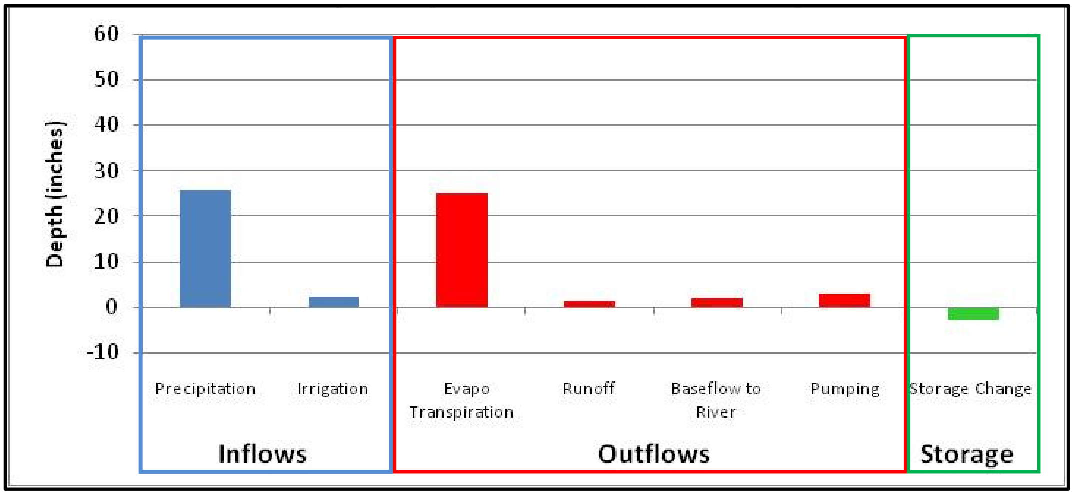


Figure 3.3. Average Dry Season (2003 – 2007) Water Budget



To assess the system characteristics during critical conditions, water budgets were developed for both the driest dry season and the wettest wet season in the simulation period. **Figure 3.4** shows the results of the 2007 dry season (November 2006 through June 2007). Total precipitation during this period amounted to about 17 inches, which is about 33 percent less than the average dry season rainfall for the entire simulation period. **Figure 3.5** represents the extremely wet 2004 rainy season (July through October 2004) when Florida experienced three hurricanes in less than 45 days. Total rainfall accumulated during that season was almost 35 inches, which is about 20 percent more than the wet season average for the model simulation period.

Results of the analysis confirm that the change in runoff volume is much larger than the change in precipitation. During the 2007 dry season, a 33 percent reduction in precipitation from the period average resulted in an approximately 90 percent reduction in runoff volume. Similarly, the 20 percent increase in precipitation during the 2004 wet season resulted in an about 50 percent increase in runoff volume. As stated previously, baseflow is not affected as drastically as runoff volume. The change in baseflow contribution is small during extremely wet conditions as demonstrated by the 10 percent increase from average during the 2004 wet season. The impact is more severe during dry weather conditions when it was reduced by about 50 percent from average. It is important to point out that this also indicates that fresh water flows in the canal in the 2007 dry conditions was almost exclusively baseflow.

The results of the annual and seasonal water budgets indicate that the management of both runoff and baseflow are key to reducing the volume of water discharged to the estuaries. During the dry season, the reduction of baseflow to the canal network appears to be the more critical issue. It should be noted that structure operations are important to managing both discharge and baseflow in the canal network.

During extreme dry weather, irrigation and pumping also increase substantially, accompanied by a substantial reduction in watershed storage. Similarly to the annual average analysis, irrigation and pumping are drastically reduced during extreme wet weather conditions and the watershed storage is quickly recovered.

Figure 3.4. 2007 – Driest Dry Season Water Budget

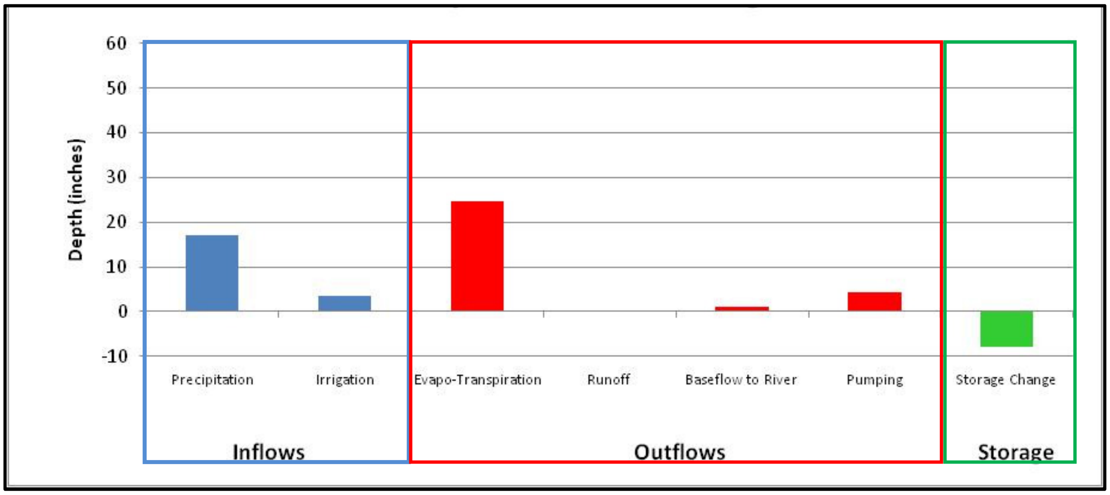
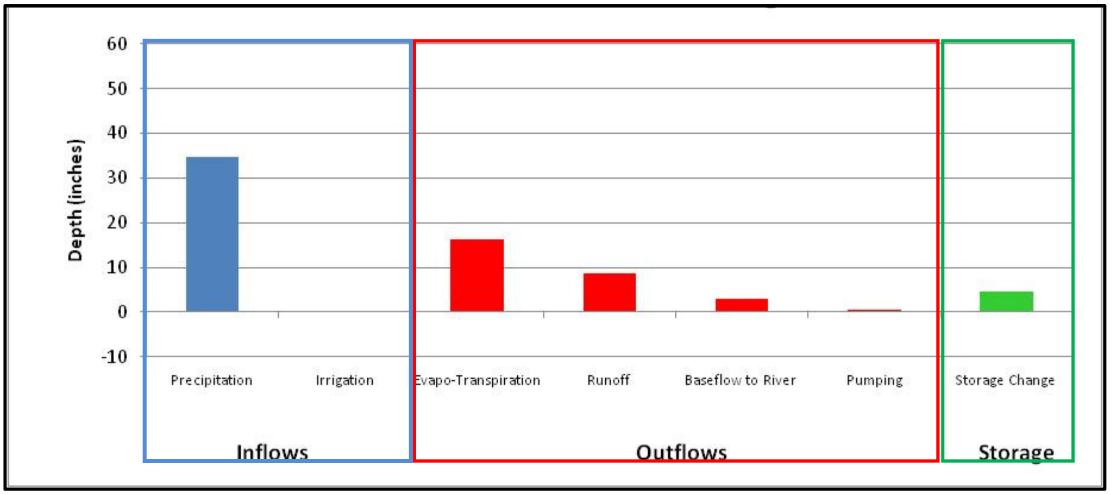


Figure 3.5. 2004 – Wettest Wet Season Water Budget



3.1.2 Water Budget Results by Watershed

Average water year and seasonal water budgets were also generated for each of the watersheds in Collier County. As described for the entire study area, the majority of the precipitation is lost to ET, which ranges between 50 and 60 percent in the wet season for all watersheds. During the dry season, ET losses equal precipitation in all watersheds except Golden Gate - Naples Bay, where ET is about 80 percent of precipitation. This is due to the high level of watershed urban development, as water is quickly routed to the drainage network.

Cocohatchee-Corkscrew Watershed. The budgets for the Cocohatchee-Corkscrew watershed are shown in **Figures 3.6 - 3.8** and in **Table 3.2.** Model results indicate that the annual average runoff volume is approximately 14 percent of rainfall. Most of the runoff comes from urban and agricultural development. As an example, in the 2003 wet season results indicate that runoff was more than nine (9) inches. Of that, 8.5 inches came from urban and agricultural development.

Figure 3.6. Average Water Year Budget – Cocohatchee-Corkscrew Watershed

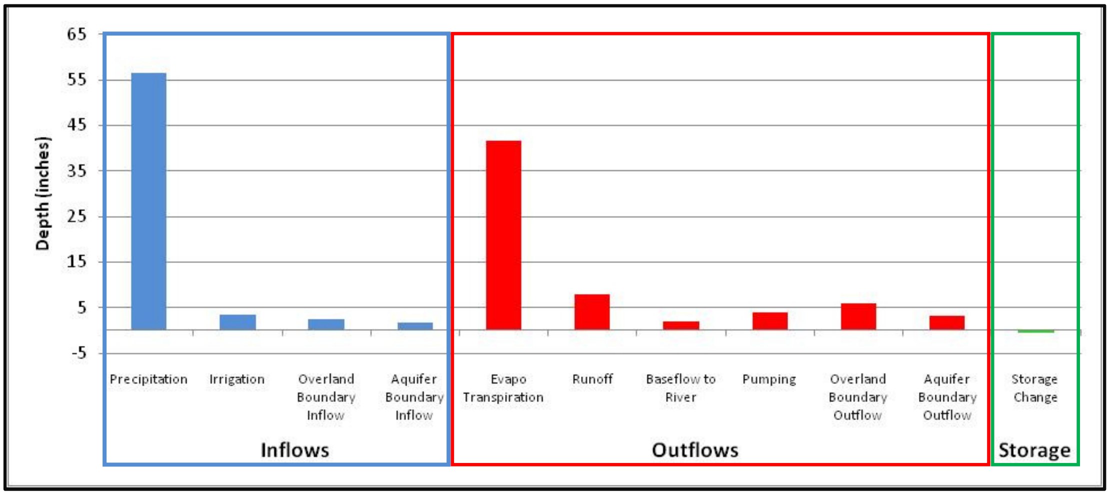


Figure 3.7. Average Wet Season Water Budget – Cocohatchee-Corkscrew Watershed

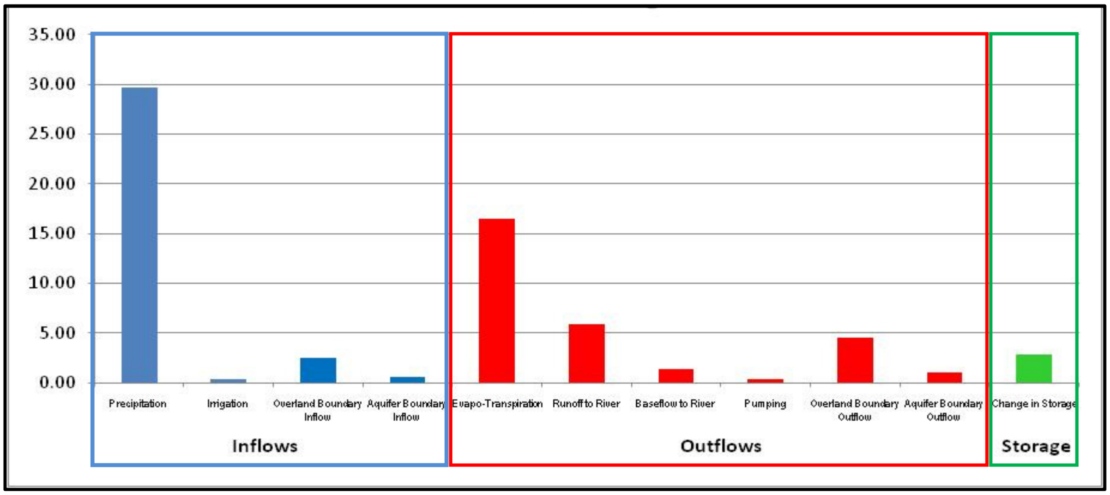


Figure 3.8. Average Dry Season Water Budget – Cocohatchee-Corkscrew Watershed

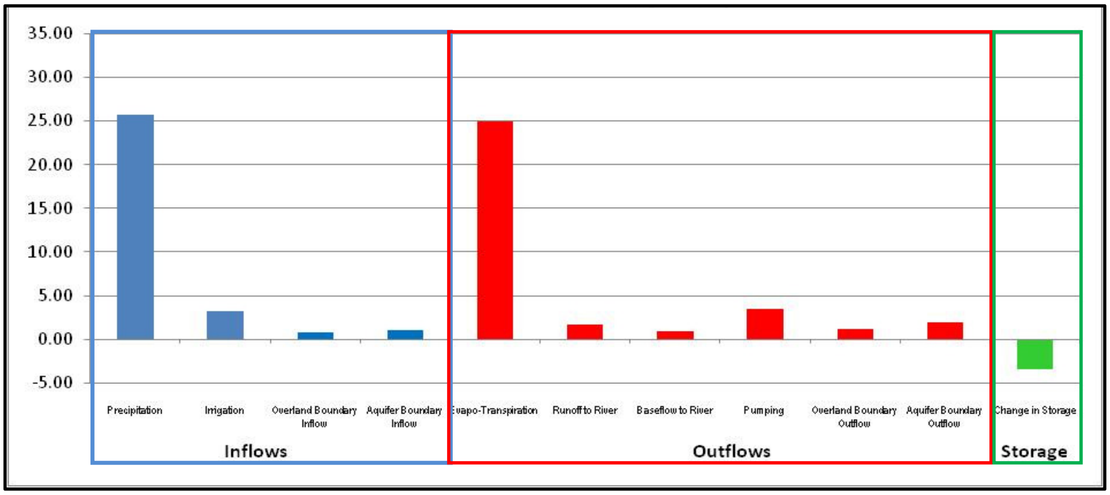


Table 3.2. Seasonal Water Budget for Cocohatchee-Corkscrew Watershed

Season	Inflows (inches)				Outflows (inches)						Storage (inches)
	Precipitation	Irrigation	Overland Boundary Inflow	Aquifer Boundary Inflow	Evapo-Transpiration	Runoff to River	Baseflow to River	Pumping	Overland Boundary Outflow	Aquifer Boundary Outflow	Storage Change
Wet 2002	23.14	0.34	0.25	0.59	15.99	2.46	1.01	0.43	0.64	0.81	2.88
Wet 2003	29.78	0.17	4.09	0.62	15.26	9.10	1.81	0.26	7.11	1.17	-0.67
Wet 2004	36.10	0.19	4.30	0.63	16.05	9.11	1.66	0.29	7.88	1.11	4.46
Wet 2005	33.54	0.11	4.72	0.62	17.36	9.14	1.91	0.22	8.61	1.25	-0.07
Wet 2006	29.79	0.55	1.35	0.67	17.11	4.89	1.33	0.65	2.76	0.98	4.33
Wet 2007	25.30	0.56	0.07	0.73	17.42	0.91	0.45	0.66	0.16	0.78	6.18
Average Wet	29.61	0.32	2.46	0.64	16.53	5.93	1.36	0.42	4.53	1.02	2.85
Dry 2003	33.32	2.31	0.56	0.97	24.43	2.80	1.09	2.51	1.08	1.72	3.37
Dry 2004	24.91	2.63	0.56	1.05	25.37	1.51	1.10	2.83	0.77	1.91	-4.40
Dry 2005	35.40	2.57	1.16	1.08	25.08	3.54	1.21	2.80	1.99	1.97	3.38
Dry 2006	19.83	3.62	1.26	1.10	25.69	1.18	1.06	3.85	1.82	1.94	-9.80
Dry 2007	15.15	5.03	0.25	1.13	24.08	-0.55	0.24	5.27	0.13	1.92	-9.52
Average Dry	25.72	3.23	0.76	1.07	24.93	1.70	0.94	3.45	1.16	1.89	-3.39

Table 3.3. Seasonal Water Budget for Golden Gate - Naples Bay Watershed

Season	Inflows (inches)				Outflows (inches)						Storage (inches)
	Precipitation	Irrigation	Overland Boundary Inflow	Aquifer Boundary Inflow	Evapo-Transpiration	Runoff to River	Baseflow to River	Pumping	Overland Boundary Outflow	Aquifer Boundary Outflow	Storage Change
Wet 2002	23.29	0.04	0.35	0.92	15.21	1.20	6.34	1.53	0.26	0.51	-0.47
Wet 2003	33.93	0.02	6.12	1.02	15.05	11.99	10.52	1.27	3.40	0.50	-1.76
Wet 2004	36.10	0.02	7.11	1.07	16.04	10.98	9.38	1.45	3.55	0.51	2.32
Wet 2005	37.47	0.01	7.82	1.25	17.08	13.32	10.74	1.56	4.12	0.59	-0.97
Wet 2006	34.29	0.06	2.39	1.05	16.36	6.69	9.23	1.37	1.34	0.59	2.13
Wet 2007	26.77	0.17	0.06	1.16	16.62	0.16	4.85	1.69	0.06	0.50	4.29
Average Wet	31.98	0.05	3.97	1.08	16.06	7.39	8.51	1.48	2.12	0.53	0.92
Dry 2003	32.81	0.89	0.75	1.83	21.24	1.52	5.01	3.70	0.35	0.84	3.59
Dry 2004	25.01	1.13	0.45	2.17	20.66	0.42	4.89	4.13	0.25	0.80	-2.40
Dry 2005	37.61	1.32	1.42	2.23	21.21	4.97	5.71	4.49	0.89	0.91	4.35
Dry 2006	19.86	1.79	1.58	2.37	19.43	0.94	5.02	4.93	0.92	0.95	-6.60
Dry 2007	14.35	2.55	0.12	2.20	19.00	-0.09	0.72	5.49	0.03	0.79	-6.71
Average Dry	25.93	1.54	0.86	2.16	20.31	1.55	4.27	4.55	0.49	0.86	-1.56

Table 3.4. Seasonal Water Budget for Rookery Bay Watershed

Season	Inflows (inches)				Outflows (inches)						Storage (inches)
	Precipitation	Irrigation	Overland Boundary Inflow	Aquifer Boundary Inflow	Evapo-Transpiration	Runoff to River	Baseflow to River	Pumping	Overland Boundary Outflow	Aquifer Boundary Outflow	Storage Change
Wet 2002	19.89	0.16	0.16	0.95	16.42	0.19	1.45	0.16	0.98	0.91	1.05
Wet 2003	33.15	0.02	0.92	0.80	16.13	9.52	3.38	0.02	4.66	1.48	-0.52
Wet 2004	30.46	0.09	0.67	1.02	16.94	4.76	3.23	0.09	2.51	1.31	3.19
Wet 2005	31.48	0.04	0.80	0.99	17.25	7.19	4.04	0.09	3.44	1.72	-0.69
Wet 2006	31.82	0.05	0.69	1.00	17.17	5.11	3.32	0.06	2.82	1.41	3.51
Wet 2007	26.51	0.17	0.22	1.15	17.41	0.43	1.15	0.17	1.00	1.01	6.83
Average Wet	28.88	0.09	0.58	0.99	16.89	4.53	2.76	0.10	2.57	1.31	2.23
Dry 2003	29.23	1.02	0.55	2.07	24.15	0.24	1.62	1.02	1.26	1.79	2.79
Dry 2004	23.84	0.84	0.56	2.17	25.13	0.03	2.19	0.84	0.88	2.07	-3.72
Dry 2005	35.71	1.08	0.82	2.39	24.10	3.22	2.15	1.13	2.62	2.17	4.56
Dry 2006	19.09	1.19	0.69	2.45	24.13	0.24	2.12	1.27	0.73	2.30	-7.40
Dry 2007	16.28	1.48	0.68	2.69	24.17	-0.10	0.89	1.48	0.58	1.79	-7.67
Average Dry	24.83	1.12	0.66	2.35	24.34	0.72	1.80	1.15	1.21	2.03	-2.29

Table 3.5. Seasonal Water Budget for Faka Union, Fakahatchee and Okaloacoochee-SR29 Watersheds

Season	Inflows (inches)				Outflows (inches)						Storage (inches)
	Precipitation	Irrigation	Overland Boundary Inflow	Aquifer Boundary Inflow	Evapo-Transpiration	Runoff to River	Baseflow to River	Pumping	Overland Boundary Outflow	Aquifer Boundary Outflow	Storage Change
Wet 2002	20.59	0.00	0.12	1.73	16.50	0.16	4.41	0.47	0.24	0.51	0.16
Wet 2003	29.37	0.00	6.57	1.81	15.98	8.31	8.66	0.43	3.07	1.06	0.31
Wet 2004	32.52	0.00	7.28	1.85	16.65	9.02	8.15	0.43	2.80	1.02	3.58
Wet 2005	33.19	0.00	9.45	1.69	17.17	12.32	11.02	0.55	3.70	1.30	-1.69
Wet 2006	32.17	0.00	4.21	1.73	17.05	7.05	8.07	0.59	2.36	1.02	2.01
Wet 2007	26.77	0.00	0.12	1.54	17.24	0.31	4.88	0.59	0.28	0.67	4.41
Average Wet	29.10	0.00	4.63	1.73	16.77	6.19	7.53	0.51	2.07	0.93	1.46
Dry 2003	27.44	0.08	0.08	3.86	23.70	0.00	3.31	1.14	0.24	0.98	2.05
Dry 2004	23.94	0.12	0.24	4.06	23.98	0.24	5.91	1.10	0.31	1.18	-4.37
Dry 2005	34.33	0.12	1.54	4.06	23.43	2.32	4.61	1.42	1.10	1.22	5.98
Dry 2006	19.88	0.16	0.59	4.21	23.19	0.39	4.92	1.57	0.24	1.14	-6.69
Dry 2007	19.13	0.20	0.04	3.90	23.39	-0.28	2.40	1.61	0.16	1.18	-5.20
Average Dry	24.94	0.13	0.50	4.02	23.54	0.54	4.23	1.37	0.41	1.14	-1.65

Runoff flow contributions from natural areas are small because the majority is stored in the Corkscrew Swamp. In addition, there is a large component of overland runoff flow that leaves the Cocohatchee-Corkscrew watershed and enters the Golden Gate–Naples Bay, Okaloacoochee-SR 29, Fakahatchee, and Faka Union watersheds during large rainfall events due to the little difference in elevation at the watershed ridges. In terms of baseflow, the amount relative to runoff is only half of that computed for the entire study area. This can be attributed to the low density of canals in the watershed.

Golden Gate-Naples Bay Watershed. The water budgets for the Golden Gate watershed are shown in **Figures 3.9 – 3.11** and in **Table 3.3**. The most important feature of this watershed is that baseflow is the primary source of water to the canal network. It often exceeds 70 percent of the canal flow during the dry season. This can be attributed to the density of canals throughout the drainage area. Reducing baseflow to the canal network could have a significant effect on the volume of water discharging to the Naples Bay Estuary.

Runoff exceeds 19 percent of rainfall and occurs primarily during the rainy season. As in the Cocohatchee – Corkscrew watershed, most of the runoff is from urban development close to the coast. The volume of water leaving the watershed via overland and aquifer flow is low and is directly influenced by the presence of the canal network that drains the Surficial Aquifer and directs water to the estuary systems.

Rookery Bay Watershed. The Rookery Bay watershed is diverse with urban development located west of the Henderson Creek Canal. The central portion of the watershed is mostly natural and consists of the Henderson Strand and portions of the Picayune Strand State Forest. The southeast portion of the watershed is agricultural. In general, the percentage of runoff relative to precipitation (11 percent) is low compared to the other watersheds. The low runoff value is most likely associated to the lack of development in large parts of the watershed.

The seasonal water budget results shown in **Figures 3.12 – 3.14** and **Table 3.4** indicate that surface runoff makes up 60 percent of canal flow during the wet season. However, during the dry season, baseflow contributions often exceed 70 percent of canal flow. Wet season runoff occurs primarily from the urbanized and agricultural areas; while dry season baseflow contributions occur primarily in the Henderson Creek Canal.

Figure 3.9. Average Water Year Budget – Golden Gate – Naples Bay Watershed

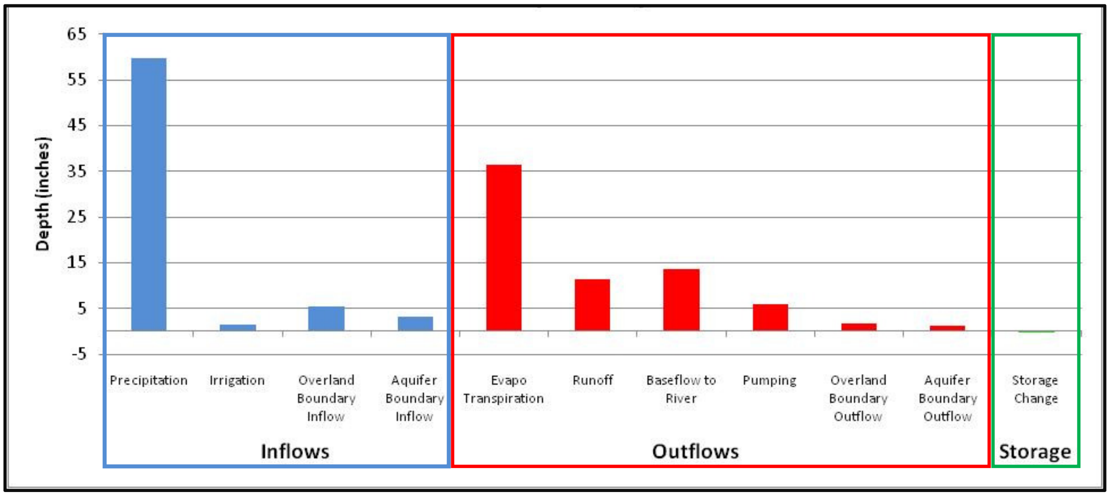


Figure 3.10. Average Wet Season Water Budget – Golden Gate – Naples Bay Watershed

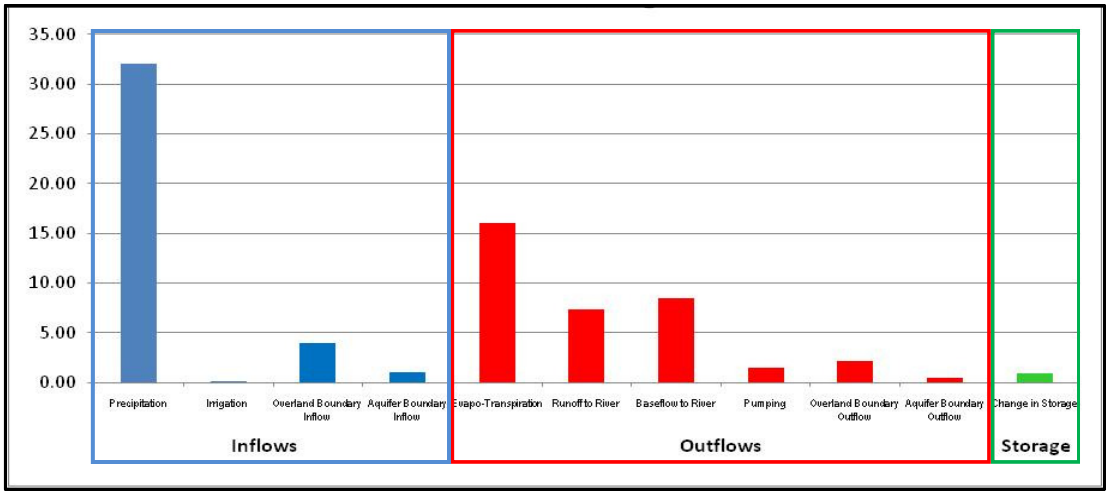


Figure 3.11. Average Dry Season Water Budget – Golden Gate – Naples Bay Watershed

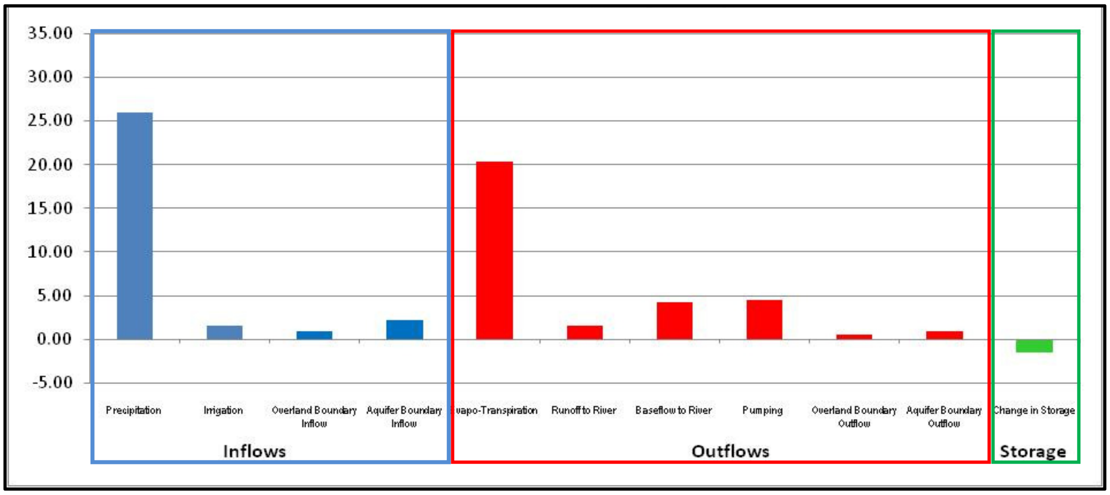


Figure 3.12. Average Annual Water Budget – Rookery Bay Watershed

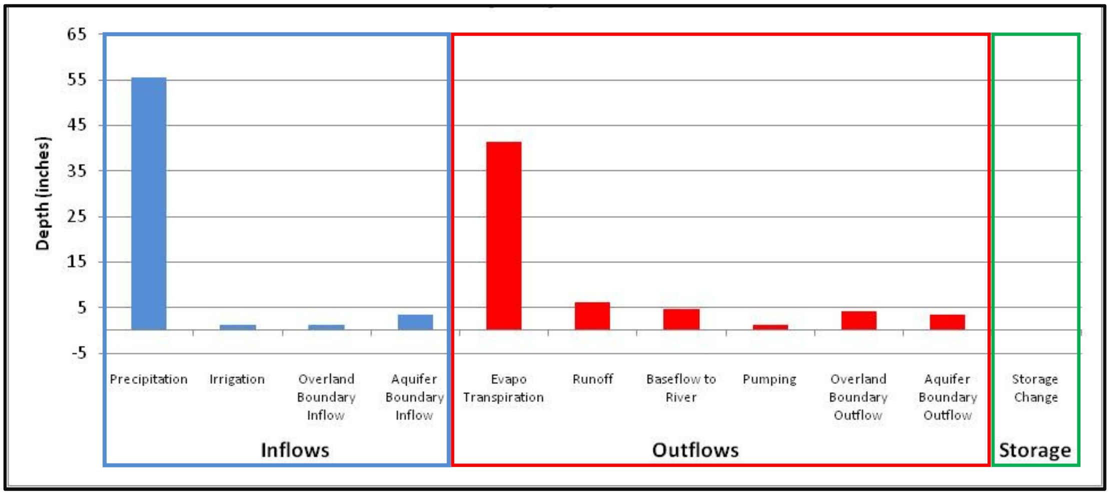


Figure 3.13. Average Wet Season Water Budget – Rookery Bay Watershed

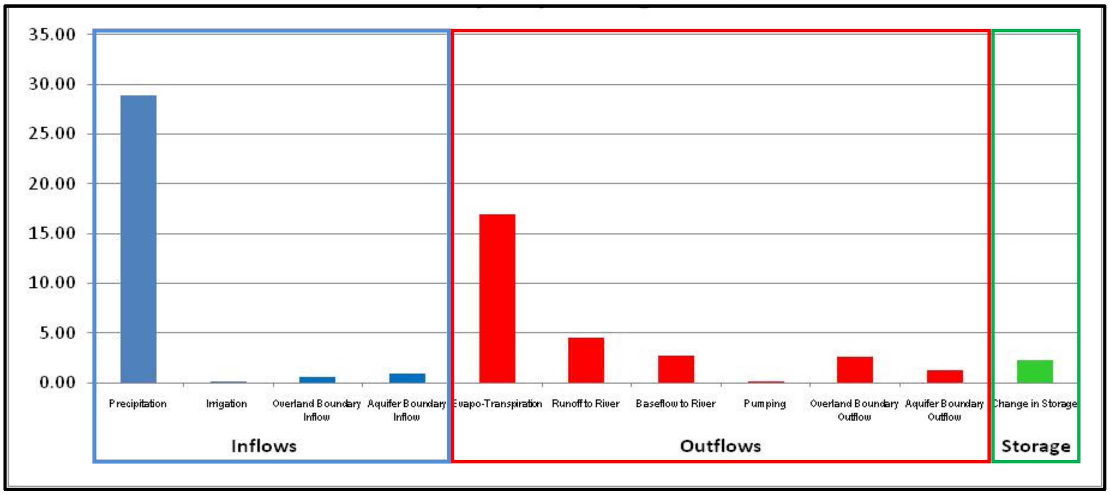
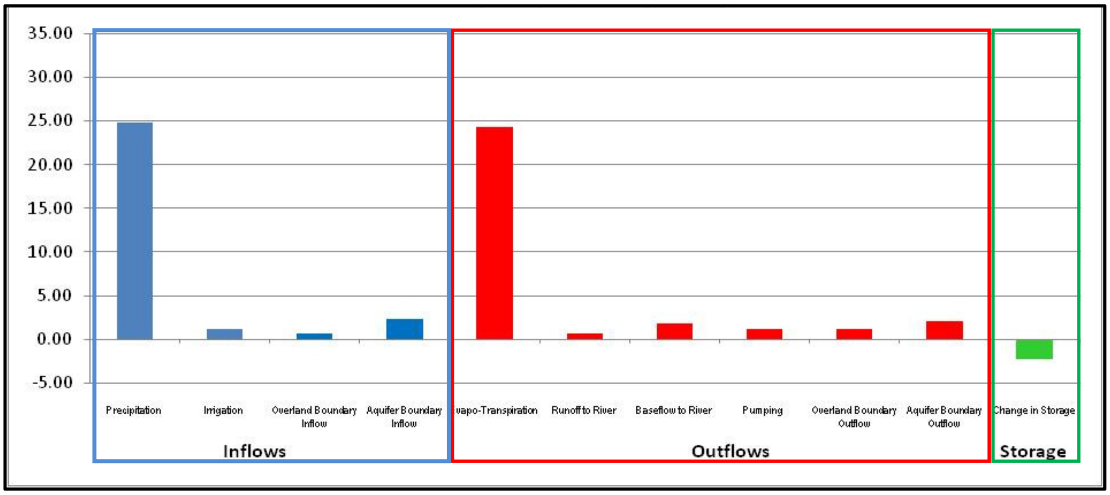


Figure 3.14. Average Dry Season Water Budget – Rookery Bay Watershed



Faka Union, Fakahatchee, and Okaloacoochee–SR29 Watersheds. The water year and seasonal water budgets for the Faka Union, Fakahatchee, and Okaloacoochee-SR29 watersheds are shown in **Figures 3.15 – 3.17** and in **Table 3.5.** There are a large percentage of agricultural lands in the northern portion of the Fakahatchee and Okaloacoochee-SR29 watersheds; whereas, the northern part of the Faka Union watershed includes rural residential areas. The remainder of the watershed consists of wetlands or other natural areas; however, portions of the Golden Gate Canal network drain large portions of the natural areas in the southern Faka Union watershed.

In the wet season, baseflow in these watersheds is equal to approximately 120 percent of runoff, but during the dry season, the volume of baseflow is more than eight (8) times that of runoff. The model results indicate that baseflow occurs primarily in the Faka Union watershed, although there are baseflow contributions to the State Road 29 Canal in the Okaloacoochee – SR29 watershed. It is expected that the Picayune Strand Restoration Project will greatly reduce the volume of baseflow in these combined watersheds.

The water budget results indicate a slight loss in stored water over the simulation period. This is most likely attributed to the high baseflow contributions to the canal network in the Faka Union watershed, although groundwater pumping for potable water supply and agricultural irrigation in the northern parts of the watershed may contribute to loss of water.

Figure 3.15. Average Water Year Budget – Faka Union, Fakahatchee and Okaloacoochee-SR29 Watersheds

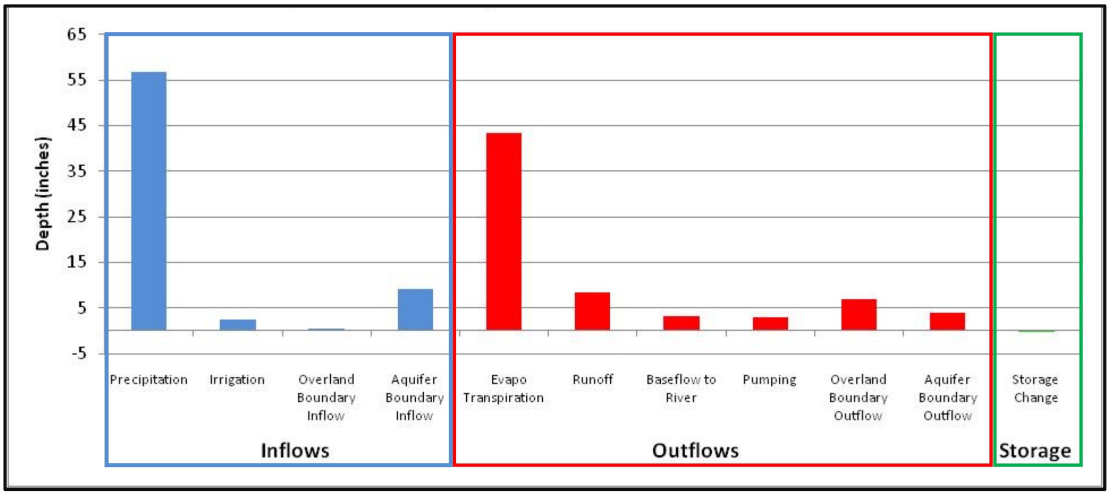


Figure 3.16. Average Wet Season Water Budget – Faka Union, Fakahatchee and Okaloacoochee-SR29 Watersheds

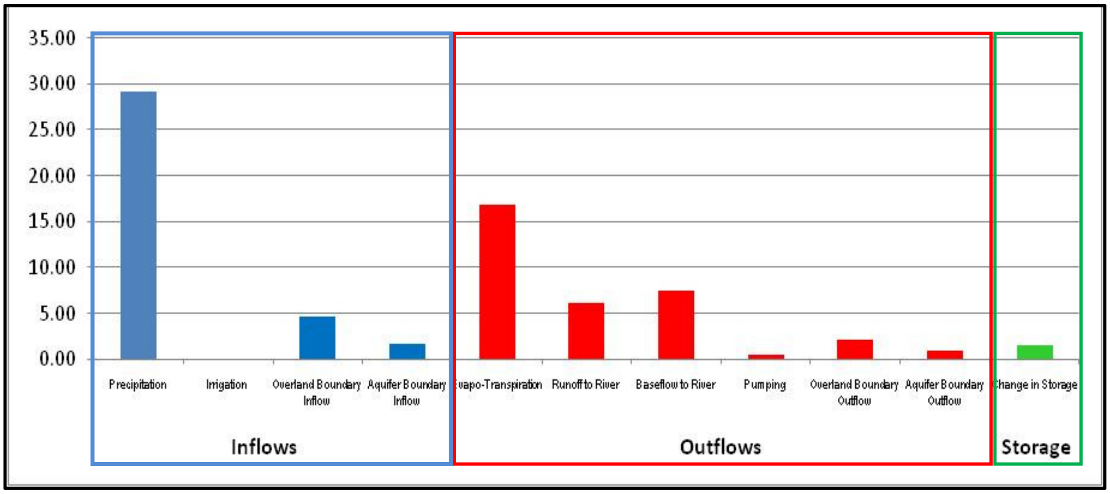
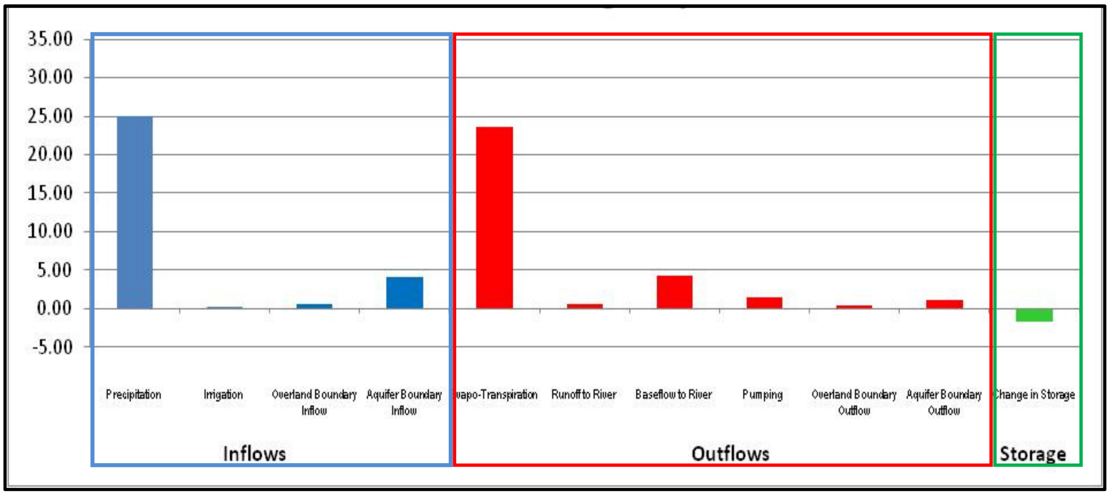


Figure 3.17. Average Dry Season Water Budget – Faka Union, Fakahatchee and Okaloacoochee-SR29 Watersheds



4.0 Baseflow and Structure Operations

As discussed previously, the water budget discussion indicated the relative importance of baseflow in the individual watersheds. **Figures 4.1 and 4.2** show the average baseflow contribution to the individual drainage features. The maps indicate that the wetland area in the Okaloacoochee Slough, Camp Keais Strand, and the Corkscrew Swamp provides groundwater recharge (negative baseflow) on a year round basis. The maps also indicate that significant baseflow contributions to the canal network occur especially in the Golden Gate and Faka Union watersheds. These maps are consistent with the water budget results discussed in **Section 3.0**.

As also indicated previously, it is expected that completion of the Picayune Strand Restoration Project will greatly reduce the baseflow contributions in the Faka Union watershed; therefore, the remainder of this discussion will focus on baseflow and structure operations in the Golden Gate – Naples Bay watershed.

A comparison of baseflow during the wet and dry seasons in the Golden Gate – Naples Bay watershed indicates that substantially more baseflow occurs during the wet season than during the dry. The water budget analysis showed that 8.51 inches of baseflow occurs in the Golden Gate – Naples Bay watershed during the wet season compared to 4.27 inches during the dry season.

Figure 4.3 and **Figure 4.4** show the average wet season and dry season baseflow contributions in the Golden Gate – Naples Bay watershed. It is interesting to note that during the dry season, recharge (negative baseflow) is predicted to occur in several locations immediately upstream of operable gates, or near shallow potable water supply well fields. The greatest volume of dry season recharge occurs immediately north of the CR951-1 structure which includes a pump to divert water from the Golden Gate Main Canal into the CR951 Canal. The results shown in **Figure 4.4** suggest that water pumped into the CR951 Canal is returning to the Golden Gate Main Canal via baseflow. Groundwater recharge influenced by pumping for potable water supply is also observed in the dry season near the GG-4 structure.

The maps also show that the highest predicted baseflow values occurs immediately downstream of the operable structures and that baseflow decreases along the canal toward the next downstream structure. This is most evident along the Cypress Canal segment between structures CYP-1 and GG-3. This pattern of baseflow along the length of a canal segment is the result of staging water at different elevations upstream of each structure.

It should be noted that the ECM was setup to replicate the standard operating rules defined by the SFWMD for each structure. These rules primarily rely upon the water levels upstream and downstream of the individual structures and are designed to stage water at different elevations for the wet and dry seasons and may contribute to the seasonal difference in baseflow. During the wet season, the structures are operated to stage the canals at an elevation that is approximately one foot (1 ft) lower than the dry season. The lower elevation, paired with higher groundwater elevations due to rainfall, leads to an increase in baseflow.

Figure 4-1. Average Wet Season Baseflow Contributions

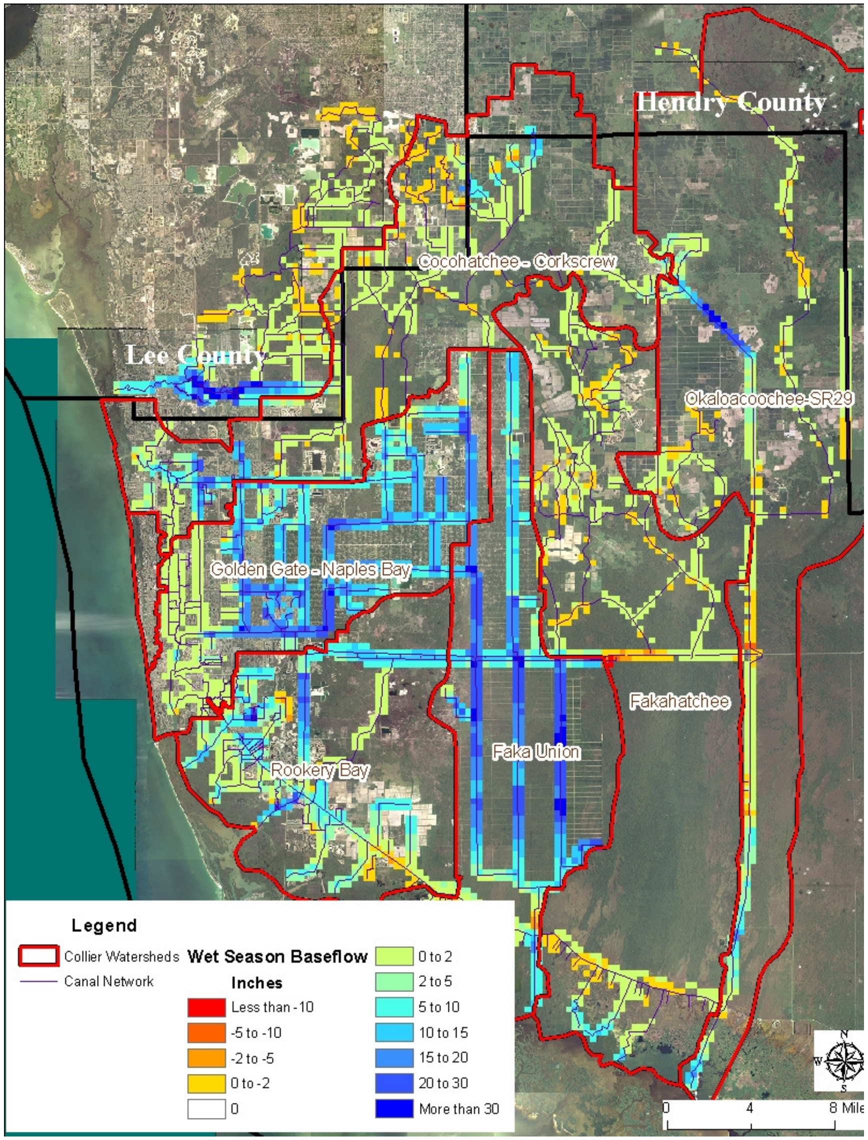


Figure 4-2. Average Dry Season Baseflow Contributions

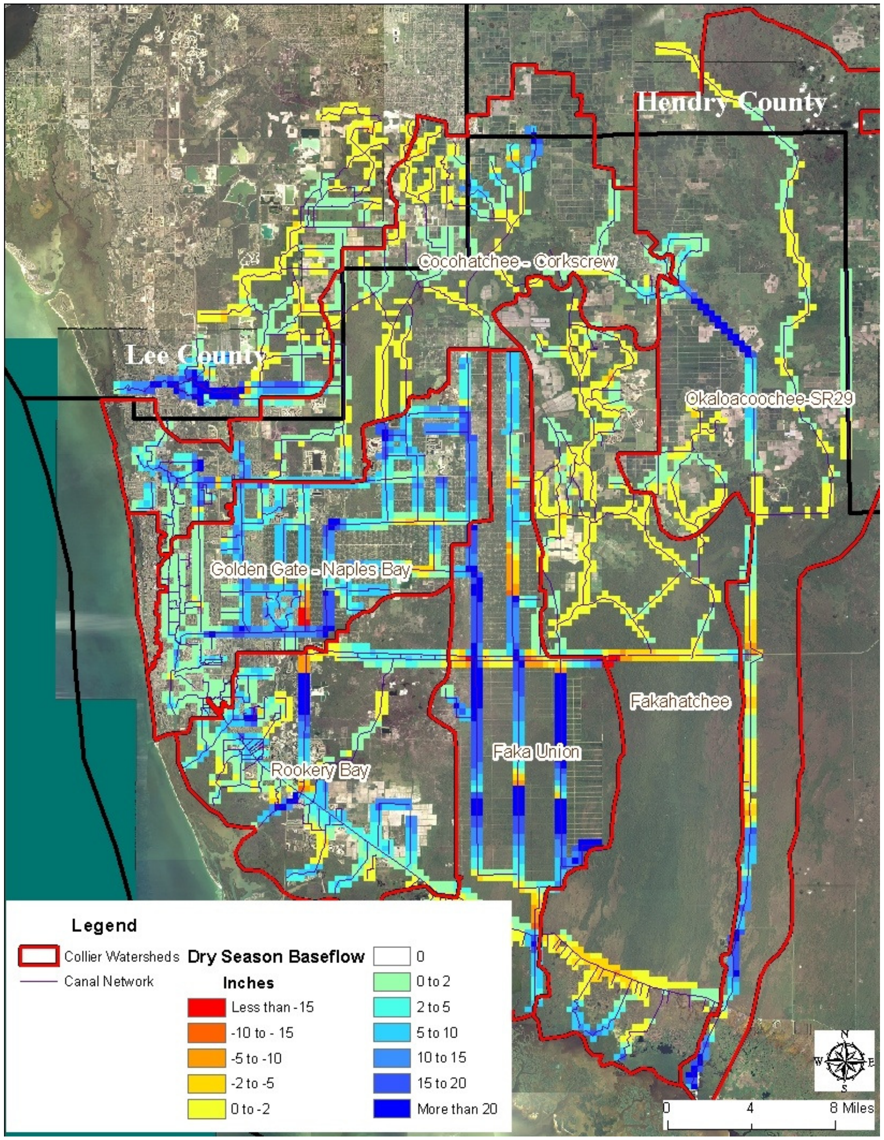


Figure 4-3. Average Wet Season Baseflow Contributions Golden Gate Watershed

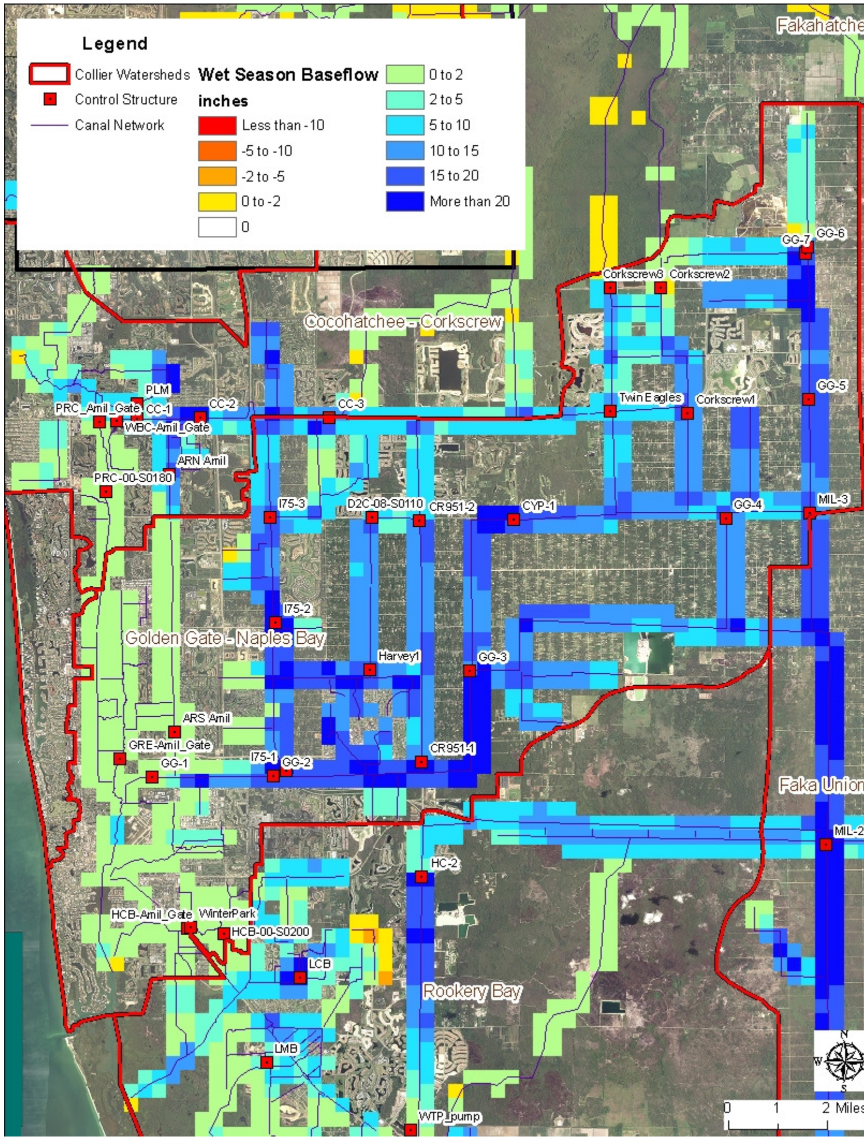


Figure 4-4. Average Dry Season Baseflow Contributions Golden Gate Watershed

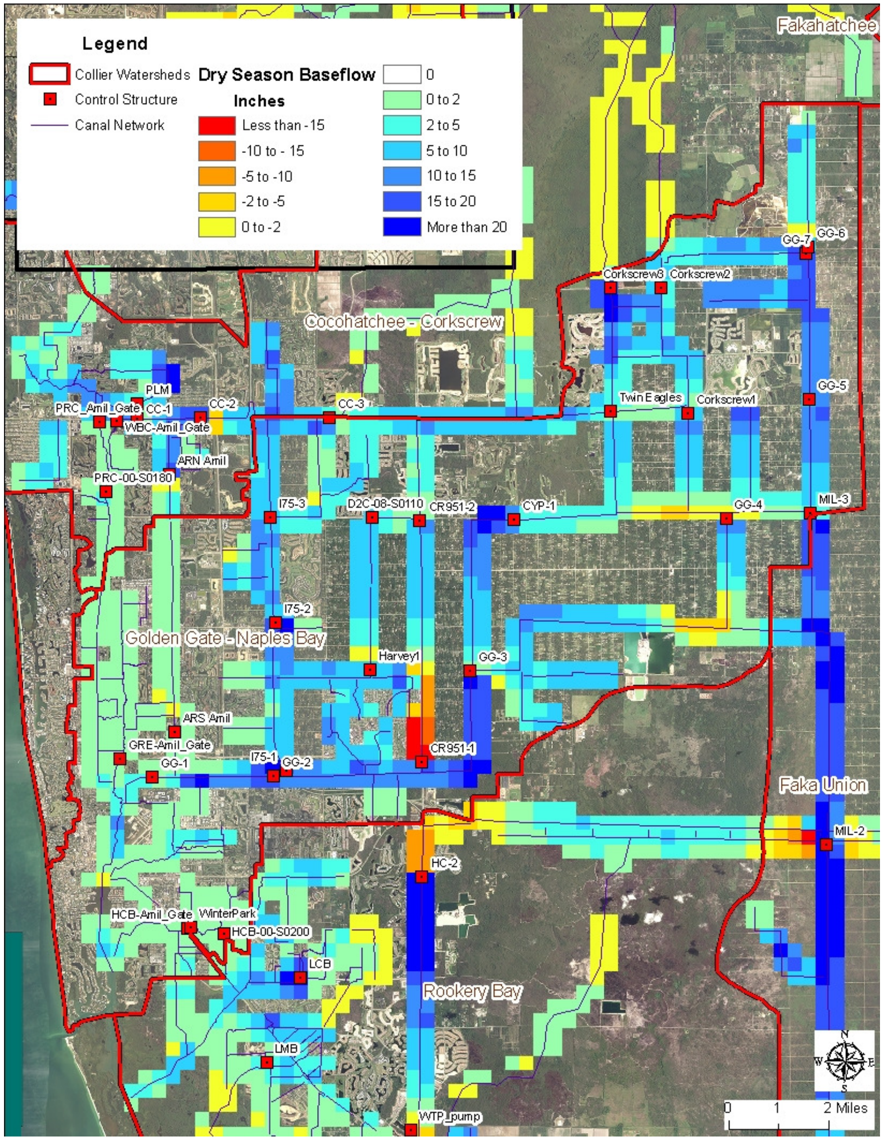
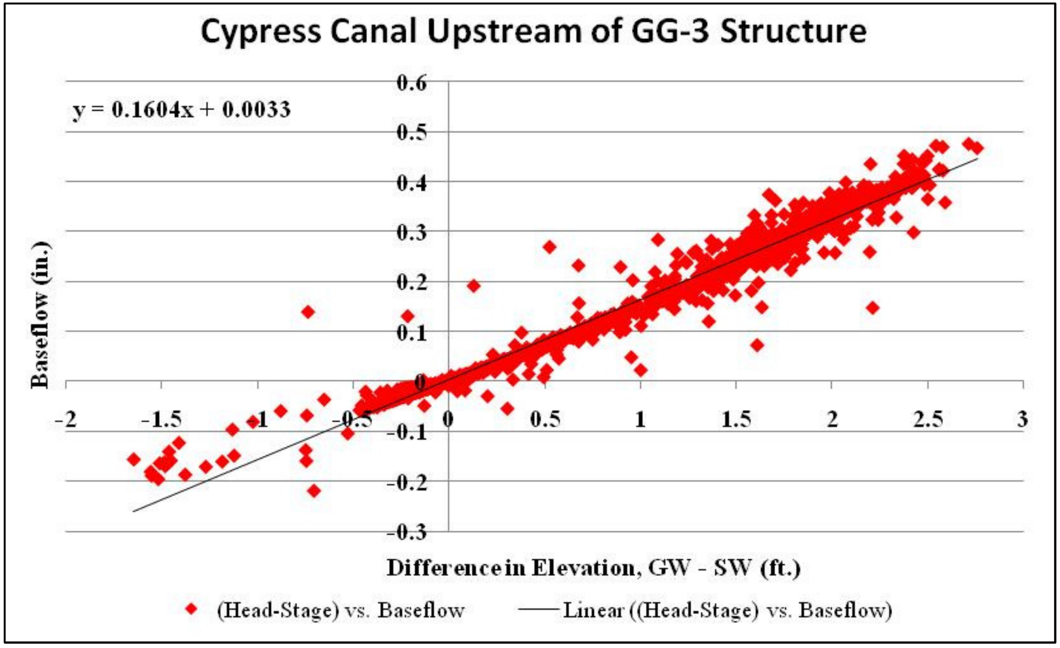


Figure 4.5 shows the typical relationship between baseflow and the difference in groundwater and canal water surface elevation in the Cypress Canal. The data clearly indicates that managing canal stage to match groundwater elevations is important to reducing the volume of baseflow entering the canal network. It is our understanding that the existing structures are physically limited in their ability to stage water at a higher elevation within the canal network. It is recommended that the design of new and replacement structures consider seasonal groundwater head elevation data. The ability to more closely match canal stage and the groundwater head elevation will have long-term benefits to reduce baseflow to the canal network.

Figure 4-5. Relationship of Baseflow and (Head – Stage) Elevation Difference



5.0 Analysis of Canal Conveyance Capacity

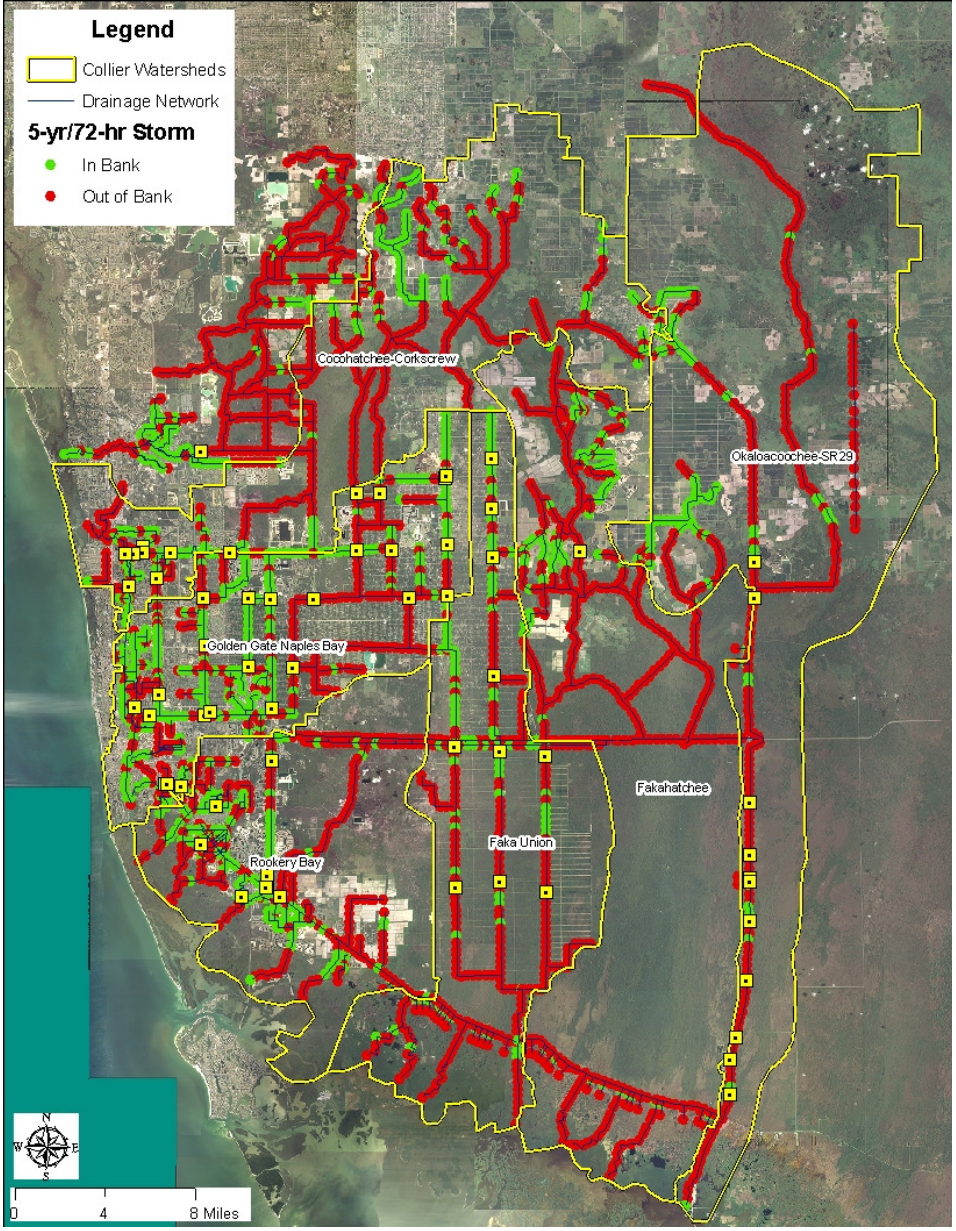
Model simulation results using the SFWMD design storm events were conducted to assess the conveyance capacity of the existing canals. To evaluate canal capacity, the maximum predicted water surface elevation at each cross-section in the canal was compared to the top of bank elevation at those locations. The water level is defined as "Out of Bank" if the predicted elevation is higher than that at one or both of the canal banks.

An important simulation parameter is the establishment of the model's initial conditions. For this analysis it was assumed that the water elevations in the canals prior to the beginning of the storm were those that occurred in September 4, 2004, after Hurricane Charley and prior to Hurricane Francis. That assumption is consistent with numerous recent H&H& studies in Florida because it is representative of a historical period when large back-to-back precipitation events occurred.

Figure 5.1 shows the locations where overtopping is predicted to occur during the 5-year, 72-hour hour storm event. The results for the 10-, 25-, and 100-year storm events are very similar indicating that canal overtopping would occur at the low lying areas. Most of the overtopping occurs in wetland areas where inundation is expected to occur. However, the results also indicate areas along the Cocohatchee Canal and within the Golden Gate –Naples Bay and Rookery Bay watersheds that may be subject to flooding conditions due to limited canal conveyance capacity.

The SFWMD has established emergency canal management protocols that require that the structures be opened and the water levels in the canal network be lowered prior to large storm events to provide additional canal conveyance to mitigate the risk of flooding. Therefore, the conditions depicted herein may be conservative. However, overall results show that future development would worsen an already difficult condition unless management strategies are established to mitigate flooding risks.

Figure 5.1. Bank Overtopping Locations for the 5-yr, 72-hr Storm Event



6.0 Conclusions

Several conclusions are drawn from the water budget analysis.

- Critical water budget processes are stormwater runoff and groundwater discharges to the canal network through baseflow.
- Annual and seasonal average stormwater runoff volumes are greatly influenced by the amount of precipitation. Relatively small variations in precipitation results in large changes in the volume of runoff.
- Baseflow contributions increase with canal density. Baseflow to the canal network in the Golden Gate and Faka Union watersheds make up approximately 55 percent of canal flow during the average year, and as much as 85 percent of canal flow during the dry season. Reducing baseflow would have a significant effect on the volume and timing of discharge to the estuary systems.
- The seasonal water budget analysis indicates a net balance in watershed storage over the simulation period. Annual losses in storage occur during the dry season and are associated with high baseflow contributions and with pumping from the Surficial and Lower Tamiami Aquifers to meet potable and irrigation water supply needs.
- Collier County and the SFWMD should consider seasonal groundwater elevations to establish updated seasonal controlled water levels in the canal network. Additional flexibility to raise the stage in the canals and reduce baseflow contributions should be considered when designing new or replacement control structures.
- Lowering the water surface in the canal network prior to large storm events is an important management tool to provide storage within the canal network and to mitigate flooding risks in Collier County.
- The existing conveyance capacity of the canal system is limited. Conditions would worsen in the future unless management actions are implemented to control for the impact of new development.