Vanasse Hangen Brustlin, Inc.

Final – February 2010

Flow Measurements from Spring Vents in Kings Bay

Crystal River, Florida

Prepared for

Southwest Florida Water Management District
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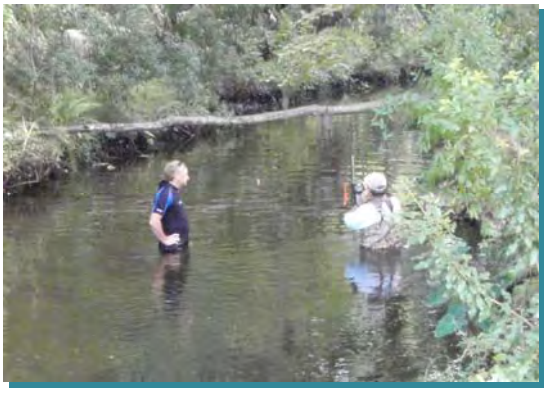
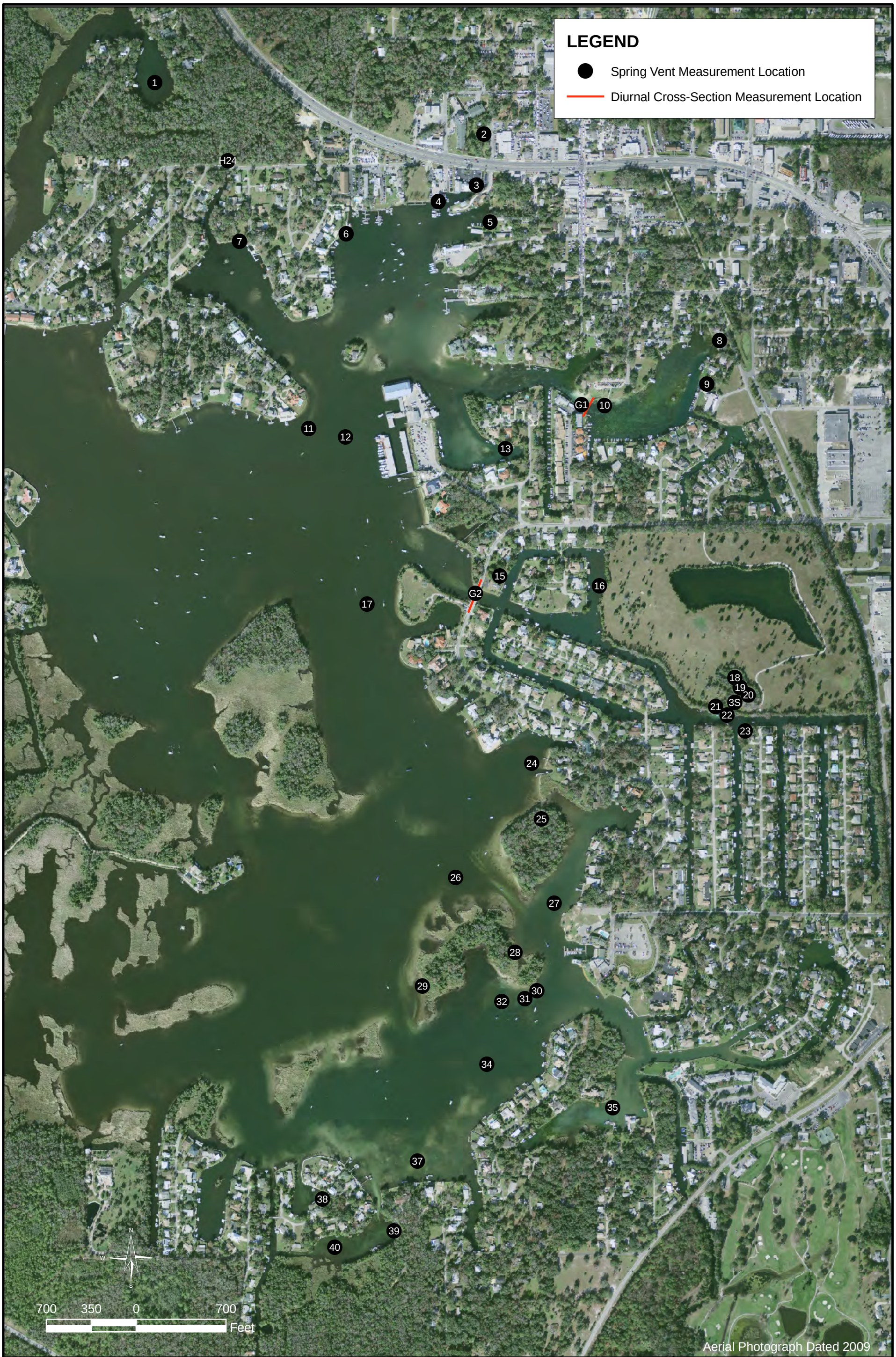
Vanasse Hangen Brustlin, Inc. (VHB) has completed flow and *in situ* water quality measurements of spring vents within the Kings Bay portion of Crystal River in Citrus County, Florida. The purpose of this project is to quantify spring discharge from submerged spring vents for use in a hydrodynamic model of Kings Bay. The model is being developed by the Southwest Florida Water Management District (District) in its efforts to establish a Minimum Flow for Kings Bay. The discharge from spring vents within Kings Bay and in its watershed are the primary sources of baseflow to the system. The flow measurements are considered the best data for model construction and, as such, the emphasis was placed on measuring those springs which contribute the most flow.

The flow measurements were obtained at spring vents previously identified by VHB in the May 2009 report to the District titled *An Inventory of Spring Vents in Kings Bay, Crystal River, Florida*. This report noted that many of the springs consisted of more than one vent in very close proximity which contributed to the overall discharge of that "spring". A total of 70 springs were documented. In some areas, particularly in the case of previously unnamed springs, groups of springs in the same geographic area were lumped into "spring complexes" with a single identification number. A total of 41 named and numbered spring complexes were depicted and discussed in the report. A priority list of springs was developed based upon qualitative flow estimates made during the inventory of spring vents.

Starting with the 41 named and numbered spring complexes identified in the inventory report, a few sites were deleted since no flow was observed during the inventory study. Two measurement sites were also added to capture known inflow sites for springs discharge not located within Kings Bay proper, but within the watershed contributing to the baseflow. The Hammett 24 site (H24), a ditch which discharges spring flow into the northern portion of Kings Bay, was identified in a U.S. Geological Survey Open File Report (Hammett, et al, 1996). The second site is slightly downstream of Fountain Spring (2) and includes the discharge from this spring as well as flow from upstream springs (this flow measurement location continues to be referred to as Fountain Spring although the majority of discharge originates upstream. **Figure 1** depicts the location of the spring vents and discharge locations measured during this study.



Flow measurements were made using a variety of methods and meters to most accurately capture the discharge for a specific vent or vent complex. The measurement of submerged spring vent discharge was complicated by the nature, complexity and depth of the vents/vent complexes as well as the tidal nature of Kings Bay. The specific method used to determine discharge for each vent/vent complex was



Date: January, 2010

Revised:

Figure 1
Kings Bay Spring Vent Flow Measurement
Location Map
Citrus County, Florida

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selected based upon its ability to provide the most accurate data for the calculation of discharge. In some cases more than one measurement technique was used to strengthen the confidence of the measurement.

All velocity measurements were made using acoustic doppler profiler (ADP) type meters. These meters can be divided into single cell and multicell categories. The single cell meter (SonTek FlowTracker) was generally used in depths of four feet or less and the two multicell ADPs (SonTek RiverCat and SonTek Shallow Water) were generally used in depths over four feet. The acoustic meters can be positioned such that they are capable of recording velocities in the horizontal or vertical.

A few sites have open channel flow conditions. In these instances the standard USGS mid-section method for the measurement of discharge in an open channel was employed using the appropriate acoustic meter. This type of measurement is referred to as an instantaneous cross-section measurement. Those springs discharging through a shallow ditch (Hammett 24 and Fountain Spring (2)) or a shallow natural spring run (Parker Island Springs (25)) were measured with the standard USGS method and a single cell ADP. The multicell ADP was used to measure discharge in deeper areas, including the natural spring run from Black Spring (38) and the narrow cross-section at House Spring (8). The Three Sisters spring run (3S) was measured using both the single cell and multicell acoustic meters.

In two locations discharge measurements of cross-sections were made to provide additional information about upstream springs. A discharge measurement was made using the multicell ADP at a narrow location in Miller Creek, below the Miller Creek Spring (1). A similar measurement was made using the multicell ADP at the northerly channel from the embayment containing Sid's Springs (39) and Gary's Grotto (40). The single cell ADP was used to make the discharge measurement in the western canal from the embayment containing Sid's Springs and Gary's Grotto.

In two locations there are several springs that discharge through a single canal. Group 1 (G1) consists of House Spring (8), Jurassic Spring (9) and Hunters Spring (10) and Group 2 consists of Paradise Isles (15), Manatee Sanctuary (16), Three Sisters Springs (18, 19, and 20), Kings Bay #1 (21), Idiots Delight #2 (22), and Idiots Delight #3 (23). These areas are subject to tidal flow influences and were monitored over several successive diurnal tide cycles using a multicell ADP recording and logging point velocity data over time at 15-minute intervals. The Group 1multicell ADP was placed approximately 25' from the southern seawall in the deepest point of a narrow cross-section previously monitored by USGS. The Group 2 multicell ADP was placed under the roadway bridge in a deep central location. Both SW devices were bolted onto a concrete slab to prevent movement and were oriented in the direction of the strongest flow.

Instantaneous discharge measurements were conducted periodically at these sites under different tidal conditions using the multicell ADP. The measurements were used to develop velocity ratings using the recorded point velocity data at the time of the discharge measurement versus the mean measured velocity for the discharge measurements. The velocity rating was used in conjunction with surveyed cross-sectional areas of the measured section to compute discharge. The discharge measurements took place under varied tidal conditions (i.e., spring and neap tides) and the cross-sections dimensions were surveyed to provide an accurate area determination. These types of measurements are referred to as diurnal cross-section measurements.

Finally, velocity measurements were made at vent openings and are referred to as vent measurements. Two pieces of information, area and velocity, are required to accurately determine discharge. After determining the vent shape and taking the appropriate measurements required to determine its area, the area was computed using common geometric formulas. The single cell ADP was placed within the vents to measure flow for the shallow vents which were easily accessible. This method was used for Pool Spring (5) where it was placed within the outflow window, NW 9th Avenue Springs (7), Parker Island Springs (25), Banana Island East Springs (28), Banana Island West Springs (29), Golfview (35) – one small spring vent, and for the Wynn Court Springs (37).

The remaining velocity measurements at vent openings were performed using a multicell ADP velocity meter mounted to a board and pipe assembly to allow the device to measure horizontally (**Figure 2**). In locations with multiple vents within a few feet of each other, the ADP measurement was made across the broader "bowl" of these vents. This measurement entailed a SCUBA diver measuring the vent opening and then placing the ADP device appropriately near the vent. A blanking distance of approximately 0.5 feet was used to account for the devices measurement restrictions. The multicell ADP recorded velocity in up to five evenly spaced "bins" based upon distance from the unit. A series of six measurements were made 10 seconds apart at each location. Velocity measurements were taken continuously for 60 seconds at each vent and the average mean velocity was used for computation of discharge.

Figure 2. Vent Discharge Measurements

Measurements of velocity were taken in multiple locations for larger vents with diffuse flow to develop an average velocity for that vent. The emphasis of this effort was based upon the finalized priority list which stressed the higher flow vents and more than one measurement of these vent were made as time allowed. In some cases vent measurements were done to supplement the other measurement methods discussed above.

Table 1 provides a summary of the type(s) of flow measurements made for each named and numbered spring. Two additional small spring vents were located and measured (beyond those mapped during the inventory) in close proximity to existing sites. One of the springs was located approximately 50 feet southwest of the original Buzzard Island Spring (17) and was included as a part of this spring, another spring (called Paul's Paradise) was located in close proximity to the FWS Spring Complex (27) and its information was summarized as part of this complex.

Specific conductance and temperature were measured and recorded, along with time, concurrent with each flow measurement. A multi-parameter water quality sonde was calibrated daily and used to obtain the specific conductance and temperature readings (**Figure 3**).

Figure 3. Vent Conductivity Measurement

The sampling schedule was based upon tide stage as estimated from tide charts of Kings Bay. The actual tide stage was determined using the time of the measurement and measured stage at the USGS gage at the mouth of Kings Bay (Site 02310742 – Crystal River at Mouth of Kings Bay FL). The times of all measurements, water quality data collection and tide stage were converted to Eastern Standard Time (EST) for consistency.

The field measurements were conducted over the period of July 27th – 31st, August 17th – 20th, September 21st – 25th and October 5th – 8th 2009, for a total of eighteen field days. The July and August monitoring efforts focused on the diurnal cross-section monitoring of Groups 1 and 2. Measurements were also performed at the individual springs which comprise Groups 1 and 2 during these monitoring weeks. The September and October monitoring period involved measuring the remaining springs not included in Groups 1 and 2, including multiple measurements at some of the larger springs during different tide stages. When possible, measurements were conducted near low tide, especially at spring vents identified as having low flow.

Table 1. Summary of Discharge Measurement Methods for Kings Bay Spring Vents

Spring Number	Spring Name	Measurement Type(s)	Measurement Instrument(s)
1	Hammett 23/Miller's Creek Spring	Vent, Instantaneous	SW, RiverCat
2	Fountain Spring/City Hall Spring	Instantaneous	FT
3	Charlie's Fish House Spring	Vent	SW
4	Hammett 25/Birds Underwater Spring	Vent	SW
5	Hammett 27/Pool Spring	Vent	FT
6	Hammett 1/Catfish Spring	Vent	SW
7	Hammett 26/NW 9th Avenue Springs	Vent	FT
8	Hammett 4/House Spring	Instantaneous	RiverCat
9	Hammett 5/Jurassic Spring	Vent	SW
10	Hammett 3/Hunters Spring/American Legion Spring	Vent	SW
11	Hammett 21/Magnolia Circle Spring	Vent	SW
12	Pete's Pier Spring	Vent	SW
13	Hammett 6/Moray Spring	Vent	SW
15	Hammett 7/Paradise Isles	Vent	SW
16	Hammett 8/Manatee Sanctuary/Gator Hole/Magnolia Spring/Crystal Spring	Vent	SW
17	Buzzard Island Spring	Vent	SW
18	Hammett 10/Three Sisters #1/Three Sisters Springs/Middle Springs # 1	Vent	SW
19	Hammett 28/Three Sisters #2/Three Sisters Springs/Middle Springs # 2	Vent	SW
20	Hammett 28/Three Sisters #3/Three Sisters Springs/Middle Springs # 3	Vent	SW
21	Hammett 9/ Kings Bay #1/ Idiots Delight #1	Vent	SW
22	Hammett 11 /Idiots Delight #2	Vent	SW
23	Hammett 11A/Idiots Delight #3/ Three Sisters Run	Vent	SW
24	Parker Island North Spring Complex	Vent	SW
25	Hammett 12/Parker Island Springs/Little Hidden Spring	Vent, Instantaneous	FT
26	Banana Island North Spring Complex	Vent	SW
27	Hammett 13/FWS Spring Complex	Vent	SW
28	Banana Island East Springs	Vent	FT
29	Banana Island West Springs	Vent	FT
30	Hammett 15/Mullets Gullet Spring/Tarpon Hole #2	Vent	SW
31	Hammett 2/Tarpon Hole/Big Hole/Crystal Spring	Vent	SW
32	Hammett 16/King Spring/Grand Canyon Spring	Vent	SW
34	Dave's Quest Springs	Vent	SW
35	Hammett 17/Golfview	Vent	SW, FT
37	Hammett 19/Wynn Court Springs	Vent	FT
38	Hammett 18/Black Spring	Vent, Instantaneous	SW, RiverCat

Table 1. (cont.) Summary of Discharge Measurement Methods for Kings Bay Spring Vent

Spring Number	*Spring Name*	*Measurement Type(s)*	*Measurement Instrument(s)*
39	Hammett 19/Sid's Springs	Vent, Instantaneous	SW, RiverCat
40	Gary's Grotto	Vent, Instantaneous	SW, FT
G1	Group 1	Instantaneous, Diurnal	SW, RiverCat
G2	Group 2	Instantaneous, Diurnal	SW, RiverCat
H24	Hammett 24	Instantaneous	FT
3S	Three Sisters Spring Run	Instantaneous	FT, RiverCat

Measurement Type(s): Diurnal - measurement through at least two tide cycle with SonTek Shallow SW ADCP; Instantaneous - USGS mid-section method measurement across a defined channel; Vent - direct measurement of vent discharge.

Measurement Instrument(s): FT – SonTek FlowTracker; RiverCat - SonTek River Cat acoustic doppler current profiler; SW - SonTek Shallow Water velocity meter

The project scope called for diurnal cross-section monitoring over two successive diurnal tides during varied tide conditions (i.e., spring and neap tides). The July monitoring occurred during neap tides with the August monitoring capturing the spring tides. The ADP velocity meters continued to be deployed between the two field measurement periods which serve to provide a much larger set of data.

The ADP was deployed at both Groups 1 and 2 on July 27, 2009 and retrieved on August 20th. There is a data gap from August 6 – 7 at Group 1 and the data becomes very erratic from August 5 to 18 which appear to be the result of algae blanketing the ADP velocity meter. **Figure 4** depicts the observed discharge for Group 1 and the stage at the USGS gauge for the initial nine days of monitoring. The Group 2 data set is complete and is depicted in **Figure 5** along with the USGS stage data.

A total of 42 instantaneous discharge measurements were made using the ADP at the Group 1 site. These measurements and the surveyed cross-sectional area allowed the development of stage vs. area and point velocity vs. mean velocity ratings for use in computing discharge. The regression analysis of the velocity rating developed for the Group 1 site had an R^2 value of 0.85. The growth of bottom algae probably affected the quality of the discharge record at this site. The stage, recorded velocity, calculated discharge and discharge measurements using the ADP for Group 1 are provided in Appendix A. The ratings were used to compute the 15-minute values of discharge. The computed discharges are the result of data and measurements collected over only a 24 day period and are considered fairly accurate for that period. A reference mark was set at the time the area cross-sections were run for Group 1 and could be used to tie in elevation, if desired.

A total of 36 instantaneous discharge measurements were made using the ADP at the Group 2 site. Similar to Group 2, these measurements and the surveyed cross-sectional area allowed the development of stage vs. area and point velocity vs. mean velocity ratings for use in computing discharge. The regression analysis of the velocity rating developed for the Group 2 site had an R^2 value of 0.94. The stage, recorded velocity, calculated discharge and discharge measurements using the ADP for Group 2 are provided in Appendix B. The ratings were used to compute the 15-minute values of discharge. The computed discharges are the result of data and measurements collected over only a 24 day period and are considered fairly accurate for that period. A reference mark was set also at the time the area cross-sections were run and could be used to tie in elevation, if desired.

Instantaneous cross-section and vent measurements were obtained throughout the four weeks of field monitoring. During the July and August neap and spring tide monitoring for Groups 1 and 2, the individual springs comprising these groups were measured as a cross check of the downstream results. Measurements at the remaining springs were conducted during the September and October monitoring

Figure 4. Calculated Discharge for Group 1 Springs, Kings Bay, Crystal River, Florida

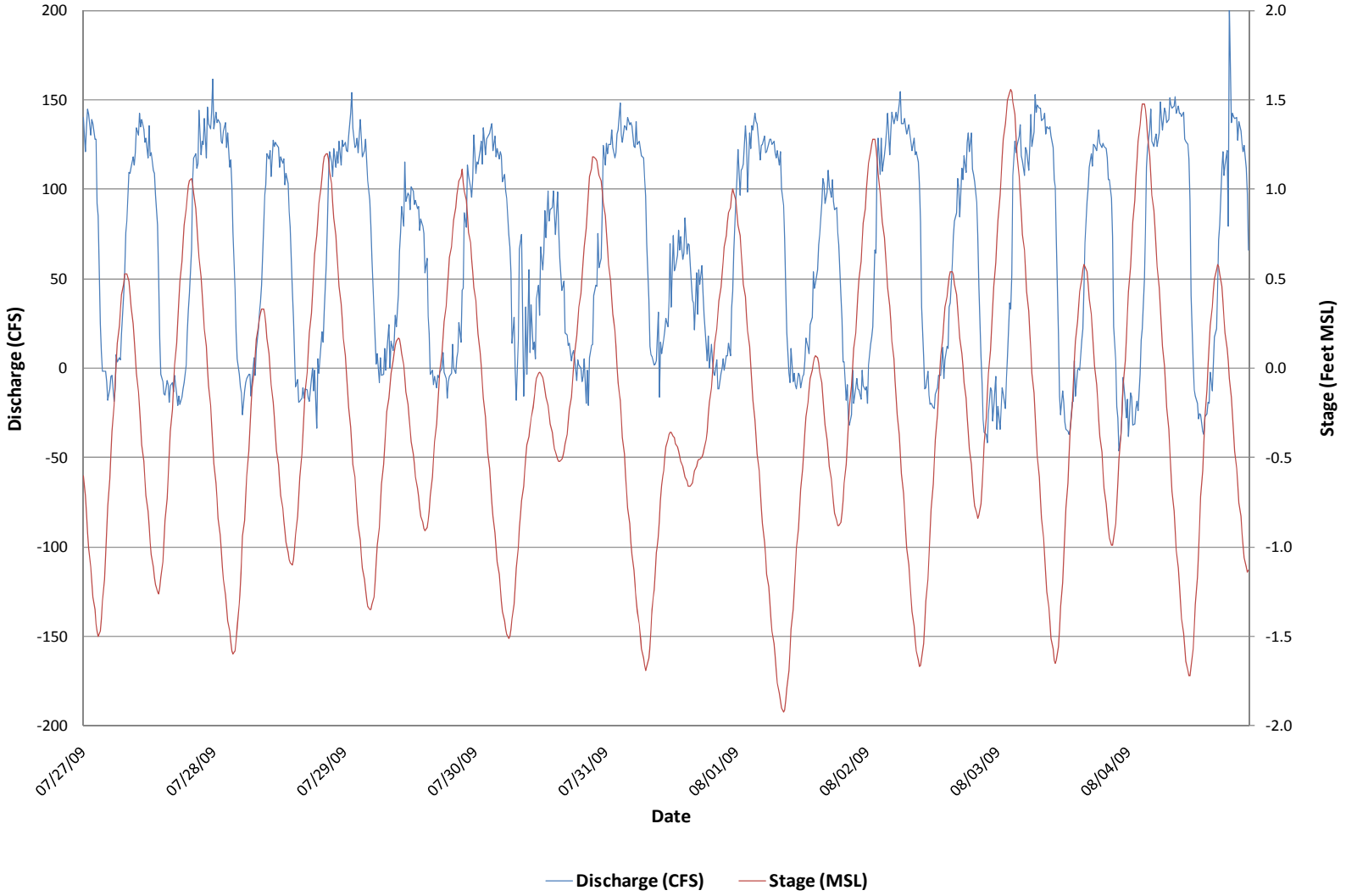
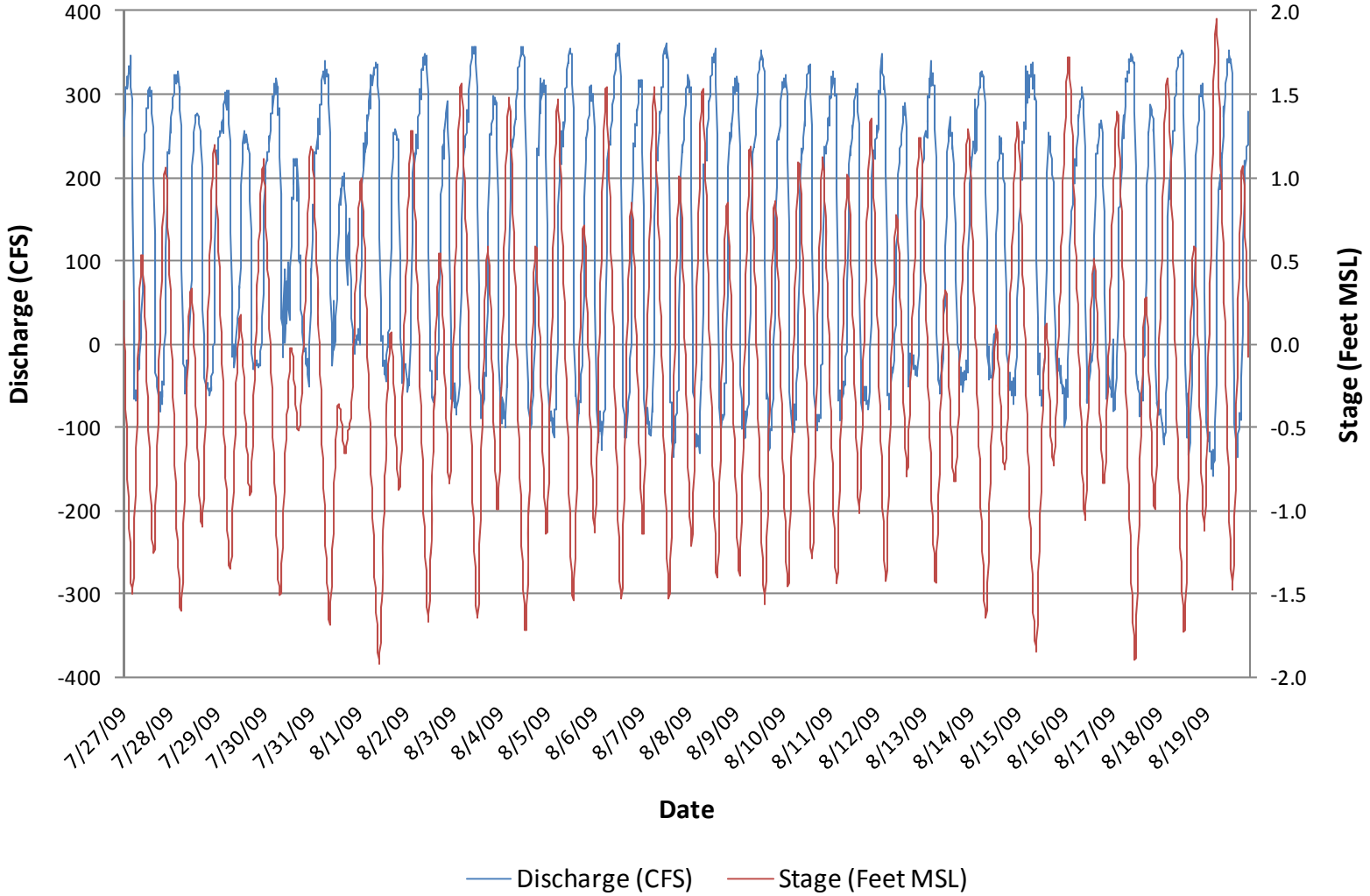


Figure 5. Calculated Discharge for Group 2 Springs, Kings Bay, Crystal River, Florida



periods. The results of the instantaneous cross-section and vent measurements are summarized in **Table 2**.

A unique number was assigned for each measurement. Each number begins with the spring vent number as referenced in Table 1, for example, measurements at Spring Vent 1 begin with "SV01". There are two exceptions to this with the Hammett 24 and Three Sisters instantaneous measurements since these were not previously identified springs, per se. The date of the measurement, month-day-year (e.g., 072709), follows the spring vent number identification number. Springs having multiple vent measurements were designated as "a", "b", "c" as appropriate, with "a" representing the second measurement location. As previously mentioned, some of these measurements are the same vent, but are over a different cross-section. Several springs were measured on more than one day and in most cases the measurement designation remained the same, *i.e,* measurements ending in the same designation ("a") where taken at the same vent and section location.

Table 2 summarizes the date, time, measurement type, measured discharge, average discharge for a vent, total discharge for the measurement day, and average discharge. The Measured Discharge represents the discharge measured for each individual measurement. When multiple cross-sections were taken consecutively of the same vent, they were averaged and are shown in the Vent Average column. The Total Discharge represents the sum of the measured discharge for all vents measured at that spring on that date (the Vent Average is summed with other individual vent measurements). Average Discharge has been calculated for those springs with more than one set of measurements. Finally, the stage elevation at the USGS gage (relative to Mean Sea Level (MSL)) is provided for information on the relative height of the tide.

The electronic output from the multicell ADP vent measurements has been provided in digital format. The data for each measurement includes the spring measurement number, spring name, vent size and area, end distance of each bin cell, measured velocity in each bin for the six consecutive measurements, comments and notes on the measurement. Based upon the size of the vent, the six measurements in the appropriate bins were averaged to get a mean cell velocity and the mean cell velocities were averaged to determine the calculated velocity and ultimately the discharge.

The average total discharge for each numbered spring, Hammett 24 and the Three Sisters Spring run are graphically depicted on **Figure 6**. The discharges have been classified in six categories and color coded for ease of review. When reviewing the measured discharge it is important to remember that the instantaneous cross-section measurements at H24, 2, 38, 39, 40, and to a lesser extent 25, include surface water discharge from upstream sources and tidal input. It appears that the Three Sisters Spring Run maintains positive flow, so all measured discharge would be from the springs.

Table 2. Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data	
							EST Time	Corrected Stage (MSL)
H24	Hammett 24 092309	9/23/09 16:05	X-Section	8.35		8.35	1600	-0.01
H24	Hammett 24 100709	10/7/09 8:05	X-Section	49.50		49.50	800	0.6
					Average Discharge	28.93		
1	SV01100609	10/6/09 13:30	X-Section	0.96		0.96	1330	-0.71
1	SV01100609a	10/6/09 13:56	Vent	1.74			1400	-0.36
1	SV01100609b	10/6/09 14:00	Vent	2.39		4.12	1400	-0.36
					Average Discharge	2.54		
2	SV02092209	9/22/09 15:01	X-Section	7.51			1500	-0.07
2	SV02092209a	9/22/09 15:18	X-Section	0.02		7.53	1515	0.08
2	SV02100709	10/7/09 7:19	X-Section	17.50		17.50	715	0.93
					Average Discharge	12.52		
3	SV03100509	10/5/09 14:32	Vent	0.02		0.02	1430	0.59
4	SV04100509	10/5/09 14:45	Vent	0.09		0.09	1445	0.75
5	SV05100509	10/5/09 14:10	Vent	2.25		2.25	1415	0.44
6	SV06092309	9/23/09 8:22	Vent	9.40			815	0.62
6	SV06092309a	9/23/09 8:24	Vent	6.09	7.74	7.74	830	0.52
6	SV06100509	10/5/09 8:39	Vent	13.95			845	-0.46
6	SV06100509a	10/5/09 8:42	Vent	16.36	15.15	15.15	845	-0.46
					Average Discharge	11.45		

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data EST Time	USGS Stage Data Corrected Stage (MSL)
7	SV07100809	10/8/09 11:18	Vent	0.57			1115	-0.9
7	SV07100809a	10/8/09 11:23	Vent	0.21			1130	-1.01
7	SV07100809b	10/8/09 11:29	Vent	0.01			1130	-1.01
					Average Discharge	0.79		
8	SV08072909	7/29/09 11:49	X-Section	3.34		3.34	1145	0.07
8	SV08073109	7/31/09 9:01	X-Section	5.99		5.99	900	1.12
8	SV08081709	8/17/09 9:23	X-Section	4.20		4.20	915	0.51
8	SV08081809	8/18/09 12:38	X-Section	7.40		7.40	1230	1.32
					Average Discharge	5.23		
9	SV09072909	7/29/09 11:07	Vent	19.30			1100	0.36
9	SV09072909a	7/29/09 11:08	Vent	18.22			1115	0.27
9	SV09072909b	7/29/09 11:10	Vent	29.16	22.23		1115	0.27
9	SV09072909c	7/29/09 11:13	Vent	3.45		25.68	1115	0.27
9	SV09073109	7/31/09 9:35	Vent	24.88			930	1.18
9	SV09073109a	7/31/09 9:44	Vent	19.60			945	1.17
9	SV09073109b	7/31/09 9:46	Vent	20.36	21.62		945	1.17
9	SV09073109c	7/31/09 9:38	Vent	2.86		24.47	945	1.17
9	SV09081709	8/17/09 8:54	Vent	16.84			900	0.41
9	SV09081709a	8/17/09 8:57	Vent	20.90			900	0.41
9	SV09081709b	8/17/09 8:59	Vent	25.60	21.11		900	0.41
9	SV09081709c	8/17/09 9:03	Vent	3.17		24.28	900	0.41
9	SV09081909	8/19/09 12:28	Vent	15.41			1230	0.99
9	SV09081909a	8/19/09 12:30	Vent	21.04			1230	0.99

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data EST Time	USGS Stage Data Corrected Stage (MSL)
9	SV09081909b	8/19/09 12:32	Vent	19.84	18.76		1230	0.99
9	SV09081909c	8/19/09 12:34	Vent	2.65		21.41	1230	0.99
					Average Discharge	23.96		
10	SV10072909	7/29/09 9:55	Vent	3.65			1000	0.74
10	SV10072909a	7/29/09 9:57	Vent	3.19			1000	0.74
10	SV10072909b	7/29/09 10:00	Vent	14.30			1000	0.74
10	SV10072909c	7/29/09 10:02	Vent	8.73		29.87	1000	0.74
10	SV10073109	7/31/09 10:16	Vent	3.89			1015	1.12
10	SV10073109a	7/31/09 10:18	Vent	3.94			1015	1.12
10	SV10073109b	7/31/09 10:19	Vent	14.93			1015	1.12
10	SV10073109c	7/31/09 10:20	Vent	5.25		28.00	1015	1.12
10	SV10081709	8/17/09 8:19	Vent	4.58			815	0.12
10	SV10081709a	8/17/09 8:21	Vent	5.08			815	0.12
10	SV10081709b	8/17/09 8:23	Vent	12.36			830	0.21
10	SV10081709c	8/17/09 8:25	Vent	11.25		33.26	830	0.21
10	SV10081909	8/19/09 11:52	Vent	5.11			1145	0.53
10	SV10081909a	8/19/09 11:54	Vent	3.23			1200	0.67
10	SV10081909b	8/19/09 11:56	Vent	19.46			1200	0.67
10	SV10081909c	8/19/09 11:59	Vent	5.13		32.93	1200	0.67
					Average Discharge	31.02		
11	SV11092109	9/21/09 8:03	Vent	1.56			800	0.4
11	SV11092109a	9/21/09 8:05	Vent	1.89	1.73	1.73	800	0.4
11	SV11100509	10/5/09 9:31	Vent	2.16		2.16	930	-0.8
					Average Discharge	1.94		

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data	
							EST Time	Corrected Stage (MSL)
12	SV12092409	9/24/09 15:24	Vent	0.23			1530	-0.65
12	SV12092409a	9/24/09 15:28	Vent	0.25	0.24		1530	-0.65
12	SV12092409b	9/24/09 15:31	Vent	0.16			1530	-0.65
12	SV12092409c	9/24/09 15:33	Vent	0.08	0.12		1530	-0.65
12	SV12092409d	9/24/09 15:39	Vent	1.14		1.50	1545	-0.5
13	SV13092509	9/25/09 14:13	Vent	0.82			1415	-0.96
13	SV13092509a	9/25/09 14:16	Vent	0.20			1415	-0.96
13	SV13092509b	9/25/09 14:20	Vent	0.12			1415	-0.96
13	SV13092509c	9/25/09 14:22	Vent	0.11			1415	-0.96
13	SV13092509d	9/25/09 14:26	Vent	0.57			1430	-0.99
13	SV13092509e	9/25/09 14:30	Vent	0.13		1.95	1430	-0.99
15	SV15072809	7/28/09 9:02	Vent	0.03			900	0.62
15	SV15072809a	7/28/09 9:07	Vent	0.05			900	0.62
15	SV15072809b	7/28/09 9:10	Vent	0.02		0.10	915	0.51
15	SV15081809	8/18/09 9:54	Vent	0.45			1000	0.15
15	SV15081809a	8/18/09 9:56	Vent	0.46			1000	0.15
15	SV15081809b	8/18/09 9:58	Vent	0.75		1.66	1000	0.15
					Average Discharge	0.88		
16	SV16072809	7/28/09 14:37	Vent	23.50			1430	-1.47
16	SV16072809a	7/28/09 14:46	Vent	17.50		41.00	1445	-1.53
16	SV16073009	7/30/09 13:37	Vent	34.50			1330	-0.27
16	SV16073009a	7/30/09 13:39	Vent	10.00			1345	-0.37
16	SV16073009b	7/30/09 13:41	Vent	9.20		53.70	1345	-0.37
16	SV16081809	8/18/09 9:10	Vent	29.30			915	-0.22

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data	
							EST Time	Corrected Stage (MSL)
16	SV16081809a	8/18/09 9:13	Vent	17.40			915	-0.22
16	SV16081809b	8/18/09 9:15	Vent	8.70		55.40	915	-0.22
					Average Discharge	50.03		
17	SV17092409	9/24/09 14:10	Vent	0.01			1415	-1.21
17	SV17092409a	9/24/09 14:12	Vent	0.09			1415	-1.21
17	SV17092409b	9/24/09 14:28	Vent	0.51		0.61	1430	-1.15
18	SV18072809	7/28/09 11:51	Vent	5.10			1145	-0.53
18	SV18072809a	7/28/09 11:53	Vent	4.90	5.00		1145	-0.53
18	SV18072809b	7/28/09 11:57	Vent	0.20		5.20	1200	-0.64
18	SV18073009	7/30/09 10:18	Vent	3.80			1015	0.86
18	SV18073009a	7/30/09 10:24	Vent	6.50			1030	0.76
18	SV18073009b	7/30/09 10:26	Vent	6.20	5.50		1030	0.76
18	SV18073009c	7/30/09 10:29	Vent	0.20		5.70	1030	0.76
18	SV18081709	8/17/09 12:45	Vent	8.10			1245	1.34
18	SV18081709a	8/17/09 12:47	Vent	9.20	8.65		1245	1.34
18	SV18081709b	8/17/09 12:49	Vent	0.20		8.85	1245	1.34
18	SV18081909	8/19/09 9:34	Vent	13.80			930	-0.85
18	SV18081909a	8/19/09 9:35	Vent	5.60	9.70		930	-0.85
18	SV18081909b	8/19/09 9:37	Vent	0.12		9.82	930	-0.85
					Average Discharge	7.39		
19	SV19072809	7/28/09 12:20	Vent	-			1215	-0.73
19	SV19072809a	7/28/09 12:24	Vent	5.90		5.90	1230	-0.84
19	SV19073009	7/30/09 10:48	Vent	35.10			1045	0.7
19	SV19073009a	7/30/09 10:51	Vent	3.30		38.40	1045	0.7

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data EST Time	USGS Stage Data Corrected Stage (MSL)
19	SV19081709	8/17/09 13:04	Vent	20.80			1300	1.28
19	SV19081709a	8/17/09 13:06	Vent	26.20	23.50	23.50	1300	1.28
19	SV19081709b	8/17/09 13:09	Vent	-			1315	1.2
19	SV19081909	8/19/09 9:57	Vent	30.40			1000	-0.55
19	SV19081909a	8/19/09 9:59	Vent	5.10		35.50	1000	-0.55
					Average Discharge	25.83		
20	SV20072809	7/28/09 11:02	Vent	40.70			1100	-0.21
20	SV20072809a	7/28/09 11:04	Vent	35.40			1100	-0.21
20	SV20072809b	7/28/09 11:06	Vent	30.30	35.47		1100	-0.21
20	SV20072809c	7/28/09 11:10	Vent	0.92			1115	-0.32
20	SV20072809d	7/28/09 11:13	Vent	0.13			1115	-0.32
20	SV20072809e	7/28/09 11:16	Vent	10.20		46.72	1115	-0.32
20	SV20073009	7/30/09 9:07	Vent	30.60			900	1.07
20	SV20073009a	7/30/09 9:09	Vent	30.10			915	1.11
20	SV20073009b	7/30/09 9:11	Vent	35.60	32.10		915	1.11
20	SV20073009c	7/30/09 9:13	Vent	0.72			915	1.11
20	SV20073009d	7/30/09 9:15	Vent	0.06			915	1.11
20	SV20073009e	7/30/09 9:18	Vent	4.50		37.38	915	1.11
20	SV20081709	8/17/09 12:20	Vent	37.50			1215	1.39
20	SV20081709a	8/17/09 12:23	Vent	1.10			1230	1.37
20	SV20081709b	8/17/09 12:24	Vent	0.05			1230	1.37
20	SV20081709c	8/17/09 12:25	Vent	6.35		45.00	1230	1.37
20	SV20081909	8/19/09 9:09	Vent	47.00			915	-0.97
20	SV20081909a	8/19/09 9:11	Vent	53.70			915	-0.97
20	SV20081909b	8/19/09 9:12	Vent	32.20	44.30		915	-0.97
20	SV20081909c	8/19/09 9:14	Vent	1.45			915	-0.97

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data EST Time	USGS Stage Data Corrected Stage (MSL)
20	SV20081909d	8/19/09 9:16	Vent	0.06			915	-0.97
20	SV20081909e	8/19/09 9:18	Vent	6.10		51.91	915	-0.97
					Average Discharge	45.25		
3S	Three Sisters 072809	7/28/09 12:53	X-Section	28.20		28.20	1300	-1.02
3S	Three Sisters 073009	7/30/09 12:08	X-Section	27.10		27.10	1215	0.19
3S	Three Sisters 081709	8/17/09 14:04	X-Section	22.60		22.60	1400	0.89
3S	Three Sisters 081909	8/19/09 10:28	X-Section	16.60		16.60	1030	-0.24
					Average Discharge	23.63		
21	SV21072809	7/28/09 10:17	Vent	4.20		4.20	1015	0.12
21	SV21073009	7/30/09 8:33	Vent	2.40		2.40	830	1.01
21	SV21081709	8/17/09 10:33	Vent	3.70			1030	0.99
21	SV21a081709	8/17/09 10:35	Vent	2.00		5.70	1030	0.99
21	SV21081809	8/18/09 10:46	Vent	3.40			1045	0.51
21	SV21a081809	8/18/09 10:48	Vent	1.80		5.20	1045	0.51
21	SV21082009	8/20/09 8:45	Vent	4.80			845	-0.73
21	SV21a082009	8/20/09 8:47	Vent	1.90		6.70	845	-0.73
					Average Discharge	4.84		
22	SV22081709	8/17/09 10:51	Vent	1.60			1045	1.07
22	SV22081709a	8/17/09 13:32	Vent	0.40			1330	1.11
22	SV22081709b	8/17/09 13:33	Vent	0.30			1330	1.11
22	SV22081709c	8/17/09 13:35	Vent	1.40		3.70	1330	1.11
22	SV22081809a	8/18/09 10:31	Vent	1.40			1030	0.39
22	SV22081809b	8/18/09 10:33	Vent	0.20			1030	0.39
22	SV22081809c	8/18/09 10:35	Vent	1.70		3.30	1030	0.39

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data EST Time	USGS Stage Data Corrected Stage (MSL)
22	SV22082009a	8/20/09 8:28	Vent	0.82			830	-0.62
22	SV22082009b	8/20/09 8:30	Vent	0.16			830	-0.62
22	SV22082009c	8/20/09 8:32	Vent	2.40		3.38	830	-0.62
					Average Discharge	3.46		
23	SV23072809	7/28/09 13:42	Vent	0.50			1345	-1.27
23	SV23072809a	7/28/09 13:48	Vent	0.10		0.60	1345	-0.37
23	SV23073009	7/30/09 12:48	Vent	0.32			1245	-0.93
23	SV23073009a	7/30/09 12:51	Vent	0.10		0.42	1245	0.01
23	SV23081709	8/17/09 11:11	Vent	0.56			1115	1.23
23	SV23081709a	8/17/09 11:13	Vent	0.05			1115	1.23
23	SV23081709b	8/17/09 11:15	Vent	0.31		0.92	1115	1.23
23	SV23081809	8/18/09 11:03	Vent	0.46			1100	0.64
23	SV23081809a	8/18/09 11:05	Vent	0.05			1100	0.64
23	SV23081809b	8/18/09 11:07	Vent	0.32		0.83	1100	0.64
23	SV23082009	8/20/09 9:03	Vent	0.46			900	-0.81
23	SV23082009a	8/20/09 9:06	Vent	0.05			900	-0.81
23	SV23082009b	8/20/09 9:10	Vent	0.45		0.95	915	-0.9
					Average Discharge	0.75		
24	SV24092409	9/24/09 10:32	Vent	0.92			1030	-0.07
24	SV24092409a	9/24/09 10:34	Vent	7.40			1030	-0.07
24	SV24092409b	9/24/09 10:43	Vent	0.25			1045	-0.18
24	SV24092409c	9/24/09 10:53	Vent	0.25			1100	-0.28
24	SV24092409d	9/24/09 11:30	Vent	0.11			1130	-0.47
24	SV24092409e	9/24/09 12:05	Vent	1.11			1200	-0.7
24	SV24092409f	9/24/09 12:07	Vent	0.23			1200	-0.7

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data EST Time	USGS Stage Data Corrected Stage (MSL)
24	SV24092409g	9/24/09 12:09	Vent	0.45			1215	-0.8
24	SV24092409h	9/24/09 12:12	Vent	0.25		10.98	1215	-0.8
25	SV25092309	9/23/09 12:53	X-Section	1.77		1.77	1245	-1.23
25	SV25092409	9/24/09 12:48	X-Section	2.06		2.06	1245	-0.97
25	SV25092409a	9/24/09 13:09	Vent	0.35			1315	-1.12
25	SV25092409b	9/24/09 13:11	Vent	0.91			1315	-1.12
25	SV25092409c	9/24/09 13:12	Vent	0.14		1.39	1315	-1.12
					Average Discharge	1.74		
26	SV26092309	9/23/09 11:59	Vent	2.21			1100	-0.58
26	SV26092309a	9/23/09 12:02	Vent	1.30			1200	-0.99
26	SV26092309b	9/23/09 12:13	Vent	1.10			1215	-1.08
26	SV26092309c	9/23/09 12:27	Vent	0.73			1230	-1.16
26	SV26092309d	9/23/09 12:30	Vent	1.21	0.97	5.57	1230	-1.16
26	SV26100509	10/5/09 10:17	Vent	0.08			1015	-1.11
26	SV26100509a	10/5/09 10:21	Vent	0.06			1015	-1.11
26	SV26100509b	10/5/09 10:24	Vent	0.27	0.17		1015	-1.11
26	SV26100509c	10/5/09 10:34	Vent	0.90			1030	-1.19
26	SV26100509d	10/5/09 10:40	Vent	0.30			1045	-1.26
26	SV26100509e	10/5/09 10:44	Vent	0.08			1045	-1.26
26	SV26100509f	10/5/09 11:36	Vent	0.22			1130	-1.26
26	SV26100509g	10/5/09 11:42	Vent	0.15			1145	-1.16
26	SV26100509h	10/5/09 11:50	Vent	0.09			1145	-1.16
26	SV26100509i	10/6/09 11:55	Vent	0.13		2.09	1200	-1.4
					Average Discharge	3.83		

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data	
							EST Time	Corrected Stage (MSL)
27	SV27092109	9/21/09 9:08	Vent	1.74			900	-0.06
27	SV27092109a	9/21/09 9:38	Vent	0.32			930	-0.3
27	SV27092109b	9/21/09 10:09	Vent	0.20		2.26	1015	-0.65
27	SV27100609	10/6/09 9:48	Vent	0.93			945	-0.61
27	SV27100609a	10/6/09 10:08	Vent	0.20			1015	-0.84
27	SV27100609b	10/6/09 10:10	Vent	0.67			1015	-0.84
27	SV27100609c	10/6/09 10:39	Vent	0.60			1045	-1.05
PP	Paul's Paradise 100709	10/7/09 13:28	Vent	0.08		2.48	1330	-1.15
					Average Discharge	2.37		
28	SV28100709	10/7/09 14:09	Vent	0.00			1415	-0.71
28	SV28100709a	10/7/09 14:10	Vent	0.01			1415	-0.71
28	SV28100709b	10/7/09 14:22	Vent	0.01			1415	-0.71
28	SV28100709c	10/7/09 14:23	Vent	0.03			1430	-0.56
28	SV28100709d	10/7/09 14:35	Vent	0.08			1430	-0.56
28	SV28100709e	10/7/09 14:47	Vent	0.12		0.24	1445	-0.4
28	SV28100809	10/8/09 10:06	Vent	0.24			1000	-0.33
28	SV28100809a	10/8/09 10:12	Vent	0.19		0.44	1015	-0.45
					Average Discharge	0.34		
29	SV29092309	9/23/09 10:27	Vent	0.09			1030	-0.35
29	SV29092309a	9/23/09 10:33	Vent	0.65	0.37		1030	-0.35
29	SV29092309b	9/23/09 10:34	Vent	0.02			1030	-0.35
29	SV29092309c	9/23/09 10:35	Vent	0.01			1030	-0.35
29	SV29092309d	9/23/09 10:36	Vent	0.05			1030	-0.35
29	SV29092309e	9/23/09 10:37	Vent	0.02		0.46	1030	-0.35

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data	
							EST Time	Corrected Stage (MSL)
30	SV30092109	9/21/09 11:04	Vent	3.25			1100	-0.97
30	SV30092109a	9/21/09 11:06	Vent	17.07			1100	-0.97
30	SV30092109b	9/21/09 11:09	Vent	10.81			1115	-1.07
30	SV30092109c	9/21/09 11:19	Vent	0.52		31.66	1115	-1.07
30	SV30092509	9/25/09 10:25	Vent	3.14			1030	0.33
30	SV30092509a	9/25/09 10:34	Vent	14.31			1030	0.33
30	SV30092509b	9/25/09 10:37	Vent	14.19			1030	0.33
30	SV30092509c	9/25/09 10:40	Vent	0.61		32.24	1045	0.24
30	SV30100609	10/6/09 8:48	Vent	3.10			845	-0.13
30	SV30100609a	10/6/09 8:49	Vent	16.54			845	-0.13
30	SV30100609b	10/6/09 8:51	Vent	2.60			845	-0.13
30	SV30100609c	10/6/09 8:53	Vent	0.59		22.83	900	-0.26
					Average Discharge	28.91		
31	SV31092109	9/21/09 12:29	Vent	13.37			1230	-1.16
31	SV31092109a	9/21/09 12:32	Vent	1.65			1230	-1.16
31	SV31092109b	9/21/09 12:34	Vent	7.34			1230	-1.16
31	SV31092109c	9/21/09 12:36	Vent	2.19			1230	-1.16
31	SV31092109d	9/21/09 12:42	Vent	13.39			1245	-1.02
31	SV31092109e	9/21/09 12:46	Vent	2.85			1245	-1.02
31	SV31092109f	9/21/09 12:48	Vent	0.92			1245	-1.02
31	SV31092109g	9/21/09 12:52	Vent	0.71		42.44	1245	-1.02
31	SV31092509	9/25/09 9:49	Vent	7.25			945	0.61
31	SV31092509a	9/25/09 9:51	Vent	1.34			945	0.61
31	SV31092509b	9/25/09 9:53	Vent	5.36			1000	0.51
31	SV31092509c	9/25/09 9:54	Vent	3.07			1000	0.51
31	SV31092509d	9/25/09 9:56	Vent	23.20			1000	0.51

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data EST Time	USGS Stage Data Corrected Stage (MSL)
31	SV31092509f	9/25/09 10:00	Vent	0.97			1000	0.51
31	SV31092509e	9/25/09 10:03	Vent	3.48			1000	0.51
31	SV31092509g	9/25/09 10:06	Vent	0.67			1000	0.51
31	SV31092509h	9/25/09 10:10	Vent	0.35		45.68	1015	0.41
31	SV31100609	10/6/09 8:18	Vent	6.61			815	0.09
31	SV31100609a	10/6/09 8:20	Vent	1.40			815	0.09
31	SV31100609b	10/6/09 8:22	Vent	4.42			815	0.09
31	SV31100609c	10/6/09 8:24	Vent	2.96			830	-0.03
31	SV31100609d	10/6/09 8:26	Vent	18.09			830	-0.03
31	SV31100609e	10/6/09 8:28	Vent	4.39			830	-0.03
31	SV31100609f	10/6/09 8:31	Vent	1.04			830	-0.03
31	SV31100609g	10/6/09 8:33	Vent	0.66			830	-0.03
31	SV31100609h	10/6/09 8:37	Vent	0.81		40.38	830	-0.03
					Average Discharge	42.83		
32	SV32092109	9/21/09 13:37	Vent	51.55			1330	-0.56
32	SV32092109a	9/21/09 13:41	Vent	62.65			1345	-0.39
32	SV32092109b	9/21/09 13:43	Vent	47.52	53.91	53.91	1345	-0.39
34	SV34092309	9/23/09 13:30	Vent	0.46			1330	-1.28
34	SV34092309b	9/23/09 14:00	Vent	0.50			1400	-1.12
34	SV34092309a	9/23/09 14:02	Vent	2.72			1400	-1.12
34	SV34092309c	9/23/09 14:23	Vent	0.59			1430	-0.85
34	SV34092309d	9/23/09 14:25	Vent	0.90		5.17	1430	-0.85
35	SV35092209	9/22/09 10:38	Vent	11.70			1045	-0.8
35	SV35092209a	9/22/09 10:42	Vent	7.36	19.06		1045	-0.8

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data EST Time	USGS Stage Data Corrected Stage (MSL)
35	SV35092209b	9/22/09 11:00	Vent	0.10			1100	-0.9
35	SV35092209c	9/22/09 11:20	Vent	0.99			1115	-1.01
35	SV35092209d	9/22/09 11:31	Vent	0.32		20.46	1130	-1.1
35	SV35092509	9/25/09 11:08	Vent	18.95		18.95	1115	0.04
					Average Discharge	19.71		
37	SV37100709	10/7/09 11:45	Vent	0.08			1145	-1.08
37	SV37100709a	10/7/09 11:49	Vent	0.10			1145	-1.08
37	SV37100709b	10/7/09 12:13	Vent	0.08			1215	-1.25
37	SV37100709c	10/7/09 12:18	Vent	0.00			1215	-1.25
37	SV37100709d	10/7/09 12:42	Vent	0.04			1245	-1.35
37	SV37100709e	10/7/09 13:03	Vent	0.02			1300	-1.33
37	SV37100709f	10/7/09 13:21	Vent	0.01		0.34	1315	-1.27
38	SV38092309	9/23/09 9:34	X-Section	8.44		8.44	930	0.09
38	SV38100509	10/5/09 13:10	X-Section	6.36		6.36	1315	-0.19
38	SV38100509a	10/5/09 13:24	Vent	0.51			1330	-0.04
38	SV38100509b	10/5/09 13:27	Vent	0.29			1330	-0.04
38	SV38100509c	10/5/09 13:28	Vent	2.08		2.88	1330	-0.04
					Average Discharge	5.89		
39	SV39092209	9/22/09 12:45	X-Section	9.24		9.24	1245	-1.35
39	SV39092509	9/25/09 12:49	Vent	5.00			1245	-0.55
39	SV39092509a	9/25/09 12:51	Vent	1.88			1245	-0.55
39	SV39092509b	9/25/09 12:53	Vent	1.62			1300	-0.64
39	SV39092509c	9/25/09 12:55	Vent	0.14			1300	-0.64
39	SV39092509d	9/25/09 12:58	Vent	0.18			1300	-0.64

Table 2. (cont.) Summary of Instantaneous Cross-section and Vents Measurements at Springs in Kings Bay, Crystal River, Florida

Site	Measurement No.	Date and Time	Measurement Type	Measured Discharge	Vent Average	Total Discharge	USGS Stage Data EST Time	USGS Stage Data Corrected Stage (MSL)
39	SV39092509f	9/25/09 13:08	Vent	0.77			1315	-0.72
39	SV39092509g	9/25/09 13:09	Vent	0.88			1315	-0.72
39	SV39092509h	9/25/09 13:13	Vent	0.86			1315	-0.72
39	SV39092509i	9/25/09 13:16	Vent	1.94		13.26	1315	-0.72
					Average Discharge	11.25		
40	SV40092209	9/22/09 13:22	X-Section	7.30		7.30	1315	-1.16
40	SV40092509	9/25/09 11:55	Vent	1.45			1200	-0.26
40	SV40092509a	9/25/09 11:57	Vent	1.49			1200	-0.26
40	SV40092509b	9/25/09 11:59	Vent	1.39			1200	-0.26
40	SV40092509c	9/25/09 12:03	Vent	8.35			1200	-0.26
40	SV40092509d	9/25/09 12:08	Vent	5.67			1215	-0.35
40	SV40092509e	9/25/09 12:10	Vent	6.27	5.97		1215	-0.35
40	SV40092509f	9/25/09 12:14	Vent	4.46			1215	-0.35
40	SV40092509g	9/25/09 12:15	Vent	3.03	3.75	22.40	1215	-0.35
					Average Discharge	14.85		

Legend

Measured Flows

Flows (CFS)

- <0.1 - 1.0
- 1.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20.0
- 20.0 - 40.0
- 40.0 - 55.0

2.5
28.9
12.5
0.0
0.1
2.2
11.4
0.8
5.2
24.0
31.0
1.9
1.5
2.0
0.9
50.0
0.6
7.4
25.8
23.6
45.2
4.8
3.5
0.7
11.0
1.7
3.8
2.4
0.3
0.5
28.9
53.9
42.8
5.2
19.7
0.3
5.9
11.3
14.9

N
W
E
S

700 350 0 700
Feet

Aerial Photograph Dated 2009

Date: January, 2010

Revised:

Figure 6
Kings Bay Spring Vent
Measured Discharge Map
Citrus County, Florida

Vanasse Hangen Brustlin, Inc.
8043 COOPER CREEK BLVD., SUITE 201
UNIVERSITY PARK, FLORIDA 34201

\\FI-orl\GISLIB\Temp\65845\GIS\project\Measured Flows.mxd

In situ water quality monitoring took place in conjunction with the discharge measurements. Discharge was usually measured for the vents in each grouping prior to the measurement of temperature and conductivity. A SCUBA diver placed the water quality sonde in the opening of each vent or at the measured cross-section. In a few locations water quality data were recorded at different locations in the water column to contrast it with the observed water quality in the vents. The results of the water quality monitoring are provided in **Table 3**.

Table 3 summarizes the site location, measurement number, date, time, depth of reading, temperature (°C), conductivity (*u*mhos/cm), salinity (ppt), average temperature for that series of measurements, average conductivity for that series of measurements, as well as the overall average temperature and conductivity for each number spring. The Event Average Temperature or Conductivity represents the average of the measured parameter for all vents measured at that spring on that date. The Overall Average Temperature and Conductivity has been calculated for those springs with more than one set of water quality measurements. Again, the stage elevation at the USGS gage (MSL) is provided for information on the relative height of the tide.

Review of the water quality data indicates that the temperature of the water leaving the vents is very similar. An average temperature of 23.4 °C was observed and the vast majority of the observed values were within one degree of the mean. The temperature of the cross-section areas were the highest and likely reflects the mixing of the springs discharge with warmer tidal waters.

The spring conductivity varied spatially within Kings Bay from a low of 203 to a high of 12,096 *u*mhos/cm, with an average of 2,045. **Figure 7** presents the Overall Average Conductivity data for each numbered spring and group cross-section over aerial photography of Kings Bay. The data were imported into GIS and conductivity contours were depicted using ESRI 3d analyst. A grid was created of the conductivity data and displayed using a gradual color scheme over the digitized shoreline. The data are sparse and so the interpolation of the contours should be viewed more on a qualitative basis to discern the general trends. The conductivities increase for very low levels in the northeast to brackish conductivities in the southwest. Both Site H24 and Site 2 measure conductivity in water flowing down ditches and it is likely that higher conductivity water from surficial groundwater seepage and tidal influences has elevated the observed conductivity levels. The Group1 and Group 2 measurements were generally at mid depth, but readings near the bottom and at the surface reveal both temperature and conductivity stratification with the cooler low conductivity water near the surface.

Site 24 is comprised of a number of scattered vents with conductivity readings ranging from 2,359 to 5,000 *u*mhos/cm. The highest conductivity was observed at a low volume vent ("c"). A measurement of the conductivity in the vicinity of this vent was also observed to be 5,000 *u*mhos/cm. This may indicate that surface water flows into these low flow vents at high tide stages and discharges at low tide stages as mentioned by District staff (personal communication, David DeWitt). A measurement of the ambient conductivity was also made at Black Spring (38) where the overall average conductivity within the vents was the highest of all sites at 10,631 *u*mhos/cm. However, for Black Spring the ambient conductivity was substantially lower at 5,503 when compared to the average vent conductivity that day of 12,080. For Black Spring it does not appear that surface water enters the vents at high tide and these vents are a source of brackish water (6.9 salinity) to Kings Bay.

Table 3. Summary of In Situ Water Quality Data at Springs in Kings Bay, Crystal River, Florida

Site No.	Measurement No.	Vent No.	Date	EST Time	Depth (m)	Temperature (°C)	Conductivity (µmhos/cm)	Salinity (ppt)	Event Average Temperature (°C)	Event Average Conductivity (µmhos/cm)	USGS Stage Data: EST Time	USGS Stage Data: Corrected Stage (MSL)
Group 1	1	X-Section	7/27/09	12:07	0.72	24.2	462	0.22	24.20	462	1200	-0.71
Group 1	1	X-Section	7/29/09	8:21	0.66	24.54	534	0.26	24.54	534	815	1.2
Group 1	1	X-Section	7/31/09	8:03	0.62	24.28	366	0.17	24.28	366	800	0.78
Group 1	1	X-Section	8/18/09	12:16	2.04	26.21	1730	0.87			1215	1.23
Group 1	2	X-Section	8/18/09	12:59	2.07	26.24	2032	1.03			1300	1.51
Group 1	3	X-Section	8/18/09	13:03	0.64	26.17	1481	0.74			1300	1.51
Group 1	4	X-Section	8/18/09	13:06	0.64	26.21	1498	0.75			1300	1.51
Group 1	5	X-Section	8/18/09	13:10	0.66	26.33	1696	0.85			1315	1.55
Group 1	6	X-Section	8/18/09	13:16	0.63	26.22	1440	0.71			1315	1.55
Group 1	7	X-Section	8/18/09	13:17	0.63	26.28	1448	0.72			1315	1.55
Group 1	8	X-Section	8/18/09	13:20	0.62	26.26	1362	0.67			1315	1.55
Group 1	9	X-Section	8/18/09	13:24	0.52	26.24	1235	0.60	26.24	1547	1330	1.59
								Overall Average	**24.82**	**727**		
Group 2	1	Bridge	7/27/09	10:01	0.9	24.26	1270				1000	0.16
Group 2	2	Bridge	7/27/09	10:17	1.8	24.27	1558		24.27	1414	1015	0.05
Group 2	1	Bridge	7/28/09	8:01	1.5 (Bottom)	26.6	2990				800	0.98
Group 2	2	Bridge	7/28/09	8:04	.2 (Surface)	25.2	1188				800	0.98
Group 2	3	Bridge	7/28/09	8:01	0.9	25	1575				800	0.98
Group 2	4	Bridge	7/28/09	8:09	0.84	24.56	1570				815	0.89
Group 2	5	Bridge	7/28/09	8:12	0.84	25.37	1860				815	0.89
Group 2	6	Bridge	7/28/09	8:15	0.83	25.55	1956		25.12	1740	815	0.89
Group 2	1	Bridge	7/29/09	13:56	0.43	24.86	766	0.37	24.86	766	1400	-0.8
Group 2	1	Bridge	7/30/09	7:49	0.86	25.7	1962	0.99	25.7	1962	745	0.83
Group 2	2	Bridge	7/30/09	14:27	0.7	24.89	749	0.41	24.89	749		
Group 2	1	Bridge	8/18/09	7:56	0.56	24.04	1008	0.49	24.04	1008	800	-0.85
								Overall Average	**24.81**	**1273**		

Table 3. (cont.) Summary of In Situ Water Quality Data at Springs in Kings Bay, Crystal River, Florida

Site No.	Measurement No.	Vent No.	Date	EST Time	Depth (m)	Temperature (°C)	Conductivity (µmhos/cm)	Salinity (ppt)	Event Average Temperature (°C)	Event Average Conductivity (µmhos/cm)	USGS Stage Data: EST Time	USGS Stage Data: Corrected Stage (MSL)
H24	Hammett24_100709	1	10/7/09	8:18	0.19	24.94	2242	1.14	24.94	2242	815	0.49
1	SV01100609a	1	10/6/09	13:27	6.98	22.95	2976	1.54			1330	-0.71
1	SV01100609b	2	10/6/09	13:30	5.69	22.91	3703	1.96	22.93	3340	1330	-0.71
2	SV02100709	1	10/7/09	8:27	0.42	24.52	1388	0.69	24.52	1388	830	0.38
3	SV03100509	1	10/5/09	14:33	1.05	23.26	208	0.1	23.26	208	1430	0.59
4	SV04100509	1	10/5/09	14:47	1.23	23.26	224	0.11	23.26	224	1445	0.75
5	SV05100509	1	10/5/09	14:03	0.391	23.37	203	0.1	23.37	203	1400	0.29
6	SV06092309	1	9/23/09	8:35	8.70	23.33	563	0.28	23.33	563	830	0.52
6	SV06100509	1	10/5/09	9:14	6.40	23.33	505	0.25	23.33	505	915	-0.69
								Overall Average	**23.33**	**534**		
7	SV07100809	1	10/8/09	11:33	1.5	23.22	869	0.43	23.22	869	1130	-1.01
8	SV08072909	1	7/29/09	11:40	1.8	23.28	219	0.1			1145	0.07
8	SV08072909	2	7/29/09	11:42	2.3	23.29	218	0.1	23.29	219	1145	0.07
8	SV08073109	1	7/31/09	9:04	2.15	23.34	213	0.1			900	1.12
8	SV08073109	2	7/31/09	9:06	2.43	23.3	212	0.1	23.32	213	900	1.12
8	SV08081709	1	8/17/09	9:17	1.13	23.35	219	0.1			915	0.51
8	SV08081709	2	8/17/09	9:19	2.36	23.28	219	0.1	23.32	219	915	0.51
8	SV08081809	1	8/18/09	12:32	2.19	23.44	221	0.1			1230	1.32
8	SV08081809	2	8/18/09	12:33	2.68	23.31	221	0.1	23.38	221	1230	1.32
								Overall Average	**23.32**	**218**		

Table 3. (cont.) Summary of In Situ Water Quality Data at Springs in Kings Bay, Crystal River, Florida

Site No.	Measurement No.	Vent No.	Date	EST Time	Depth (m)	Temperature (°C)	Conductivity (μmhos/cm)	Salinity (ppt)	Event Average Temperature (°C)	Event Average Conductivity (μmhos/cm)	USGS Stage Data: EST Time	USGS Stage Data: Corrected Stage (MSL)
9	SV09072909	1	7/29/09	11:22		23.3	259	0.12			1115	0.27
9	SV09072909c	2	7/29/09	11:23		23.3	242	0.11	23.30	251	1130	0.17
9	SV09073109	1	7/31/09	9:53	6.87	23.31	251	0.12			1000	1.16
9	SV09073109c	2	7/31/09	9:54	4.46	23.33	235	0.11	23.32	243	1000	1.16
9	SV09081709	1	8/17/09	8:44	7.46	23.31	256	0.12			845	0.32
9	SV09081709c	2	8/17/09	8:46	4.28	23.31	244	0.12	23.31	250	845	0.32
9	SV09081909	1	8/19/09	12:25	7.05	23.3	256	0.12			1230	0.99
9	SV09081909c	2	8/19/09	12:26	4.07	23.32	245	0.12	23.31	251	1230	0.99
								Overall Average	**23.31**	**249**		
10	SV10072909	1	7/29/09	10:11		23.3	649	0.31			1015	0.64
10	SV10072909a	2	7/29/09	10:12		23.3	616	0.3			1015	0.64
10	SV10072909b	3	7/29/09	10:12		23.3	578	0.28			1015	0.64
10	SV10072909c	4	7/29/09	10:13		23.3	619	0.3	23.30	616	1015	0.64
10	SV10073109	1	7/31/09	10:35	5.61	23.3	576	0.28			1030	1.08
10	SV10073109a	2	7/31/09	10:37	5.83	23.3	557	0.27			1030	1.08
10	SV10073109b	3	7/31/09	10:38	5.5	23.3	573	0.28			1045	1.05
10	SV10073109c	4	7/31/09	10:39	5.74	23.3	592	0.29	23.30	575	1045	1.05
10	SV10081709	1	8/17/09	8:00	5.11	23.35	612	0.3			800	0.02
10	SV10081709a	2	8/17/09	8:01	5.55	23.35	611	0.29			800	0.02
10	SV10081709b	3	8/17/09	8:04	4.85	23.32	579	0.28			800	0.02
10	SV10081709c	4	8/17/09	8:05	5.49	23.32	644	0.31	23.34	612	800	0.02
10	SV10081909	1	8/19/09	11:39	5.21	23.33	624	0.30			1145	0.53
10	SV10081909a	2	8/19/09	11:40	4.98	23.35	610	0.30			1145	0.53
10	SV10081909b	3	8/19/09	11:42	5.03	23.32	587	0.28			1145	0.53
10	SV10081909c	4	8/19/09	11:43	5.53	23.32	646	0.31	23.33	617	1145	0.53
								Overall Average	**23.32**	**605**		

Table 3. (cont.) Summary of In Situ Water Quality Data at Springs in Kings Bay, Crystal River, Florida

Site No.	Measurement No.	Vent No.	Date	EST Time	Depth (m)	Temperature (°C)	Conductivity (µmhos/cm)	Salinity (ppt)	Event Average Temperature (°C)	Event Average Conductivity (µmhos/cm)	USGS Stage Data: EST Time	USGS Stage Data: Corrected Stage (MSL)
11	SV11092109	1	9/22/09	9:51	3.07	23.34	1125	0.56	23.34	1125	945	-0.35
11	SV11100509	1	10/5/09	9:34	3.30	23.33	1084	0.54	23.33	1084	930	-0.8
								Overall Average	**23.34**	**1105**		
12	SV12092409	1	9/24/09	15:43	4.78	23.4	998	0.49			1545	-0.5
12	SV12092409b	2	9/24/09	15:46	4.58	23.44	1166	0.58	23.42	1082	1545	-0.5
13	SV13092509	1	9/25/09	14:36	2.00	23.48	559	0.27			1430	-0.99
13	SV13092509d	2	9/25/09	14:38	2.30	23.49	561	0.27	23.49	560	1445	-0.98
15	SV15072809	1	7/28/09	9:16	4.1	23.48	1453	0.73			915	0.51
15	SV15072809a	2	7/28/09	9:18	4.1	23.48	1452	0.73			915	0.51
15	SV15072809b	3	7/28/09	9:20	4.0	23.48	1421	0.71	23.48	1442	915	0.51
15	(Site 15) *Bottom*		7/28/09	8:52	2.6	23.67	1334	0.67			845	0.7
15	(Site 15) *Mid*		7/28/09	8:53	1.3	24.57	1315	0.66			900	0.62
15	SV15081809	1	8/18/09	9:46	3.92	23.48	1387	0.69			945	0.03
15	SV15081809a	2	8/18/09	9:49	4.16	23.47	1373	0.69			945	0.03
15	SV15081809b	3	8/18/09	9:50	4.13	23.48	1391	0.7	23.48	1384	945	0.03
								Overall Average	**23.48**	**1413**		
16	SV16072809	1	7/28/09	14:45		23.48	710	0.35	23.48	710	1445	-1.53
16	SV16073009	1	7/30/09	13:46	8.46	23.5	686	0.33			1345	-0.37
16	SV16073009a	2	7/30/09	13:47	7.53	23.5	709	0.34			1345	-0.37
16	SV16073009b	3	7/30/09	13:48	7.69	23.5	694	0.33	23.50	696	1345	-0.37
16	SV16081809	1	8/18/09	9:24	9.15	23.48	652	0.32			930	-0.09
16	SV16081809a	2	8/18/09	9:25	8.17	23.47	628	0.30			930	-0.09
16	SV16081809b	3	8/18/09	9:26	8.17	23.48	609	0.29	23.48	630	930	-0.09
								Overall Average	**23.49**	**679**		

Table 3. (cont.) Summary of In Situ Water Quality Data at Springs in Kings Bay, Crystal River, Florida

Site No.	Measurement No.	Vent No.	Date	EST Time	Depth (m)	Temperature (°C)	Conductivity (µmhos/cm)	Salinity (ppt)	Event Average Temperature (°C)	Event Average Conductivity (µmhos/cm)	USGS Stage Data: EST Time	USGS Stage Data: Corrected Stage (MSL)
17	SV17092409	1	9/24/09	14:16	2.39	23.85	2130	1.11			1415	-1.21
17	SV17092409a	2	9/24/09	14:18	2.20	24.92	3769	1.6			1415	-1.21
17	SV17092409b	3	9/24/09	14:31	3.86	23.46	1883	0.94	24.08	2594	1430	-1.15
18	SV18072809	1	7/28/09	12:03		23.42	737	0.36			1200	-0.64
18	SV18072809c	2	7/28/09	12:04		23.40	862	0.42	23.41	800	1200	-0.64
18	SV18073009	1	7/30/09	10:34	2.86	23.4	643	0.31			1030	0.76
18	SV18073009c	2	7/30/09	10:35	2.66	23.4	782	0.38	23.40	713	1030	0.76
18	SV18081709	1	8/17/09	12:52	3.03	23.46	621	0.33			1245	1.34
18	SV18081709b	2	8/17/09	12:23	2.74	23.45	732	0.32	23.46	677	1230	1.37
18	SV18081909	1	8/19/09	9:28	2.48	23.4	638	0.31			930	-0.85
18	SV18081909b	2	8/19/09	9:29	2.3	23.4	766	0.31	23.40	702	930	-0.85
								Overall Average	**23.42**	**723**		
19	SV19072809		7/28/09	12:30		23.47	421	0.20	23.47	421	1230	-0.84
19	SV19073009	1	7/30/09	11:00	5.14	23.4	460	0.22			1100	0.61
19	SV19073009a	2	7/30/09	11:02	4.99	23.4	461	0.22	23.40	461	1100	0.61
19	SV19081709	1	8/17/09	13:09	5.15	23.46	432	0.21	23.46	432	1315	1.2
19	SV19081909	1	8/19/09	9:50	4.61	23.4	443	0.21			945	-0.71
19	SV19081909a	2	8/19/09	9:52	4.73	23.4	428	0.21	23.40	436	945	-0.71
								Overall Average	**23.43**	**437**		
20	SV20072809	1	7/28/09	11:23		23.38	748	0.37			1130	-0.42
20	SV20072809c	2	7/28/09			23.39	669	0.32				
20	SV20072809d	3	7/28/09	11:26		23.38	725	0.35			1130	-0.42
20	SV20072809e	4	7/28/09			23.38	850	0.42	23.38	748		
20	SV20073009	1	7/30/09	9:25	4.22	23.4	692	0.34			930	1.04
20	SV20073009c	2	7/30/09	9:28	3.21	23.4	636	0.31			930	1.04

Table 3. (cont.) Summary of In Situ Water Quality Data at Springs in Kings Bay, Crystal River, Florida

Site No.	Measurement No.	Vent No.	Date	EST Time	Depth (m)	Temperature (°C)	Conductivity (µmhos/cm)	Salinity (ppt)	Event Average Temperature (°C)	Event Average Conductivity (µmhos/cm)	USGS Stage Data EST Time	USGS Stage Data Corrected Stage (MSL)
20	SV20073009d	3	7/30/09	9:29	2.66	23.4	675	0.33			930	1.04
20	SV20073009e	4	7/30/09	9:31	3.71	23.4	747	0.37	23.40	688	930	1.04
20	SV20081709	1	8/17/09	12:28	4.37	23.39	665	0.32			1230	1.37
20	SV20081709c	2	8/17/09	12:29	3.37	23.39	619	0.3			1230	1.37
20	SV20081709d	3	8/17/09	12:30	2.84	23.14	650	0.32			1230	1.37
20	SV20081709e	4	8/17/09	12:31	3.89	23.38	765	0.37	23.33	675	1230	1.37
20	SV20081909	1	8/19/09	9:03	3.58	23.4	715	0.34			900	-1.07
20	SV20081909c	2	8/19/09	9:04	2.37	23.4	615	0.30			900	-1.07
20	SV20081909d	3	8/19/09	9:05	1.97	23.4	669	0.32			900	-1.07
20	SV20081909e	4	8/19/09	9:06	2.95	23.4	803	0.39	23.40	701	900	-1.07
								Overall Average	**23.38**	**703**		
21	SV21072809	1	7/28/09	10:31	1.4	23.39	783	0.38	23.39	783	1030	0
21	SV21073009	1	7/30/09	8:28	2.15	23.38	726	0.35	23.38	726	830	1.01
21	SV21081709	1	8/17/09	10:27	1.81	23.39	691	0.34			1030	0.99
21	SV21081709a	2	8/17/09	10:29	2.03	23.44	709	0.35	23.42	700	1030	0.99
21	SV21081809	1	8/18/09	10:41	1.65	23.39	706	0.34			1045	0.51
21	SV21081809a	2	8/18/09	10:42	2.02	23.44	730	0.36	23.42	718	1045	0.51
21	SV21082009	1	8/20/09	8:50	1.38	23.38	733	0.36			845	-0.73
21	SV21082009a	2	8/20/09	8:51	1.69	23.4	750	0.37	23.39	742	845	-0.73
								Overall Average	**23.40**	**734**		
22	SV22081709	1	8/17/09	13:42	2.33	23.38	555	0.26			1345	0.98
22	SV22081709a	2	8/17/09	13:43	2.27	23.38	541	0.26			1345	0.98
22	SV22081709b	3	8/17/09	13:44	2.49	23.38	431	0.26	23.38	509	1345	0.98
22	SV22081809	1	8/18/09	10:24	2.02	23.39	564	0.27			1030	0.39
22	SV22081809a	2	8/18/09	10:24	2.02	23.39	574	0.28			1030	0.39
22	SV22081809b	3	8/18/09	10:24	2.34	23.39	468	0.22	23.39	535	1030	0.39

Table 3. (cont.) Summary of In Situ Water Quality Data at Springs in Kings Bay, Crystal River, Florida

Site No.	Measurement No.	Vent No.	Date	EST Time	Depth (m)	Temperature (°C)	Conductivity (µmhos/cm)	Salinity (ppt)	Event Average Temperature (°C)	Event Average Conductivity (µmhos/cm)	USGS Stage Data EST Time	USGS Stage Data Corrected Stage (MSL)
22	SV22082009a	1	8/20/09	8:37	1.71	23.39	568	0.27			830	-0.62
22	SV22082009b	2	8/20/09	8:36	1.74	23.47	544	0.29			830	-0.62
22	SV22082009c	3	8/20/09	8:39	2.04	23.39	475	0.23	23.42	529	845	-0.73
								Overall Average	**23.40**	**524**		
23	SV23072809	1	7/28/09	13:43		23.39	511	0.25			1345	-1.27
23	SV23072809a	2	7/28/09	13:45		23.39	527	0.25	23.39	519	1345	-1.27
23	SV23073009	1	7/30/09	12:59	2.56	23.4	496	0.24			1300	-0.08
23	SV23073009a	2	7/30/09	13:01	2.12	23.4	496	0.24	23.40	496	1300	-0.08
23	SV23081709	1	8/17/09	11:05	2.99	23.4	469	0.23			1100	1.16
23	SV23081709a	2	8/17/09	11:06	2.54	23.44	506	0.24			1100	1.16
23	SV23081709b	3	8/17/09	11:07	2.64	23.43	493	0.24	23.42	489	1100	1.16
23	SV23081809	1	8/18/09	10:58	2.74	23.39	465	0.22			1100	0.64
23	SV23081809a	2	8/18/09	10:59	2.35	23.39	466	0.22			1100	0.64
23	SV23081809b	3	8/18/09	11:00	2.93	23.39	468	0.22	23.39	466	1100	0.64
23	SV23082009	1	8/20/09	8:58	2.32	23.39	471	0.23			900	-0.81
23	SV23082009a	2	8/20/09	8:59	1.92	23.43	469	0.23			900	-0.81
23	SV23082009b	3	8/20/09	9:00	2.06	23.44	471	0.23	23.42	470	900	-0.81
								Overall Average	**23.40**	**488**		
24	SV24092409	1	9/24/09	11:14	3.64	23.3	2359	1.21			1115	-0.39
24	SV24092409a	2	9/24/09	11:19	2.02	23.36	2598	1.35			1115	-0.39
24	SV24092409b	3	9/24/09	11:21	2.82	23.3	2550	1.32			1115	-0.39
24	SV24092409c	4	9/24/09	11:24	2.09	26.87	5000	2.54			1130	-0.47
24	SV24092409d	5A	9/24/09	12:17	2.92	23.24	3250	1.7			1215	-0.8
24	SV24092409e	5B	9/24/09	12:20	3.04	24.74	4294	2.18			1215	-0.8
24	SV24092409f	5C	9/24/09	12:22	2.57	23.28	3304	1.74	24.01	3336	1215	-0.8
24	Spring 24 Background		9/24/09	11:30			5000	2.67				

Table 3. (cont.) Summary of In Situ Water Quality Data at Springs in Kings Bay, Crystal River, Florida

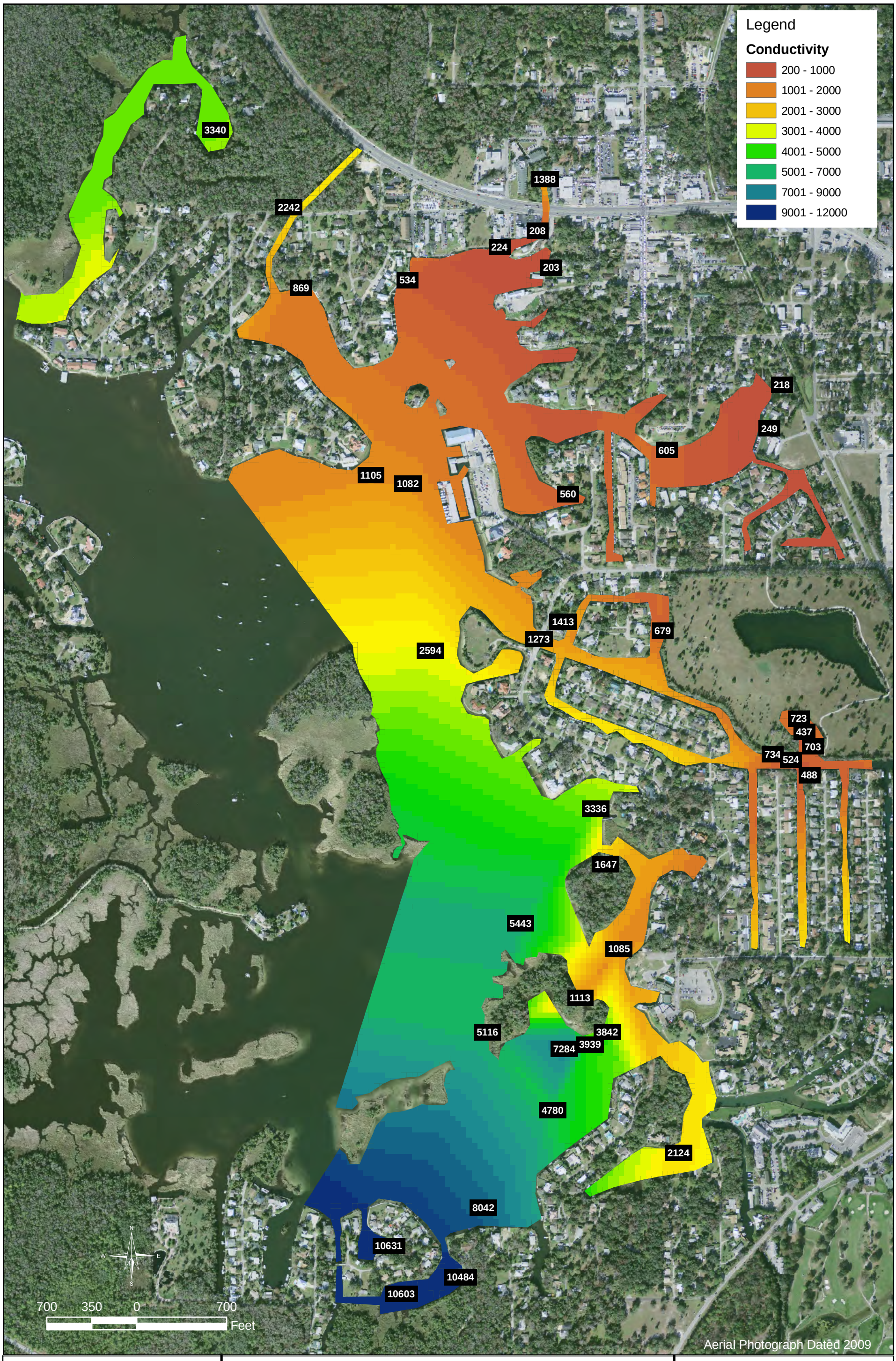
Site No.	Measurement No.	Vent No.	Date	EST Time	Depth (m)	Temperature (°C)	Conductivity (µmhos/cm)	Salinity (ppt)	Event Average Temperature (°C)	Event Average Conductivity (µmhos/cm)	USGS Stage Data: EST Time	USGS Stage Data: Corrected Stage (MSL)
25	SV25092409a	1	9/24/09	12:54	1.68	23.3	1724	0.87			1300	-1.05
25	SV25092409b	2	9/24/09	12:56	1.20	23.31	1628	0.82			1300	-1.05
25	SV25092409c	3	9/24/09	12:57	0.31	23.29	1589	0.8	23.30	1647	1300	-1.05
26+	SV26092309	1	9/23/09	12:33	5.50	23.13	6961	3.82	23.13	6961	1230	-1.16
26	SV26100509	1	10/5/09	10:53	4.50	23.16	5961	3.24			1100	-1.31
26	SV26100509b	2	10/5/09	10:54	5.24	23.11	6967	3.83			1100	-1.31
26	SV26100509c	3	10/5/09	11:58	3.82	23.21	6399	3.5	23.16	6442	1200	-1.01
26	SV26100509i	1	10/6/09	11:57	2.15	23.3	2926	1.51	23.3	2926	1200	-1.4
								Overall Average	**23.20**	**5443**		
27	SV27092109	1	9/21/09	9:17	3.67	23.33	780	0.38			915	-0.18
27	SV27092109b	2	9/21/09	9:44	1.77	23.33	1141	0.57	23.33	961	945	-0.42
27	SV27100609	1	10/6/09	10:00	3.18	23.61	1227	0.61			1000	-0.73
27	SV27100609b	2	10/6/09	10:18	2.61	23.37	765	0.38			1015	-0.84
27	SV27100609c	3	10/6/09	10:45	1.59	23.34	1079	0.53	23.44	1024	1045	-1.05
27	Paul's Paradise_100709	E	10/7/09	15:29	0.83	23.36	1271	0.63	23.36	1271	1530	0.04
								Overall Average	**23.38**	**1085**		
28	SV28100709	1	10/7/09	14:13	0.46	23.32	779	0.38			1415	-0.71
28	SV28100709a	2	10/7/09	14:24	0.06	23.33	772	0.38			1430	-0.56
28	SV28100709b	3	10/7/09	14:36	0.32	23.34	760	0.37			1430	-0.56
28	SV28100709c	4	10/7/09	14:50	0.88	23.32	1236	0.61			1445	-0.4
28	SV28100809a	5	10/8/09	10:16	1.02	23.31	2017	1.03	23.32	1113	1015	-0.45
29	SV29092309	1	9/23/09	10:57	1.30	23.24	5084	2.73			1100	-0.58
29	SV29092309b	2	9/23/09	11:06	1.30	23.24	5148	2.77	23.24	5116	1100	-0.58

Table 3. (cont.) Summary of In Situ Water Quality Data at Springs in Kings Bay, Crystal River, Florida

Site No.	Measurement No.	Vent No.	Date	EST Time	Depth (m)	Temperature (°C)	Conductivity (μmhos/cm)	Salinity (ppt)	Event Average Temperature (°C)	Event Average Conductivity (μmhos/cm)	USGS Stage Data: EST Time	USGS Stage Data: Corrected Stage (MSL)
30	SV30092109	1	9/21/09	11:56	4.65	23.3	4396	2.34	23.3	4396	1200	-1.25
30	SV30092509	1	9/25/09	10:43	5.09	23.29	3425	1.80			1045	0.24
30	SV30092509b	2	9/25/09	10:45	5.36	23.28	3237	1.69	23.29	3331	1045	0.24
30	SV30100609	1	10/6/09	9:00	3.67	23.28	3800	2.01			900	-0.26
30	SV30100609a	2	10/6/09	9:01	4.46	23.27	3797	2	23.28	3799	900	-0.26
								Overall Average	**23.29**	**3842**		
31	SV31092109	1	9/21/09	11:59	4.37	23.3	4589	2.45	23.3	4589	1200	-1.25
31	SV31092509	1	9/25/09	10:48	5.37	23.27	3593	1.89			1045	0.24
31	SV31092509d	2	9/25/09	10:49	5.16	23.27	3536	1.86	23.27	3565	1045	0.24
31	SV31100609	1	10/6/09	9:02	4.10	23.28	3710	1.96			900	-0.26
31	SV31100609d	2	10/6/09	9:03	5.08	23.28	3619	1.9	23.28	3665	900	-0.26
								Overall Average	**23.28**	**3939**		
32	SV32092109	1	9/21/09	13:22	10.17	23.3	7284	4.01	23.3	7284	1315	-0.72
34	SV34092309	1	9/23/09	13:35	2.80	23.28	4399	2.34			1330	-1.28
34	SV34092309a	2	9/23/09	14:14	2.88	23.26	5093	275			1415	-0.98
34	SV34092309b	3	9/23/09	14:30	2.33	23.27	4759	2.55			1430	-0.85
34	SV34092309c	4	9/23/09	14:32	2.46	23.26	4870	2.61	23.27	4780	1430	-0.85
35	SV35092209	1	9/22/09	10:42	2.96	23.3	2188	1.12			1045	-0.8
35	SV35092209b	2	9/22/09	10:57	0.27	23.29	2637	1.36			1100	-0.9
35	SV35092209c	3	9/22/09	11:37	2.08	23.3	1793	0.91			1130	-1.1
35	SV35092209d	4	9/22/09	11:34	2.06	23.3	1871	0.95	23.30	2122	1130	-1.1
35	SV35092509	1	9/25/09	11:12	2.60	23.3	2125	1.09	23.3	2125	1115	0.04
								Overall Average	**23.30**	**2124**		

Table 3. (cont.) Summary of In Situ Water Quality Data at Springs in Kings Bay, Crystal River, Florida

Site No.	Measurement No.	Vent No.	Date	EST Time	Depth (m)	Temperature (°C)	Conductivity (µmhos/cm)	Salinity (ppt)	Event Average Temperature (°C)	Event Average Conductivity (µmhos/cm)	USGS Stage Data: EST Time	USGS Stage Data: Corrected Stage (MSL)
37	SV37100709a	1	10/7/09	13:39	1.59	23.33	8088	4.49			1345	-1.02
37	SV37100709c	3	10/7/09	13:33	1.49	23.38	7867	4.36			1330	-1.15
37	SV37100709d	4	10/7/09	13:09	1.38	23.36	8203	5.56			1315	-1.27
37	SV37100709e	5	10/7/09	13:25	0.94	23.65	8011	4.44	23.43	8042	1330	-1.15
38	SV38092309	1	9/23/09	9:51	1.96	23.89	9183	5.14	23.89	9183	945	-0.02
38	Spring 38	Ambient	10/5/09	13:29	Surface	26.02	5503	2.96			1330	-0.04
38	SV38100509a	1	10/5/09	13:09	1.52	23.29	12072	6.91			1315	-0.19
38	SV38100509b	2	10/5/09	13:11	2.00	23.25	12096	6.92			1315	-0.19
38	SV38100509c	3	10/5/09	13:12	2.02	23.25	12071	6.91	23.26	12080	1315	-0.19
								Overall Average	**23.58**	**10631**		
39	SV39092509	1	9/25/09	13:21	4.14	23.18	10893	6.18			1315	-0.72
39	SV39092509b	2	9/25/09	13:23	3.46	23.23	10074	5.68	23.21	10484	1330	-0.8
40	SV40092509	1	9/25/09	12:20	1.98	24.00	10371	5.86			1215	-0.35
40	SV40092509d	2	9/25/09	12:22	2.55	23.75	10834	6.15	23.88	10603	1215	-0.35



Date: January, 2010

Revised:

Figure 7
Kings Bay Spring Vent
Conductivity Map
Citrus County, Florida

Vanasse Hangen Brustlin, Inc.
8043 COOPER CREEK BLVD., SUITE 201
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Conducting multiple discharge measurements using different methodologies, as well as the diurnal cross-sections revealed occasional inconsistencies in the measured discharge. This was most apparent at Three Sisters Springs where the sum of the individual vents measurements exceeded the discharge measured within the spring run. As discussed earlier, multiple vents located within the same "bowl" were measured as a unit – usually with multiple measurements at different angles. These bowls were usually encompassed a sizable sectional area (the Middle Spring (19) measured 10.5 X 8.5 and a bowl at the southern spring (20) measured 12.0 X 9.0). The field measurements would have scanned over the larger springs in the bowl and likely captured the higher velocities, which, when multiplied by the large area, would have indicated large flow volumes. As a result, it is likely that the estimated discharge from Springs 19 and 20 overestimate the actual discharge. The discharge recorded in the Three Sisters Springs Run is believed to better represent the discharge from these three springs because of the accuracy of the cross-section measurements. A similar "bowl" area involves Spring 24 (measurement SV240924a).

In some cases the calculated discharge seems high compared to the impression of the field sampling personnel. Again, these instances relate to those vents with large cross-sectional areas – usually long vents. Multiple measurements in different locations were taken at some of these vents to determine the averages, and these discharge calculations are not questioned. However, the discharge calculated at some large vents associated with Manatee Sanctuary Spring (16), and to a lesser extent at Gary's Grotto (40), may overestimate the discharge.

Conversely, not all of the vents at each spring could be measured. So although the largest vents and those deemed to have the strongest flow were measured, not all discharge was measured and the total flow from those springs would be slightly greater. This is particularly true at Springs 13 (Moray), 15 (Paradise Isles), 16 (Manatee Sanctuary), 22 (Idiots Delight #2) and, to a lesser extent, 23 (Idiots Delight #3).

The precision of the measurement methods likely differed. Wading cross-section measurements with the single cell ADP and vent measurements where the single cell ADP was inserted into the throat of the vent represent the most accurate velocity measurement because of the exactness of placement. Multicell ADP vent measurements of small springs were also relatively precise along with the multicell ADP instantaneous cross-section measurements in narrower areas. The accuracy of the discharge measurements was likely lower when the multicell ADP was used on large vents and the long deep cross-sections.

Electronic files of this report, GIS files of Figures 1, 6 and 7, spreadsheets of stage, discharge and water quality measurements, vent measurement output and copies of the field notes were provided to the District.

References:

Hammett, K. M., C.R. Goodwin, and G. L. Sanders 1996. Tidal-Flow, Circulation, and Flushing Characteristics of Kings Bay, Citrus County, Florida, U.S. Geological Survey Open File Report 96-230, Tallahassee, FL.

Serviss, G. 2009. An Inventory of Spring Vents in Kings Bay, Crystal River, Florida. Report prepared by Vanasse Hangen Brustlin, Inc. for the Southwest Florida Water Management District, Brooksville, Florida.