APPENDIX

Southwest Florida Water Management District. 2017. District response to the Crystal River/Kings Bay MFLs peer review. Brooksville, Florida.

District Response to the Crystal River/Kings Bay MFLs Peer Review

February 21, 2017

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Minimum Flow Peer Review Process

In October, November, and December 2016, the Southwest Florida Water Management District convened a panel for the independent, scientific peer review of minimum flows proposed for the Crystal River/Kings Bay system. The peer review panel, i.e., the Panel, consisted of a Chairperson, Steve Peene with Applied Technology & Management Inc., Panelist Ken Watson, with HSW Engineering Inc., and Panelist Adam Munson, a sub-contractor with Jones, Edmunds & Associates, Inc.

To support the Panel's review, District staff provided initial verbal and written responses to numerous Panel inquiries concerning the proposed minimum flows and their development. Most of these responses were incorporated into summary tables included as appendices to the Panel's final report titled, "Crystal River/Kings Bay Minimum Flow and Level Peer Review", that was submitted to the District on December 12, 2016. In some instances, the summary tables included in the Panel's final report contain Panelist references to staff's initial responses.

The Panel's final report has been posted on the District web site, made available upon request to interested parties, and will be provided to members of the District Governing Board. As directed by Section 373.042 of the Florida Statutes, the Governing Board is to give significant weight to the peer review Panel's final report when establishing minimum flows for the river system.

Staff has reviewed the Panel's final report and developed this document to summarize staff responses to Panel comments. The Panel's final report is reproduced here and amended with staff responses that are highlighted in blue. These responses are provided as replies to previously unanswered Panelist questions or comments and to describe activities that have been or will be undertaken in response to the Panelist's review and input. Yellow highlighting is used judiciously in this document to emphasize key points included in the Panel's final report and identify text from the Panel's report that is relevant to specific District responses. This District response document will be made available to all interested parties, including the District Governing Board.

CRYSTAL RIVER/KINGS BAY
MINIMUM FLOW AND LEVEL
PEER REVIEW

TWA NOS: 16TW0000363, 16TW0000364, AND 16TW0000411

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
2379 BROAD STREET
BROOKSVILLE, FLORIDA 34604

DECEMBER 2016

Attachments

EXECUTIVE SUMMARY OF PEER REVIEW

The Southwest Florida Water Management District (District) contracted with an independent panel of experts to provide a technical peer review of the proposed Minimum Flows and Levels (MFL) for the Crystal River/Kings Bay Springs system. The Kings Bay/Crystal River system is located in Citrus County on Florida's Springs Coast. The system consists of Kings Bay, an approximately 600-acre estuarine embayment fed by more than 70 spring vents that discharge fresh to slightly saline water. From Kings Bay, the system flows out approximately 6 miles to the Gulf of Mexico through Crystal River. The system is tidally influenced throughout its extent.

Two critical components of the MFL analyses are: a hydrodynamic model developed by the District used to evaluate the changes in salinity and temperature under varied inflow conditions; and a methodology to calculate the submarine groundwater discharge (SGD) to the system. The SGD calculations constitute the long-term flows utilized as the basis for the MFL development. The U.S. Geological Survey (USGS) flow measurements on the system at Bagley Cove were deemed unreliable by the District.

The proposed MFL for the Kings Bay Crystal River system is based primarily on having less than a 15 percent change in salinity habitat (volume, shoreline length, and bottom area), with the key metric being a 15 percent change in the volume of water under 2 parts-per-thousand (ppt) salinity. Other metrics directly assessed included the volume of thermal manatee habitat, residence time, and some components of water quality. The flow reduction defined for the MFL was determined to be protective of these other components.

Overall, the Peer Review Panel supports the conclusions presented within the MFL report and the use of the salinity habitat as the primary metric. A key component of the MFL analyses, the hydrodynamic model, was generally found to be sufficiently developed and calibrated for use in evaluating the changes in the temperature and salinity as a function of SGD. Additionally, the methodology utilized for the calculating the SGD, while containing some degree of uncertainty and potential errors, represents the best available information for use in estimating the present and historical flows from the spring vents.

The Peer Review Panel did identify key comments/recommendations to improve the MFL report, supporting documentation, and associated analyses. The full document provides detailed comments and recommendations including grammatical edits. A summary of some of the key recommendations are listed below;

- The calculation and validation of the historical and present flows from the spring vents remain an issue for this system. The District has determined that the Bagley Cove data, collected by USGS, is not reliable. The SGD methodology developed by the District also has a level of uncertainty, and ancillary calculations of long-term flow using alternate methodologies do not fully support either the USGS or District calculations. The District needs to do a better job of identifying the uncertainty in both methods of flow determination and the limitations this creates.

Staff Response: Staff have analyzed USGS-reported Bagley Cove data and compared it with SGD estimated by the District with an empirical formula. As described in Chen (2014), the hydrodynamic model used for our minimum flow analyses was tested using reported Bagley Cove discharge as total SGD to the system. The results of this modeling effort showed poor agreement between model-predicted and measured salinities. This is because reported discharge for the Bagley Cove gage includes signals from wind action, storm surges, storages in Kings Bay, and interactions of these and other factors. These influences can be seen in the frequent negative daily and monthly mean values reported for the Bagley Cove site. Negative monthly discharge is clearly not indicative of spring flow into this system.

Given that Bagley Cove discharge record yields poor predictive capacity when used as input to the hydrodynamic model and includes negative daily and monthly means throughout the 2002 to 2016 period of record, the empirical-formula-derived SGD represents the best information available for estimating spring discharge to this system. Staff will emphasize this point in a revised version of the minimum flow report and will characterize the reported Bagley Cove discharge record as less suitable than the estimated SGD record for our minimum flow analyses, rather than “unreliable.” Staff notes that error in hydrodynamic model output is quantified on page 41 of the draft minimum flow report, where skill parameter and R^2 values are given for agreement between simulated output and measured data during the verification period of April 2007 to February 2010. Staff will expand upon discussion of these issues in the revised minimum flow report. We will also emphasize that reevaluation efforts will focus on new data collection sites and approaches for better estimation of spring flow.

- The salinity habitat change analyses relied upon a system-wide assessment of change. The District should consider if any habitats aggregated into the volume, area and length categories should be further parsed. One recommendation is to consider the difference between sloped and sediment and vegetated shoreline and hardened vertical shoreline (i.e., seawall). The District should assess (for all habitats) if this type of parsing makes sense and would strengthen the MFL conclusions.

Staff Response: District staff agree, and are developing data for analysis of shoreline salinity based habitat changes that can be used to distinguish between vegetative, altered, and natural shoreline. This analyses may be completed for consideration in the minimum flow adoption process scheduled for completion by July 1, 2017 in accordance with Section 373.042(2)(a) of the Florida Statutes, or may be incorporated into the planned reevaluation of the minimum flow that is established for the system

- While the hydrodynamic model was deemed sufficient for use in determining the changes in salinity and temperature habitat as of function of SGD, there were some issues identified within the review that should be resolved before final submission of the MFL report and supporting documentation. Some specific issues include: evaluation of the sensitivity of the offshore boundary to changes in flows (initial results of this have been provided to the Peer Review Panel); removal of periods of the model runs from the calibration statistics where boundary data are not available; and more complete documentation of the volume of additional flow added into the model to account for seepage and as a tuning parameter for the model calibration.

Staff Response: District staff agree, and are working to address and implement the Panel's recommended changes and comments. Regarding boundary conditions, newly-run model scenarios indicate that a minor increase in salinity at the downstream boundary due to reduced flow has minimal, non-significant effects on model predictions used for the minimum flow analyses. This information will be included in the updated minimum flow report as will Panel suggested improvements concerning presentation of model calibration statistics and documentation of model-tuning or parameterization associated with seepage estimates.

A component of the Peer Review Panel scope of work was to provide an assessment of the MFL report and supporting documentation against specific listed criteria. These are outlined in Section 3 of the report. The findings of the Peer Review Panel are that, with the implementation of some of the edits/recommendations made within this report, there are no fatal flaws within the MFL report and supporting documentation relative to the specified criteria.

Staff Response: We are pleased that the Panel found “no fatal flaws”, indicating that the issues, comments, questions and concerns they identified may be addressed by the District to improve the minimum flows report, but are not considered necessary. As appropriate and indicated in this summary response document, suggested edits and other recommendations made by the Panel will be incorporated into future drafts of the minimum flows report. In addition, Panel recommendations will guide future assessments associated with the reevaluation of minimum flows that are expected to be adopted for the system in 2017.

1.0 INTRODUCTION

1.1 BACKGROUND AND SYSTEM DESCRIPTION

The Southwest Florida Water Management District (District) contracted with an independent panel of experts to provide a technical peer review of the proposed Minimum Flows and Levels (MFL) for the Crystal River/Kings Bay Springs system. The peer review panel includes:

- Dr. Steven Peene (panel chair)
- Dr. Ken Watson
- Dr. Adam Munson

The Kings Bay/Crystal River system is located in Citrus County on Florida's Springs Coast. The system consists of Kings Bay, an approximately 600-acre estuarine embayment fed by more than 70 spring vents that discharge fresh to slightly saline water. From Kings Bay, the system flows out approximately 6 miles to the Gulf of Mexico through Crystal River. Figure 1-1, taken from the MFL Report (SWFWMD, 2016), shows the layout of Kings Bay and Crystal River along with the locations of the numerous spring vents to the system. Based upon historic studies, the District has identified that the spring vents provide more than 99 percent of the freshwater entering the system in Kings Bay. Crystal River connects to the Gulf of Mexico at two locations: near Shell Island and through the Salt River (Figure 1-1).

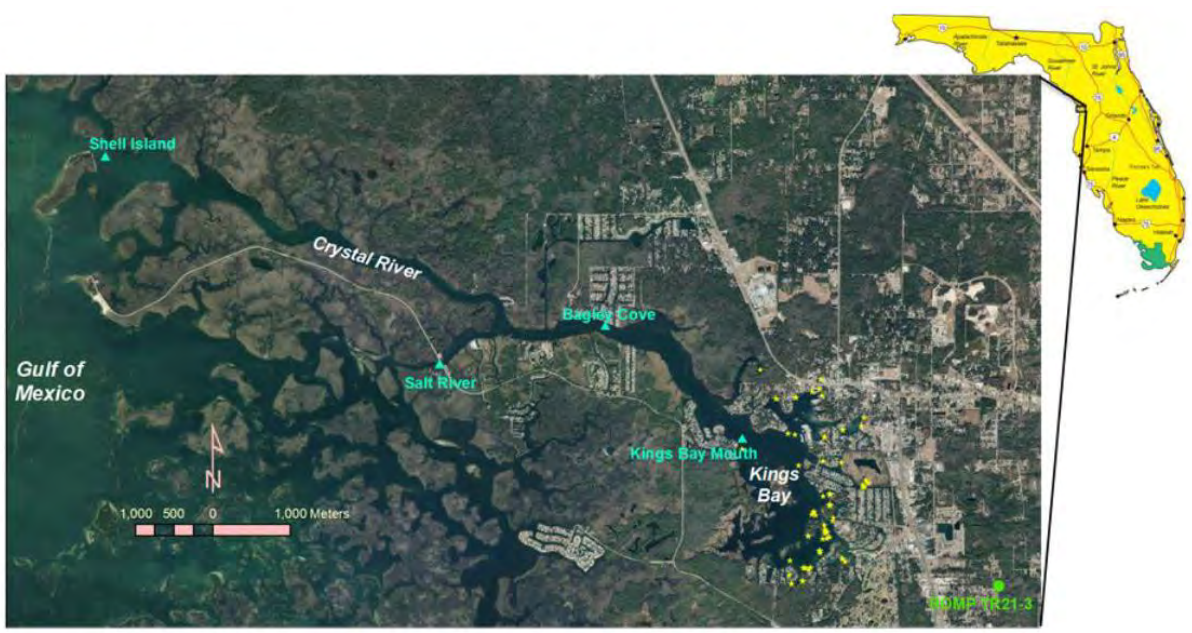

Figure 1-1. Location and Layout of Crystal River/Kings Bay System (SWFWMD, 2016)

The discharge from the spring vents derives from groundwater within the system's springshed. The Crystal River/Kings Bay springshed spans approximately 310 square miles in northern Citrus County (Figure 1-2).

Flow measurements within the system have consisted of long-term monitoring at Bagley Cove (see Figure 1-1) by the U.S. Geologic Survey (USGS) and more recent data the District collected on direct flows from the spring vents. USGS flow measurement techniques have been modified throughout their period of record and, as identified by discussions with USGS staff, changes are ongoing. Additional data collection has included water level and salinity measurements at Shell Island, Salt River, Bagley Cove, and the Kings Bay Mouth, along with groundwater levels at three wells located near Kings Bay (Figure 1-1).

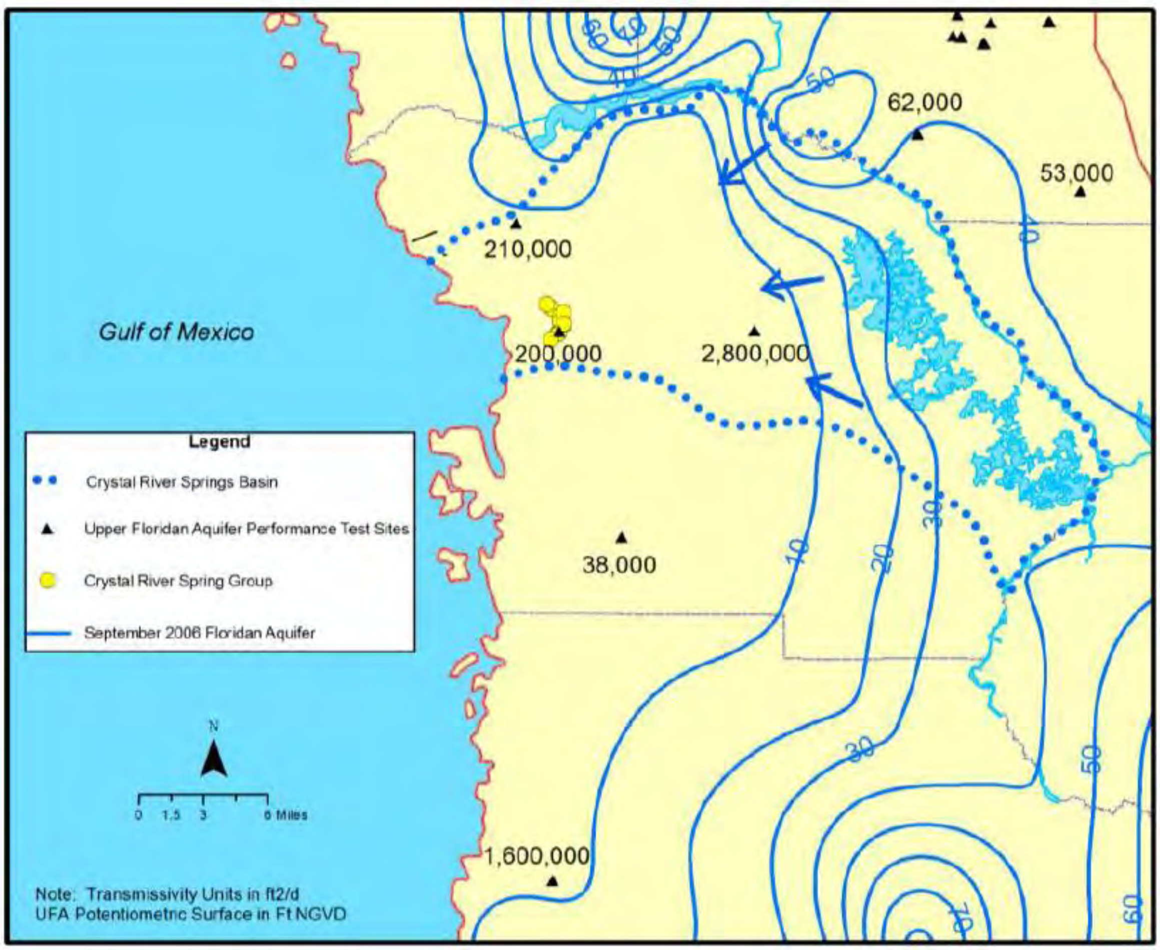

Figure 1-2. Extent of the Crystal River/Kings Bay Springshed (SWFWMD, 2016)

The accurate determination of the long-term total flow record is a critical component of the MFL development and is discussed in detail in the MFL report and supporting documentation. Discussions center on the use of the data from the USGS station at Bagley Cove (raw and tidally filtered) versus empirically derived direct flows from the spring vents based upon direct vent measurements and water levels in Crystal River and a nearby monitoring well.

A key component of the MFL development was a hydrodynamic model of the system that was utilized to assess the impacts of flow reductions from the spring vents on salinity and thermal habitat. The development, calibration, and application of the hydrodynamic model is discussed in detail in the MFL report and supporting documentation. The assessment of the development, calibration and application of the hydrodynamic model is a primary focus of the peer review.

The Florida Department of Environmental Protection (FDEP) has designated the Crystal River/Kings Bay system as a Class III surface water body, an Outstanding Florida Water (OFW), and a Surface Water Improvement and Management (SWIM) Priority Water Body. The Crystal River Springs group is also classified as an Outstanding Florida Spring. Key environmental resources in the area that were specifically targeted for protection in this MFL include submerged aquatic vegetation (SAV) as well as manatee thermal habitat. The MFL also examined water quality conditions in the system and the impacts of flow reductions on residence times.

The final MFL presented within the report was based on allowance of a 15 percent reduction in the volume of salinity habitat for the most sensitive salinity isohaline [2 parts per thousand (ppt)] using the hydrodynamic model. Based on the 15 percent habitat reduction, an allowable flow reduction of 12 percent was identified.   Current water withdrawals are at or less than 2 percent of the baseline flow condition. Based on the comparison of the current withdrawals with the allowable, the MFL document concluded that no recovery strategy was needed.

1.2 <u>REGULATORY BASIS FOR MFL AND PEER REVIEW</u>

Florida Statutes (F.S.) mandate that the District must establish MFLs for state surface waters and aquifers within its boundaries for the purpose of protecting the water resources and the ecology of the area from "significant harm." Section 373.042, F.S., provides that the minimum flow for a given watercourse is the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area and the minimum water level is the level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources or ecology of the area.

Section 373.042, F.S., also provides that MFLs shall be calculated using the best information available, that the Governing Board shall consider and may provide for non-consumptive uses in the establishment of MFLs and, when appropriate, MFLs may be calculated to reflect seasonal variation. The law also requires that when establishing MFLs, changes and structural alterations to watersheds, surface waters, and aquifers shall also be considered (Section 373.0421, F.S.). The State Water Resource Implementation Rules (Chapter 62-40, Florida Administrative Code) includes additional guidance for establishing MFLs, providing that "…consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows or levels, and environmental values associated with coastal, estuarine, aquatic, and wetlands ecology, including:

a) Recreation, in and on the water;
b) Fish and wildlife habitats and the passage of fish;
c) Estuarine resources;
d) Transfer of detrital material;
e) Maintenance of freshwater storage and supply;
f) Aesthetic and scenic attributes;
g) Filtration and absorption of nutrients and other pollutants;
h) Sediment loads;
i) Water quality; and
j) Navigation."

Section 373.042, F.S., also addresses independent scientific peer review of MFLs, specifying the review of all scientific or technical data, methodologies, and models, including all scientific and technical assumptions employed in each model, used to establish a minimum flow or minimum water level. In addition, the law requires that FDEP or the District Governing Board shall give significant weight to the final peer review panel report when establishing MFLs.

1.3 DOCUMENTS AND DATA UTILIZED IN THE PEER REVIEW

The following documents and data were provided to the panel members to be utilized in the peer review.

- Recommended Minimum Flow for the Crystal River/Kings Bay System – Draft Report for Peer Review (SWFWMD, 2016a)
- Chapter 6 – Appendices: Recommended Minimum Flow for the Crystal River/Kings Bay System – Draft Report for Peer Review (SWFWMD, 2016b)
- Estimate of Submarine Groundwater Discharge to Crystal River/Kings Bay in Florida with the Help of a Hydrodynamic Model (Chen, 2014)
- On the Estimation of Submarine Groundwater Discharge to Kings Bay (Chen, 2014)
- SWFWMD Presentation – King's Bay – Simulated Spring Flow History
- Northern District Groundwater Flow Model, Version 5.0 (SWFWMD, 2016c)
- Peer Review of the Northern District Model Version 5 and Predictive Simulations, October 10, 2016, Final Report (SWFWMD, 2016d)
- Comparison of Bagley Cove Qs (graphs developed by Dr. Chen of SWFWMD)
- Excel data files from Dr. Chen of Bagley Cove, Salt River, Kings Bay Mouth, and Shell Island measured flows, levels, temperature and conductivity.

1.4 PEER REVIEW PANEL SCOPE AND APPROACH

The Peer Review Panel was scoped to complete the following tasks as part of the MFL Peer Review:

- Review draft of the Crystal River/Kings Bay MFL Report along with available supporting documentation and data
- Participate in Public Meetings including:
    - Kickoff Meeting and Site Visit (November 4, 2016)
    - Web-Meetings (November 15,16, and 21, and December 5, 2016)
- Post written review comments and collaborate with other panelists to develop a single peer review panel report
- Review and provide support in development of meeting agendas and meeting summaries

Following the process outlined in the scope above, the following sections present the results, comments, and recommendations of the Peer Review Panel.

Section 2 of this report utilizes a tabular template (completed by each of the three peer reviewers) to meet the District's peer review requirements. The tabular comments are presented for each section of the MFL report, as well as key supporting documentation within the appendices. Narrative comments on various key aspects of the MFL report and supporting documentation, precedes the tabularized comments. The tabularized comments include the specific comment, whether the comment has significant impact on the conclusions of the MFL, and recommendations on how to address the comment.

Section 3 presents tabularized results of the panel member's comments concerning the District's peer review assessment criteria, which are outlined in Attachment A of this report. These criteria were specific scoped sub-tasks outlined by the District for the panel members to address.

Section 4 presents referenced literature.

2.0 REVIEW OF MFL REPORT, APPENDICES, AND EXTERNAL REPORTS

The following sections provide detailed review and comments on the MFL report and supporting documentation provided by the District for use by the Peer Review Panel. Section 2.1 presents the review of the MFL Report. Section 2.2 presents the review of the appendices and supporting documentation. A narrative review is provided relative to key aspects of the MFL development as identified by the review panel. Following the narrative comments, tables are provided for each Chapter of the report and for the supporting documentation with detailed comments, identifying if the comment is significant (i.e., impacts the MFL determination), and proposed action items to address the comments.

2.1 MFL REPORT

Specific components of the MFL report and supporting documentation were identified by the peer review panel as critical in the MFL development. These were identified for specific review and discussion. These included;

- Determination of the Submarine Groundwater Discharge
- Development, Calibration and Application of the Hydrodynamic Model

The following presents the reviewers discussion of these items. Following the narrative discussion, tables are provided with detailed comments from each of the reviewers along with the significance of the comment and recommendations for resolution.

Determination of Submarine Groundwater Discharge

Discharge measurements at USGS gage 02310750 Crystal River Near Crystal River FL (1964 to 1977) were determined to be unreliable and were not used in the MFL study. Average flow during that period was estimated to be 971 cfs. A new gage was activated in 2002 (USGS gage 02310747 Crystal River at Bagley Cove) and tidally adjusted average flow between 2002 and 2015 was calculated to be 447 cfs. This value is the result of adjustments made to the rating curves in 2011. The District concluded for the MFL that the Bagley Cove record, including the most recent adjustments, was unreliable for this MFL work. Discussions with USGS personnel identified that USGS has recently installed new instrumentation at Bagley Cove to obtain more complete data at the cross-section. In the future, a revised rating curve will be developed using the new data and new flow projections can be evaluated.

The District estimated an average flow of 374 cfs for the period of 1969 to 2015 using direct field flow measurements at select spring vents and at two channels which contain the input from multiple spring vents. The channel measurements were taken during July-August 2009. At this same time, water level measurements were collected at the mouth of Crystal river and in groundwater wells adjacent to Kings Bay. The District developed relationships between the water level measurements at the mouth, the water level in the wells and the measured flow at the channels. The relationships developed reflected approximately 60 percent of the flow coming into the system. The relationships were then extrapolated to the other vents to calculate the remaining 40 percent of flow. The flows were then checked using the hydrodynamic model to assure salinity predictions were reasonable and from those simulations a remaining approximately 10% additional flow was added to the system to account for seepage.

Staff Response: For clarification, the formula to predict submarine groundwater discharge relied on data from the mouth of Kings Bay at United States Geological Survey (USGS) gage #02310742. The Panel's report incorrectly notes that these data were collected at the "mouth of Crystal river" rather than the mouth of Kings Bay.

Based on the above, the MFL flow record and various metrics for developing the MFL are based on empirically derived results without verification against a complete gaged flow record, and the independent drivers are tidal stage, water temperature, and salinity; groundwater elevation at a tidally influenced well; and salinity assigned to spring flow.

The USGS results were defined as unreliable in the MFL document, but discussions with USGS personnel identified that USGS does not believe the data, following the 2011 corrections, and if averaged over a sufficient period, are unreliable. Additionally, the predictions from the Northern District Groundwater Model are closer to the long-term average from the USGS gage (450 cfs versus 447 cfs). Also, the USGS flow at Bagley Cove for the model time period (2006 to 2015) was about 354 cfs and the District estimated springs discharge was 332 cfs, or about a 6% less but reasonably similar.

Staff Response: In the original minimum flows report, the District stated that discharge estimates based on data collected at the USGS Bagley Cove gage (#02310747) are not reliable estimates of groundwater discharge for use in minimum flow analyses. Future drafts will clarify that the discharge reported for this gage is not objectively 'unreliable', as it is not the intent of the District to criticize the discharge reported by the USGS. However, we found reported discharge from this gage was inappropriate as an estimate of submarine groundwater discharge for our minimum flow analyses for two reasons: 1) Long-term negative values exist in reported daily and monthly averages, 2) discharge, when used as an input to the hydrodynamic model in a trial run, produced inferior model-verification results relative to those derived from model runs involving discharge estimates from the District-generated formula for estimating submarine groundwater discharge. The District was therefore able to make better predictions using the alternative estimates of submarine groundwater discharge described in the minimum flow report.

Looking at how the differences impact the MFL development, if the MFL results are used to estimate available water (i.e., 12% of say 374 cfs), then the result is conservative compared to using the USGS estimated flow. However, if the MFL result is viewed as a flow (i.e., 88% of 374 cfs), then it is not conservative.

Staff Response: The recommended minimum flow is expressed as percent-of-flow, not as a specific flow value, and is thus conservative, as indicated in the first scenario described above by the Panel.

As there is a level of uncertainty with both the USGS gaged flow and the SWFWMD empirically derived flow, the MFL must note the uncertainty in both, recognize that the impact evaluation is a relative one, i.e., based on percent reductions, and identify that future efforts must be focused on verifying what the total flow into the system is.

Staff Response: Staff will further clarify the uncertainty in reported discharge at the Bagley Cove gage and estimated submarine groundwater discharge derived using the District empirical formula.

Hydrodynamic Model Development, Calibration and Application

A 3-dimensional hydrodynamic model was applied to the Crystal River/King's Bay system to simulate time dependent water levels, currents, salinity and temperature throughout the system. The model utilized is called UnLESS3D. This is an unstructured Cartesian grid model. Within the MFL Report Appendices a report entitled "An Evaluation of Effects of Flow Reduction on Salinity and Thermal Habitats and Transport Time Scales in Crystal River/Kings Bay" was provided. The report included write ups on the UnLESS3D model equations, the physical characteristics of the Crystal River/Kings Bay system and the available field data, the hydrodynamic model calibration and verification, the model scenarios for the flow reduction, and simulations based upon the sea level rise.

The hydrodynamic model boundary inputs include; tides, temperature and salinity at two boundaries (Salt River at the bridge and at the mouth of Crystal River where it meets the Gulf of Mexico); groundwater discharge, temperature and salinity at multiple vent locations along the eastern and southern ends of Kings Bay; and atmospheric forcing at the water surface. The data for the tidal boundaries came from measured data at the two locations. The groundwater discharge came from empirically derived submarine groundwater discharge (SGD) (see previous discussion) and the temperatures and salinities associated with these inflows came from available measured data. As the modeled groundwater discharge includes inputs of water surface elevation at the mouth, this value is a dynamic parameter that is calculated for each model time step using the model equations. The atmospheric inputs came from measurements at a nearby meteorologic station.

The model was calibrated to data collected at two interior stations. The first station is at Bagley Cove. The Bagley Cove station is approximately two-thirds of the way up Crystal River between the mouth at the gulf and the entrance to Kings Bay. At the Bagley Cove station, continuous water level, salinity, discharge, and temperature data were available for the calibration. The salinity and temperature data at this station were from the bottom. The second station was located at the mouth of Kings Bay. This station had continuous water level, salinity and temperature data. The salinity and temperature data were at the bottom and surface. The total simulation period was a 34-month period (1037 days), from April 24, 2007 to February 23, 2010. The model was calibrated against real-time data of water level, salinity and temperature for a 150-day period during December 28, 2007 – May 26, 2008 after a spin-up run for 25 days. It was then verified for the remaining days before and after the 150-day calibration period.

Comparisons of the modeled and measured data are presented in the report along with statistics including the R^2 (correlation coefficient), the mean error, the mean absolute error, and the skill assessment. The following bullets discuss the evaluation of the calibration.

- Water Level: The graphical comparisons as well as the various statistical analyses are within acceptable ranges of error for the water level. Generally, the statistics show better than normal results.
- Salinity: The statistical analyses show that the calculated statistics of the errors are within acceptable ranges. The graphical plots show that the model generally captures the temporal and spatial changes in salinity in the system, indicating that the behavior of the salinity under varying tidal and flow conditions is reasonable.
- Temperature: The statistical analyses show that the calculated statistics of the errors are within acceptable ranges and generally better than usual. The graphical plots show that the model generally captures the temporal and spatial changes in temperature in the system, indicating that the behavior of the temperature under varying tidal and flow conditions is reasonable. One comment is that the model

results presented in the report should focus on the critical winter period so that the reader can see how the model performs graphically during this time.

Staff Response: Staff will include graphical presentation of these results in the revised minimum flow report.

- Cross-Sectional Flux: The comparisons of the simulated and measured cross-sectional flux shows that the model consistently under predicts the maximum flows passing at Bagley Cove. These maximums as seen in the data are generally short lived. Similar statistical analyses performed on the other data should be performed on the discharge data.

Examination of some of the results in the appendices identified that there are periods of time where the model boundary conditions were not available. During these periods the model was simply run through the two points (start and end of missing data) and used linear interpolation between as it ran. While most likely this is not causing significant issues with the model predictions outside of these periods and some period after, this is highly unusual and it is recommended that these periods be filled in as best as possible with reasonable forcing data, or these periods be taken out of the calibration/verification periods.

The hydrodynamic model was applied from October 6, 2006 through October 13, 2015 for the scenario analyses. This is a 9-year period where measured data were available for the forcing functions. The flow reductions were then applied through this period. One issue identified is that the boundary conditions at the mouth of Crystal River and at Salt River Bridge are not altered under the flow reductions. Examination of the salinity time series at these locations does show that they are influenced by the freshwater flow coming out of the system, i.e., they are close enough to shore to be impacted by the flows. A sensitivity analysis should be performed to determine the degree to which these boundaries are expected to increase in salinity overall as a result of the flow reductions. If the differences are significant, the model scenarios should be re-run with the increased downstream boundary salinities.

The hydrodynamic model has been applied to determine the change in volume, bottom area, and shoreline length associated with different salinity ranges, when modeled flows are reduced. The criteria applied is a 15% reduction in the volume, area, or shoreline length of any one of the modeled salinity ranges. While it would be preferable to link changes in flow directly to changes in ecology, the difficulty of measuring or expressing this causality is well established and the use of habitat as a more easily measured proxy is reasonable. However, it is desirable to delineate habitat when reasonable since not all habitat offers equal ecologic benefit. This is consistent with the district historical mapping of wetland communities and substrate mapping used in riverine systems in conjunction with HEC-RAS and PHABSIM models. The challenges of the estuarine systems are different and the District has documented the difficulty with identify some community-specific thresholds in its discussion of SAV. However, the District should consider if any habitats aggregated into the volume, area and length categories should be further parsed. One recommendation is to consider the difference between sloped and sediment and vegetated shoreline and hardened vertical shoreline (i.e., seawall). While this may not alter the recommended MFL on Crystal River, it is suggested that, in other applications, there might exist unique or critical habitats that decline over 15% if they are aggregated into the broader categories of volume length and area.

The following tables present detailed comments by chapter and appendices and supporting documentation.

Table 2-1. Review of Executive Summary

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s): A. Reviewer's Specific Comments	To be completed by Reviewer(s): B. Reviewer's Specific Recommended Corrective Action
1	SP	Paragraph 5	No – Because the data seem to not exist but could potentially be considered during re-evaluation.	The report states "These models allowed evaluation of salinity-based habitats, manatee thermal refuge, and residence time as potential indicators of significant harm. Each of these three factors are related to the 10 environmental values put forth in the State Water Resource Implementation Rule. Particular importance was placed on the effect of salinity on promoting submerged aquatic vegetation and reducing algal blooms to promote water clarity.". While the salinity intrusion and the thermal refuge were evaluated fully relative to the MFL development, the residence time and any potential impacts on the system water quality and algal blooms were not fully evaluated in relation to the MFL. This section should be reworded to reflect this.	At this time, based on discussions with District staff, it appears that data are not available to fully quantify the relationship between decreased residence time and specific water quality parameters impacted by residence time (i.e., Chl a). Based on this, the recommendation is that the District acknowledge in the MFL report that a full evaluation of the potential impacts on water quality are not feasible at this time and recommend that future work focus on attempting to quantify the impacts through additional data collection. Staff Response: Future drafts of the minimum flow report will acknowledge that water quality analysis for various parameters, including nutrient and chlorophyll a concentrations are not currently suitable for use in the development of criteria for setting the

Table 2-1. Review of Executive Summary

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					minimum flow, and will recommend that future work focus on data collection and analysis of water quality parameters. Water quality analyses performed for the recommended minimum flow were inconclusive with respect to relationships between chlorophyll a and flow. Similarly, there are no data analyses showing clear quantitative links between residence time and chlorophyll (algal blooms) in this system. However, the analysis in Table 3.5 shows that residence time will increase by 11% with a 12% decrease from baseline flow, which indicates that it is less sensitive than salinity. Previous analyses did not support direct linkage between discharge and chlorophyll a. However, there are known links between salinity and chlorophyll a in many lotic systems which support using salinity as a criterion for MFL development or assessment. Staff are continuing to

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				A. Reviewer's Specific Comments	**B. Reviewer's Specific Recommended Corrective Action**
					assess water quality linkages to flow into and within the system and expect to complete a more thorough assessment of potential flow-related water quality as part of the planned minimum flow reevaluation.
2	SP	Paragraph 6	No	The report states "In addition to model outputs, we also investigated water quality measurements related to the recent Total Maximum Daily Loads established by the Florida Department of Environmental Protection. Our analysis found no consistent relationship between spring flow and water quality measurements for nitrogen, phosphorus, or dissolved oxygen. As such, these water quality measures were not considered as criteria for setting the minimum flow for this system." Chl a and/or other nuisance macro-algal species were not assessed and these are key parameters that may be impacted by the residence time changes.	See resolution recommended for Comment 1. Staff Response: See our response for Comment 1.

Table 2-1. Review of Executive Summary

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
				This will be outlined in more detailed comments in the specific chapters.	
3	KW	Executive Summary Page v	No	The sufficiency of manatee thermal habit as expressed may be arguable.	Reconsider how thermal habitat is evaluated. Staff Response: As discussed in Sections 3.2 and 4.3 of the draft minimum flow report, thermally-favorable habitat sufficient for the known population of manatees would exist in the Crystal River/Kings Bay system at even the highest flow reduction scenario (i.e., a 30% flow reduction) that we modeled. Given this finding, we believe that it is accurate to indicate that habitat sufficient for meeting manatee thermal requirements during cold periods should be available if the minimum flow requirement that natural flow not be reduced by more than 12% is met.
4	KW	Executive Summary Page v	No	Define the baseline time period.	Explicitly define. Staff Response: The baseline period is from October 6, 2006 to October 13,

Table 2-1. Review of Executive Summary

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					2015. It is mentioned on Page 31 of the hydrodynamic model report (one of the appendixes). We add that in the referenced use of "baseline" in the executive summary of the draft minimum flow report is included to describe natural flow, i.e., flows expected in the absence of withdrawals, associated with the proposed minimum flow, that are associated with proposed minimum flow.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL					
				To be completed by Reviewer(s)	
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
5	SP	Page 13, first paragraph	No	In the first sentence after the parenthesis, need to bring line back up.	Correct in report. Staff Response: This formatting error will be corrected in future drafts of the report.
6	SP	Page 14, Section 1.4.3, first paragraph	No	The text states "Starting in August 2002, tide-corrected flows have been continuously recorded in the river by the USGS at the Crystal River at Bagley Cove near Crystal River, FL gage #02310747". A more accurate description of the measured flows would be that USGS utilized their Index Velocity Method to calculate flows and reference the USGS publication on index velocity. Additionally, it may be appropriate to further elaborate on the potential errors in the previous flow measurements (prior to 2002).	Reword. Staff Response: Section 1.4.3 will be revised in future draft reports to indicate the U.S. Geological Survey estimates discharge at the Bagley Cove site using an index velocity approach and a reference to the most recent USGS Water Data Report for the site will be included. Staff notes that the second paragraph of Section 1.4.3 addresses potential errors associated with historic discharge estimates made at the downstream "Near Crystal River" site, citing the Yobbi (2014) report which include additional information on the potential errors and is included as an appendix to the minimum flow report.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL

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				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action

7	SP	Page 15, Section 1.4.3, 3rd paragraph	No	The document states “Based on the information described here, we concluded that discharge estimates based on the historic flow record for the Crystal River near Crystal River gage (#02310750), and the currently reported flows at the Crystal River at Bagley Cove gage #02310747 include a mixture of groundwater, stormwater runoff, and marine water, and are not reliable estimates of groundwater discharge from the Crystal River spring group for use in minimum flow analyses.” This is an overstatement on the issues with the USGS data. There is uncertainty with both the USGS and SWFWMD data. There is also evidence showing at times where each appears to agree with other analyses. The report should not discount the USGS data outright, but should acknowledge the uncertainty in both, state why, at this time, the SWFWMD data were used, and identify the need for more comprehensive verification of the actual flow.	Reword. Staff Response: The referenced sentence from Section 1.4.3 of the minimum flows report will be revised to note that staff do not consider the discharge reported by the U.S. Geological Survey “unreliable.” We will instead note that when used as input to the hydrodynamic model, these data yielded poorer model-verification results relative to those from model runs involving discharge values derived with the District-generated formula for estimating submarine groundwater discharge (SGD). The section text will also be revised to note that the SGD estimates, which are described in Sections 2-1 and 2-2, were used in the modeling described in Section 2-3. Additional text will also be included to highlight the ongoing methodological advancements concerning discharge measurement at the Bagley Cove gage site (i.e., the installation of new equipment for measuring channel velocities) and the recent and ongoing installation of two new sites for measuring flows in the bay, at the Saragassa Canal and Hunters Cove.
8	SP	Page 19, Figure 1-13	No	Need to identify the time scale (averaging) of these data, i.e., is this a plot of the annual averages or some type of running average. Given the tidal	Reword graph figure, title, or identify in text.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL					
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
				signal identified in the later measurements, I assume these plots must be some form of averaged data.	Staff Response: The graphic caption will be reworded to indicate that these are monthly-averaged water levels.
9	SP	Page 25, Section 1.4.7.2, second to last paragraph	No	The text states "although 566 animals were observed in Kings Bay on a the extremely cold day of January 13, 2010 (Kleen 2014)." Grammatical fix.	Delete the "a." Staff Response: This has been fixed in the draft report.
10	SP	Page 32, Table 1-6	No	The table lists the water quality criteria for the system. While mentioned in the paragraphs above, the chl *a* criteria are not listed in the table. Also, the table needs to include the applicable criteria for Crystal River (1341I) including the Chl *a* criteria. Additionally, some of these criteria have time scales (i.e., annual mean, annual geometric mean) associated with them that need to be properly identified.	Include the appropriate time scales in the criteria table. Staff Response: The criteria table will be modified as suggested.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	**B. Reviewer's Specific Recommended Corrective Action**
11	SP	Page 35, Table 1-7	No	For the Recreation in and on the Water in the table, only protection of salinity habitats is identified. As manatee are a part of the recreational value of the system, manatee thermal refuge should be listed here also.	Reword. Staff Response: Table 1-7 in the report has been modified accordingly.
12	SP	Page 35, Table 1-7	No	Salinity habitats are identified for navigation. As this is a tidal system and water levels are dominated by tides rather than freshwater inflow, is this Use applicable to this system relative to freshwater withdrawal.	Potentially reword. Staff Response: Hydrilla beds were a hindrance to navigation in the past. Hydrilla are sensitive to salinity. This is explained in Section 1.7.10.
13	SP	Page 35, Section 1.7.1, first paragraph	No	As in the previous comment on Table 1-7, as manatee are part of recreation (as identified in the paragraph) the thermal analyses apply here.	Reword. Staff Response: District staff agree and will make appropriate changes to the report.
14	SP	Page 36, Section 1.7.4	No	After the second sentence, there appears to be text "*However, managing*." That should be deleted.	Delete text. Staff Response: This text has been deleted.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL					
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
15	SP	Page 36, Section 1.7.6	No	The text states "Residents and users of Kings Bay and Crystal River are concerned with water clarity and preventing / reducing algal blooms (Evans et al. 2007; SWFWMD 2015)." The text indicates that these issues are dealt with in the MFL through the salinity and thermal analyses. The analyses performed in this MFL do not directly address the issue of impacts of flow reduction on algal blooms. The model is used to evaluate the impacts of flow reduction on residence time, but no analyses are performed to relate flow and Chl *a*. Based upon conversations during the public meeting on this topic, it was identified that data at present are limited for this analysis, but efforts are underway to collect more. The text here may need to be modified to reflect this.	Reword, see suggestions in Comment 1. Staff Response (also see our response to Comment 1): Past analyses did not support direct link between discharge and chl a. However, there are known links between salinity and chlorophyll a in many systems which support using salinity as a criterion for MFL development or assessment. Further analyses addressing this issue will be completed as part of the planned minimum flow reevaluation.
16	SP	Page 37, Section 1.7.9	No	The previous comment on the evaluation of Chl *a* should also be addressed in this section.	Reword. See recommendations in Comment 1.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s) A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					Staff Response: See our response to Comment 1.
17	KW	Page 3, Section 1.3.2	No	Consider adding definitions for tidally filtered flow and spring/neap tides; throughout report change tide-corrected to tidally filtered.	Define terms. Staff Response: Definition for tidally filtered flow added. All instances of "tide-corrected" changed to "tidally filtered".
18	KW	Page 2, Section 1.3.1	No	Can harm to WRVs be measured or are we measuring criteria linked to harm – e.g., change in salinity?	Reword. Staff Response: Wording changed from "measure harm to environmental values" to "measure criteria linked to environmental values"
19	KW	Page 3, Section 1.3.2 and Page 66, Section 4.5	No	Consider adding an explanation of how an allowable flow reduction expressed as a percent flow reduction would be applied to the SGD "flow regime" per item #8 in Section 1.3.2 may be helpful.	Explain further. Staff Response: Explanation added to section 1.3.2.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL					
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					The definition of "flow regime" was modified to include an explanation of how a percent of flow reduction preserves the flow regime.
20	KW	Page 3, Section 1.3.2	No	Do historical flows occur in the absence of withdrawal impacts? Historical flows would seem to include impacts.	Reword. Staff Response: Staff notes that in addition to the definition of "long-term" referenced in Section 1.3.2, Rule 40D-8.021 also defines "historic" as a "long-term period when there are no measurable impacts due to withdrawals and Structural Alterations are similar to current conditions." This information will be included in the definition for "baseline" included in the revised report.
21	KW	Page 5, Section 1.4	No	Maps of land surface topography within CR/KB watershed/springshed and KB bathymetry may be useful.	Consider adding graphic. Staff Response: A map of bathymetry will be included with brief description.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL					
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Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
22	KW	Page 11, Section 1.4.1 Figure 1-5	No	Callout(s) for CR/KB may be helpful.	Add to figure. Staff Response: Comment noted by District Staff.
23	KW	Pages 12 13, Section 1.4.2	No	As a companion to Figures 1-6 and 1-7, a cumulative deviation plot might be helpful to show persistence. Annual rainfall volumes on Figure 1-6 would be useful. The Y-axis of Figure 1-7 is the departure from long-term average rainfall.	Consider adding graphic. Staff Response: Staff can add a cumulative departure graph to the report and will update the y-axis title on Figure 1-7.
24	KW	Page 14, Section 1.4.3	No	Are tide corrected flows recorded or calculated? Suggest changing tide corrected to tidally filtered.	Reword. Staff Response: Staff agrees that the term "tidally-filtered" is preferable to "tide-corrected" and will revise the report accordingly.
25	KW	Page 15, Section 1.4.3	Maybe	The two gages include runoff as part of flow measurement. The measured flows are stated to not be reliable estimates of groundwater discharge from the springs group. Is runoff otherwise included in the hydrodynamic model? How well do average tidally filtered flows (or unfiltered	Consider additional analysis now or in the future. Staff Response: Runoff contributes <1% of the total hydrologic loading to the system and was not included in the hydrodynamic model. It is,

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL

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				over longer time periods) at Bagley Cove correlate with rainfall, perhaps based on weekly, monthly, or annual averages? This may be another way of evaluating tidally filtered flow records.	however, possible that measured Bagley Cove flow is somewhat correlated with seasonal or annual average rainfall. Although these correlations are expected to be weak, we will examine these potential relationships.
26	KW	Page 15, Section 1.4.3	Maybe	Has the USGS weighed in on the assertion that current gaged tidally filtered flow (and unfiltered flow) is unreliable? It would be useful to see the index-velocity ratings for the Bagley Cove station and open-channel sites G1 and G2.	Provide ratings. Staff Response: As mentioned by Dr. Peene, the USGS recognizes that there are issues with their flow measurement at Bagley Cove. They plan to further improve their flow measurement at Bagley Cove, including replacing the current ADCP with a new one. The District does not have the referenced index-velocity ratings but can obtain them from the USGS.
27	KW	Page 21, Section 1.4.4.1	No	How were "observed" CR Spring Group flows determined? The definition of mean error (enclosed by parentheses) is missing a "divided by…" term.	Reword. Staff Response: The values were estimated from a water budget of the

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL					
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					springshed. This information is contained within the NDM version 4 calibration report by HydoGeologic, Inc.
28	KW	Page 23, Section 1.4.6	No	The top paragraph is a little confusing – Crystal River group versus Crystal River Spring Group discussion. It may be useful to add a column in Table 1-2 for the withdrawals located within the CR/KB springshed.	Reword. Staff Response: Staff will modify the report to clarify the presentation of flow changes predicted with the NDM 5 model. The model withdrawals are those over the entire 10,000 square mile domain of the NDM in Table 1-2.
29	KW	Page 24, Section 1.4.7	No	Is Crystal River an impounded estuary or just the Kings Bay portion?	Explain. Staff Response: The term "impounded estuary" has been removed in favor of a clearer description of the system.
30	KW	Page 29, Section 1.5.1.1	No	Do the references regarding SAV salinity tolerance differentiate between bottom salinity and water-column average salinity?	Explain.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL					
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				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					Staff Response: There are multiple references cited in this section. Some of which experimentally manipulated salinity in mesocosm experiments, some describe storm events, and others compared sites with varying salinity habitats. Our analysis included water column salinity and bottom salinity. District staff stand by the interpretation that salinity is an important driver of SAV distribution and abundance in Kings Bay.
31	KW	Page 34, Section 1.6.2	No	It may be useful to discuss the mean sea level trend NOAA has documented for one of the tide stations (e.g., Cedar Key) and impact on model and hindcasting.	Explain. Staff Response: Hindcasting was done with measured water level data that was historically affected by sea level. The mean sea level trend at Cedar Key is 1.97 millimeters/year with a 95% confidence interval of +/- 0.18 mm/yr based on monthly mean sea level data from 1914 to 2015 which is equivalent to a change of

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL					
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					0.65 feet in 100 years. Staff can add this information to this section and mention that hindcasted water levels in the bay based on historical water levels elsewhere will have been affected by past changes in sea level.
32	KW	Page 35, Section 1.7, Table 1.7, and Page 37, Section 1.7,	No	Clarify in the table that the factor evaluated for Sediment Load is the stability of bottom sediment. It is not clear (in table and text) how protection of native SAV is applicable to Navigation.	Clarify. Staff Response: Clarified in the table and text.
33	KW	Page 37, Section 1.7.8	No	Consider re-phrasing "positive impacts".	Reword. Staff Response: Rephrased.
34	AM	Page 4	No	The District does a good job providing some of the history and buttressing the 15% reduction criterion.	No action needed. Staff Response: District staff appreciate this feedback.
35	AM	Page 4	No	The District states "it is preferable when possible, to explicitly link reductions in flow to critical resources; this is the	Reword.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL					
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s) A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
				approach we used with our 15% resource reduction standard" Would it be more correct to say the District protects habitat than resource?	Staff Response: Ecologically, a "resource" is a broad term than may include habitat in addition to other substances such as food or nutrients. The 15% criterion could potentially be applied to any resource linked to flow.
36	AM	Page 24	Likely not	The District lists several habitats that are less mobile than others (i.e., Oysters Beds, Hydric Hammocks, and Mangroves). However, the report is not clear concerning the location of these habitats or that salinity changes that occur at their current location. If the goal is to protect these habitats in place, further discussion might be warranted.	Provide further discussion either explaining why it is not an issue or that while this is generally true, data for Crystal river do not exist to assess these habitat specifically. Staff Response: We plan to add analysis of vegetated shoreline to changes in shoreline salinity to address this problem. Shoreline vegetation is the only well-mapped data we could use to identify changes in habitat for sessile species.
37	AM	Page 24	No	Suggest referring to one plant by one name. *Vallisneria Americana* for	Word consistently.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL

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				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
				example is listed as both Eelgrass and native wild celery.	Staff Response: We will simply not use a common name in the revised report.
38	AM	Page 24	No	The last sentence on the page is confusing and I only bring it up because it is contrary to a verbal statement during the field trip that Lynbya is declining.	In light of our conversations, this is not likely to change the outcome of the current MFL recommendation, but it Is related to the recreational value and to residence time, which has the potential of connecting flow to water quality. If there is evidence that Lynbya is diminishing in the bay, it should be documented in the report. Staff Response: Lyngyba is sensitive to salinity, and recent pulses in salinity due to storm surge from Hurricane Hermine had caused a recent die back in Lyngbya within the bay. This recent die back was mentioned during the peer review panel site visit. However, Lyngbya and other filamentous algae

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s) A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					continue to be an ongoing issue in the bay.
39	AM	Page 28	No	Makes the case that it is important to manage shoreline habitat for emergent and shoreline species. This is true but the model contains significant hardened shore length (such as the sea walls in the finger canals near the three sisters), which possibly, because of their location within the bay, will not likely experience significant changes in what are likely to be low salinity conditions due to a reduction in flow. This may add to the shoreline length at low salinities and buffer the percent reduction calculated. It would be useful to run the model and isolate the cells that border naturally vegetated shoreline.	Dr. Chen has provided model output suggesting this issue not likely to change the MFL. However, where the District has the data to delineate markedly different habitats, it should consider disaggregation of the volume, area and length categories to provide more specific habitat protection. For example, as mentioned here, vertical hardened shoreline might be too different a habitat from vegetated shoreline to aggregate the two. Further, the District should review its available data and determine if further disaggregation is appropriate or feasible. Staff Response: The District is working on disaggregating shoreline length into different shoreline types.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s) A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					More data collection is needed to identify shoreline types along the finger channels associated with the bay.
40	AM	Page 32	No – Because the data seem to not exist but could potentially be considered during re-evaluation.	Question…. A significant water quality concern in the past at Crystal River was water clarity and thus in part chlorophyll. There is also a 4.4 microgram per liter target for chlorophyll-a in the river and 5.7 for Kings Bay. On Page 34 it is noted that Burghart and Peebles (2011) recommended that residence time be managed to limit phytoplankton blooms. Finally, the author's note that chlorophyll-a is potentially related to residence time and that substantial increases in residence time is potentially harmful. It is partially addressed in section 2.8 and table 2-6 and again in 3.4 and table 3-5 but perhaps a more full discussion of why it is not a factor in the MFL.	Buttress the current discussion. Staff Response (also see our response to Comment 1): Water quality analyses performed for draft minimum flow report were inconclusive with respect to chlorophyll a relationships to flow. However, staff are looking closely at water quality linkages to flow and expect to complete an enhanced water quality assessment as part of the planned minimum flow reevaluation.
41	AM	Page 32	No – Because the data seem	A recommendation for future work might be to understand how the increases in	See earlier recommendation, Comment 1.

Table 2-2. Review of Chapter 1 – Introduction: Purpose and Background of MFL

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
			to not exist but could potentially be considered during re-evaluation.	ERT potentially correlate with environmental values (specifically Chl-a).	Staff Response: See our response to Comment 40.
42	AM	Page 35, Table 1-7	No	Aesthetic and scenic – Would include protection of natural shoreline vegetation.	Reword. Staff Response: Staff will add this to the report.

Table 2-3. Review of Chapter 2 – Methods

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
43	SP	Section 2.2	Maybe	The equations that are utilized to define all the flows into the system have some basic error associated with them as well as certain levels of uncertainty. For example, in Figure 2-4 looking at plot (a), it is clear that for the period when measured flows were available, there are errors in the estimated flow that would indicate that the model under-predicts the overall net flow out. This error is then carried through an additional level of uncertainty as the equations and coefficients are extrapolated out to other vents in the system. Based on these known errors and uncertainty, it would be important to developed additional ways to verify the total flows. This could be done using the Bagley data, if this data is demonstrated to be useful for this. Still working on the evaluation of the Bagley data. The equations are utilized to hindcast flows so some additional verification (beyond the model predictions of salinity) of the modeled flows would be beneficial.	The report needs to be more definitive in outlining the uncertainty associated with the SGD calculations and the errors in the various steps and how those might impact the calculated flows. The Figure 2-4a differences are a good example. The graph clearly shows there are errors between the predicted and measured flows at this cross-section. Simple visual inspection indicates that this error would tend to make the calculations under-predict the long-term net flow out. This relationship is then potentially extrapolated to other vents and this error carries over. Also, some more definitive discussion of the degree of variation in the direct vent measurements and how they were used to carry the calculations forward is needed. Again, highlighting how the errors might impact the ultimate flow calculation.

Table 2-3. Review of Chapter 2 – Methods					
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					Staff Response: Just like any data collection and data fitting processes, there are errors associated with every step of these process we used to estimate SGD. Inevitably, there are some uncertainties in the SGD estimates used in the hydrodynamic model, which, combined with errors from other sources, eventually contribute to the uncertainties of the model results. A factor parameter is built in the hydrodynamic model that can be tuned to control the diffuse flux and allow the SGD uncertainties to be limited to a certain degree. Model calibrations using different values for this factor parameter suggested that the SGD uncertainty should be of the order of 20 cfs or less. As shown in the hydrodynamic model report (one of the appendixes), the final errors of simulated water levels, salinities, and temperatures are in ranges that are acceptable.

Table 2-3. Review of Chapter 2 – Methods

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	**B. Reviewer's Specific Recommended Corrective Action**
44	SP	Section 2.2	Maybe	The groundwater model predictions of flow from the springs group is on the order of 440 cfs under present conditions. The hindcast flows show averages more around 350 cfs. This further supports the need for verification of the total flow.	See previous recommendations on dealing with uncertainty in the flow measurements, i.e., Comment 43 Staff Response: The estimated SGD average was 355 cfs for the period 1/1/2002 through 10/13/2015. It was 332 cfs for the 9-year simulation period (10/6/2006 through 10/13/2015), and 374 cfs for the period between 11/5/1969 and 10/13/2015. Dr. Ken Watson calculated the average of USGS Bagley Cove flow to be 432 cfs and 354 cfs for the period of record (1/1/2002 through 11/15/2016) and for the 9-year model simulation period, respectively. Interestingly, the USGS Bagley Cove average was only about 7% greater than the estimated SGD average during the 9-year simulation period.

Table 2-3. Review of Chapter 2 – Methods

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	**B. Reviewer's Specific Recommended Corrective Action**
45	SP	Page 44, Section 2.3, Paragraph 2	No	The text identifies that the model statistics indicate that the model agrees well with measured data based on R2 values and other statistical analyses. I am in agreement with the statement that the statistics are reasonable given the type of data (continuous) being compared to for salinity and temperature.	No action required.
46	SP	Section 2.3, Paragraph 3	No	Based upon the materials in the appendix on the model, along with conversations with District Staff, there was around 10% of the flow that was utilized as a tuning parameter, i.e., to represent the unmeasured flows coming in through diffuse flow and flow from hairline fractures. Not sure if that was included in the flows presented in Table 2-1.	Clarify. Staff Response: Yes, the unmeasured flow quantity is included in Table 2-1. This portion of SGD contribution is 20 cfs or less, or about 6% of total SGD (please see our response to Comment 41). Correction: the 7.4% contribution on Page 24 of the hydrodynamic model report (one of the appendixes) is a mistake and should be changed to 6%.
47	SP	Section 2.3	Maybe	The salinity boundary conditions utilized for the scenario runs assume that there	Some results of sensitivity tests were provided by Dr. Chen showing that

Table 2-3. Review of Chapter 2 – Methods					
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
				will be no change in the salinity conditions at the locations of the boundaries from the reductions in flows. Need to test the validity of that assumption by doing some sensitivity tests on changes in that area based on flow reductions.	this issue would not have a significant impact on the MFL conclusions. Document the sensitivity tests in the report and/or the appendices. Staff Response: New model runs were conducted and it is estimated that the increase of salinity at the mouth of Crystal River is in the range of 0.05 psu (for a 2.5% flow reduction) to 0.77 psu (for a 30% flow reduction.) New scenario runs were conducted and results were analyzed. It was found that the minor increase of salinity at the downstream boundary due to reduced flow has only insignificant effects on the final results.
48	SP	Section 2.6	No	The section discusses analyses of water quality data through trend analyses as well as correlation of flow with water quality data. The methods identify that flows weren't available unless a hindcasting were done. As this was done ultimately for the MFL report, I	Clarify and address the issue of the availability of Chl a data for analyses. Staff Response: The district has chlorophyll a data and is conducting an ongoing analysis of this data with respect to flow. At the time of peer-

Table 2-3. Review of Chapter 2 – Methods

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s): A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
				assume the water quality analyses were done before the hindcasting so they were not available. Additionally, the methods do not discuss analyses of Chl a data which are assumed to be part of the long-term monitoring. If these data were not available, the text should state that.	review draft development, there were no conclusive results of this analysis. Staff recommend further data collection and analysis for trends between Chl a and other water quality and quantity variables.
49	SP	Section 2.8	No	The method used for the residence time calculations were based on dye releases at specific times and tide conditions. The number of periods appear sufficient to characterize the residence times using dye. Another potential method would be to examine water age. This would allow the use of the complete simulation to examine the change in the overall water age in the same way salinity or temperature were evaluated, i.e., over the full simulation cycle.	Consider using the water age method, but if not feasible, the existing method is sufficient. In a re-evaluation, where more data are available for evaluation of the impacts of residence time on Chl a, consider using water age. Staff Response: The District will consider this recommendation as part of the planned minimum flow reevaluation.
50	KW	Page 40, Section 2.2	No	Reference to the third term (i.e., partial derivative) in Equation 1 relating to pressure is contrary to Equation 1 caption note and Chen (2014) report that	Clarify. Staff Response: The caption for Equation 1 will be revised. We note, that in the caption, long-term is roughly the time scale within which the

Table 2-3. Review of Chapter 2 – Methods					
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	**B. Reviewer's Specific Recommended Corrective Action**
				describe the term as relating to tidal flux. Define "long term".	2009 flow measurement was conducted.
51	KW	Page 41, Section 2.2	No	Would N be needed if the groundwater elevation at the "G" well were not influenced by tide? I.e., a true background well. Or is the term needed because of the short time frames being analyzed with the model?	Clarify. Staff Response: It is not clear what N the reviewer was referring to.
52	KW	Page 41, Section 2.2	No	Clarify that the flows from two subsets of springs, G1 with 3 springs and G2 with 8 springs, were evaluated to determine C1 and C2 for each group. Clarify that Figure 2-4 represents the flows from just 11 of the 70 springs and that Figure 2-5 represents the combined flow from all 70 springs.	Clarify. Staff Response: Yes, Fig. 2-4 represents 11 of 70 springs.
53	KW	Page 43, Section 2.2, Figure 2-5	No	The daily average line in the graph is missing,	Modify. Staff Response: This line is plotted with red color but is overlaid by other lines for most of the depicted time. The figure caption will be modified to note this plotting artifact.
54	KW	Page 43, Section 2.3	No	Is the vertical coordinate system a fixed z-grid or sigma grid? it is useful to know	Clarify.

Table 2-3. Review of Chapter 2 – Methods

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	**B. Reviewer's Specific Recommended Corrective Action**
				when interpreting water-quality and AVF point velocity data collected using a fixed-position monitoring device.	Staff Response: It is a z-coordinate model.
55	KW	Page 44, Section 2.3	No	Is the diffuse flow about 10% or so? Runoff? Direct rainfall?	Clarify. Staff Response: Diffuse flow should be less than about 6%. Runoff and direct rainfall should not be greater than 1% of the total hydrologic loading to the estuary.
56	KW	Page 44, Section 2.3	No	It may be useful to mention spin up period for establishing a numerically balanced initial condition?	Clarify. Staff Response: For the 9-year simulation, the spin-up period is 26 days, from 10/6/2016 to 10/31/2016. It is mentioned on Page 33 of the hydrodynamic model report.
57	KW	Page 46, Section 2.3, Table 2.2	No	Is rainfall included as a meteorological input?	Clarify. Staff Response: No, it is not included as a meteorological input.
58	KW	Page 47, Section 2.4	No	A volume exceedance curve may be helpful.	Consider adding. Staff Response: Staff will consider adding a volume exceedance curve as

Table 2-3. Review of Chapter 2 – Methods					
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					part of the planned minimum flow reevaluation.
59	KW	Page 47, Section 2.5	No	For what time period were instantaneous measurements of water temperature evaluated?	Clarify. Staff Response: Predicted, not measure instantaneous water temperatures were used to identify time periods during the model simulation period (October 6, 2006 through October 13, s005) with the smallest water volume and area available as refuge from chronic thermal stress.
60	KW	Page 47, Section 2.4	No	"averaged across time" how much time? Daily, POR?	Clarify. Staff Response: Averaged over the entire 9-year simulation period, excluding the first 26 days (spin-up period).
61	KW	Page 47, Section 2.4	No	How was shoreline length calculated?	Clarify. Staff Response: Shoreline was calculated based on bottom elevations at the four corners of a model grid and

Table 2-3. Review of Chapter 2 – Methods

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	**B. Reviewer's Specific Recommended Corrective Action**
					the simulated water surface elevation. This is more thoroughly explained in Figure 2 on page 10 of the hydrodynamic model report (Chen 2016)
62	KW	Page 48, Section 2.6, second paragraph	No	It is not clear how many water quality samples are associated with concurrent measurements of both groundwater level and sea level versus the number of samples associated with measured values for GW level or sea level.	Clarify. Staff Response: Eighty-four percent of the matching discharge values were calculated values and sixteen percent were interpolated.
63	KW	Page 50, Section 2.7	No	It may be useful to compare the ACOE tide projections with the mean sea level change which has occurred over the past 9 and/or 46 years at the Cedar Key tide station.	Consider adding. Staff Response: The "low" projection by the USACOE is a linear continuation of the long term historical trend, which for Cedar Key is 1.97 mm/yr. The ACOE methods cited in the minimum flow report provide more detail about the sea level rise projections used for our analyses.

Table 2-3. Review of Chapter 2 – Methods

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
64	KW	Page 51, Section 2.8, Table 2.6	No	Explain the tide terminology (i.e., spring, neap, average) and whether neap and spring are winter-time lows or summer-time highs; explain the spring discharge percentiles (i.e., exceedance or non-exceedance).	Clarify. Staff Response: Spring tides are tides during new or full moon, while neap tides refer tides when the sun and moon are at right angles to each other. Average tides are those between spring and neap tides. The spring discharge percentiles presented in Table 2-6 are percent non-exceedance values. We will consider including footnotes to Table 2-6 to enhance understanding of the tabular information.
65	AM	General	No	No current concerns except the note about residence time above (Comment 39).	No action required.

Table 2-4. Review of Chapter 3 – Results

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s): A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
66	SP	Section 3.4, Table 3-5	Maybe	Table 3-5 shows that there are some relatively significant changes in residence time associated with the flow reductions. As such, the impact of these residence times on water quality (specifically algal blooms) could be important. This needs to be identified in the report and if data are insufficient to do this type of analyses, that needs to be stated.	See recommendations in previous comments. Staff Response: There is no data analysis showing a clear quantitative link between residence time and chlorophyll (algal blooms) in this system. However, the analysis in Table 3.5 shows that residence time will increase by 11% with a 12% decrease from baseline flow, which makes it less sensitive than salinity.
67	SP	Section 3.5	No	The analyses of the data do show that Chl a values are above the criteria a significant portion of the time. One issue is that the analyses should examine the Chl a against the time scale of the criteria, i.e., annual average time frame. If the data still show the system in violation, then the residence time becomes even more important.	If the criteria are going to be used in analyses, and presented in the report, they need to be used properly, accounting for the value and how the data should be compared to the value, i.e., time averaging, etc. Staff Response: The water quality analysis presented in the report is representative of an ongoing

Table 2-4. Review of Chapter 3 – Results

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s) A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					investigation of water quality data in the system. Staff will present an updated analysis as part of the planned minimum flow reevaluation, and will consider presenting annual average chlorophyll a concentrations along with relevant water quality standards.
68	SP	Section 3.5	Maybe	Analyses of correlations of nutrients and flow were presented, but no analyses of flow versus Chl a were presented.	See previous recommendations in dealing with evaluation of Chl a data. Staff Response: Analysis of Chlorophyll a vs. daily discharge did not reveal any significant trends that were consistent across the system. This analysis will be included as an appendix to the revised minimum flow report.
69	KW	Page 52, Section 3.1	No	Is the volume calculation across all layers? Or bottom layers for SAV for example or bottom area for benthic. Or does it matter? Well mixed?	Clarify. Staff Response: Yes, the volume calculation is across all model layers.

Table 2-4. Review of Chapter 3 – Results					
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s) A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					The bottom area calculation used bottom-layer salinity. The model does not assume salinity to be well-mixed.
70	KW	Page 52, Section 3.1	No	Is bottom area in Table 3-1 associated with salinity in the bottom layer of the model?	Clarify. Staff Response: Yes.
71	KW	Page 52, Section 3.1	No	Confirm that the < 2 ppt includes the freshwater portions <0.5 ppt.	Confirm. Staff Response: Yes, it includes < 0.5 psu.
72	KW	Page 52, Section 3.1, Table 3.1	No	The values listed for <2 ppt appear to be inconsistent with values for preceding and succeeding salinities, although I can see how it is possible.	Confirm. Staff Response: The effect of flow reduction on salinity habitats is not necessarily monotonic. Table 3-1 shows that salinity habitats in the range of 1 – 2 psu are most sensitive to the flow reduction. We do not think there are any consistency issues associated with the information presented in the table.

Table 2-4. Review of Chapter 3 – Results

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
73	KW	Page 52, Section 3.1	No	Is average volume most appropriate? What about the change in the occurrences of high salinity, short term events - like the acute thermal refuge analysis?	Consider addressing. Staff Response: Staff considers use of central-tendency salinities (e.g., mean values) the most appropriate approach for identifying minimum flows.
74	KW	Page 53, Section 3.2 and elsewhere	No	The statements regarding the sufficiency of manatee thermal refuge for much larger populations may be overreaching; same for the two right-most columns that list manatee capacity in Table 3-3 on Page 54. As a reality check, do we think there would be no impact to manatee use of system if flows were reduced to levels such that the thermal refuge volume just exceeded the manatee space requirements? What about habitat volume reduced to twice the volume estimated to be needed? I agree that it would be difficult to make this metric a driver given the overall volume of suitable habitat. It seems that the assumption of a 15 % reduction in habitat causing significant	Consider rewording. Staff Response: We understand the recommended approach for documenting that change in manatee thermal refuge habitat is not a limiting factor for the existing manatee population and should therefore not be considered for minimum flow development. However, we think it is worthwhile to assess potential flow-related changes in thermal refuge as part of the minimum flow development process. We also note that the methods used for assessing manatee habitat needs in the Crystal River/Kings Bay System are consistent with other springs MFLs that have been established, peer reviewed and considered by state and

Table 2-4. Review of Chapter 3 – Results					
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
				harm is not appropriate in the case of manatee thermal refuge. Perhaps calculate the amount (as a percent) of habitat reduction needed to impact the known manatee population, and then state that manatee habitat is therefore not a limiting metric.	federal agency staff associated with manatee management.
75	KW	Page 53, Section 3.2, Figure 3.2, caption	No	The maps illustrate the spatial distribution of warm water, not volumes.	Reword. Staff Response: We note that these maps are three dimensional, with x, y, and z axes, and thus show volume, and are therefore labeled correctly. We do acknowledge, however, that a lack of scales presented for the axes limits the represented volumes to dimensionless values.
76	KW	Page 55, Section 3.3	No	Should the flow reduction be 12% not 9%; clarify that "habitat" is represented by volume of salinity <2 ppt as opposed to bottom area salinity <2 ppt.	Clarify. Staff Response: Text referring to a 9% reduction in flow refers to information that was included in a previous version of Table 3-4 but not included in the version of the table in the draft

Table 2-4. Review of Chapter 3 – Results					
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					report. This error will be corrected in the revised minimum flow report, and text in Section 3.3 will be revised to indicate the modeled habitat changes discussed are based on water column volumes.
77	KW	Page 55, Section 3.3	No	The model input data for the 9-year simulation period reflect a sea level rise of about 0.06 feet, hence the baseline period includes some habitat loss attributable to sea level rise. This is not substantial but it may be useful to mention/discuss the sea level rise that occurred during the model and historic period.	Consider new language. Staff Response: Sea level rise is ongoing. Impacts to baseline flows are assessed as a percent-of-flow using a regional groundwater model. It is true that model input includes water level in Kings Bay which has increased due to sea level rise. These sea level rises would have impacted baseline flows as well, so the percent-of-flow method we used for assessing flow-related changes in salinity habitat accounts for this.
78	KW	Page 55, Section 3.4	No	Would looking at percentile flows be appropriate for salinity as well?	Consider adding.

Table 2-4. Review of Chapter 3 – Results

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					Staff Response: We could have assessed flow-related salinity habitat changes based on flow percentiles. However, we believe comparison of mean responses provides a reasonable approach for identifying the appropriate minimum flow.
79	KW	Page 56, Section 3.4, Table 3-5	No	Define the SGD percentiles as exceedances or non-exceedances.	Define. Staff Response: It is defined as non-exceedance. We will consider including footnotes to Table 2-6 to enhance understanding of the tabular information and also addressing this issue with revisions to the text included in Section 3.4
80	KW	Page 58, Section 3.5.2	No	Define "spring flow" and how it was determined (i.e., measured or calculated).	Define. Staff Response: In this section, spring flow used in the discussion is the daily average of the entire SGD entering Kings Bay. We will insert a parenthetic

Table 2-4. Review of Chapter 3 – Results

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
					definition for springflow in the topic sentence of the paragraph preceding Table 3-8.
81	KW	Page 58, Section 3.5.2	No	Rephrase "over the time period" to "over the course of 91 dates…" similar to Figure 3-4 caption.	Reword. Staff Response: This will be rephrased for consistency.
82	AM	Page 52, Table 3-1	No	Table 3-1 is the linkage between the model and the ecology. As mentioned in the meeting, the District should consider including absolute volume, area, and length, and not just percent. How much habitat is being preserved and how much is being lost?	Dr. Chen has already provided the Panel these numbers. Recommend including them in the report. Staff Response: These values will be added to the revised minimum flow report.
83	AM	General	No	It would be interesting to understand the uncertainty in the model as it applies to length, area, and volume, though this information is not necessary for the purposes of using the model to recommend an MFL.	None – Just a note.

Table 2-4. Review of Chapter 3 – Results

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s): A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
84	AM	General	No	The discussion of Manatee habitat is thorough enough to make compelling argument that Manatee habitat will not be limiting even if other habitat assumptions were used.	The manatee discussion is sometimes distracting from the factors that directly limit the MFL. However, manatees are also an important factor to many CR/KB stakeholders. Recommend considering if the manatee information should be compiled as a single appendix or left in the if report. Staff Response: Many stakeholders are concerned about the manatee population of the southeastern United States. Manatee habitat is one of the primary factors we assess in setting minimum flows for spring systems that are accessible from coastal waters . Therefore, we find it appropriate to include discussion of potential flow-related changes in manatee habitat in the MFL report.

Table 2-5. Review of Chapter 4 – Discussion: Using Results to Set Minimum Flow					
Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
85	SP	Section 4.1, Paragraph 1, third sentence	No	There is an extra "the" in the sentence.	Delete text. Staff Response: This typographic error will be corrected in future drafts.
86	SP	Section 4.1	No	The estimated long-term flow for the 46-year period based on the hindcast flow projection from the modeled equations is 374 cfs. Based on the Bagley Cove site the median flow from 2002 to 2015 is 437 cfs. The output from the groundwater flow model for the present conditions is around 440 cfs. The text states "The cross-sectional flux through Bagley Cove is a combination of tidal fluxes, spring flows entering Kings Bay during the preceding 6 – 20 days, stormwater runoff, wind action, and nonlinear interactions among factors affecting circulation and transport processes in the estuary. Furthermore, these previous estimates of discharge do not match the water budget for the springshed, which is able to account for	Reword. Staff Response (also see our response to Comments 6, 26, 43 and 44): We will modify the discussion in the report to indicate that estimated submarine groundwater discharge is within 6 percent of the long-term average of the Bagley Cove flow measured by the USGS from 2006-2015.

Table 2-5. Review of Chapter 4 – Discussion: Using Results to Set Minimum Flow

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
				455 cfs of spring flow from the Crystal River Springs group given 20 inches of recharge per year." While this statement is true for the previously uncorrected Bagley Cove data, it is not accurate relative to the corrected data, which in the text above it is stated that the median flow is 437 cfs, which does agree with the recharge rates. It is important to note that the methodology utilized to develop the modeled flow equations (index velocity measurements at G1 and G2) was the same as that utilized to measure the flows at the Bagley Station. The uncertainty in both measurements needs to be outlined in the report and the USGS gage flow not fully dismissed.	
87	SP	Section 4.4	No	Reiterate the comment that the analyses do not address the potential for changes in water quality (specifically Chl a) due to changes in residence time. If data are insufficient for this analysis at this time, which was identified through conversations with District personnel,	See previous recommendations on dealing with impact of residence time on Chl a. Staff Response: As stated in several of our responses above, there is no data or analysis linking residence time to Chl a concentration in the Crystal

Table 2-5. Review of Chapter 4 – Discussion: Using Results to Set Minimum Flow

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s) A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
				then this should be stated within the report and identified for future evaluation.	River/Kings Bay System. This will be noted in the revised minimum flow report and identified for future evaluation.
88	KW	Page 62, Section 4.2	No	Resolve the possible inconsistency in Table 3-1 noted previously and revise text if necessary.	Check. Staff Response: As note in our response to Comment 72 above, we do not think there is any inconsistency in Table 3-1.
89	KW	Page 64, Section 4.3	No	It may be helpful to list the allowable flow reductions determined for the Homosassa (3%) and Weeki Wachee (10%).	Add reference. Staff Response: The MFLs for Homosassa and Weeki Wachee will be added to the first chapter of the report.
90	KW	Page 65, Section 4.4.2, paragraph beginning with "None of the vents…."	No	Clarify what "effect of date was removed" means.	Clarify. Staff Response: This is in reference to the residual analysis detailed in Figures 3-4 and 3-5. These figures will be cited in the noted sentence.

Table 2-5. Review of Chapter 4 – Discussion: Using Results to Set Minimum Flow

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s)	
				A. Reviewer's Specific Comments	B. Reviewer's Specific Recommended Corrective Action
91	KW	Page 66, Section 4.5	No	The thermal refuge "is" (not "seems to be") more conservative regardless of the hypothetical manatee populations that might be supported.	Clarify. Staff Response: Habitat suitable for use as thermal refuge is more sensitive to flow-related change than the 2 ppt salinity-based habitat discusses in Section 4.5. However, the actual volume of useable thermal refuge required by the number of manatee visiting Kings Bay will be unimpacted by flow reductions of up to 40%. Staff will revise the report to further clarify this issue.
92	KW	Page 69, Section 5.7	No	Clarify that groundwater pumping impacts are from regional pumping.	Clarify. Staff Response: Table 1-2 has been modified to provide clarity to this issue.

Table 2-5. Review of Appendices and External Reports

Comment No.	Peer Reviewer	Figure, Table, or Page and Paragraph Number	Does Comment Directly and Materially Affect Conclusions of Report? (Yes/No)	To be completed by Reviewer(s): A. Reviewer's Specific Comments	To be completed by Reviewer(s): B. Reviewer's Specific Recommended Corrective Action
93	KW	VHB (2010)	No	Report Appendixes A and B are missing. It would be useful to see the index-velocity ratings developed for open-channel locations G1 and G2.	Consider adding the ratings. Staff Response: Appendixes A and B to the VHB, Inc. report were delivered as MS Excel files, which can be provided upon request. The index-velocity ratings developed for G1 and G2 were not required as a delivery in the contract, but VHB, Inc. followed the same USGS procedure in developing these index-velocity ratings.
94	KW	Chen (2014) Pages 12 – 14 and Figures 4 and 5	No	Confirm if the graphics illustrate the total open-channel flow measured at locations G1 and G2 (i.e., spring flow plus the tidal flux component).	Confirm. Staff Response: The referenced figures depict net spring flow (measured flows minus tidal fluxes).

3.0 SUMMARY OF FINDINGS AND MFL REVIEW GUIDELINES RESPONSE

A component of the Peer Review Panel scope of work was to provide an assessment of the MFL report and supporting documentation against specific listed criteria. The following items outline those specific criteria.

1. Determine whether the conclusions in the Crystal River/Kings Bay springs system MFLs report are supported by the analyses presented.
2. Supporting Data and Information: Review the relevant data, and information that support the conclusions made in the report to determine whether:
   a. The data and information used were properly collected;
   b. Reasonable quality assurance assessments were performed on the data and information;
   c. Exclusion of available data from analyses was justified; and
   d. The data used were the best information available.
3. Technical Assumptions: Review the technical assumptions inherent to the analysis used in the Crystal River/Kings Bay springs system MFLs report to determine whether:
   a. The assumptions are clearly stated, reasonable and consistent with the best information available;
   b. The assumptions were eliminated to the extent possible, based on available information; and
   c. Other analyses that would require fewer assumptions but provide comparable or better results are available.
4. Procedures and Analyses: Review the procedures and analyses used in the Crystal River/Kings Bay system MFLs report to determine whether:
   a. The procedures and analyses were appropriate and reasonable, based on the best information available;
   b. The procedures and analyses incorporate all necessary factors;
   c. The procedures and analyses were correctly applied;
   d. The procedures and analyses are repeatable; and
   e. Conclusions based on the procedures and analyses are supported by the data.

5. If a proposed method used in the Crystal River/Kings Bay Springs system MFLs report is not scientifically reasonable, the CONSULTANT shall:
    a. List and describe scientific deficiencies and, if possible, evaluate the error associated with the deficiencies;
    b. Determine if the identified deficiencies can be remedied.
    c. If the identified deficiencies can be remedied, then describe the necessary remedies and an estimate of time and effort required to develop and implement each remedy.
    d. If the identified deficiencies cannot be remedied, then, if possible, identify one or more alternative methods that are scientifically reasonable. If an alternative method is identified, provide a qualitative assessment of the relative strengths and weaknesses of the alternative method(s) and the effort required to collect data necessary for implementation of the alternative methods.
6. If a given method or analyses used in the Crystal River/Kings Bay Springs system MFLs report is scientifically reasonable, but an alternative method is preferable, the CONSULTANT shall:
    a. List and describe the alternative scientifically reasonable method(s), and include a qualitative assessment of the effort required to collect data necessary for implementation of the alternative method(s).

Table 3-1 presents the detailed assessments by each of the Peer Review Panelists for each of the criteria. The findings of the Peer Review Panel are that, with the implementation of some of the edits/recommendations made within this report, there are no fatal flaws within the MFL report and supporting documentation relative to the specified criteria.

Table 3-1. Responses to SWFWMD's Peer Review Assessment Requirements			
Task	**Subtask**	**Sub-Subtask**	**Reviewer's Specific Comments** **SP = Steven Peene, KW = Ken Watson, AB = Adam Munson**
Determine whether the conclusions in the Crystal River/Kings Bay Springs system MFLs report are supported by the analyses presented.			KW: The report documents a comprehensive and complex analysis that was concise and well done. Although conclusions are supported by analyses, an explanation of how an allowable flow reduction expressed as a percent flow reduction would be applied to the SGD "flow regime" per item #8 in Section 1.3.2 is not provided and may be helpful. Staff Response: See our response to Comment 19 in Table 2-2. AM: Overall the report is reasonable and the analysis presented is consistent with other MFL efforts within the District. At times the repost is inclusive of information which is ancillary to the MFL determination and that information could be shifted to the appendix and play a less prominent role in the report. Staff Response: During Panel meetings, the possibility of moving some water quality analyses to appendices was discussed. However, this conflicts with Panel advice to discuss chlorophyll a and residence time more thoroughly within the report. SP: Overall the MFL conclusions are supported by the analyses presented. One area in the report that need to be clarified is the present uncertainty in both available flow measurements (USGS and SWFWMD) and this needs to be reworded in the report along with recommendations for verification in future work. Another area is to recognize the potential impacts to water quality (specifically Chl a and residence time) and that at present the data are not available to quantify. Staff Response: See our responses to Comments 7 and 43 regarding discharge uncertainty and Comment 1 regarding residence time and chlorophyll.

Table 3-1. Responses to SWFWMD's Peer Review Assessment Requirements			
Task	**Subtask**	**Sub-Subtask**	**Reviewer's Specific Comments** **SP = Steven Peene, KW = Ken Watson, AB = Adam Munson**
	2. Supporting Data and Information: Review the relevant data, and information that support the conclusions made in the report to determine whether:	a. The data and information used were properly collected;	KW: Much of the data used were collected by entities with established field SOPs and are presumed to have been properly collected. AM: A majority of the data have been collected by agencies other than SWFWMD or in the pursuit of other studies. However, all data seems to be collected by entities with trained samplers and SOPs and while, likely not error free, are likely to represent the best available data. SP: The data collected by the SWFWMD for this project appears to have been collected properly. Also the data from outside groups appears to have been collected properly based on existing protocols. Issues with the data are primarily related to limitations in collection methodology and processing.
		b. Reasonable quality assurance assessments were performed on the data and information;	KW: It may be helpful to prepare double-mass curves to characterize associations between rainfall, SGD, and river discharge reported by the USGS. Staff Response: Please see our response to Comment 25 within Table 2-2. SP: Saw no issues with the quality assurance on the data collected. More explanation (especially on the direct flow and vent measurements) of the uncertainty associated with the data should be provided.

Table 3-1. Responses to SWFWMD's Peer Review Assessment Requirements			
Task	**Subtask**	**Sub-Subtask**	**Reviewer's Specific Comments** **SP = Steven Peene, KW = Ken Watson, AB = Adam Munson**
		c. Exclusion of available data from analyses was justified; and	KW: The data for the reported discharge for the Crystal River gage (#02310750) and for the USGS gage at Bagley Cove (#02310747) were determined to be unreliable estimates of groundwater discharge. Both gages record a mixture of groundwater, storm water runoff, and marine water. Tidal filtering is used in an attempt to exclude the marine water flux and, to the extent runoff is important, a means of accounting for runoff is needed. We take no exception to excluding the gage #2310705 data. However, we think the gage #02310747 data may be useable to help verify the groundwater discharge with either appropriate tide filtering or as an estimate of long term total freshwater discharge (i.e., groundwater discharge and surface water runoff). Staff Response: Tidally-filtered discharge reported at USGS gage #02310747 shows negative daily and monthly average values, which the District takes as sufficient evidence to exclude these data as estimates of freshwater discharge. Further, hydrodynamic modeling using this gage data was done, and showed inferior results see Chen (2014) as cited in MFL report. Note the USGS gage #02310750 (Crystal River near Crystal River with a period of record from 3/1/1964 to 9/30/1977) is incorrectly identified as #02310705 in the comment above. SP: There is clearly uncertainty in both sets of the data for the SGD (USGS and SWFWMD). Complete exclusion or dismissal of this data does not seem warranted. This would not alter how the analyses were performed, as it is recognized that the SWFWMD data works better in the analyses, but the report should identify the potential uncertainty in both and not just completely dismiss the USGS data. Staff Response: See responses pertaining to USGS data in Comments 6, 7, 26, and 86.

Table 3-1. Responses to SWFWMD's Peer Review Assessment Requirements			
Task	**Subtask**	**Sub-Subtask**	**Reviewer's Specific Comments** **SP = Steven Peene, KW = Ken Watson, AB = Adam Munson**
		d. The data used were the best information available.	KW: In Section 1.4.4 it would be helpful to mention whether groundwater level data are available for locations in the springshed that are more distant from the CR/KB system and tidal influences. Bagley Cove gage data may be usable in some form. Staff Response: Groundwater level data are shown for Lecanto 7, Romp 21-2 and Romp 21-3, see Figures 1-12 and 1-13. Use of Bagley Cove data has been discussed in several of our responses above and will be further explained in revised MFL report. AM: Vegetation: The District provides some significant information from historic SAV studies. Because of the importance of SAV it is appropriate to include it in the report since this is presumably some of the habitat protected by the change in area and volume analysis. While SAV information is documented, the historic concern of filamentous algae could be more thoroughly addressed in the report or the appendix. Especially, if it is less of a concern than in the past as indicated during a field trip. Staff Response: See response to Comment 38. SP: The data used in the hydrodynamic modeling, and the calculation of the flows was the best available with the caveat of the comments on the USGS in earlier sub-tasks.

Table 3-1. Responses to SWFWMD's Peer Review Assessment Requirements			
Task	**Subtask**	**Sub-Subtask**	**Reviewer's Specific Comments** **SP = Steven Peene, KW = Ken Watson, AB = Adam Munson**
	3. Technical Assumptions: Review the technical assumptions inherent to the analysis used in the Crystal River/Kings Bay springs system MFLs report to determine whether:	a. The assumptions are clearly stated, reasonable and consistent with the best information available;	KW: The definition of baseline and historical flows occurring" in the absence of withdrawal impacts" (i.e., Section 1.3.2) should be qualified. The baseline period of time should be clearly stated in the text. Staff Response: The flow definitions given in Section 1.3.2 are general definitions applying to all systems. This section is not meant to serve as a detailed description of methods. Groundwater impacts relative to baseline are shown in Table 1-2, where the baseline flow is reported for the year 2010 and 2014. Similarly, the baseline period used for assessment of flow-related changes in salinity and thermal-based habitats using the hydrodynamic model is discussed in Section 2.3 of the report. We plan to revise this discussion to more clearly identify the baseline period for the hydrodynamic modeling efforts and also note the baseline period in relevant sections of the results presented in Chapter 3. AM: The largest assumption is the 15% loss of habitat criteria as a harm threshold. This criterion has been discussed for well over a decade and it has continuously been determined to be reasonable and consistent with other environmental flow standards. SP: The assumptions are generally clearly stated and other than the complete exclusion of the USGS data are consistent with the best available information. The sensitivity associated with the offshore boundary for the hydrodynamic scenarios needs to be addressed to complete the analyses. Staff Response: As noted in our response to Comments 6, 7 and 47 above, USGS data for the Bagley Cove gage site and hydrodynamic boundary conditions will be discussed in more detail in future drafts.

Table 3-1. Responses to SWFWMD's Peer Review Assessment Requirements			
Task	**Subtask**	**Sub-Subtask**	**Reviewer's Specific Comments** **SP = Steven Peene, KW = Ken Watson, AB = Adam Munson**
		b. The assumptions were eliminated to the extent possible, based on available information; and	KW: The assumption that 15% habitat reduction causing significant harm could be explicitly eliminated for manatee thermal refuge. Staff Response: Please see our responses above to Comments 3, 74, 84, and 91 regarding manatee thermal refuge. SP: No unjustified assumption eliminations were identified
		c. Other analyses that would require fewer assumptions but provide comparable or better results are available.	SP: No alternate analyses that would require fewer assumptions were identified through this review.
	4. Procedures and Analyses: Review the procedures and analyses used in the Crystal River/Kings Bay system MFLs report to determine whether:	a. The procedures and analyses were appropriate and reasonable, based on the best information available;	KW: The thermal analysis for manatee could be simplified and presented differently. Based on the space requirements of manatee, the known manatee population, and the available thermal refuge, the default 15% allowable reduction in habitat does not appear to be appropriate – i.e., a much greater reduction in habitat would be needed to cause significant harm and therefore a much greater reduction in flow would be allowable. This a relevant concept because it points out that scenario specific information should be used when available and that default values (i.e., 15 % reduction in habitat) should only be used in the absence of better information. In my view, the report correctly deduces that manatee thermal refuge is not a limiting metric for an MFL. Staff Response: Please see our responses above to Comments 3, 74, 84, and 91 regarding manatee thermal refuge. SP: The salinity habitat volume change determination was based upon the best available information. The exclusion of the manatee thermal habitat was based upon the best available information.

Table 3-1. Responses to SWFWMD's Peer Review Assessment Requirements			
Task	**Subtask**	**Sub-Subtask**	**Reviewer's Specific Comments** **SP = Steven Peene, KW = Ken Watson, AB = Adam Munson**
		b. The procedures and analyses incorporate all necessary factors;	KW: It is unclear whether direct rainfall on the CR/KB system is an input variable in the hydrodynamic model (see Section 2.3). Staff Response: See our response to Comment 57 in Table 2-3 above. AM: As discussed during the third meeting natural shorelines should be delineated from hardened shoreline or that case should be made that they may appropriately substitute for one another as the location of isohalines shift. Staff Response: See our response to Comment 39 in Table 2-2 above.
		c. The procedures and analyses were correctly applied;	KW: Discuss procedure for estimating relative change in shoreline habitat. Staff Response: See our response to Comment 39 in Table 2-2 above.
		d. Limitations and imprecisions in the information were reasonably handled;	KW: Insufficient information is provided from the SGD regression analysis to evaluate the reasonableness of the SGD hindcasted for a 46-year period. It may be helpful to include plots of residuals vs. predictions and observed vs. predicted values. Staff Response. Model skill assessment results discussed in Section 2.2 are the best estimate of the reasonableness of SGD for use in this system. SP: The limitations in the flow calculations were not sufficiently identified in relation to the USGS flow measurements. Staff Response: See our responses to Comments 6, 7, 26, and 86 pertaining to USGS data.

Table 3-1. Responses to SWFWMD's Peer Review Assessment Requirements			
Task	**Subtask**	**Sub-Subtask**	**Reviewer's Specific Comments** **SP = Steven Peene, KW = Ken Watson, AB = Adam Munson**
		e. The procedures and analyses are repeatable; and	SP: The procedures and analyses seem repeatable for all aspects. Further clarification of key analyses could be provided within the report and these are outlined in the detailed comments.
		f. Conclusions based on the procedures and analyses are supported by the data.	KW: Conclusions are supported by best available data and repeatable procedures and analyses. The relative flow reductions determined for a salinity regime <2 ppt (i.e., Table 3-1) appear inconsistent (although possible) with those for the <1 and <3 ppt regimes and should be checked. Staff Response: See response to Comment 72 regarding inconsistency in salinity response. SP: The conclusions relative to salinity habitat and manatee thermal habitat are supported by the analyses and the data. Conclusions on the lack of impact upon water quality in the system are not supported by the data because the key aspects, Chl a versus residence time changes is not presented. Staff Response: See response to Comment 1 regarding residence time and chlorophyll.

Table 3-1. Responses to SWFWMD's Peer Review Assessment Requirements			
Task	**Subtask**	**Sub-Subtask**	**Reviewer's Specific Comments** **SP = Steven Peene, KW = Ken Watson, AB = Adam Munson**
5. If a proposed method used in the Crystal River/Kings Bay Springs system MFLs report is not scientifically reasonable, the CONSULTANT shall:	a. List and describe scientific deficiencies and, if possible, evaluate the error associated with the deficiencies; b. Determine if the identified deficiencies can be remedied. c. If the identified deficiencies can be remedied, then describe the necessary remedies and an estimate of time and effort required to develop and implement each remedy. d. If the identified deficiencies cannot be remedied, then, if possible, identify one or more alternative methods that are scientifically reasonable. If an alternative method is identified, provide a qualitative assessment of the relative strengths and weaknesses of the alternative method(s) and the effort required to collect data necessary for implementation of the alternative methods.		KW: Methods are scientifically reasonable. AM: While some methods seem debatable all methods incorporate uncertainty and the ones use by the district are reasonable. SP: The final verification of the total flow remains a deficiency, but at present there is no better data to be utilized. This should be identified as a future need for this system. SP: Another are identified as having some deficiency is the evaluation of the impacts to water quality. The deficiency is in the establishment of the relationship between flow reduction, residence times, and the water quality parameters (Chl a for example) that would be impacted by longer residence times. At present based upon discussions with District personnel, the data to support this analysis is not available. Within the report the District needs to first determine that there are not data that weren't used which might allow this analysis to be completed at this time. If not, then identify this as potential future work. Staff Response: See response to Comment 1 regarding residence time and chlorophyll.

Table 3-1. Responses to SWFWMD's Peer Review Assessment Requirements			
Task	**Subtask**	**Sub-Subtask**	**Reviewer's Specific Comments** **SP = Steven Peene, KW = Ken Watson, AB = Adam Munson**
6. If a given method or analyses used in the Crystal River/Kings Bay Springs system MFLs report is scientifically reasonable, but an alternative method is preferable, the CONSULTANT shall:	a. List and describe the alternative scientifically reasonable method(s), and include a qualitative assessment of the effort required to collect data necessary for implementation of the alternative method(s).		KW: Percent change in habitat is appropriate for this system. By selecting the most conservative salinity regime, other salinity regimes are protected. SP: No preferred alternate method with the available data has been identified through this review.

Attachment A

MFL Review Guidelines

<u>MFL Review Guidelines</u>

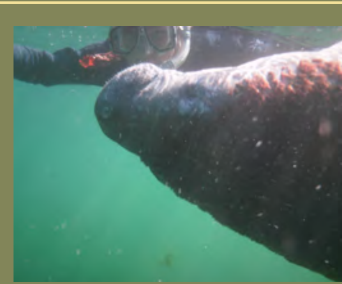
1. Determine whether the conclusions in the Crystal River/Kings Bay Springs system MFLs report are supported by the analyses presented.
2. <u>Supporting Data and Information</u>: Review the relevant data, and information that support the conclusions made in the report to determine whether:
    a. The data and information used were properly collected;
    b. Reasonable quality assurance assessments were performed on the data and information;
    c. Exclusion of available data from analyses was justified; and
    d. The data used were the best information available.
3. <u>Technical Assumptions</u>: Review the technical assumptions inherent to the analysis used in the Crystal River/Kings Bay springs system MFLs report to determine whether:
    a. The assumptions are clearly stated, reasonable and consistent with the best information available;
    b. The assumptions were eliminated to the extent possible, based on available information; and
    c. Other analyses that would require fewer assumptions but provide comparable or better results are available.
4. <u>Procedures and Analyses</u>: Review the procedures and analyses used in the Crystal River/Kings Bay system MFLs report to determine whether:
    a. The procedures and analyses were appropriate and reasonable, based on the best information available;
    b. The procedures and analyses incorporate all necessary factors;
    c. The procedures and analyses were correctly applied;
    d. Limitations and imprecisions in the information were reasonably handled;
    e. The procedures and analyses are repeatable; and
    f. Conclusions based on the procedures and analyses are supported by the data.
5. If a proposed method used in the Crystal River/Kings Bay Springs system MFLs report is not scientifically reasonable, the CONSULTANT shall:
    a. List and describe scientific deficiencies and, if possible, evaluate the error associated with the deficiencies;
    b. Determine if the identified deficiencies can be remedied.

   c. If the identified deficiencies can be remedied, then describe the necessary remedies and an estimate of time and effort required to develop and implement each remedy.
   d. If the identified deficiencies cannot be remedied, then, if possible, identify one or more alternative methods that are scientifically reasonable. If an alternative method is identified, provide a qualitative assessment of the relative strengths and weaknesses of the alternative method(s) and the effort required to collect data necessary for implementation of the alternative methods.
6. If a given method or analyses used in the Crystal River/Kings Bay Springs system MFLs report is scientifically reasonable, but an alternative method is preferable, the CONSULTANT shall:
   a. List and describe the alternative scientifically reasonable method(s), and include a qualitative assessment of the effort required to collect data necessary for implementation of the alternative method(s).

APPENDIX

Vanasse Hangen Brustlin, Inc. 2009. An inventory of spring vents in Kings Bay Crystal River, Florida. University Park, Florida. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Transportation | Land Development | Environmental Services | Water Resources | GIS | Planning | Survey


An Inventory of Spring Vents in Kings Bay
Crystal River, Florida

SUBMITTED TO
SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
2379 Broad Street
Brooksville, FL 34604-6899
For projects: 07PO0001717 and 09POSOW0483
Michael Flannery and Dave Dewitt, Project Managers

SUBMITTED BY

Vanasse Hangen Brustlin, Inc.
8043 Cooper Creek Blvd., Suite 201
University Park, FL 34201
Gary Serviss, Project Manager

MAY 2009

An Inventory of Spring Vents in Kings Bay

Crystal River, Florida

Vanasse Hangen Brustlin, Inc. (VHB) has completed a field inventory and documentation of spring vents within the Kings Bay portion of Crystal River in Citrus County, Florida. The field inventory was conducted over the period of October 14th – 16th and 27th – 29th 2008, and January 26th – 27th 2009, for a total of eight field days. A summary and cross-reference table of previously identified spring vents was provided to the Southwest Florida Water Management District (District) in a letter report dated October 28, 2008 which evaluated the following documents.

- 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.
- Rosenau, J. C., G. L. Faulkner, C. W. Hendry, Jr., and R. W. Hull. 1977. Springs of Florida (revised): Florida Bureau of Geology Bulletin 31, 461 p.
- Scott, T. M., G. H. Means, R. P. Meegan, R. C. Means, S. B. Upchurch, R. E. Copeland, J. Jones, T. Roberts, and A. Willet. 2004. Springs of Florida (Revised): Florida Bureau of Geology Bulletin No. 66, 658 p.

VHB also included information on spring vent locations and names provided by District staff (Dave Dewitt) during the field surveys.

The survey method consisted of navigation by boat to the approximate locations of previously documented spring vents summarized in the above described letter report. Upon arrival at a previously documented spring location efforts were made to detect the spring's presence, including visual observation of spring "boils" from the boat, and surveys along the surface and bay bottom via snorkel and SCUBA equipped divers. In addition to the previously documented springs, other potential spring vents detected by spring signs (i.e., boils) were also investigated.

When a spring vent location was field confirmed, its location was recorded in latitude and longitude coordinates via a GPS equipped arc pad. In addition, the vents depth, dimensions and orientation/configuration were noted. Digital photographs were taken of the vent mouth, when possible, along with occasional surface images.

The survey revealed that many of the springs consist of more than one vent in very close proximity. Multiple discharge locations were often observed in a relatively small area that jointly contributed to the overall discharge for that "spring". A single set of GPS coordinates was obtained to mark these vent clusters and each vent cluster was considered a single spring for the purposes of this study. A total of 70 springs were documented and their coordinates are provided in Table 1. This is substantially more than reported in the cross-reference table which noted a potential of 42 springs.

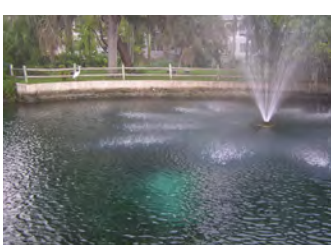
In some areas there are springs that are so close together that they could not be depicted separately on Figure 1 for mapping purposes. A single location was used on Figure 1 to depict the location of these springs, but the individual GPS coordinates of each spring are provided in Table 1. Combining close proximity springs for mapping purposes resulting in the depiction of 52 locations for the 70 springs.

Finally, especially in the case of previously unnamed springs, groups of springs in the same geographic area of Kings Bay were lumped into a single site designation. These "spring complexes" were given the same site name and site number in Table 1 and the same site number on Figure 1. The grouping into spring complexes resulted in a total of 41 named and numbered springs/spring complexes as listed in Table 1 and depicted on Figure 1.

The spring vents varied greatly in flow magnitude from 1st order magnitude vents to 3rd order or less. Many of these vents were previously identified in the earlier reports identified above, however several of the vents were not identified in these reports. When possible these vents were identified or labeled consistent with their historic designations. In some instances, names have been provided (in italics) for previously unnamed springs of suitable size.

Provided below are physical descriptions of the vents/vent complexes surveyed during the field events. Information relative to approximate flow and depth are based upon the conditions at the time of the survey. Most of the surveys took place from mid to low tides so the approximate flows were likely on the high side and the depths on the low side. The descriptions are presented in a general north to south order based upon the vents geographic locations. The number in parentheses at the end of the spring name corresponds to the spring numbers on Figure 1 and Table 1.

- Hammett 23/Miller's Creek Spring (1). This spring is located at the head of Miller's Creek at coordinates 28°54'05.10"N, 82°36'12.49"W and consists of a two vents within a large fracture in the bottom. Dimensions of these vents were approximately 1.2 feet X 1.0 feet, and 2.4 feet X 0.75 feet, respectively. Water depths at the edge of the fracture were approximately 10.0 feet, while the deeper center of the vents was approximately 28 feet. Discharge volumes were low.

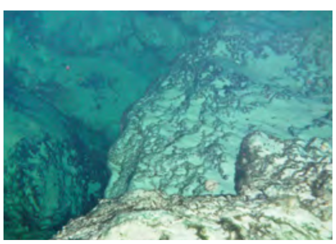


- Fountain Spring/City Hall Spring/Little Spring/Independence Spring (2). This spring is located adjacent to the City of Crystal River City Hall at 28°54'01.29"N, 82°35'43.60"W. The center of this spring is within a walled and lined pond that is roughly circular in shape, with an approximate diameter of 85 feet and an estimated depth of five to six feet deep. As access into the pond is restricted, a physical description of the spring vent mouth was not made. Spring flow was moderate. This walled pond discharges on its western side to an approximately 15 foot wide vertical sided ditch, which flows south under U.S. HWY 19 and into Kings Bay.

- *Charlie's Fish House Spring* (3). This spring is located immediately adjacent to the parking lot seawall of Charlie's Fish House restaurant at 28°53'57.32"N, 82°35'44.23"W, which is at the very northeastern corner of Kings Bay. This very small spring vent is estimated at approximately 0.5 feet in diameter and had a low flow. Water depths ranged from exposed at low tide, to approximately two feet deep at high tide. This spring was not identified on any of the previous studies.

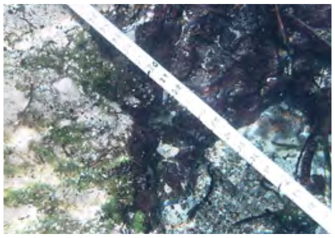
- Hammett 25/*Birds Underwater Spring* (4). This spring is located adjacent to Birds Underwater Tours dive shop at 28°53'56.05"N, 82°35'47.56"W under a covered dock slip, and consists of two very small spring vents estimated at approximately 0.5 to 0.75 feet in diameter. Water depths are estimated to range from approximately 1.0 feet at low tide to 3 feet at high tide. Discharge volumes associated with this spring were minimal.

- Hammett 27/Pool Spring (5). This spring is enclosed within a walled off swimming area associated with the Kings Bay Lodge resort, creating a spring fed swimming pool. This spring is located at 28°53'54.48"N, 82°35'43.02"W and consists of multiple small spring vents. One vent is located within the "pool" itself, and has approximate dimensions of 3.0 feet X 0.5 feet. Three other vents are located outside of the main pool area, but discharge into the pool through a small flow-way under the pool stairs. Measurements could not be made on these vents due to lack of access. Collectively pool spring discharges into Kings Bay through a small square orifice. Water depths within the pool were estimated at 3 feet deep, and the discharge was minimal.



- Hammett 1/Catfish Spring (6). This spring is located near the Best Western Crystal River Resort and adjacent to a residential single family dock at 28°53'53.50"N, 82°35'55.54"W. It consists of one main spring vent opening with approximate dimensions of four feet by eight feet, and numerous other associated smaller cracks and vents ranging from 0.5 feet X 0.5 feet to 1.0 feet X 1.0 feet. This spring has numerous pieces of lumber and tree limbs within its opening, and the water depth was approximately 15 feet. Discharge was estimated to be moderate to high.

- Hammett 26/*NW 9th Avenue Springs* (7). This spring complex is located at the head of the western most embayment of the northern portion of Kings Bay at 28°53'52.93"N, 82°36'04.96"W. It is approximately 8 feet off of the sea-walled edge, and consists of three small vents with approximate dimensions of 1.0 feet X 0.8 feet, 0.3 feet X 0.4 feet, and 0.9 feet X 0.8 feet. Water depths were approximately 3.5 feet to 4.0 feet deep, with depths inside the spring vents ranging from 4.0 feet to 4.8 feet. Discharge volumes were estimated to be low to minimal. It appears unlikely that these small springs represent those measured by Hammett due to their small size and location to the east of the canal indicated in the Hammett report. The location of Hammett 26 near the mouth of the canal would seem to indicate that this was a cross-section location for flow measurement.



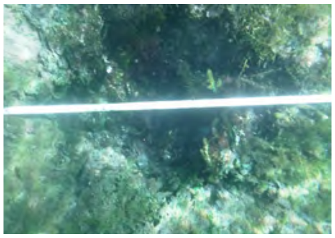
- Hammett 4/House Spring (8). This spring is located at the head of the eastern most embayment of the northern portion of Kings Bay at 28°53'45.44"N, 82°35'22.84"W within a sea–walled enclosure. This enclosure is obviously intended to be used as a swimming area, complete with a pool slide and ladder, for a single family residence. This multiple vent spring area is approximately four feet deep at the center of the "pool"/swimming enclosure. Approximate dimensions of the larger vents within this spring complex include a 2.4 X 2.3 foot vent, a 0.2 X 0.5 foot vent, and a 1.0 X 0.5 foot vent. Numerous other "sand boils" were also observed within this area. Discharge volumes were estimated to be low to moderate.

- Hammett 5/Jurassic Spring (9). This spring is located approximately 360 feet south of House Spring, within the eastern embayment off of the northern portion of Kings Bay at 28°53'42.08"N, 82°35'23.93"W. Like House Spring, Jurassic Spring has been partially sea-walled with a few boat docks installed as well. This spring consists of two larger vent mouths, one measuring approximately 16 feet long and with varying widths of between 3.5 and 4.2 feet, and the second vent mouth measuring approximately 4.9 feet long X 0.9 feet wide. Within the larger vent mouth the flow was determined to exit from three primary points, the first measured at 0.9 X 1.8 feet, the second measured at 0.3 X 0.3 feet, and the third measured at 2.1 X 4.0 feet. Approximate depths to bottom within the spring area ranged between 13 and 15 feet. Discharge volumes within this spring complex were estimated to be moderate to high.

- Hammett 3/Hunters Spring/American Legion Spring (10). This spring is located approximately 800 feet west of Jurassic Spring within the eastern embayment off of the northern portion of Kings Bay at 28°53'40.41"N, 82°35'32.91"W. It is immediately offshore of Hunters Spring Park and consists of five individual spring vents clustered within an approximate 10 foot diameter circle and at approximate 15 foot depth. Approximate dimensions of the vent mouths include two approximately round vents of 2.0 and 1.5 feet diameters, respectively, an oblong vent of 4.0 feet X 1.1 feet, an oblong vent with a length of 5.0 feet and widths of 1.5 to 2.5 feet, and a kidney bean shaped vent approximately 4.0 feet long by 1.5 feet wide at one end of the "bean" and 2.0 feet wide at the other end of the "bean" (and connected by a narrower area). Discharge volumes within this spring complex were estimated to be moderate to high.

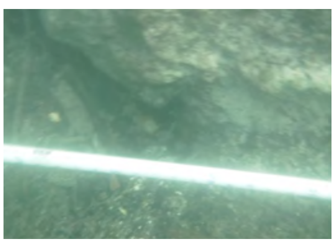
- Hammett 21/Magnolia Circle Spring (11). This spring is located near the eastern tip of the Magnolia Shores subdivision/residential area at 28°53'38.49"N, 82°35'58.84"W. It consists of a single vent that is shaped somewhat like a kidney, and has approximate dimensions of 3.1 feet X 2.0 feet and an approximate depth of 5 feet. Most of the flow was determined to be coming from the left hand lobe of the vent, which has dimensions of 2.0 feet X 0.5 feet. The right hand lobe has approximate dimensions of 1.6 feet X 0.5 feet. Discharge volumes from this spring were estimated to be high.

- *Pete's Pier Spring* (12). This spring complex is located in the northern half of Kings Bay at 28°53'37.85"N, 82°35'55.60"W. It is approximately 400 to 450 feet west of the Pete's Pier boat ramp, at an approximate 6 foot depth, and consists of two vents aligned in an approximately north/south direction. The northern of the two vents is approximately 0.75 feet X 1.1 feet, while the southern of the two vents is approximately 0.1 feet X 1.6 feet. This vent system is believed to be part of a larger fracture line in the bay bottom in this area, and more vents, though unobserved during the field event, are thought to be probable. Discharge volumes from this spring complex were estimated to be moderate.



- Hammett 6/*Moray Springs* (13). This spring complex is located at the head of the moderately sized cove behind Pete's Pier Marina in the northern portion of Kings Bay. It is surrounded by homes, sea-walls and larger boat docks associated with the Agua Vista subdivision. Multiple spring vent clusters with coordinates of 28°53'37.03"N, 82°35'41.57"W; 28°53'37.01"N, 82°35'41.4"W; and 28°53'36.99"N, 82°35'41.09"W are present within this complex. Some of the larger vent dimensions within each of these clusters measured approximately 2.0 X 1.5 feet, 2.0 X 0.8 feet, 0.8 X 0.9 feet, 0.8 X 0.8 feet, and 0.5 X 0.9 feet. Numerous other smaller and ill-defined vents were also observed. Discharge volumes were estimated to be low to moderate.

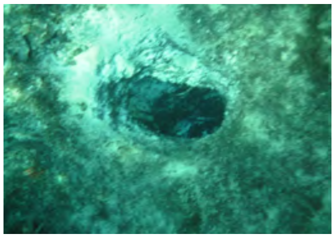
- Hammett 20/Shark Sink (14). This feature is located on the extreme western edge of Kings Bay, just south of the discharge point into the Crystal River at 28°53'31.69"N, 82°36'20.86"W. This feature is approximately 30 to 40 feet deep and consists of a limestone bottom covered in a thick layer of silt and fine sediment. No spring flow was observed at this feature, however this result must be viewed with caution at this time as visibility was so poor that minor spring flow could be undetected.



- Hammett 7/*Paradise Isles* (15). This spring is located approximately opposite 1218 SE Kings Bay Drive within a sea walled cove associated with a canal lot in the Paradise Isles subdivision at 28°53'27.18"N, 82°35'42.02"W. This spring complex consists of approximately 12 vents mouths/fractures, most of which are very small. Dimensions of the larger vents include an approximately 0.5 foot diameter circular vent, an oblong 1.0 X 0.5 foot vent, and a large fracture vent approximately 5.0 feet X 0.5 feet in size. Water depths within this area are approximately 10 to 12 feet deep. Discharge volumes were estimated to be low.

- Hammett 8/Manatee Sanctuary/Gator Hole/Magnolia Spring/Crystal Spring (16). This spring, also associated with the Paradise Isles subdivision canal system, is approximately 720 east of the Hammett 7 spring complex at 28°53'26.50"N, 82°35'33.27"W. This complex of approximately 13 vents is aligned along an approximately 60 foot long fracture that is sinusoidal in shape within the greater "bowl" shape of the spring formation. Depths of this fracture range from approximately 15 feet deep at the shallow end of the fracture, to approximately 25 feet deep at the deepest areas of the fracture. Individual vent sizes along the fracture ranged between approximately 1.2 feet X 1.0 feet, up to approximately 5.0 feet X 2.0 feet. Discharge volumes were estimated to be high.

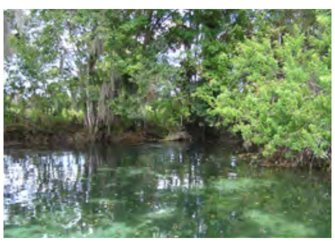
- *Buzzard Island Spring* (17). This spring is located east of the northern tip of Buzzard Island at 28°53'24.97"N, 82°35'53.64"W. This spring appears to have been evaluated by Rosenau. It consists of a single vent that is oval in shape with dimensions of 1.7 feet X 0.8 feet, and an approximate depth from the surface of 8 feet. Discharge volumes were estimated to be moderate.



- Hammett 10/Three Sisters # 1/Three Sisters Springs/Middle Springs # 1 (18). This spring is part of a larger complex that consists of three spring "bowls" aligned upon an approximate northwest -southeast axis and with an approximate total length of 250 feet. Each bowl of this spring complex contained spring vents, and for purposes of this survey only the center coordinates of each bowl were recorded. The north-western bowl of this trio is centered at 28°53'19.46"N, 82°35'21.37"W, and contains approximately twelve circular vents with dimensions ranging between 1.0 feet and 0.5 feet. Water depths were estimated at 8 to 10 feet deep and discharge volumes were low to moderate.

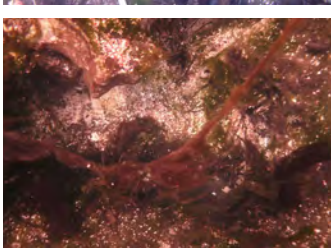
- Hammett 28/Three Sisters # 2/Three Sisters Springs/Middle Springs # 2 (19). The middle bowl of the trio is centered at 28°53'18.70"N, 82°35'20.87"W and contains what is effectively (due to debris, including tree limbs and vegetation within the spring) a very large kidney shaped vent approximately 20 feet long by 5 feet wide. Water depths within this bowl were approximately 20 feet deep and discharge volumes were high.

- Hammett 28/Three Sisters # 3/Three Sisters Springs/Middle Springs # 3 (20). The southeastern bowl of the trio is centered at 28°53'18.14"N, 82°35'20.16"W, and contains approximately six vents with dimensions ranging between 2.1 feet X 2.1 feet to 0.4 feet X 0.4 feet. Water depths were estimated at approximately 15 to 20 feet deep and discharge volumes were high.



- Hammett 9/Kings Bay #1/Idiots Delight #1 (21). This spring complex is located within the Paradise Isles and Palm Island subdivision canal system approximately 1400 feet southeast of the Hammett 8 spring complex. These vents are located at 28°53'17.22"N, 82°35'23.03"W and consist of two vents, one with approximate dimensions of 3.0 feet X 2.8 feet, the other with dimensions of 0.5 X 0.3 feet, both of which are located immediately adjacent to the shoreline and west of Three Sisters Springs run. Water depths in this area were approximately 4 feet deep and discharge volumes were moderate.

- Hammett 11/ Idiots Delight #2 (22). The vents in this complex are southeast of Hammett 9 and are located at 28°53'16.55"N, 82°35'22.04"W. The vent complex consists of six vents with dimensions ranging from 3.5 feet X 1.5 feet, to 0.4 feet X 0.3 feet. These vents are approximately 6.0 feet deep and discharge volumes were moderate.



- Hammett 11A/ Idiots Delight #3/Three Sisters Run (23). Another spring, herein identified as Hammett 11A, is located south of Hammett 9 and Hammett 11 within the center of the dredged canal at 28°53'16.24"N, 82°35'22.55"W. This spring consists of a single vent with approximate dimensions of 2.0 feet X 1.9 feet. The water depth was approximately 9.5 feet deep and discharge volume was moderate.
- *Parker Island North Spring Complex* (24). This spring complex consists of approximately 5 to 8 vents in water depths ranging between 5 and 12 feet of water scattered over a moderately sized area. This spring complex appears to have been evaluated by Rosenau. Coordinates of these vents include the following locations: 28°53'13.30"N, 82°35'38.33"W; 28°53'13.23"N, 82°35'38.51"W; 28°53'13.21"N, 82°35'38.76"W;

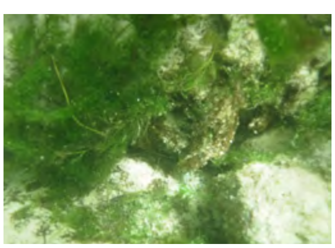
28°53'13.10"N, 82°35'38.3"W; and 28°53'12.33"N, 82°35'41.58"W. All vents were irregular in shape, this due to fractured limestone along the bottom in this area, and vent sizes ranged from 1.0 feet X 0.25 feet to 3.0 feet X 4.0 feet. Discharge volumes were low to moderate.

- Hammett 12/Parker Island Springs/Little Hidden Spring (25). This three vent spring complex is located within the interior of Parker Island, and the spring bowl edges are exposed at low tide. Coordinates of these three vents include the following locations: 28°53'08.84"N, 82°35'38.69"W; 28°53'08.74"N, 82°35'38.47"W; and 28°53'08.48"N, 82°35'38.26"W. Vent sizes ranged between approximately 4.0 feet X 1.5 feet to approximately 0.4 feet in diameter. Discharge volumes were low to moderate.

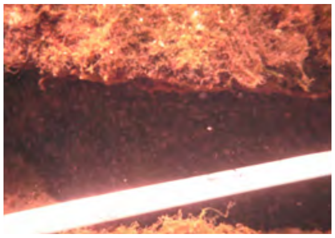
- *Banana Island North Spring Complex* (26). This complex of somewhat widely separated springs is located on the north side of Banana Island and consists of at least four separate spring vent areas, some with multiple vents. Some of these springs appear to have been evaluated by Rosenau and one may correspond with Hammett 14. Coordinates of these vents include the following locations: 28°53'05.92"N, 82°35'46.10"W; 28°53'05.46"N, 82°35'46.09"W; 28°53'04.48"N, 82°35'47.12"W; and 28°53'04.40"N, 82°35'45.35"W. The vent dimensions ranged from a 15 foot X 4 foot crack/fracture line in the bottom, to a 2.5 foot X 0.25 foot crack/fracture line. Water depths ranged from approximately 2.0 feet at the shallowest vent, to approximately 12 feet deep at the deepest vent. Discharge volumes were estimated to range from low to moderate, depending on the vent.

- Hammett 13/*FWS Spring Complex* (27). This spring system consists of two main spring vents located at coordinates 28°53'03.29"N, 82°35'36.87"W and 28°53'01.98"N, 82°35'37.11"W. These vents consisted of fractures in the limestone along the bottom, and ranged in size from 6.0 X 0.5 feet to 2.3 feet X 1.5 feet. Water depths were approximately 10 feet and discharge volumes were estimated to be moderate to high.

- *Banana Island East Springs* (28). This multiple vent spring complex consisted of six main vent areas observed on the east end of Banana Island. Coordinates for these areas include: 28°52'58.18"N, 82°35'40.51"W; 28°52'58.09"N, 82°35'39.95"W; 28°52'57.85"N, 82°35'40.45"W, 28°52'57.65"N, 82°35'40.27"W; 28°52'57.38"N, 82°35'39.76"W; and 28°52'57.03"N, 82°35'40.16"W. These spring vents were all located on or near the waters edge at the time of the field event, and consisted of very small vents in the mud bottom. Water depths ranged from exposed, to approximately 1 foot, and discharge volumes were estimated to be low.



- *Banana Island West Springs* (29). This multiple vent spring complex consisted of three main boils observed on the west end of Banana Island primarily located at coordinates 28°52'55.63"N, 82°35'48.63"W and 28°52'55.53"N, 82°35'48.62"W. One of these springs may have been evaluated by Rosenau. One boil consisted of an approximately 12 foot long fracture with approximately 3 vents along its length. These vents ranged in length between 1.0 feet and 0.5 feet, and were all approximately 0.25 feet wide. This fracture line was approximately 4 feet deep and discharge volumes were low. The second, and volume wise greater spring, was found to be encircled by cement blocks and exiting into Kings Bay via a 0.75 foot X 0.5 foot hole. This spring vent was approximately 2.0 feet deep and discharge volumes were moderate. A third boil was observed at the water's edge and consisted of numerous small vents with approximately 0.15 to 0.25 foot diameters. The discharge volume from these vents was low.

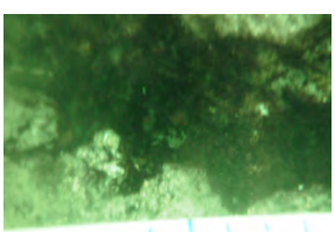


- Hammett 15/Mullets Gullet Spring/Tarpon Hole #2 (30). This spring system is the eastern most vent of a large three vent systems in this area, and is located at coordinates 28°52′54.82″N, 82°35′39.29″W. It consists of multiple large undercut type fractures in the bottom through which the spring is discharging. These cracks were measured at 15 feet X 4 feet wide, 14 feet long X 2 feet wide, and 9 feet X 2 feet wide, and were roughly orientated in a circular formation. Water depths at the edge of the circular fracture formation were approximately 4 to 5 feet deep, and approximately 15 feet deep in the center. Discharge volume was high.

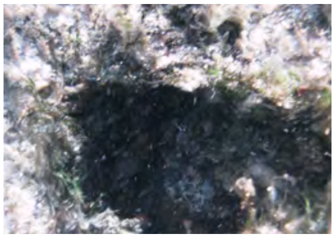
- Hammett 2/Tarpon Hole/Big Hole/Crystal Spring (31). This spring vent system is the middle vent of the three large vent systems in this area, and is located at coordinates 28°52′54.68″N, 82°35′39.37″W. It consists of multiple fractures and holes in the bottom through which flow was detected. The fractures can generally be described to be trending in a roughly circular formation, and appear to represent a large undercut shelf/cavern which collapsed sometime in the past. Approximate dimensions of the cracks/fractures in the limestone ranged from 7.0 feet by varying widths up to 2.5 feet, 10 feet x 0.9 feet, 7 feet X 0.4 to 2.0 feet, and 5.0 feet X 2.0 feet. In addition, the small holes in the bottom can be described as irregular in shape, and all with similar dimensions of approximately 1.5 X 1.0 feet. Water depths at the edge of the spring formation were approximately 4 to 5 feet, while depths at the deepest center were approximately 10 to 15 feet. Discharge volumes at this spring system were high.

- Hammett 16/King Spring/Grand Canyon Spring (32). This spring vent system is located south of Banana Island at coordinates 28°52′54.37″N, 82°35′41.64″W, and is the western most spring boil of the three large vent systems in this area. Three spring vents are found in this spring with dimensions ranging from 20 feet long X 8 feet wide, to two vents with similar dimensions of approximately 3.0 feet X 1.5 feet. Water depths at the vent mouths were approximately 28 feet, and discharge volumes were moderate.

- *Plantation Point Hole* (33). This historic spring vent is located just off of a seawall to the northeast of the Plantation Inn property at coordinates 28°52′51.89″N, 82°35′29.22″W. A knowledgeable individual informed District staff that it used to flow (David DeWitt, personal communication). The edges of the former vent are approximately 5 feet deep (from the surface) and slope to approximately 10 feet at the bottom. No flow was observed at this former spring.



- *Dave's Quest Springs* (34). This three vent spring complex is located approximately 200 feet south-southwest of King Spring at coordinates 28°52′49.54″N, 82°35′42.92″W, 28°52′49.24″N, 82°35′43.29″W, and 28°52′48.41″N, 82°35′42.71″W. At least one of these springs appears to have been evaluated by Rosenau. The spring vents consist of both fractures and solution holes in the shallow limestone shelf in this area. Dimensions of these fractures ranged from 6 feet long X 0.5 feet wide, to 4 feet long X 2 feet wide. Depths at the edges of the fractures ranged from 6 feet to 8 feet, and discharge volumes were moderate.

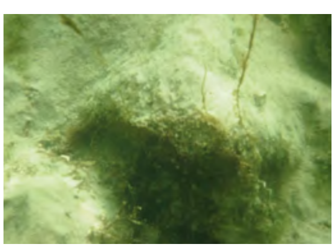


- Hammett 17/*Golfview* (35). This multiple vent spring complex is located north of the Golfview subdivision. It consists of two closely spaced vents at coordinates 28°52'46.32"N, 82°35'32.19"W, and 28°52'46.26"N, 82°35'31.9"W, with dimensions of 3.0 feet x 1.5 feet and 1.5 feet x 1.5 feet, respectively, located within the middle of the channel area at an approximate 5 foot depth. Discharge volumes at these vents were low. In addition, a third multiple spring vent complex, located approximately 150 to 200 feet away to the southeast, was noted near the edge of the channel at 28°52'45.02"N, 82°35'30.7"W. This third vent complex consisted of approximately 10 spring vents within the deep algae covered bottom, with dimensions ranging from 2.0 feet x 1.8 feet to 0.3 feet x 0.3 feet. Discharge volumes at this third vent complex were low to moderate. A follow up visit was made to the third vent complex approximately 3 months later, and it was noted that the dimensions and number of spring vents had changed, and there was now only one large vent with approximate dimensions of 5 feet X 4 feet and strong flow.

- *Lightbourn's Ledge* (36). This limestone feature is located at 28°52'45.26"N, 82°35'57.09"W and consists of an undercut ledge approximately 8 to 10 feet deep. No spring flow was observed at this feature, though it appears that flow was likely at some point in the past based upon the ledges morphologic features. This spring appears to have been evaluated by Rosenau.

- *Wynn Court Springs* (37). These vents consist of several small to moderately large fractures in the limestone shelf. At least one of these springs appears to have been evaluated by Rosenau. Coordinates for these various vent locations include: 28°52'42.41"N, 82°35'50.60"W; 28°52'42.31"N, 82°35'47.33"W; 28°52'42.18"N, 82°35'49.62"W; 28°52'42.00"N, 82°35'50.68"W; and 28°52'41.34"N, 82°35'48.20"W. Dimensions of these fractures ranged between 6 feet long X 0.2 feet wide, to 3 feet long x 0.25 feet wide. Water depths at the edges of these fractures were all about 1 foot deep, and discharge volumes were low.

- Hammett 18/Black Spring (38). This spring complex consists of multiple fractures within the limestone bottom. It is located at coordinates 28°52'39.08"N, 82°35'57.28"W. Dimensions of these fractures ranged between 15 feet long X 0.5 feet wide and 6 feet long X 0.5 feet wide. Water depths were 3 to 5 feet deep and discharge volumes were moderate.



- Hammett 19/*Sid's Springs* (39). This multiple vent spring complex consists of two larger adjacent bowl areas, each populated by several spring vents. It is located at coordinates 28°52'36.66"N, 82°35'50.99"W. Approximately 14 individual vents are located within this complex, with dimensions ranging between 6.0 feet X 3.0 feet to 1.5 feet X 1.5 feet. Water depths at the edge of the spring bowls were approximately 1.0 feet, and water depths of approximately 12 to 15 feet deep were observed within the deeper centers. Discharge volumes were moderate to high.

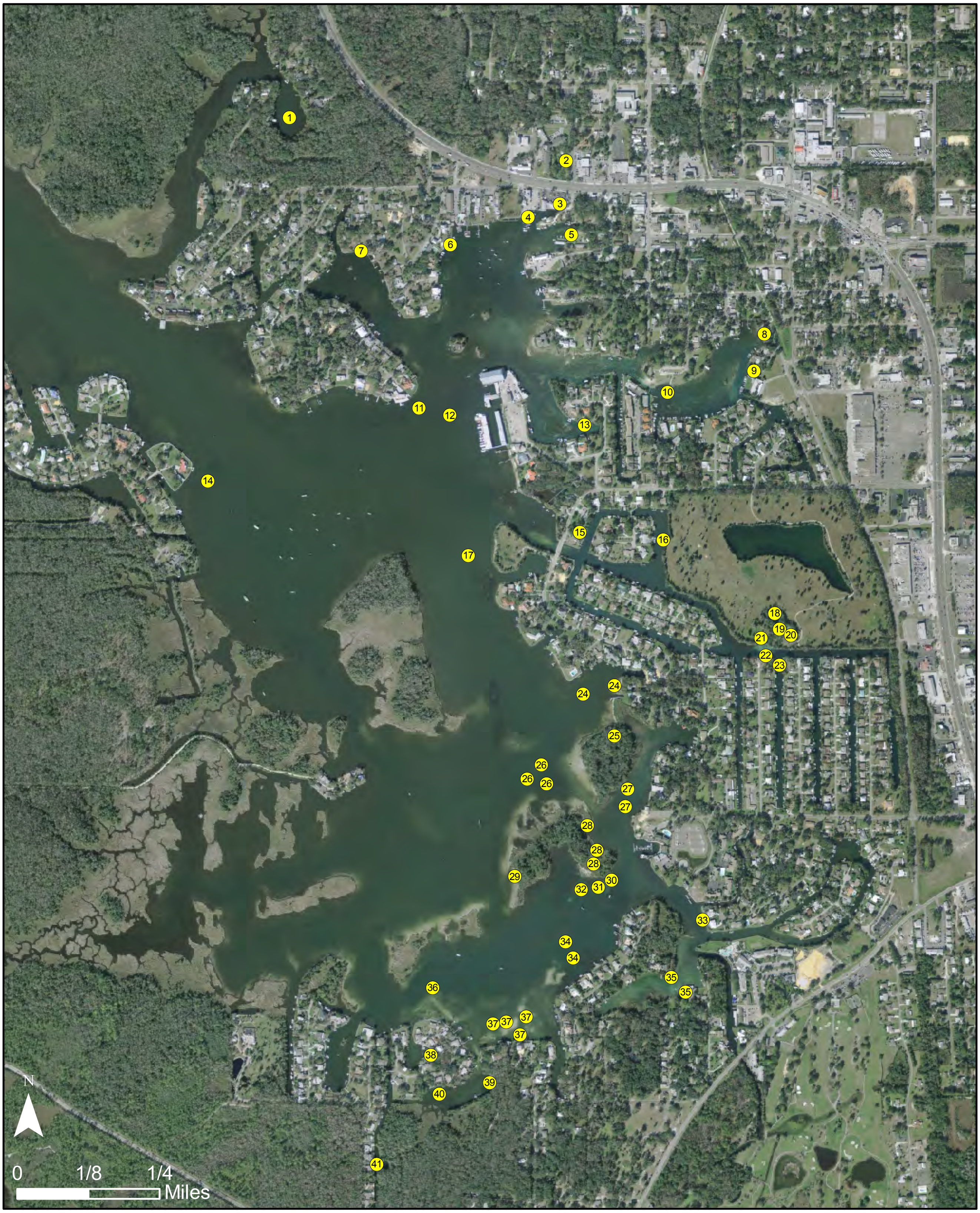
- *Gary's Grotto* (40). This spring complex consists of fractures within the shallow limestone bottom. It is located approximately 400 feet west southwest of Hammett 19 at coordinates 28°52'35.51"N, 82°35'56.35"W and 28°52'35.38"N, 82°35'56.18"W. Dimensions of these fractures ranged between 15 to 6 feet long X 2 to 1 foot wide. Water depths ranged from 0.5 feet to 10 feet below the surface and discharge volumes were moderate.

- *Swamp Sink* (41). The southernmost site visited is a circular feature located off a canal. This area is surrounded by swamp and appears to have been at least partially bermed. The area is uniformly five feet deep. No vents were located, but stratified water appears to indicate diffuse flow. An adjacent resident indicated that the area no longer flows.

There is a karst feature at the east end of Hook Island within the southwest portion of Kings Bay. This feature is an apparent historical location of a spring. Discharge was not observed at this location during several investigations by District staff during 2007 and 2008 (David DeWitt, personal communication). This feature is located at 28°52′52.77″N, 82°36′15.00″W, but has not been depicted on Figure 1.

Three springs designated by Hammett as 22, 24 and 26 could not be located. They are theorized to have been discharge measurement cross-section locations. Apparent spring discharge was observed at 24 (and subsequently further down the canal at 26), but the source of the discharge was quite a distance upstream.

Electronic files of this report, GIS files of Figure 1, copies of the field notes, and digital surface and underwater photography of the springs were provided to the District.



Date: 2/10/09

Revised:

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

Vanasse Hangen Brustlin, Inc.

8043 Cooper Creek Blvd.
Suite 201
University Park, Florida 34201

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Table 1. Documented Kings Bay Spring Vents

ID NUMBER	NAME	LATITUDE	LONGITUDE
1	Hammett 23/Miller's Creek Spring	28° 54'05.10"N	82° 36'12.49"W
2	Fountain Spring/City Hall Spring	28° 54'01.29"N	82° 35'43.60"W
3	*Charlie's Fish House Spring*	28° 53'57.32"N	82° 35'44.23"W
4	Hammett 25/*Birds Underwater Spring*	28° 53'56.05" N	82° 35'47.56"W
5	Hammett 27/Pool Spring	28° 53'54.48" N	82° 35'43.02"W
6	Hammett 1/Catfish Spring	28° 53'53.50"N	82° 35'55.54"W
7	Hammett 26/*NW 9th Avenue Springs*	28° 53'52.93"N	82° 36'04.75"W
7	Hammett 26/*NW 9th Avenue Springs*	28° 53'52.93"N	82° 36'04.96"W
7	Hammett 26/*NW 9th Avenue Springs*	28° 53'52.91"N	82° 36'04.97"W
8	Hammett 4/House Spring	28° 53'45.44"N	82° 35'22.84"W
9	Hammett 5/Jurassic Spring	28° 53'42.08"N	82° 35'23.93"W
10	Hammett 3/Hunters Spring/American Legion Spring	28° 53'40.41"N	82° 35'32.91"W
11	Hammett 21/Magnolia Circle Spring	28° 53'38.49"N	82° 35'58.84"W
12	*Pete's Pier Spring*	28° 53'37.85"N	82° 35'55.60"W
13	Hammett 6/*Moray Springs*	28° 53'37.03"N	82° 35'41.57"W
13	Hammett 6/*Moray Springs*	28° 53'37.01"N	82° 35'41.40"W
13	Hammett 6/*Moray Springs*	28° 53'36.99"N	82° 35'41.09"W
14	Hammett 20/Shark Sink	28° 53'31.69"N	82° 36'20.86"W
15	Hammett 7/*Paradise Isles*	28° 53'27.18"N	82° 35'42.02"W
16	Hammett 8/Manatee Sanctuary/Gator Hole/Magnolia Spring/ Crystal Spring	28° 53'26.50"N	82° 35'33.27"W
17	*Buzzard Island Spring*	28° 53'24.97"N	82° 35'53.64"W
18	Hammett 10/Three Sisters #1/Three Sisters Springs/Middle Springs # 1	28° 53'19.46"N	82° 35'21.37"W
19	Hammett 28/Three Sisters #2/Three Sisters Springs/Middle Springs # 2	28° 53'18.70"N	82° 35'20.87"W
20	Hammett 28/Three Sisters #3/Three Sisters Springs/Middle Springs # 3	28° 53'18.14"N	82° 35'20.16"W
21	Hammett 9/ Kings Bay #1/ Idiots Delight #1	28° 53'17.22"N	82° 35'23.03"W

ID NUMBER	NAME	LATITUDE	LONGITUDE
22	Hammett 11 /Idiots Delight #2	28° 53'16.55"N	82° 35'22.04"W
23	Hammett 11A/Idiots Delight #3/ Three Sisters Run	28° 53'16.24"N	82° 35'22.55"W
24	*Parker Island North Spring Complex*	28° 53'13.30"N	82° 35'38.33"W
24	*Parker Island North Spring Complex*	28° 53'13.23"N	82° 35'38.51"W
24	*Parker Island North Spring Complex*	28° 53'13.21"N	82° 35'38.76"W
24	*Parker Island North Spring Complex*	28° 53'13.10"N	82° 35'38.30"W
24	*Parker Island North Spring Complex*	28° 53'12.33"N	82° 35'41.58"W
25	Hammett 12/Parker Island Springs/Little Hidden Spring	28° 53'08.84"N	82° 35'38.69"W
25	Hammett 12/Parker Island Springs/Little Hidden Spring	28° 53'08.74"N	82° 35'38.47"W
25	Hammett 12/Parker Island Springs/Little Hidden Spring	28° 53'08.48"N	82° 35'38.26"W
26	*Banana Island North Spring Complex*	28° 53'05.92"N	82° 35'46.10"W
26	*Banana Island North Spring Complex*	28° 53'05.46"N	82° 35'46.09"W
26	*Banana Island North Spring Complex*	28° 53'04.48"N	82° 35'47.12"W
26	*Banana Island North Spring Complex*	28° 53'04.40"N	82° 35'45.35"W
27	Hammett 13/*FWS Spring Complex*	28° 53'03.29"N	82° 35'36.87"W
27	Hammett 13/*FWS Spring Complex*	28° 53'01.98"N	82° 35'37.11"W
28	*Banana Island East Springs*	28° 52'58.18"N	82° 35'40.51"W
28	*Banana Island East Springs*	28° 52'58.09"N	82° 35'39.95"W
28	*Banana Island East Springs*	28° 52'57.85"N	82° 35'40.45"W
28	*Banana Island East Springs*	28° 52'57.65"N	82° 35'40.27"W
28	*Banana Island East Springs*	28° 52'57.38"N	82° 35'39.76"W
28	*Banana Island East Springs*	28° 52'57.03"N	82° 35'40.16"W
29	*Banana Island West Springs*	28° 52'55.63"N	82° 35'48.63"W
29	*Banana Island West Springs*	28° 52'55.53"N	82° 35'48.62"W
30	Hammett 15/Mullets Gullet Spring/Tarpon Hole #2	28° 52'54.82"N	82° 35'39.29"W

ID NUMBER	NAME	LATITUDE	LONGITUDE
31	Hammett 2/Tarpon Hole/Big Hole/Crystal Spring	28° 52'54.68"N	82° 35'39.37"W
32	Hammett 16/King Spring/Grand Canyon Spring	28° 52'54.37"N	82° 35'41.64"W
33	*Plantation Point Hole*	28° 52'51.89"N	82° 35'29.22"W
34	*Dave's Quest Springs*	28° 52'49.54"N	82° 35'42.92"W
34	*Dave's Quest Springs*	28° 52'49.24"N	82° 35'43.29"W
34	*Dave's Quest Springs*	28° 52'48.41"N	82° 35'42.71"W
35	Hammett 17/*Golfview*	28° 52'46.32"N	82° 35'32.19"W
35	Hammett 17/*Golfview*	28° 52'46.26"N	82° 35'31.90"W
35	Hammett 17/*Golfview*	28° 52'45.02"N	82° 35'30.70"W
36	*Lightbourn's Ledge*	28° 52'45.26"N	82° 35'57.09"W
37	*Wynn Court Springs*	28° 52'42.41"N	82° 35'50.60"W
37	*Wynn Court Springs*	28° 52'42.31"N	82° 35'47.33"W
37	*Wynn Court Springs*	28° 52'42.18"N	82° 35'49.62"W
37	*Wynn Court Springs*	28° 52'42.00"N	82° 35'50.68"W
37	*Wynn Court Springs*	28° 52'41.34"N	82° 35'48.20"W
38	Hammett 18/Black Spring	28° 52'39.08" N	82° 35'57.28"W
39	Hammett 19/*Sid's Springs*	28° 52'36.66"N	82° 35'50.99"W
40	*Gary's Grotto*	28° 52'35.51"N	82° 35'56.35"W
40	*Gary's Grotto*	28° 52'35.38"N	82° 35'56.18"W
41	*Swamp Sink*	28° 52'29.10"N	82° 36'02.06"W

Vanasse Hangen Brustlin, Inc.

APPENDIX

Vanasse Hangen Brustlin, Inc. 2010. Spring flow evaluation in Kings Bay Crystal River, Florida. University Park, Florida. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Vanasse Hangen Brustlin, Inc.

Report

Spring Flow Evaluation in Kings Bay, Crystal River, Florida

Transportation | Land Development | Environmental Services | Water Resources | GIS | Planning




August 2010

SUBMITTED TO
Southwest Florida Water Management District
2379 Broad Street
Brooksville, Florida 34604-6899
Michael Flannery, Project Manager
Xinjian Chen, Project Manager
Project No. 09POSOW1468

SUBMITTED BY
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Gary Serviss, Project Manager

Spring Flow Evaluation in Kings Bay

Crystal River, Florida

August 2010

Prepared for

Southwest Florida Water Management District
2379 Broad Street
Brooksville, FL 34604-6899
Michael Flannery and Xinjian Chen, Project Managers
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Summary

The Southwest Florida Water Management District (District) contracted Vanasse Hangen Brustlin, Inc. (VHB) to evaluate the discharge from the numerous spring vents in Kings Bay, Crystal River, Florida. Specifically, VHB obtained flow and in situ water quality measurements to quantify spring discharge from submerged spring vents for the District in its efforts to establish a Minimum Flow for Kings Bay. The flow measurements were obtained at spring vents previously identified by VHB in a May 2009 report to the District titled *An Inventory of Spring Vents in Kings Bay, Crystal River, Florida*. Flow measurements were made using a variety of methods with acoustic doppler profiler (ADP) type meters to most accurately capture the discharge for a specific vent or vent complex. The specific method(s) used to determine discharge for each vent/vent complex was selected based upon its ability to provide the most accurate data for the calculation of discharge. In two locations there are several springs that discharge through a single canal. Since these areas are subject to tidal flow influences they were monitored over several successive diurnal tide cycles with the ADP recording and logging point velocity data over time at 15-minute intervals. A total of 78 instantaneous discharge measurements were made at these locations under varied tidal conditions (i.e., spring and neap tides) 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 standard USGS mid-section method for the measurement of discharge in an open channel was employed at a few sites (20 total measurements) with open channel flow conditions. In addition, a total of 276 discharge measurements were made at individual vents and vent complexes. Measurements of the cross-sectional area and velocity of the vents were obtained to accurately determine discharge. Most spring vents were measured on more than one occasion on different days. Specific conductance and temperature were also measured and recorded, along with time, concurrent with each flow measurement (total of 212 measurements each). 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 measured discharge was averaged for each vent or vent complex and ranged from <0.1 cubic feet per second (cfs) to 53.9 cfs. The overall average temperature and conductivity was also calculated for those springs with more than one set of water quality measurements. An average temperature of 23.4 ^{o}C was observed and the vast majority of the observed values were within one degree of the mean. The spring conductivity varied spatially within Kings Bay from a low of 203 to a high of 12,096 umhos/cm, with an average of 2,045. The conductivity data were imported into

GIS and conductivity contours were depicted using ESRI 3d analyst, using a gradual color scheme, over the digitized shoreline. The graphical analysis shows that conductivities increase for very low levels in the northeast to brackish conductivities in the southwest.

Introduction

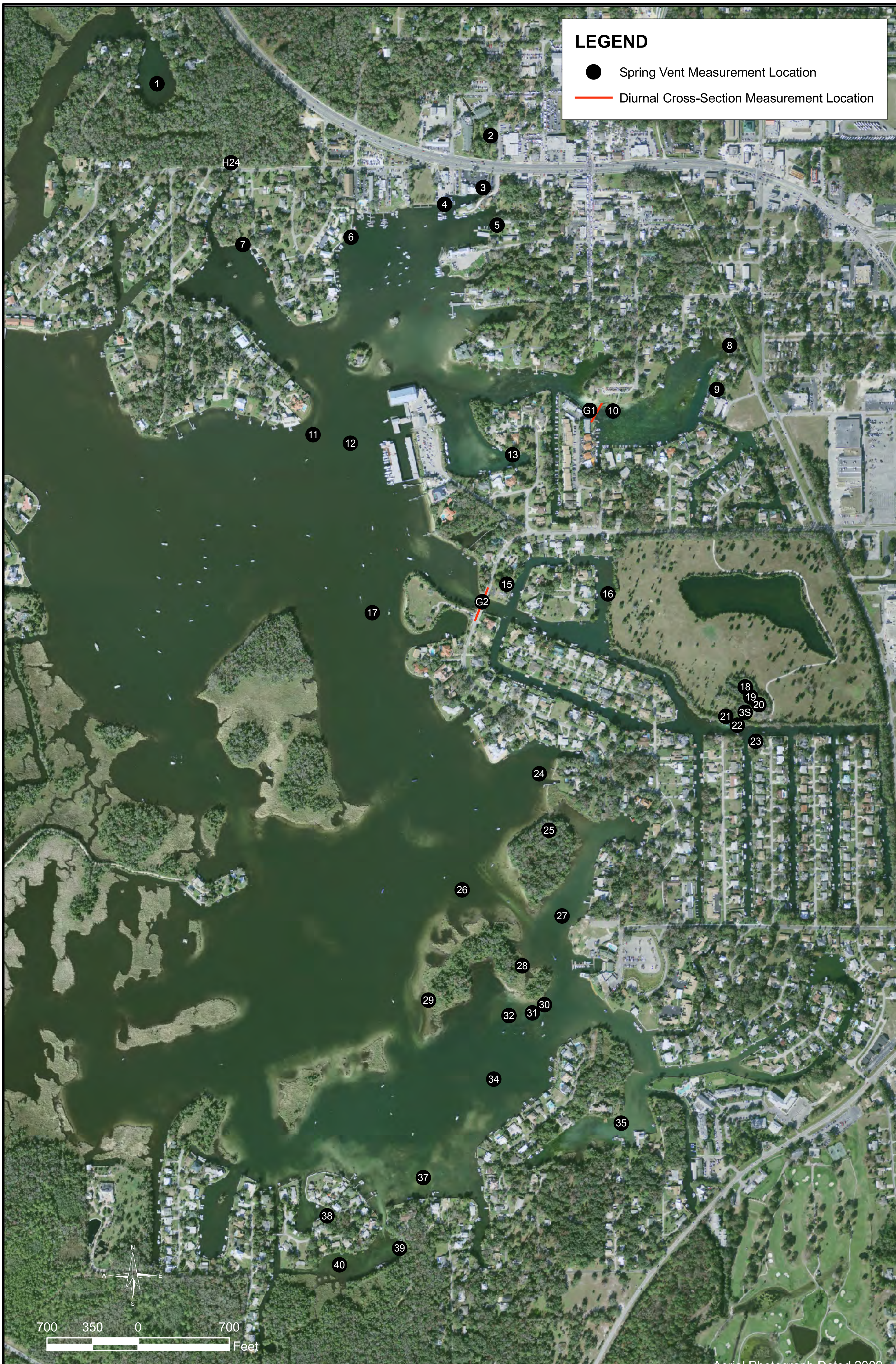
Vanasse Hangen Brustlin, Inc. (VHB) has completed flow and in *situ* water quality measurements of spring vents within the Kings Bay portion of Crystal River in Citrus County, Florida. The purpose of this project is to quantify spring discharge from submerged spring vents for use in a hydrodynamic model 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.

Methods

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 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.



Date: January, 2010

Revised:

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

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

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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 Measurement

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.

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	Loudoun County	Most	Yes*
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
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

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.

Results

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.

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.

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

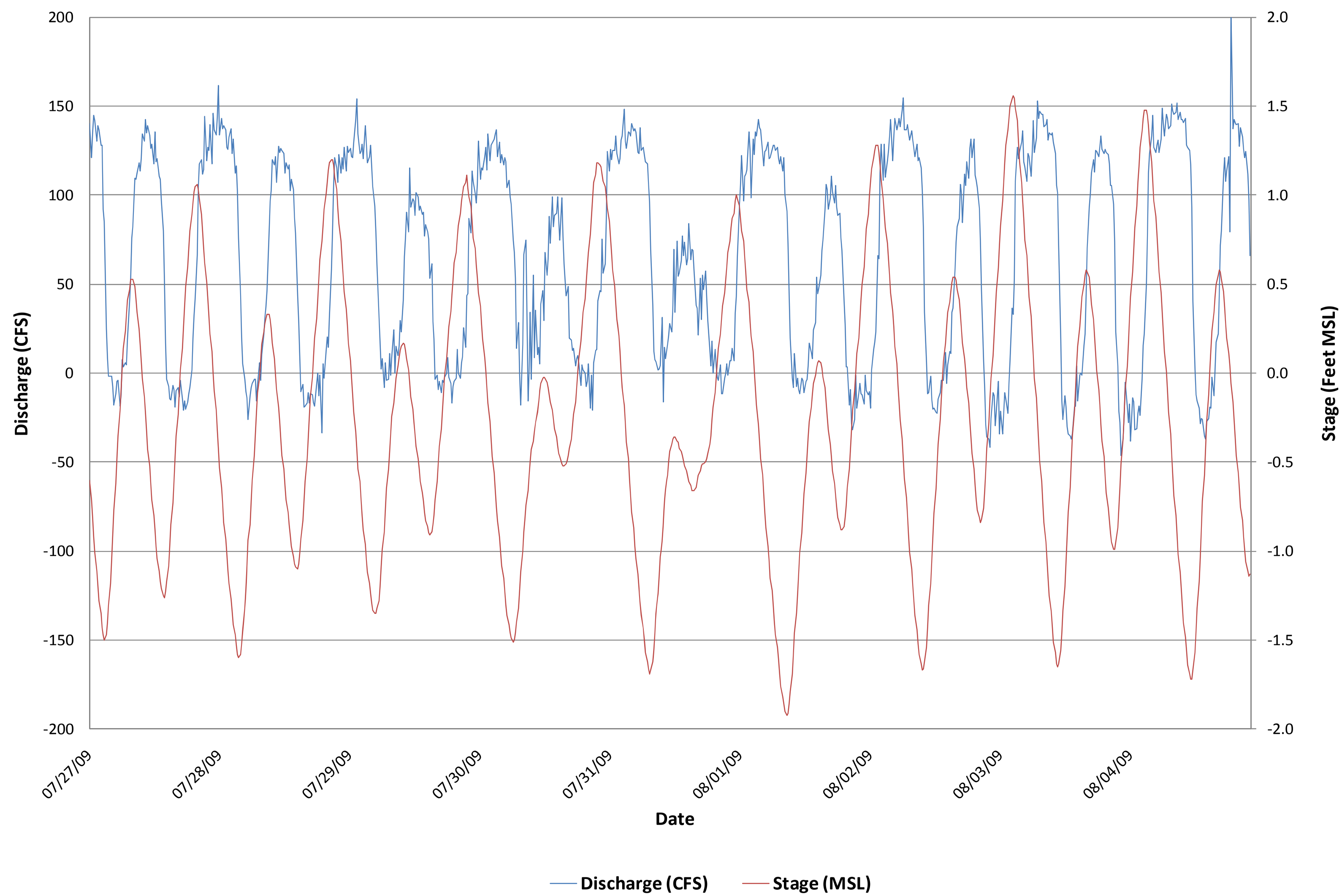
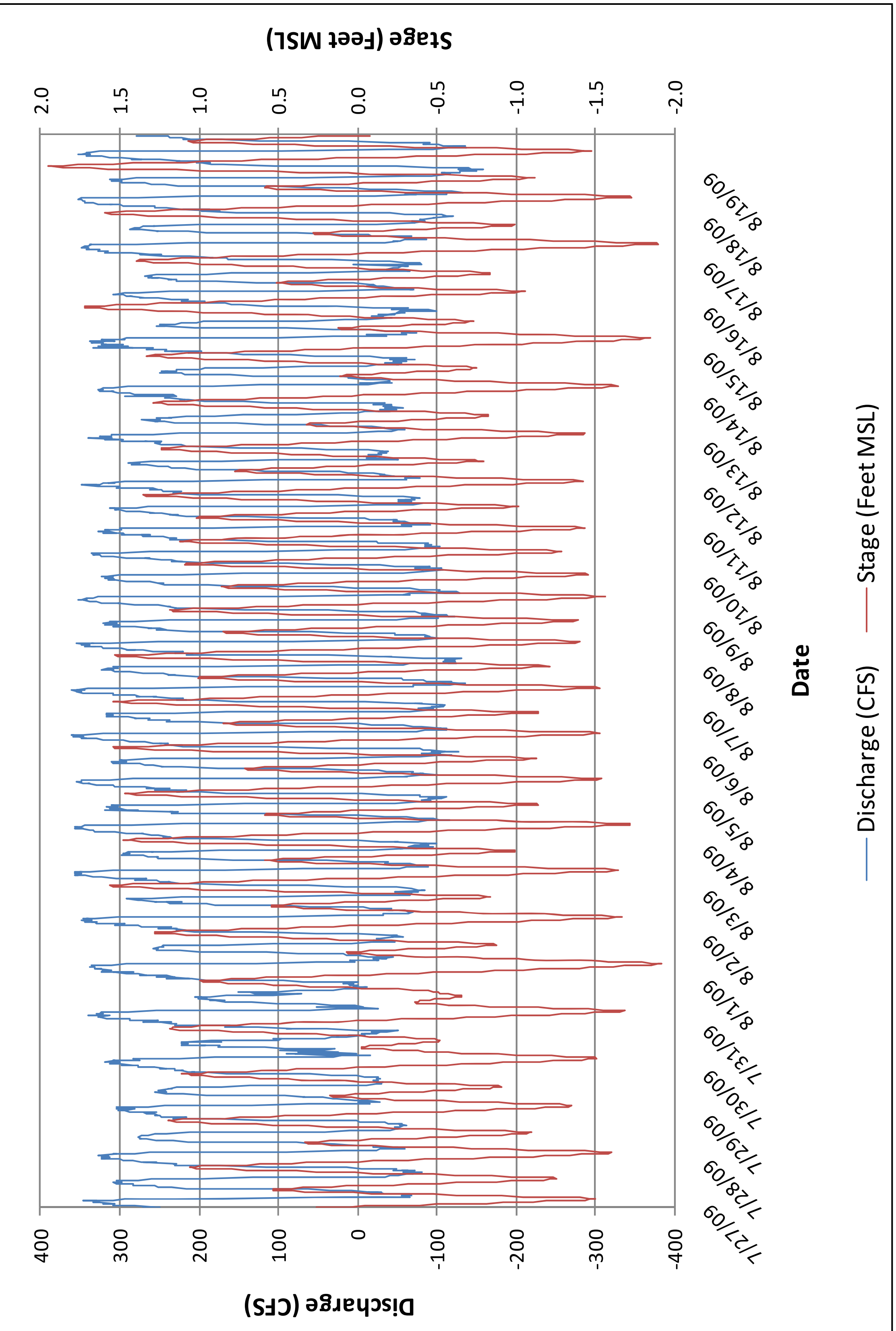


Figure 5. Calculated Discharge for Group 2 Springs, Kings Bay, Crystal River, Florida



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 R2 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 R2 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 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

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

							USGS STAGE DATA	
SITE	MEASUREMENT NO.	DATE & TIME	MEASUREMENT TYPE	MEASURED DISCHARGE	VENT AVERAGE	TOTAL DISCHARGE	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		
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

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

							USGS STAGE DATA	
SITE	MEASUREMENT NO.	DATE & TIME	MEASUREMENT TYPE	MEASURED DISCHARGE	VENT AVERAGE	TOTAL DISCHARGE	EST TIME	CORRECTED STAGE (MSL)
9	SV09081909a	8/19/09 12:30	Vent	21.04			1230	0.99
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		
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		

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

							USGS STAGE DATA	
SITE	MEASUREMENT NO.	DATE & TIME	MEASUREMENT TYPE	MEASURED DISCHARGE	VENT AVERAGE	TOTAL DISCHARGE	EST TIME	CORRECTED STAGE (MSL)
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
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
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

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

							USGS STAGE DATA	
SITE	MEASUREMENT NO.	DATE & TIME	MEASUREMENT TYPE	MEASURED DISCHARGE	VENT AVERAGE	TOTAL DISCHARGE	EST TIME	CORRECTED STAGE (MSL)
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
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
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

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

							USGS STAGE DATA	
SITE	MEASUREMENT NO.	DATE & TIME	MEASUREMENT TYPE	MEASURED DISCHARGE	VENT AVERAGE	TOTAL DISCHARGE	EST TIME	CORRECTED STAGE (MSL)
					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
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

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

							USGS STAGE DATA	
SITE	MEASUREMENT NO.	DATE & TIME	MEASUREMENT TYPE	MEASURED DISCHARGE	VENT AVERAGE	TOTAL DISCHARGE	EST TIME	CORRECTED STAGE (MSL)
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		
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
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

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

							USGS STAGE DATA	
SITE	MEASUREMENT NO.	DATE & TIME	MEASUREMENT TYPE	MEASURED DISCHARGE	VENT AVERAGE	TOTAL DISCHARGE	EST TIME	CORRECTED STAGE (MSL)
					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
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
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

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

SITE	MEASUREMENT NO.	DATE & TIME	MEASUREMENT TYPE	MEASURED DISCHARGE	VENT AVERAGE	TOTAL DISCHARGE	USGS STAGE DATA EST TIME	USGS STAGE DATA CORRECTED STAGE (MSL)
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
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		

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.

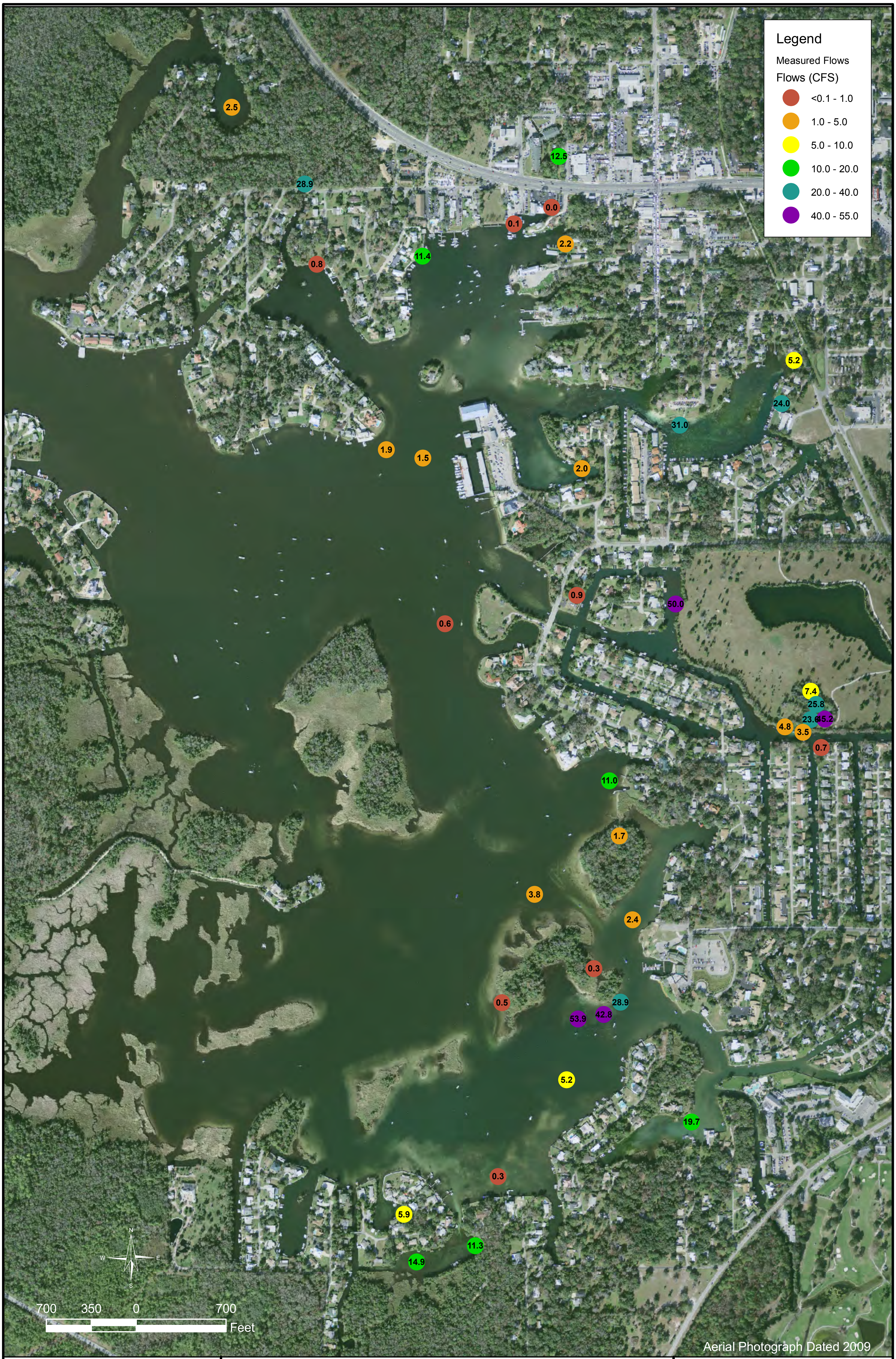
The electronic output from the multicell ADP vent measurements has been provided in digital format. The data for each measurement includes the spring measurement number, spring name, vent size and area, end distance of each bin cell, measured velocity in each bin for the six consecutive measurements, 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.

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 (oC), conductivity (umhos/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 oC 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.



Date: January, 2010

Revised:

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

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

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

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

											USGS STAGE DATA	
SITE NO.	MEASUREMENT NO.	VENT NO.	DATE	EST TIME	DEPTH (M)	TEMPERATURE (°C)	CONDUCTIVITY (umhos/cm)	SALINITY (ppt)	EVENT AVG. TEMP. (°C)	EVENT AVG. CONDUCTIVITY (umhos/cm)	EST TIME	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	25.0	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**		
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

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

											USGS STAGE DATA	
SITE NO.	MEASUREMENT NO.	VENT NO.	DATE	EST TIME	DEPTH (M)	TEMPERATURE (°C)	CONDUCTIVITY (umhos/cm)	SALINITY (ppt)	EVENT AVG. TEMP. (°C)	EVENT AVG. CONDUCTIVITY (umhos/cm)	EST TIME	CORRECTED STAGE (MSL)
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**		
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	0.30			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	0.30	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	0.30			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**		
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

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

											USGS STAGE DATA	
SITE NO.	MEASUREMENT NO.	VENT NO.	DATE	EST TIME	DEPTH (M)	TEMPERATURE (ºC)	CONDUCTIVITY (umhos/cm)	SALINITY (ppt)	EVENT AVG. TEMP. (ºC)	EVENT AVG. CONDUCTIVITY (umhos/cm)	EST TIME	CORRECTED STAGE (MSL)
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	0.70	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**		
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	1.60			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		**23.43**	**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
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	0.30			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

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 (⁰C)	CONDUCTIVITY (umhos/cm)	SALINITY (ppt)	EVENT AVG. TEMP. (⁰C)	EVENT AVG. CONDUCTIVITY (umhos/cm)	USGS STAGE DATA EST TIME	USGS STAGE DATA CORRECTED STAGE (MSL)
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
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

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

											USGS STAGE DATA	
SITE NO.	MEASUREMENT NO.	VENT NO.	DATE	EST TIME	DEPTH (M)	TEMPERATURE (⁰C)	CONDUCTIVITY (umhos/cm)	SALINITY (ppt)	EVENT AVG. TEMP. (⁰C)	EVENT AVG. CONDUCTIVITY (umhos/cm)	EST TIME	CORRECTED STAGE (MSL)
24	Spring 24 Background		9/24/09	11:30			5000	2.67				
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	23.30	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
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

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

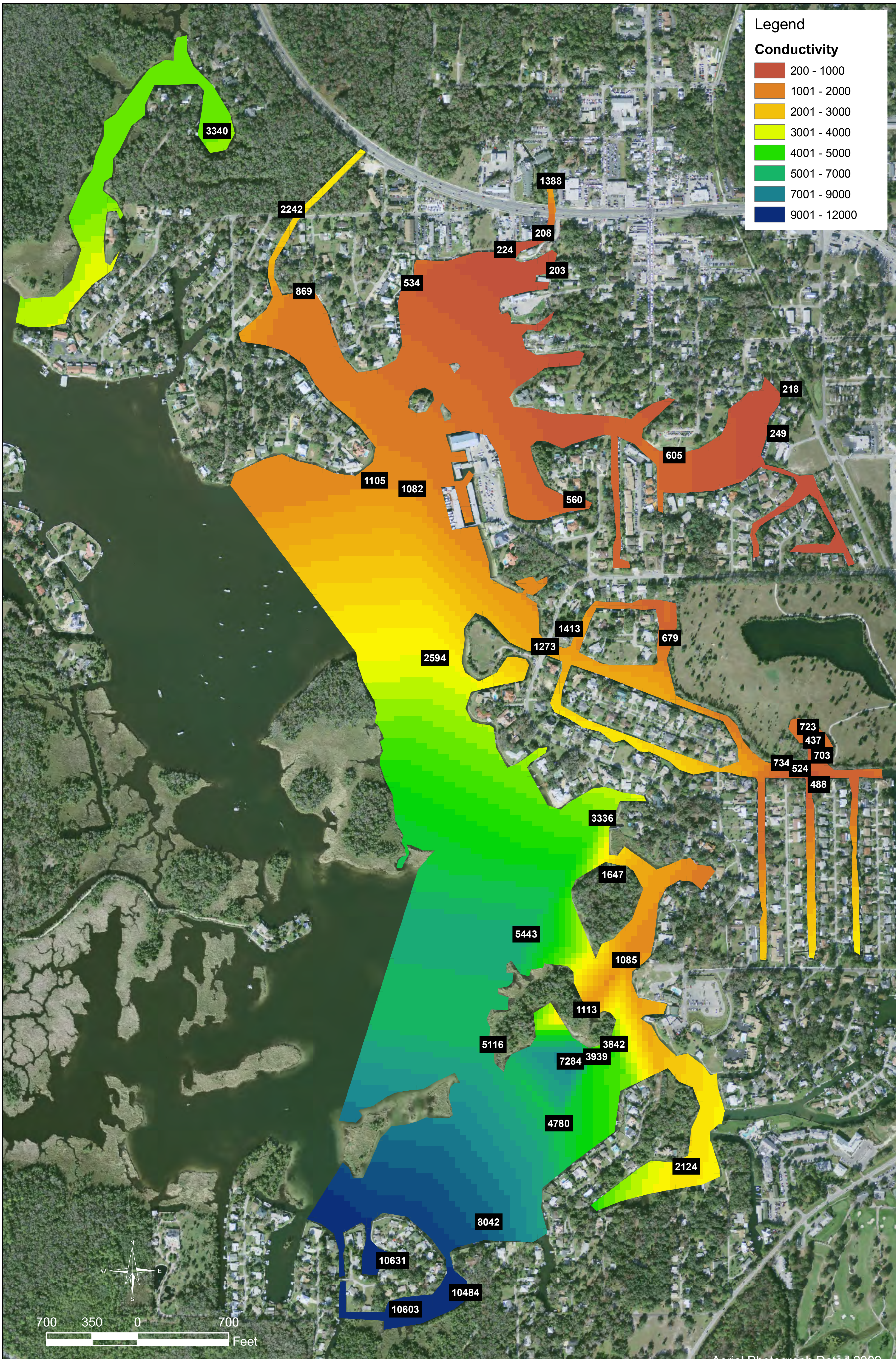
SITE NO.	MEASUREMENT NO.	VENT NO.	DATE	EST TIME	DEPTH (M)	TEMPERATURE (⁰C)	CONDUCTIVITY (umhos/cm)	SALINITY (ppt)	EVENT AVG. TEMP. (⁰C)	EVENT AVG. CONDUCTIVITY (umhos/cm)	USGS STAGE DATA EST TIME	USGS STAGE DATA CORRECTED STAGE (MSL)
34	SV34092309	1	9/23/09	13:35	2.80	23.28	4399	2.34			1330	-1.28
34	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**		
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

The spring conductivity varied spatially within Kings Bay from a low of 203 to a high of 12,096 umhos/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 umhos/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 umhos/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 umhos/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.

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).



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
UNIVERSITY PARK, FLORIDA 34201

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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.

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APPENDIX

Wang, P. 2008. Shoreline mapping and bathymetric survey for the Crystal River and King’s Bay system. Department of Geology, University of South Florida, Tampa, Florida. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Shoreline Mapping and Bathymetric Survey for the Crystal River and King's Bay System

Final Report

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March 1, 2008

INTRODUCTION

The Crystal River and King's Bay system survey project included: 1) the Crystal River and King's Bay and all the side creeks, 2) the Crystal River estuary, and 3) nearly all the navigable tidal creeks in the estuary. The project included two tasks: 1) mapping of the shoreline and 2) surveying of the bathymetry.

The shoreline configuration was mapped in the field using a RTK (Real-Time Kinematics) global positioning system (GPS). The shoreline position was obtained by navigating the survey vessel along the shoreline. The bathymetry was measured using a synchronized precision echo sounder with the GPS. Sections across the water body and centerlines were surveyed.

STUDY AREA

The project area along the Crystal River system is shown in Figure 1. The survey coverage began at King's Bay and covered all navigable natural creeks and channels leading to spring heads. Along the main river all the navigable branches and side creeks were included in the survey. A considerable number of tidal creeks exist in the lower stream (Figure 1). The bathymetry measurement included cross-section surveys spaced at 500 ft (150 m) or less and at least one centerline survey for every open navigable area. The shoreline of the main river and all the branches were mapped in the field by navigating the survey vessel along the shoreline. To cover the entire stretch of the river, the GPS base station (control point) was established at three different locations, including one on the north side of King's Bay, one at Crystal River State Archaeological Site, and one at Fort Island State Park.

Figure 1. Study area at the Crystal River system. The project area extends over the entire map.

FIELD METHODOLOGY

A 24-ft pontoon boat and a 15-ft aluminum boat were used for the shoreline and bathymetry survey (Figure 2). Both boats require only 1 ft (0.3 m) or less draft, but needs calm water to operate. The smaller boat was used to survey the shoreline and most of the narrow tidal creeks and the upper stretch of the river. These boats are ideal for this project.

Figure 2. The survey vessels, upper: the pontoon boat; lower: the 15-ft aluminum boat.

Shoreline Mapping

The shoreline was mapped with the RTK GPS mounted on board the survey vessels. The shoreline positions were obtained by navigating the survey vessel as close to the vegetated shoreline as possible. In the present study, the shoreline is defined as the clear boundary between vegetated land and water. Same definition would apply to digitize shoreline from aerial photos or maps. Given the relatively low tidal range, typically less than 3 ft (1 m), the shoreline (as defined here) position is not significantly influenced by tidal water-level variations in most areas. The shoreline survey was mostly conducted during high tide. Most of the vegetated boundary remains clear regardless of tidal stage.

The shoreline survey was conducted using the 15-ft boat. The shoreline mapped here is typically 3 to 6 ft from the actual vegetation line along the riverbank. Given the typical width of several hundred feet, this limitation should not have any significant influence on the mapping of the river configuration. However, this limitation may induce considerable uncertainty in the shoreline position at some of the narrow creeks, simply because 3- to 6-ft length equals a considerable portion of the creek width.

A portion of the end stretch of the Crystal River, i.e., near the Gulf, has numerous biohermal (oyster bar) structures. These oyster bars caused some difficulties of navigating the boat for both shoreline and cross-section surveys. The shoreline survey along this section was conducted at a substantial distance from the actual shoreline to avoid the rocks, but to also capture the bathymetry near the structures. Some of the cross-section surveys were also conducted at locations away from the rocks for safety.

The positions of the shoreline were corrected during the data processing phase by manually moving the survey points about 4.5 feet (1.5 m) landward, as discussed and agreed with the SWFWMD researchers. The moved shoreline position is double-checked with rectified LABIN aerial photos. At places where the surveyed shoreline was obviously far from the actual shoreline dune to protruding docks, very shallow water, or rock outcrops, the LABIN photo was used to position the shoreline. No elevation values were assigned to this "edited" shoreline position. Water depth was measured during the mapping of the shoreline. These water depths were used in the mapping of the bathymetric contours.

The software HYPACK version 6.2 was used to manage the sampling of the RTK GPS system and the Odem survey grade echo sounder. Dynamic sampling regulated largely by the quality of the RTK GPS position reading was conducted using this newest version of HYPACK. The close spacing reduced the uncertainty of interpolation between points. Given the complicated shoreline configuration, closely spaced sampling is important for accurate mapping.

Additional uncertainties in the shoreline mapping were caused by obstacle intrusions, both natural and artificial. Along some parts of the populated shoreline, the protruding boat docks caused some uncertainties for shoreline mapping (Figure 3). The survey vessel had to be navigated around the docks. The relative errors caused by the boat docks are not high because they tend to concentrate in areas with relatively wide water body.

The shoreline mapping is also influenced by various protruding natural objects, particularly overturned tree trunks. These tree trunks might become dangerous navigational hazard because many of them extending underwater. The survey vessel had to be navigated around them. Another shoreline-mapping obstacle is the low overhanging trees, especially those "horizontally-growing" palm trees (Figure 4). It was not possible for the survey vessel to be navigated under the trees. Therefore, the vessel had to deviate from the shoreline to avoid the trees. As discussed above, rock outcrops was a substantial problem for sections of Crystal River.

Some of the obvious shoreline intrusions, e.g., those that created a sharp concave shape along an otherwise straight stretch of shoreline, were corrected in the lab during the processing of the shoreline data. Also, field notes were taken at some of the substantial intrusions. These were also corrected based on the field notes, and rectified LABIN aerial photos.

Figure 3. Protruding boat docks caused some problem in shoreline mapping.

Figure 4. Protruding palm trees caused some problem in the shoreline mapping.

These obstacles, both artificial and natural, did not have significant influence on the overall shoreline mapping. Their impacts were mostly scarce and local. Limited by the scope and budget of the present project, most of their locations were not marked in the shoreline mapping. These artificial and natural protruding obstacles had minimal impact on the bathymetry survey. The survey lines were selected such that the obstacles were avoided.

Bathymetry Survey

The bathymetry was measured with a narrow-beam (2.8 degrees) echo sounder. The narrow beam sensor was designed to obtain accurate depth measurement over steep slope, which is ideal for the present project. The sensor was mounted at 0.59 ft (18 cm) below the water surface on the pontoon boat and 0.39 ft (12 cm) below on the aluminum boat (Figure 5). The sensor has a minimum range of approximately 1 ft (30 cm). Therefore, the minimum measurable water depth for the present system is roughly 1.6 ft (50 cm).

Under most circumstances, the survey lines are roughly perpendicular to the shoreline (Figure 6). The survey lines were space at 500 ft (150 m) or less to ensure adequate spatial coverage. Additional survey lines were added at areas with complicated bathymetry. Some of the creeks are too narrow, e.g., less than 80 ft (25 m) wide. A large portion of the creek could not be covered by the survey vessel simply because the sensor was mounted in the middle of the vessel. In this case, in addition to cross sections, a survey line following a zigzag pattern along the creek was added. A centerline was surveyed over the entire project area.

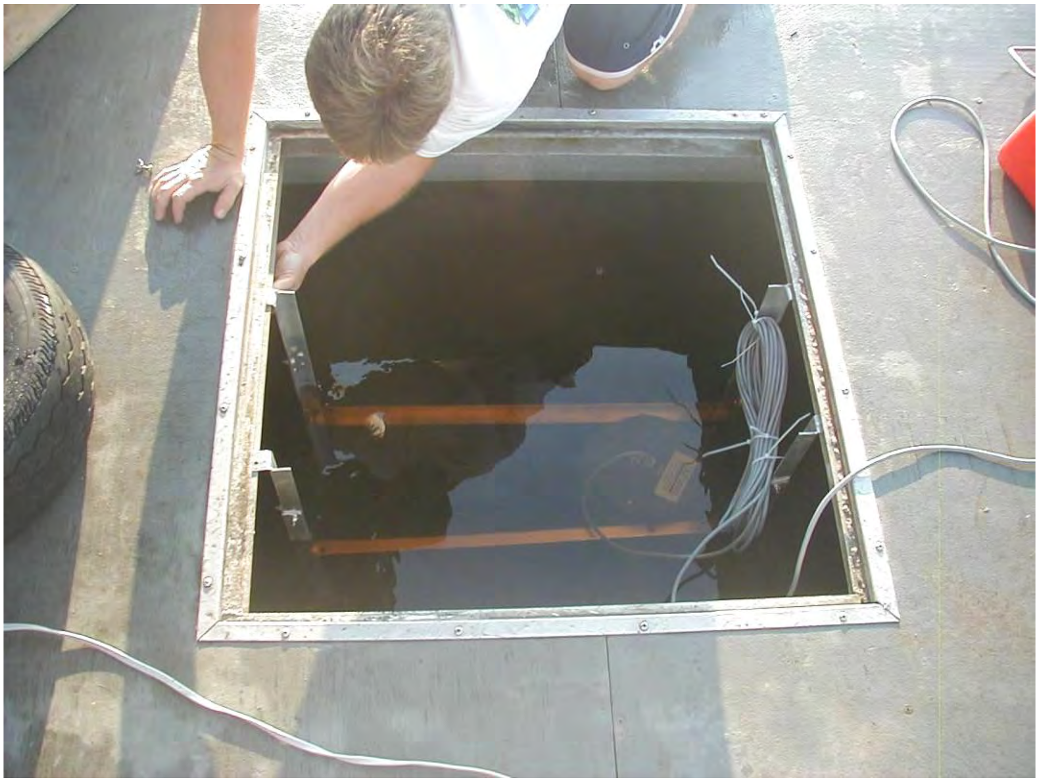


Figure 5. The survey echo sounder was mounted at 18 cm below water surface.

The echo sounder is synchronized and co-located with the GPS system. The GPS yields horizontal position, in terms of latitude and longitude, and the echo sounder provides water depth measured at the same time as the geographic position. The survey was administrated using the most recent HYPACK survey software version 6.2.

Figure 6. Surveying cross sections.

Several sources may induce errors in the survey. The echo sounder sometimes became unstable in shallower water, mostly when water depth became shallower than 2 ft (0.6 m) in combination with relatively rough conditions. Occasionally, the echo sounder will return a reading of zero. These erroneous readings were removed during the data processing. The reason for the zero reading is related to the echo sounder interpretation of soundings.

Occasionally, the echo sounder returned a reading that was apparently twice the water depth (Figure 7). This seems to be caused by multiple reflections of the sound signal, i.e., the signal was reflected back and forth twice between the bottom and the sensor. The signal was never reflected back and forth for more than two times. These points were corrected by simply dividing the multiple reflections by two. A computer routine was developed to correct these apparent multi-reflections. Hypack software in conjunction with the precision echo sounder, record the full spectrum of soundings with each file recorded in Hypack. This sounding file is visualized in Hypack with the overlain recorded values displayed in an editing menu. The program will check the general trend of water depth and compare with adjacent depth. If a point was approximately twice of those adjacent measurement, it would be corrected by dividing by two (or three or four under rare occasions). Also, because of the visualized sounding editing window, adjusted or edited depths are double checked with the first bottom sounding signal. Figure 7 illustrates the multiple reflections and the corrected water depth (solid square). The reason for the multiple reflections is not clear. Bottom conditions, e.g., hard sand and oyster-reef bottom versus soft mud bottom, may have some influences. The HYPACK software also allows a certain degree of data smoothing during the initial data quality check and processing.

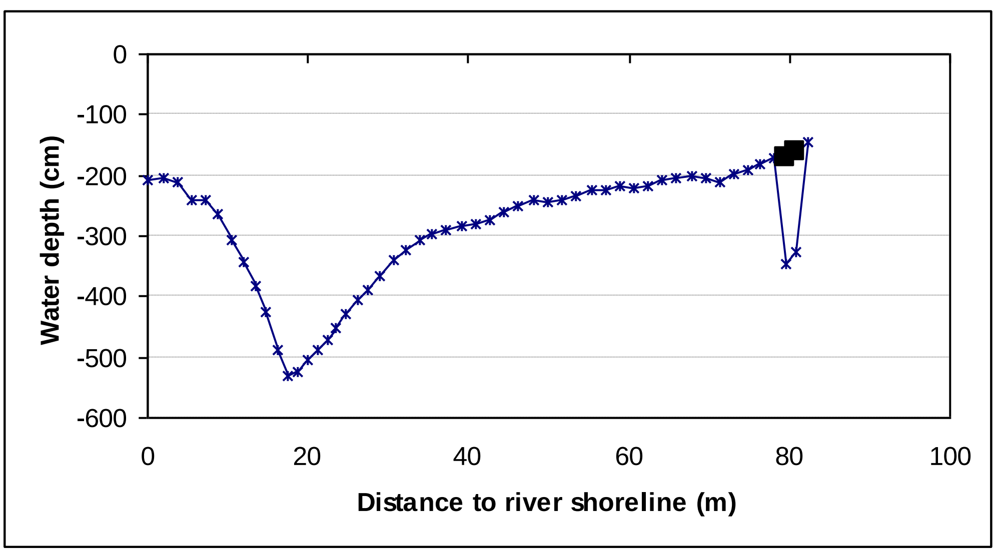


Figure 7. Multiple reflections in the echo sounder record. The solid squares are corrected water depth. An example of a cross section at Peace River (from an earlier SWFWMD project).

Because the echo sounder is mounted on a floating platform, wave motions can cause errors in the measurement. Various software packages are available to remove uncertainties caused by wave motion. Typically, a certain filter is applied to remove regulated wave motions. For the present project, influences of wave motions were minimal due to the relatively restricted water bodies.

The field operation over relatively open water, e.g., in the estuaries, was conducted during calm conditions to minimize influences of waves. No field operation was conducted when the waves were higher than 1 ft. The waves in the project area were largely local-wind generated, with short wavelength and wave period. Most of the time, the wavelength is shorter than the length of the survey vessel. Motions caused by these short waves are not apparent in the record. Given that all the field operations were conducted with waves far less than 1 ft, it was decided that wave-motion filtering was not necessary and was not likely to improve the data accuracy.

Wave motions seemed to have some influence on the performance of the echo sounder. The wave motion may induce pitch and roll of the survey vessel. The influences of the pitch and roll are not apparent in the data record. It was difficult to detect because of the short wave period and wavelength, which tend to induce rather irregular motion. No procedure was adopted to remove the potential influence of pitch and roll. Their influences are believed to be negligible for this project.

Another uncertainty associated with the floating platform survey was caused by the tidal water-level variations. Nearly the entire study area is influenced by tides, both astronomical and meteorological. To improve the sensor performance, especially in shallow areas, the field operations were mostly conducted during high tides. It is necessary to remove the influence of tidal water-level variations. The elevation of the water surface was measured by the RTK GPS. The trend of tidal water level change was clearly reflected in the GPS elevation measurements. The elevation of the bed level is obtained by subtracting the depth reading obtained from the echo sounder from the water surface elevation obtained from the RTK GPS. The vertical datum NAVD88 was used in the survey.

Data Format and Organization

The horizontal latitude and longitude positions were recorded by the GPS in reference to NAD83. The latitude and longitude positions were converted to Florida State Plane coordinates (NAD 83) and UTM 17, in meters, using the CORPSCON (Version 6) software developed by the U.S. Army Corps of Engineers. The digital files are submitted in the formats of Excel spreadsheet and ASCII Text. The data are submitted in three sets includes:

Set I: Edited and Surveyed data, which include

a) Surveyed shoreline positions in Florida State Plane and UTM 17 coordinates in meters and elevations in meters (NAVD88 – m);
b) Surveyed centerline positions in Florida State Plane and UTM 17 coordinates in meters and elevations in meters (NAVD88 – m);
c) Surveyed cross-sections in State Plane and UTM17 Northing in meters, State Plane and UTM17 Easting in meters, and elevation in meters (NAVD88-m);
d) Edited shoreline positions in State Plane coordinates in meters with elevations in centimeters (100 cm shoreline elevation);

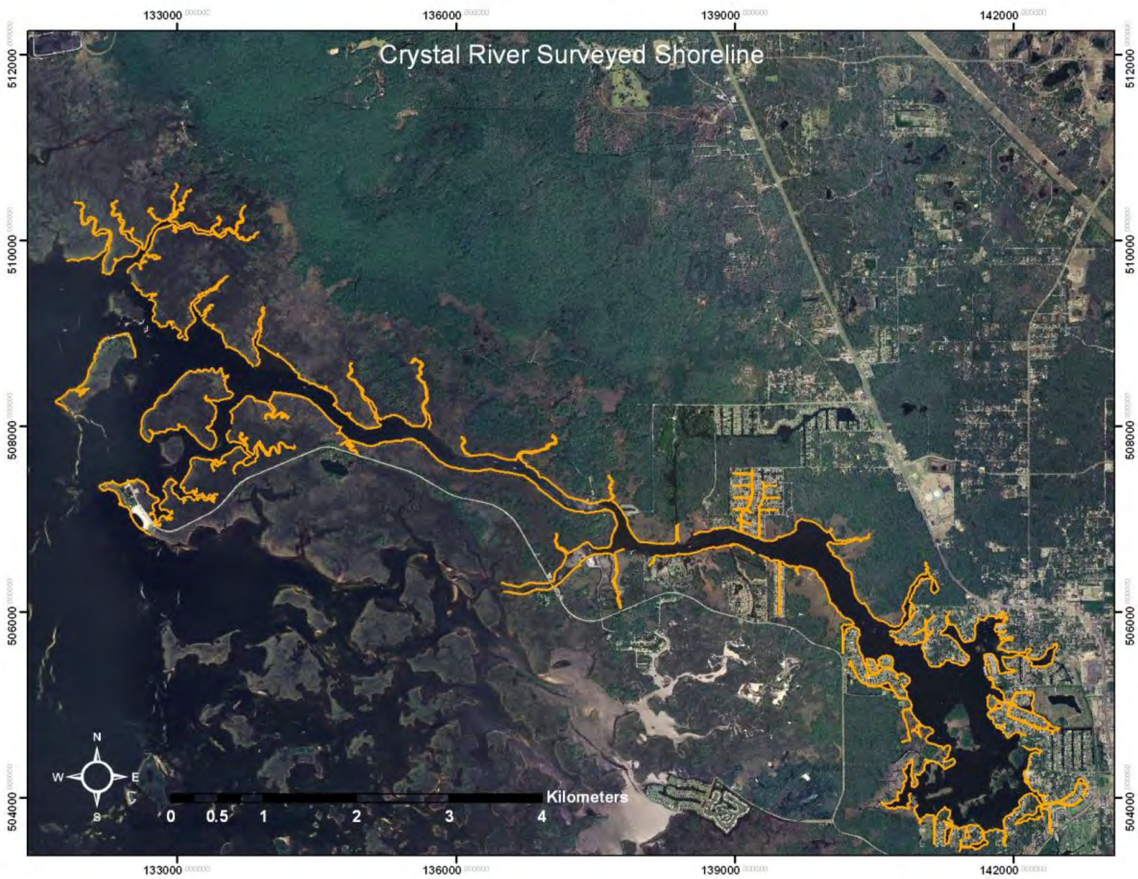
Set II: GIS maps including the bathymetry contour and shoreline and surveyed data maps of the entire project area, in State Plane West FIPS 0902 coordinate system. All GIS datasets are in Shapefile format and are included in the ArcGIS map file.

Set III: JPG format of the GIS maps including the bathymetry contour and shoreline maps of the entire project area.

The GIS maps are preliminary in the sense that detailed work to improve the map presentation was not conducted. However, the data processing was completed. The details of the contour maps can also be improved by improving the data interpolation schemes in areas with complicated sinuosity. However, the overall bathymetric characteristics are clearly reflected in the present maps. It is beyond the scope of this project to produce detailed local bathymetry maps although the coverage of the field data is adequate to do so. It is worth emphasizing that the bathymetry here is interpreted by the USF researchers and may be different from other interpretations, although the differences are expected to be minor.

Deliverables

The final deliverables include a final report, consisting of two parts. Part I (this volume) documents the field operation procedures, data processing schemes, estimates of uncertainties, and data organization. Part II (accompanying volume) includes the GIS datasets (in State Plane West FIPS 0902 Coordinates in meters, bathymetry in meters). All the processed data are delivered on one CD with each set as one folder.



Crystal River Surveyed Shoreline
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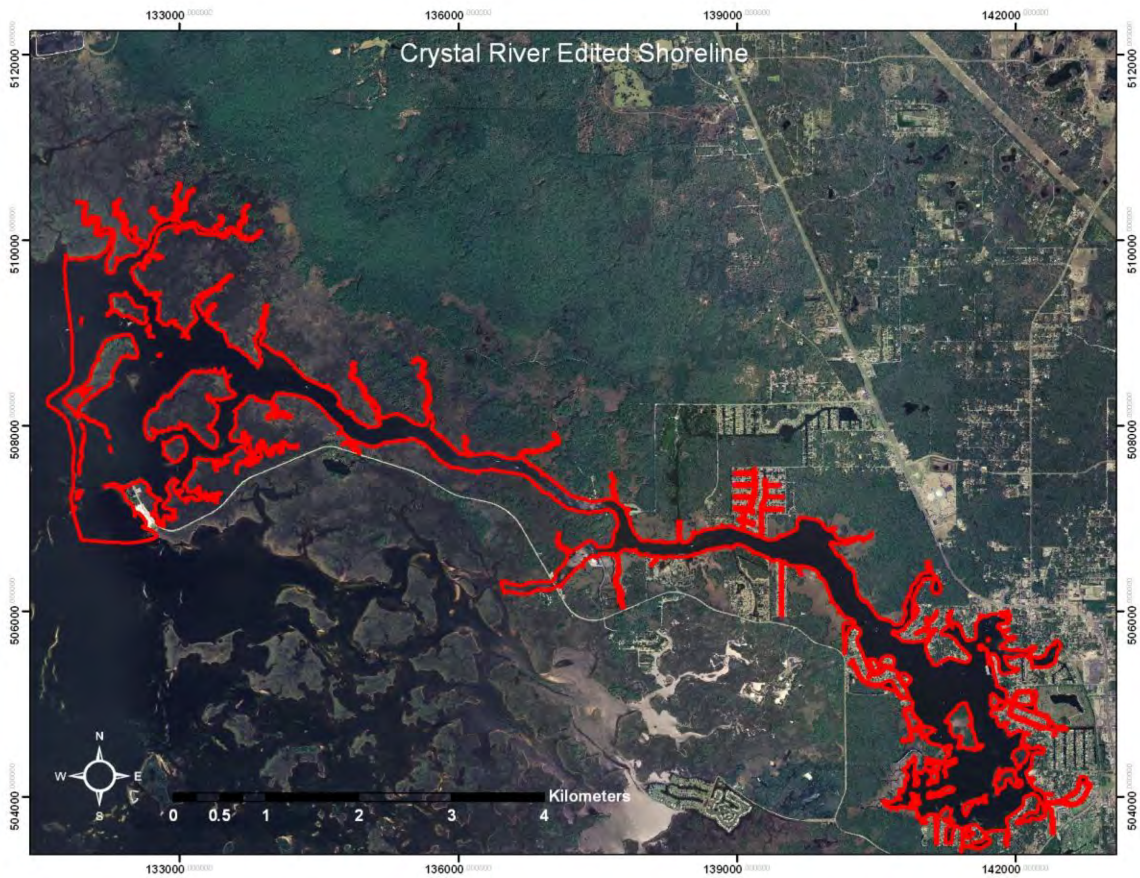

Crystal River Edited Shoreline
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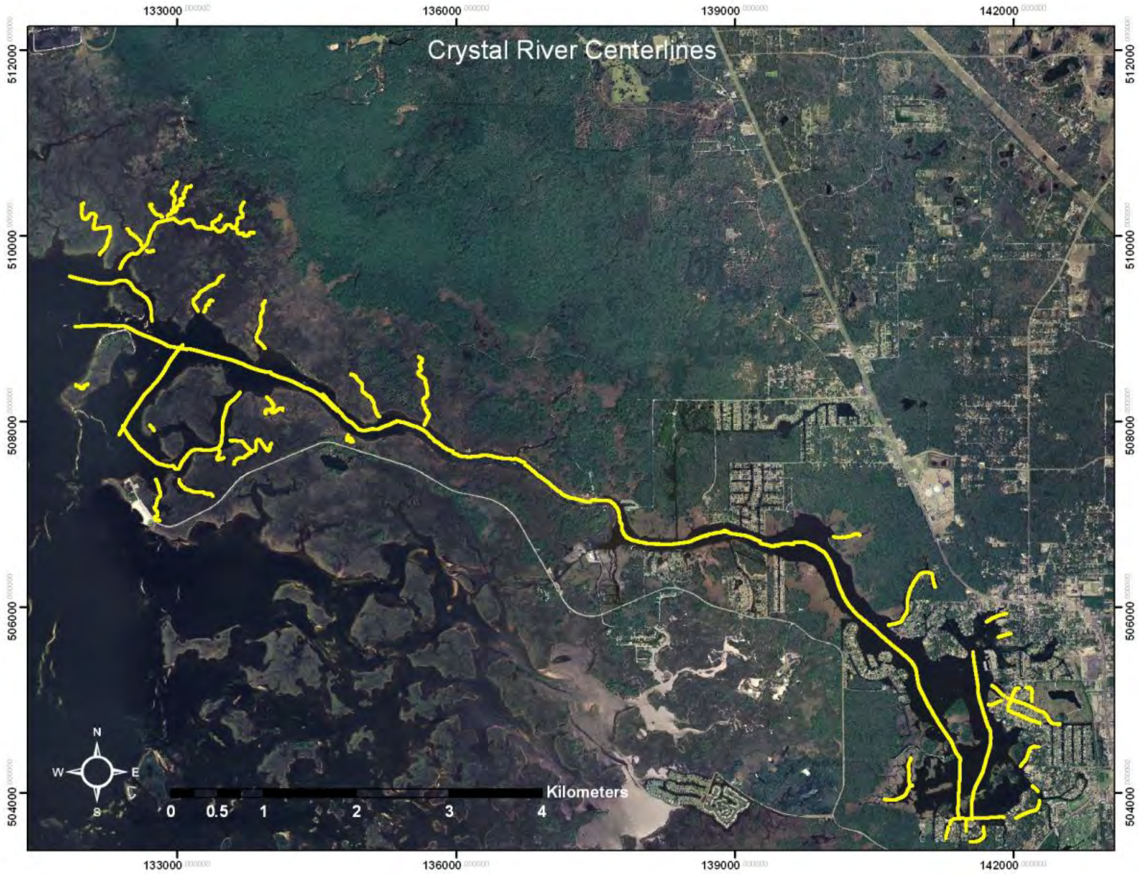
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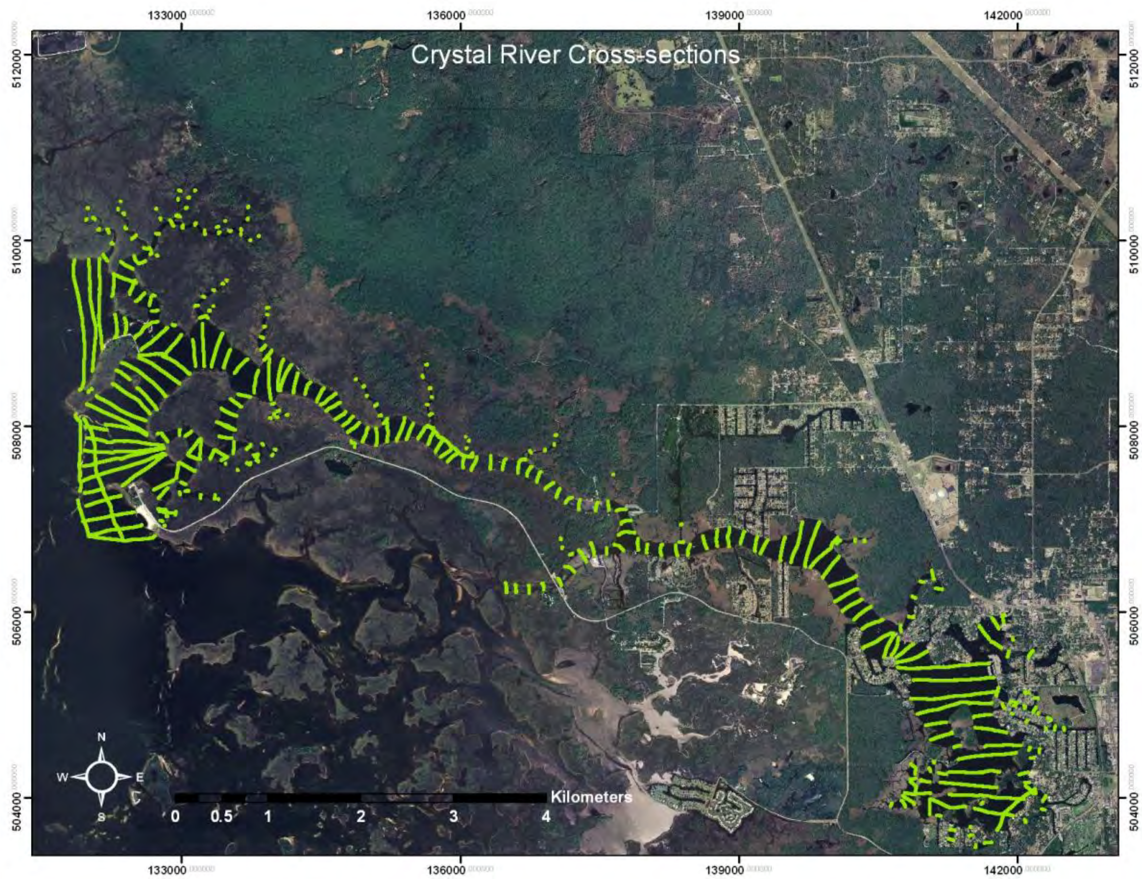
Crystal River Cross-sections
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Crystal River Islands
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Crystal River Surveyed Data
Legend
Shoreline
Islands
Cross-sections
Centerlines
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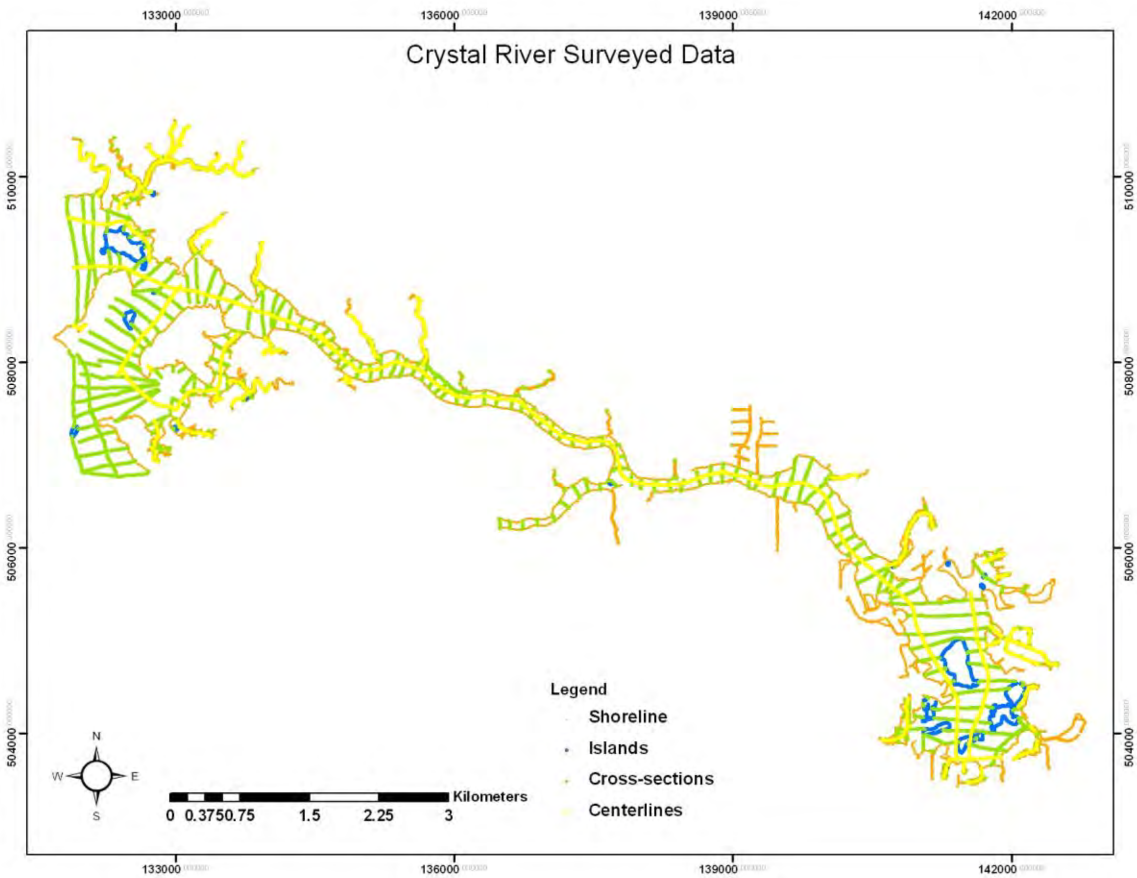

Crystal River Surveyed Data
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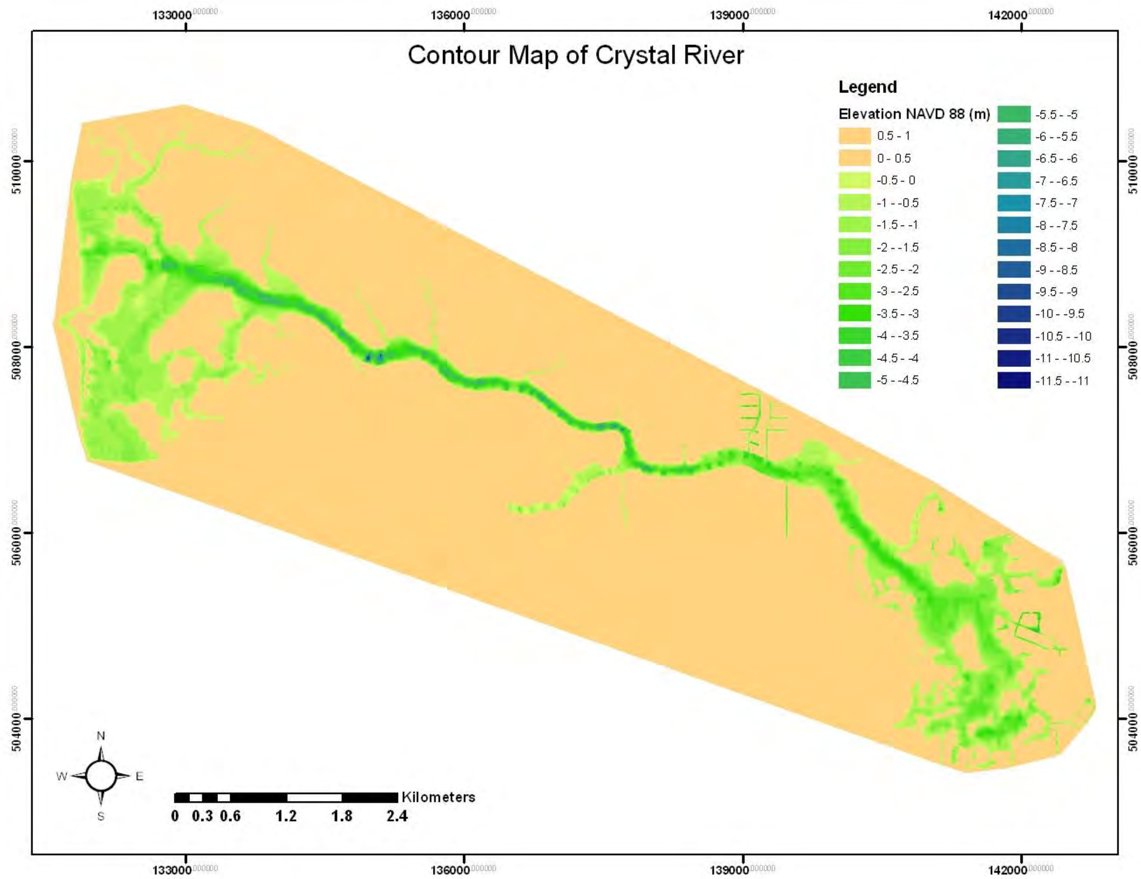

Contour Map of Crystal River
Legend
Elevation NAVD 88 (m)
0.5 - 1
0 - 0.5
-0.5 - 0
-1 - -0.5
-1.5 - -1
-2 - -1.5
-2.5 - -2
-3 - -2.5
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APPENDIX

Yobbi, D. 2014. Review of the response memo and technical report “On the estimation of submarine groundwater discharge to Kings Bay” by XinJian Chen, dated November 4, 2014 and November 20, 2014 respectively. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Review of the response memo and technical report "On the estimation of submarine groundwater discharge to Kings Bay", by XinJian Chen, dated December 4, 2014 and November 20, 2014 respectively.

By

Dann Yobbi

December 15, 2014

The scope of this memorandum is two-fold. The first objective is to provide a final review of the response memo and latest technical memo dated December 4 and November 20, 2014, respectively. The second objective is to provide a brief discussion of the reported discharge at the USGS gaging station 02310750 (Crystal River near Crystal River).

To summarize, I provided a written review in the form of a memo dated May 19, 2014 for the draft technical memo "On the estimation of submarine groundwater discharge to Kings Bay" dated February 27, 2014. On July 25, 2014, Dr. Chin provided a power point thoroughly describing the research and clarifying definitions of various technical words used in the report. As requested by the Southwest Florida Water Management District, I reviewed Dr. Chen's memo and technical report. While Dr. Chen provided an answer to each of my questions, several hydrologic issues were not sufficiently addressed. These hydrologic issues are:

One, I'm concerned about the calculation of negative flow into the springs without convincing field evidence to support this hydrologic condition. The field data presented in this report do not support your hypothetical model results presented at our July 25, 2014 of reverse (negative) flow into the springs. Table 1 of the technical memo (see below) contain no negative values for measured spring flow indicating that negative spring flows were not observed during the data collection period from July 28 through October 8, 2009. However, figure 15 found in this report and enclosed with this memo, shows that negative discharges occur about 10 percent of the 60-day record (August 22, 2007 to October 20, 2007). My concerns regarding spring flow reversals were dismissed in the response memo stating "spring flow can be temporary negative and data indicating this phenomenon occurs in Kings Bay are available" but no data or real ground-water system analysis of this phenomenon is presented.

Two, the hydrologic data collected over a 2 1/2-month period of record (July 28 through October 8, 2009) are listed in table 1. The short period of record greatly reduces the likelihood that the mean value of this limited data set is the long-term mean spring flow. The long-term seasonal and annual fluctuations would seldom if ever be adequately reflected in a single 2 1/2 data collection period; therefore it is unlikely the 467 ft^3/s represent the long-term mean ground-water discharge to Kings Bay.

Three, the estimates (quantification) of groundwater discharge to Kings Bay were calculated using the derived empirical equation described in the report. Conclusions presented in the report include extrapolating spring flow (groundwater discharge) estimates beyond the limited range of observed groundwater levels at ROMP TR 21-3. A report section discussing the uncertainty in the flow estimates outside the observed field data is advised.

Discharge of Crystal River near Crystal River (02310750)

Discharge of Crystal River (02310750) measured about 3 miles downstream of Kings Bay is highly tidal and includes spring flow from Kings Bay, diffuse seepage along the reach between Kings Bay and the gaging station, and upstream tidal flows and storage in Crystal River and Salt Creek. Separation of groundwater discharge from tidal flows at this site is difficult because of the relatively small ratio of freshwater flow to instantaneous tidal flows. At Crystal River during normal high tidal cycles the maximum positive (downstream) flow can be 4,000 ft^3/s and the instantaneous negative flow (upstream) can be more than 10,000 ft^3/s (Mann and Cherry, 1969).

Discharge data for Crystal River (02310750) were computed by the USGS from 1965 to 1977 and for periodic days in 1983-85 (fig.1). A deflection (vane) meter was used from 1965-77 and an advanced acoustic velocity meter was in use during 1983-85 to provide an index to calculate discharge. Calculated mean discharge of Crystal River across this section was highly variable ranging from about from 507 to 975 cubic feet per second (table 2). The higher values of 975 and 916 ft^3/s were calculated from 13 and 11 mean annual discharges, respectively (Yobbi and Knochenmus, 1989; Rosenau and others, 1977). Discharge calculated at this site using the more precise acoustic velocity-index method for 65 periodic days in 1983-85 (fig. 1) was 534 (441 ft^3/s lower than in 1965-77). Based on 50 days of record, mean discharge for water year 1985 was 507 ft^3/s while the mean annual water level in the Weeki Wachee well was 0.5 ft higher in 1985 than during the 13-year period from 1966-77.

There are several problems in the estimation of discharge at this site. The large variation from 507 to 975 ft^3/s (table 2 enclosed) reflect changes in equipment, error introduced from equipment malfunction, rating development difficulties (poor site), period of record, and method of analysis used to calculate means. Difficulties (lack of precision) when estimating discharge are errors associated with the cross-sectional area and mean-velocity ratings. Sources of measurement error are from instrument issues and rating difficulties related to natural hydrologic conditions at the site. The measurement of deflection meter index velocity (1965-77) is problematic due to the vane design. The most serious design flaw is the tendency to collect floating debris, affecting calibration of the vane. This debris problems also occurred during 1983-85 and as a result most of the velocity data collected using an advanced acoustic velocity meter at the site were unusable.

It appears that the reported discharge for Crystal River during 1965-77 may be overestimated, based on the significantly lower discharge data calculated using better instrumentation during the generally higher ground-water hydrologic conditions in 1983-85, as compare to 1965-77. Instrument precision and rating accuracies are critical for accurate calculations of discharge for Crystal River below Kings Bay.

Selected References

Mann J.A. and Cherry, R.N., 1969, Large springs of Florida's "Sun Coast", Citrus and Hernando Counties, Florida: Florida Bureau of Geology Leaflet no. 9.

Rosenau, J.C., Faulkner, G.L., Hendry, C.W., Jr., and Hull, R.W., 1977, Springs of Florida (revised): Florida Bureau of Geology Bulletin 31.

Yobbi, D.K. and Knochenmus, L.A., 1989, Effects of river discharge and high-tide stage on salinity intrusion in the Weeki Wachee, Crystal, and Withlacoochee River estuary, southwest Florida: U.S. Geological Survey Water Resources Investigations Report 88-4146.

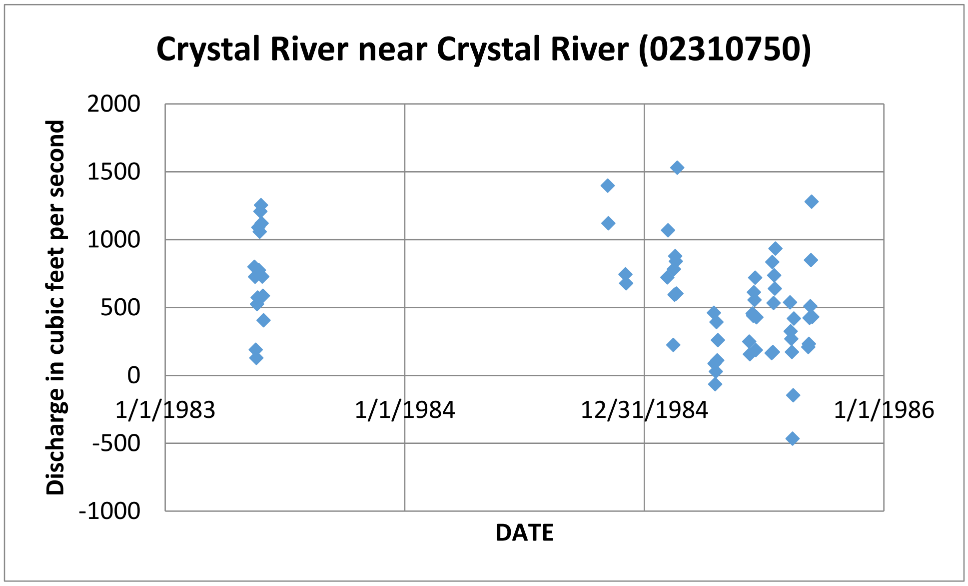

Figure 1. Mean daily discharge of Crystal River near Crystal River for select days, 1983-85.

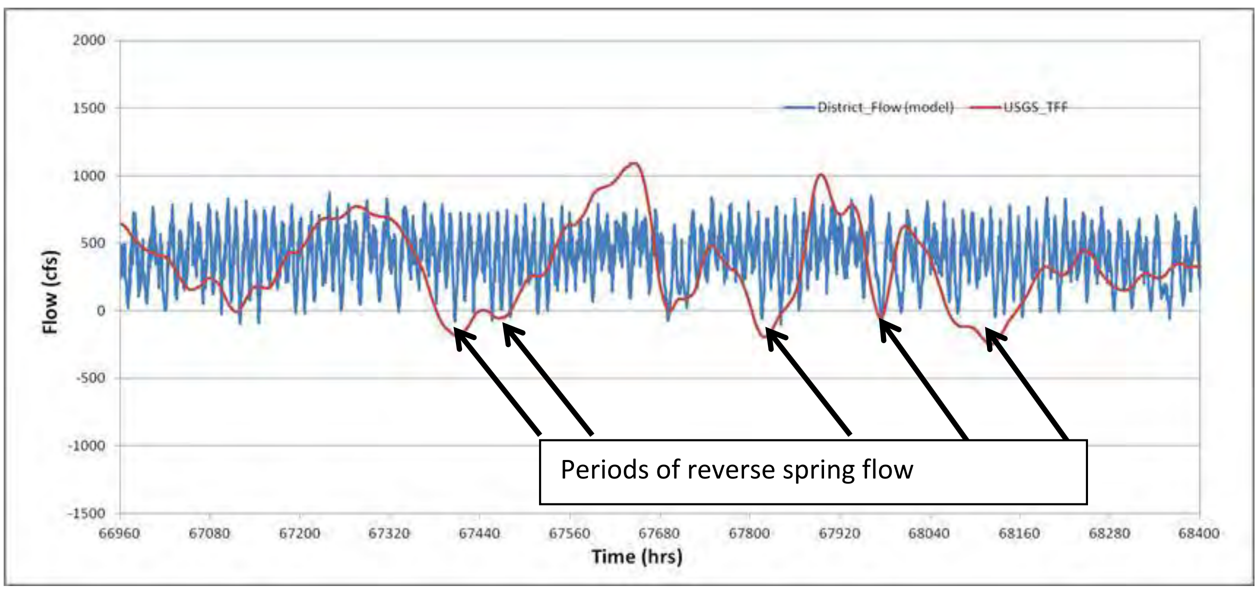

Figure 15. Comparison of USGS tidally-filtered discharge through Bagley Cove (red line) with the total SGD estimated using the empirical formula (blue line, marked as "District_Flow (model)" in the legend of the graph) during a 60-day period from August 22, 2007 to October 20, 2007. 1 cfs = 0.0283 m^3/s.

Spring Site	Field Trip #	Min Q	Max Q	Mean Q	Mean Sal	Mean Temp
H24	2	0.236	1.401	0.819	1.14	24.94
1	2	0.027	0.117	0.072	1.75	22.93
2	2	0.213	0.495	0.354	0.69	24.52
3	1	0.001	0.001	0.001	0.10	23.26
4	1	0.003	0.003	0.003	0.11	23.26
5	1	0.064	0.064	0.064	0.10	23.37
6	2	0.219	0.429	0.324	0.27	23.33
7	3	0.022	0.022	0.022	0.43	23.22
8	4	0.095	0.209	0.148	0.10	23.32
9	4	0.606	0.727	0.678	0.12	23.31
10	4	0.792	0.941	0.878	0.29	23.32
11	2	0.049	0.061	0.055	0.55	23.34
12	1	0.042	0.042	0.042	0.54	23.42
13	1	0.055	0.055	0.055	0.27	23.49
15	2	0.003	0.047	0.025	0.71	23.48
16	3	1.160	1.568	1.416	0.33	23.49
17	1	0.017	0.017	0.017	1.22	24.08
18	4	0.147	0.278	0.209	0.34	23.42
19	4	0.167	1.087	0.731	0.21	23.43
20	4	1.058	1.469	1.281	0.34	23.38
21	5	0.068	0.190	0.137	0.36	23.40
22	3	0.093	0.105	0.098	0.26	23.40
23	5	0.012	0.027	0.021	0.24	23.40
24	1	0.311	0.311	0.311	1.72	24.01
25	3	0.039	0.058	0.049	0.83	23.30
26	2	0.064	0.158	0.111	2.95	23.20
27	2	0.064	0.070	0.067	0.54	23.38
28	2	0.007	0.059	0.033	0.55	23.32
29	1	0.013	0.013	0.013	2.75	23.24
30	3	0.646	0.912	0.818	2.03	23.29
31	3	1.143	1.293	1.212	2.09	23.28
32	1	1.526	1.526	1.526	4.01	23.30
34	1	0.146	0.146	0.146	2.56	23.27
35	2	0.536	0.579	0.558	1.09	23.30
37	1	0.010	0.010	0.010	4.71	23.43
38	3	0.082	0.239	0.167	6.03	23.58
39	2	0.261	0.375	0.318	5.93	23.21
40	2	0.207	0.634	0.420	6.01	23.88

Table 1. Measured min, max, and mean discharges (in m^3/s), mean salinities (in psu), and mean temperatures (in ^oC) in Kings Bay springs during the 2009 survey.

Weeki Wachee Well		Crystal River			
Period of Record	Mean Water Level	Period of Record	Q, ft^3/s	Source	Remarks
1966-77	18.4 ft	1965-77	975	Yobbi, 1989	Well only 1966-77
1966-75	18.6 ft	1965-75	916	Rosenau and others, 1977	
1983, 1985	19.0 ft	1983, 1985	534	Yobbi, 1989	May 1983, distributed 1985
1985	18.9 ft	1985	507	Yobbi, 1989	1985 water year only

Table 2. Summary of mean annual discharge of Crystal River (02310750) and mean annual water levels in Weeki Wachee well 283201082315601.

APPENDIX

Yobbi, D. 2015. Review of technical method to hindcast spring flow record for Kings Bay. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Review of Technical Method to Hindcast Spring Flow Record for Kings Bay
Dann Yobbi
September 25, 2015

OBJECTIVE:

The purpose of this document is to provide a written review of the proposed methodology for hindcasting the spring flow record for Kings Bay. Hindcast is defined as a statistical calculation determining probable past conditions (Merriam-Webster Dictionary). In this context, the District plans to estimate the probable past spring flow using an empirical formula that correlates flow with gradient between groundwater and surface water altitudes recorded at ROMP TR21-3 well and Kings Bay tide stage gaging station, respectively. When a correlative relation exists between spring flows and gradient it may be possible to hindcast flow for the period of groundwater level and tide stage records.

BACKGROUND:

I previously provided a written review of the draft technical report "On the estimation of submarine groundwater discharge to Kings Bay" by Dr. XinJian Chen. The report discusses the methodology for estimating spring discharge of Kings Bay. In response to my review memo dated May 19, 2014, Dr. Chen, other District staff, and I met on July 25, 2014. Dr. Chen provided illustrations and graphs to more thoroughly describe the research, and clarified usage of technical terms in the report. In addition, Dr. Chen responded to my written review. However, I continued to have the following hydrologic issues:

1. Calculation of negative flow into the springs without convincing field evidence supporting this hydrologic condition.

2. Limited hydrologic data collected over the 2 1/2-month period of record (July 28 through October 8, 2009) greatly reduces the likelihood that the mean value of this limited data set is the long-term mean spring flow.

3. Estimates (quantification) of spring flow of Kings Bay were extrapolated beyond the range of observed groundwater levels at ROMP TR 21-3.

At a follow up meeting on January 30, 2015, these issues were discussed. In summary, the District and I agreed to the following:

1. Mean daily rather than instantaneous spring flow data will be reported to eliminate negative values. Dr. Chen stated that he tested the sensitivity of the simulated salinity and temperature distributions by setting a minimum threshold of zero (no flow) for spring flow. These parameters are insensitive to the imposed threshold.

2. Additional text will be added to discuss the qualitative uncertainty ascribed to this method but no attempt will be made to quantify uncertainty.

3. Mean groundwater discharge from Dr. Chen's model was 467 cfs. To bolster this result Ron Basso calculated the recharge volume needed to attain a groundwater discharge of 467 cfs using an analytical water budget method. While the computed recharge is at the high end, it falls within the reasonable recharge volumes for the study area.

DISCUSSION:

On the basis of the follow-up discussions with District scientists and report revisions, the empirical formula that correlates flow with gradient between groundwater and surface water altitudes is an appropriate approach to estimate the probable past flow estimates for Kings Bay and, is in agreement with previous studies. Published research shows that spring discharge is a function of the aquifer head, but is more precisely a function of the difference in head between the spring pool and the Upper Floridan aquifer (German 2010). This head difference can be affected by tides, such as observed in Kings Bay, and can be taken into account by using spring discharge rating relations that are based on head gradient between the spring pool and the aquifer. In central Florida, correlation between spring flow and groundwater altitudes or gradients between groundwater and surface water altitudes in tidal reaches has been documented in Yobbi (1992), Knochenmus and Yobbi (2001), and German (2010). Currently (2015) the USGS uses groundwater altitude or gradients to estimated spring flow at Weeki Wachee Springs, Hidden River, Homosassa Springs, Silver Springs, and Rainbow Springs. Additionally, Yobbi (1992) presented estimates of mean monthly spring flow at Weeki Wachee springs for the period 1966-84 based on hydrologic data collected in 1988-89. To bolster the defensibility of hindcasting the spring flow in Kings Bay, it is recommended that additional spring flow data be collected spanning the range of values for the independent variables, groundwater levels and surface water stage. The current rating is based on a narrower range in values than observed long-term hydrologic conditions.

REFERENCES:

Chen, XinJian, 2012, Simulating hydrodynamics in a spring-fed estuary using a three-dimensional unstructured Cartesian grid model. Estuarine, Coastal and Shelf Science, 115, 246 – 259.

Chen, XinJian, 2014, On the Estimation of Submarine Groundwater Discharge to Kings Bay.Technical Report, Southwest Florida Water Management District, Tampa, Fla.

German, E.R., 2010, Evaluation and Recomputation of Daily-Discharge for Silver Springs near Ocala, Florida: Special Publication SJ2010-SP-9; St. Johns River Water Management District, Palatka FL.

Knochenmus, L.A. and Yobbi, D.K., 2001, Hydrology of the coastal springs ground-water Basin and adjacent areas of Pasco, Hernando, and Citrus Counties, Florida: U.S. Geological Survey Water-Resources Investigation Report 01-4230.

Yobbi, D.K., 1992, Effects of tidal stage and ground-water levels on the discharge and water quality of springs in coastal Citrus and Hernando Counties, Florida: U.S. Geological Survey Water-Resources Investigation Report 92-4069