SPECIAL PUBLICATION SJ2008-SP6

SILVER SPRINGS SPRING VENT DOCUMENTATION AND GEOCHEMICAL CHARACTERIZATION

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

Special Publication SJ2008-SP6

Silver Springs Spring Vent Documentation and Geochemical Characterization

by

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Silver Springs Spring Vent Documentation
And Geochemical Characterization

Errata Sheet

Appendix 5

Results of Discharge Measurements of Timber Spring, Marion County, Florida;
September 30, 2006

Results and Discussion

Second paragraph, replace first sentence with text below:

The estimated discharge of Timber Spring on September 30, 2006, was 0.765 CFS (cubic feet per second). This result is also expressed as 343 GPM (gallons per minute) or 0.494 MGD (million gallons per day), see Table 1.

Table 1

Replace Timber Spring Total Discharge with text below:

Timber Spring Total Discharge	
CFS	0.765
MGD	0.494
GPM	343

Executive Summary

Background

The Silver Springs spring group is one of Florida's 33 first-magnitude springs and is the largest spring within the St. Johns River Water Management District (the District). The median flow of the Silver Springs group accounts for nearly 45% of all spring flow within the District.

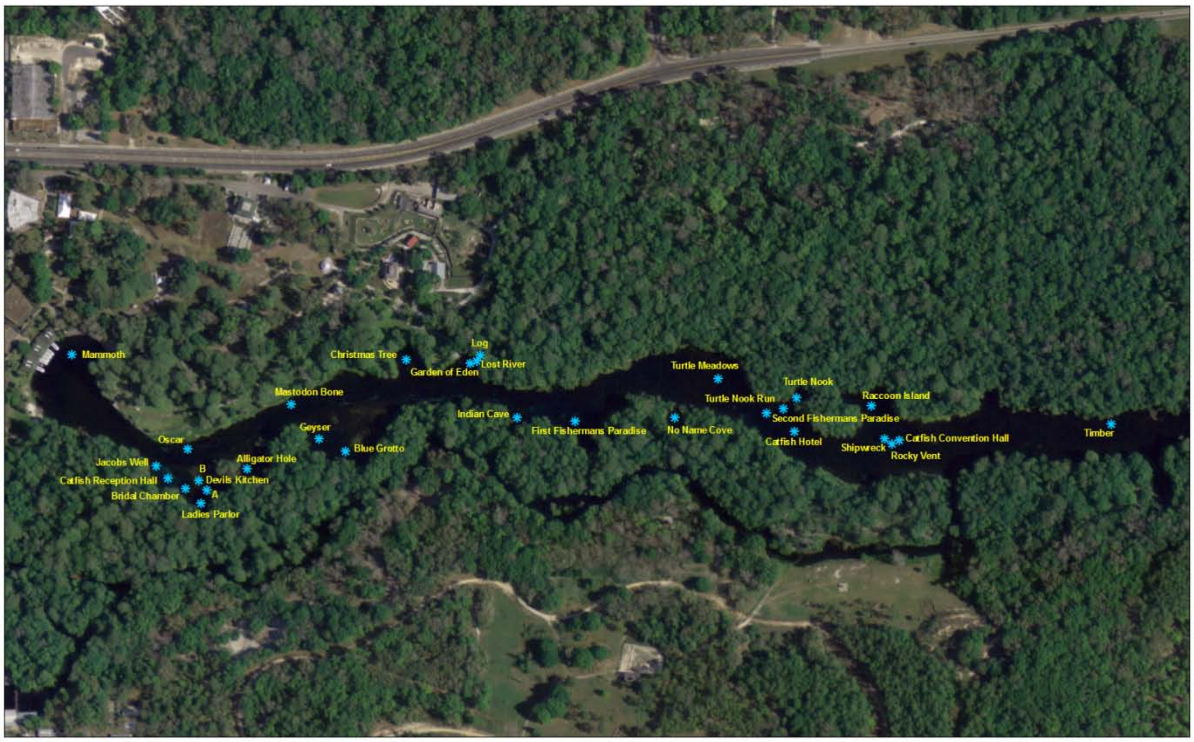
Currently, 30 separate vents are known to make up the Silver Springs group. Some of the known 30 vents have multiple vent discharge points that are believed to be part of the same conduit system, but this has not been verified and documented. Routine water quality sampling by the U.S. Geological Survey over the years has been confined to composite sampling of Mammoth Springs, which are really two large vents with documented temperature and visual water clarity differences. Visual observations of water clarity variations and vegetation variations among the various vents lead to the conclusion that water quality may be spatially and seasonally variable. Because many important water quality variables, such as nutrients, do not cause visible changes in the clarity of water the variation between the vents may be considerable. There is no documentation or even a baseline measurement of the current water quality concentrations discharged from all the Silver Springs group vents. This report is the first comprehensive study of the discharge and quality of water from different vents at Silver Springs in the upper 1,200 meters of the Silver River.

As part of the Florida Springs Initiative (FDEP 2000), on a year-by-year basis, the Florida Department of Environmental Protection (FDEP) requests from the Legislature an amount for funding hydrologic monitoring and research investigations that are critical to developing strategies to manage spring-related water resources. Silver Springs is important to study because of elevated levels of nitrates in Mammoth Springs. The nitrate concentrations (about 1.1 mg/L nitrate–nitrogen) are higher than background levels and have been increasing since 1950 (Munch et al., 2006). During fiscal year 2006–2007, the FDEP funded phase 1, the first phase of a four-phase project. The overall project is expected to last four years. Phase 2 involves the tracing of vent subgroups to source regions in the springshed. It is expected to last one year and is budgeted for fiscal year 2007–2008. Phase 3 (-isotope, anthropogenic, pesticide, and wastewater chemical characterization of the Silver Springs main vents) began in 2007 and is planned to last two years. The seasonality of water quality at Silver Springs will be examined during phase 4. It is expected to last two years and is planned for fiscal years 2008–2009 and 2009–2010.

The topic of this report is the phase 1 documentation, flow discharge measurement, and water quality sampling of all of the spring vents in the Silver Springs spring group. During phase 1, numerous vents at Silver Springs were sketched, photographed, sampled for water quality and, where possible, measured for discharge. Karst Environmental Services, Inc. (KES) sketched and photographed the different vents; assisted in the water quality sampling, made biological observations at the different vents; and conducted discharge measurements, where possible. Intera, Inc. performed multivariate statistical analysis consisting of cluster analysis and principal component analysis on the water quality data. The purpose of Intera's work was to reduce the number of water quality samples required to characterize the water quality of the spring group and to correlate springs relative to source water characteristics. This resulted in the design of a sampling plan that represents the variation of the clusters to simplify large volumes of data into simpler groups. Cluster analysis was aimed at determining the smallest number of spring groups that represent the water quality at Silver Springs.

<u>Spring Vent Documentation</u> <u>(Appendix 3)</u> **<u>and Water Quality Characteristics</u>** <u>(Appendix 4):</u>

Counting Mammoth Spring as two discrete spring vents, Silver Springs consists of 30 different springs, with 61 vents in the upper 1,200 meters of the Silver River. In September 2006, KES



Silver Springs

sketched, photographed, and sampled most of these discrete springs. KES also made discharge measurements at many of these spring vents. The sketches, photographs, discharge measurements, and water quality data are included in this report. All of the sampled springs discharge a calcium-bicarbonate type water.

The two vents at Mammoth Spring (Mammoth-East and Mammoth-West) produce slightly different water quality and differed in temperature by 1.4º Celsius (C). They also differed in dissolved oxygen, field conductivity, total nitrate plus nitrite (NOx-total), sulfate, and total dissolved solids (TDS). Dissolved oxygen (DO) was 1.98 milligrams per liter (mg/L) in Mammoth-East and 0.94 mg/L in Mammoth-West. DO was highest at Indian Cave Spring (3.70 mg/L) and lowest at Log Spring (0.08 mg/L). The NOx-total concentration at Mammoth-East and

Mammoth-West was 1.27 mg/L and 0.91 mg/L, respectively. Total NOx concentration was highest at No Name Cove Spring (1.89 mg/L) and lowest at Log Spring (0.87 mg/L). The mean and median total NOx concentrations were 1.36 mg/L and 1.40 mg/L, respectively.

Sulfate was highest at Ladies Parlor Spring (74.4 mg/L) and lowest at Log Spring (16.7 mg/L). Sulfate was 45.5 mg/L at Mammoth-East and 17.7 mg/L at Mammoth-West. Generally, sulfate concentration is lower in the downriver spring vents than in those closest to the Mammoth Spring vents. Spring vents with higher sulfate concentrations probably have a deeper flow system than spring vents with lower sulfate concentrations. The source for the sulfate may be the dissolution of gypsum and anhydrite at the top of the middle semi-confining unit of the Floridan aquifer system.

TDS concentrations were highest in Catfish Reception Hall-1 Spring (318 mg/L) and lowest in Shipwreck-1 Spring (195 mg/L). TDS concentration was 304 mg/L in Mammoth-East and 236 mg/L in Mammoth-West. Generally, TDS concentrations were lower in the downstream spring vents than in those closest to the Mammoth Spring vents.

Discharge (Appendix 5):

KES made discharge measurements at the Silver Springs group in September 2006. The largest discharge, 240 cubic feet per second (cfs) occurred at Mammoth Springs. The second largest discharge, 36 cfs, occurred at Catfish Reception Hall. The remaining discharges at 21 vents were less than 10 cfs each. The smallest discharge, 0.24 cfs, occurred at No Name Cove and Devils Kitchen B. No discharge measurements were performed at six vents because of an absence of a suitable cross section at four of the vents and because of very little discharge at two of the vents. The vents without suitable cross sections were First Fishermans Paradise, Turtle Meadows, Catfish Hotel, and Rocky vent. The vents with little discharge were Lost River and Log. The total discharge from all of the measured vents was 327 cfs.

Geochemical Characterization (Appendix 6):

Intera, Inc. performed a statistical cluster analysis on the water quality data from these different spring groups. Cluster analysis was used to simplify large volumes of data into simpler groups to describe most of the essential characteristics of the data. Cluster analysis of the Silver Springs water samples reveals five distinct groups. Groups 1 and 2 contain 11 vents; group 3 contains 10 vents; groups 4 and 5 contain one vent each. Cluster analysis was performed on water quality samples from 34 vents. Group 1 is located in the southern and western part of the Silver River and has the highest total dissolved solids, dissolved oxygen (DO), calcium, magnesium, bicarbonate, sulfate (SO_4), nitrate, and phosphorus (P) concentrations. Group 2, which includes vents in the northern part of the springs, has lower concentrations of most solutes than group 1 and particularly low DO, SO_4 and P concentrations. Group 3 is intermediate between groups 1 and 2. Group 4 had a high total-organic carbon concentration and group 5 had a high P concentration. However, two of the groups consist of only one spring and are distinguished from the other groups due to anomalously high total-organic carbon

(TOC) or phosphorus concentrations. These two groups are considered to be outliers and are probably the result of sampling errors or anomalies. Both samples contained suspended material. Excluding the samples with outliers, Silver Springs consists of three distinct groups.

The clusters show continuous rather than discrete changes from one group to the next. This suggests that water from many of the springs represents a mixture of different source waters, rather than distinct end-members. An ‘end-member’ can be viewed as a spring with specific chemical characteristics. A few vents within each cluster can be singled out as end-members corresponding to each of the three groups. The rest of the samples can be viewed as mixtures of these three waters.

References

[FDEP] Florida Department of Environmental Protection. 2000. *Florida’s Springs—Strategies for Protection and Restoration.* Tallahassee.

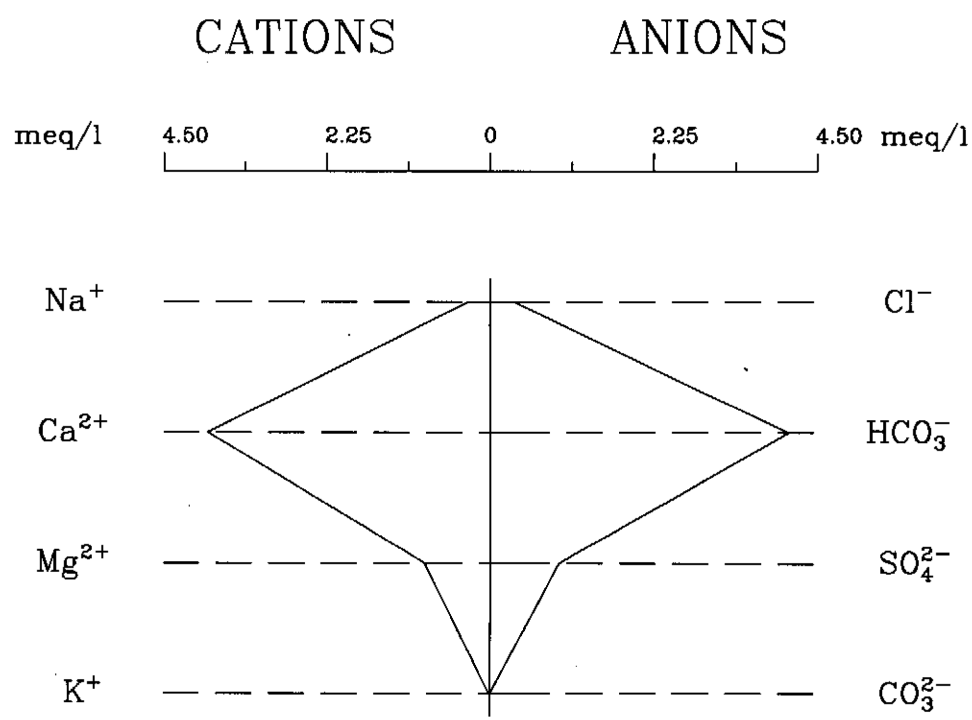
Munch, D.A., Toth, D.J., Huang, C-tzu, Davis, J.B., Fortich, C.M., Osburn, W.L., Phlips, E.J., Allen, M.S., and Knight, R.L., 2006, *Fifty-Year Retrospective Study of the Ecology of Silver Springs, Florida.* Prepared for Florida Department of Environmental Protection, Tallahassee.

Contents

Appendix 1
Stiff Diagrams

SSG−Mammoth−East

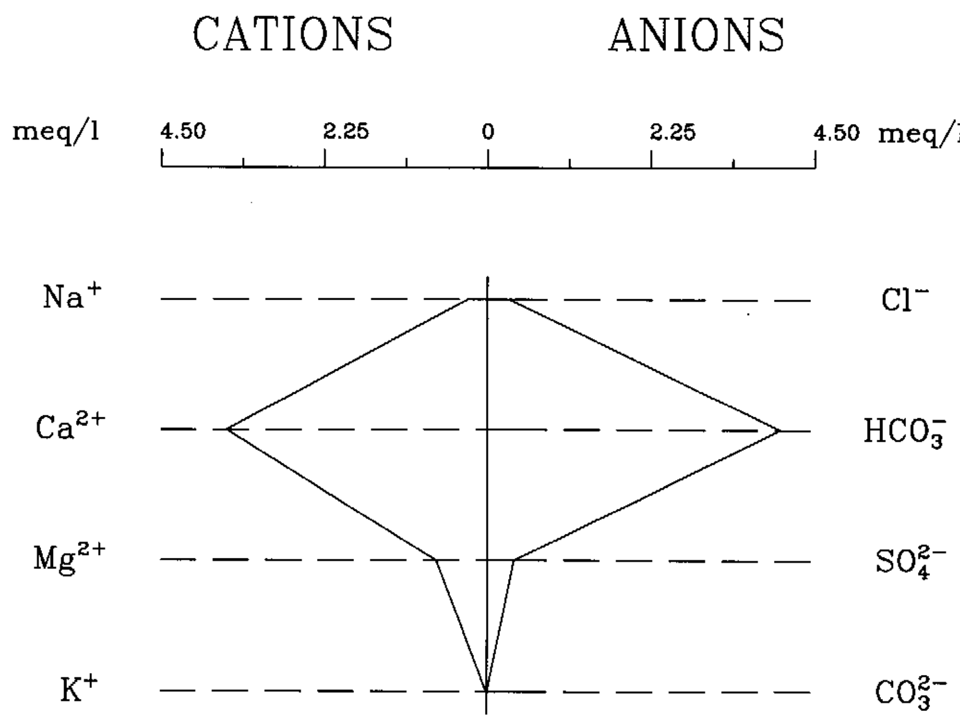
Ion	meq/l	meq/l
Na^+	.30	
Ca^{2+}	3.89	
Mg^{2+}	.90	
K^+	.02	
Cl^-		.32
HCO_3^-		4.11
SO_4^{2-}		.95
CO_3^{2-}		.00
	5.12	5.39



SAMPLE 1

SSG–Mammoth–West

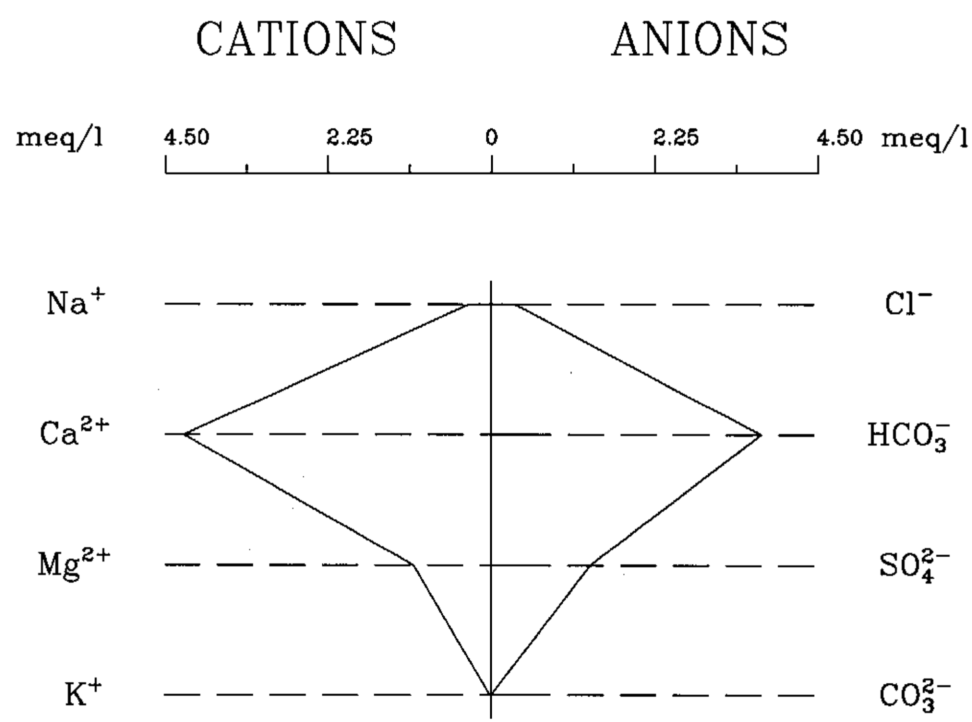
Ion	meq/l	meq/l
Na^+	.27	
Ca^{2+}	3.59	
Mg^{2+}	.70	
K^+	.01	
Cl^-		.30
HCO_3^-		4.03
SO_4^{2-}		.37
CO_3^{2-}		.00
	4.58	4.70



SAMPLE 2

SSG–Jacobs–Well

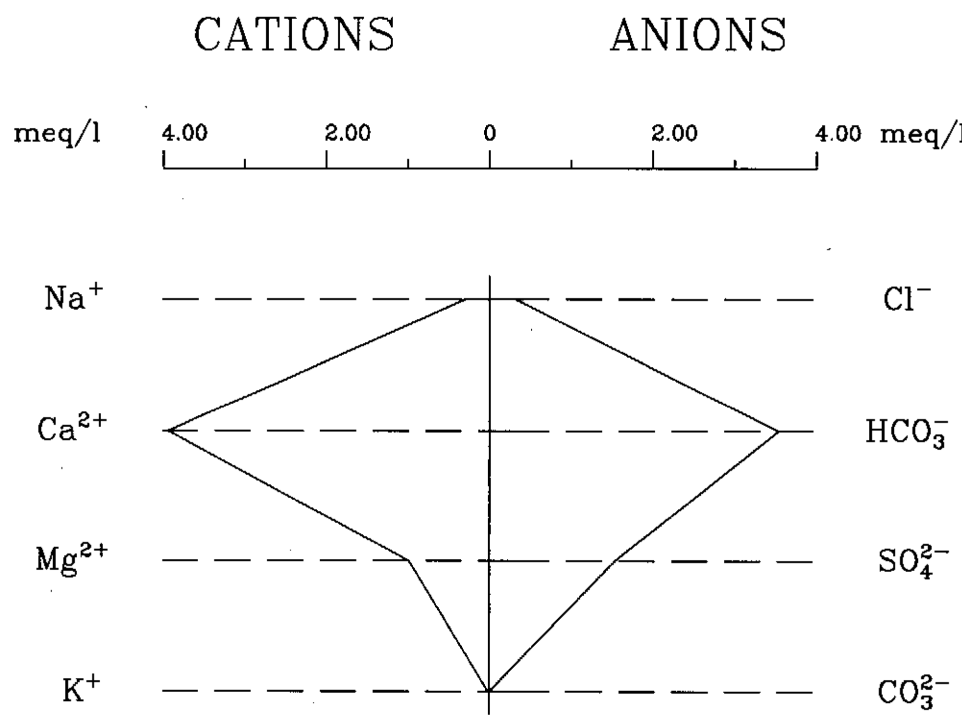
Ion	meq/l	meq/l
Na^+	.31	
Ca^{2+}	4.24	
Mg^{2+}	1.07	
K^+	.02	
Cl^-		.33
HCO_3^-		3.72
SO_4^{2-}		1.36
CO_3^{2-}		.00
	5.64	5.41



SAMPLE 3

SSG-Cat-Rec-Hall-1

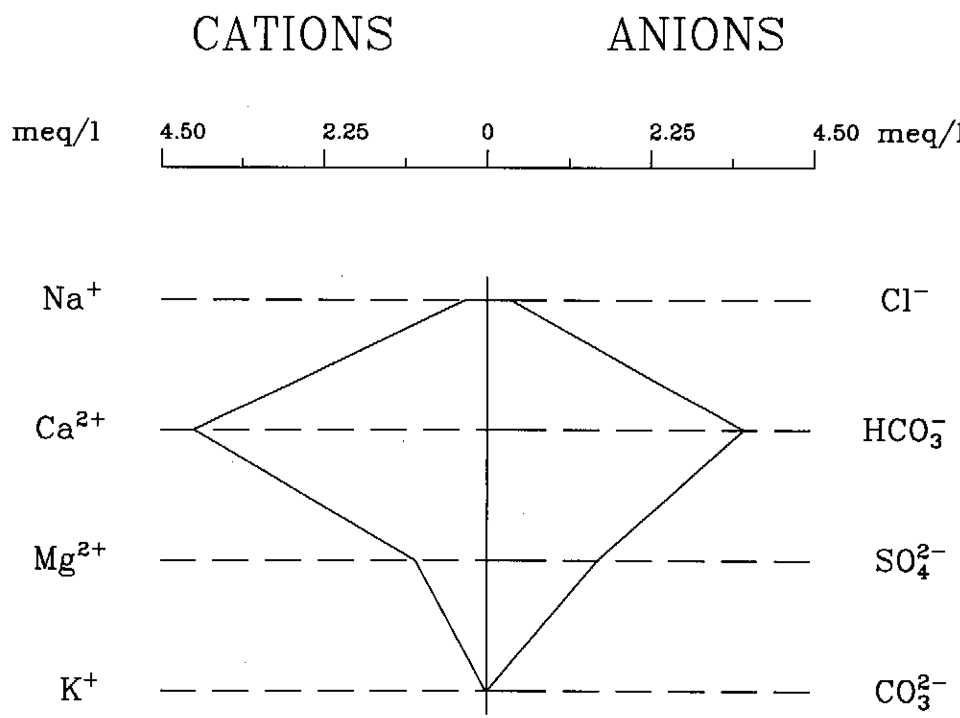
Ion	meq/l	meq/l
Na^+	.30	
Ca^{2+}	3.94	
Mg^{2+}	.99	
K^+	.02	
Cl^-		.33
HCO_3^-		3.54
SO_4^{2-}		1.53
CO_3^{2-}		.00
	5.24	5.40



SAMPLE 4

SSG–Bridal–Chamber

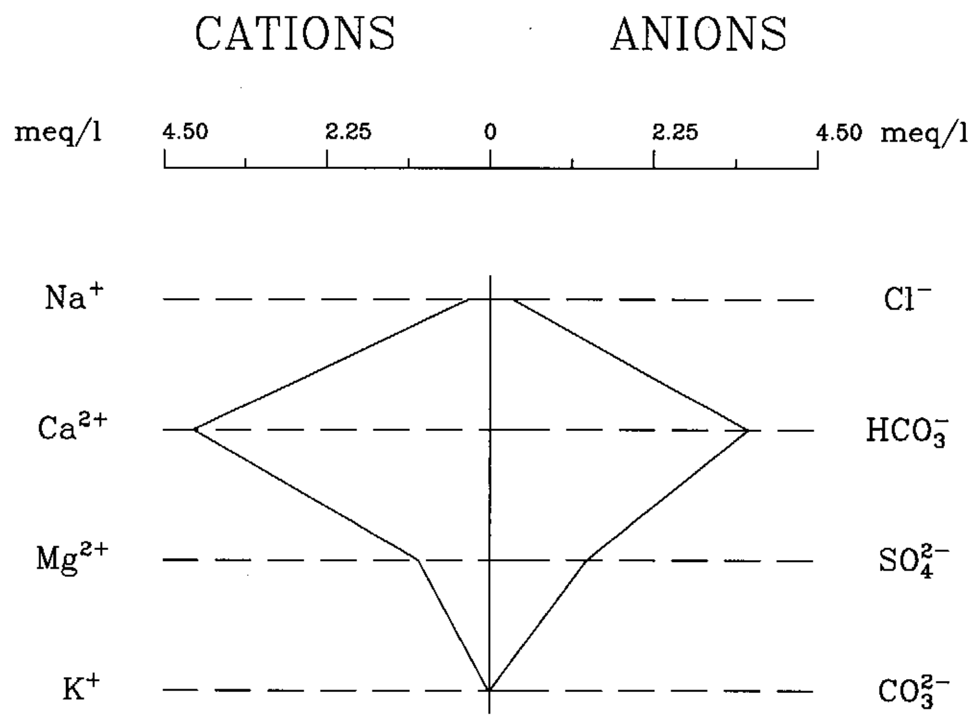
Ion	meq/l	meq/l
Na^+	.30	
Ca^{2+}	4.04	
Mg^{2+}	.99	
K^+	.02	
Cl^-		.33
HCO_3^-		3.54
SO_4^{2-}		1.52
CO_3^{2-}		.00
	5.35	5.39



SAMPLE 5

SSG–Oscar

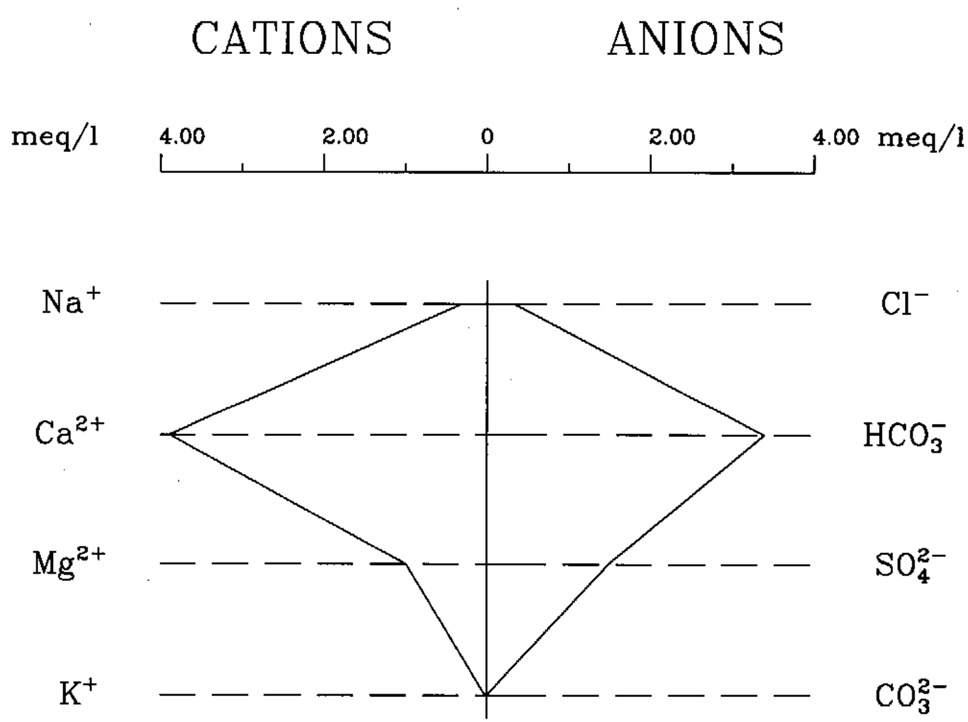
Ion	meq/l	meq/l
Na^+	.30	
Ca^{2+}	4.09	
Mg^{2+}	.99	
K^+	.02	
Cl^-		.32
HCO_3^-		3.56
SO_4^{2-}		1.33
CO_3^{2-}		.00
	------	------
	5.39	5.21



SAMPLE 6

SSG-Devils-Kit-B

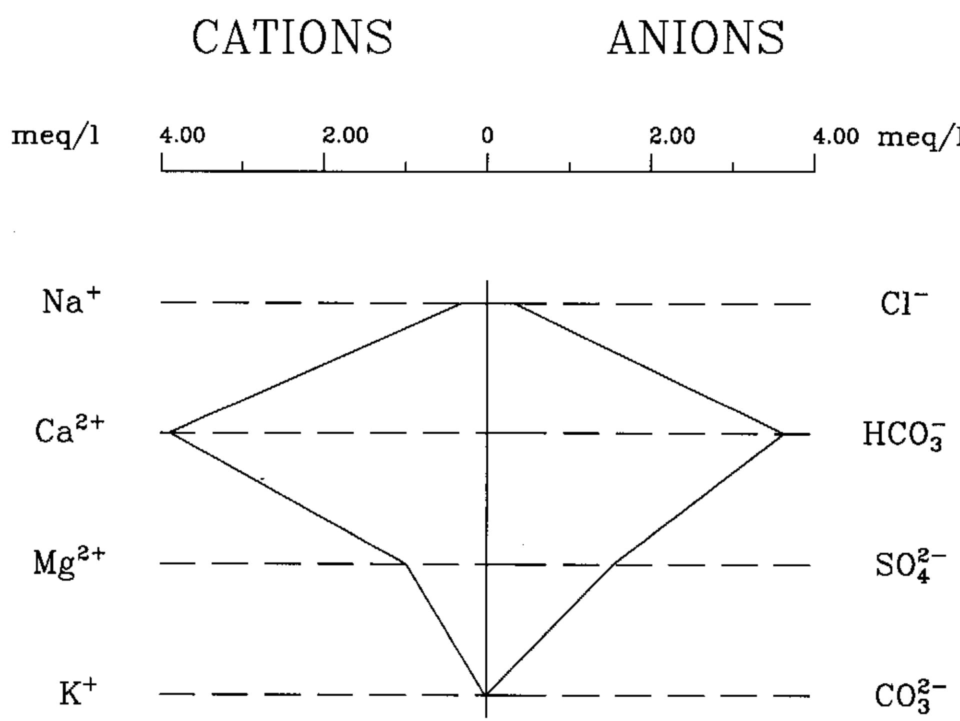
Ion	meq/l	meq/l
Na^{+}	.29	
Ca^{2+}	3.89	
Mg^{2+}	.99	
K^{+}	.02	
Cl^{-}		.32
HCO_3^{-}		3.39
SO_4^{2-}		1.49
CO_3^{2-}		.00
	5.19	5.21



SAMPLE 7

SSG–Ladies–Parlor

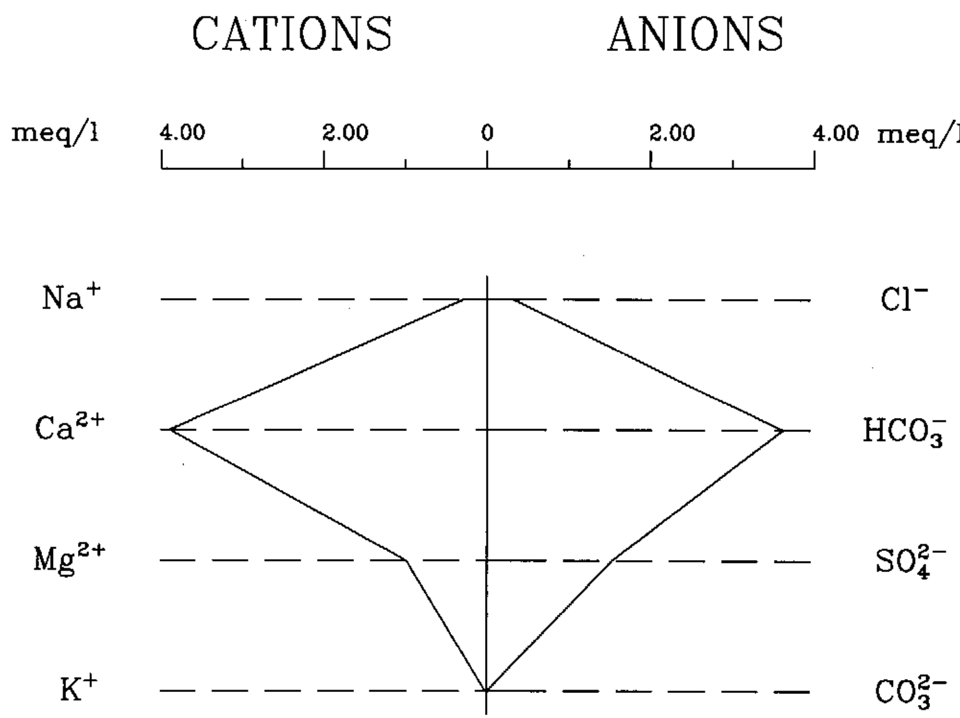
Ion	meq/l	meq/l
Na^{+}	.31	
Ca^{2+}	3.89	
Mg^{2+}	.99	
K^{+}	.02	
Cl^{-}		.33
HCO_3^{-}		3.64
SO_4^{2-}		1.55
CO_3^{2-}		.00
	5.21	5.52



SAMPLE 8

SSG-Devils-Kit-A1

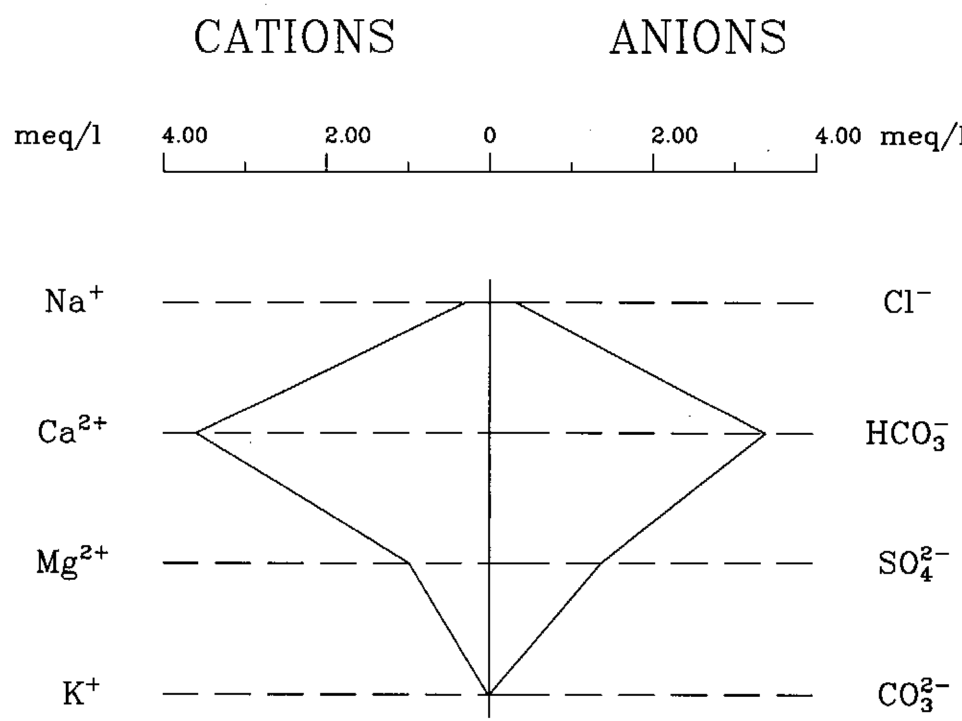
Ion	meq/l	meq/l
Na^{+}	.29	
Ca^{2+}	3.89	
Mg^{2+}	.99	
K^{+}	.02	
Cl^{-}		.32
HCO_3^{-}		3.62
SO_4^{2-}		1.53
CO_3^{2-}		.00
	------	------
	5.19	5.47



SAMPLE 9

SSG-Alligator-Hole-1

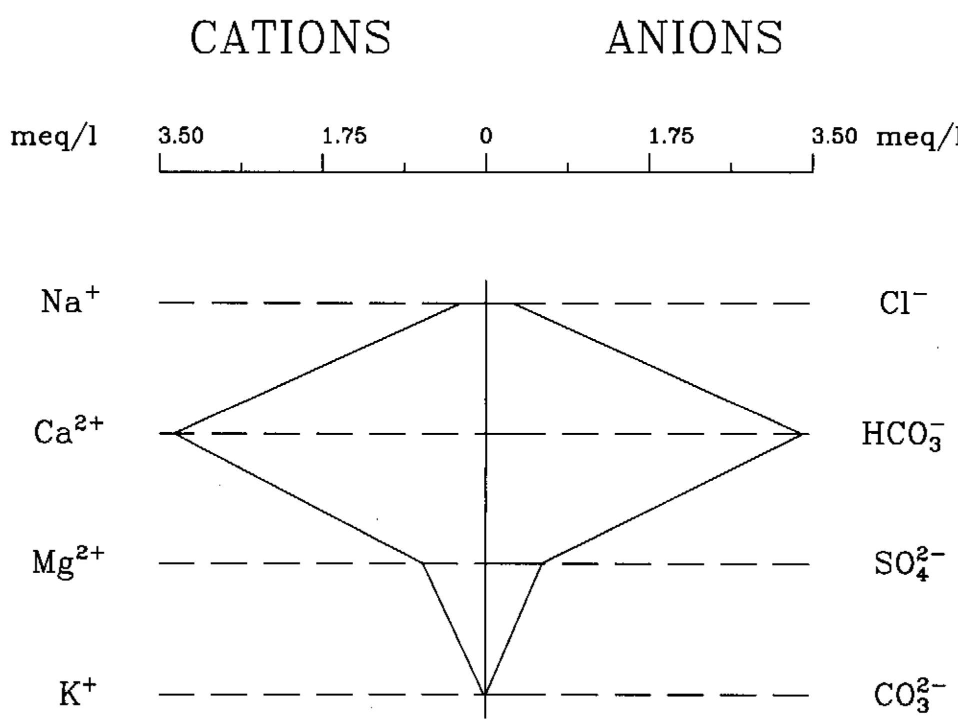
Ion	meq/l	meq/l
Na^+	.29	
Ca^{2+}	3.59	
Mg^{2+}	.99	
K^+	.02	
Cl^-		.32
HCO_3^-		3.38
SO_4^{2-}		1.37
CO_3^{2-}		.00
	------	------
	4.89	5.07



SAMPLE 10

SSG–Mastodon–Bone

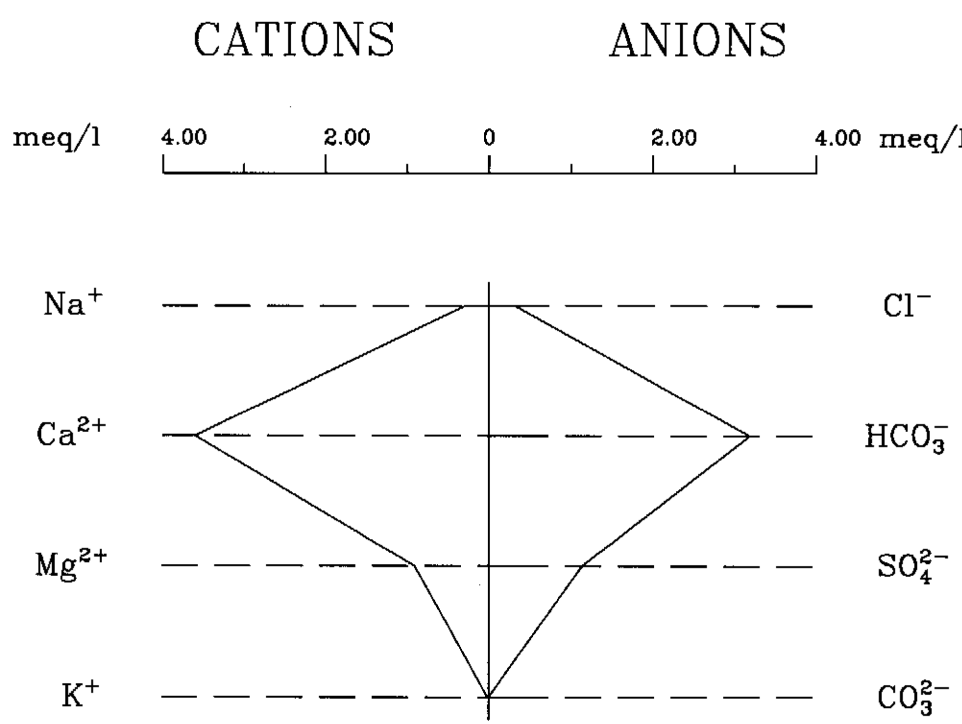
Ion	meq/l	meq/l
Na^+	.26	
Ca^{2+}	3.34	
Mg^{2+}	.67	
K^+	.02	
Cl^-		.29
HCO_3^-		3.39
SO_4^{2-}		.60
CO_3^{2-}		.00
	4.30	4.28



SAMPLE 11

SSG-Geyser-1

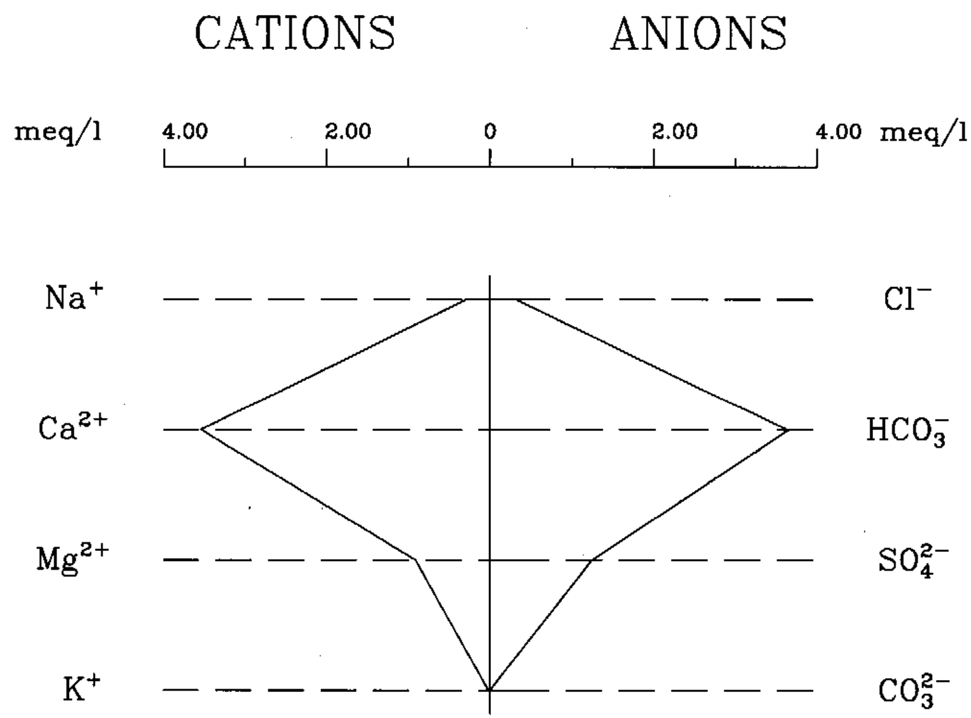
Ion	meq/l	meq/l
Na^+	.29	
Ca^{2+}	3.59	
Mg^{2+}	.90	
K^+	.02	
Cl^-		.32
HCO_3^-		3.20
SO_4^{2-}		1.15
CO_3^{2-}		.00
	------	------
	4.80	4.66



SAMPLE 12

SSG–Blue–Grotto

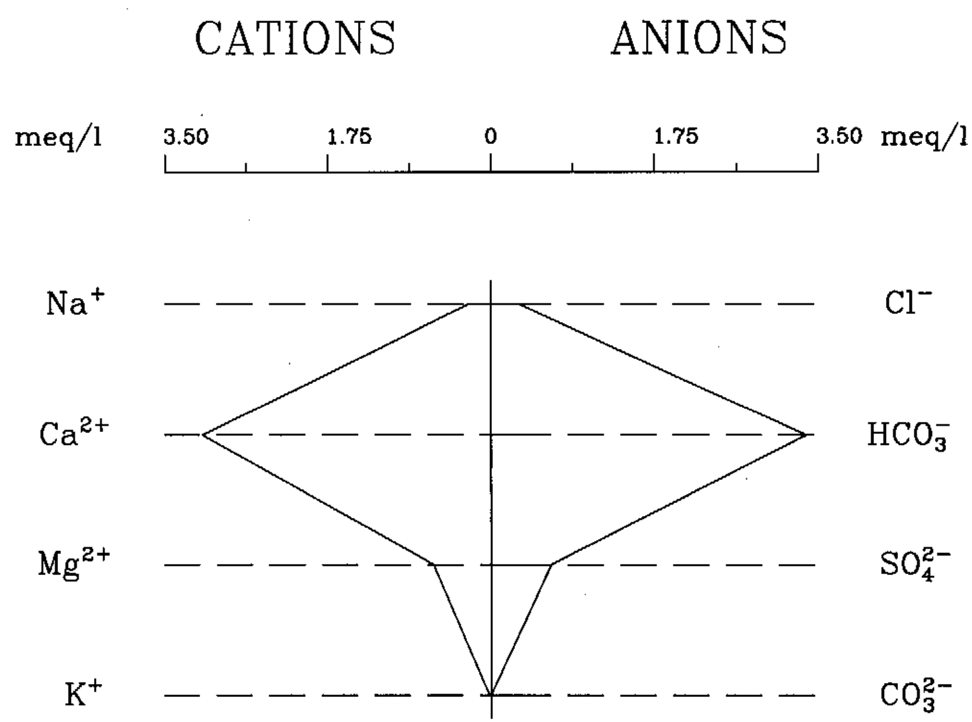
Ion	meq/l	meq/l
Na^+	.28	
Ca^{2+}	3.54	
Mg^{2+}	.90	
K^+	.02	
Cl^-		.32
HCO_3^-		3.65
SO_4^{2-}		1.25
CO_3^{2-}		.00
	4.75	5.22



SAMPLE 13

SSG–Christ–Tree–Cent

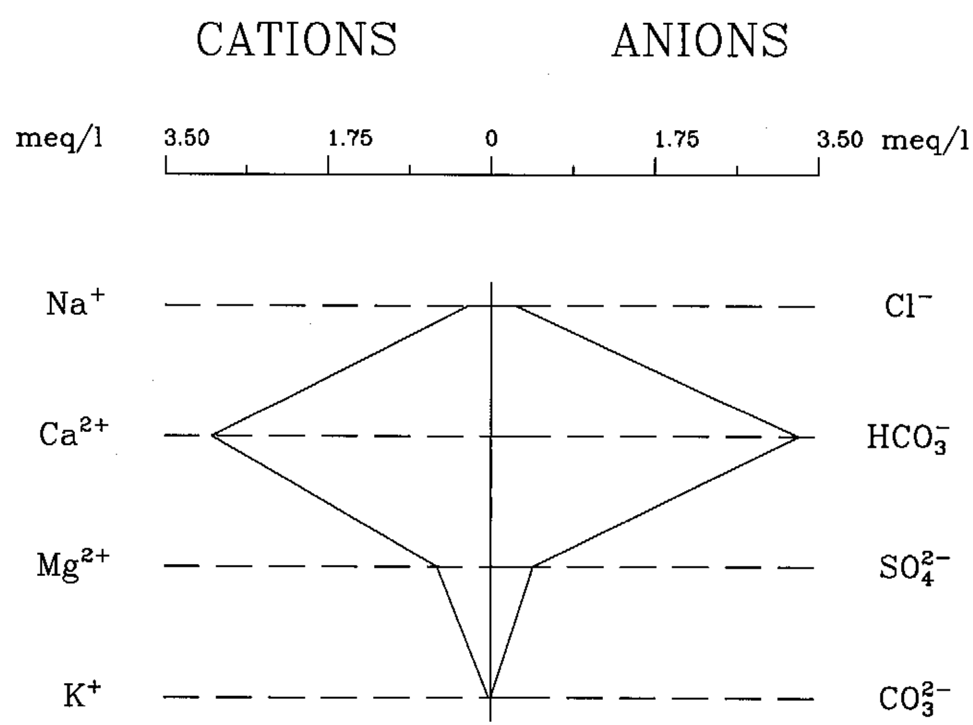
Ion	meq/l	meq/l
Na^+	.23	
Ca^{2+}	3.09	
Mg^{2+}	.62	
K^+	.02	
Cl^-		.29
HCO_3^-		3.38
SO_4^{2-}		.65
CO_3^{2-}		.00
	------	------
	3.96	4.32



SAMPLE 14

SSG-Christ-Tree-N

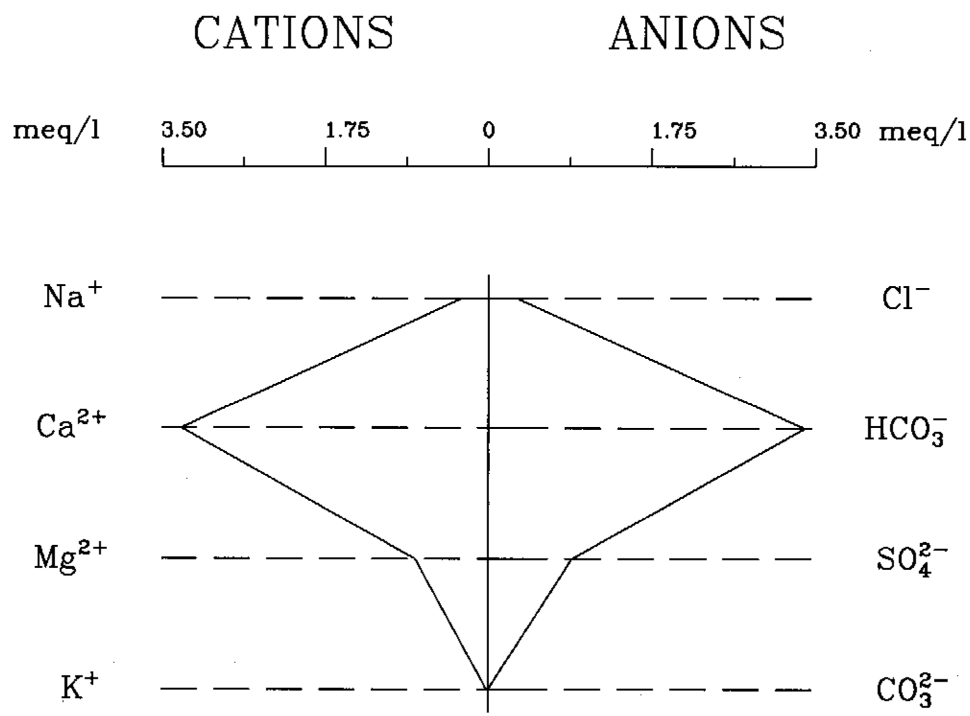
Ion	meq/l	meq/l
Na^+	.23	
Ca^{2+}	2.99	
Mg^{2+}	.58	
K^+	.02	
Cl^-		.26
HCO_3^-		3.29
SO_4^{2-}		.45
CO_3^{2-}		.00
	3.82	4.00



SAMPLE 15

SSG-Garden-of-Eden-1

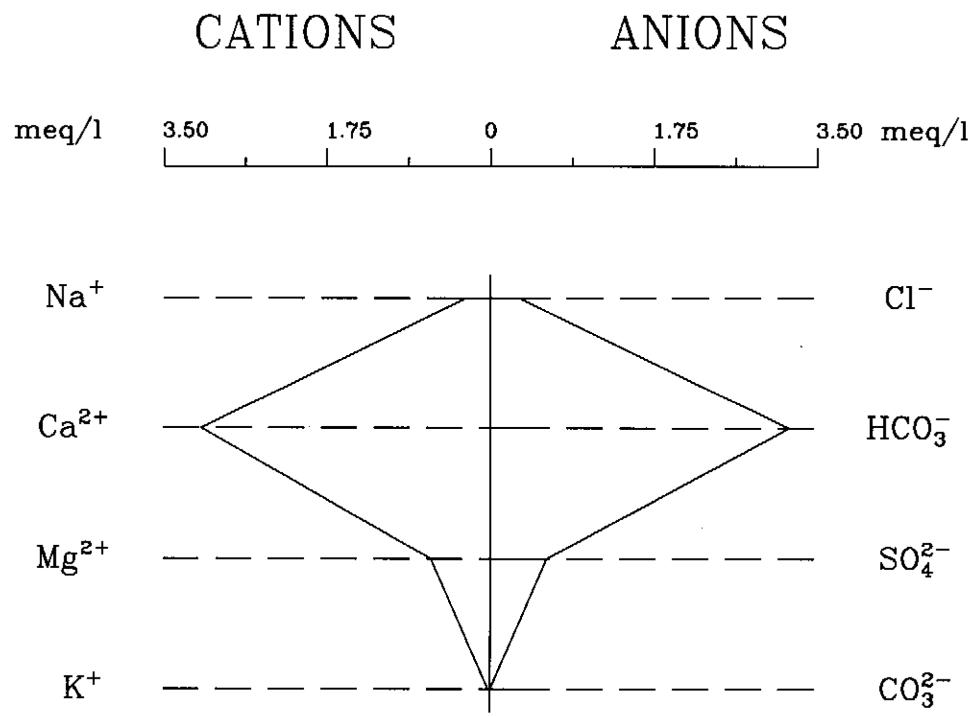
Ion	meq/l	meq/l
Na^+	.28	
Ca^{2+}	3.29	
Mg^{2+}	.78	
K^+	.02	
Cl^-		.30
HCO_3^-		3.39
SO_4^{2-}		.90
CO_3^{2-}		.00
	4.38	4.59



SAMPLE 16

SSG-Garden-of-Eden-2

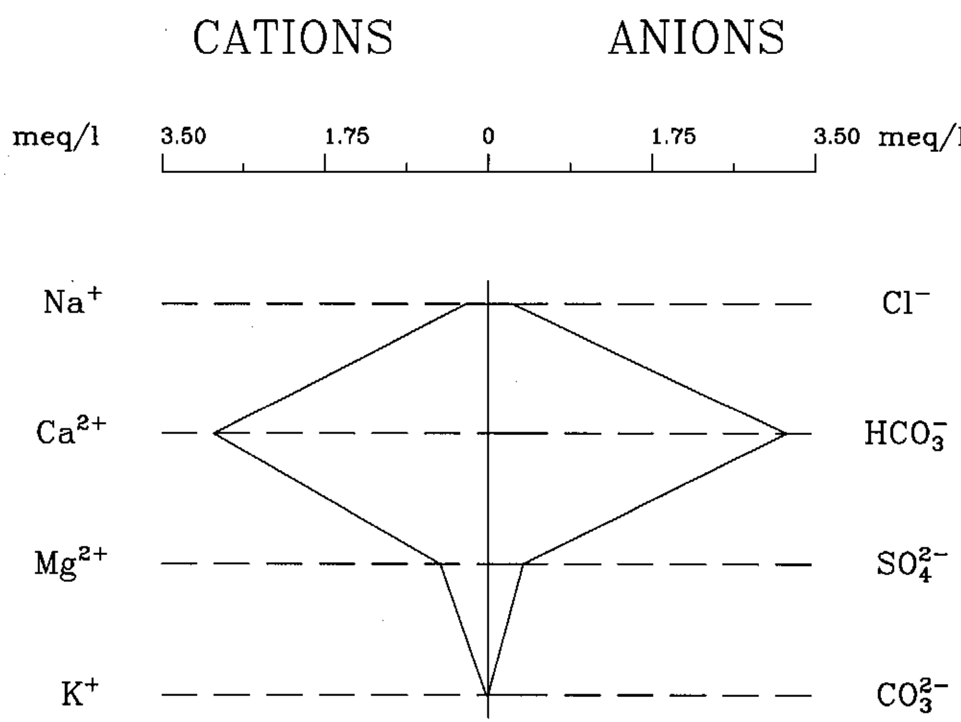
Ion	meq/l	meq/l
Na^+	.26	
Ca^{2+}	3.09	
Mg^{2+}	.63	
K^+	.02	
Cl^-		.31
HCO_3^-		3.20
SO_4^{2-}		.61
CO_3^{2-}		.00
	4.01	4.11



SAMPLE 17

SSG–Lost–River

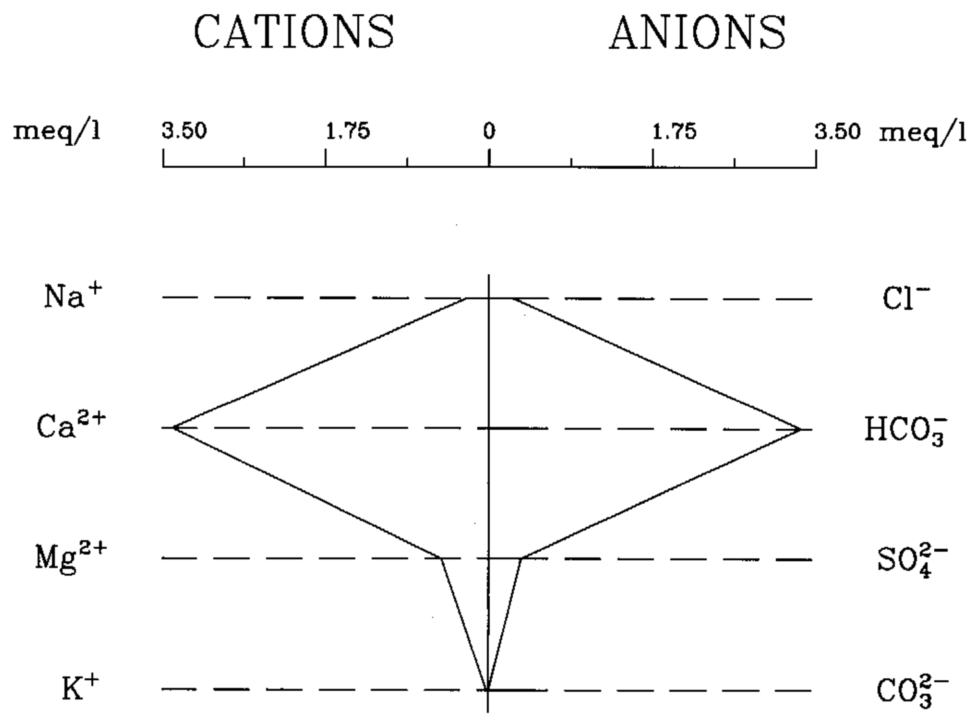
Ion	meq/l	meq/l
Na^+	.23	
Ca^{2+}	2.94	
Mg^{2+}	.51	
K^+	.02	
Cl^-		.25
HCO_3^-		3.20
SO_4^{2-}		.38
CO_3^{2-}		.00
	3.71	3.83



SAMPLE 18

SSG–Log

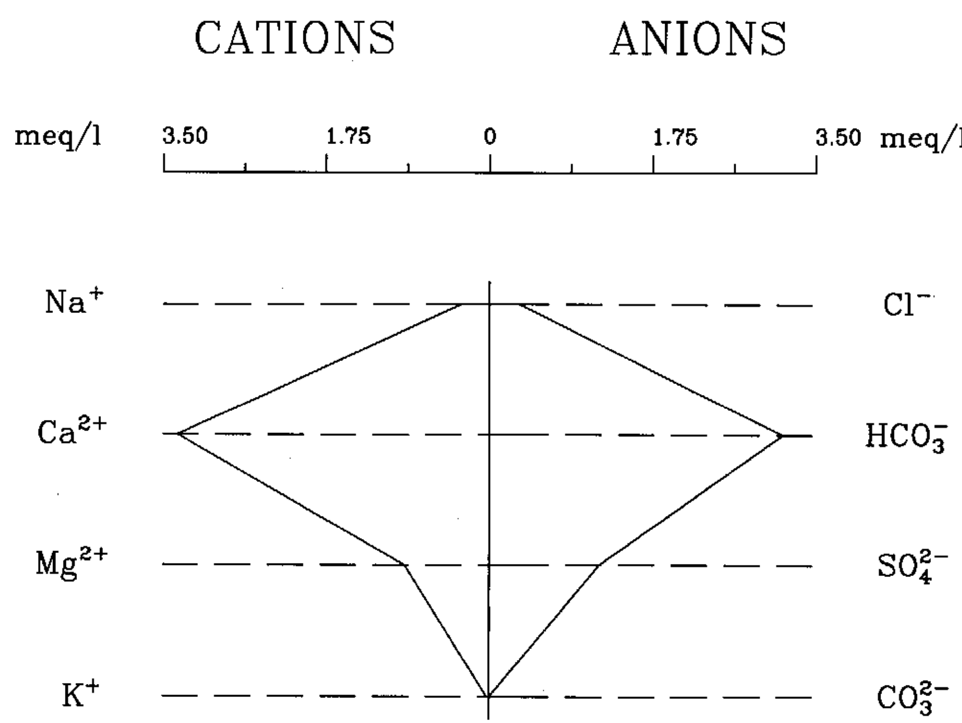
Ion	meq/l	meq/l
Na^+	.23	
Ca^{2+}	3.39	
Mg^{2+}	.50	
K^+	.02	
Cl^-		.26
HCO_3^-		3.34
SO_4^{2-}		.35
CO_3^{2-}		.00
	4.15	3.95



SAMPLE 19

SSG–Indian–Cave–1

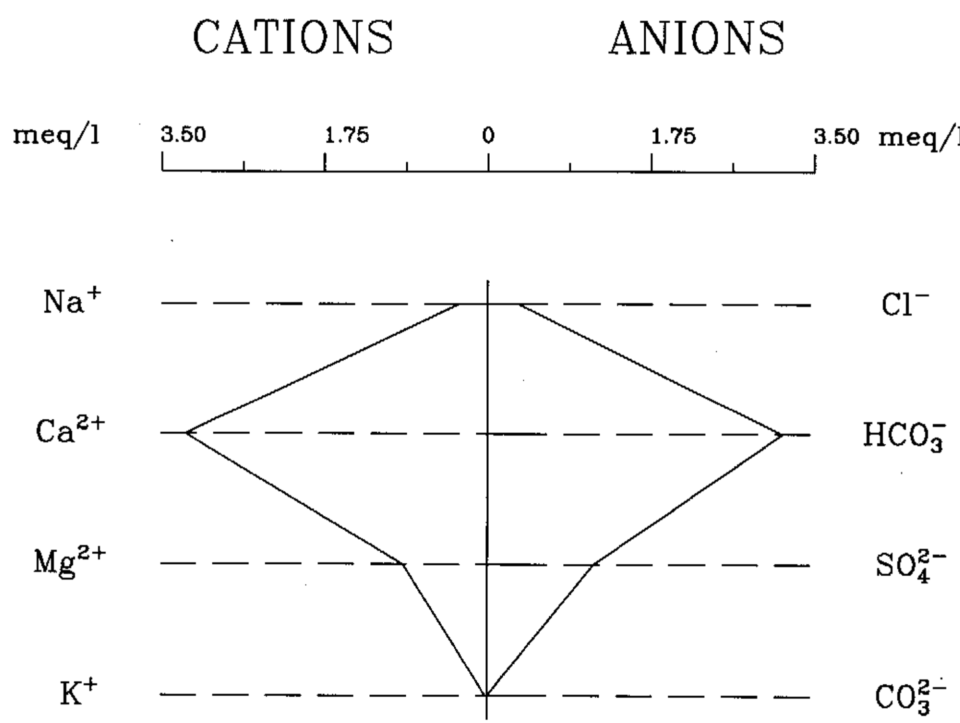
Ion	meq/l	meq/l
Na^+	.30	
Ca^{2+}	3.34	
Mg^{2+}	.90	
K^+	.02	
Cl^-		.32
HCO_3^-		3.15
SO_4^{2-}		1.18
CO_3^{2-}		.00
	4.57	4.65



SAMPLE 20

SSG-First-Fish-Par-1

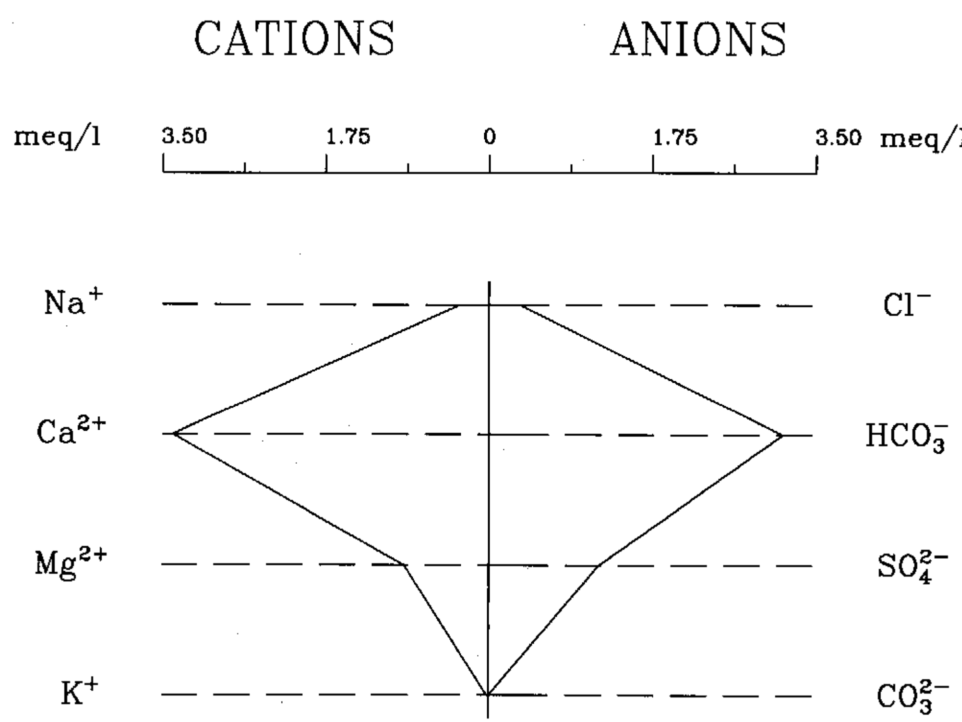
Ion	meq/l	meq/l
Na^+	.30	
Ca^{2+}	3.24	
Mg^{2+}	.90	
K^+	.02	
Cl^-		.33
HCO_3^-		3.16
SO_4^{2-}		1.14
CO_3^{2-}		.00
	4.47	4.63



SAMPLE 21

SSG-First-Fish-Par-5

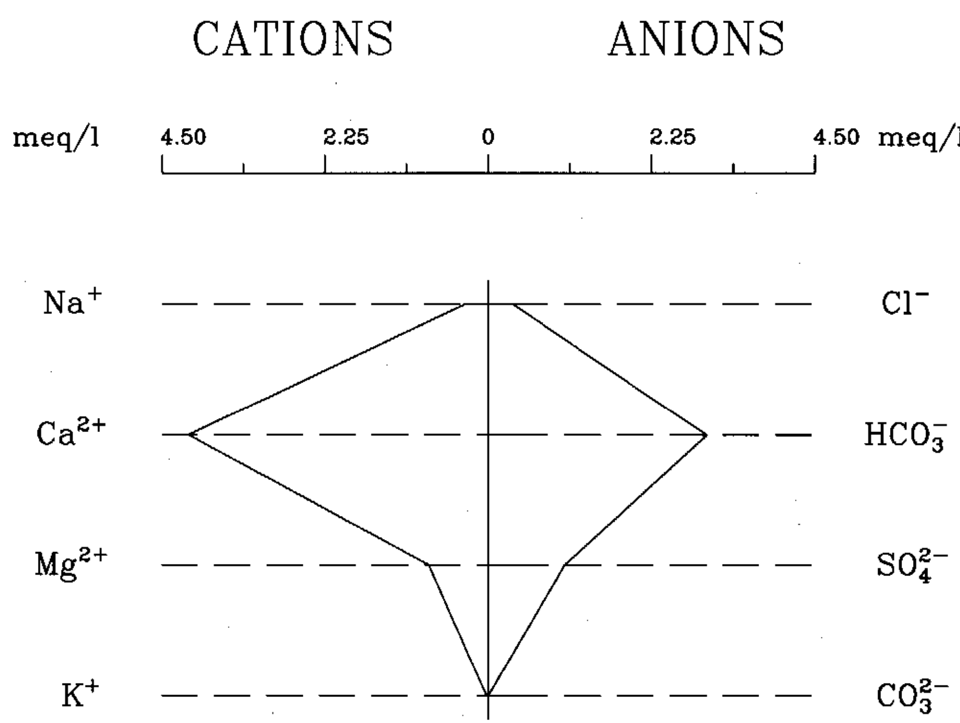
Ion	meq/l	meq/l
Na^{+}	.31	
Ca^{2+}	3.39	
Mg^{2+}	.90	
K^{+}	.02	
Cl^{-}		.33
HCO_3^{-}		3.15
SO_4^{2-}		1.18
CO_3^{2-}		.00
	------	------
	4.63	4.66



SAMPLE 22

SSG–No–Name–Cove

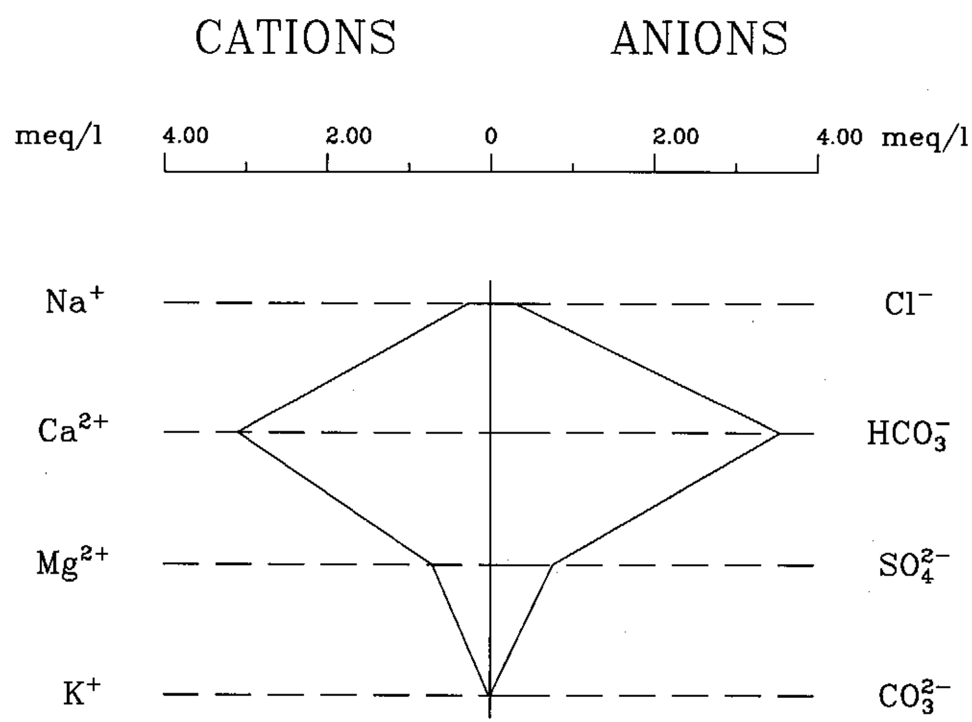
Ion	meq/l	meq/l
Na^{+}	.30	
Ca^{2+}	4.14	
Mg^{2+}	.82	
K^{+}	.02	
Cl^{-}		.33
HCO_3^{-}		3.02
SO_4^{2-}		1.05
CO_3^{2-}		.00
	5.29	4.40



SAMPLE 23

SSG–Turtle–Meadows–1

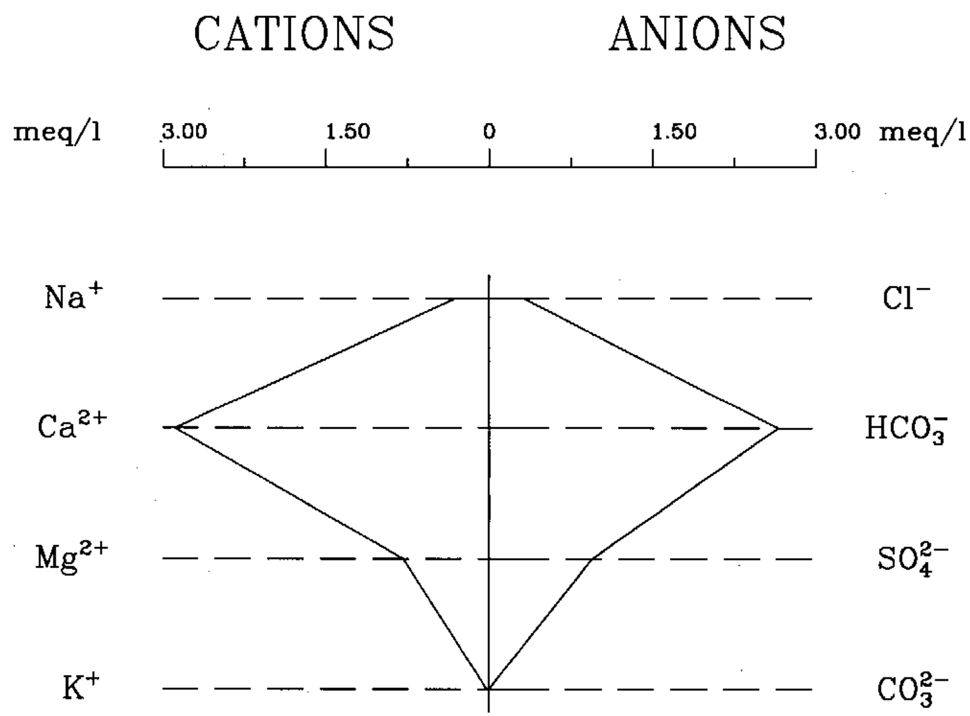
Ion	meq/l	meq/l
Na^{+}	.27	
Ca^{2+}	3.09	
Mg^{2+}	.71	
K^{+}	.02	
Cl^{-}		.30
HCO_3^{-}		3.54
SO_4^{2-}		.76
CO_3^{2-}		.00
	4.09	4.60



SAMPLE 24

SSG-Sec-Fish-Par

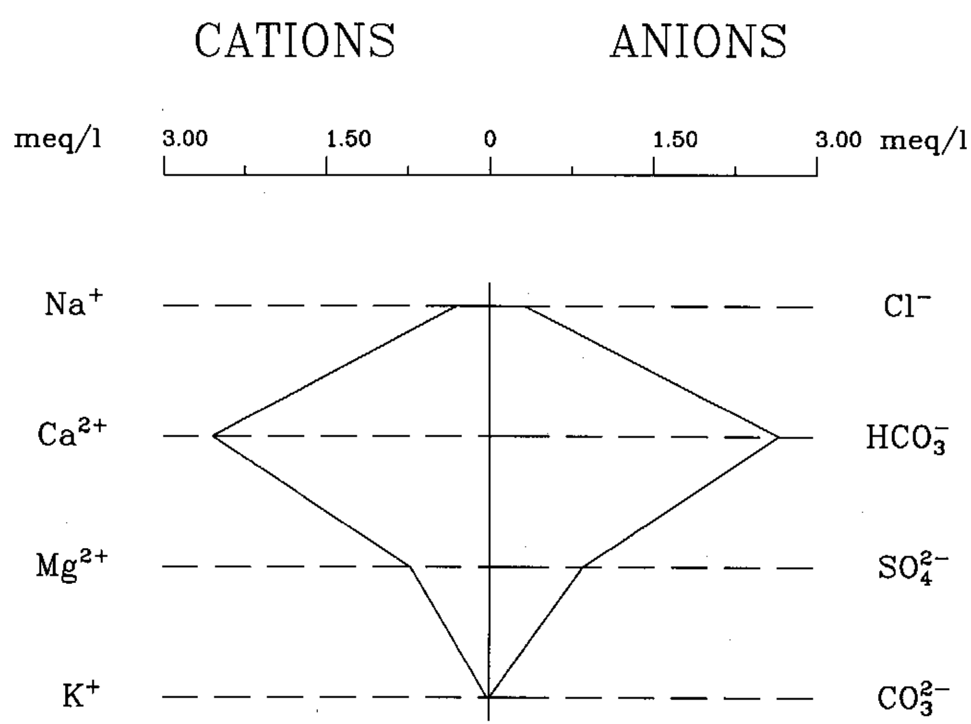
Ion	meq/l	meq/l
Na^{+}	.31	
Ca^{2+}	2.89	
Mg^{2+}	.79	
K^{+}	.02	
Cl^{-}		.32
HCO_3^{-}		2.65
SO_4^{2-}		.95
CO_3^{2-}		.00
	4.02	3.93



SAMPLE 25

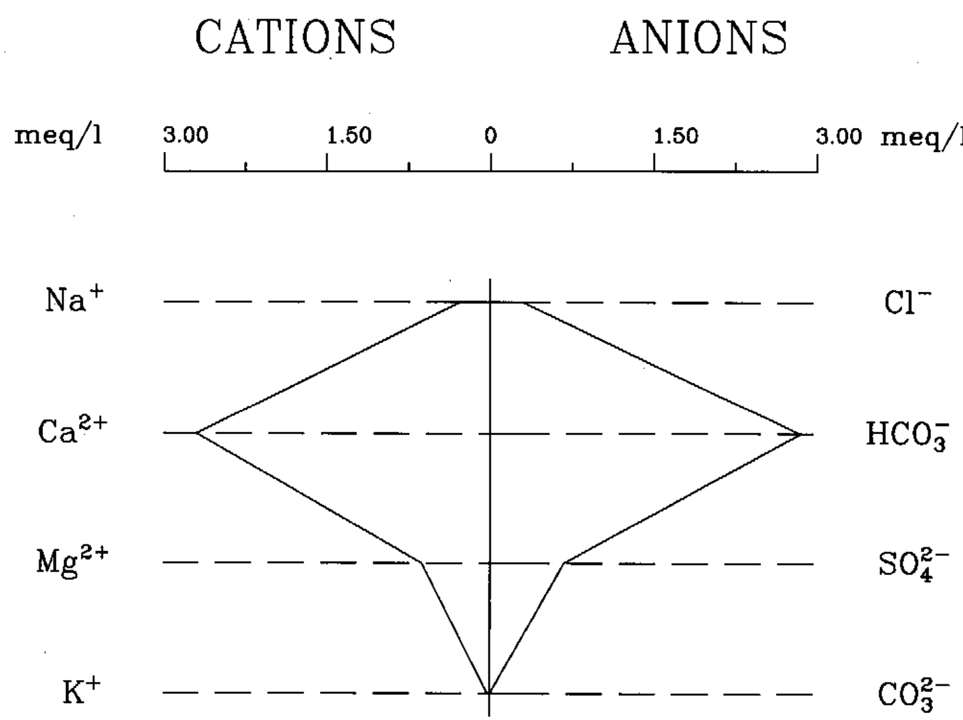
SSG-Catfish-Hotel-1

Ion	meq/l	meq/l
Na^+	.30	
Ca^{2+}	2.54	
Mg^{2+}	.72	
K^+	.02	
Cl^-		.32
HCO_3^-		2.65
SO_4^{2-}		.86
CO_3^{2-}		.00
	3.59	3.83



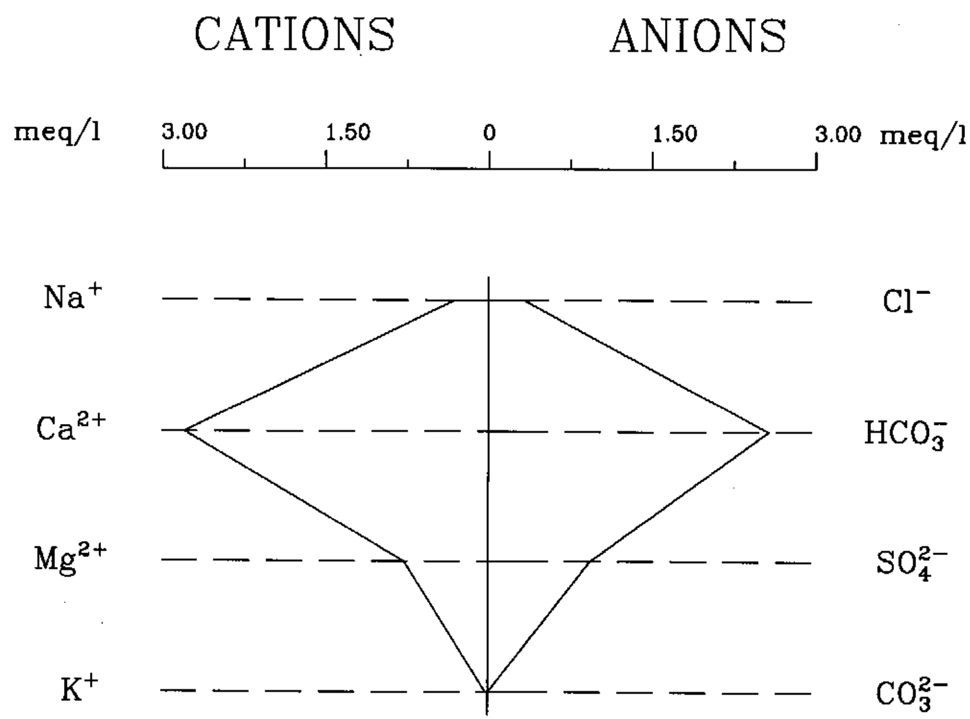
SSG–Turtle–Nook

Ion	meq/l	meq/l
Na^+	.28	
Ca^{2+}	2.69	
Mg^{2+}	.63	
K^+	.02	
Cl^-		.30
HCO_3^-		2.85
SO_4^{2-}		.68
CO_3^{2-}		.00
	3.62	3.83



SSG–Turtle–Nook–Run

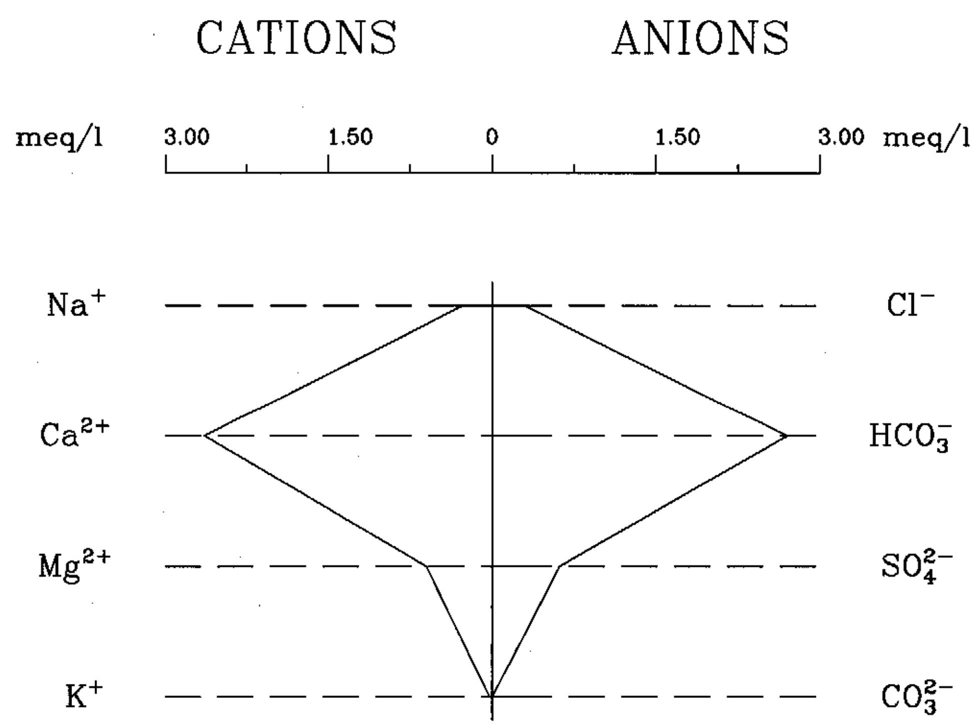
Ion	meq/l	meq/l
Na^+	.31	
Ca^{2+}	2.79	
Mg^{2+}	.77	
K^+	.02	
Cl^-		.32
HCO_3^-		2.57
SO_4^{2-}		.94
CO_3^{2-}		.00
	3.90	3.83



SAMPLE 28

SSG–Rac–Isl–inland

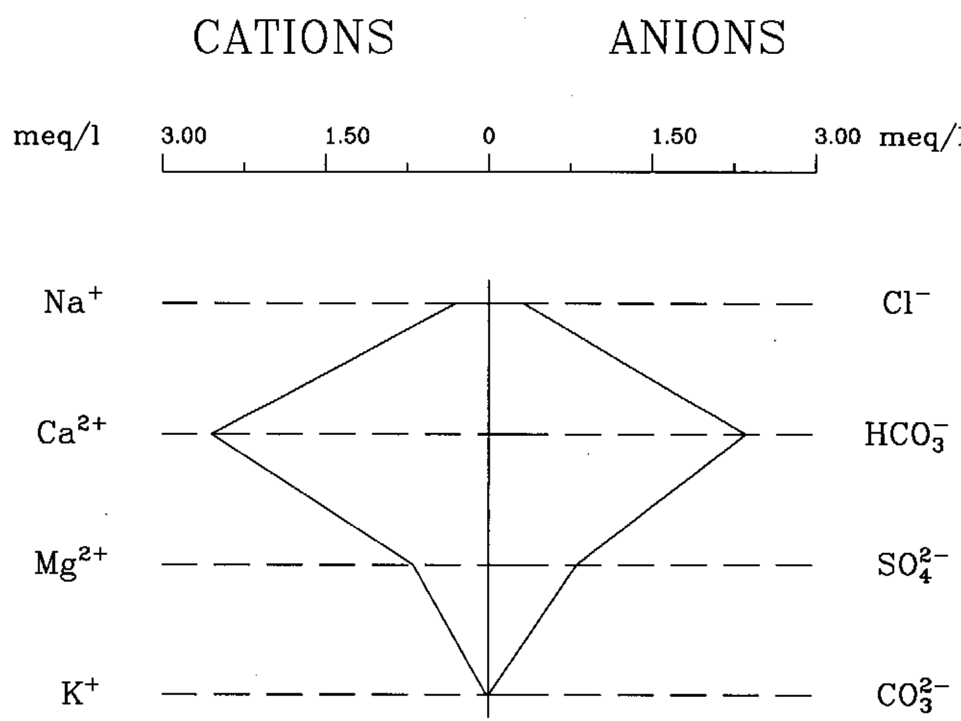
Ion	meq/l	meq/l
Na^+	.27	
Ca^{2+}	2.64	
Mg^{2+}	.60	
K^+	.02	
Cl^-		.30
HCO_3^-		2.70
SO_4^{2-}		.62
CO_3^{2-}		.00
	------	------
	3.54	3.62



SAMPLE 29

SSG–Rocky–Vent

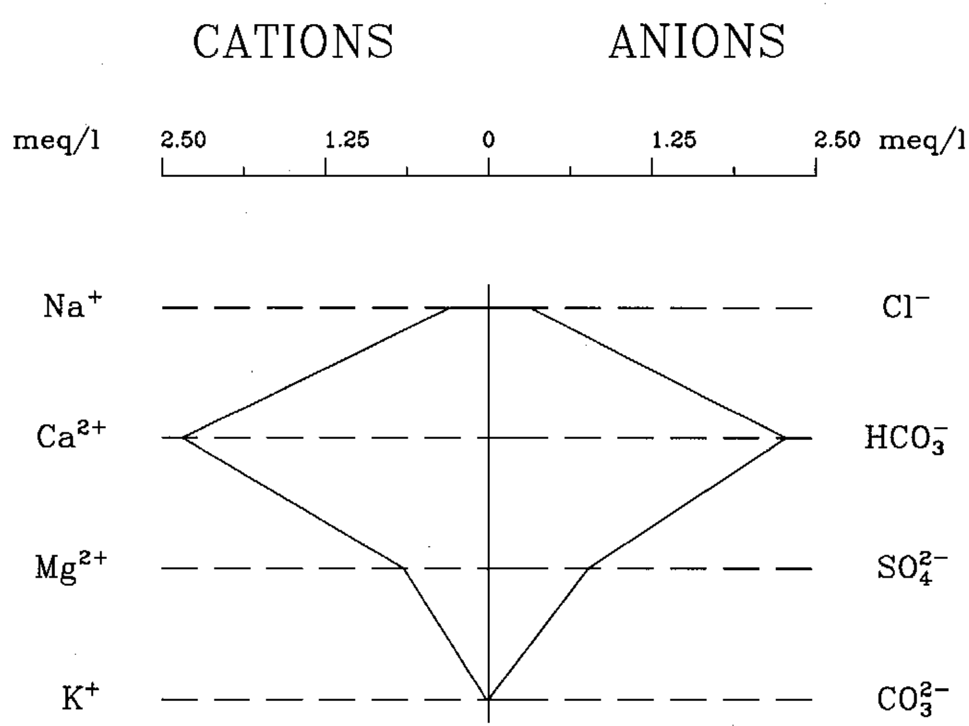
Ion	meq/l	meq/l
Na^+	.30	
Ca^{2+}	2.54	
Mg^{2+}	.69	
K^+	.02	
Cl^-		.32
HCO_3^-		2.36
SO_4^{2-}		.81
CO_3^{2-}		.00
	------	------
	3.56	3.49



SAMPLE 30

SSG–Shipwreck–1

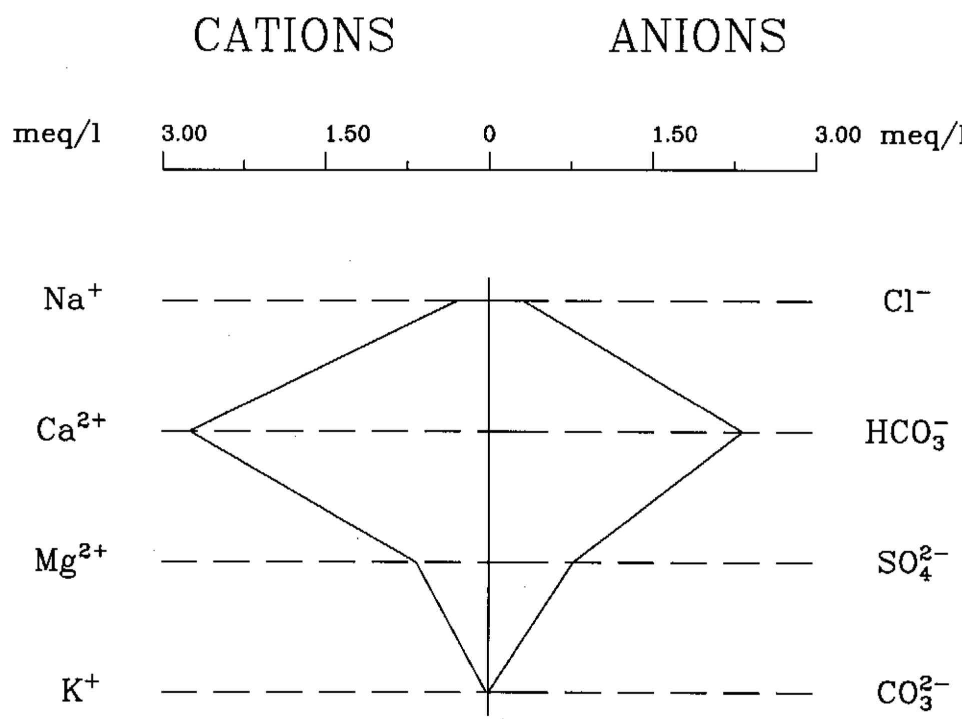
Ion	meq/l	meq/l
Na^+	.29	
Ca^{2+}	2.35	
Mg^{2+}	.65	
K^+	.02	
Cl^-		.31
HCO_3^-		2.28
SO_4^{2-}		.76
CO_3^{2-}		.00
	3.31	3.35



SAMPLE 31

SSG-Cat-Conv-Hall-1

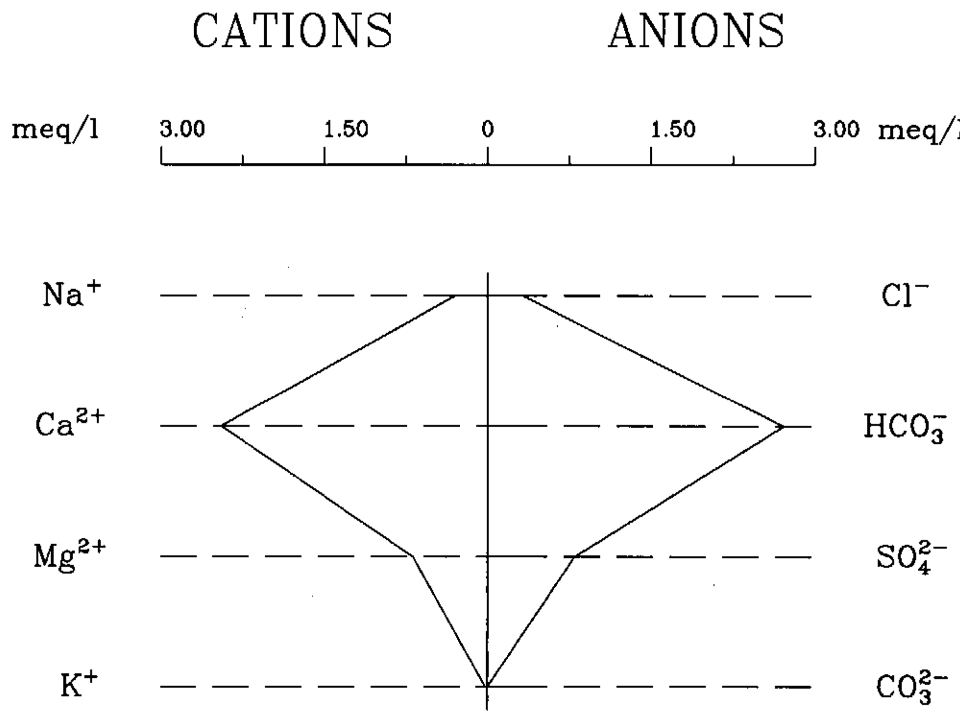
Ion	meq/l	meq/l
Na^+	.29	
Ca^{2+}	2.74	
Mg^{2+}	.67	
K^+	.02	
Cl^-		.32
HCO_3^-		2.33
SO_4^{2-}		.77
CO_3^{2-}		.00
	3.72	3.42



SAMPLE 32

SSG–Cat–Conv–Hall–2

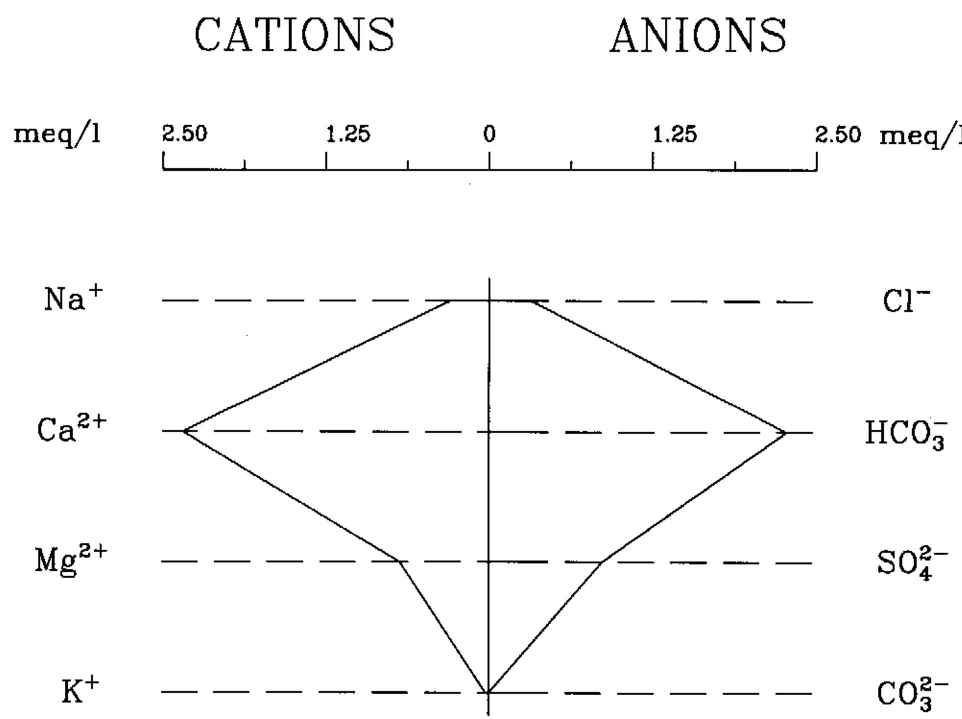
Ion	meq/l	meq/l
Na^+	.30	
Ca^{2+}	2.45	
Mg^{2+}	.68	
K^+	.02	
Cl^-		.33
HCO_3^-		2.72
SO_4^{2-}		.80
CO_3^{2-}		.00
	3.45	3.85



SAMPLE 33

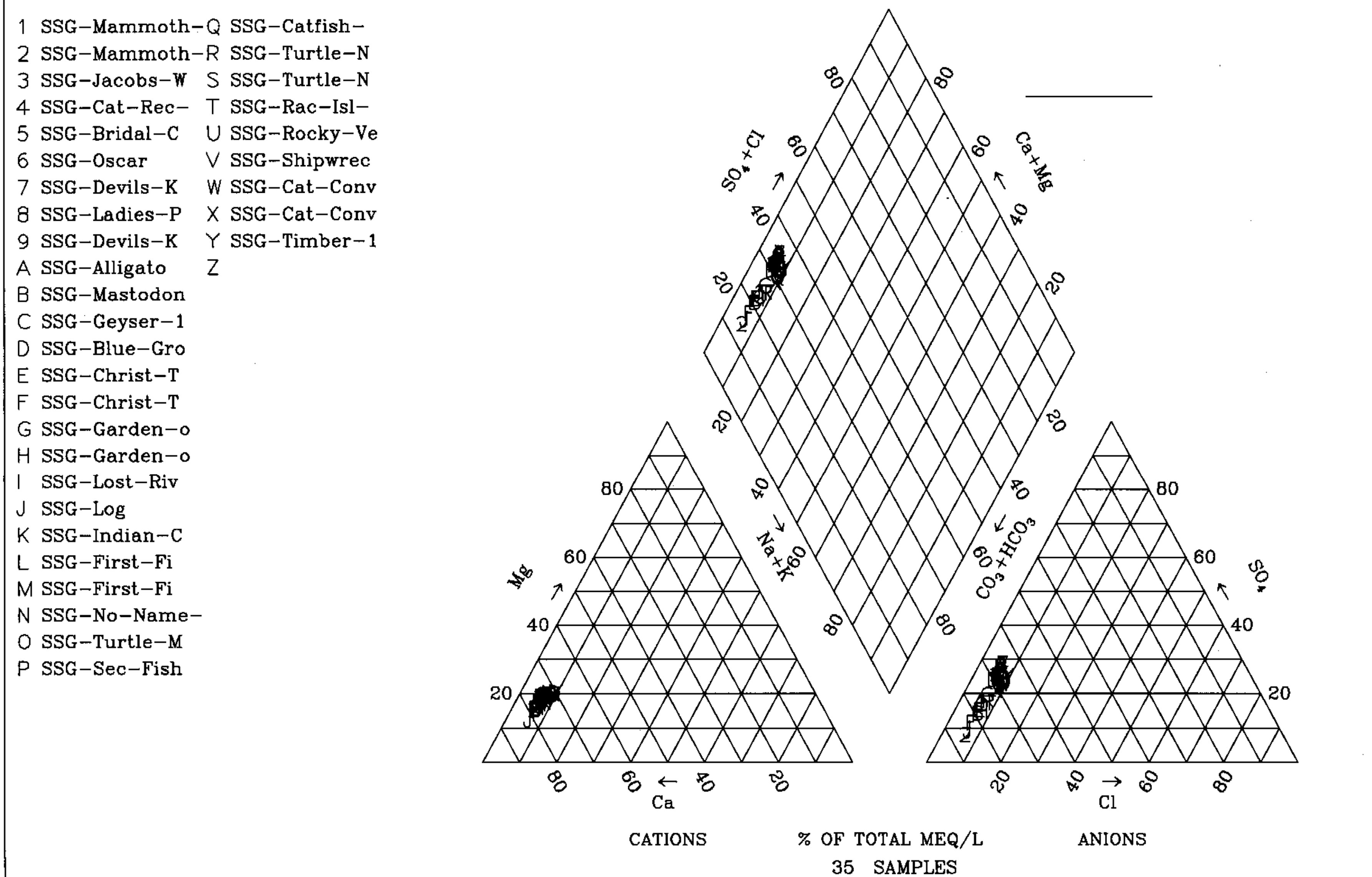
SSG–Timber–1

Ion	meq/l	meq/l
Na^+	.30	
Ca^{2+}	2.35	
Mg^{2+}	.68	
K^+	.02	
Cl^-		.32
HCO_3^-		2.28
SO_4^{2-}		.87
CO_3^{2-}		.00
	3.35	3.47



SAMPLE 34

Appendix 2
Trilinear Diagram


1 SSG-Mammoth-
2 SSG-Mammoth-
3 SSG-Jacobs-W
4 SSG-Cat-Rec-
5 SSG-Bridal-C
6 SSG-Oscar
7 SSG-Devils-K
8 SSG-Ladies-P
9 SSG-Devils-K
A SSG-Alligato
B SSG-Mastodon
C SSG-Geyser-1
D SSG-Blue-Gro
E SSG-Christ-T
F SSG-Christ-T
G SSG-Garden-o
H SSG-Garden-o
I SSG-Lost-Riv
J SSG-Log
K SSG-Indian-C
L SSG-First-Fi
M SSG-First-Fi
N SSG-No-Name-
O SSG-Turtle-M
P SSG-Sec-Fish
Q SSG-Catfish-
R SSG-Turtle-N
S SSG-Turtle-N
T SSG-Rac-Isl-
U SSG-Rocky-Ve
V SSG-Shipwrec
W SSG-Cat-Conv
X SSG-Cat-Conv
Y SSG-Timber-1
Z
SO_4+Cl
Ca+Mg
Na+K
CO_3+HCO_3
Mg
Ca
SO_4
Cl
CATIONS
% OF TOTAL MEQ/L
35 SAMPLES
ANIONS

Appendix 3
Silver Springs Vent Documentation, September 2006

Silver Springs Spring Vent Documentation
Marion County, Florida;
September, 2006

For:

St. Johns River Water Management District

4049 Reid Street
Palatka, Florida 32177

By:

Karst Environmental Services, Inc.

5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

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Silver Springs Spring Vent Documentation
Marion County, Florida; September, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to assist in the collection of data from the various springs that constitute the Silver Springs Group in Marion County, Florida. This report documents the results of the work done at the site during September, 2006, which includes the first comprehensive physical and ecological description and mapping of all the springs in the first 1,200 meters (m) of the Silver River, as well as an estimation of their discharge. Water samples were also collected for water quality analysis by the SJRWMD. The Silver River starts at the first spring called Mammoth Spring.

Silver Springs consists of a group of at least 30 named springs or spring groups located along about 0.5 mile of the Silver River. Mammoth Spring makes up two of these spring groups. It is thought that Silver Springs is increasingly threatened by activities associated with the tremendous population growth in its watershed. These threats include: groundwater overpumping, overuse and inappropriate use of pesticides and fertilizers, urban sprawl, and stormwater and agricultural runoff.

Monitoring of water quality at Silver Springs has found contaminants entrained in its discharge, indicating at least localized and possibly generalized pollution of groundwater in its springshed. Some of these contaminants, most notably nitrate, are thought to be adversely affecting the spring environment, chiefly by accelerating the growth of algae, such as the filamentous *Lyngbya*, with subsequent shifts in vegetative patterns and loss of certain physical habitats, such as sandy bottom.

Since the 1950’s, there have been several ecological studies at Silver Springs that have documented a gradual deterioration of conditions in the river and springs (Whitford, 1954, 1956; Odum, 1957; Martin, 1966; Stevenson, et.al. 2004; Phlips and Allen, 2004; and Phelps and Walsh, 2005; Munch et al, 2006). Silver Spring is almost unique in this respect; at most other Florida springs, researchers studying ecological trends have nothing to rely upon but anecdotal accounts of past conditions. This study will add to the literature on this great spring group, and hopefully provide a “snapshot” of flow, water quality, and ecological conditions that will be useful in understanding and protecting this natural wonder.

PURPOSE and SCOPE OF WORK

The following tasks were to be performed at 30 or more selected vents:

1. Collect water samples (directly for SJRWMD staff), assist with positioning of boats for handheld GPS locations.

2. Make sketch maps and record physical descriptions of each vent, make and note biological/ecological observations, process data and prepare report. Take photographs of each spring and its features.

3. Perform underwater discharge measurements, process data and prepare report.

PERSONNEL

Fieldwork was conducted by Peter Butt, Project Manager, Tom Morris, Biologist, and Mark Long, Field Technician. Photography was performed by Jill Heinerth and Georgia Shemitz. Watercraft support was provided by Scott Braunsroth. Data management and report preparation was performed by Peter Butt and Tom Morris.

METHODS

The fieldwork for this study was carried out during the month of September, 2006. Jon boats were used to access all previously known Silver River springs and spring groups, as well as several springs that were discovered during the study.

During the first part of the study, KES divers assisted SJRWMD personnel in collecting water samples from each of the springs or spring groups. Samples were collected by divers running tubing directly into spring vents and pumping the water up to the boats. Water samples were analyzed immediately for field parameters and sent by SJRWMD to labs for further analysis.

In the second part of the study, information was gathered at each spring or spring group for the preparation of descriptions and sketch maps, which are included in this report. Also, a visual ecological survey of the relative dominance of several cover-types was completed at each spring basin, and interesting biological observation were recorded. Underwater photographs of the springs were taken throughout the water sampling and data collection activities.

During the third part of the study, discharge measurements of the springs were made and additional ecological observations were made.

The delineation of spring and spring group boundaries was necessarily somewhat subjective. Most of the springs occur as distinct openings in the rock bottom of the Silver River, or within sediment-mantled depressions located in coves along the bank. However, many of the springs consist of groupings or clusters of two or more spring vents, or as groups of vent clusters. Furthermore, several of the springs discharge through complex areas of boulders and ledges.

Spring and springs group boundaries were generally delineated at more-or-less distinct topographic breaks, where the upward-sloping walls of the basins level out to the depth of the surrounding bottom. However, some of the springs have no "natural" boundary formed by an easily recognizable topographic break. Nevertheless, these springs usually have an obvious zone of influence, where bottom sediments and vegetation differ from the surrounding area. These factors, as well as relative distance between features, were all used in delineating these spring and spring group boundaries.

Cover-type survey was based on a visual survey of each spring basin; no measured transects or plots were utilized. However, these are likely good order of magnitude vegetation cover estimates which may be useful for tracking future changes at the springs. All ecological observations described herein were made by KES biologist Tom Morris using SCUBA or snorkeling gear. Wildlife observations were recorded at a few springs and include remarkable occurrences of native fish or the presence of non-indigenous fish.

The cover-type survey and ecological observations were made during the second week of September, 2006. The main observations include: an estimate of the coverage, given as a percent of spring basin bottom area, of submerged macropyhtic plant species; coverage of spring basin bottom area by filamentous macroalgae; growth of filamentous algae on submerged macrophytic vegetation, and percent of basin remaining in sandy and rocky bottom habitat.

Algal standing crop may consist of a consortium or association of several species. However, the scope of this work did not include the identification of extant algae; instead, its focus was on the relative dominance of vegetation types in the spring basins, such as coverage by filamentous algal growths.

Physical measurements of the springs were made using underwater compass and fiberglass tape, with data recorded on plastic slates. Data was transferred to grid paper, scanned and finished using Canvas drawing software.

Photographs were also taken at each site. Photographs of the springs are included in "Silver River Springs Photographic Documentation" by KES.

Discharge measurements were taken at most of the spring vents. These measurements were taken using an electronic flowmeter adapted for underwater use. Many of the springs were measured using the standard cross-section method used by KES. Many vents (especially those discharging through soft bottom sediments and algae) that did not lend themselves to this method were measured using a Vent Discharge Capture Device specially designed for this purpose. Data was processed using Golden Surfer 8 software. The results and summary of these measurements are presented under separate cover.

A brief description of each of the various springs or spring groups, a plan view map of each site, and the results of the ecological survey are presented herein. The springs are listed in upstream to downstream order.

ECOLOGICAL SURVEY AND OBSERVATIONS

General Description of Study Site

Silver Springs consists of a large head spring, and at least 28 other individual springs and clusters or groups of springs located in the bed of the river, or in coves, along the upper one-half mile of the Silver River. The depth at the mouth of Mammoth Spring is about 30 feet. Much of the Silver River is about 10 ft deep or less. Many of the spring vents are between 15 and 20 feet deep. Mammoth Spring consists of two vents.

Assemblages of submerged aquatic macrophytes and macroalgae vary among the springs, probably due to the influence of physical characteristics, such as bottom type or strong current.

The dominant submerged macrophytic vegetation in the Silver River and its individual spring basins is strap-leaf sagittaria (*Sagittaria kurtziana*). The only other submerged macrophyte present is coontail (*Ceratophyllum demersum*). Strap-leaved sagittaria and coontail are both considered to be desirable aquatic plants, providing habitat for micro and macro invetebrates, and food and cover for many wildlife species. Epiphytic algae, including green and diatomaceous algae, as well as filamentous blue-green algae, generally cover the leaves of strap-leaf sagittaria to varying degree.

Benthic algal species dominate or cover a significant part of the bottom of the Silver River and many of the springs. The most common algae are *Lyngbya sp*. *Lyngbya* are nitrogen fixing blue green algae, or cyanobacteria, and their recent rapid colonization of many Florida springs has alarmed biologists. This genera was not present during Odum's (1957) classic study at Silver Springs, although he reported small mats of *Spirogyra sp*. A decade later, Martin (1966) found dense growths of *Spirogyra* in Mammoth Spring, as well as attached *Lyngbya*. By 2003, Stevenson (2004) reported macroalgal cover at Silver Springs to be about 70 percent, of which about three-quarters was *Lyngbya majuscule*. Many ecologists suspect the apparent increase in macroalgae is a response to increasing levels of nutrients in groundwater. It has also been suggested that Lyngbya may be a recently introduced species that is going through the explosive growth phase characteristic of troublesome exotics.

Survey Results

The coverage (in percent) of the bottom of the Silver River spring basins by filamentous macroalgae, strap-leaved sagittaria, coontail, and bare sand and/or rock was estimated by visual survey. These categories included almost all the significant bottom variety in the basins. Ten of the 30 named spring/spring groups were divided into sub-basins for the cover-type survey, so a total of 33 individual basins were surveyed. The results of the cover-type survey for the springs and spring group basins are summarized in Table 1.

Filamentous algae, mostly *Lyngbya sp*. was the dominant cover-type in the spring basins, averaging about 60 percent coverage for all the basins, with a minimum coverage of zero percent and a maximum coverage of 100 percent. Strap-leaved sagittaria was the second most widespread cover-type, averaging about 25 percent coverage, with a minimum coverage of zero percent and a maximum coverage of 85 percent. Only about 9 percent of the basin bottoms had bare sand or rock substrates. Coontail, the only submerged macrophyte other than strap-leaved sagittaria, covered about 7 percent of the basin bottoms on average, varying from zero to 35 percent.

This survey’s estimated coverage by filamentous macroalgae is consistent with Stevenson’s (2004) report of 70 percent macroalgal cover at Silver Springs in 2003. Filamentous macroalgae was present in all flow conditions, but was noticeably dominant in areas of gentle flow, such as in protected coves and below the canopy of strap-leaved sagittaria., Conversely, filamentous macroalgae cover was reduced in most areas of strong flow. An uncommon, strongly attached moss-like macroalgae, which occurred as a thick carpet on rocky substrates, was only found in the exceptionally strong flow at a few vent orifices. These observations agree with Whitford (1954, 1956), who found water velocity to be the most important factor for algal distribution.

In the Geyser and Jacob's Well Spring basins, two to three feet of filamentous macroalgae sediments have accumulated, burying underlying sand and rock substrates. (Probing these deposits reveals a sharp transition from soft algal deposits to hard substrate.) These are extreme examples, but many of the former sand and rock substrates in the basins are now covered with several inches of algae. The authors are unaware of any studies addressing the ecological effects of the loss of "hard" substrates (sand and rock) in the Silver Springs ecosystem. However, it is possible that some organisms might be affected by these changes. For example, darters were strongly associated with sand substrates, and were never seen on algal substrates.

Vermiculated sailfin catfish (Pterygoplichthys disjunctivus) and their burrows were seen at several of the spring basins. These non-indigenous species from South America have colonized many springs and spring runs in the St. Johns River drainage. They do not appear to be nearly as numerous as in the Silver River springs as they do in other St. Johns River springs, such as Wekiva Springs.

The results of the cover-type survey, and incidental ecological observations, are given for each spring in the following "Spring Description, Ecology & Map" section.

Table 1. Bottom Cover Conditions				
Silver Springs Spring Vent Documentation, Marion County, Florida; September 2006				
Percent of Coverage of Silver River Spring Basins by Four Cover Types				
	Cover Type and Percent of Basin Bottom			
	Filamentous	**Strap-leaved**	**Coontail**	**Sand/Rock**
Spring Basin Name	**Algae**	**Sagittaria**		
Mammoth	80	10	-	10
Jacob's Well	40	20	-	40
Catfish Reception Hall	60	10	-	30
Bridal Chamber	65	30	-	5
Oscar	-	85	10	5
Ladies Parlor	70	5	-	25
Devil's Kitchen A	75	15	-	10
Devil's Kitchen B	65	35	-	-
Alligator Hole (Main Basin)	85	15	-	-
Alligator Hole (South Basin)	95	5	-	-
Mastodon Bone	20	50	30	-
Geyser	80	5	-	15
Blue Grotto	50	20	-	30
Christmas Tree	60	35	5	-
Garden of Eden (Main Vents)	75	20	5	-
Lost River and Log	100	-	-	-
Garden of Eden (SW Vent Line)	39	60	1	-
Indian Cave	60	35	5	-
First Fisherman's Paradise (Ledge)	28	50	2	20
First Fisherman's Paradise (East)	75	-	-	25
No Name Cove	70	30	-	-
Turtle Meadows (Main)	20	30	30	20
Turtle Meadows (SE)	45	10	35	10
Turtle Meadows (South)	20	40	30	10
Second Fisherman's Paradise	50	35	5	10
Catfish Hotel	70	15	10	5
Turtle Nook	95	-	5	-
Turtle Nook Run	80	-	10	10
Raccoon Island	95	-	5	-
Shipwreck	80	5	10	5
Catfish Convention Hall	40	45	15	-
Rocky Vent	40	40	10	10
Timber	10	50	30	10
Total Percent Coverage:	**59**	**24**	**7**	**9**

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SPRING DESCRIPTION, ECOLOGY & MAP

Mammoth Spring

Description: This is the largest and most upstream of the spring vents. It discharges horizontally into a large basin just east of the glass-bottom boat loading area. The vent is a horizontal, oval-shaped opening 2 to 6 feet high and about 65 feet wide at the base of a limestone wall. The bottom of the vent’s mouth is composed largely of breakdown boulders and rubble. The depth of water measured in front of the vent opening is about 34 feet. Water from at least two distinct sources (called Mammoth East and Mammoth West) discharge from the cave opening. These sources differ in temperature and chemistry. The spring basin measures about 300 feet north to south and 200 feet east to west.

Ecology: Benthic filamentous algae were the dominant vegetation in the deep parts of the basin, covering up to 80 percent of the rock or sand substrate in front of the vent. The wall above the vent was almost completely shrouded in filamentous algae, and "streamers" of algae attached to the roof of the vent undulated in the strong flow. An unidentified moss-like macroalgae covered many of the rocks in front of the cave entrance where flow was strong. The shallower parts of the head spring area supported strap-leaved sagittaria, with especially vigorous stands in the high flow zone in the south of the basin. The sagittaria leaf blades were generally covered with epiphytic algae, with filamentous algae mostly confined to the low flow microenvironment below the sagittaria "canopy". About ten percent of the Mammoth Spring basin was covered by strap-leaved sagittaria and 10 percent by sandy or rock bottom. Sagittaria growing on the rocky shelf above the basin headwall was covered with filamentous algae.

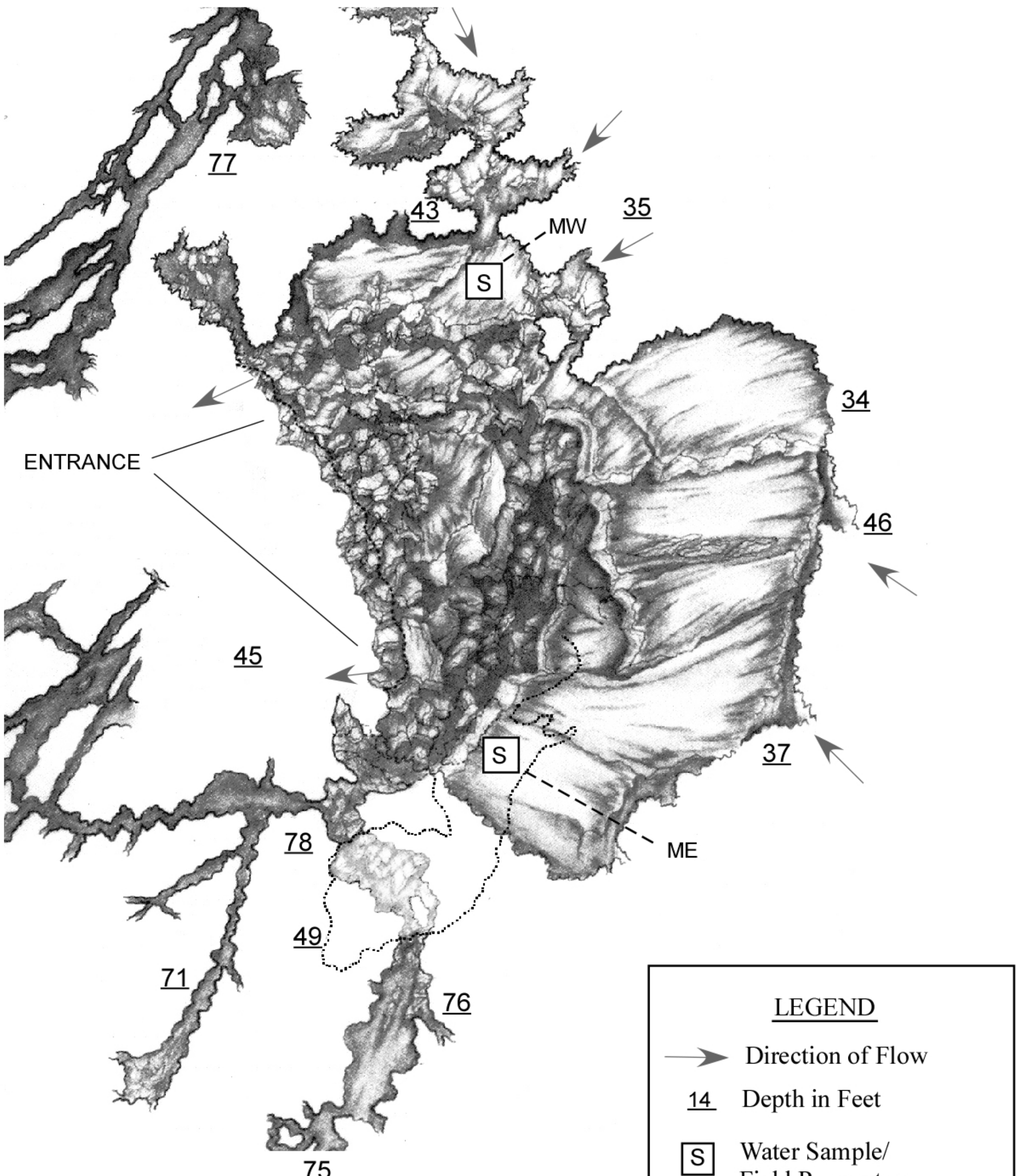
Crayfish (*Procambarus sp*.) were easy to find under rocks in the boulder-strewn bottom in front of the vent. Centrarchids, including long-ear and red-belly sunfish, and largemouth bass were common in the basin.

MAMMOTH SPRING

SILVER SPRINGS GROUP

MARION COUNTY, FLORIDA

PLAN VIEW



Adapted from "Silver Springs Cave System" Map
by Eric Hutcheson and the Silver Springs Cave diving Team, 1993

KARST ENVIRONMENTAL SERVICES, INC. 2007

Jacob's Well Spring

Description: Jacob's Well Spring is located on the south side of the upper Silver River, approximately 500 feet downstream from Mammoth Spring. The spring is in a large, sandy-bottomed depression shared with Catfish Reception Hall Spring to the southeast, and is about 22 feet deep. Water discharges horizontally from a narrow 10 foot long rocky vent beneath a limestone ledge. The ledge is at the bottom of the relatively steep western wall of the depression.

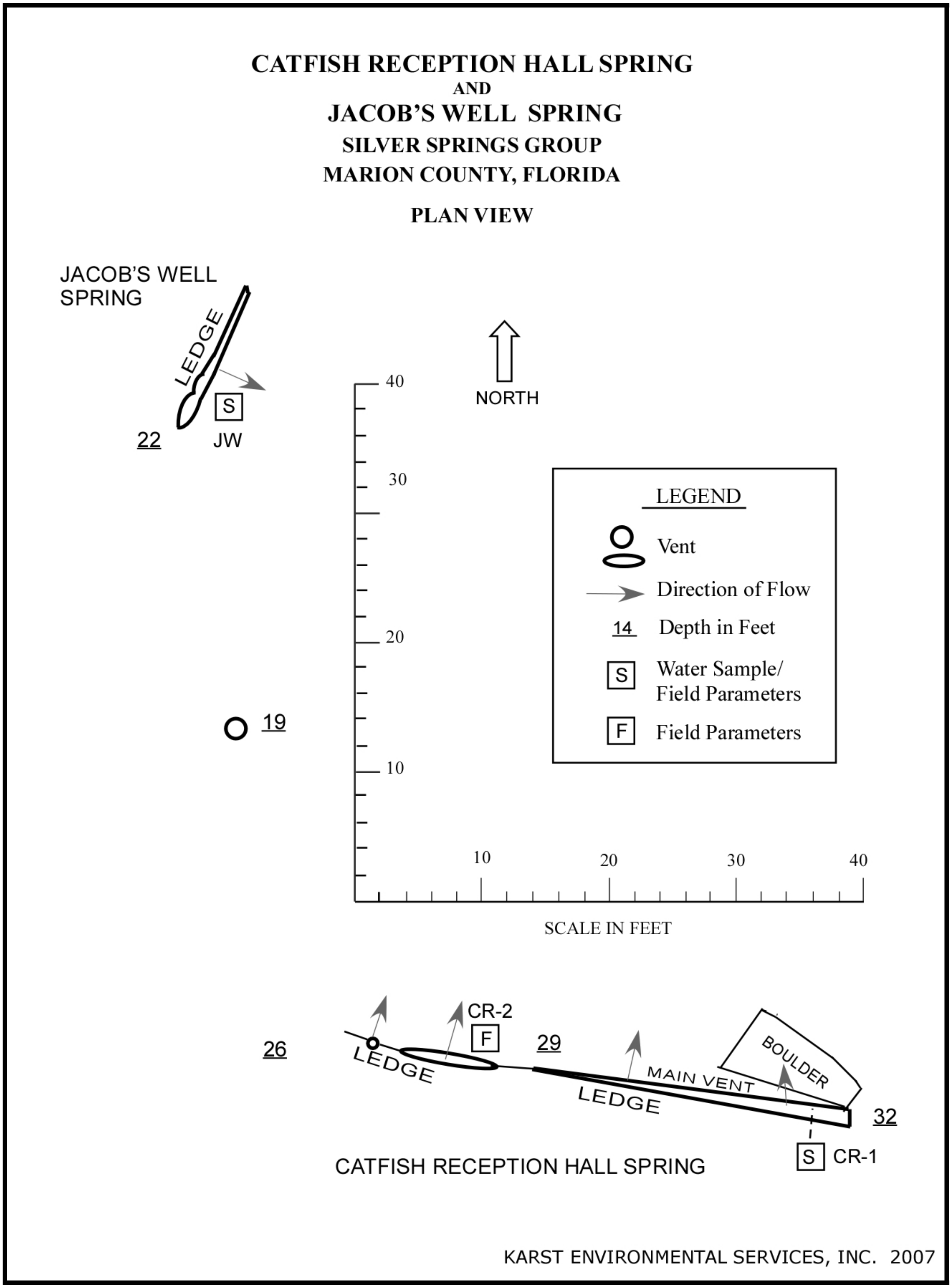
Ecology: About 40 percent of the basin was sandy, about 40 percent was sand covered with filamentous algae, and about 20 percent (the upper slopes) was covered by strap-leaved sagittaria. In places, filamentous algae was over two feet deep, with healthy algae covering older dead algae.

Several species of sunfish were common in the spring basin.

Catfish Reception Hall Spring

Description: Catfish Reception Hall Spring is located in the western part of a cove on the south side of the Silver River, approximately 50 feet southeast of Jacob's Well Spring, and shares a large sandy-bottomed depression with that spring. Catfish Reception Hall Spring discharges horizontally from a limestone ledge that forms a vent 26 feet long and up to five feet high at its eastern end, and tapering in height to its western side. The deepest portion of the vent bottom is 32 feet deep. A second narrow vent, about 7 feet long and less than one foot high extends along the rock ledge beginning about 3 feet west of the first vent. One other small vent in soft sediment was located about midway between this spring and Jacob's Well Spring.

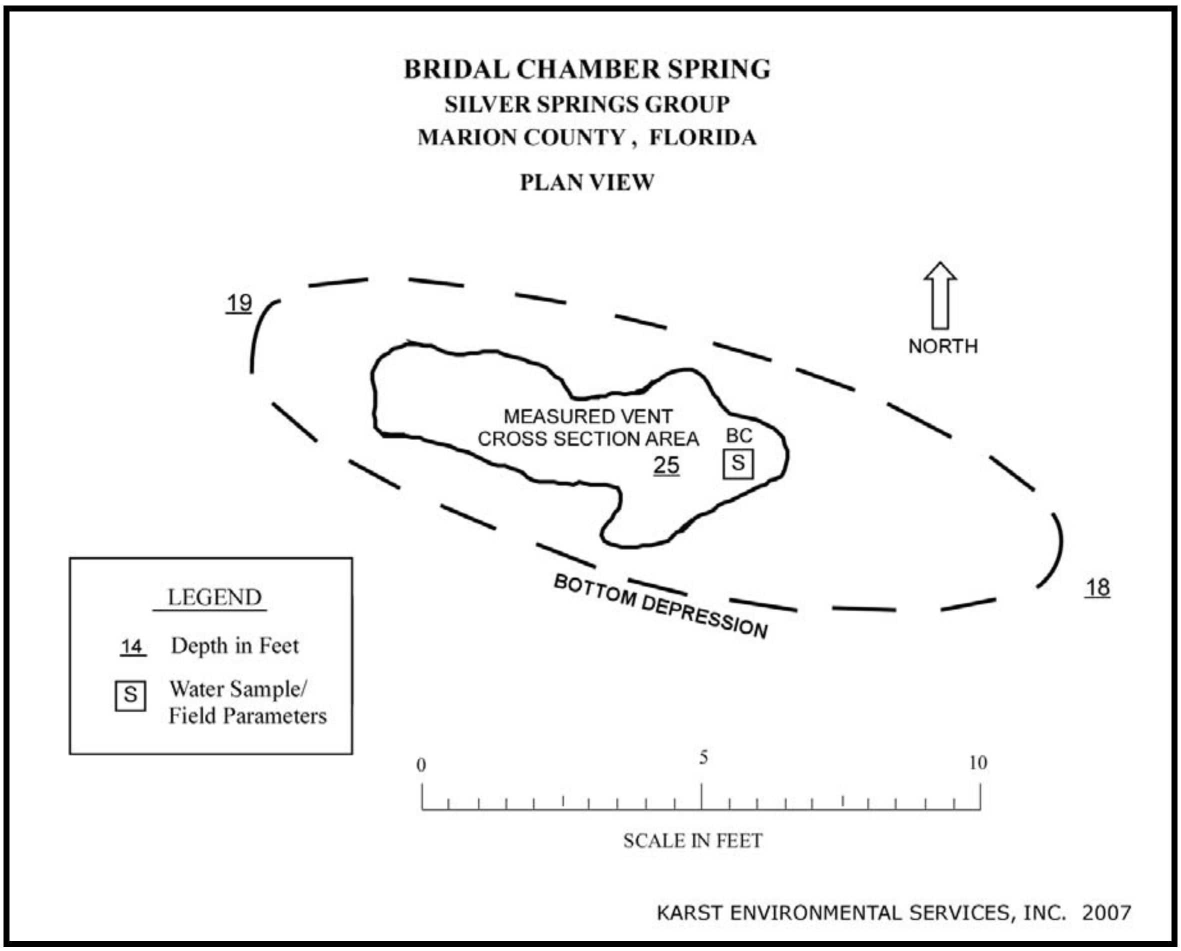
Ecology: The deeper parts of the basin were dominated by filamentous algae, which covered about 60 percent of the bottom. The remaining 30 percent was sand, including the high flow area just outside the vent. The upper slopes were dominated by strap-leaved sagittaria, with about 10 percent cover. Two unidentified species of small snails were common on rocks at the spring vent.


CATFISH RECEPTION HALL SPRING
AND
JACOB'S WELL SPRING
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
JACOB'S WELL SPRING
LEDGE
S
22
JW
NORTH
40
30
20
10
19
LEGEND
Vent
Direction of Flow
14 Depth in Feet
S Water Sample/ Field Parameters
F Field Parameters
10
20
30
40
SCALE IN FEET
CR-2
F
26
29
LEDGE
MAIN VENT
BOULDER
LEDGE
32
S CR-1
CATFISH RECEPTION HALL SPRING
KARST ENVIRONMENTAL SERVICES, INC. 2007

Bridal Chamber Spring

Description: Bridal Chamber Spring is located in a large basin on the south side of the Silver River, approximately 100 feet southeast of Catfish Reception Hall. Discharge is from an elongated vertical vent in the limestone, about 15 feet long, up to 2.5 feet wide, and about 18 feet deep.

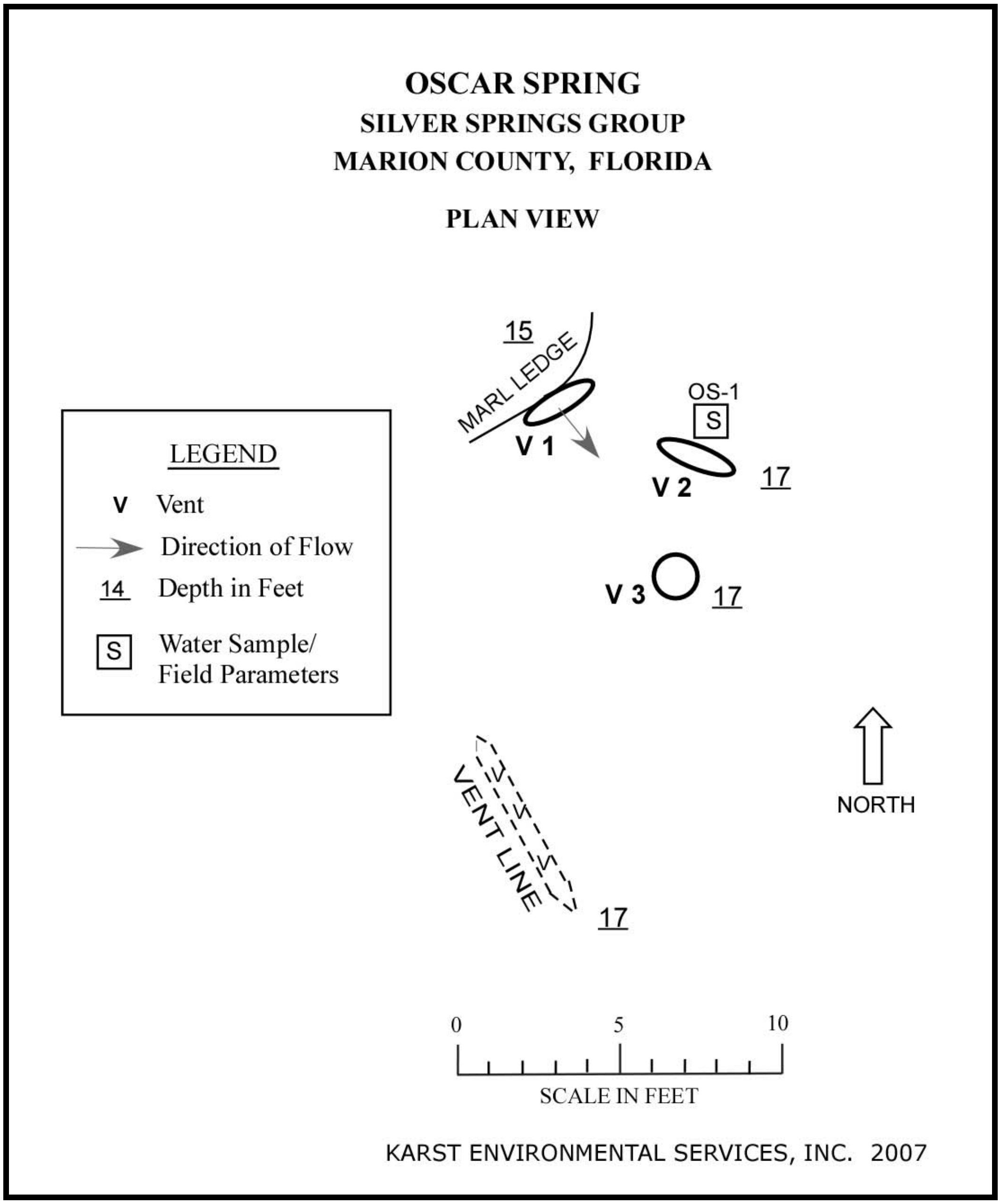
Ecology: About 30 percent of the basin, mainly on the sloping sides and shoulders, was covered by strap-leaved sagittaria. Five percent of the basin was sandy bottom, and 65 percent was sand or rock covered by filamentous algae.



Oscar Spring

Description: Oscar Spring is a group of spring vents in a shallow depression on the north side of the center of the river channel, about 140 feet northeast of Jacob's Well Spring. There are three small vents in the depression, one of which discharges from a marl ledge, and a line of vents about 8 feet long about ten feet to the southwest of the marl ledge. The deepest part of the depression is about 17 feet deep.

Ecology: The area around this spring was dominated by strap-leaved sagittaria, which covered about 85 percent of the basin. Coontail covered about ten percent, and the rest, about five percent, was sandy bottom in front of the vents. A large school of shad was in the area.

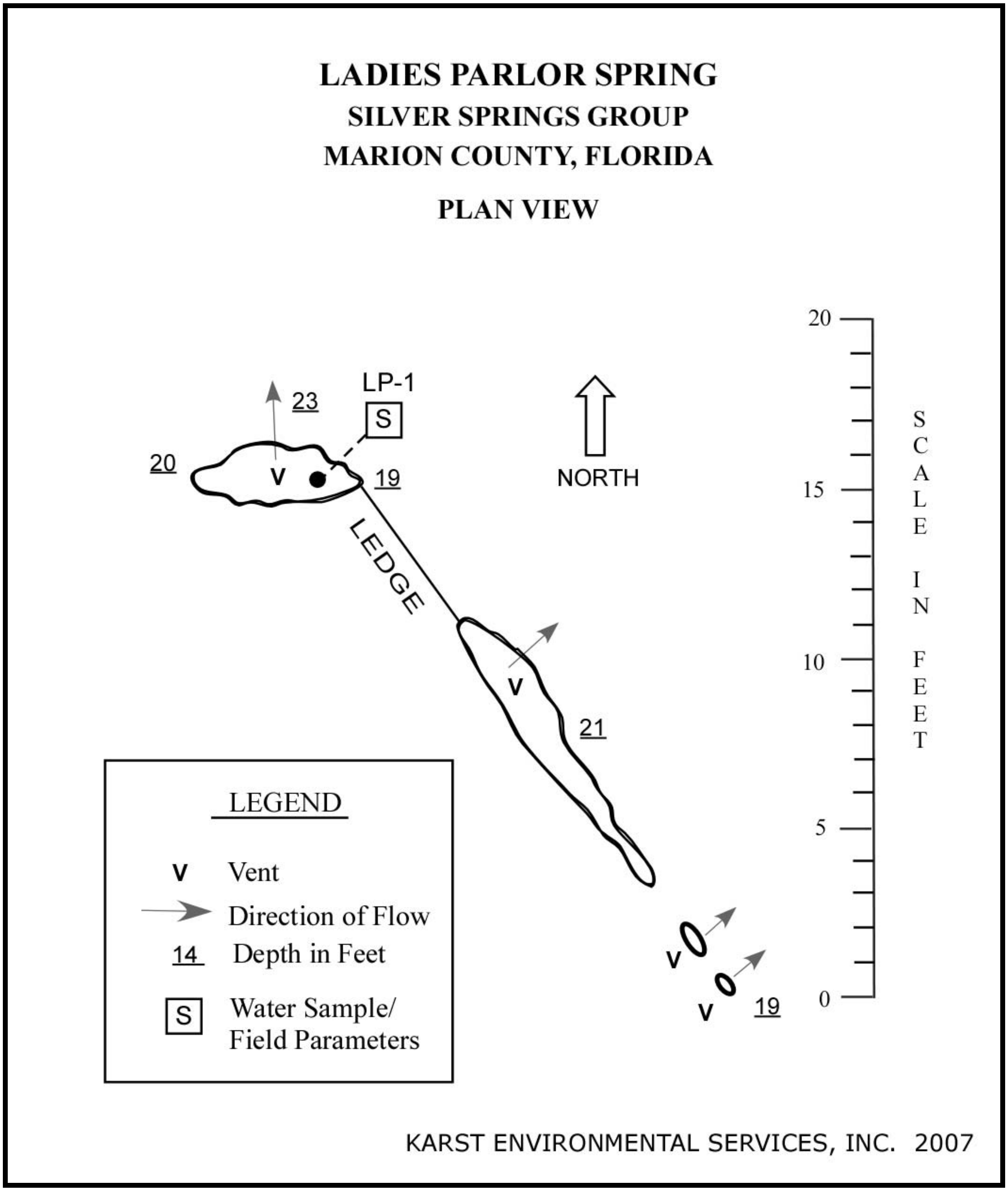


Ladies Parlor Spring

Description: Ladies Parlor Spring is located in the south side of a cove, approximately 60 feet southeast of Bridal Chamber Spring. Water discharges from a long vent beneath a ledge on the bottom of the southwest side of a large depression. The long vent is composed of two sections, one about 14 feet long, separated by about 5 feet of rock from the narrower vent that is about five feet wide. There is a strong flow moving the sand and shell fragments as water exits the vent. South of the long vent and also along the ledge are several very small vents, mostly obscured by algae.

Ecology: Vigorous flow keeps the sand and shell covered apron in front of the long vent free of algae. The sand and shell bottom covered about 25 percent of the basin, filamentous algae covered about 70 percent of the basin, and strap-leaved sagittaria covered about five percent of the shallow part of the upper slope above the vent.

A group of about ten darters, probably the black-banded darter (*Percina nigrofasciata*), were seen in the strong flow at the mouth of the vent.


LADIES PARLOR SPRING
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
LP-1
S
23
20
V
19
NORTH
LEDGE
V
21
V
V
19
20
15
10
5
0
SCALE IN FEET
LEGEND
V Vent
Direction of Flow
14 Depth in Feet
S Water Sample/ Field Parameters
KARST ENVIRONMENTAL SERVICES, INC. 2007

Devil's Kitchen Springs A and B

Description: Devil's Kitchen Spring A is located approximately 90 feet northeast of Ladies Parlor Spring. Water flows from vents beneath a 26 foot long linear limestone ledge, at a depth of 20 feet, at the bottom of a bowl-shaped depression. There are vents at each end of the ledge and several smaller vents between these.

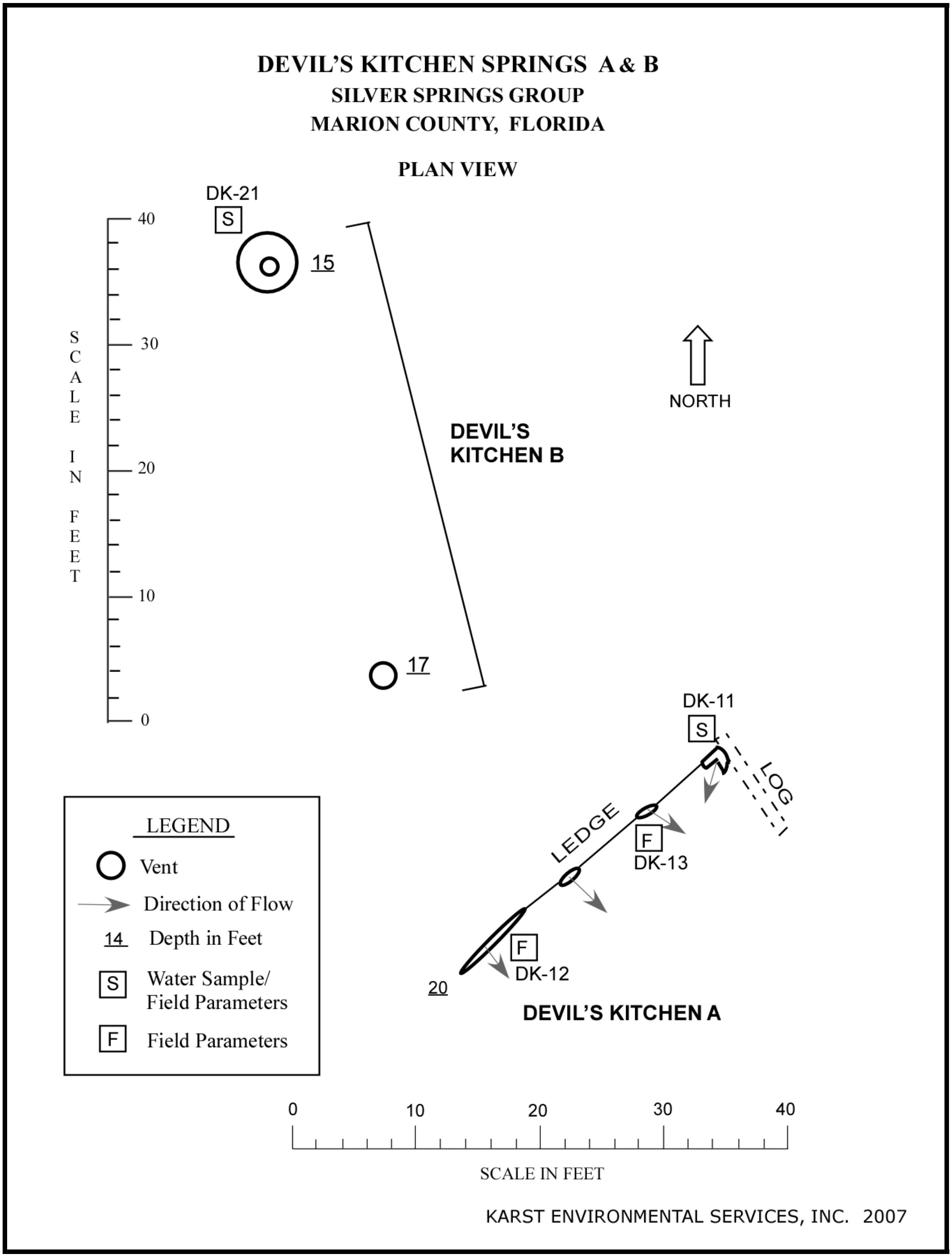
The depression extends to the northwest with a low saddle separating the deeper Devil's Kitchen Spring A basin and the slightly shallower Devil's Kitchen B basin. There is one small vent located between the two springs.

Devil's Kitchen Spring B is located approximately 60 feet northwest of Devil's Kitchen Spring A. It discharges from a roughly circular vent, about 15 feet deep, at the bottom of a sediment-sided depression.

Ecology: Devil's Kitchen A has a sandy area along the linear vent that covered about ten percent of the basin. Strap-leaved sagittaria covered about 15 percent of the basin and filamentous algae covered about 75 percent of the basin.

About 35 percent of the Devil's Kitchen B basin was covered by strap-leaved sagittaria, and 65 percent was sand covered by filamentous algae.

The slopes of both Devil's Kitchen spring basins had a half-dozen or so burrows dug by the vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*). This non-indigenous species from South America has colonized many springs and spring runs in the St. Johns drainage. Several of the catfish were seen in the burrows.



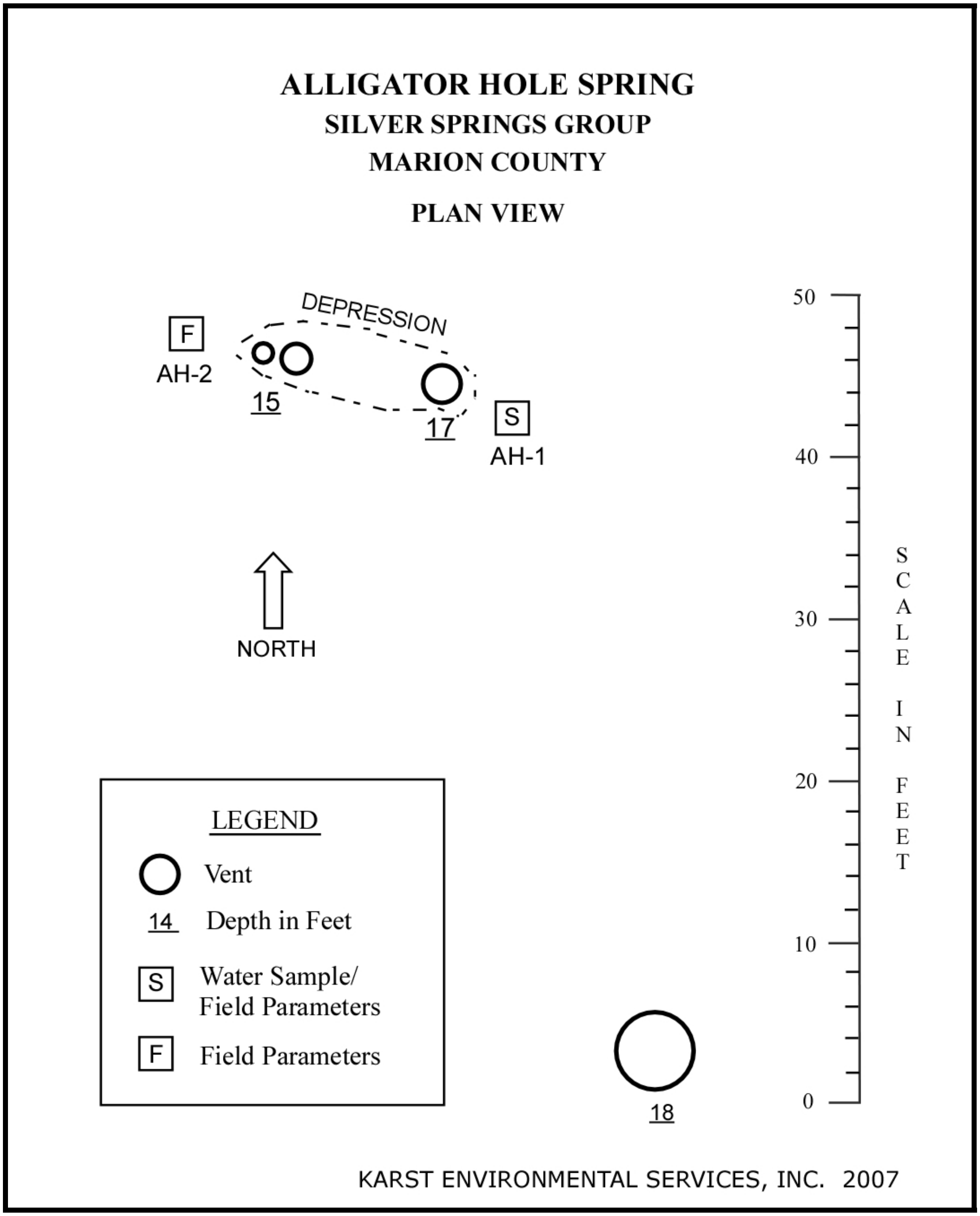
DEVIL'S KITCHEN SPRINGS A & B
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
DK-21
S
15
17
SCALE IN FEET
40
30
20
10
0
DEVIL'S KITCHEN B
NORTH
DK-11
S
LOG
LEDGE
F
DK-13
F
DK-12
20
DEVIL'S KITCHEN A
LEGEND
Vent
Direction of Flow
14 Depth in Feet
S Water Sample/ Field Parameters
F Field Parameters
0
10
20
30
40
SCALE IN FEET
KARST ENVIRONMENTAL SERVICES, INC. 2007

Alligator Hole Spring

Description: The main vents at Alligator Hole Spring are located in a somewhat elongated, oval basin along the south side of the Silver River, approximately 150 feet northeast of Devils Kitchen A. This depression is formed in soft sediments and is about 14 feet long. There are vents at both the upstream and downstream end of this depression, at depths of 15 and 17 feet, respectively. There is also a smaller vent about 40 feet southeast of Alligator Hole, about 18 feet deep, within a conical, silty depression, about 12 feet in diameter.

Ecology: Filamentous algae covered about 85 percent of the main basin and about 95 percent of the south basin. Strap-leaved sagittaria covered about 15 percent of the main basin and five percent of the shoulders of the south basin.

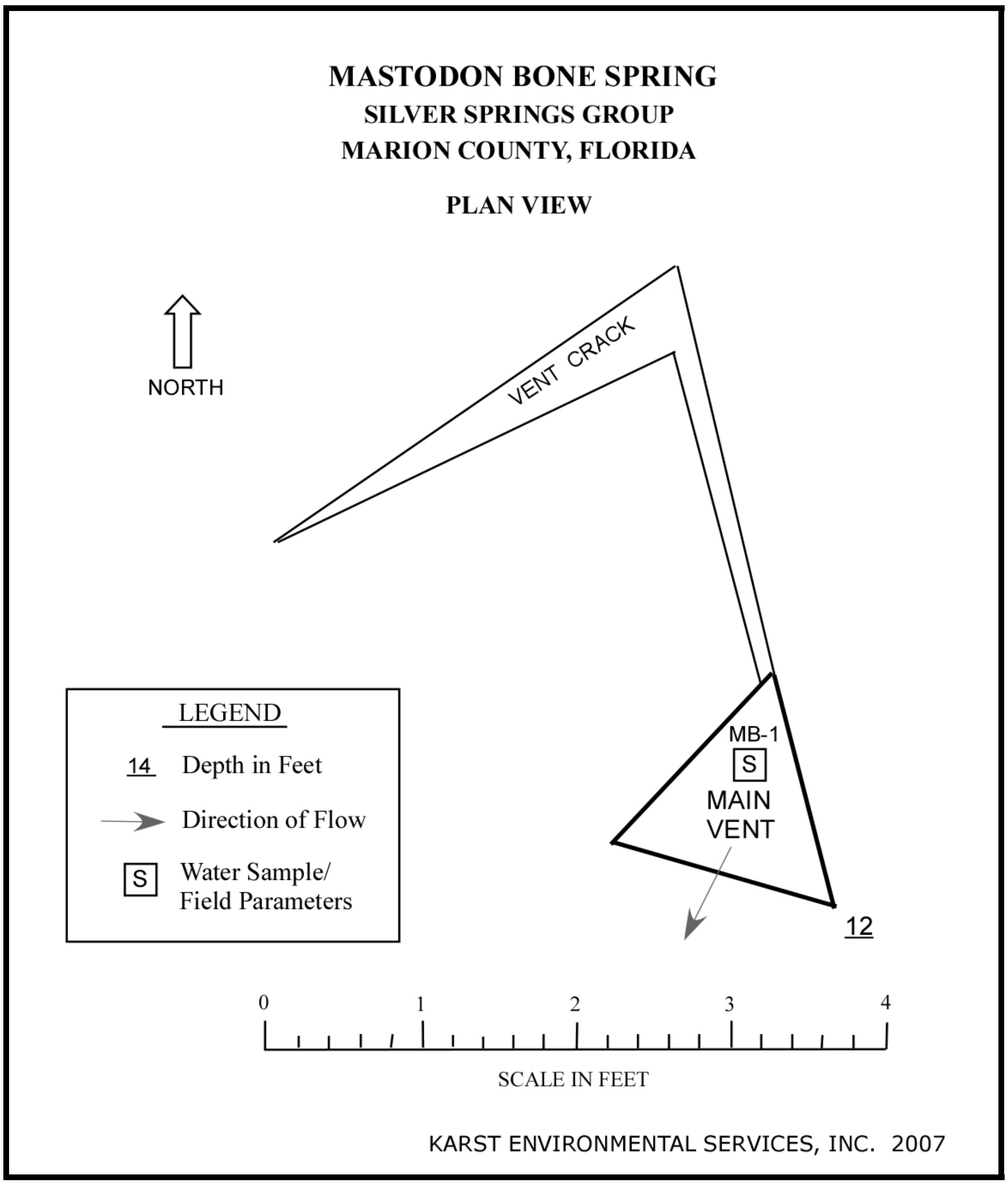
A large number of chain pickerel (*Esox niger*) were present among the cover of algal draped dead tree limbs in this cove.


ALLIGATOR HOLE SPRING
SILVER SPRINGS GROUP
MARION COUNTY
PLAN VIEW
DEPRESSION
F
AH-2
15
17
S
AH-1
NORTH
50
40
30
20
10
0
SCALE IN FEET
LEGEND
Vent
14 Depth in Feet
S Water Sample/ Field Parameters
F Field Parameters
18
KARST ENVIRONMENTAL SERVICES, INC. 2007

Mastodon Bone Spring

Description: Mastodon Bone Spring is located within the Silver River, on the north side, and opposite from a peninsula on the south side that is immediately upstream of the Geyser Spring Group. This spring discharges vigorously from two 4-foot long linear cracks that form a roughly triangular vent in the limestone, at the bottom of a conical basin. This spring is rocky, with little sediment around it, and is about 12 feet deep.

Ecology: Strap-leaved sagittaria and coontail are present at the vents and up the sloping sides of the basin, covering 50 percent and 30 percent of the basin, respectively. Twenty percent of the basin is covered by filamentous algae. Coontail is also entangled in the limbs of a fallen tree, anchoring it in the fairly strong flow of the river.



Geyser Spring Group

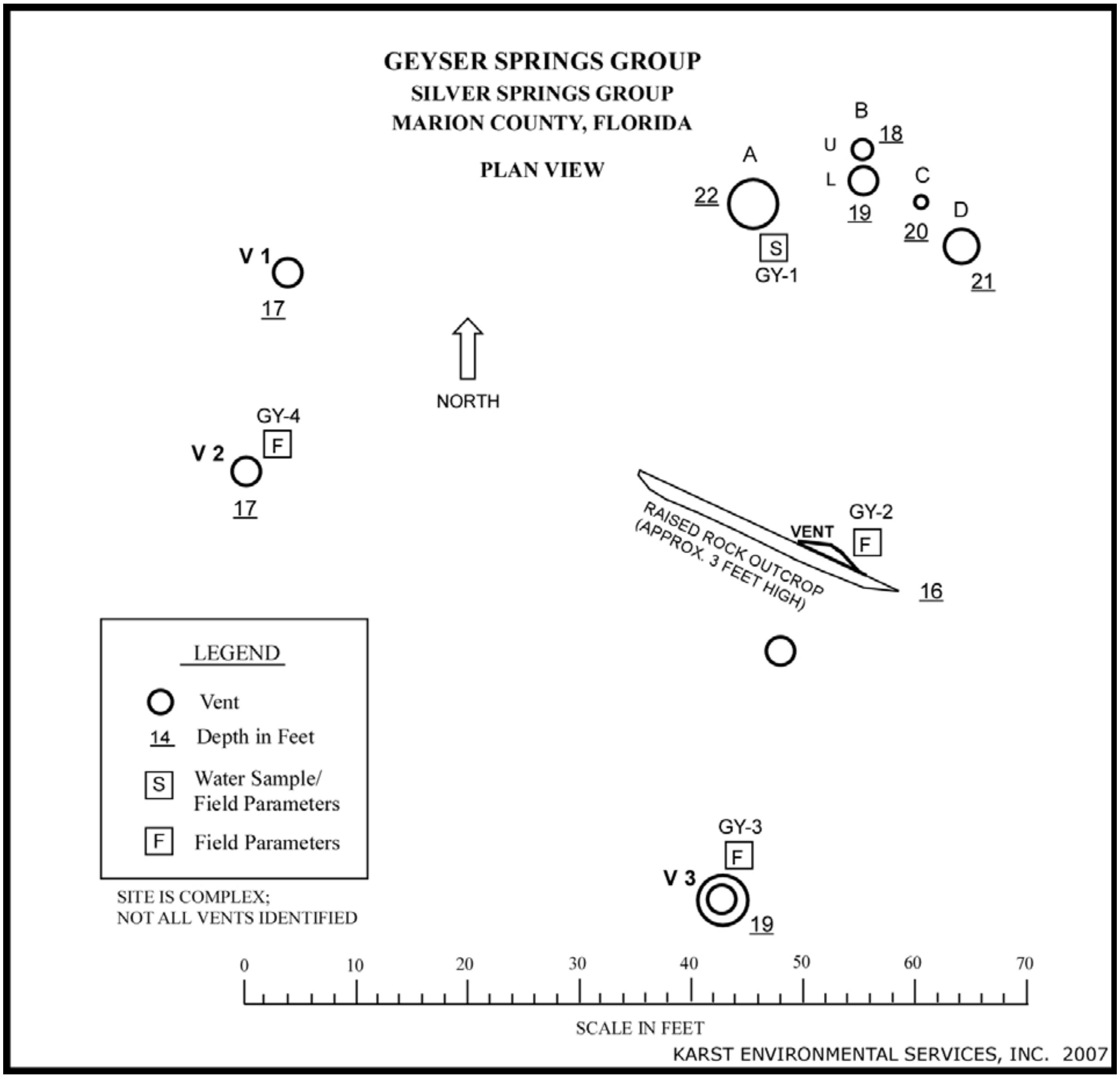
Description: The Geyser Spring Group is located in the western side of a large cove on the south side of the Silver River, east and downstream of Alligator Hole. There is a small peninsula of land between Alligator Hole Spring and Geyser Spring.

The Geyser Spring Group encompasses a number of vents of varying description. The large basin containing this spring group is dominated by a linear outcrop of limestone about 3 feet high and 26 feet long, at about 16 feet of depth. There are vents all along the base of this outcrop, with the largest vent on the northern side of its eastern end. Numerous other vents can be observed on the bottom of the basin around this outcrop, discharging through the filamentous algae that covers the bottom.

On the north side of the basin, about 35 to 40 feet north of the outcrop, there is a group of five large vents formed within the thick peaty deposits that overly the limestone. These vents lie along the bottom of the north slope of the basin, at about 18 to 20 feet deep.

About 30 to 40 feet west of the outcrop, there are several vents at about 17 feet of depth discharging through the algae covering the bottom. About 30 feet south of the outcrop, another vent discharges from the bottom of a conical depression at about 19 feet deep.

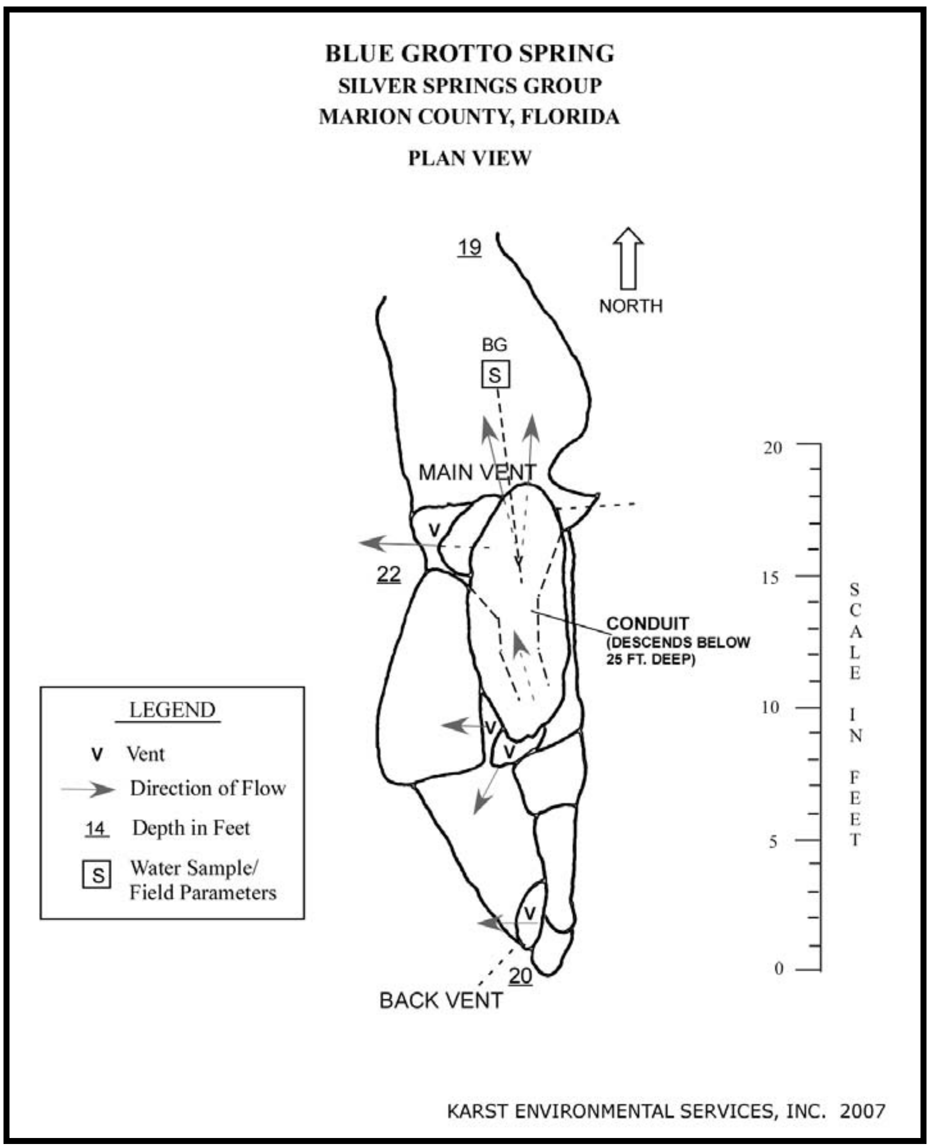
Ecology: Algae deposits up to three feet deep cover about 80 percent of this basin. Sand covers about 15 percent of the basin around the vents, and strap-leaved sagittaria covers about five percent of the rim of the basin. A thick mantle of organic deposits lie along the base of the north slope of the basin, and surround the larger rocky northern vents.


GEYSER SPRINGS GROUP
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
A
22
S
GY-1
B
U
18
L
19
C
20
D
21
V 1
17
NORTH
GY-4
F
V 2
17
RAISED ROCK OUTCROP
(APPROX. 3 FEET HIGH)
VENT
GY-2
F
16
LEGEND
Vent
14 Depth in Feet
S Water Sample/ Field Parameters
F Field Parameters
SITE IS COMPLEX;
NOT ALL VENTS IDENTIFIED
GY-3
F
V 3
19
0 10 20 30 40 50 60 70
SCALE IN FEET
KARST ENVIRONMENTAL SERVICES, INC. 2007

Blue Grotto Spring

Description: Blue Grotto Spring is located within a basin in the same cove as the Geyser Spring Group, about 100 feet to the southeast. There is an exposure of limestone bedrock and boulders at the bottom of the basin. Most of the discharge flows from vents at the northern end of this rocky structure, and a small conduit can be observed descending below 25 feet of depth. Water also discharges from a smaller vent on the south end of the structure, about 15 feet south of the large northern vent. Several smaller vents also discharge from numerous cracks between the boulders that make up the top and west side of this structure. Discharge from several of the vents is strong enough to suspend agitated sand and shell fragments.

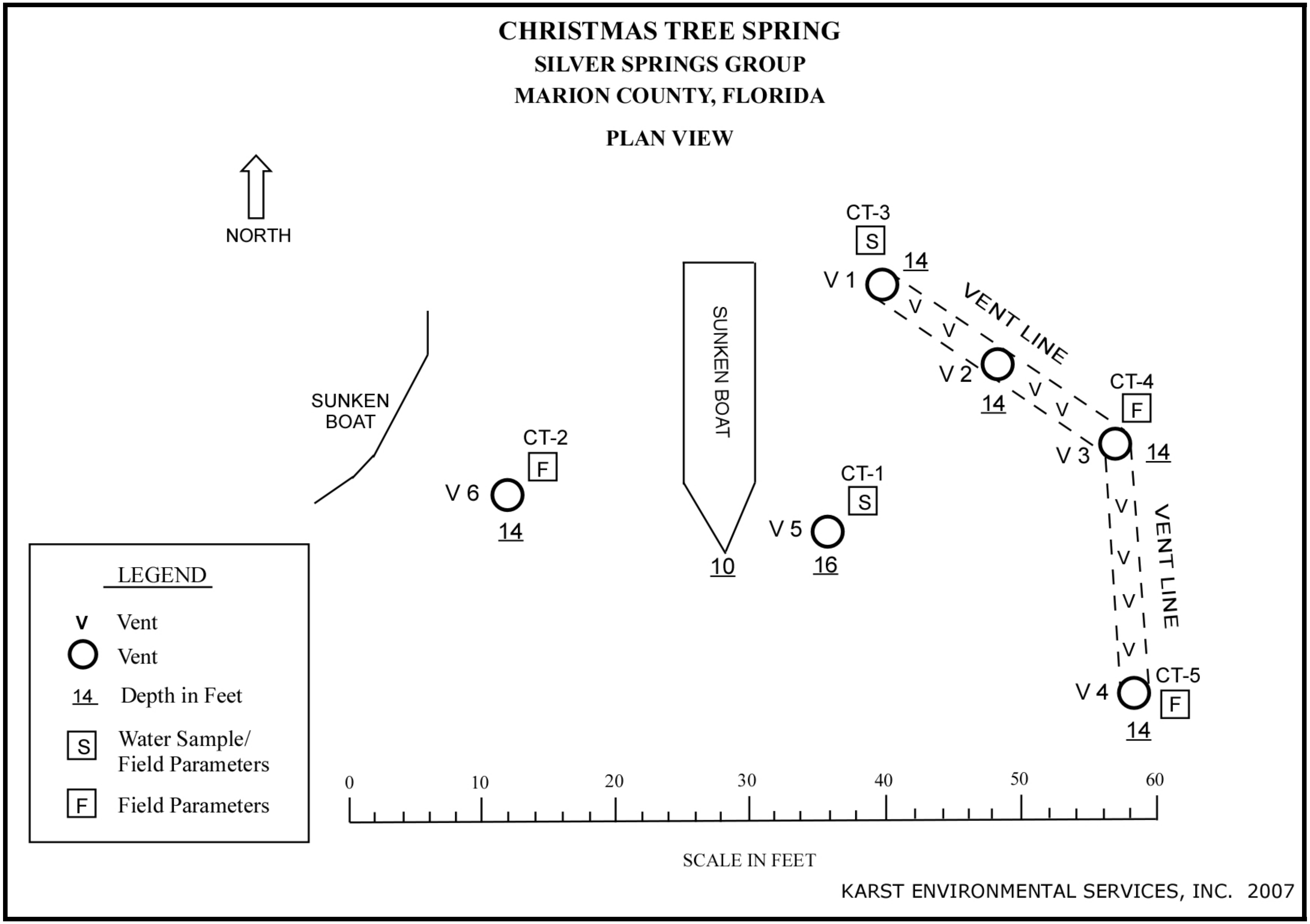
Ecology: About 30 percent of this basin is sand bottom or sand with a thin cover of filamentous algae. Strap-leaved sagittaria covered about 20 percent of the rim and sloping sides, and the remaining 50 percent was covered by a thick cover of filamentous algae. Many sunfish were present at this spring.



Christmas Tree Spring

Description: Christmas Tree Spring is located in a cove on the north side of the Silver River, south of the attraction's main stage area. It consists of a cluster of vents within a depression that surround a sunken boat. A second sunken boat lies along the west bank. A line of vents begins at the north end of the cove at about 14 feet deep, runs for 20 feet to the southeast, and then angles to the south for 18 feet, ending at 14 feet of depth. This vent line accounts for most of the discharge from this basin and contains debris and considerable aquatic vegetation. West of the vent line, and near the bow of the sunken boat, is a roughly circular vent about 16 feet deep. Another vent lies west of the sunken boat at 14 feet of depth. Discharge was also observed near the second sunken boat on the western edge of the basin.

Ecology: Strap-leaved sagittaria covered about 35 percent of the sloping sides of the basin and the basin bottom, including around the vents. Coontail covered about five percent of the basin. The remaining 60 percent of the basin was covered in soft sediments with varying amounts of filamentous algae. In areas of low flow the algae had risen from the bottom, forming stalagmite-like columns. Many fish were present here, especially under the cover of a nearby bankside sudd. These included bass, sunfish, and mudfish or bowfin (*Amia calva*). A few vermiculated sailfin catfish were seen at this spring.


CHRISTMAS TREE SPRING
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
NORTH
SUNKEN BOAT
SUNKEN BOAT
CT-3
S
14
V 1
V
V
VENT LINE
V 2
14
V
V
CT-4
F
V 3
14
CT-2
F
V 6
14
10
CT-1
S
V 5
16
V
V
V
V
VENT LINE
CT-5
V 4
F
14
LEGEND
V Vent
Vent
14 Depth in Feet
S Water Sample/ Field Parameters
F Field Parameters
0 10 20 30 40 50 60
SCALE IN FEET
KARST ENVIRONMENTAL SERVICES, INC. 2007

Garden of Eden Spring Group

Description: The Garden of Eden Spring Group is located in a cove about 240 feet east of Christmas Tree Spring. Garden of Eden is in the same cove as the jungle boat docks. A linear depression about 24 feet long and 15 feet deep contains a line of vents. This vent line accounts for most of the discharge from this group, and contains debris. About 30 feet west of this vent line, there is a roughly circular vent about 4 feet in diameter and 14 feet deep.

Another line of vents, about 17 feet long and 15 feet deep, lies 110 feet southwest of the main vent line. This vent line lies within a depression at the edge of the strong flow of the Silver River. The vents discharge through sand and gravel sediments.

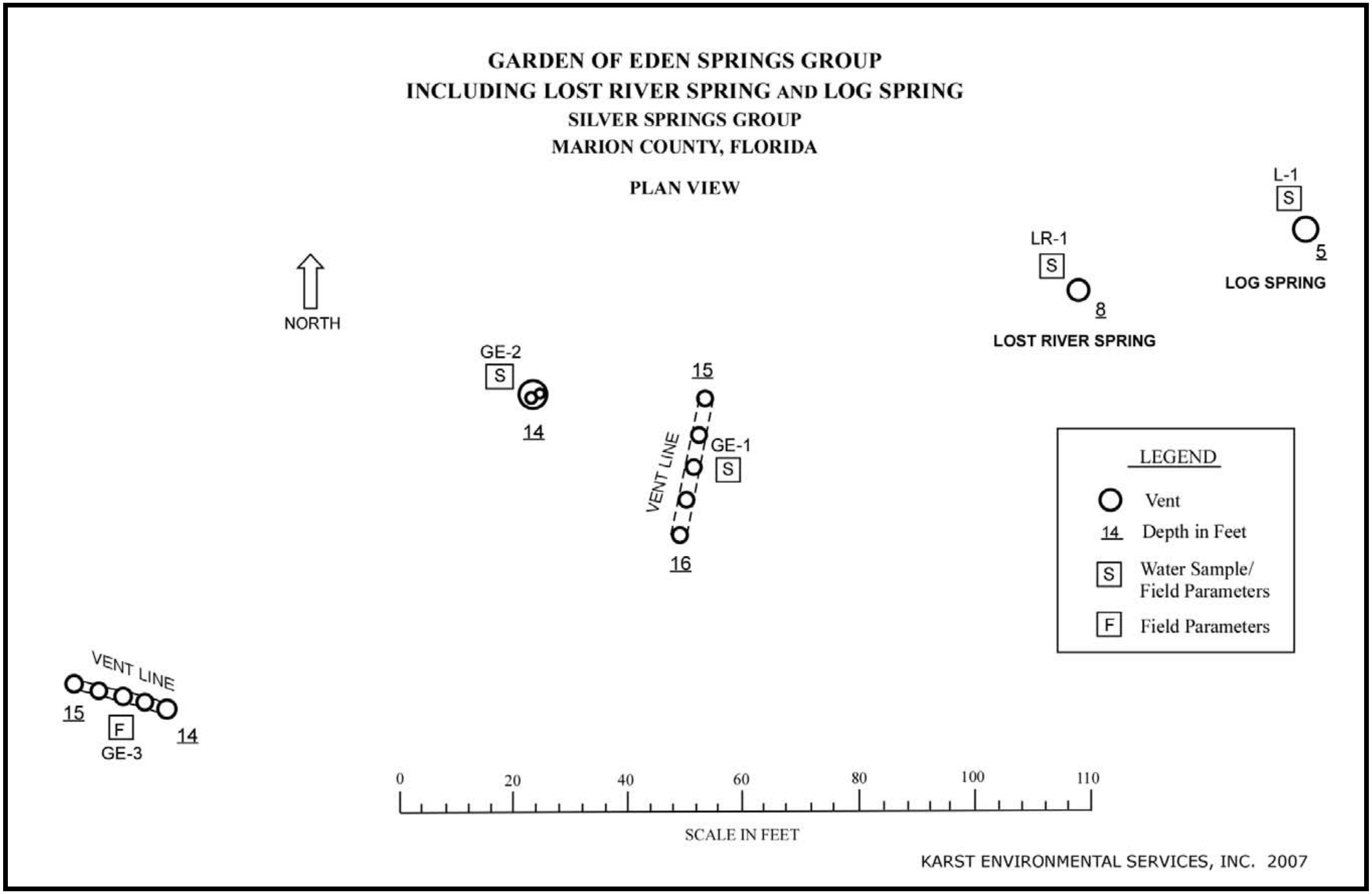
Lost River Spring and Log Spring

Two additional vents were discovered during this study east of the vent line, in a shallow swampy extension of the cove. The nearest of these, named Lost River Spring, is about 70 feet to the east, and is about two feet in diameter and about 8 feet deep. The second vent, named Log Spring, is 110 feet to the east of the vent line, and is about 3 feet in diameter and 5 feet deep. The vents of both of these springs gently discharge through detrital sediments and are beneath fallen tree limbs.

Ecology: Water current is low in the Garden of Eden basin due to its diffuse discharge and its protected position from river current in the cove. Strap-leaved sagittaria covered about 20 percent of the rim of the basin, and coontail covered about five percent. Both species were covered with filamentous algae. The remaining 75 percent of the basin had a sandy bottom with a light cover of filamentous algae. Sunfish were numerous in this basin and largemouth bass were present.

Lost River and Log Springs lie in a shallow swampy cove due east of Garden of Eden Spring main vent line. Both springs discharge vertically through detrital sediments. The soft bottom and the branches of several fallen trees were 100 percent covered in filamentous algae. A half dozen or so peninsula cooters (*Pseudemys floridana peninsularis*) were seen in the cove.

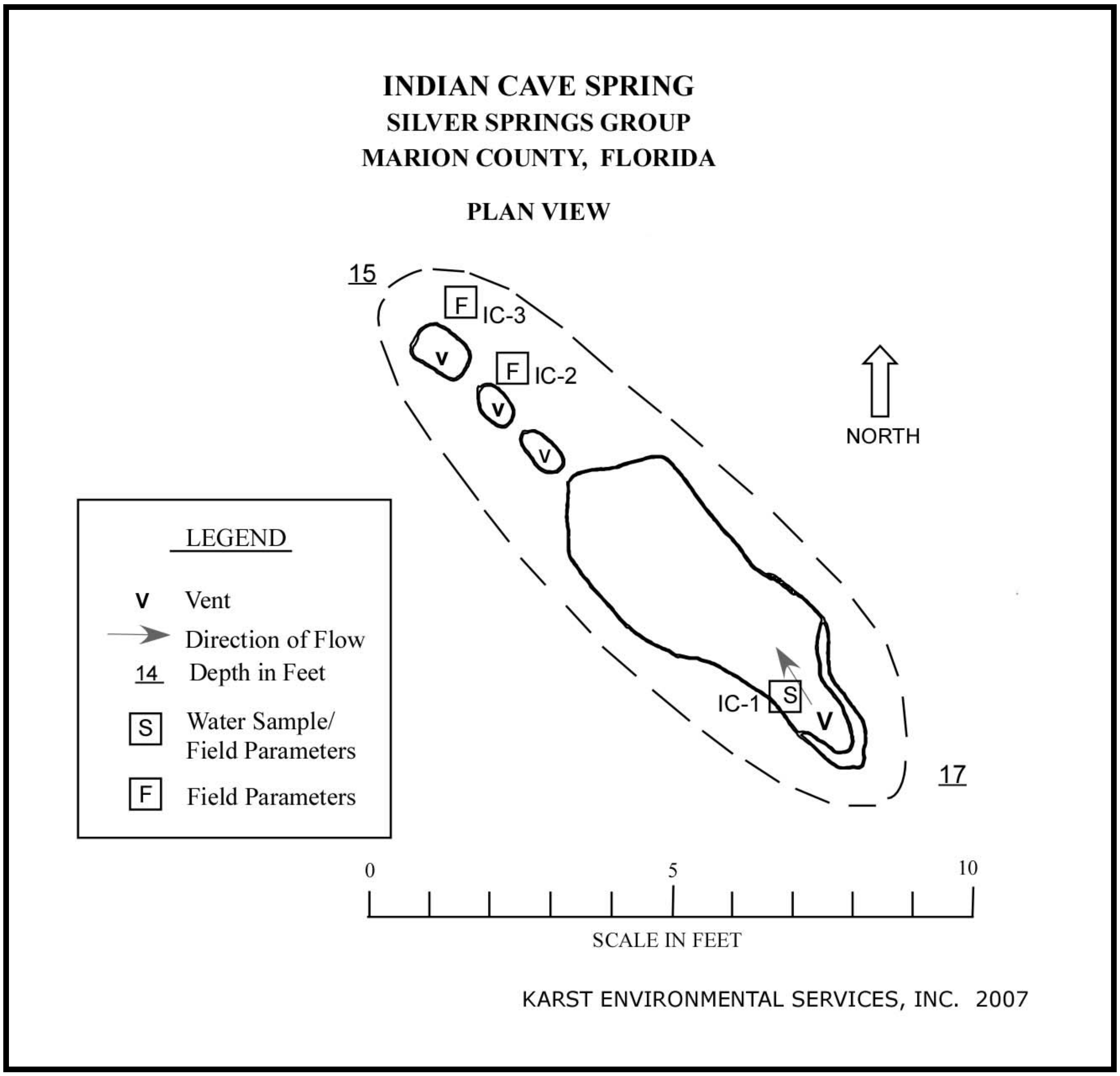
The sides of the basin containing the vent line southwest of the main Garden of Eden Spring vents were about 60 percent covered with strap-leaved sagittaria, which was largely covered with filamentous algae. A small amount of coontail, with about one percent coverage, was present. The coontail was also covered with algae. The remaining 39 percent of the basin was sand covered with algae. Sunfish were common in this basin. The location of this spring protects it from strong river current.


GARDEN OF EDEN SPRINGS GROUP
INCLUDING LOST RIVER SPRING AND LOG SPRING
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
NORTH
GE-2
S
14
15
VENT LINE
GE-1
S
16
LR-1
S
8
LOST RIVER SPRING
L-1
S
5
LOG SPRING
LEGEND
Vent
14 Depth in Feet
S Water Sample/ Field Parameters
F Field Parameters
VENT LINE
15
F
14
GE-3
0 20 40 60 80 100 110
SCALE IN FEET
KARST ENVIRONMENTAL SERVICES, INC. 2007

Indian Cave Spring

Description: Indian Cave Spring is located within a small cove on the south side of the Silver River, about 250 feet southeast of the Garden of Eden Spring Group. The main vent, about 11 feet long, lies within a sediment-sided basin, about 17 feet deep. The main vent discharges from a rocky opening at its southeastern end, and has additional smaller vents discharging through detritus at its western end. There is an additional vent about 40 feet to the south in the bottom of a conical basin formed in soft sediment, and about 15 feet deep. (This additional vent is not shown on the map.)

Ecology: In the main basin, strap-leaved sagittaria covered about 35 percent of the sides. Algae covered coontail covered about five percent of the area, mostly hanging from the branches of a dead tree. Filamentous algae covered the remaining 60 percent of the basin.
Strap-leaved sagittaria covered about 80 percent of the basin to the south. The remaining 20 percent was covered in filamentous algae.



First Fisherman’s Paradise Springs Group

Description: The First Fisherman’s Paradise Springs Group is located approximately 200 feet east of Indian Cave. Water discharges horizontally from vents beneath and along a limestone ledge that parallels the river channel. This ledge lies no more than about a foot above the bottom of the channel, is at 17 feet of depth, and is about 43 feet long. About 25 feet to the northwest of the west end of the ledge is a line of spring vents along the bottom about 10 feet long, at 18 feet deep.

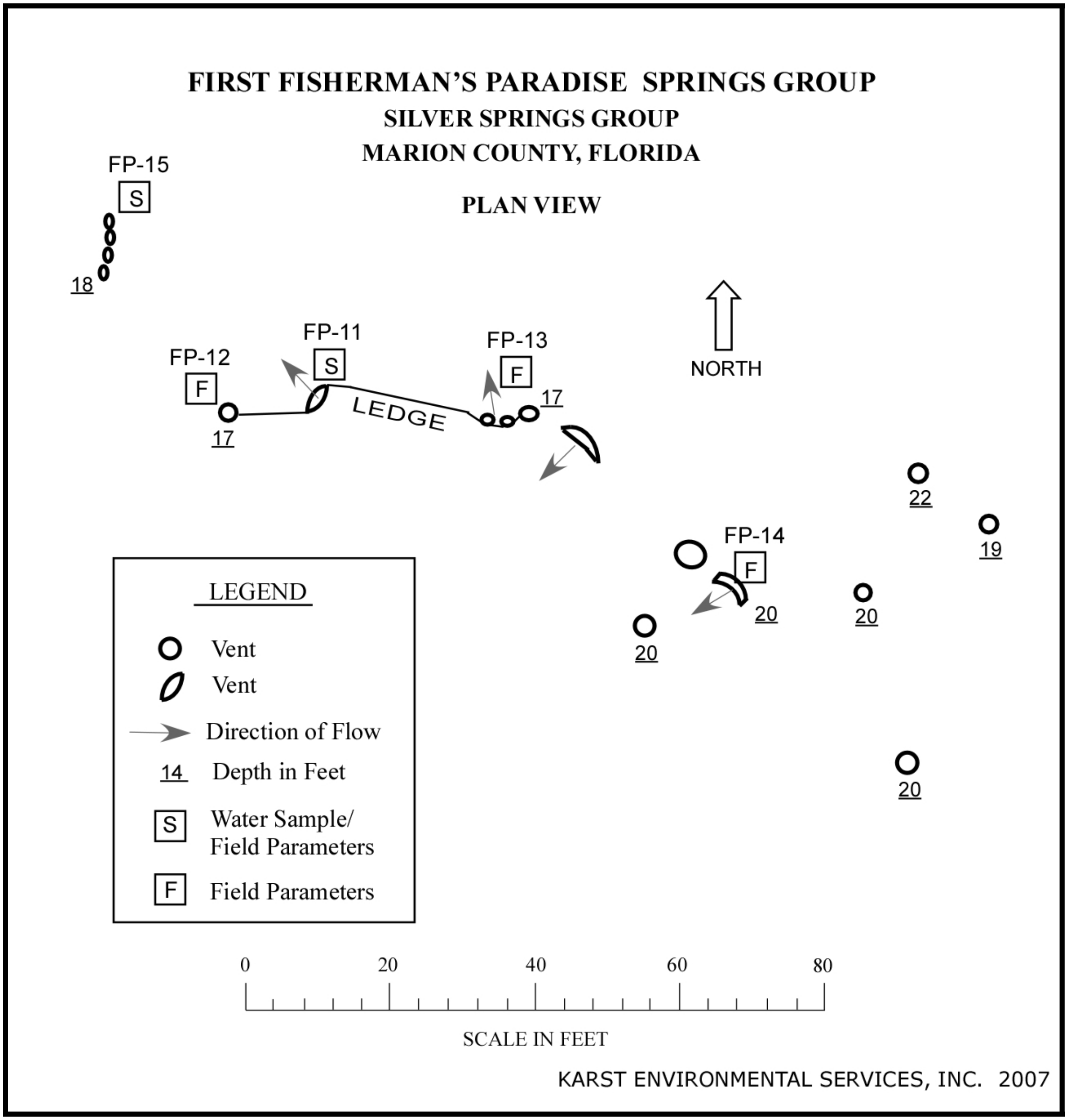
Beyond the eastern end of the ledge, and in a generally southeastern direction, are at least eight more vents, located within a basin along the outside edge of the flow of the main river channel. They all lie between 30 and 70 feet southeast of the east end of the ledge. Some of these vents discharge directly from rock, but some discharged through a thick layer of filamentous algae, at depths of 19 to 22 feet deep.

The physical structure and complexity of this spring did not lend itself to the application of the underwater discharge measurement methods used at the other springs.

Ecology: The vegetation changed considerably from the western, upstream vents to the eastern, downstream vents, so the site was divided into upper and lower sections for the ecological survey.

The upper vents section, the ledge area, was covered by about 50 percent strap-leaved sagittaria, 28 percent filamentous algae, and two percent coontail, with the remaining 20 percent being sandy bottom.

The lower, southeastern vents section, the deeper basin area, had a very open and flat bottom which was 75 percent covered by filamentous algae. The remaining 25 percent was rock and sand bottom.

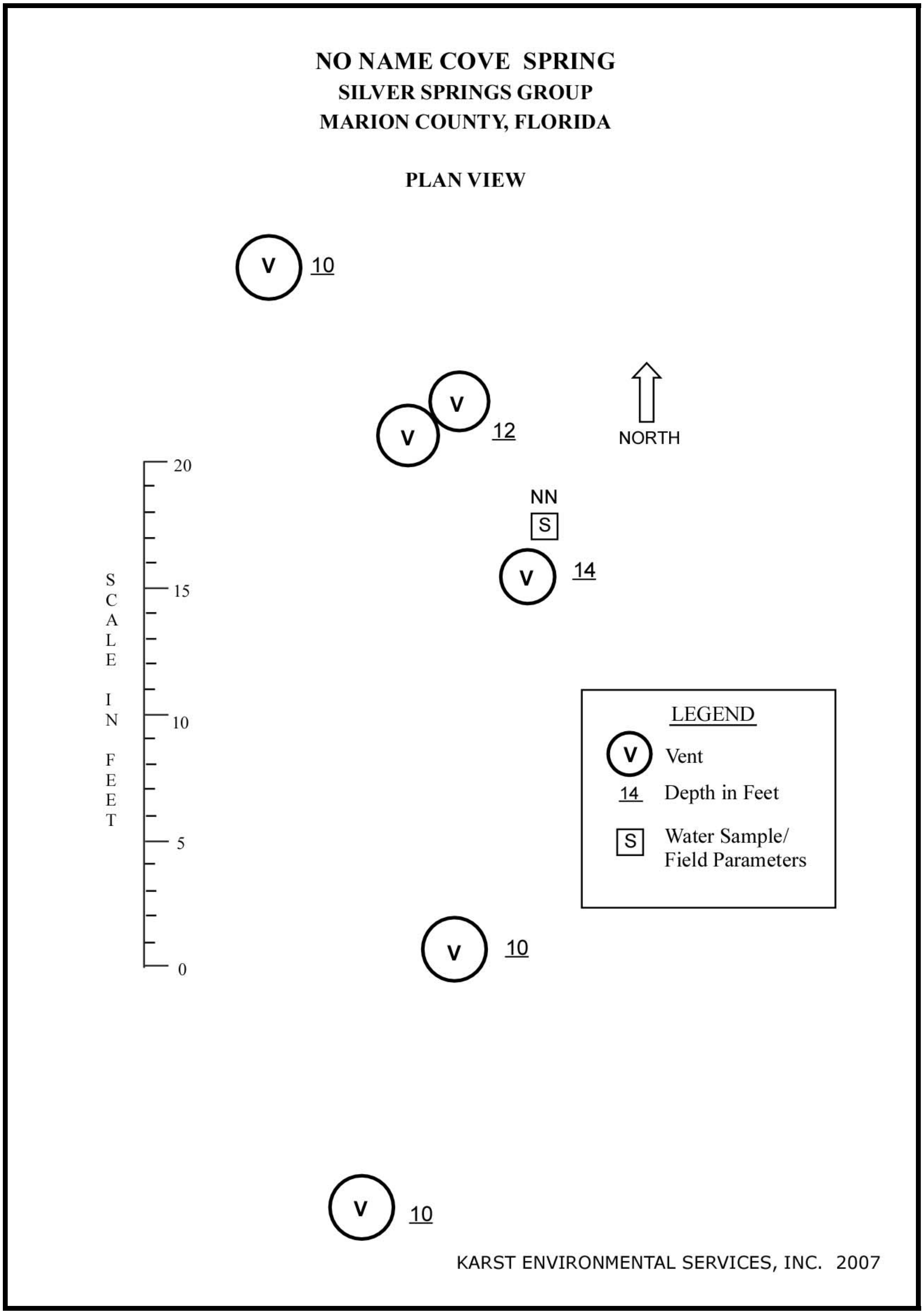

FIRST FISHERMAN'S PARADISE SPRINGS GROUP
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
FP-15
S
18
FP-12
F
17
FP-11
S
LEDGE
FP-13
F
17
NORTH
22
19
FP-14
F
20
20
20
20
LEGEND
Vent
Vent
Direction of Flow
14 Depth in Feet
S Water Sample/ Field Parameters
F Field Parameters
0
20
40
60
80
SCALE IN FEET
KARST ENVIRONMENTAL SERVICES, INC. 2007

No Name Cove Spring

Description: No Name Cove Spring is a line of six vents spread along the bottom of linear depression located in a small cove along the south side of the Silver River, about 450 feet east of First Fisherman's Paradise. The vents discharge vertically through soft bottom sediments, from between 10 to 14 feet deep.

Ecology: Algae-covered strap-leaved sagittaria covered about 30 percent of the basin and filamentous algae covered the remaining 70 percent of the soft bottom.

Chain pickerel and longnose gar (*Lepisosteus osseus*) were numerous in this cove. Schooling redeye chubs (*Notropis harperi*) were present in the cove.


NO NAME COVE SPRING
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
V
10
V
V
12
NORTH
NN
S
V
14
SCALE IN FEET
20
15
10
5
0
LEGEND
V Vent
14 Depth in Feet
S Water Sample/
Field Parameters
V
10
V
10
KARST ENVIRONMENTAL SERVICES, INC. 2007

Turtle Meadows Spring

Description: Turtle Meadows Spring is a complex area of ledges, limestone boulders and bedrock exposures with many vents. It is located approximately 200 feet northeast of No Name Cove, slightly north of the center of the Silver River. There are several tiers of ledges that slope from 9 feet deep to a depth of 18 feet on the eastern side of the basin. One large vent in the northern section discharges into a small room formed under a large boulder. Other vents discharge throughout the piles of boulders and along the ledges. At many of the vents, voids extend down beyond the boulders. The flow from the numerous vents was generally strong.

Two other spring vent clusters are located beyond the ledge and boulder pile area of this spring. One of these clusters lies about 15 feet to the southeast, and the other, a twenty foot long line of vents, lies about 25 feet south of the “main” spring.

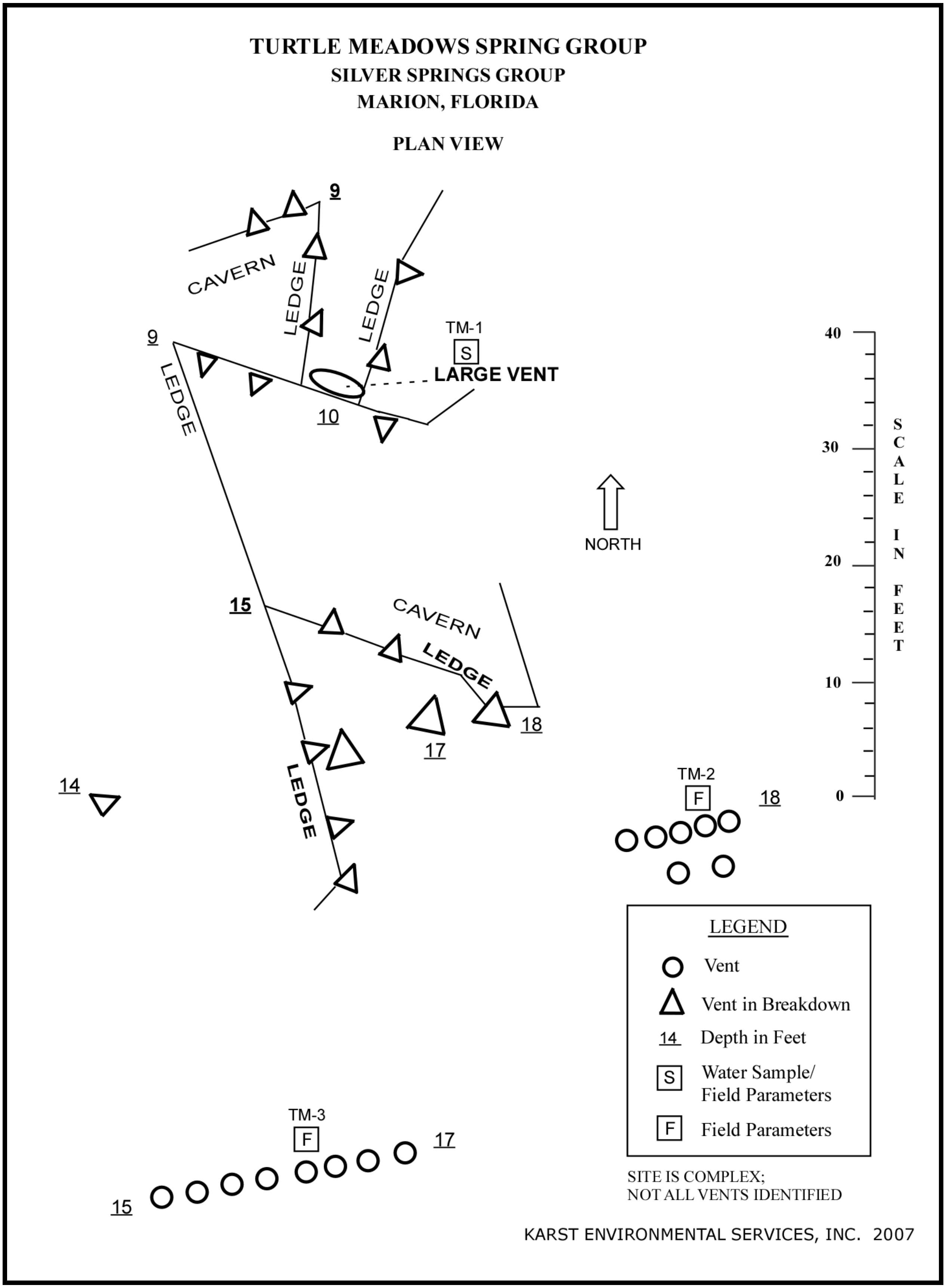
The physical structure and complexity of this spring did not lend itself to the application of the underwater discharge measurement methods used at the other springs.

Ecology: Strap-leaved sagittaria was present in several of the vents in the main boulder pile, covering about 30 percent of the area. Coontail covered about 30 percent of the area, and the remaining 20 percent was covered by filamentous algae. Sand and rock covered 20 percent of the bottom here.

Many sunfish were present in the area. Four darters, probably black-banded darters, were seen in a sandy area among sagittaria. Several red-eyed chub were also seen at this site.

Forty-five percent of the southeastern vents area was covered by filamentous algae, 35 percent by coontail, and 10 percent by strap-leaved sagittaria. Sand and rock covered 10 percent of the bottom here.

There was no obvious basin associated with the southernmost line of vents, and river flow was strong. Strap-leaved sagittaria covered about 40 percent of the river bottom in this area, coontail about 30 percent, and filamentous algae about 20 percent. Sand and rock covered 10 percent of the bottom here.

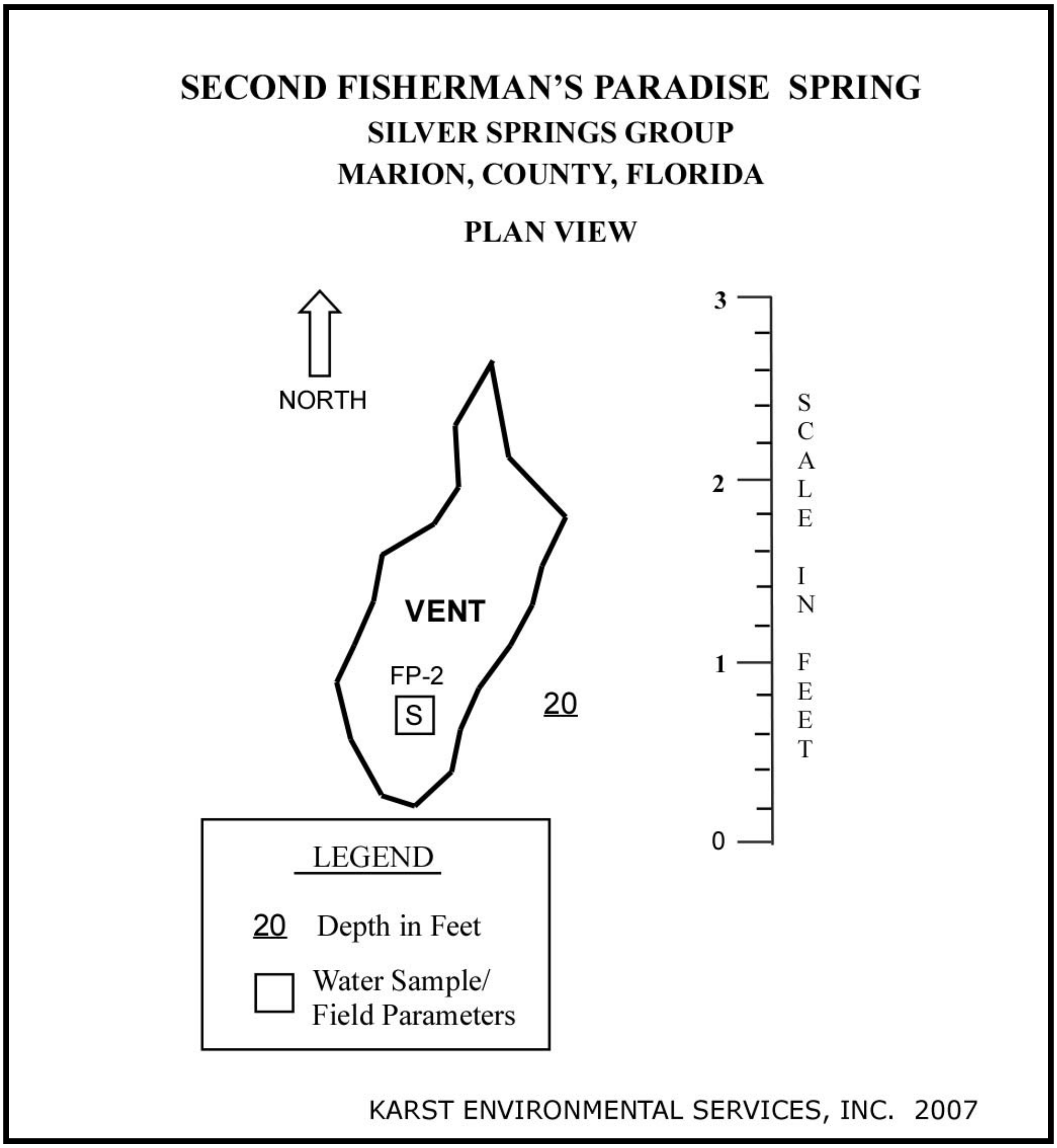


TURTLE MEADOWS SPRING GROUP
SILVER SPRINGS GROUP
MARION, FLORIDA
PLAN VIEW
9
CAVERN
LEDGE
LEDGE
TM-1
S
LARGE VENT
9
LEDGE
10
NORTH
15
CAVERN
LEDGE
17
18
LEDGE
14
TM-2
F
18
40
30
20
10
0
SCALE IN FEET
LEGEND
Vent
Vent in Breakdown
14 Depth in Feet
S Water Sample/ Field Parameters
F Field Parameters
TM-3
F
17
15
SITE IS COMPLEX;
NOT ALL VENTS IDENTIFIED
KARST ENVIRONMENTAL SERVICES, INC. 2007

Second Fisherman's Paradise Spring

Description: Second Fisherman's Paradise Spring is a distinct vent in the bare limestone bottom in the middle of the river channel about 200 feet southeast of Turtle Meadows Spring. The oval vent is about 2.5 feet long and about one foot wide. The shoulders of the vent are 20 feet deep, and the vent descends vertically into the rock for at least 5 feet.

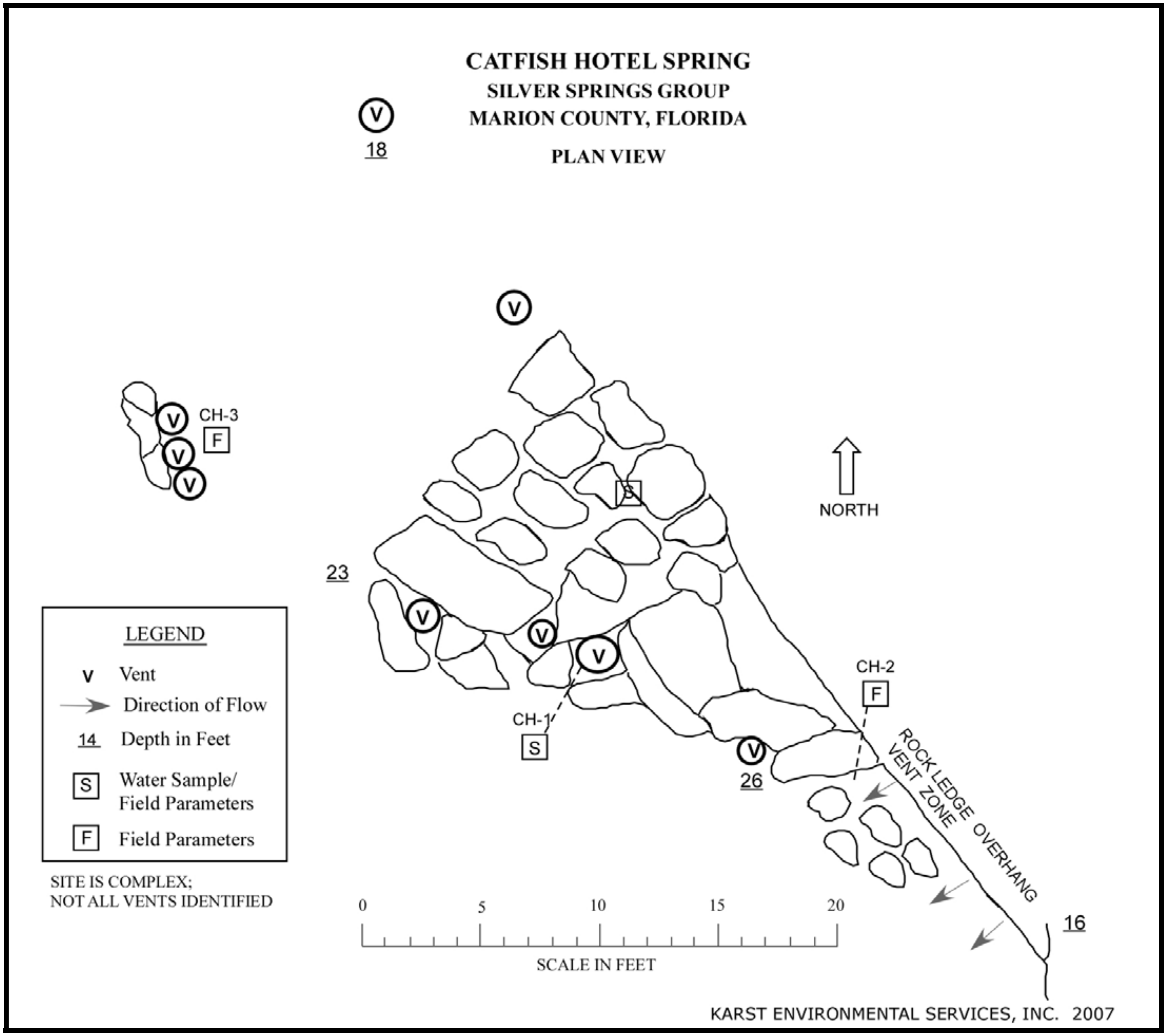
Ecology: Scattered strap-leaved sagittaria near the vent and nearby in the river covered about 35 percent of area. Coontail caught on rocks covered about five percent of the area. Rocky bottom near vents accounted for about ten percent of the area. Rocks covered in moss-like algae and filamentous algae accounted for about 50 percent of area.



Catfish Hotel Spring

Description: Catfish Hotel Spring is located in the main channel approximately 100 feet southeast of Second Fisherman's Paradise Spring. This spring has a deep basin that is bordered on the east by a limestone ledge. West of this ledge is a large and complex area of angular boulders and slabs. Discharge was strong from the numerous vents scattered among the boulders and ledges. Void spaces below the rocks extend down past depths of 25 feet. The physical structure and complexity of this spring did not lend itself to the application of the underwater discharge measurement methods used at the other springs.

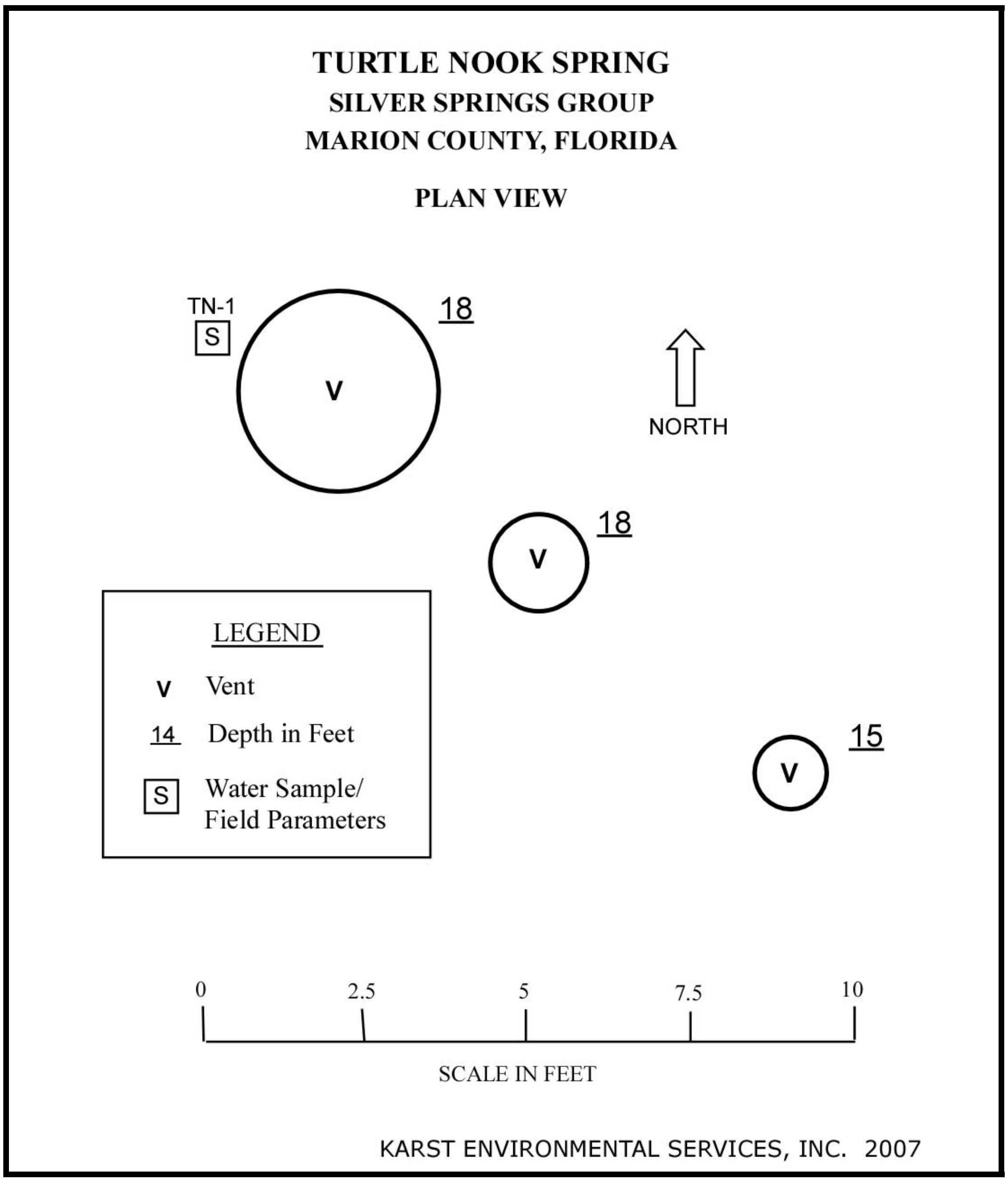
Ecology: An unidentified moss-like algae was common on rocks in the strong flow near the vents, and a reddish filamentous algae was present in the vents. Seventy percent of the basin was covered with filamentous algae, and coontail and strap-leaved sagittaria covered 10 and 15 percent of the basin, respectively. The remaining five percent was bare sand and rock. Vermiculated sailfin catfish were present at this spring.


CATFISH HOTEL SPRING
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
V
18
V
CH-3
F
V
V
NORTH
S
23
V
V
V
CH-2
F
CH-1
S
V
26
ROCK LEDGE OVERHANG
VENT ZONE
16
LEGEND
V Vent
Direction of Flow
14 Depth in Feet
S Water Sample/ Field Parameters
F Field Parameters
SITE IS COMPLEX;
NOT ALL VENTS IDENTIFIED
0
5
10
15
20
SCALE IN FEET
KARST ENVIRONMENTAL SERVICES, INC. 2007

Turtle Nook Spring

Description: Turtle Nook Spring is located on the northwest side of a forested island in the river, approximately 100 feet northeast of Second Fisherman's Paradise. Water discharges from three vents along a line about 10 feet long at the bottom of a small, conical basin. The vents are between 15 and 18 feet deep.

Ecology: The bottom of the cove was composed of soft sediments covered with filamentous algae. Filamentous algae also covered 95 percent of the spring basin. Coontail covered five percent of the basin. A sudd was floating over the spring and was composed of duckweed (*Lemna sp.*), water lettuce (*Pistia stratiodes*), and broken pieces of strap-leaved sagittaria. Sunfish were numerous in the cove. They behaved like they are used to being fed.



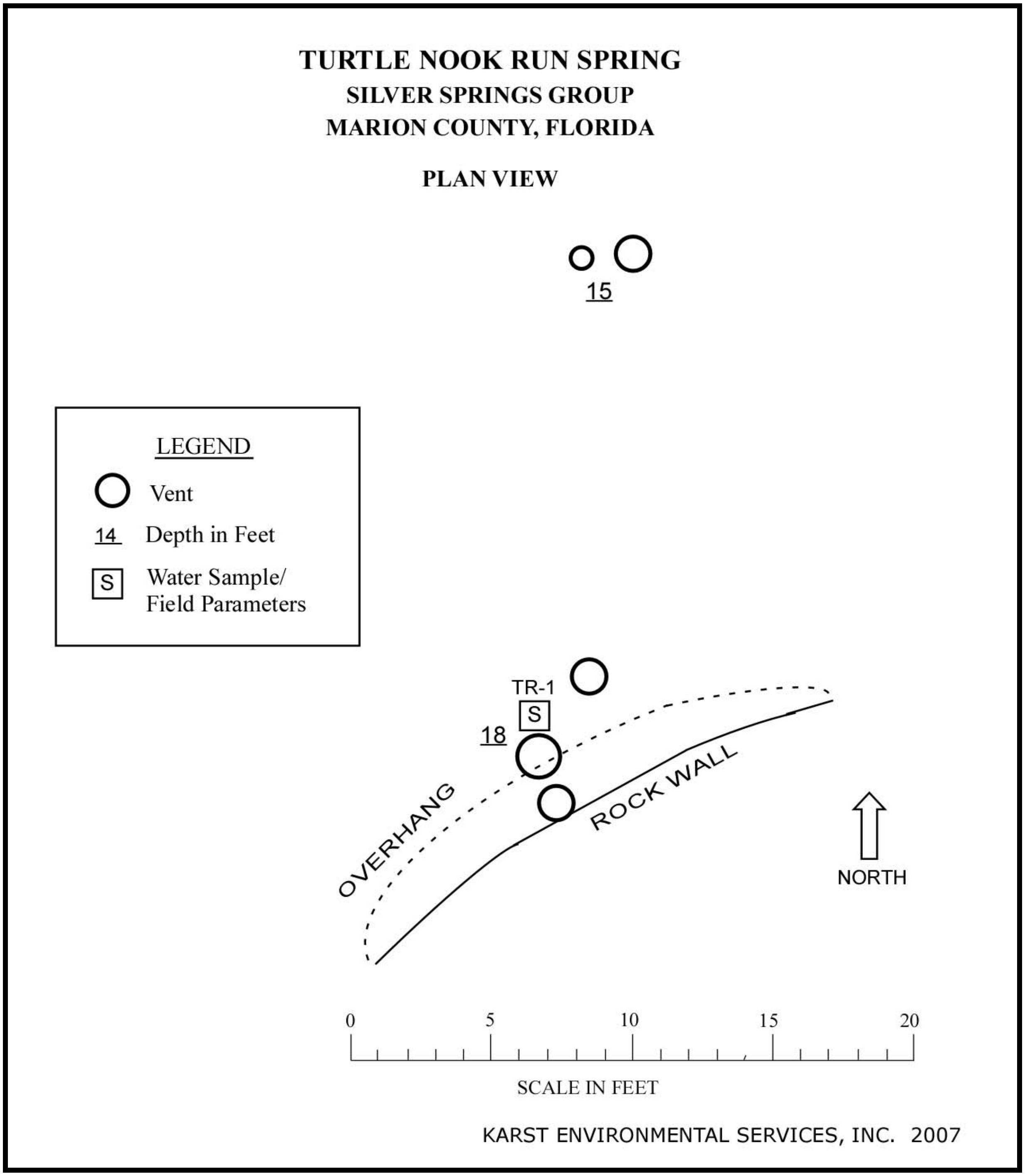
Turtle Nook Run Spring

Description: Turtle Nook Run Spring is located about 30 feet southwest of Turtle Nook Spring, at the west side of the entrance to the cove. Water discharges from several rocky vents and one detrital vent cluster.

The main vent discharges from along a rock outcrop, 18 feet deep, and beneath a ledge on the south side of a basin about 25 feet in diameter. Several smaller vents also discharge through sediment and algae to the north of the main vent. The top of the limestone outcrop in the basin is 13 feet below the water surface. The basin is just north of and out of the main channel of the Silver River.

Ecology: Filamentous algae covered 80 percent of the basin, including the limestone boulders. Algal "stalagmites", which only form in still water, were present. A moss-like algae was attached to the boulders in the strong flow near the vents. Coontail, which was covered with filamentous algae, covered about ten percent of the basin. Ten percent of the bottom here was exposed sand and rock.

Sunfish were numerous in the basin.

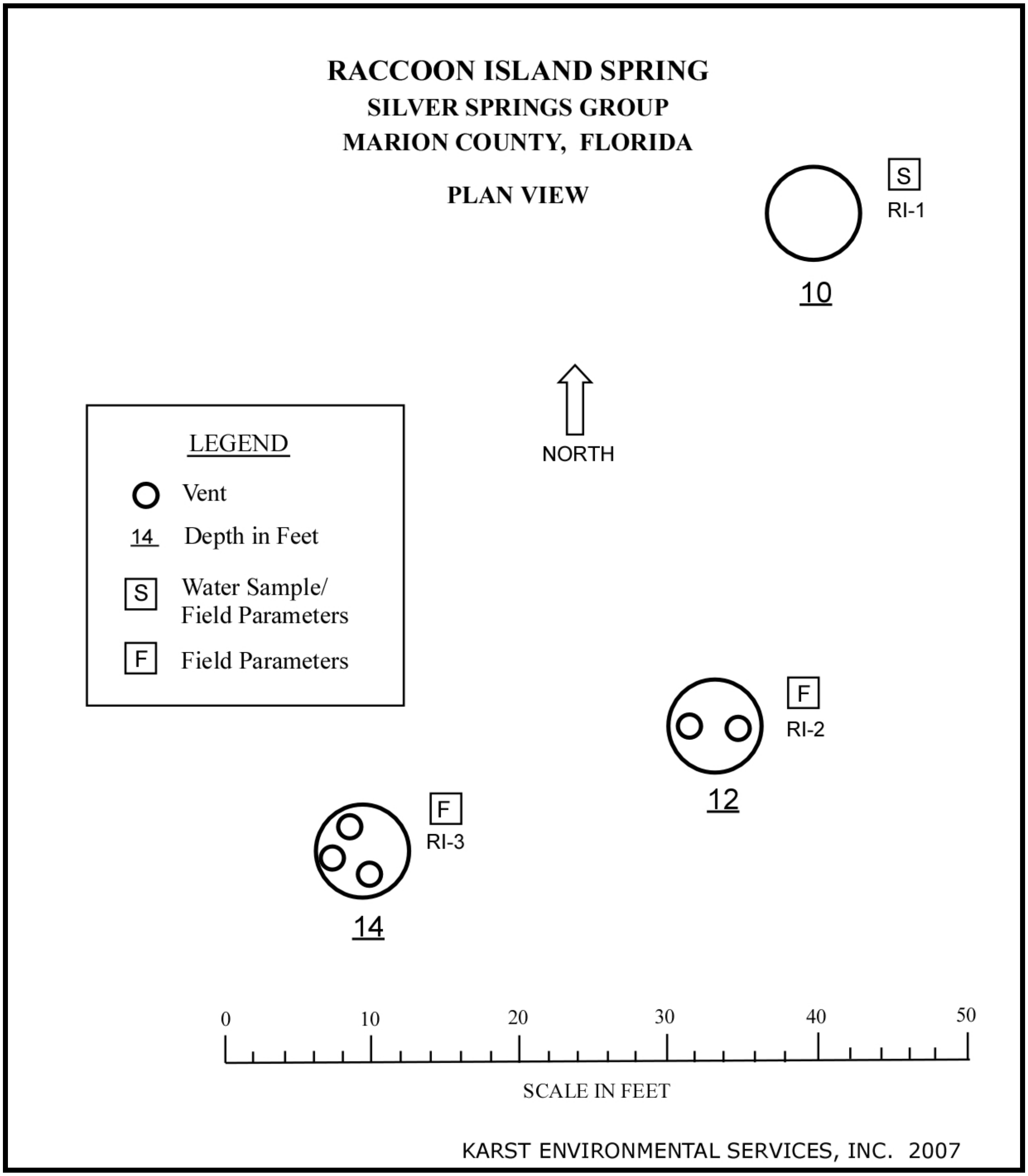

TURTLE NOOK RUN SPRING
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
15
LEGEND
Vent
14 Depth in Feet
S Water Sample/
Field Parameters
TR-1
S
18
OVERHANG
ROCK WALL
NORTH
0
5
10
15
20
SCALE IN FEET
KARST ENVIRONMENTAL SERVICES, INC. 2007

Raccoon Island Spring

Description: Raccoon Island Spring is located in Gar Cove northeast of a forested island. Discharge is primarily from three vent clusters, with each cluster located in the bottom of three broad, low relief depressions. The vents discharge through a layer of sediment and filamentous algae. The "central" vent cluster comprises an area of about six feet in diameter, and is 12 feet deep. A second vent cluster lies 25 feet to the southwest in 14 feet of water, and a third vent cluster lies 35 feet to the north (towards the bank) in 10 feet of water.

Ecology: Gar Cove is a large shallow area, about eight feet deep, with an open bottom about 95 percent covered by filamentous algae. Three slightly deeper basins are located within about 50 feet of each other. Each basin has one or several small vents discharging water through deep organic sediments covered by filamentous algae. Clumps of coontail were scattered around the area, with about five percent coverage.

Longnose gar and sunfish were common in the cove. One loggerhead musk turtle (*Sternotherus minor minor*) was seen in the cove.


RACCOON ISLAND SPRING
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
S
RI-1
10
NORTH
LEGEND
Vent
14
Depth in Feet
S
Water Sample/
Field Parameters
F
Field Parameters
F
RI-2
12
F
RI-3
14
0
10
20
30
40
50
SCALE IN FEET
KARST ENVIRONMENTAL SERVICES, INC. 2007

Shipwreck Springs Group

Shipwreck Spring

Description: The main vent of the Shipwreck Springs Group is located at the bow of a sunken boat on the bottom of a large, 20 foot deep depression north of the main river channel, and east of the eastern tip of a forested island. The main vent discharges from rock through a layer of sediment and algae. Another similar but smaller vent lies about 15 feet to the east. Discharging from the algae-covered bottom of the western side of the basin, and about 20 to 30 feet from the stern section of the sunken boat, are numerous small vents.

Ecology: The area around the Shipwreck Spring is a broad, open basin, with soft bottom sediments, which was about 80 percent covered by filamentous algae three to eight inches thick.

Coontail covered about ten percent of the bottom, strap-leaved sagittaria about five percent, and about five percent of the bottom was sandy with no algae.

Catfish Convention Hall Spring

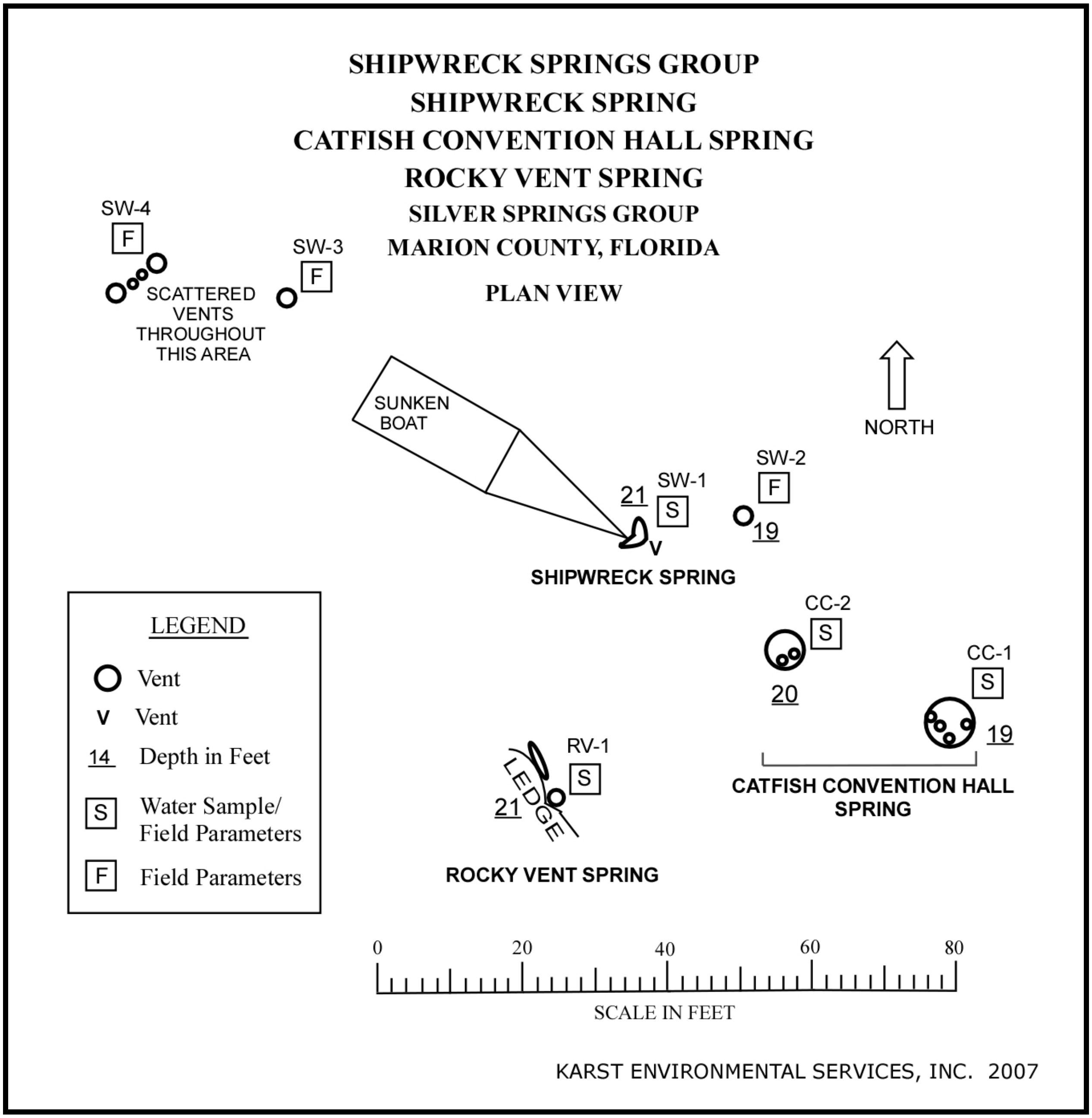
Description: Catfish Convention Hall Spring is comprised of two clusters of small vents, about 20 feet deep, and located directly downstream from Shipwreck Spring and the bow of the namesake sunken boat. They lie in the eastern end of the basin that is an extension of the Shipwreck Spring basin. The main vent cluster contains about five small vents within an area of about six feet in diameter, all discharging through sediments.

Ecology: Forty-five percent of the area was covered by strap-leaved sagittaria, 15 percent by coontail, and 40 percent was open bottom mostly covered by filamentous algae.

Rocky Vent Spring

Description: Rocky Vent Spring is located west of Catfish Convention Hall Spring and south of Shipwreck Spring and the bow of the namesake sunken boat. It lies at the outer edge of the Shipwreck Spring basin, and within the main river channel. This spring is comprised of a small group of small vents that discharge from beneath and along a low rock ledge, along with a few other scattered small vents nearby.

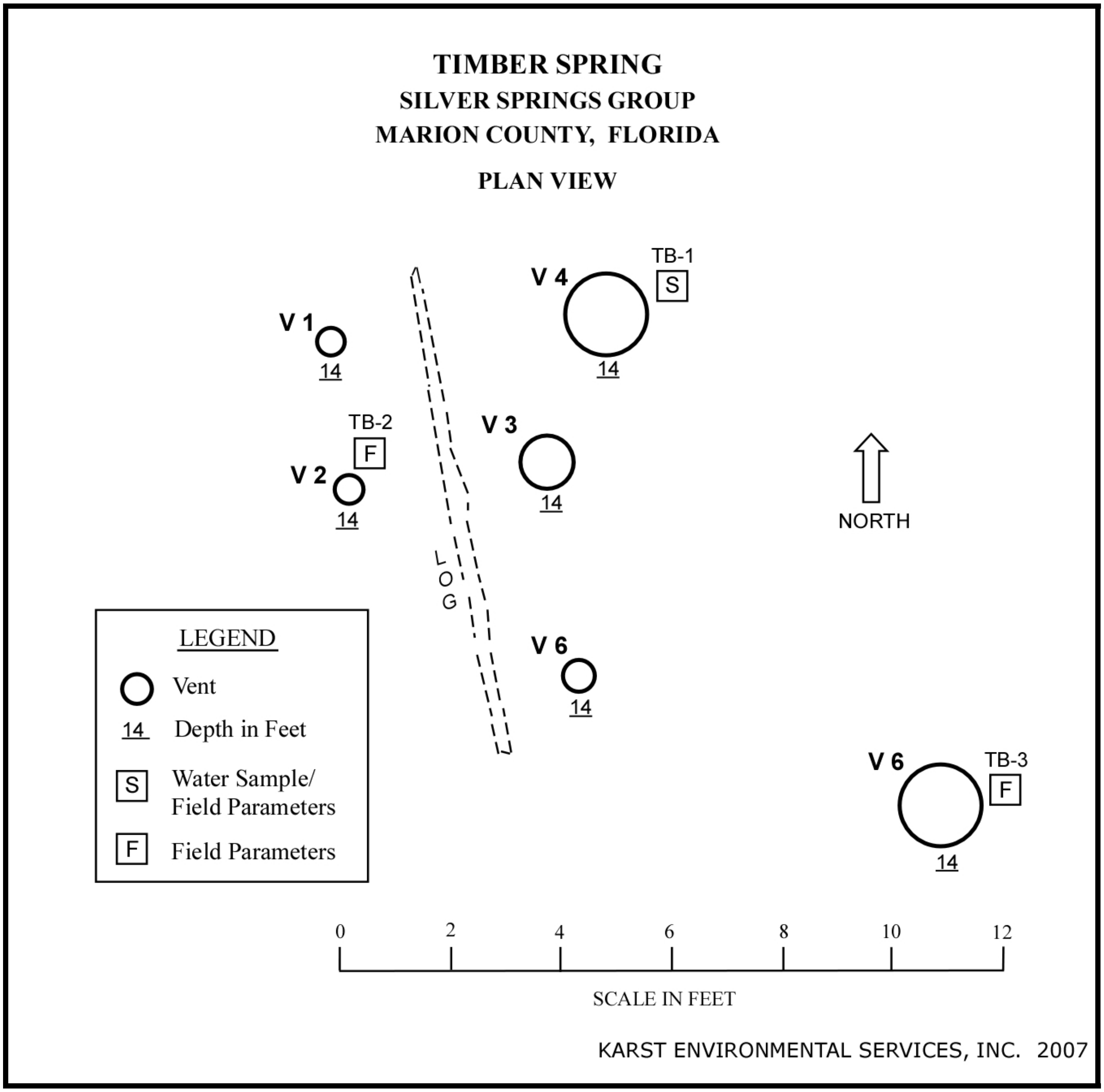
Ecology: The area around the vents was rocky, with slab-like boulders scattered around. About 40 percent of the rock was covered with filamentous algae. Forty percent of the area supported strap-leaved sagittaria and coontail covered about 10 percent of the bottom. Ten percent of the area was covered by exposed sand and rock.


SHIPWRECK SPRINGS GROUP
SHIPWRECK SPRING
CATFISH CONVENTION HALL SPRING
ROCKY VENT SPRING
SILVER SPRINGS GROUP
MARION COUNTY, FLORIDA
PLAN VIEW
SW-4
F
SW-3
F
SCATTERED VENTS THROUGHOUT THIS AREA
SUNKEN BOAT
NORTH
SW-2
F
SW-1
S
21
V
19
SHIPWRECK SPRING
LEGEND
Vent
V Vent
14 Depth in Feet
S Water Sample/ Field Parameters
F Field Parameters
CC-2
S
20
CC-1
S
19
CATFISH CONVENTION HALL SPRING
RV-1
S
LEDGE
21
ROCKY VENT SPRING
0
20
40
60
80
SCALE IN FEET
KARST ENVIRONMENTAL SERVICES, INC. 2007

Timber Spring

Description: Timber Spring lies in the north side of the Silver River, about 800 feet downstream of the Shipwreck Springs Group. It is the most downstream of the springs in the upper 1,200 meters of the Silver River. It has at least six vents about 14 feet deep in a 20 foot long roughly oval depression with a bottom of detritus, sand, and pebbles. A few fallen branches and logs lie across some of the spring vents.

Ecology: The vents in Timber Spring discharge vertically, with enough vigor to keep sand and shell fragments agitated. Strap-leaved sagittaria covered about 50 percent of the basin area, coontail 30 percent, bare sand 10 percent, and filamentous algae 10 percent. Sunfish and largemouth bass were present in the area.



Appendix 4
Water Quality

Silver Springs Spring Vent Geochemical Characterization

Spectrum Data Services, with the assistance of divers from Karst Environmental Services Inc. (KES), collected water quality samples from 34 vents at Silver Springs on September 12 and 13, 2006. They measured temperature, pH, dissolved oxygen (DO), and field conductivity at each vent. The water samples were analyzed by Columbia Analytical Services for lab conductivity, alkalinity, total nitrate plus nitrite (NOx-total), total phosphorus (P-total), total organic carbon (TOC), total calcium (Ca-T), total magnesium (Mg-T), total sodium (Na-T), total potassium (K-T), chloride, sulfate, total dissolved solids (TDS), and total orthophosphate (PO4-T), table 2.

The two vents at Mammoth Spring (Mammoth-East and Mammoth-West) had different water quality and differed by 1.4 degrees C in temperature. They also differed in DO, field conductivity, NOx-total, sulfate, and TDS.

For most vents, temperature was near 23.7ºC. However, temperature was lower at Christmas Tree Springs, Garden of Eden Springs, Lost River Spring, and Log Spring.

DO was highest at Indian Cave spring (3.70 mg/L) and lowest at Log spring (0.08 mg/L). DO was below 1.5 mg/L in Mammoth-West Spring, Mastodon Bone Spring, Christmas Tree Springs, Garden of Eden-2 and 3 springs, Lost River Spring, Log Spring, and Racoon Island-1 Spring. DO was 1.98 mg/L in Mammoth-East and 0.94 mg/L in Mammoth-West.

Total NOx concentration was highest at No Name Cove Spring (1.89 mg/L) and lowest at Log Spring (0.869 mg/L). The mean and median total NOx concentrations were 1.36 mg/L and 1.40 mg/L, respectively. The NOx-total concentration at Mammoth-East and Mammoth-West was 1.27 mg/L and 0.91 mg/L, respectively. About half the discharge from Silver Springs comes from Mammoth Springs.

Sulfate was highest at Ladies Parlor spring (74.4 mg/L) and lowest at Log spring (16.7 mg/L). Sulfate was 45.5 mg/L at Mammoth-East and 17.7 mg/L at Mammoth-West. Generally, sulfate concentration decreases in the downriver springs. Springs with higher sulfate concentrations probably have a deeper flow system than springs with lower sulfate concentrations. The source for the sulfate is the dissolution of gypsum and anhydrite at the top of the middle confining unit.

TDS concentrations was highest in Catfish Reception Hall-1 Spring (318 mg/L) and lowest in Shipwreck-1 Spring (195 mg/L). TDS concentration was 304 mg/L in Mammoth-East and 236 mg/L in Mammoth-West. Generally, TDS concentrations decrease in the downstream springs.

All of the springs have a calcium-bicarbonate type water (Appendix 1). The water type is determined by plotting the relative proportions, in milli-equivalents/liter, of major ions in the sample on a Stiff (1951) diagram.

All samples are plotted on a Piper diagram (Piper, 1944), which relates the changes in proportions, but not concentrations, between samples (Appendix 2). The Silver Springs spring vents have a similar chemistry as those from Rainbow Springs (Jones et. al., 1966).

References

Jones, G.W., Upchurch, S.B., and Champion, K.M., 1996, Origin of nitrate in groundwater discharging from Rainbow Springs, Marion County, Florida, Southwest Florida Water Management District: Brooksville, Fla.

Piper, A.M., 1944, A graphic procedure in the geochemical interpretation of water-analyses, American Geophysical Union Transactions, 25: 914–923.

Stiff, H.A., Jr., 1951, The interpretation of chemical water analysis by means of patterns, Journal of Petroleum Technology, vol 3, no. 10, sec 1, pp. 15-16, sect. 2,3.

Number	Spring Name	Abreviation	Lat	Long	depth (ft)	Temp (degC)	pH	DO	Field Cond	Lab Cond	Alkalinity	Nox-total	P-total	TOC	Ca-T	Mg-T	Na-T	K-T	Chloride	Sulfate	TDS	PO4-T
1	SSG-Mammoth East	ME	291258.2	820309.6	40	23.4	7.29	1.98	458.6	465	206	1.27	0.03	0.54T	78	11	6.9	0.7T	11.5	45.5	304	0.02
2	SSG-Mammoth-West	MW	291258.7	820309.8	38	22.0	7.43	0.94	408.1	434	202	0.91	0.028	0.21T	72	8.5	6.2	0.54T	10.6	17.7	236	0.016
3	SSG-Jacobs Well	JW	291254.2	820306.8	22	23.7	7.35	2.84	455.5	514	186	1.5	0.031	0.13T	85	13	7.2	0.74T	11.6	65.4	310	0.016
4	SSG-Catfish Reception Hall-1	CR-1	291253.8	820306.4	20	23.8	7.34	3.18	473.3	509	177	1.4	0.021	0.03T	79	12	6.8	0.7T	11.6	73.7	318	0.0051T
	SSG-Catfish Reception Hall-2	CR-2			20	23.7	7.32	2.70	493.9													
5	SSG-Bridal Chamber	BC	291253.2	820305.5	30	23.7	7.40	3.38	480.7	485	177	1.4	0.028	0.79T	81	12	7	0.78T	11.6	73	314	0.009T
6	SSG-Oscar	OS-1	291255.9	820302.8	17	23.8	7.30	3.35	453.0	477	178	1.6	0.35J	0.17T	82	12	6.8	0.69T	11.3	64	292	0.0257
7	SSG-Devils Kitchen B	DK-21	291254	820305.2	16	23.7	7.43	3.66	482.6	502	170	1.43	0.0297	0.53T	78	12	6.7	0.82T	11.5	71.5	315	0.02
8	SSG-Ladies Parlor	LP-1	291252.7	820305.2	21	23.7	7.37	3.47	464.0	486	182	1.6	0.027	0.2T	78	12	7.1	0.77T	11.8	74.4	304	0.013
9	SSG-Devils Kitchen A-1	DK-11	291253.6	820304.8	20	23.7	7.37	3.46	487.0	492	181	1.6	0.028	0.28T	78	12	6.6	0.75T	11.5	73.4	312	0.014
	SSG-Devils Kitchen A-2	DK-12			21	23.7	7.37	3.36	485.0													
	SSG-Devils Kitchen A-3	DK-13			21	23.7	7.35	3.47	452.5													
10	SSG-Alligator Hole-1	AH-1	291254.4	820303.33	17	23.7	7.30	3.59	452.6	477	169	1.5	0.026	0.05T	72	12	6.7	0.67T	11.5	65.6	303	0.11T
	SSG-Alligator Hole-2	AH-2			15	23.8	7.33	3.44	452.0													
11	SSG-Mastodon Bone	MB-1	291256.6	820301.5	16	23.2	7.38	1.21	388.4	402	170	1.2	0.0274	0.41T	67	8.2	6	0.74T	10.2	29	242	0.012
12	SSG-Geyser-1	GY-1	291255.4	820300.3	22	23.6	7.30	2.71	437.2	446	160	1.3	0.0266	0.2T	72	11	6.6	0.62T	11.2	55	279	0.013
	SSG-Geyser-2	GY-2			18	23.6	7.40	3.01	445.8													
	SSG-Geyser-3	GY-3			18	23.7	7.38	3.32	454.6													
	SSG-Geyser-4	GY-4			18	23.6	7.32	2.62	437.0													
13	SSG-Blue Grotto	BG	291254.8	820259.3	26	23.7	7.35	3.29	446.2	467	183	1.3	0.0282	0.11T	71	11	6.5	0.66T	11.3	59.9	282	0.0088T
14	SSG-Christmas Tree-1 (Central)	CT-1	291258.3	820257.3	18	23.1	7.36	1.41	392.5	395	169	1.1	0.0252	0.23T	62	7.5	5.4	0.72T	10.4	31.1	246	0.011
	SSG-Christmas Tree-2 (West)	CT-2			14	23.3	7.41	1.21	402.9													
	SSG-Christmas Tree-3 (North)	CT-3			16	23.1	7.01	0.50	367.2	360	165	1.1	0.0304	0.17T	60	7	5.4	0.75T	9.17	21.7	213	0.015
	SSG-Christmas Tree-4 (East)	CT-4			15	23.2	7.45	1.45	396.3													
	SSG-Christmas Tree-5 (Southeast)	CT-5			14	23.2	7.48	1.41	395.1													
15	SSG-Garden of Eden-1	GE-1	291258.1	820254.8	16	23.5	7.37	2.45	414.9	425	170	1.32	0.0296	0.19T	66	9.5	6.5	0.77T	10.7	43	248	0.01T
	SSG-Garden of Eden-2	GE-2			16	23.2	7.40	1.16	382.4	395	160	1.11	0.0341	0.21T	62	7.7	5.9	0.86T	10.9	29.1	231	0.016
	SSG-Garden of Eden-3	GE-3			16	23.2	7.39	1.34	358.5													
Number	Spring Name	Abreviation	Lat	Long	depth (ft)	Temp (degC)	pH	DO	Field Cond	Lab Cond	Alkalinity	Nox-total	P-total	TOC	Ca-T	Mg-T	Na-T	K-T	Chloride	Sulfate	TDS	PO4-T
16	SSG-Lost River	LR-1	291258.6	820253.5	10	23.0	7.56	0.20	362.5	361	160	1.02	0.0306	33	59	6.2	5.3	0.8	9.01	18.1	209	0.011T
17	SSG-Log	L-1	291258.6	820253.3	6	22.9	7.47	0.08	316.7	355	167	0.869	0.0305	0.72T	68	6.1	5.4	0.78T	9.17	16.7	207	0.014
18	SSG-Indian Cave-1	IC-1	291256.1	820252.8	18	23.7	7.47	3.51	440.4	436	157	1.59	0.0323	0.25T	67	11	6.9	0.86T	11.5	56.6	270	0.011T
	SSG-Indian Cave-2	IC-2			12	23.7	7.34	3.70	441.8													

	SSG-Indian Cave-3	IC-3			12	23.7	7.44	3.14	441.4													
19	SSG-First Fishermans Paradise-1 (middle)	FP-11	291256.1	820250.4	18	23.7	7.35	3.65	433.1	437	158	1.54	0.0262	0.2T	65	11	7	0.74T	11.6	54.7	269	0.013
	SSG-First Fishermans Paradise-2 (upstream)	FP-12	291256.5	820250.6	18	23.7	7.42	3.59	435.8													
	SSG-First Fishermans Paradise-3 (downstream)	FP-13			19	23.5	7.25	3.62	448.2													
	SSG-First Fishermans Paradise-4	FP-14	291256.0	820250.0	21	23.7	7.27	3.70	432.9													
	SSG-First Fishermans Paradise-5	FP-15	291255.7	820250.3	18	23.7	7.44	3.71	440.1	442	157	1.57	0.0346	0.29T	68	11	7.1	0.79T	11.7	56.6	274	0.011T
20	SSG-No Name Cove	NN	291256.2	820246.7	15	23.8	7.30	3.64	413.5	416	151	1.89	0.33J	0.61T	83	10	7	0.86T	11.7	50.6	250	0.031
21	SSG-Turtle Meadows-1	TM-1	291257.2	820245.2	15	23.4	7.32	2.07	395.2	394	177	1.49	0.0305	0.3T	62	8.6	6.3	0.75T	10.6	36.7	232	0.013
	SSG-Turtle Meadows-2	TM-2			19	23.7	7.38	2.73	407.7													
	SSG-Turtle Meadows-3	TM-3			18	23.8	7.43	3.15	399.4													
22	SSG-Second Fishermans Paradise	FP-2	291256.4	820243.2	24	23.8	7.33	3.46	389.8	370	133	1.45	0.0328	0.38T	58	9.6	7.2	0.82T	11.5	45.5	234	0.0095T
23	SSG-Catfish Hotel-1	CH-1	291255.4	820242.4	29	23.8	7.49	3.07	361.6	352	133	1.56	0.0295	0.23T	51	8.8	7	0.8	11.3	41.2	208	0.011T
	SSG-Catfish Hotel-2	CH-2			21	23.8	7.43	2.97	356.8													
	SSG-Catfish Hotel-3	CH-3			22	23.8	7.43	3.15	361.1													
24	SSG-Turtle Nook	TN-1	291257	820242	19	23.6	7.39	1.84	371.4	356	143	1.36	0.0322	0.2T	54	7.6	6.4	0.81T	10.6	32.6	213	0.013
25	SSG-Turtle Nook Run	TR-1	291256.5	820243.3	19	23.8	7.45	3.45	388.5	383	129	1.41	0.0284	0.13T	56	9.4	7.1	0.77T	11.4	45	229	0.01T
26	SSG-Raccoon Island-1 (inland)	RI-1	291256.7	820239	11	23.5	7.44	0.99	342.4	333	135	1.09	0.0359	0.41T	53	7.3	6.3	0.74T	10.7	29.6	203	0.019
	SSG-Raccoon Island-2 (downstream)	RI-2			13	23.5	7.38	1.73	342.2													
	SSG-Raccoon Island-3 (upstream)	RI-3			14	23.7	7.36	2.27	344.6													
27	SSG-Rocky Vent	RV-1	291255.5	820238.3	21	23.7	7.51	2.77	341.3	330	118	1.46	0.0284	0.1T	51	8.4	6.9	0.81T	11.3	38.9	202	0.013
28	SSG-Shipwreck-1	SW-1	291255.6	820238.4	21	23.7	7.54	2.44	340.2	327	114	1.39	0.0324	0.09T	47	7.9	6.7	0.73T	11	36.7	195	0.015
	SSG-Shipwreck-2	SW-2			19	23.7	7.55	2.35	338.8													
	SSG-Shipwreck-3	SW-3			17	23.8	7.47	2.50	345.5													
	SSG-Shipwreck-4	SW-4			18	23.7	7.61	2.32	343.1													
Number	Spring Name	Abreviation	Lat	Long	depth (ft)	Temp (degC)	pH	DO	Field Cond	Lab Cond	Alkalinity	Nox-total	P-total	TOC	Ca-T	Mg-T	Na-T	K-T	Chloride	Sulfate	TDS	PO4-T
29	SSG-Catfish Convention Hall-1	CC-1	291255.6	820237.9	19	23.7	7.50	2.61	240.2	322	116	1.38	2.1J	0.14T	55	8.1	6.7	0.77T	11.2	37.2	198	0.0291
	SSG-Catfish Convention Hall-2	CC-2			20	23.7	7.47	2.53	320.4	320	136	1.35	0.25J	0.26T	49	8.3	6.9	0.79T	11.6	38.4	196	0.029
30	SSG-Timber-1	TB-1	291256.3	820229.8	14	23.8	7.60	2.70	300.2	325	114	1.26	0.022	0.17T	47	8.3	6.9	0.83T	11.4	41.6	207	0.0267
	SSG-Timber-2	TB-2			14	23.8	7.52	2.69	343.2													
	SSG-Timber-3	TB-3			15	23.8	7.49	2.65	344.9													

Appendix 5
Silver Springs Discharge Reports
September 2006

Discharge Measurement:
Second Fisherman's Paradise Spring,
Marion County, Florida;
September 22, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Second Fisherman's Paradise Spring, Marion County, Florida; September 22, 2006

LIST OF CONTENTS

Results of Discharge Measurements of Second Fisherman's Paradise Spring, Marion County, Florida; September 22, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Second Fisherman's Paradise Spring on September 22, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Second Fisherman's Paradise Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Tom Morris, both of KES. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida.

SITE DESCRIPTION

Second Fisherman's Paradise Spring is a distinct vent in the bare limestone bottom in the middle of the river channel about 200 feet southeast of Turtle Meadows Spring. The oval vent is about 2.5 feet long and about one foot wide. The shoulders of the vent are 20 feet deep, and the vent descends vertically into the rock for at least 5 feet. See Figure 1.

Since the orifice of this spring is located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

Pete Butt positioned the sensor, and recorded positional data, while Tom Morris read the velocity readings, after taking meter reset cues from Butt. During all measurements, the sensor handler completely removed himself from the cross section of the flow. The meter operator was also positioned outside the cross-section. This eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. Fourteen station readings were taken.

The approximate depth for the measurement grid was 20 feet. A telescoping aluminum pole with 1, 0.5, 0.25 and 0.1 foot interval markings was positioned horizontally to allow for a grid of velocity measurements. The sensor-support pole was positioned at a right angle to the main flow path, so no angle coefficient corrections for velocity readings were made. The flowmeter sensor was positioned on the pole with a quick release clamp. Several hand-held velocity measurements were also made. Spring vent dimensions and positions were measured with a metal tape.

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figure 2. Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Table 3. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift, an anisotropy ratio of 1 at an angle of 0°, and a variogram slope of 1.0. The results of the contour processing are illustrated in Figures 3 and 4.

During this measurement, two negative velocities were measured. Negative velocity stations typically represent slight back eddies near walls. In order to incorporate any negative values, calculations were made using a Surfer 8 "blanking file" operation to define the measurement cross-section boundary. The total discharge is shown on Table 2 as the **Net Volume (Cut-Fill)**, and has been calculated as the Positive Volume (Cut) less that portion of the Negative Volume (Fill) lying within the measurement cross-section boundary walls that define the plane of measurement.

The software also calculates the total cross-sectional area of the measurement location within the passage, and is presented on Table 2 as the **Operational Planar Area**. The Operational Planar Area is the sum of the Positive (Cut) and that portion of the Negative (Fill) Planar areas lying within the measurement cross-section boundary walls that define the plane of measurement.

RESULTS AND DISCUSSION

This measurement is the first one performed at Second Fisherman's Paradise Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Second Fisherman's Paradise Spring on September 22, 2006 was 0.564 CFS (cubic feet per second). This result is also expressed as 253 GPM (gallons per minute) or 0.365 MGD (million gallons per day), see Table 1. Fourteen (14) readings were made, see Figures 2, 3 and 4. The point velocity readings ranged from -0.07 to 1.09 feet per second (fps), with an overall average station reading of 0.59 fps. The total cross-sectional area was calculated as 1.205 square feet. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 17:01 hours and were completed by 17:24 hours.

UNDERWATER DISCHARGE MEASUREMENT						
Location:	**2nd FISHERMAN'S PARADISE SPRING**			Date:	**September 22, 2006**	
	Silver Springs Group,			Time Start:	17:01	
	Marion County, Florida			Time End:	17:24	
Personnel:	Peter Butt, Tom Morris					
Method:	Grid within irregular conduit					
Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles					
Msmt. Periods:		60 seconds				
Analysis Method: Surfer 8 with kriging						
Second Fisherman's Paradise Spring Total Discharge:						
CFS	0.564					
MGD	0.365					
GPM	253					
Total Cross-sectional Area (sq/ft):		1.205				
Avg. Station Point Velocity (ft/sec):		0.59				
Cross-section Depth (feet deep):		20				
Velocity Reading by Station:		(All velocity readings in feet per second.)				
Station #	Point Velocity					
1	0.67					
2	0.85					
3	0.85					
4	0.84					
5	0.74					
6	0.41					
7	0.05					
8	-0.07					
9	-0.07					
10	0.65					
11	0.44					
12	1.01					
13	1.09					
14	0.81					

Table 1. Discharge of Second Fisherman's Paradise Spring, Marion County, Florida on September 22, 2006. Data record and calculation of discharge measurement.

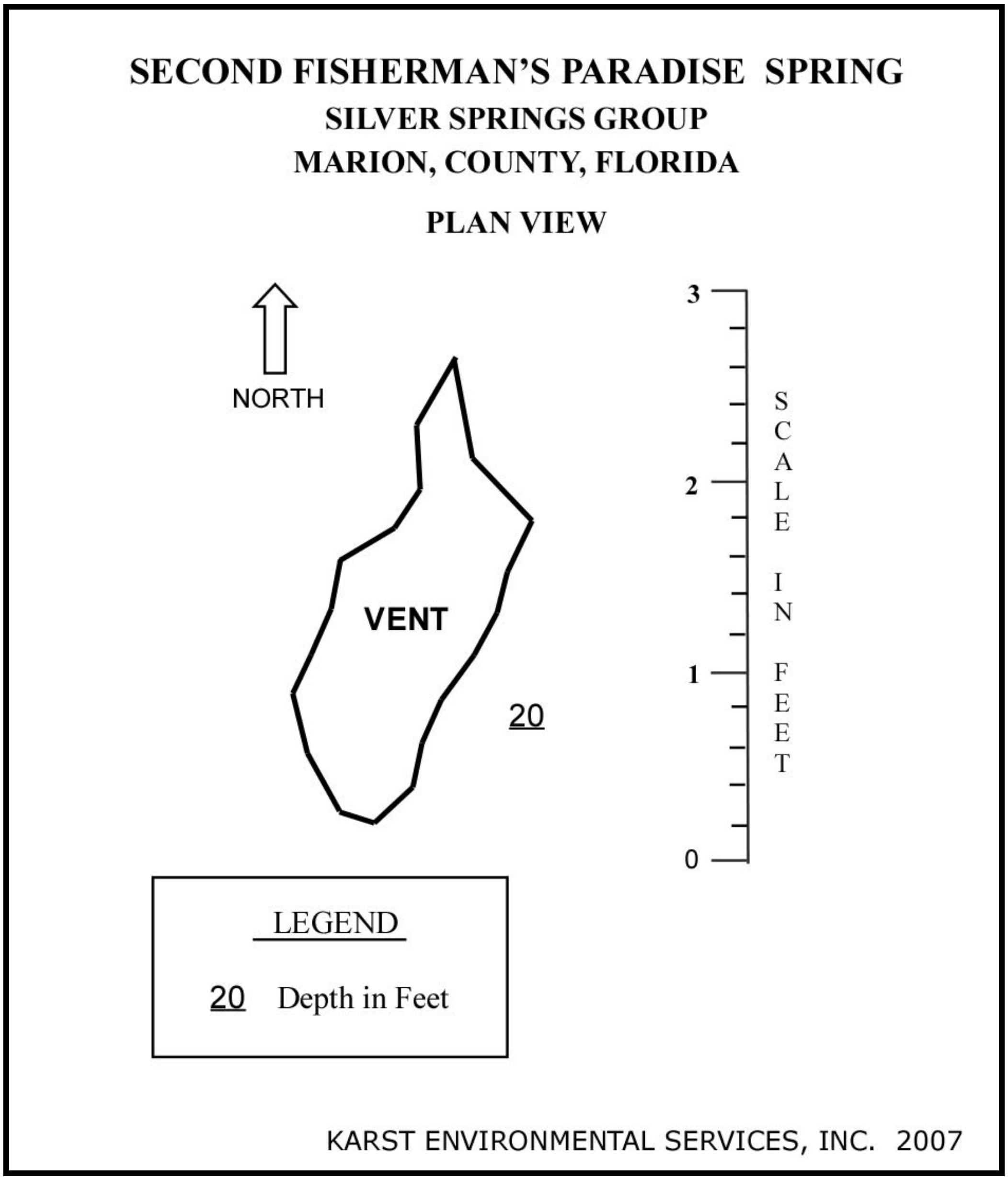


Figure 1. Map of Second Fisherman's Paradise Spring.

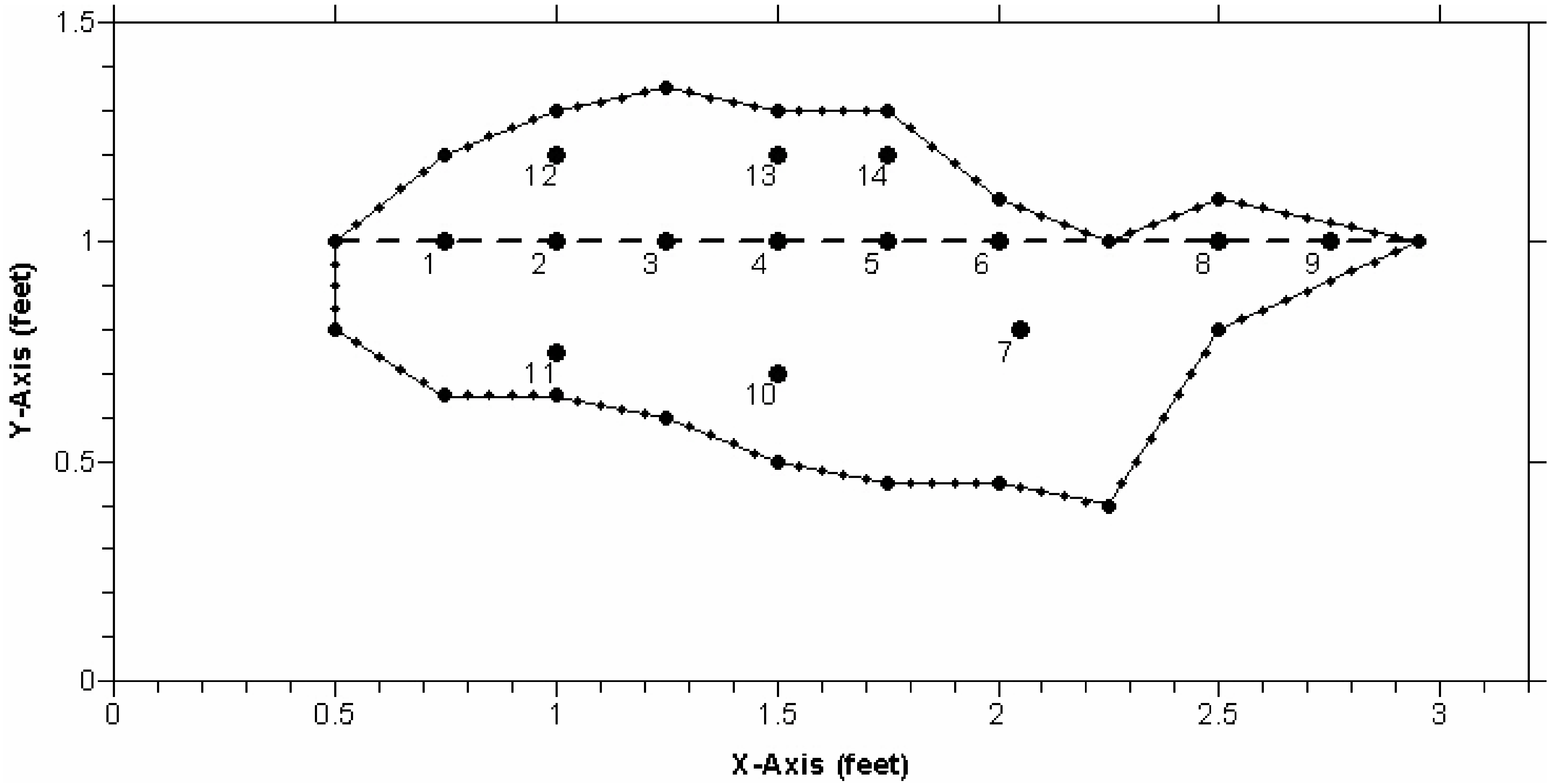


Figure 2. Discharge measurement cross-section; Second Fisherman's Paradise Spring, Marion County, Florida, September 22, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 20-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

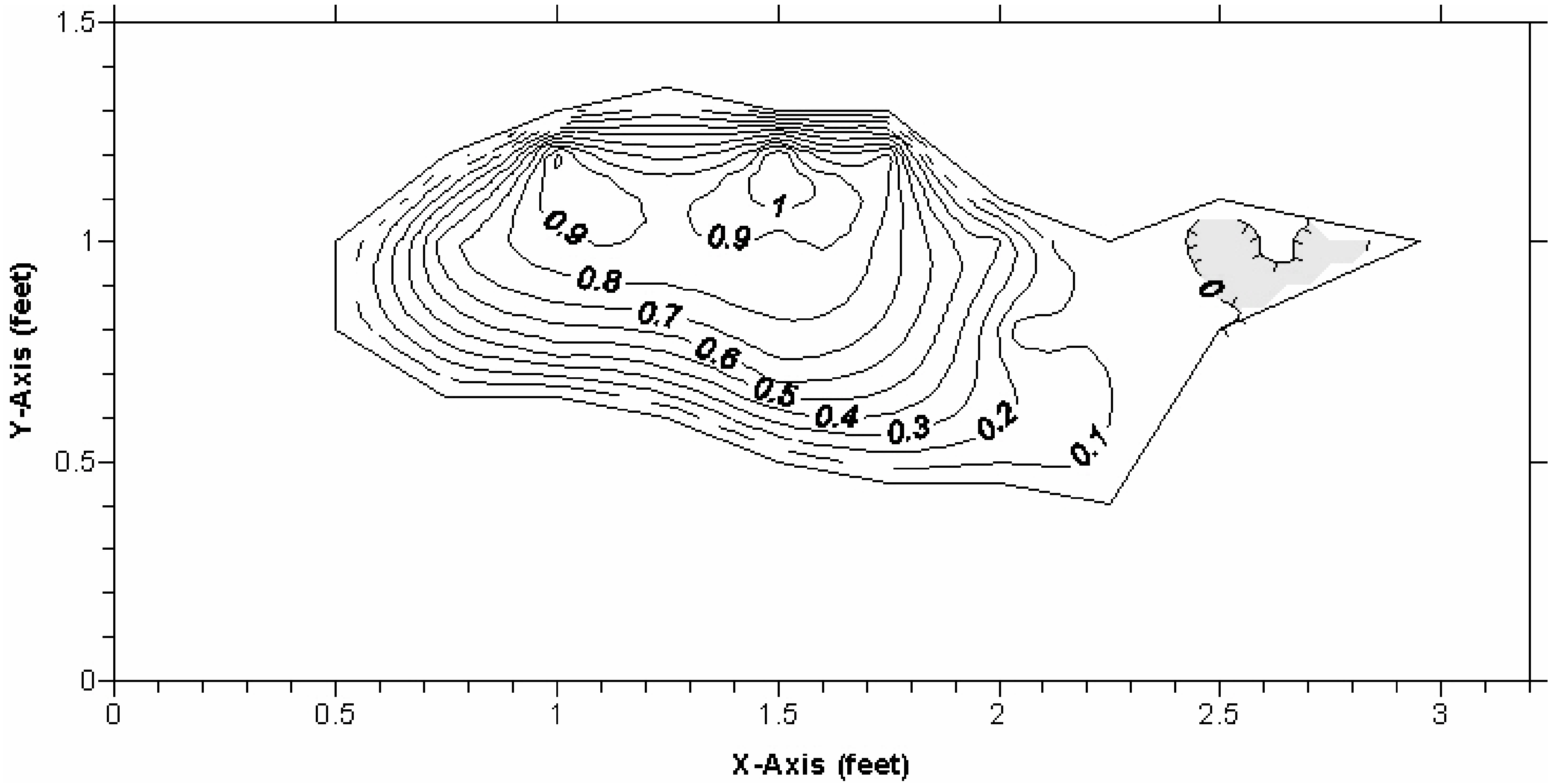


Figure 3. Discharge measurement cross-section; Second Fisherman's Paradise Spring, Marion County, Florida, September 22, 2006 measurement. Flow contour velocities are shown in feet per second. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

TABLE 2. SECOND FISHERMAN’S PARADISE SPRING, SEPTEMBER 22, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\FishermansParadise\FishermansParadise2_9-06.bln.grd
Grid Size:	31 rows x 65 columns
X Minimum:	0
X Maximum:	3.2
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	1.5
Y Spacing:	0.05
Z Minimum:	-0.070000001351811
Z Maximum:	1.0900000008725

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES

Z Scale Factor:	1
Total Volumes by:	
Trapezoidal Rule:	0.5639816929985
Simpson's Rule:	0.56392672419669
Simpson's 3/8 Rule:	0.56322154773733

CUT & FILL VOLUMES

Positive Volume [Cut]:	0.56474821909307
Negative Volume [Fill]:	0.00076652609456318
Net Volume [Cut-Fill]:	**0.5639816929985<<<<<<Total Discharge in CFS**

(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 1.205 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)

Positive Planar Area [Cut]:	1.1623253407311
Negative Planar Area [Fill]:	0.042674659268919
Blanked Planar Area:	3.595
Total Planar Area:	4.8

Surface Areas

Positive Surface Area [Cut]:	3.005023176162
Negative Surface Area [Fill]:	0.051637038949547

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\FishermansParadise\FisherPara2 9-06 SURFER XYZ T3 BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	119
Original Data:	119
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.5	0.4	-0.07
25%-tile:	1.05	0.65	0
Median:	1.7	1	0
75%-tile:	2.3125	1.12	0
Maximum:	2.95	1.35	1.09
Midrange:	1.725	0.875	0.51
Range:	2.45	0.95	1.16
Interquartile Range:	1.2625	0.47	0
Median Abs. Deviation:	0.64375	0.26	0
Mean:	1.6846638655462	0.901678991596664	0.069495798319328
Trim Mean (10%):	1.6837155963303	0.90375963302752	0.034587155963303
Standard Deviation:	0.71532580756129	0.29236179763257	0.22886585091149
Variance:	0.51169101096321	0.085475420714949	0.052379577713438
Coef. of Variation:			3.2932329212173
Coef. of Skewness:			3.1350965156207

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.069	-0.150
Y:		1.000	0.136
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	0.51169101096321	-0.014496284372573	-0.024619077042582
Y:		0.085475420714949	0.0090765944495445
Z:			0.052379577713438

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-0.045322565764271	0.098503003288039	0.057030998482238
Standard Error:	0.029200995506968	0.071446494931144	0.08627729549038

Inter-Parameter Correlations

	A	B	C
A:	1.000	-0.069	-0.622
B:		1.000	0.786
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.23917471459586	0.11958735729793	2.3143
Residual:	116	5.9939950333033	0.051672370976753	
Total:	118	6.2331697478992		

Coefficient of Multiple Determination (R^2): 0.038371282071449

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.03335	0
25%-tile:	0.050990195135928	0
Median:	0.051221620435125	0
75%-tile:	0.058309518948453	0
Maximum:	0.25	1.09

Table 2. Bridal Chamber Spring, September 22, 2006.

Midrange:	0.141675	0.545
Range:	0.21665	1.09
Interquartile Range:	0.0073193238125253	0
Median Abs. Deviation:	0.0026300276362202	0
Mean:	0.063608833540175	0.051596638655462
Trim Mean (10%):	0.057868953302751	0.017522935779817
Standard Deviation:	0.036097051438436	0.18375167383118
Variance:	0.0013029971225491	0.03376467763576
Coef. of Variation:	0.56748488267181	3.5613109423307
Coef. of Skewness:	3.5048336872728	4.0846093279673
Root Mean Square:	0.073137410583714	0.1908583002028
Mean Square:	0.0053490808268908	0.036426890756303

Complete Spatial Randomness
Lambda: 51.127819548872
Clark and Evans: 0.90965364291078
Skellam: 204.48585033448

Exclusion Filtering
Exclusion Filter String: Not In Use

Duplicate Filtering
Duplicate Points to Keep: First
X Duplicate Tolerance: 2.9E-007
Y Duplicate Tolerance: 1.1E-007
No duplicate data were found.

Breakline Filtering
Breakline Filtering: Not In Use

Gridding Rules
Gridding Method: Kriging
Kriging Type: Point
Polynomial Drift Order: 2
Kriging std. deviation grid: no

Semi-Variogram Model
Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 1
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\FishermansParadise\FishermansParadise2_9-06.grd
Grid Size:	31 rows x 65 columns
Total Nodes:	2015
Filled Nodes:	2015
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	3.2
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	1.5
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-5.075080504521
Z 25%-tile:	-1.3441108685009
Z Median:	-0.4842795698062
Z 75%-tile:	0.0237942075502
Z Maximum:	1.0900000008725
Z Midrange:	-1.9925402518243
Z Range:	6.1650805053935
Z Interquartile Range:	1.3679050760511
Z Median Abs. Deviation:	0.61274020284566
Z Mean:	-0.71771601472079
Z Trim Mean (10%):	-0.64976068588311
Z Standard Deviation:	1.1035812373635
Z Variance:	1.2178915474607
Z Coef. of Variation:	-1
Z Coef. of Skewness:	-0.93146816705129
Z Root Mean Square:	1.3164375508346
Z Mean Square:	1.7330078252474

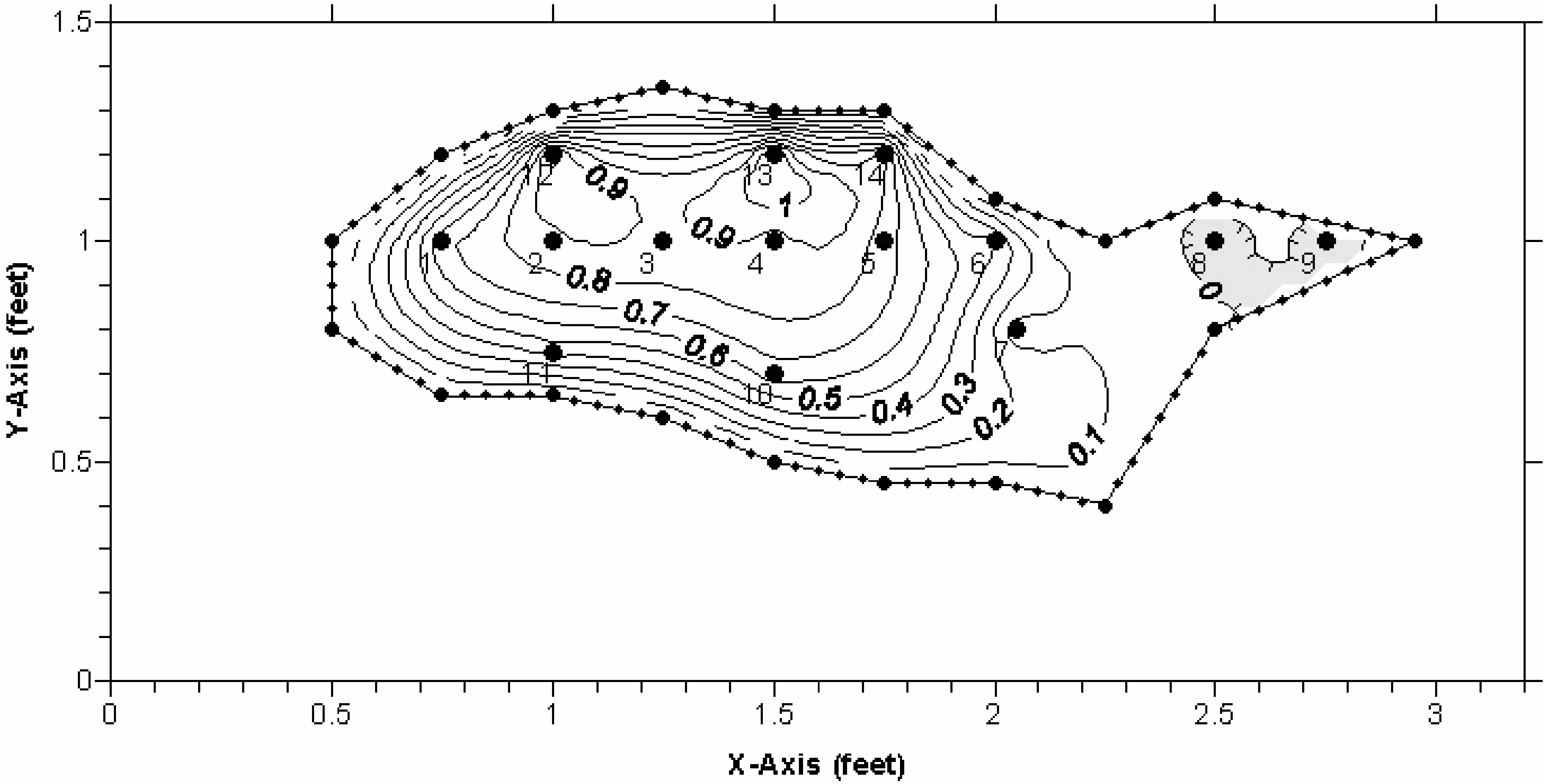


Figure 4. Discharge measurement cross-section; Second Fisherman's Paradise Spring, Marion County, Florida, September 22, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. See Table 1 for station velocities. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

Table 3. Second Fisherman's Paradise Spring XYZ Grid Data, September 22, 2006.						
X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
0.75	1	0.67	1	15	20	
1	1	0.85	2	20	20	
1.25	1	0.85	3	25	20	
1.5	1	0.84	4	30	20	
1.75	1	0.74	5	35	20	
2	1	0.41	6	40	20	
2.05	0.8	0.05	7	41	16	
2.5	1	-0.07	8	50	20	
2.75	1	-0.07	9	55	20	
1.5	0.7	0.65	10	30	14	
1	0.75	0.44	11	20	15	
1	1.2	1.01	12	20	24	
1.5	1.2	1.09	13	30	24	
1.75	1.2	0.81	14	35	24	
0.5	1	0	A	10	20	
0.5	0.8	0	B	10	16	
0.75	0.65	0	C	15	13	
1	0.65	0	D	20	13	
1.25	0.6	0	E	25	12	
1.5	0.5	0	F	30	10	
1.75	0.45	0	G	35	9	
2	0.45	0	H	40	9	
2.25	0.4	0	I	45	8	
2.5	0.8	0	J	50	16	
2.95	1	0	K	59	20	
2.5	1.1	0	L	50	22	
2.25	1	0	M	45	20	
2	1.1	0	N	40	22	
1.75	1.3	0	O	35	26	
1.5	1.3	0	P	30	26	
1.25	1.35	0	Q	25	27	
1	1.3	0	R	20	26	
0.75	1.2	0	S	15	24	
0.5	0.95	0	A1	10	19	
0.5	0.9	0	A2	10	18	
0.5	0.85	0	A3	10	17	
0.55	0.77	0	B1	11	15.4	
0.6	0.74	0	B2	12	14.8	
0.65	0.71	0	B3	13	14.2	
0.7	0.68	0	B4	14	13.6	
0.8	0.65	0	C1	16	13	
0.85	0.65	0	C2	17	13	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
0.9	**0.65**	**0**	**C3**	18	13	
0.95	**0.65**	**0**	**C4**	19	13	
1.05	**0.64**	**0**	**D1**	21	12.8	
1.1	**0.63**	**0**	**D2**	22	12.6	
1.15	**0.62**	**0**	**D3**	23	12.4	
1.2	**0.61**	**0**	**D4**	24	12.2	
1.3	**0.58**	**0**	**E1**	26	11.6	
1.35	**0.56**	**0**	**E2**	27	11.2	
1.4	**0.54**	**0**	**E3**	28	10.8	
1.45	**0.52**	**0**	**E4**	29	10.4	
1.55	**0.49**	**0**	**F1**	31	9.8	
1.6	**0.48**	**0**	**F2**	32	9.6	
1.65	**0.47**	**0**	**F3**	33	9.4	
1.7	**0.46**	**0**	**F4**	34	9.2	
1.8	**0.45**	**0**	**G1**	36	9	
1.85	**0.45**	**0**	**G2**	37	9	
1.9	**0.45**	**0**	**G3**	38	9	
1.95	**0.45**	**0**	**G4**	39	9	
2.05	**0.44**	**0**	**H1**	41	8.8	
2.1	**0.43**	**0**	**H2**	42	8.6	
2.15	**0.42**	**0**	**H3**	43	8.4	
2.2	**0.41**	**0**	**H4**	44	8.2	
2.28125	**0.45**	**0**	**I1**	45.625	9	
2.3125	**0.5**	**0**	**I2**	46.25	10	
2.34375	**0.55**	**0**	**I3**	46.875	11	
2.375	**0.6**	**0**	**I4**	47.5	12	
2.40625	**0.65**	**0**	**I5**	48.125	13	
2.4375	**0.7**	**0**	**I6**	48.75	14	
2.46875	**0.75**	**0**	**I7**	49.375	15	
2.55	**0.82222**	**0**	**J1**	51	16.4444	
2.6	**0.84444**	**0**	**J2**	52	16.8888	
2.65	**0.86666**	**0**	**J3**	53	17.3332	
2.7	**0.8888**	**0**	**J4**	54	17.776	
2.75	**0.9111**	**0**	**J5**	55	18.222	
2.8	**0.93332**	**0**	**J6**	56	18.6664	
2.85	**0.95554**	**0**	**J7**	57	19.1108	
2.9	**0.97776**	**0**	**J8**	58	19.5552	
2.9	**1.01111**	**0**	**K1**	58	20.2222	
2.85	**1.02222**	**0**	**K2**	57	20.4444	
2.8	**1.03333**	**0**	**K3**	56	20.6666	
2.75	**1.04444**	**0**	**K4**	55	20.8888	

Table 3. Second Fisherman’s Paradise Spring XYZ Grid Data, September 22, 2006.

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
2.7	**1.05555**	**0**	**K5**	54	21.111	
2.65	**1.06666**	**0**	**K6**	53	21.3332	
2.6	**1.07777**	**0**	**K7**	52	21.5554	
2.55	**1.08888**	**0**	**K8**	51	21.7776	
2.45	**1.08**	**0**	**L1**	49	21.6	
2.4	**1.06**	**0**	**L2**	48	21.2	
2.35	**1.04**	**0**	**L3**	47	20.8	
2.3	**1.02**	**0**	**L4**	46	20.4	
2.2	**1.02**	**0**	**M1**	44	20.4	
2.15	**1.04**	**0**	**M2**	43	20.8	
2.1	**1.06**	**0**	**M3**	42	21.2	
2.05	**1.08**	**0**	**M4**	41	21.6	
1.95	**1.14**	**0**	**N1**	39	22.8	
1.9	**1.18**	**0**	**N2**	38	23.6	
1.85	**1.22**	**0**	**N3**	37	24.4	
1.8	**1.26**	**0**	**N4**	36	25.2	
1.7	**1.3**	**0**	**O1**	34	26	
1.65	**1.3**	**0**	**O2**	33	26	
1.6	**1.3**	**0**	**O3**	32	26	
1.55	**1.3**	**0**	**O4**	31	26	
1.45	**1.31**	**0**	**P1**	29	26.2	
1.4	**1.32**	**0**	**P2**	28	26.4	
1.35	**1.33**	**0**	**P3**	27	26.6	
1.3	**1.34**	**0**	**P4**	26	26.8	
1.2	**1.34**	**0**	**Q1**	24	26.8	
1.15	**1.33**	**0**	**Q2**	23	26.6	
1.1	**1.32**	**0**	**Q3**	22	26.4	
1.05	**1.31**	**0**	**Q4**	21	26.2	
0.95	**1.28**	**0**	**R1**	19	25.6	
0.9	**1.26**	**0**	**R2**	18	25.2	
0.85	**1.24**	**0**	**R3**	17	24.8	
0.8	**1.22**	**0**	**R4**	16	24.4	
0.7	**1.16**	**0**	**S1**	14	23.2	
0.65	**1.12**	**0**	**S2**	13	22.4	
0.6	**1.08**	**0**	**S3**	12	21.6	
0.55	**1.04**	**0**	**S4**	11	20.8	

Table 3. Second Fisherman's Paradise Spring XYZ Grid Data, September 22, 2006.

CALIBRATION CERTIFICATE

Model: 2ØØØ-21 Serial Number: 2ØØ2679

Unit Gain Ratio: ____________ Time Constant: ____________

SensorSer # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ______

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.ØØ	N/A
Measured:	Ø.ØØ	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: Stan Cullski Date: 18 Apr 2006

QA Technician: BHall Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

P/N 101001 301

Discharge Measurement: Alligator Hole Spring, Marion County, Florida; September 28, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Alligator Hole Spring, Marion County, Florida; September 28, 2006

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Results of Discharge Measurements of Alligator Hole Spring, Marion County, Florida; September 28, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Alligator Hole Spring on September 28, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Alligator Hole Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

The main vents at Alligator Hole Spring are located in a somewhat elongated, oval basin along the south side of the Silver River, approximately 150 feet northeast of Devils Kitchen A. This depression is formed in soft sediments and is about 14 feet long. There are vents at both the upstream and downstream end of this depression, at depths of 15 and 17 feet, respectively. There is also a smaller vent about 40 feet southeast of Alligator Hole, about 18 feet deep, within a conical, silty depression, about 12 feet in diameter. See Figure 1.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Alligator Hole Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Alligator Hole Spring on September 28, 2006 was 0.77 CFS (cubic feet per second). This result is also expressed as 346 GPM (gallons per minute) or 0.498 MGD (million gallons per day), see Table 1. Three readings were made at each of three vents, for a total of nine (9) readings. Individual point velocity readings ranged from 0.93 to 1.85 feet per second (fps), with an overall average station reading of 1.36 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 15 to 18 feet. The measurements commenced at about 16:35 hours and were completed by 17:00 hours.

	UNDERWATER DISCHARGE MEASUREMENT					
	Location:	**ALLIGATOR HOLE SPRING**			Date:	**September 28, 2006**
		Silver Springs Group,			Time Start:	16:35
		Marion County, Florida			Time End:	17:00
	Personnel:	Peter Butt, Tom Morris				
	Method:	Vent Discharge Capture Device		(0.49' Diameter)		
	Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe.				
	Calculation Method: Discharge = V x *pi* x r^2					
	Measurement Periods:		60 seconds			
	Alligator Hole Spring Total Discharge:			**Main U/S Vent:**	**Main D/S Vent:**	**South Vent:**
	CFS	**0.77**		**0.348**	**0.248**	**0.175**
	MGD	**0.498**		**0.225**	**0.160**	**0.113**
	GPM	**346**	All Vents:	**156**	**111**	**79**
	Avg. Point Velocity (ft/sec):		1.36	1.84	1.31	0.93
	Vent Depth (feet deep):			15	17	18
	Velocity Readings:		(All velocity readings in feet per second.)			
	Main U/S Vent (tag)		**Main D/S Vent**		**South Vent**	
	Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity
	1	1.84	1	1.36	1	0.93
	2	1.84	2	1.31	2	0.93
	3	1.85	3	1.27	3	0.93
	Average:	1.84	Average:	1.31	Average:	0.93
	Discharge:	0.348	Discharge:	0.248	Discharge:	0.175

Table 1. Discharge of Alligator Hole Spring, Marion County, Florida on September 28, 2006. Data record and calculation of discharge measurement.

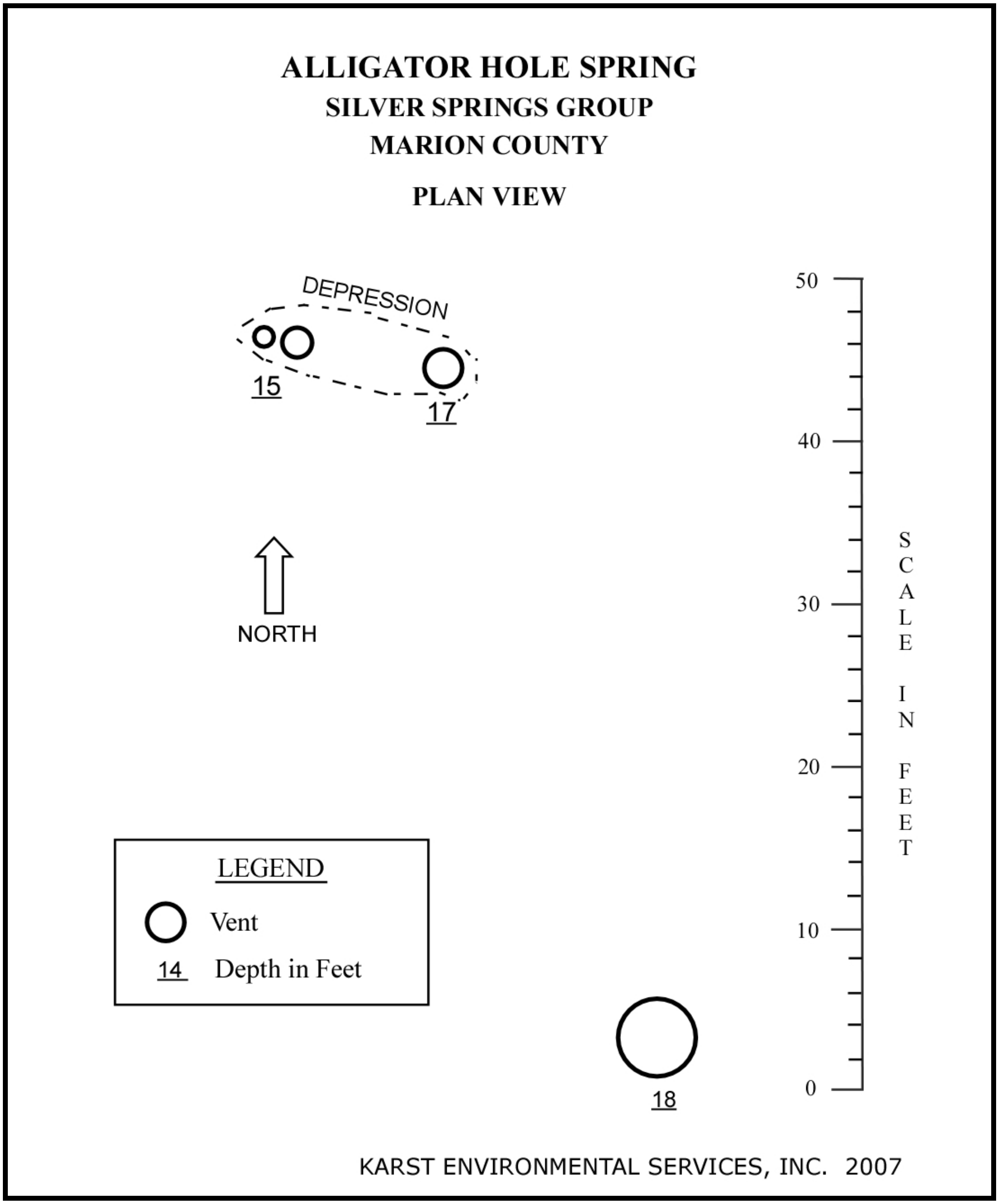

Figure 1. Map of Alligator Hole Spring.

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ____ Time Constant: ____

SensorSer # N/A

Type of Reading

Velocity:
- X FPS
- _ CMS
- _ ____

Level:
- _ IN
- _ CM
- X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____

Calibration Technician: Stan Cinloski Date: 18 Apr 2006

QA Technician: BHall Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452
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P/N 101001 301

Discharge Measurement: Blue Grotto Spring, Marion County, Florida; September 29, 2006

Prepared for:

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Discharge Measurement: Blue Grotto Spring, Marion County, Florida; September 29, 2006

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Results of Discharge Measurements of Blue Grotto Spring, Marion County, Florida; September 29, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Blue Grotto Spring on September 29, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Blue Grotto Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida.

SITE DESCRIPTION

Blue Grotto Spring is located on the south side of the Silver River, within a basin in the same cove as the Geyser Springs Group, about 100 feet to the southeast. There is an exposure of limestone bedrock and boulders at the bottom of the basin. Most of the discharge flows from a large "Main" vent (Vent 1) at the northern end of this rocky structure, and a small conduit can be observed descending below 26 feet of depth. Water also discharges from a smaller vent on the south end of the structure (Vent 2, also called the "Back" vent), about 15 feet south of the main vent. Water also discharges through numerous smaller vents in the network of cracks between the boulders that make up the top and west side of this structure. Discharge from several of the vents is strong enough to suspend agitated sand and shell fragments. See Figure 1.

Since the orifice of this spring is located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter.

One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

Pete Butt positioned the sensor, and recorded positional data, while Mark Long read the velocity readings, after taking meter reset cues from Butt. During all measurements, the sensor handler completely removed himself from the cross section of the flow. The meter operator was also positioned outside the cross-section. This eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. A total of forty (40) station readings were taken.

The approximate depth for the measurement grids was 24 to 26 and 21 feet. Telescoping aluminum poles with 1, 0.5, 0.25 and 0.1 foot interval markings were positioned horizontally to allow for a grid of velocity measurements. As all sensor-support poles were positioned at right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was positioned on the poles with a quick release clamp. Spring vent dimensions and positions were measured with a metal tape.

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figures 2(AB). Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Tables 3A and 3B. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used for both vents was point Kriging with linear drift, an anisotropy ratio of 1 at an angle of 0°, and a variogram slope of 1.0. The results of the contour processing are illustrated in Figures 3(AB) and 4(AB).

During this measurement, three negative velocities were measured in Vent 1. Negative velocity stations typically represent slight back eddies near walls. In order to incorporate any negative values, calculations were made using a Surfer 8 “blanking file” operation to define the measurement cross-section boundary. The total discharge is shown on Tables 2A and 2B as the **Net Volume (Cut-Fill)**, and has been calculated as the Positive Volume (Cut) less that portion of the Negative Volume (Fill) lying within the measurement cross-section boundary walls that define the plane of measurement.

The software also calculates the total cross-sectional area of the measurement location within the passage, and is presented on Tables 2A and 2B as the **Operational Planar Area**. The Operational Planar Area is the sum of the Positive (Cut) and that portion of the Negative (Fill) Planar areas lying within the measurement cross-section boundary walls that define the plane of measurement.

RESULTS AND DISCUSSION

This measurement is the first one performed at Blue Grotto Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. There was additional discharge from various cracks at this site that were not measurable. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated total discharge of Blue Grotto Spring (both vents) on September 29, 2006 was 6.28 CFS (cubic feet per second). This result is also expressed as 2818 GPM (gallons per minute) or 4.058 MGD (million gallons per day), see Table 1. A total of forty (40) readings were made, see Figures 2(AB), 3(AB) and 4(AB). The total cross-sectional area was calculated as 8.95 square feet. The point velocity readings ranged from -0.09 to 1.87 feet per second (fps), with an overall average station reading of 0.92 fps. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 14:34 hours and were completed by 15:51 hours. The results for each of the individual vents are detailed below.

The estimated discharge of Blue Grotto Spring Vent 1 (Main) on September 29, 2006 was 5.763 CFS. This result is also expressed as 2587 GPM or 3.725 MGD, see Table 1. Thirty-four (34) readings were made, see Figures 2A, 3A and 4A. The total cross-sectional area was calculated as 7.964 square feet. The point velocity readings ranged from -0.09 to 1.87 feet per second (fps), with an overall average station reading of 0.92 fps.

The estimated discharge of Blue Grotto Spring Vent 2 (Back) on September 29, 2006 was 0.515 CFS. This result is also expressed as 231 GPM or 0.333 MGD, see Table 1. Six (6) readings were made, see Figures 2B, 3B and 4B. The total cross-sectional area was calculated as 0.98 square feet. The point velocity readings ranged from 0.84 to 1.03 feet per second (fps), with an overall average station reading of 0.93 fps.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**BLUE GROTTO SPRING**		Date:	**September 29, 2006**	
	Silver Springs Group,		Time Start:	14:34	
	Marion County, Florida		Time End:	15:51	
Personnel:	Peter Butt, Mark Long				
Method:	Grid within irregular conduit				
Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles				
Msmt. Periods:		60 seconds			
Analysis Method: Surfer 8 with kriging					
Blue Grotto Spring Total Discharge:			**Vent 1 (Main):**	**Vent 2 (Back):**	
CFS	**6.28**		**5.763**	**0.515**	
MGD	**4.058**		**3.725**	**0.333**	
GPM	**2818**	All Vents:	**2587**	**231**	
Total Cross-sectional Area (sq/ft):		8.95	7.964	0.98	
Avg. Station Point Velocity (ft/sec):		0.92	0.92	0.93	
Cross-section Depth (feet deep):			24-26	21	
Velocity Reading by Station:		(All velocity readings in feet per second.)			
Station #	Point Velocity	Station #	Point Velocity	Station #	Point Velocity
VENT 1 (Main)		**VENT 1 (Main) contd.**		**VENT 2 (Back)**	
1	0.41	18	1.51	1	0.94
2	0.59	19	0.1	2	0.87
3	1.12	20	0.74	3	0.91
4	1.12	21	1.66	4	0.99
5	1.28	22	-0.1	5	1.03
6	1.26	23	-0.09	6	0.84
7	1.09	24	1.04		
8	1.24	25	1.32		
9	1.67	26	0.54		
10	1.11	27	1.11		
11	-0.08	28	0.17		
12	1.12	29	0.19		
13	1.87	30	0.79		
14	0.3	31	0.52		
15	1.73	32	1.24		
16	0.43	33	1.5		
17	1.12	34	1.64		

Table 1. Discharge of Blue Grotto Spring, Marion County, Florida on September 29, 2006. Data record and calculation of discharge measurement.

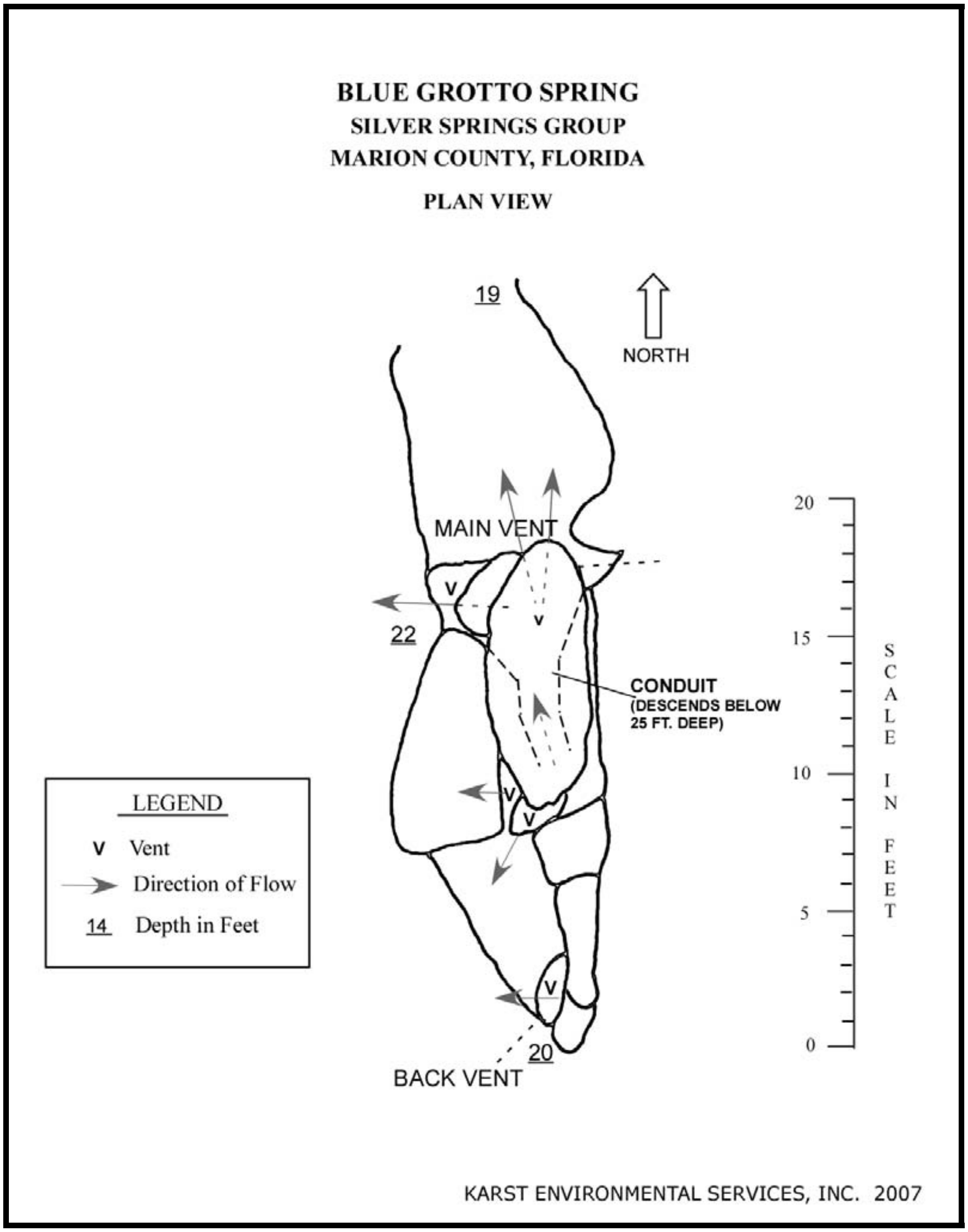

Figure 1. Map of Blue Grotto Spring.

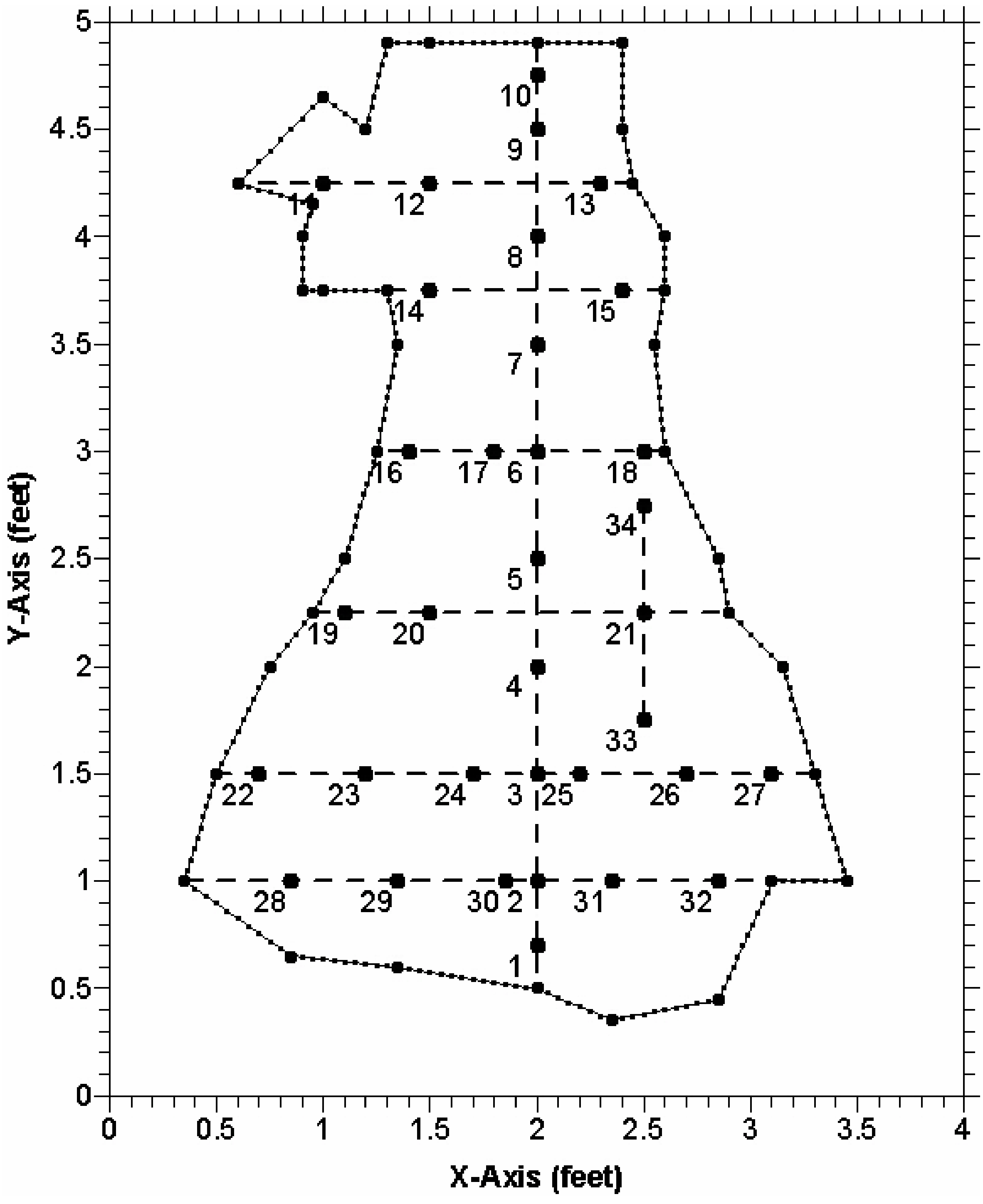

Figure 2A. Discharge measurement cross-section; Blue Grotto Spring Vent 1 (Main Vent), Marion County, Florida, September 29, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 24 to 26-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

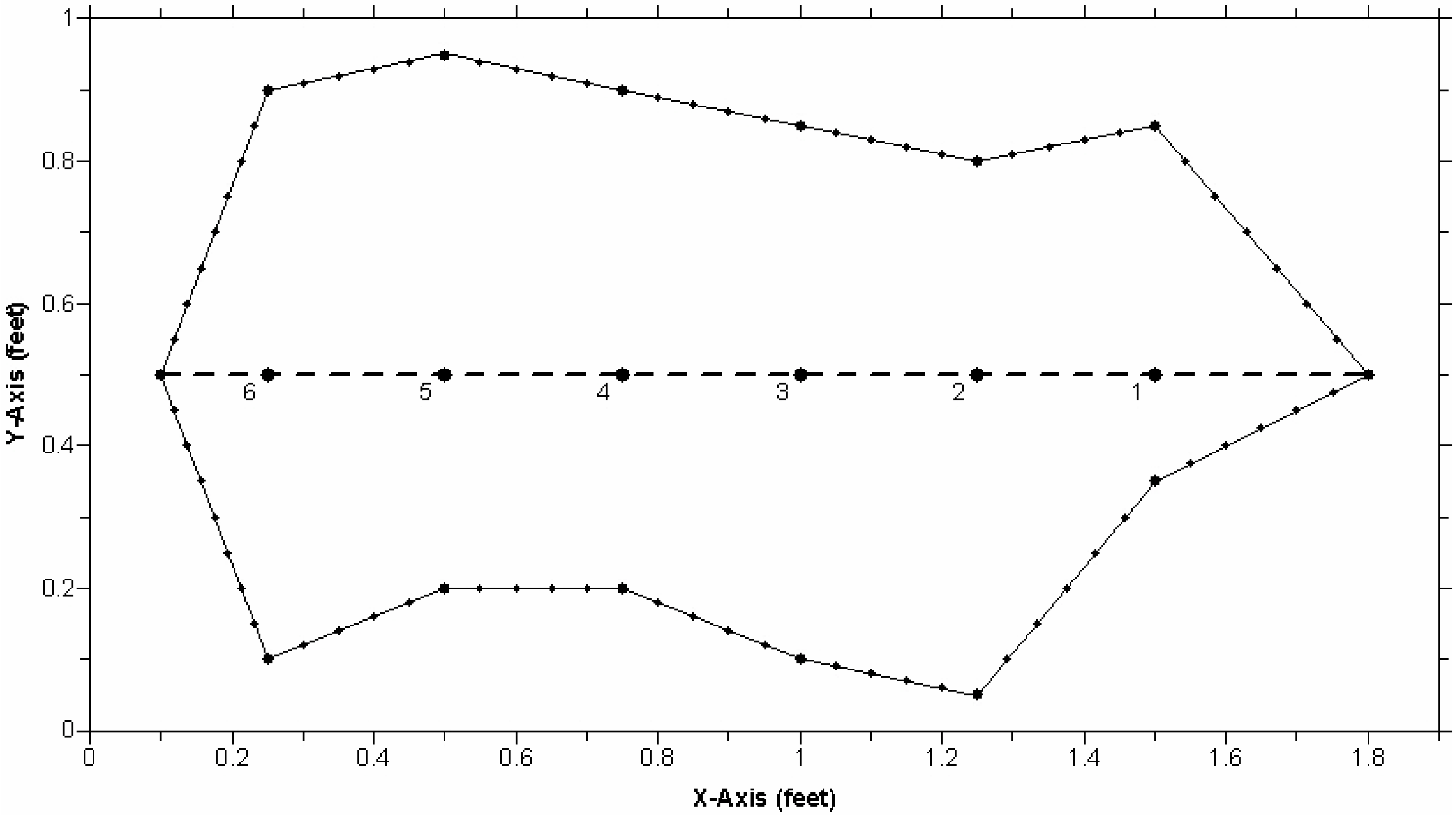

Figure 2B. Discharge measurement cross-section; Blue Grotto Spring Vent 2 (Back Vent), Marion County, Florida, September 29, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 21-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

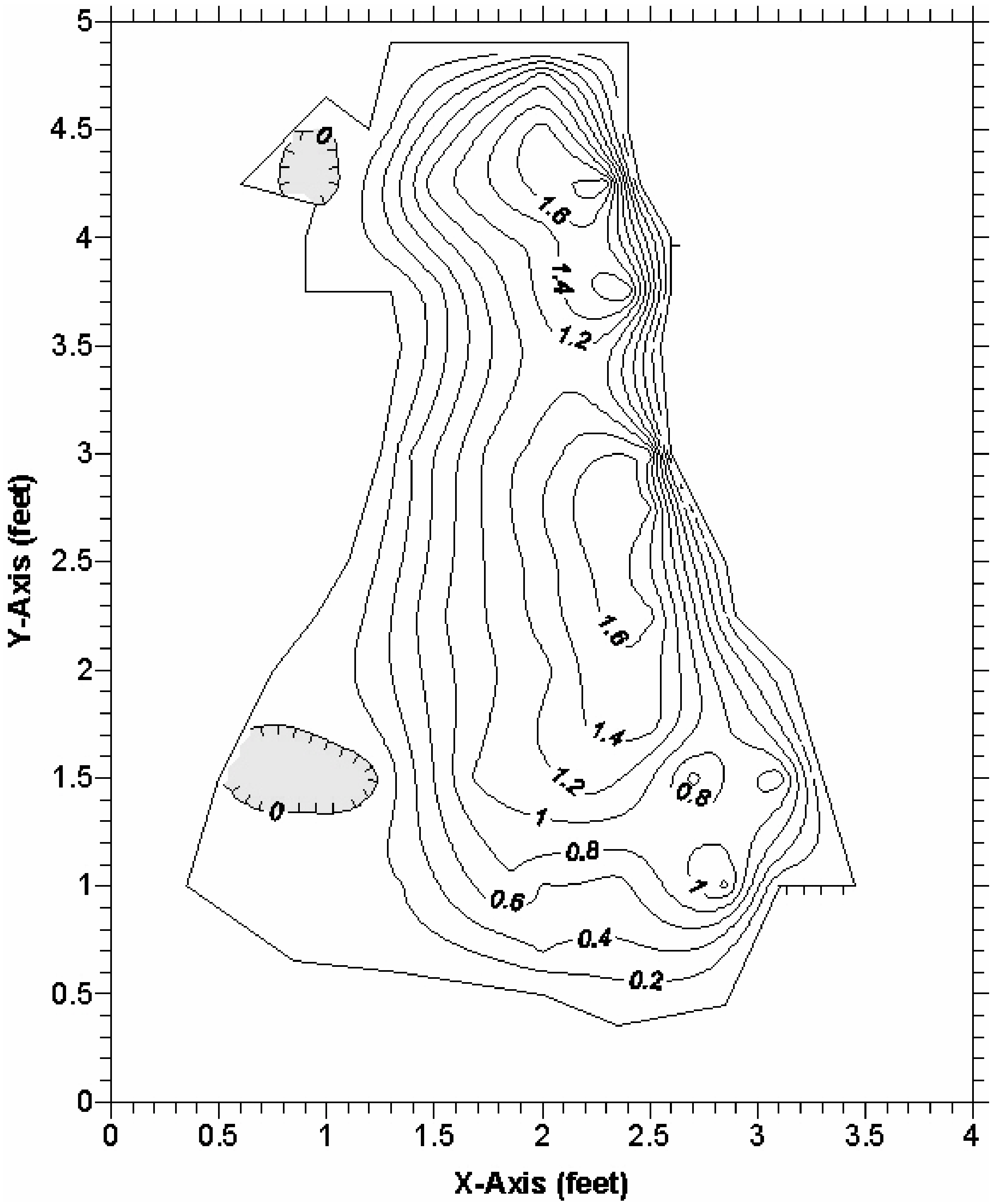

Figure 3A. Discharge measurement cross-section; Blue Grotto Spring Vent 1 (Main Vent), Marion County, Florida, September 29, 2006 measurement. Flow contour velocities are shown in feet per second. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

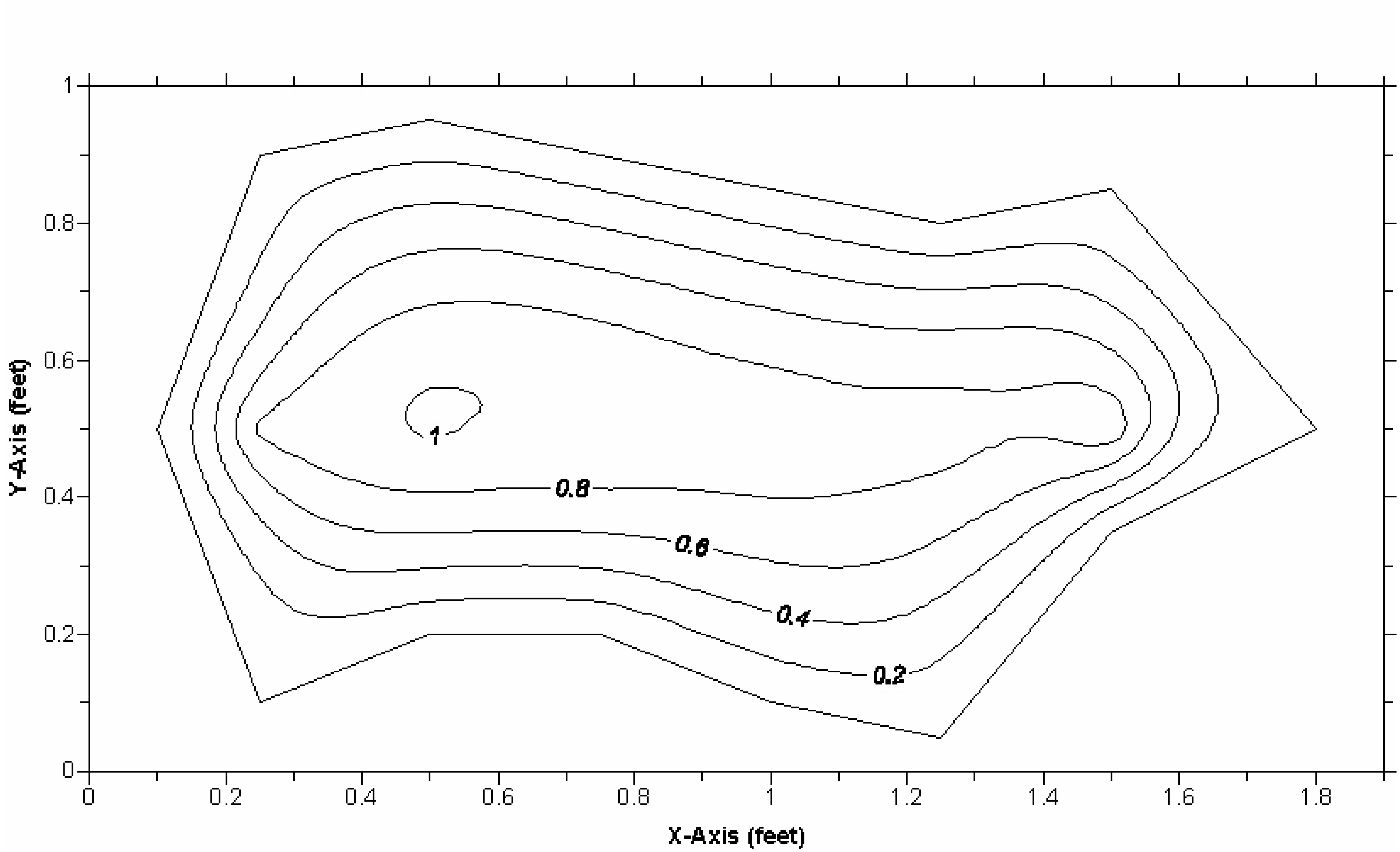

Figure 3B. Discharge measurement cross-section; Blue Grotto Spring Vent 2 (Back Vent), Marion County, Florida, September 29, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

TABLE 2A. BLUE GROTTO SPRING, MAIN VENT, SEPTEMBER 29, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\BlueGrotto_Main\Blue_Grotto_Main_9-06.bln.grd
Grid Size:	101 rows x 71 columns
X Minimum:	0
X Maximum:	3.5
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	5
Y Spacing:	0.05
Z Minimum:	-0.09999999993944
Z Maximum:	1.8700000001211

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES
Z Scale Factor: 1
Total Volumes by:

Trapezoidal Rule:	5.7625840992995
Simpson's Rule:	5.7639321415871
Simpson's 3/8 Rule:	5.7625473203968

CUT & FILL VOLUMES
Positive Volume [Cut]: 5.7715718227459
Negative Volume [Fill]: 0.0089877234464345
Net Volume [Cut-Fill]: 5.7625840992995 <<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 7.964 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 7.6788263454663
Negative Planar Area [Fill]: 0.2849236545337
Blanked Planar Area: 9.53625
Total Planar Area: 17.5

Surface Areas
Positive Surface Area [Cut]: 17.0639513975
Negative Surface Area [Fill]: 0.3222253780419

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\BlueGrotto_Main\Blue Grotto Main 9-06 SURFER XYZ T3A BLF-macro.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	300
Original Data:	300
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.35	0.35	-0.1
25%-tile:	1.1	1	0
Median:	1.85	2.55	0
75%-tile:	2.59	4	0
Maximum:	3.45	4.9	1.87
Midrange:	1.9	2.625	0.885
Range:	3.1	4.55	1.97
Interquartile Range:	1.49	3	0
Median Abs. Deviation:	0.75	1.5	0
Mean:	1.8452504	2.5885477833333	0.1042
Trim Mean (10%):	1.8391300740741	2.5816667962963	0.037962962962963
Standard Deviation:	0.88793396313521	1.5263962331337	0.34840641019744
Variance:	0.78842672288901	2.3298854605247	0.12138702666667
Coef. of Variation:			3.3436315757912
Coef. of Skewness:			3.3913233622281

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.142	0.110
Y:		1.000	0.019
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	0.78842672288901	-0.19228951428161	0.034083241653333
Y:		2.3298854605247	0.0099383209766667
Z:			0.12138702666667

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.045179165638709	0.0079942989080623	0.00013950181573744
Standard Error:	0.022846858036717	0.013290455493383	0.061446547389603

Inter-Parameter Correlations

	A	B	C
A:	1.000	-0.142	-0.766
B:		1.000	0.657
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.48579069860755	0.24289534930378	2.0078
Residual:	297	35.930317301392	0.12097749933129	
Total:	299	36.416108		

Coefficient of Multiple Determination (R^2): 0.013339994999124

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.050249378105604	0
Median:	0.052201532544552	0
75%-tile:	0.055901699437495	0
Maximum:	0.5	1.87

Midrange:	0.275	0.935
Range:	0.45	1.87
Interquartile Range:	0.0056523213318903	0
Median Abs. Deviation:	0.0022015325445524	0
Mean:	0.077411124564493	0.0723333333333333
Trim Mean (10%):	0.061859035695728	0.0138888888888889
Standard Deviation:	0.078861265510455	0.27882112944004
Variance:	0.0062190991979105	0.0777412222222222
Coef. of Variation:	1.0187329786787	3.8546699922587
Coef. of Skewness:	3.6680586243133	4.5229832649136
Root Mean Square:	0.1105060242894	0.2880509214242
Mean Square:	0.01221158140425	0.0829733333333333

Complete Spatial Randomness

Lambda:	21.269053527118
Clark and Evans:	0.71401519537594
Skellam:	489.57721354803

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	3.6E-007
Y Duplicate Tolerance:	5.4E-007

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	2
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\BlueGrotto_Main\Blue_Grotto_Main_9-06 .grd
Grid Size:	101 rows x 71 columns
Total Nodes:	7171
Filled Nodes:	7171
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	3.5
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	5
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-3.6082622616273
Z 25%-tile:	-0.43684709244721
Z Median:	-0.044476168674593
Z 75%-tile:	0.59230899678273
Z Maximum:	1.8700000001211
Z Midrange:	-0.86913113075312
Z Range:	5.4782622617485
Z Interquartile Range:	1.0291560892299
Z Median Abs. Deviation:	0.48371241524235
Z Mean:	-0.024153328787679
Z Trim Mean (10%):	0.018342101351005
Z Standard Deviation:	0.91097057394001
Z Variance:	0.82986738658459
Z Coef. of Variation:	-1
Z Coef. of Skewness:	-0.6229512741844
Z Root Mean Square:	0.9112907164435
Z Mean Square:	0.83045076987611

TABLE 2B. BLUE GROTTO SPRING, BACK VENT, SEPTEMBER 29, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\BlueGrotto_Back\Blue_Grotto_Back_9-06.bln.grd
Grid Size:	41 rows x 77 columns
X Minimum:	0
X Maximum:	1.9
X Spacing:	0.025
Y Minimum:	0
Y Maximum:	1
Y Spacing:	0.025
Z Minimum:	-1.0054116983405E-009
Z Maximum:	1.0300000010496

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES
Z Scale Factor: 1
Total Volumes by:
Trapezoidal Rule: 0.51544610644649
Simpson's Rule: 0.51545315374961
Simpson's 3/8 Rule: 0.51544488497162

CUT & FILL VOLUMES
Positive Volume [Cut]: 0.51544610644712
Negative Volume [Fill]: 6.3236712945569E-013
Net Volume [Cut-Fill]: 0.51544610644649<<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 0.981 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 0.9809375
Negative Planar Area [Fill]: 1.1223574916769E-018
Blanked Planar Area: 0.9190625
Total Planar Area: 1.9

Surface Areas
Positive Surface Area [Cut]: 3.0377142692774
Negative Surface Area [Fill]: 4.5412944833673E-018

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\BlueGrotto_Back\Blue Grotto Back 9-06 SURFER XYZ T3B BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	86
Original Data:	86
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.1	0.05	0
25%-tile:	0.35	0.2	0
Median:	0.85	0.5	0
75%-tile:	1.33334	0.83	0
Maximum:	1.8	0.95	1.03
Midrange:	0.95	0.5	0.515
Range:	1.7	0.9	1.03
Interquartile Range:	0.98334	0.63	0
Median Abs. Deviation:	0.5	0.31	0
Mean:	0.8677323255814	0.51424418604651	0.064883720930233
Trim Mean (10%):	0.86062275641026	0.51544871794872	0.021923076923077
Standard Deviation:	0.52447620241959	0.30354352724332	0.23755412693398
Variance:	0.27507528690448	0.092138672931314	0.056431963223364
Coef. of Variation:			3.6612284796276
Coef. of Skewness:			3.4090337592444

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.003	0.003
Y:		1.000	-0.013
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	0.27507528690448	0.00048368489724175	0.00038434445646295
Y:		0.092138672931314	-0.00092421579232017
Z:			0.056431963223364

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.0014148844617483	-0.010038131884699	0.068818030906285
Standard Error:	0.049712082404103	0.08589477901393	0.066933223429385

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.003	-0.642
B:		1.000	0.658
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.00084462345908687	0.00042231172954343	0.0072238
Residual:	83	4.8523042137502	0.058461496551207	
Total:	85	4.8531488372093		

Coefficient of Multiple Determination (R^2): 0.0001740361747431

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.050990195135928	0
Median:	0.053400023408235	0
75%-tile:	0.055901699437495	0
Maximum:	0.25	0.94
Midrange:	0.15	0.47

Range:	0.2	0.94
Interquartile Range:	0.0049115043015669	0
Median Abs. Deviation:	0.0024098282723067	0
Mean:	0.065160800034783	0.023372093023256
Trim Mean (10%):	0.056459343628095	0.001025641025641
Standard Deviation:	0.042971158758496	0.13454151658992
Variance:	0.0018465204850479	0.018101419686317
Coef. of Variation:	0.65946333893319	5.7565026998674
Coef. of Skewness:	3.7907379499815	6.273863312207
Root Mean Square:	0.078054150089671	0.13655648801359
Mean Square:	0.0060924503462209	0.018647674418605

Complete Spatial Randomness
Lambda: 56.209150326797
Clark and Evans: 0.97705702974537
Skellam: 185.04499302138

Exclusion Filtering
Exclusion Filter String: Not In Use

Duplicate Filtering
Duplicate Points to Keep: First
X Duplicate Tolerance: 2E-007
Y Duplicate Tolerance: 1E-007
No duplicate data were found.

Breakline Filtering
Breakline Filtering: Not In Use

Gridding Rules
Gridding Method: Kriging
Kriging Type: Point
Polynomial Drift Order: 2
Kriging std. deviation grid: no

Semi-Variogram Model
Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 1
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\BlueGrotto_Back\Blue_Grotto_Back_9-06.grd
Grid Size:	41 rows x 77 columns
Total Nodes:	3157
Filled Nodes:	3157
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	1.9
X Spacing:	0.025
Y Minimum:	0
Y Maximum:	1
Y Spacing:	0.025

Grid Statistics

Z Minimum:	-1.5010038418826
Z 25%-tile:	-0.29067154932768
Z Median:	0.036780703502293
Z 75%-tile:	0.53007151371379
Z Maximum:	1.0300000010496
Z Midrange:	-0.2355019204165
Z Range:	2.5310038429323
Z Interquartile Range:	0.82074306304147
Z Median Abs. Deviation:	0.38919939345847
Z Mean:	0.085807086237219
Z Trim Mean (10%):	0.097260680368286
Z Standard Deviation:	0.5210522718665
Z Variance:	0.27149547001724
Z Coef. of Variation:	6.0723687834594
Z Coef. of Skewness:	-0.10352248837477
Z Root Mean Square:	0.52807037984132
Z Mean Square:	0.27885832606576

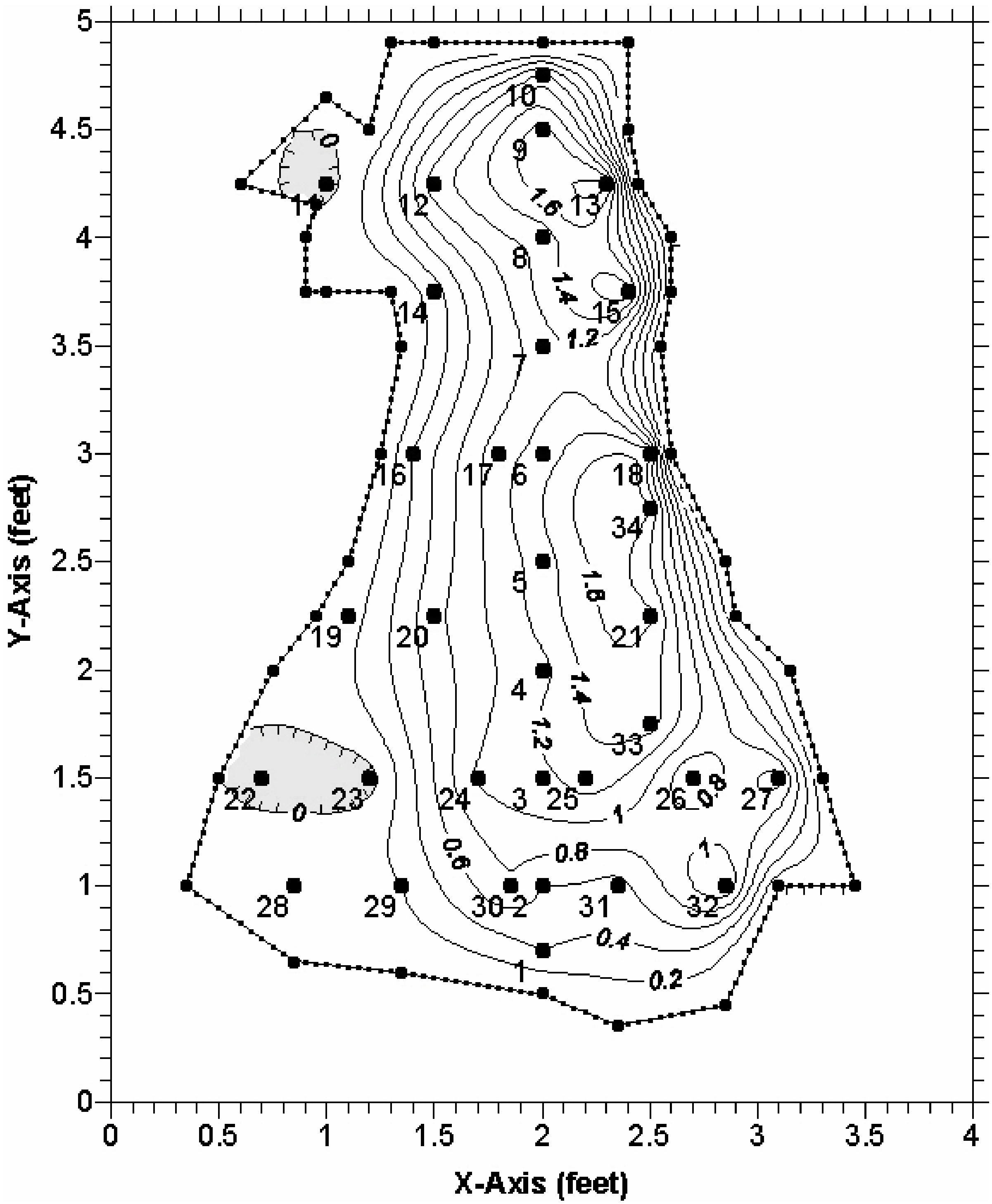

Figure 4A. Discharge measurement cross-section; Blue Grotto Spring Vent 1 (Main Vent), Marion County, Florida, September 29, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. See Table 1 for station velocities. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

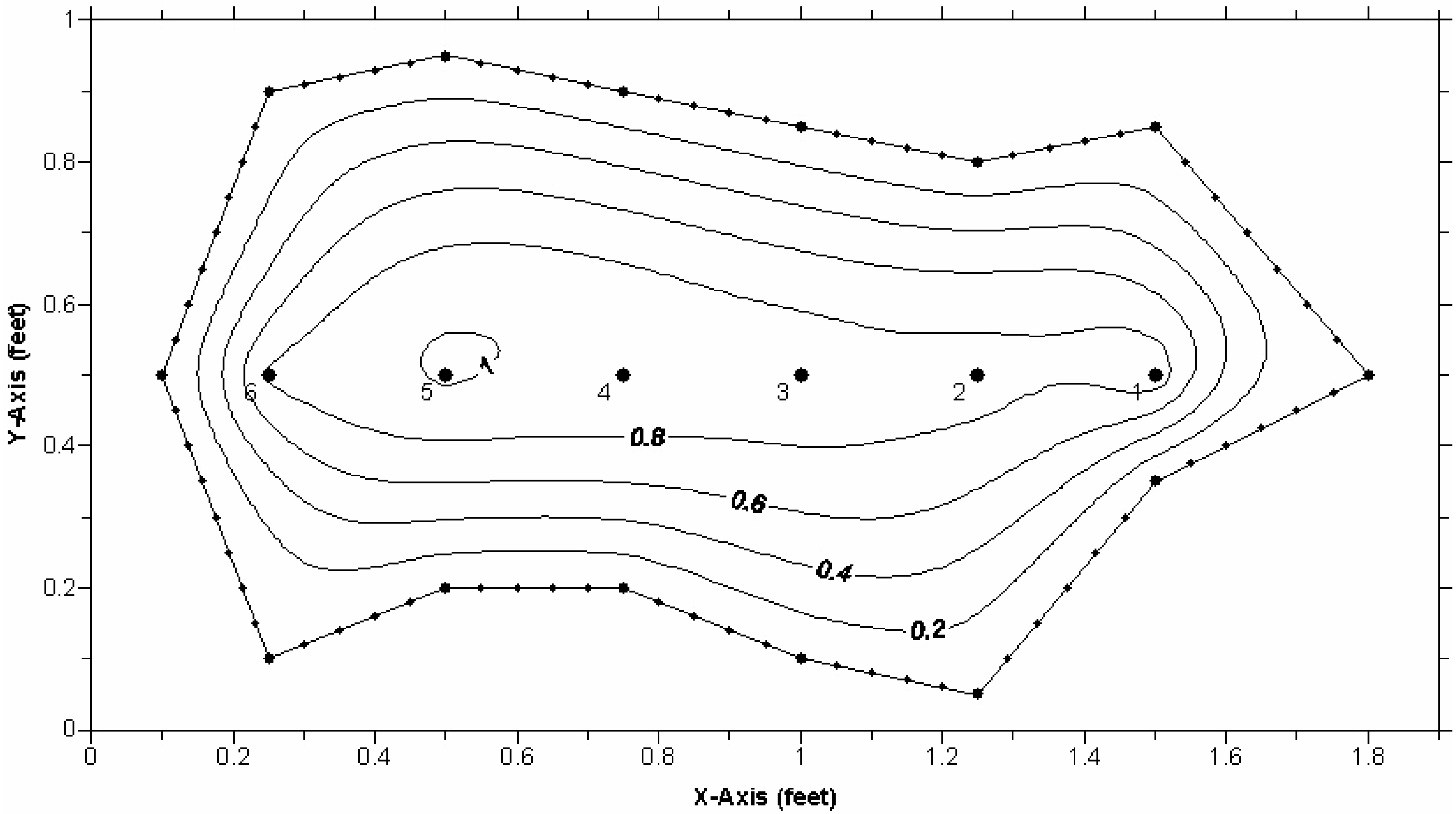

Figure 4B. Discharge measurement cross-section; Blue Grotto Spring Vent 2 (Back Vent), Marion County, Florida, September 29, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

Table 3A. Blue Grotto Spring Vent 1 (Main Vent) XYZ Grid Data, September 29, 2006.						
X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
2	0.7	0.41	1	40	14	
2	1	0.59	2	40	20	
2	1.5	1.12	3	40	30	
2	2	1.12	4	40	40	
2	2.5	1.28	5	40	50	
2	3	1.26	6	40	60	
2	3.5	1.09	7	40	70	
2	4	1.24	8	40	80	
2	4.5	1.67	9	40	90	
2	4.75	1.11	10	40	95	
1	4.25	-0.08	11	20	85	
1.5	4.25	1.12	12	30	85	
2.3	4.25	1.87	13	46	85	
1.5	3.75	0.3	14	30	75	
2.4	3.75	1.73	15	48	75	
1.4	3	0.43	16	28	60	
1.8	3	1.12	17	36	60	
2.5	3	1.51	18	50	60	
1.1	2.25	0.1	19	22	45	
1.5	2.25	0.74	20	30	45	
2.5	2.25	1.66	21	50	45	
0.7	1.5	-0.1	22	14	30	
1.2	1.5	-0.09	23	24	30	
1.7	1.5	1.04	24	34	30	
2.2	1.5	1.32	25	44	30	
2.7	1.5	0.54	26	54	30	
3.1	1.5	1.11	27	62	30	
0.85	1	0.17	28	17	20	
1.35	1	0.19	29	27	20	
1.85	1	0.79	30	37	20	
2.35	1	0.52	31	47	20	
2.85	1	1.24	32	57	20	
2.5	1.75	1.5	33	50	35	
2.5	2.75	1.64	34	50	55	
1.3	4.9	0	A	26	98	
1.5	4.9	0	B	30	98	
2	4.9	0	C	40	98	
2.4	4.9	0	D	48	98	
2.4	4.5	0	E	48	90	
2.45	4.25	0	F	49	85	
2.6	4	0	G	52	80	
2.6	3.75	0	H	52	75	
2.55	3.5	0	I	51	70	
2.6	3	0	J	52	60	
2.85	2.5	0	K	57	50	
2.9	2.25	0	L	58	45	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
3.15	2	0	M	63	40	
3.3	1.5	0	N	66	30	
3.45	1	0	O	69	20	
3.1	1	0	P	62	20	
2.85	0.45	0	Q	57	9	
2.35	0.35	0	R	47	7	
2	0.5	0	S	40	10	
1.35	0.6	0	T	27	12	
0.85	0.65	0	U	17	13	
0.35	1	0	V	7	20	
0.5	1.5	0	W	10	30	
0.75	2	0	X	15	40	
0.95	2.25	0	Y	19	45	
1.1	2.5	0	Z	22	50	
1.25	3	0	AA	25	60	
1.35	3.5	0	BB	27	70	
1.3	3.75	0	CC	26	75	
1	3.75	0	DD	20	75	
0.9	3.75	0	EE	18	75	
0.9	4	0	FF	18	80	
0.95	4.15	0	GG	19	83	
0.6	4.25	0	HH	12	85	
1	4.65	0	II	20	93	
1.2	4.5	0	JJ	24	90	
1.35	4.9	0	A1	27	98	
1.4	4.9	0	A2	28	98	
1.45	4.9	0	A3	29	98	
1.55	4.9	0	B1	31	98	
1.6	4.9	0	B2	32	98	
1.65	4.9	0	B3	33	98	
1.7	4.9	0	B4	34	98	
1.75	4.9	0	B5	35	98	
1.8	4.9	0	B6	36	98	
1.85	4.9	0	B7	37	98	
1.9	4.9	0	B8	38	98	
1.95	4.9	0	B9	39	98	
2.05	4.9	0	C1	41	98	
2.1	4.9	0	C2	42	98	
2.15	4.9	0	C3	43	98	
2.2	4.9	0	C4	44	98	
2.25	4.9	0	C5	45	98	
2.3	4.9	0	C6	46	98	
2.35	4.9	0	C7	47	98	
2.4	4.85	0	D1	48	97	
2.4	4.8	0	D2	48	96	

Table 3A. Blue Grotto Spring XYZ Grid Data, September 29, 2006.

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
2.4	4.75	0	D3	48	95	
2.4	4.7	0	D4	48	94	
2.4	4.65	0	D5	48	93	
2.4	4.6	0	D6	48	92	
2.4	4.55	0	D7	48	91	
2.41	4.45	0	E1	48.2	89	
2.42	4.4	0	E2	48.4	88	
2.43	4.35	0	E3	48.6	87	
2.44	4.3	0	E4	48.8	86	
2.48	4.2	0	F1	49.6	84	
2.51	4.15	0	F2	50.2	83	
2.54	4.1	0	F3	50.8	82	
2.57	4.05	0	F4	51.4	81	
2.6	3.95	0	G1	52	79	
2.6	3.9	0	G2	52	78	
2.6	3.85	0	G3	52	77	
2.6	3.8	0	G4	52	76	
2.59	3.7	0	H1	51.8	74	
2.58	3.65	0	H2	51.6	73	
2.57	3.6	0	H3	51.4	72	
2.56	3.55	0	H4	51.2	71	
2.555	3.45	0	I1	51.1	69	
2.56	3.4	0	I2	51.2	68	
2.565	3.35	0	I3	51.3	67	
2.57	3.3	0	I4	51.4	66	
2.575	3.25	0	I5	51.5	65	
2.58	3.2	0	I6	51.6	64	
2.585	3.15	0	I7	51.7	63	
2.59	3.1	0	I8	51.8	62	
2.595	3.05	0	I9	51.9	61	
2.625	2.95	0	J1	52.5	59	
2.65	2.9	0	J2	53	58	
2.675	2.85	0	J3	53.5	57	
2.7	2.8	0	J4	54	56	
2.725	2.75	0	J5	54.5	55	
2.75	2.7	0	J6	55	54	
2.775	2.65	0	J7	55.5	53	
2.8	2.6	0	J8	56	52	
2.825	2.55	0	J9	56.5	51	
2.86	2.45	0	K1	57.2	49	
2.87	2.4	0	K2	57.4	48	
2.88	2.35	0	K3	57.6	47	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
2.89	**2.3**	**0**	**K4**	57.8	46	
2.95	**2.2**	**0**	**L1**	59	44	
3	**2.15**	**0**	**L2**	60	43	
3.05	**2.1**	**0**	**L3**	61	42	
3.1	**2.05**	**0**	**L4**	62	41	
3.165	**1.95**	**0**	**M1**	63.3	39	
3.18	**1.9**	**0**	**M2**	63.6	38	
3.195	**1.85**	**0**	**M3**	63.9	37	
3.21	**1.8**	**0**	**M4**	64.2	36	
3.225	**1.75**	**0**	**M5**	64.5	35	
3.24	**1.7**	**0**	**M6**	64.8	34	
3.255	**1.65**	**0**	**M7**	65.1	33	
3.27	**1.6**	**0**	**M8**	65.4	32	
3.285	**1.55**	**0**	**M9**	65.7	31	
3.315	**1.45**	**0**	**N1**	66.3	29	
3.33	**1.4**	**0**	**N2**	66.6	28	
3.345	**1.35**	**0**	**N3**	66.9	27	
3.36	**1.3**	**0**	**N4**	67.2	26	
3.375	**1.25**	**0**	**N5**	67.5	25	
3.39	**1.2**	**0**	**N6**	67.8	24	
3.405	**1.15**	**0**	**N7**	68.1	23	
3.42	**1.1**	**0**	**N8**	68.4	22	
3.435	**1.05**	**0**	**N9**	68.7	21	
3.4	**1**	**0**	**O1**	68	20	
3.35	**1**	**0**	**O2**	67	20	
3.3	**1**	**0**	**O3**	66	20	
3.25	**1**	**0**	**O4**	65	20	
3.2	**1**	**0**	**O5**	64	20	
3.15	**1**	**0**	**O6**	63	20	
3.07728	**0.95**	**0**	**P1**	61.5455	19	
3.05455	**0.9**	**0**	**P2**	61.091	18	
3.03183	**0.85**	**0**	**P3**	60.6365	17	
3.0091	**0.8**	**0**	**P4**	60.182	16	
2.98638	**0.75**	**0**	**P5**	59.7275	15	
2.96365	**0.7**	**0**	**P6**	59.273	14	
2.94093	**0.65**	**0**	**P7**	58.8185	13	
2.9182	**0.6**	**0**	**P8**	58.364	12	
2.89548	**0.55**	**0**	**P9**	57.9095	11	
2.87275	**0.5**	**0**	**P10**	57.455	10	
2.8	**0.44**	**0**	**Q1**	56	8.8	
2.75	**0.43**	**0**	**Q2**	55	8.6	
2.7	**0.42**	**0**	**Q3**	54	8.4	
2.65	**0.41**	**0**	**Q4**	53	8.2	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
2.6	0.4	0	Q5	52	8	
2.55	0.39	0	Q6	51	7.8	
2.5	0.38	0	Q7	50	7.6	
2.45	0.37	0	Q8	49	7.4	
2.4	0.36	0	Q9	48	7.2	
2.3	0.37143	0	R1	46	7.4286	
2.25	0.39286	0	R2	45	7.8572	
2.2	0.41429	0	R3	44	8.2858	
2.15	0.43572	0	R4	43	8.7144	
2.1	0.45715	0	R5	42	9.143	
2.05	0.47858	0	R6	41	9.5716	
1.95	0.50769	0	S1	39	10.1538	
1.9	0.51538	0	S2	38	10.3076	
1.85	0.52307	0	S3	37	10.4614	
1.8	0.53076	0	S4	36	10.6152	
1.75	0.53845	0	S5	35	10.769	
1.7	0.54614	0	S6	34	10.9228	
1.65	0.55383	0	S7	33	11.0766	
1.6	0.56152	0	S8	32	11.2304	
1.55	0.56921	0	S9	31	11.3842	
1.5	0.5769	0	S10	30	11.538	
1.45	0.58459	0	S11	29	11.6918	
1.4	0.59228	0	S12	28	11.8456	
1.3	0.605	0	T1	26	12.1	
1.25	0.61	0	T2	25	12.2	
1.2	0.615	0	T3	24	12.3	
1.15	0.62	0	T4	23	12.4	
1.1	0.625	0	T5	22	12.5	
1.05	0.63	0	T6	21	12.6	
1	0.635	0	T7	20	12.7	
0.95	0.64	0	T8	19	12.8	
0.9	0.645	0	T9	18	12.9	
0.8	0.685	0	U1	16	13.7	
0.75	0.72	0	U2	15	14.4	
0.7	0.755	0	U3	14	15.1	
0.65	0.79	0	U4	13	15.8	
0.6	0.825	0	U5	12	16.5	
0.55	0.86	0	U6	11	17.2	
0.5	0.895	0	U7	10	17.9	
0.45	0.93	0	U8	9	18.6	
0.4	0.965	0	U9	8	19.3	
0.365	1.05	0	V1	7.3	21	
0.38	1.1	0	V2	7.6	22	
0.395	1.15	0	V3	7.9	23	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
0.41	**1.2**	**0**	**V4**	8.2	24	
0.425	**1.25**	**0**	**V5**	8.5	25	
0.44	**1.3**	**0**	**V6**	8.8	26	
0.455	**1.35**	**0**	**V7**	9.1	27	
0.47	**1.4**	**0**	**V8**	9.4	28	
0.485	**1.45**	**0**	**V9**	9.7	29	
0.525	**1.55**	**0**	**W1**	10.5	31	
0.55	**1.6**	**0**	**W2**	11	32	
0.575	**1.65**	**0**	**W3**	11.5	33	
0.6	**1.7**	**0**	**W4**	12	34	
0.625	**1.75**	**0**	**W5**	12.5	35	
0.65	**1.8**	**0**	**W6**	13	36	
0.675	**1.85**	**0**	**W7**	13.5	37	
0.7	**1.9**	**0**	**W8**	14	38	
0.725	**1.95**	**0**	**W9**	14.5	39	
0.79	**2.05**	**0**	**X1**	15.8	41	
0.83	**2.1**	**0**	**X2**	16.6	42	
0.87	**2.15**	**0**	**X3**	17.4	43	
0.91	**2.2**	**0**	**X4**	18.2	44	
0.98	**2.3**	**0**	**Y1**	19.6	46	
1.01	**2.35**	**0**	**Y2**	20.2	47	
1.04	**2.4**	**0**	**Y3**	20.8	48	
1.07	**2.45**	**0**	**Y4**	21.4	49	
1.115	**2.55**	**0**	**Z1**	22.3	51	
1.13	**2.6**	**0**	**Z2**	22.6	52	
1.145	**2.65**	**0**	**Z3**	22.9	53	
1.16	**2.7**	**0**	**Z4**	23.2	54	
1.175	**2.75**	**0**	**Z5**	23.5	55	
1.19	**2.8**	**0**	**Z6**	23.8	56	
1.205	**2.85**	**0**	**Z7**	24.1	57	
1.22	**2.9**	**0**	**Z8**	24.4	58	
1.235	**2.95**	**0**	**Z9**	24.7	59	
1.26	**3.05**	**0**	**AA1**	25.2	61	
1.27	**3.1**	**0**	**AA2**	25.4	62	
1.28	**3.15**	**0**	**AA3**	25.6	63	
1.29	**3.2**	**0**	**AA4**	25.8	64	
1.3	**3.25**	**0**	**AA5**	26	65	
1.31	**3.3**	**0**	**AA6**	26.2	66	
1.32	**3.35**	**0**	**AA7**	26.4	67	
1.33	**3.4**	**0**	**AA8**	26.6	68	
1.34	**3.45**	**0**	**AA9**	26.8	69	
1.34	**3.55**	**0**	**BB1**	26.8	71	
1.33	**3.6**	**0**	**BB2**	26.6	72	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
1.32	**3.65**	**0**	**BB3**	26.4	73	
1.31	**3.7**	**0**	**BB4**	26.2	74	
1.25	**3.75**	**0**	**CC1**	25	75	
1.2	**3.75**	**0**	**CC2**	24	75	
1.15	**3.75**	**0**	**CC3**	23	75	
1.1	**3.75**	**0**	**CC4**	22	75	
1.05	**3.75**	**0**	**CC5**	21	75	
0.95	**3.75**	**0**	**DD1**	19	75	
0.9	**3.8**	**0**	**EE1**	18	76	
0.9	**3.85**	**0**	**EE2**	18	77	
0.9	**3.9**	**0**	**EE3**	18	78	
0.9	**3.95**	**0**	**EE4**	18	79	
0.91667	**4.05**	**0**	**FF1**	18.3333	81	
0.93333	**4.1**	**0**	**FF2**	18.6666	82	
0.9	**4.16379**	**0**	**GG1**	18	83.2757	
0.85	**4.17757**	**0**	**GG2**	17	83.5514	
0.8	**4.19136**	**0**	**GG3**	16	83.8271	
0.75	**4.20514**	**0**	**GG4**	15	84.1028	
0.7	**4.21893**	**0**	**GG5**	14	84.3785	
0.65	**4.23271**	**0**	**GG6**	13	84.6542	
0.65	**4.3**	**0**	**HH1**	13	86	
0.7	**4.35**	**0**	**HH2**	14	87	
0.75	**4.4**	**0**	**HH3**	15	88	
0.8	**4.45**	**0**	**HH4**	16	89	
0.85	**4.5**	**0**	**HH5**	17	90	
0.9	**4.55**	**0**	**HH6**	18	91	
0.95	**4.6**	**0**	**HH7**	19	92	
1.05	**4.6125**	**0**	**II1**	21	92.25	
1.1	**4.575**	**0**	**II2**	22	91.5	
1.15	**4.5375**	**0**	**II3**	23	90.75	
1.2125	**4.55**	**0**	**JJ1**	24.25	91	
1.225	**4.6**	**0**	**JJ2**	24.5	92	
1.2375	**4.65**	**0**	**JJ3**	24.75	93	
1.25	**4.7**	**0**	**JJ4**	25	94	
1.2625	**4.75**	**0**	**JJ5**	25.25	95	
1.275	**4.8**	**0**	**JJ6**	25.5	96	
1.2875	**4.85**	**0**	**JJ7**	25.75	97	

Table 3B. Blue Grotto Spring Vent 2 (Back Vent) XYZ Grid Data, September 29, 2006.						
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**	
1.5	**0.5**	**0.94**	**1**	30	10	
1.25	**0.5**	**0.87**	**2**	25	10	
1	**0.5**	**0.91**	**3**	20	10	
0.75	**0.5**	**0.99**	**4**	15	10	
0.5	**0.5**	**1.03**	**5**	10	10	
0.25	**0.5**	**0.84**	**6**	5	10	
0.25	**0.9**	**0**	**A**	5	18	
0.5	**0.95**	**0**	**B**	10	19	
0.75	**0.9**	**0**	**C**	15	18	
1	**0.85**	**0**	**D**	20	17	
1.25	**0.8**	**0**	**E**	25	16	
1.5	**0.85**	**0**	**F**	30	17	
1.8	**0.5**	**0**	**G**	36	10	
1.5	**0.35**	**0**	**H**	30	7	
1.25	**0.05**	**0**	**I**	25	1	
1	**0.1**	**0**	**J**	20	2	
0.75	**0.2**	**0**	**K**	15	4	
0.5	**0.2**	**0**	**L**	10	4	
0.25	**0.1**	**0**	**M**	5	2	
0.1	**0.5**	**0**	**N**	2	10	
0.3	**0.91**	**0**	**A1**	6	18.2	
0.35	**0.92**	**0**	**A2**	7	18.4	
0.4	**0.93**	**0**	**A3**	8	18.6	
0.45	**0.94**	**0**	**A4**	9	18.8	
0.55	**0.94**	**0**	**B1**	11	18.8	
0.6	**0.93**	**0**	**B2**	12	18.6	
0.65	**0.92**	**0**	**B3**	13	18.4	
0.7	**0.91**	**0**	**B4**	14	18.2	
0.8	**0.89**	**0**	**C1**	16	17.8	
0.85	**0.88**	**0**	**C2**	17	17.6	
0.9	**0.87**	**0**	**C3**	18	17.4	
0.95	**0.86**	**0**	**C4**	19	17.2	
1.05	**0.84**	**0**	**D1**	21	16.8	
1.1	**0.83**	**0**	**D2**	22	16.6	
1.15	**0.82**	**0**	**D3**	23	16.4	
1.2	**0.81**	**0**	**D4**	24	16.2	
1.3	**0.81**	**0**	**E1**	26	16.2	
1.35	**0.82**	**0**	**E2**	27	16.4	
1.4	**0.83**	**0**	**E3**	28	16.6	
1.45	**0.84**	**0**	**E4**	29	16.8	
	0					

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
1.54286	**0.8**	**0**	**F1**	30.8571	16	
1.58571	**0.75**	**0**	**F2**	31.7142	15	
1.62857	**0.7**	**0**	**F3**	32.5713	14	
1.67142	**0.65**	**0**	**F4**	33.4284	13	
1.71428	**0.6**	**0**	**F5**	34.2855	12	
1.75713	**0.55**	**0**	**F6**	35.1426	11	
1.75	**0.475**	**0**	**G1**	35	9.5	
1.7	**0.45**	**0**	**G2**	34	9	
1.65	**0.425**	**0**	**G3**	33	8.5	
1.6	**0.4**	**0**	**G4**	32	8	
1.55	**0.375**	**0**	**G5**	31	7.5	
	0					
1.45834	**0.3**	**0**	**H1**	29.1667	6	
1.41667	**0.25**	**0**	**H2**	28.3334	5	
1.37501	**0.2**	**0**	**H3**	27.5001	4	
1.33334	**0.15**	**0**	**H4**	26.6668	3	
1.29168	**0.1**	**0**	**H5**	25.8335	2	
1.2	**0.06**	**0**	**I1**	24	1.2	
1.15	**0.07**	**0**	**I2**	23	1.4	
1.1	**0.08**	**0**	**I3**	22	1.6	
1.05	**0.09**	**0**	**I4**	21	1.8	
0.95	**0.12**	**0**	**J1**	19	2.4	
0.9	**0.14**	**0**	**J2**	18	2.8	
0.85	**0.16**	**0**	**J3**	17	3.2	
0.8	**0.18**	**0**	**J4**	16	3.6	
0.7	**0.2**	**0**	**K1**	14	4	
0.65	**0.2**	**0**	**K2**	13	4	
0.6	**0.2**	**0**	**K3**	12	4	
0.55	**0.2**	**0**	**K4**	11	4	
0.45	**0.18**	**0**	**L1**	9	3.6	
0.4	**0.16**	**0**	**L2**	8	3.2	
0.35	**0.14**	**0**	**L3**	7	2.8	
0.3	**0.12**	**0**	**L4**	6	2.4	
0.23125	**0.15**	**0**	**M1**	4.625	3	
0.2125	**0.2**	**0**	**M2**	4.25	4	
0.19375	**0.25**	**0**	**M3**	3.875	5	
0.175	**0.3**	**0**	**M4**	3.5	6	
0.15625	**0.35**	**0**	**M5**	3.125	7	
0.1375	**0.4**	**0**	**M6**	2.75	8	
0.11875	**0.45**	**0**	**M7**	2.375	9	
0.11875	**0.55**	**0**	**N1**	2.375	11	
0.1375	**0.6**	**0**	**N2**	2.75	12	

Table 3B. Blue Grotto Spring XYZ Grid Data, September 29, 2006.

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
0.15625	**0.65**	**0**	**N3**	3.125	13	
0.175	**0.7**	**0**	**N4**	3.5	14	
0.19375	**0.75**	**0**	**N5**	3.875	15	
0.2125	**0.8**	**0**	**N6**	4.25	16	
0.23125	**0.85**	**0**	**N7**	4.625	17	

CALIBRATION CERTIFICATE

Model: 20000-21 Serial Number: 2002679

Unit Gain Ratio: ______ Time Constant: ______

SensorSer # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ______

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ______

Calibration Technician: Stan Cwikiski Date: 18 Apr 2006

QA Technician: [signature] Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

P/N 101001 301

Discharge Measurement: Bridal Chamber Spring, Marion County, Florida; September 22, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Bridal Chamber Spring,
Marion County, Florida; September 22, 2006

LIST OF CONTENTS

Results of Discharge Measurements of Bridal Chamber Spring, Marion County, Florida; September 22, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Bridal Chamber Spring on September 22, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Bridal Chamber Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Tom Morris, both of KES. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida.

SITE DESCRIPTION

Bridal Chamber Spring is located in a large basin on the south side of the Silver River, approximately 100 feet southeast of Catfish Reception Hall. Discharge is from an elongated vertical vent in the limestone, about 15 feet long, up to 2.5 feet wide, and about 18 feet deep. See Figure 1.

Since the orifice of this spring is located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

Pete Butt positioned the sensor, and recorded positional data, while Tom Morris read the velocity readings, after taking meter reset cues from Butt. During all measurements, the sensor handler completely removed himself from the cross section of the flow. The meter operator was also positioned outside the cross-section. This eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. Thirty-one station readings were taken.

The approximate depth for the measurement grid was 25 feet. Telescoping aluminum poles with 1, 0.5, 0.25 and 0.1 foot interval markings were positioned horizontally to allow for a grid of velocity measurements. As all sensor-support poles were positioned at right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was positioned on the poles with a quick release clamp. Spring vent dimensions and positions were measured with a metal tape.

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figure 2. Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Table 3. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift, an anisotropy ratio of 1 at an angle of 0°, and a variogram slope of 1.0. The results of the contour processing are illustrated in Figures 3 and 4.

During this measurement, three negative velocities were measured. Negative velocity stations typically represent slight back eddies near walls. In order to incorporate any negative values, calculations were made using a Surfer 8 "blanking file" operation to define the measurement cross-section boundary. The total discharge is shown on Table 2 as the **Net Volume (Cut-Fill)**, and has been calculated as the Positive Volume (Cut) less that portion of the Negative Volume (Fill) lying within the measurement cross-section boundary walls that define the plane of measurement.

The software also calculates the total cross-sectional area of the measurement location within the passage, and is presented on Table 2 as the **Operational Planar Area**. The Operational Planar Area is the sum of the Positive (Cut) and that portion of the Negative (Fill) Planar areas lying within the measurement cross-section boundary walls that define the plane of measurement.

RESULTS AND DISCUSSION

This measurement is the first one performed at Bridal Chamber Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Bridal Chamber Spring on September 22, 2006 was 4.61 CFS (cubic feet per second). This result is also expressed as 2069 GPM (gallons per minute) or 2.98 MGD (million gallons per day), see Table 1. Thirty-one (31) readings were made, see Figures 2, 3 and 4. The point velocity readings ranged from -0.03 to 1.25 feet per second (fps), with an overall average station reading of 0.50 fps. The total cross-sectional area was calculated as 12.72 square feet. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 12:18 hours and were completed by 13:10 hours.

UNDERWATER DISCHARGE MEASUREMENT						
Location:	**BRIDAL CHAMBER SPRING**			Date:	**September 22, 2006**	
	Silver Springs Group,			Time Start:	12:18	
	Marion County, Florida			Time End:	13:10	
Personnel:	Peter Butt, Tom Morris					
Method:	Grid within irregular conduit					
Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles					
Msmt. Periods:		60 seconds				
Analysis Method: Surfer 8 with kriging						
Bridal Chamber Spring Total Discharge:						
CFS	**4.61**					
MGD	**2.980**					
GPM	**2069**					
Total Cross-sectional Area (sq/ft):		12.72				
Avg. Station Point Velocity (ft/sec):		0.50				
Cross-section Depth (feet deep):		25				
Velocity Reading by Station:		(All velocity readings in feet per second.)				
Station #	Point Velocity	Station #	Point Velocity			
1	0.03	17	0.3			
2	0.71	18	0.65			
3	0.85	19	0.51			
4	0.91	20	0.23			
5	1.09	21	0.28			
6	0.77	22	0.65			
7	0.72	23	0.71			
8	1.25	24	0.15			
9	0.49	25	0.28			
10	0.39	26	0.18			
11	0.41	27	0.19			
12	0.82	28	0.19			
13	1.18	29	0.05			
14	0.66	30	-0.01			
15	-0.02	31	-0.03			
16	0.88					

Table 1. Discharge of Bridal Chamber Spring, Marion County, Florida on September 22, 2006. Data record and calculation of discharge measurement.

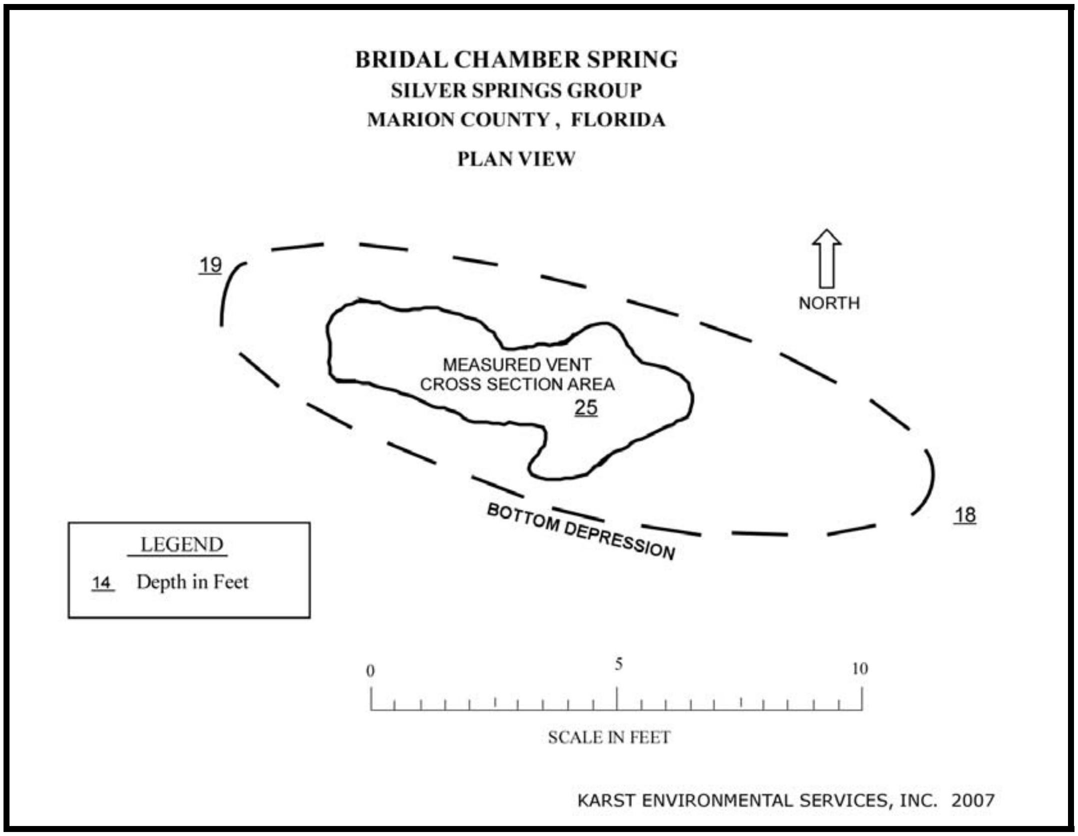

Figure 1. Map of Bridal Chamber Spring.

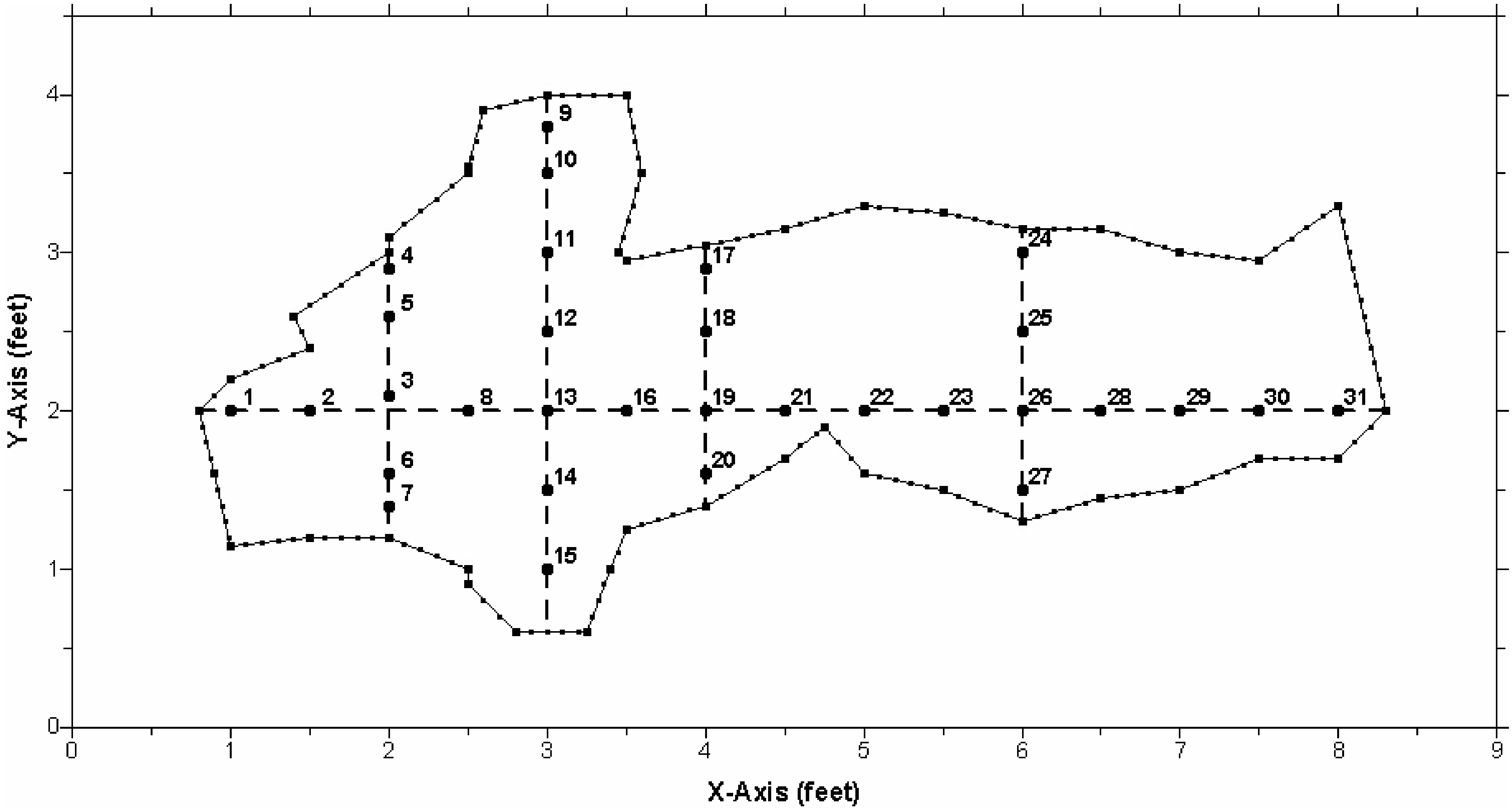

Figure 2. Discharge measurement cross-section; Bridal Chamber Spring, Marion County, Florida, September 22, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 25-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

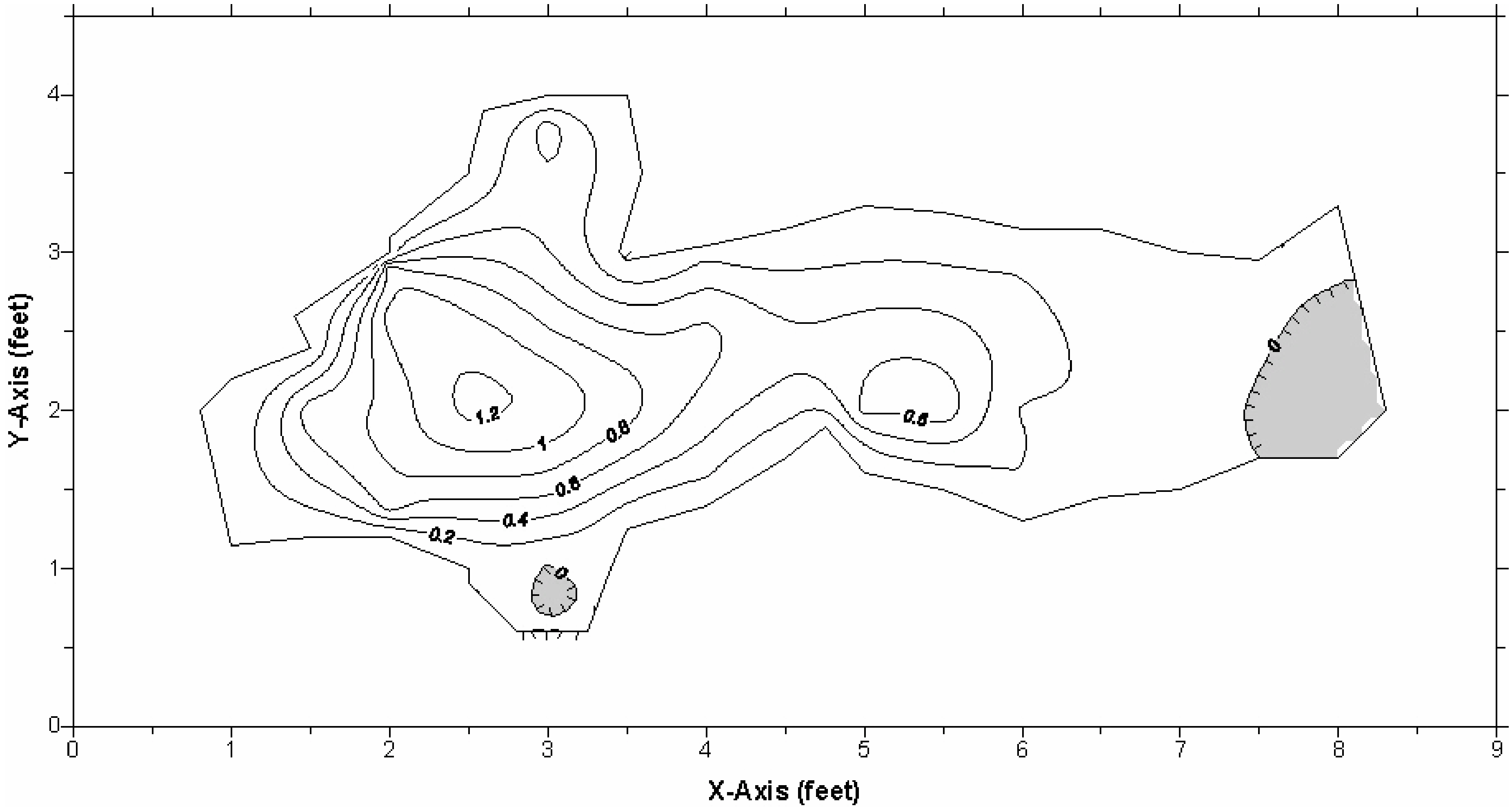

Figure 3. Discharge measurement cross-section; Bridal Chamber Spring, Marion County, Florida, September 22, 2006 measurement. Flow contour velocities are shown in feet per second. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

TABLE 2. BRIDAL CHAMBER SPRING, SEPTEMBER 22, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Bridal\Bridal Chamber9-06.bln.grd
Grid Size:	91 rows x 181 columns
X Minimum:	0
X Maximum:	9
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	4.5
Y Spacing:	0.05
Z Minimum:	-0.029999999906424
Z Maximum:	1.2499999994179

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES

Z Scale Factor:	1
Total Volumes by:	
Trapezoidal Rule:	4.6093688398188
Simpson's Rule:	4.6092627410793
Simpson's 3/8 Rule:	4.6098884317064

CUT & FILL VOLUMES

Positive Volume [Cut]:	4.6151646099565
Negative Volume [Fill]:	0.0057957701377344
Net Volume [Cut-Fill]:	**4.6093688398188 <<<<<<Total Discharge in CFS**

(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 12.72 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)

Positive Planar Area [Cut]:	11.99149711077
Negative Planar Area [Fill]:	0.72975288922952
Blanked Planar Area:	27.77875
Total Planar Area:	40.5

Surface Areas

Positive Surface Area [Cut]:	16.35953150765
Negative Surface Area [Fill]:	0.73244394340526

GRIDDING REPORT

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Bridal\Bridal Chamber 9-06 SURFER XYZ T3BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	223
Original Data:	223
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.8	0.6	-0.03
25%-tile:	2.5	1.49	0
Median:	4	2.1	0
75%-tile:	6.2	3.12	0
Maximum:	8.3	4	1.25
Midrange:	4.55	2.3	0.61
Range:	7.5	3.4	1.28
Interquartile Range:	3.7	1.63	0
Median Abs. Deviation:	1.9	0.87	0
Mean:	4.3493159192825	2.2925556053812	0.069372197309417
Trim Mean (10%):	4.3271433333333	2.2890044776119	0.028059701492537
Standard Deviation:	2.2286133008764	0.93158148746953	0.21924567078906
Variance:	4.966717244843	0.86784406779593	0.048068664159746
Coef. of Variation:			3.1604256358087
Coef. of Skewness:			3.4267443026346

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.109	-0.168
Y:		1.000	-0.023
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	4.966717244843	0.22620160250045	-0.081923395835428
Y:		0.86784406779593	-0.0046315480504333
Z:			0.048068664159746

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-0.016446652060644	-0.0010500607567238	0.1433112056095
Standard Error:	0.0065778190739264	0.015736052375547	0.045906263539468

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.109	-0.538
B:		1.000	0.718
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.30154706561347	0.15077353280673	3.184
Residual:	220	10.41776504201	0.047353477463681	
Total:	222	10.719312107623		

Coefficient of Multiple Determination (R^2): 0.028131195601536

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.10049875621121	0
Median:	0.10307764064044	0
75%-tile:	0.11180339887499	0
Maximum:	0.5	0.91

Table 2. Bridal Chamber Spring, September 22, 2006.

Midrange:	0.275	0.455
Range:	0.45	0.91
Interquartile Range:	0.011304642663781	0
Median Abs. Deviation:	0.0030776406404412	0
Mean:	0.13639607897281	0.04542600896861
Trim Mean (10%):	0.12105971477001	0.016517412935323
Standard Deviation:	0.098360125541042	0.14821409991367
Variance:	0.0096747142964495	0.02196741941322
Coef. of Variation:	0.72113602005123	3.2627585667077
Coef. of Skewness:	2.8894187016816	3.9104284279017
Root Mean Square:	0.16816243532848	0.15501916560231
Mean Square:	0.028278604655605	0.024030941704036

Complete Spatial Randomness

Lambda: 8.7450980392157
Clark and Evans: 0.806704022803
Skellam: 346.50331222287

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 8.9E-007
Y Duplicate Tolerance: 4E-007
No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point
Polynomial Drift Order: 1
Kriging std. deviation grid: no

Semi-Variogram Model

Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 1
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Bridal\Bridal Chamber9-06.grd
Grid Size:	91 rows x 181 columns
Total Nodes:	16471
Filled Nodes:	16471
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	9
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	4.5
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-0.69156485723707
Z 25%-tile:	-0.18958634260201
Z Median:	-0.051560767315862
Z 75%-tile:	0.048322778353817
Z Maximum:	1.2499999994179
Z Midrange:	0.27921757109043
Z Range:	1.941564856655
Z Interquartile Range:	0.23790912095583
Z Median Abs. Deviation:	0.12867322019532
Z Mean:	-0.0019552326059334
Z Trim Mean (10%):	-0.023973527001435
Z Standard Deviation:	0.33092260225407
Z Variance:	0.1095097686826
Z Coef. of Variation:	-1
Z Coef. of Skewness:	1.2914153557695
Z Root Mean Square:	0.33092837837989
Z Mean Square:	0.10951359161715

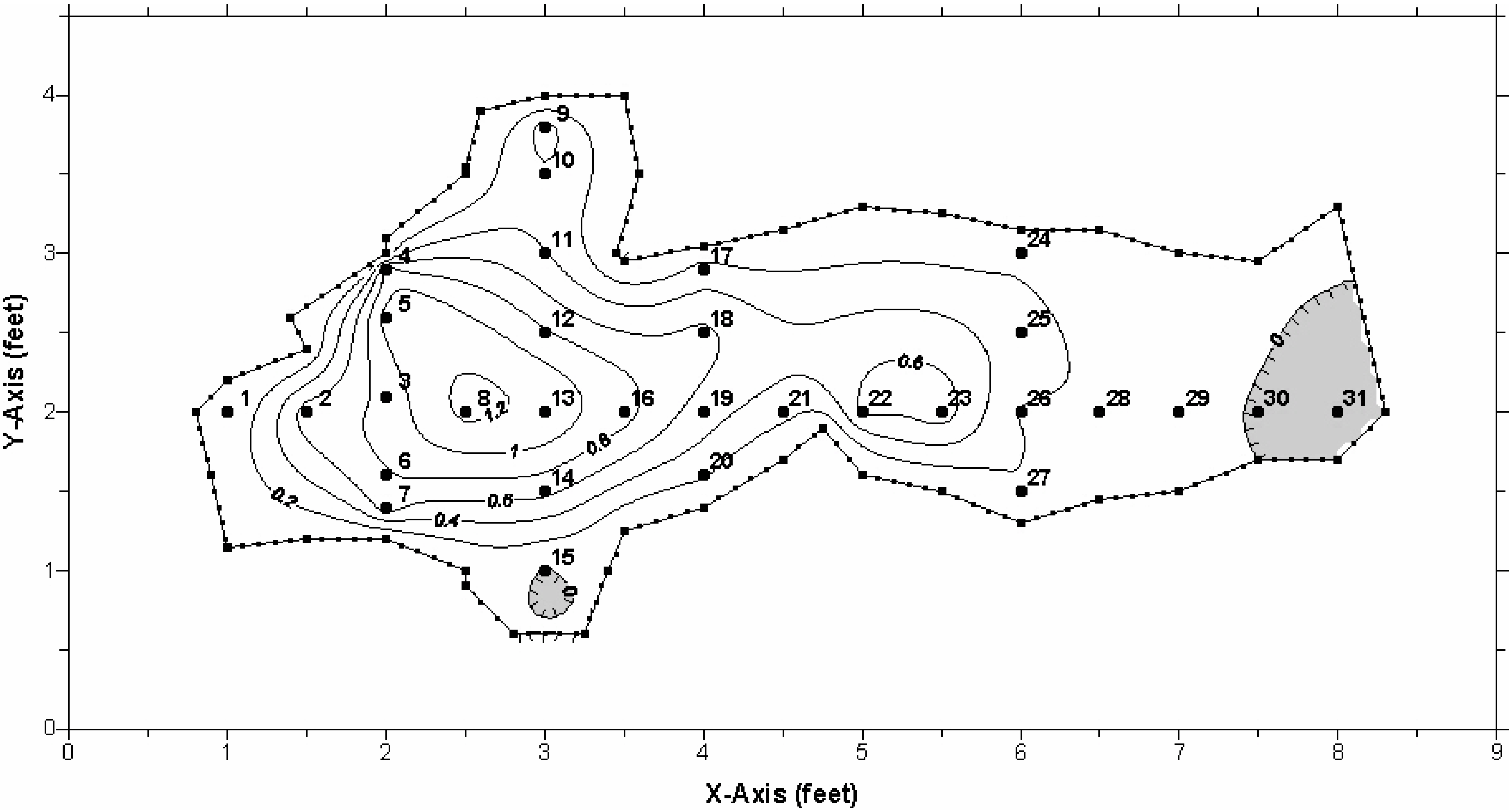

Figure 4. Discharge measurement cross-section; Bridal Chamber Spring, Marion County, Florida, September 22, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. See Table 1 for station velocities. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

Table 3. Bridal Chamber Spring XYZ Grid Data, September 22, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
1	**2**	**0.03**	**1**	10	20
1.5	**2**	**0.71**	**2**	15	20
2	**2.1**	**0.85**	**3**	20	21
2	**2.9**	**0.91**	**4**	20	29
2	**2.6**	**1.09**	**5**	20	26
2	**1.6**	**0.77**	**6**	20	16
2	**1.4**	**0.72**	**7**	20	14
2.5	**2**	**1.25**	**8**	25	20
3	**3.8**	**0.49**	**9**	30	38
3	**3.5**	**0.39**	**10**	30	35
3	**3**	**0.41**	**11**	30	30
3	**2.5**	**0.82**	**12**	30	25
3	**2**	**1.18**	**13**	30	20
3	**1.5**	**0.66**	**14**	30	15
3	**1**	**-0.02**	**15**	30	10
3.5	**2**	**0.88**	**16**	35	20
4	**2.9**	**0.3**	**17**	40	29
4	**2.5**	**0.65**	**18**	40	25
4	**2**	**0.51**	**19**	40	20
4	**1.6**	**0.23**	**20**	40	16
4.5	**2**	**0.28**	**21**	45	20
5	**2**	**0.65**	**22**	50	20
5.5	**2**	**0.71**	**23**	55	20
6	**3**	**0.15**	**24**	60	30
6	**2.5**	**0.28**	**25**	60	25
6	**2**	**0.18**	**26**	60	20
6	**1.5**	**0.19**	**27**	60	15
6.5	**2**	**0.19**	**28**	65	20
7	**2**	**0.05**	**29**	70	20
7.5	**2**	**-0.01**	**30**	75	20
8	**2**	**-0.03**	**31**	80	20
0.8	**2**	**0**	**AE1**	8	20
0.9	**1.6**	**0**	**AE2**	9	16
1	**1.15**	**0**	**AS**	10	11.5
1	**2.2**	**0**	**AT**	10	22
1.5	**1.2**	**0**	**ABS**	15	12
1.5	**2.4**	**0**	**ABT1**	15	24
1.4	**2.6**	**0**	**ABT2**	14	26
2	**3**	**0**	**ABT3**	20	30
2	**1.2**	**0**	**BS**	20	12
2	**3.1**	**0**	**BT**	20	31
2.5	**1**	**0**	**BCS1**	25	10
2.5	**0.9**	**0**	**BCS2**	25	9
2.8	**0.6**	**0**	**BCS3**	28	6
2.5	**3.5**	**0**	**BCT1**	25	35
2.5	**3.55**	**0**	**BCT2**	25	35.5
2.6	**3.9**	**0**	**BCT3**	26	39

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
3	0.6	0	CS	30	6
3	4	0	CT	30	40
3.25	0.6	0	CDS1	32.5	6
3.4	1	0	CDS2	34	10
3.5	1.25	0	CDS3	35	12.5
3.5	4	0	CDT1	35	40
3.6	3.5	0	CDT2	36	35
3.45	3	0	CDT3	34.5	30
3.5	2.95	0	CDT4	35	29.5
4	1.4	0	DS	40	14
4	3.05	0	DT	40	30.5
4.5	1.7	0	DES1	45	17
4.75	1.9	0	DES2	47.5	19
4.5	3.15	0	DET	45	31.5
5	1.6	0	ES	50	16
5	3.3	0	ET	50	33
5.5	1.5	0	EFS	55	15
5.5	3.25	0	EFT	55	32.5
6	1.3	0	FS	60	13
6	3.15	0	FT	60	31.5
6.5	1.45	0	FGS	65	14.5
6.5	3.15	0	FGT	65	31.5
7	1.5	0	GS	70	15
7	3	0	GT	70	30
7.5	2.95	0	GHS	75	29.5
7.5	1.7	0	GHT	75	17
8	1.7	0	HS	80	17
8	3.3	0	HT	80	33
8.3	2	0	HE	83	20
0.98888	1.2	0	A1	9.8888	12
0.96666	1.3	0	A2	9.6666	13
0.94444	1.4	0	A3	9.4444	14
0.92222	1.5	0	A4	9.2222	15
0.875	1.7	0	A5	8.75	17
0.85	1.8	0	A6	8.5	18
0.825	1.9	0	A7	8.25	19
0.9	2.1	0	A8	9	21
1.1	1.16	0	AS1	11	11.6
1.2	1.17	0	AS2	12	11.7
1.3	1.18	0	AS3	13	11.8
1.4	1.19	0	AS4	14	11.9
1.6	1.2	0	AS5	16	12
1.7	1.2	0	AS6	17	12
1.8	1.2	0	AS7	18	12
1.9	1.2	0	AS8	19	12
2.1	1.16	0	BS1	21	11.6

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
2.2	1.12	0	BS2	22	11.2
2.3	1.08	0	BS3	23	10.8
2.4	1.04	0	BS4	24	10.4
2.6	0.8	0	BS5	26	8
2.7	0.7	0	BS6	27	7
2.9	0.6	0	BS7	29	6
3.1	0.6	0	CS1	31	6
3.2	0.6	0	CS2	32	6
3.2875	0.7	0	CS3	32.875	7
3.325	0.8	0	CS4	33.25	8
3.3625	0.9	0	CS5	33.625	9
3.45	1.1	0	CS6	34.5	11
3.6	1.28	0	CS7	36	12.8
3.7	1.31	0	CS8	37	13.1
3.8	1.34	0	CS9	38	13.4
3.9	1.37	0	CS10	39	13.7
4.1	1.46	0	DS1	41	14.6
4.2	1.52	0	DS2	42	15.2
4.3	1.58	0	DS3	43	15.8
4.4	1.64	0	DS4	44	16.4
4.6	1.78	0	DS5	46	17.8
4.7	1.86	0	DS6	47	18.6
4.83334	1.8	0	DS7	48.3334	18
4.91667	1.7	0	DS8	49.1667	17
5.1	1.58	0	ES1	51	15.8
5.2	1.56	0	ES2	52	15.6
5.3	1.54	0	ES3	53	15.4
5.4	1.52	0	ES4	54	15.2
5.6	1.46	0	ES5	56	14.6
5.7	1.42	0	ES6	57	14.2
5.8	1.38	0	ES7	58	13.8
5.9	1.34	0	ES8	59	13.4
6.1	1.33	0	FS1	61	13.3
6.2	1.36	0	FS2	62	13.6
6.3	1.39	0	FS3	63	13.9
6.4	1.42	0	FS4	64	14.2
6.6	1.46	0	FS5	66	14.6
6.7	1.47	0	FS6	67	14.7
6.8	1.48	0	FS7	68	14.8
6.9	1.49	0	FS8	69	14.9
7.1	1.54	0	GS1	71	15.4
7.2	1.58	0	GS2	72	15.8
7.3	1.62	0	GS3	73	16.2
7.4	1.66	0	GS4	74	16.6

Table 3. Bridal Chamber Spring XYZ Grid Data, September 22, 2006.

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
7.6	1.7	0	GS5	76	17
7.7	1.7	0	GS6	77	17
7.8	1.7	0	GS7	78	17
7.9	1.7	0	GS8	79	17
8.1	1.8	0	HS1	81	18
8.2	1.9	0	HS2	82	19
1.1	2.24	0	AT1	11	22.4
1.2	2.28	0	AT2	12	22.8
1.3	2.32	0	AT3	13	23.2
1.4	2.36	0	AT4	14	23.6
1.45	2.5	0	AT5	14.5	25
1.5	2.66666	0	AT6	15	26.6666
1.6	2.73332	0	AT7	16	27.3332
1.7	2.79998	0	AT8	17	27.9998
1.8	2.86664	0	AT9	18	28.6664
1.9	2.9333	0	AT10	19	29.333
2.1	3.18	0	BT1	21	31.8
2.2	3.26	0	BT2	22	32.6
2.3	3.34	0	BT3	23	33.4
2.4	3.42	0	BT4	24	34.2
2.525	3.6	0	BT5	25.25	36
2.55	3.7	0	BT6	25.5	37
2.575	3.8	0	BT7	25.75	38
2.7	3.925	0	BT8	27	39.25
2.8	3.95	0	BT9	28	39.5
2.9	3.975	0	BT10	29	39.75
3.1	4	0	CT1	31	40
3.2	4	0	CT2	32	40
3.3	4	0	CT3	33	40
3.4	4	0	CT4	34	40
3.52	3.9	0	CT5	35.2	39
3.54	3.8	0	CT6	35.4	38
3.56	3.7	0	CT7	35.6	37
3.58	3.6	0	CT8	35.8	36
3.57	3.4	0	CT9	35.7	34
3.54	3.3	0	CT10	35.4	33
3.51	3.2	0	CT11	35.1	32
3.48	3.1	0	CT12	34.8	31
3.6	2.97	0	CT13	36	29.7
3.7	2.99	0	CT14	37	29.9
3.8	3.01	0	CT15	38	30.1
3.9	3.03	0	CT16	39	30.3
4.1	3.07	0	DT1	41	30.7
4.2	3.09	0	DT2	42	30.9

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
4.3	3.11	0	DT3	43	31.1
4.4	3.13	0	DT4	44	31.3
4.6	3.18	0	DT5	46	31.8
4.7	3.21	0	DT6	47	32.1
4.8	3.24	0	DT7	48	32.4
4.9	3.27	0	DT8	49	32.7
5.1	3.29	0	ET1	51	32.9
5.2	3.28	0	ET2	52	32.8
5.3	3.27	0	ET3	53	32.7
5.4	3.26	0	ET4	54	32.6
5.6	3.23	0	ET5	56	32.3
5.7	3.21	0	ET6	57	32.1
5.8	3.19	0	ET7	58	31.9
5.9	3.17	0	ET8	59	31.7
6.1	3.15	0	FT1	61	31.5
6.2	3.15	0	FT2	62	31.5
6.3	3.15	0	FT3	63	31.5
6.4	3.15	0	FT4	64	31.5
6.6	3.12	0	FT5	66	31.2
6.7	3.09	0	FT6	67	30.9
6.8	3.06	0	FT7	68	30.6
6.9	3.03	0	FT8	69	30.3
7.1	2.99	0	GT1	71	29.9
7.2	2.98	0	GT2	72	29.8
7.3	2.97	0	GT3	73	29.7
7.4	2.96	0	GT4	74	29.6
7.6	3.02	0	GT5	76	30.2
7.7	3.09	0	GT6	77	30.9
7.8	3.16	0	GT7	78	31.6
7.9	3.23	0	GT8	79	32.3
8.02308	3.2	0	HT1	80.2308	32
8.04616	3.1	0	HT2	80.4616	31
8.06924	3	0	HT3	80.6924	30
8.09232	2.9	0	HT4	80.9232	29
8.1154	2.8	0	HT5	81.154	28
8.13848	2.7	0	HT6	81.3848	27
8.16156	2.6	0	HT7	81.6156	26
8.18464	2.5	0	HT8	81.8464	25
8.20772	2.4	0	HT9	82.0772	24
8.2308	2.3	0	HT10	82.308	23
8.25388	2.2	0	HT11	82.5388	22
8.27696	2.1	0	HT12	82.7696	21

CALIBRATION CERTIFICATE

Model: 2ØØØ-J1 Serial Number: 2ØØ2679

Unit Gain Ratio: ____________ Time Constant: ____________

SensorSer # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ____

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.ØØ	N/A
Measured:	Ø.ØØ	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: Stan Cwilski Date: 18 Apr 2006

QA Technician: BHall Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

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P/N 101001 301

Discharge Measurement: Catfish Convention Hall Spring, Marion County, Florida; September 30, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
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(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Catfish Convention Hall Spring, Marion County, Florida; September 30, 2006

LIST OF CONTENTS

Results of Discharge Measurements of Catfish Convention Hall Spring, Marion County, Florida; September 30, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Catfish Convention Hall Spring on September 30, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Catfish Convention Hall Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

Catfish Convention Hall Spring is comprised of two clusters of small vents, about 20 feet deep, and located directly downstream from Shipwreck Spring and the bow of the namesake sunken boat. They lie in the eastern end of the basin that is an extension of the Shipwreck Spring basin. The main vent cluster contains about five small vents within an area of about six feet in diameter, all discharging through sediments.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Catfish Convention Hall Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Catfish Convention Hall Spring on September 30, 2006 was 0.32 CFS (cubic feet per second). This result is also expressed as 142 GPM (gallons per minute) or 0.204 MGD (million gallons per day), see Table 1. Three readings were made at each of three vents, for a total of nine (9) readings. Individual point velocity readings ranged from 0.42 to 0.75 feet per second (fps), with an overall average station reading of 0.56 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 19 feet. The measurements commenced at about 15:00 hours and were completed by 15:16 hours.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**CATFISH CONVENTION HALL SPRING**			Date:	**September 30, 2006**
	Silver Springs Group,			Time Start:	15:00
	Marion County, Florida			Time End:	15:16
Personnel:	Peter Butt, Mark Long				
Method:	Vent Discharge Capture Device		(0.49' Diameter)		
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe				
Calculation Method: Discharge = V x *pi* x r^2					
Measurement Periods:		60 seconds			
Catfish Convention Hall Spring Total Discharge:			**Vent 1**	**Vent 2**	**Vent 3**
CFS	**0.32**		**0.096**	**0.080**	**0.140**
MGD	**0.204**		**0.062**	**0.052**	**0.091**
GPM	**142**	All Vents:	**43**	**36**	**63**
Avg. Point Velocity (ft/sec):		0.56	0.51	0.42	0.74
Vent Depth (feet deep):			19	19	19
Velocity Readings:		(All velocity readings in feet per second.)			
Vent 1		**Vent 2**		**Vent 3**	
Tagged vent					
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity
1	0.51	1	0.42	1	0.75
2	0.51	2	0.43	2	0.75
3	0.51	3	0.42	3	0.73
Average:	0.51	Average:	0.42	Average:	0.74
Discharge:	0.096	Discharge:	0.080	Discharge:	0.140

Table 1. Discharge of Catfish Convention Hall Spring, Marion County, Florida on September 30, 2006. Data record and calculation of discharge measurement.

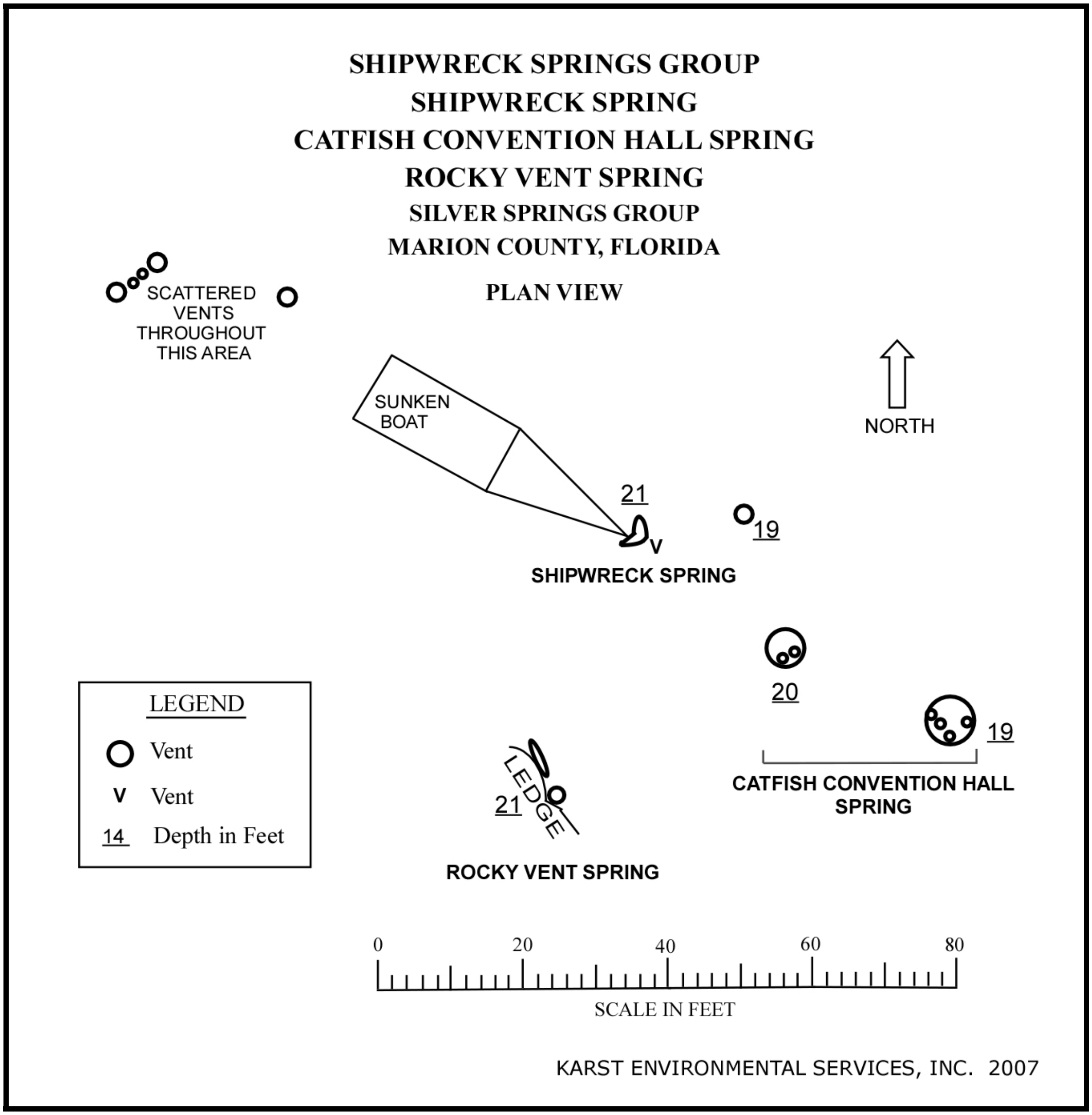

Figure 1. Map of Catfish Convention Hall Spring.

CALIBRATION CERTIFICATE

Model: 2ØØØ-21 Serial Number: 2ØØ2679

Unit Gain Ratio: ____________ Time Constant: ________

SensorSer # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ____

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.ØØ	N/A
Measured:	Ø.ØØ	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: Stan Cinlski Date: 18 Apr 2006

QA Technician: BHall Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

Discharge Measurement:
Catfish Reception Hall Spring,
Marion County, Florida;
September 21, 2006

Prepared for:

St. Johns River Water Management District
Post Office Box 1429
Palatka, FL 32178-1429

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Catfish Reception Hall Spring, Marion County, Florida; September 21, 2006

LIST OF CONTENTS

Results of Discharge Measurements of Catfish Reception Hall Spring, Marion County, Florida; September 21, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a discharge measurement at the Catfish Reception Hall Spring in Marion County, Florida. This report documents the results of the measurement made at the site on September 21, 2006. A summary of the results and collected data for that measurement are presented in Table 1.

PURPOSE and SCOPE OF WORK

The purpose of this work was to obtain accurate discharge measurements of the Catfish Reception Hall Spring, located within the Silver Springs Group, and a source of groundwater discharge into the Silver River. A discharge measurement was to be made at the orifices of Catfish Reception Hall Spring during September, 2006.

SITE DESCRIPTION

Catfish Reception Hall Spring is located about 600 feet downstream of Mammoth Spring, on the bottom of Silver Springs Run. It is also referred to as "The Abyss" and Reception Hall Spring. The three vents that comprise the spring lie within a depression on the bottom that is located in an embayment along the right bank of the run. The depression containing the vents lies between 20 to 33 feet of depth, with a sand floor and surrounded by aquatic vegetation. Limestone is exposed around the vents.

This spring consists of a long horizontal vent (Vent 1, also referred to as the Main Vent in this report) with an adjacent smaller vent (Vent 2) extending along the same rock ledge. A third vent (Vent 3) also lies along the same rock ledge a few feet further to the west. The rock that comprises the ceiling of these vents is solid and self-supported, with the floor beneath composed of solid rock, sand, rubble and boulders. The outer edges of these long horizontal openings provide suitable locations for discharge measurements with the application of an appropriately adapted instrument.

PERSONNEL

Fieldwork for this discharge measurement was conducted by KES personnel Peter Butt and Tom Morris. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech-HAI of Orlando, Florida.

METHODS

<u>Instrumentation</u>

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter.

One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

Field Operations

Velocity measurements were taken at locations just inside the ceiling ledges of all three vents. At the measurement site, the floor of Vent 1 (Main Vent) was 33 feet deep, and the ceiling was 29 feet deep. Vent 2 and Vent 3 were located along the 27 foot depth level.

A positioning grid of telescoping aluminum poles with 0.5-foot interval markings that provided support for the sensor was set up by Pete Butt. Butt also recorded measurements of the grid and surrounding walls. At Vent 1, fourteen poles were positioned vertically to provide a primary positioning grid for velocity measurements, and seven horizontal poles fastened to the vertical poles for support were used for spacing reference. A single horizontal pole was used at Vent 2, and Vent 3 was a hand-held reading. Conduit dimensions around the grid were measured with a collapsible steel tape. As all sensor-support poles were positioned at roughly right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was attached to the poles with a low-profile metal spring clamp. Most measurement stations were set using one-foot intervals on the vertical poles. Velocity stations and boundary points are identified with alpha-numeric labels, based on the letter assigned to identify each vertical pole. See Figure 1.

Pete Butt positioned the sensor and recorded positional data. Tom Morris took the velocity readings after taking reset cues from Butt, and also re-positioned the sensor and recorded positional data. During all measurements, the sensor handler was able to move away from the measurement cross-section, and remove himself from the cross section of the flow. The meter operator was also positioned downstream and away from the cross-section. This minimized or eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in the "Fixed Point Averaging" mode. Fixed Point Averaging is an average of velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. Sixty-two (62) station readings were made.

Data Processing

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figures 2A, 2B and 2C. Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Tables 3A, 3B and 3C. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift, an anisotropy ratio of 3 at an angle of 0°, and a variogram slope of 1.0 for Vents 1 and 2. The anisotropy ratio for Vent 3 was 1. The high anisotropy ratio was selected due to the extremely elongated horizontal aspect of the measurement cross-sections. The results of the contour processing are illustrated in Figures 3(ABC) and 4(ABC).

Discharge and measurement cross-section areas are given on the Grid Volume Computations Report feature of the software, included in this report on page 1 of Tables 2A, 2B and 2C. The total discharge is shown as the "Net Volume (Cut-Fill)". The Net Volume value is used because a Surfer 8 “blanking file” operation was used to define the measurement cross-section boundary and eliminate artifacts present in the contouring process that would create inaccuracies in the flow calculations. The software also calculated the total cross-sectional area of the measurement location within the passage, and is shown in square feet as the “Positive Planar Area (Cut)”.

RESULTS AND DISCUSSION

This measurement is the second one performed at Catfish Reception Hall Spring applying the method and data processing used at other spring sites by KES. Based on KES’ experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. As a result of the prior measurement performed here, additional velocity station readings close to the boundary walls of the cross-section were made to provide the additional data needed for Surfer to more accurately account for the higher flows present near the boundary edge and adjust the contours more appropriately. Due to the extremely elongated cross-section, a high anisotropy ratio setting was used to minimize a “bull’s eye” or “curtain” effect that occurs in the contouring and has the unwanted effect of lowering the actual discharge value.

The estimated total discharge of Catfish Reception Hall Spring (all three vents) on September 21, 2006 was 36.43 CFS (cubic feet per second). This result is also expressed as 16,349 GPM (gallons per minute) or 23.543 MGD (million gallons per day), see Table 1. A total of sixty-two (62) readings were made, see Figures 2(ABC), 3(ABC) and 4(ABC). The total cross-sectional area was calculated as 59.45 square feet. The point velocity readings ranged from 0.13 to 1.29 feet per second (fps). The overall average station reading was 0.69 fps. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 14:17 hours and were completed by 17:29 hours. The results for each of the individual vents are summarized below.

The estimated discharge of Catfish Reception Hall Spring Vent 1 ((Main Vent) on September 21, 2006 was 35.62 CFS (cubic feet per second). This result is also expressed as 15,987 GPM (gallons per minute) or 23.022 MGD (million gallons per day), see Table 1. A total of fifty-four (54) readings were made, see Figures 2A, 3A and 4A. The Vent 1 cross-sectional area was calculated as 56.58 square feet. The point velocity readings ranged from 0.13 to 1.29 feet per second (fps). The average station reading for Vent 1 was 0.77 fps.

The estimated discharge of Catfish Reception Hall Spring Vent 2 on September 21, 2006 was 0.732 CFS (cubic feet per second). This result is also expressed as 329 GPM (gallons per minute) or 0.473 MGD (million gallons per day), see Table 1. A total of seven (7) readings were made, see Figures 2B, 3B and 4B. The Vent 2 cross-sectional area was calculated as 2.48 square feet. The point velocity readings ranged from 0.4 to 0.89 feet per second (fps). The average station reading for Vent 2 was 0.65 fps.

The estimated discharge of Catfish Reception Hall Spring Vent 3 on September 21, 2006 was 0.074 CFS (cubic feet per second). This result is also expressed as 33 GPM (gallons per minute) or 0.048 MGD (million gallons per day), see Table 1. A total of one (1) reading was made, see Figures 2C, 3C and 4C. The Vent 3 cross-sectional area was calculated as 0.39 square feet. The point velocity reading was 0.65 feet per second (fps).

UNDERWATER DISCHARGE MEASUREMENT						
Location:	**CATFISH RECEPTION HALL SPRING**			Date:	**September 21, 2006**	
	Silver Springs Group,			Time Start:	14:17	
	Marion County, Florida			Time End:	17:29	
Personnel:	Peter Butt, Tom Morris					
Method:	Grid within irregular conduit					
Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles					
Msmt. Periods:		60 seconds				
Analysis Method: Surfer 8 with kriging						
Catfish Reception Hall Spring Total Discharge:			**Vent 1 (Main):**	**Vent 2:**	**Vent 3:**	
CFS	**36.43**		**35.62**	**0.732**	**0.074**	
MGD	**23.543**		**23.022**	**0.473**	**0.048**	
GPM	**16349**	All Vents:	**15987**	**329**	**33**	
Total Cross-sectional Area (sq/ft):		59.45	56.575	2.48	0.391	
Avg. Station Point Velocity (ft/sec):		0.69	0.77	0.65	0.65	
Cross-section Depth (feet deep):			29-33	27	27	
Velocity Reading by Station:		(All velocity readings in feet per second.)				
Station #	Point Velocity	Station #	Point Velocity	Station #	Point Velocity	
VENT 1 (MAIN)		**VENT 1 (MAIN) contd.**		**VENT 2**		
A1	0.69	F1	1.1	1	0.45	
A2	0.83	F2	1.02	2	0.4	
A3	0.42	F3	1.17	3	0.77	
A4	0.48	FG	1.08	4	0.37	
A5	0.53	G1	0.7	5	0.83	
A6	0.9	G2	0.85	6	0.89	
AB	0.72	G3	1.24	7	0.83	
B1	0.71	G4	1.29			
B2	0.77	GH	0.76	**VENT 3**		
B3	0.57	H1	0.7	1	0.65	
B4	0.31	H2	1.05			
B5	0.13	H3	1.23			
BC	0.66	HI	0.92			
C1	0.54	I1	0.67			
C2	0.65	I2	0.88			
C3	0.63	I3	1.2			
C4	0.36	HM	0.92			
CD	0.42	J1	0.82			
D1	0.45	J2	0.91			
D2	0.71	J3	0.86			
D3	0.6	JK	0.84			
D4	0.57	K1	0.74			
DE	0.74	K2	0.79			
E1	0.72	K3	0.77			
E2	0.81	K4	0.82			
E3	0.78	K5	0.89			
EF	1	K6	0.79			

Table 1. Discharge of Catfish Reception Hall Spring, Marion County, Florida on September 21, 2006. Data record and calculation of discharge measurement.

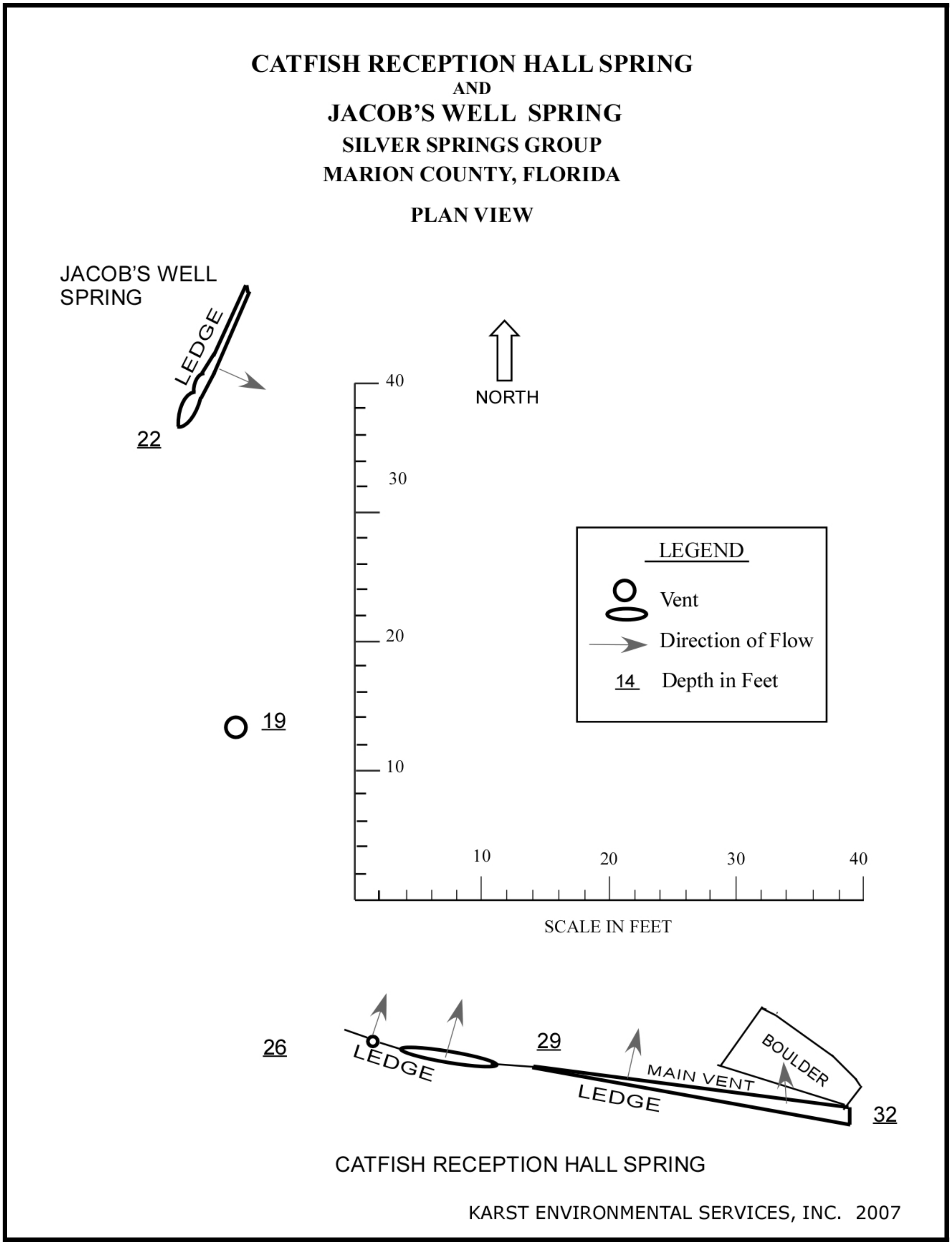

Figure 1. Map of Catfish Reception Hall Spring.

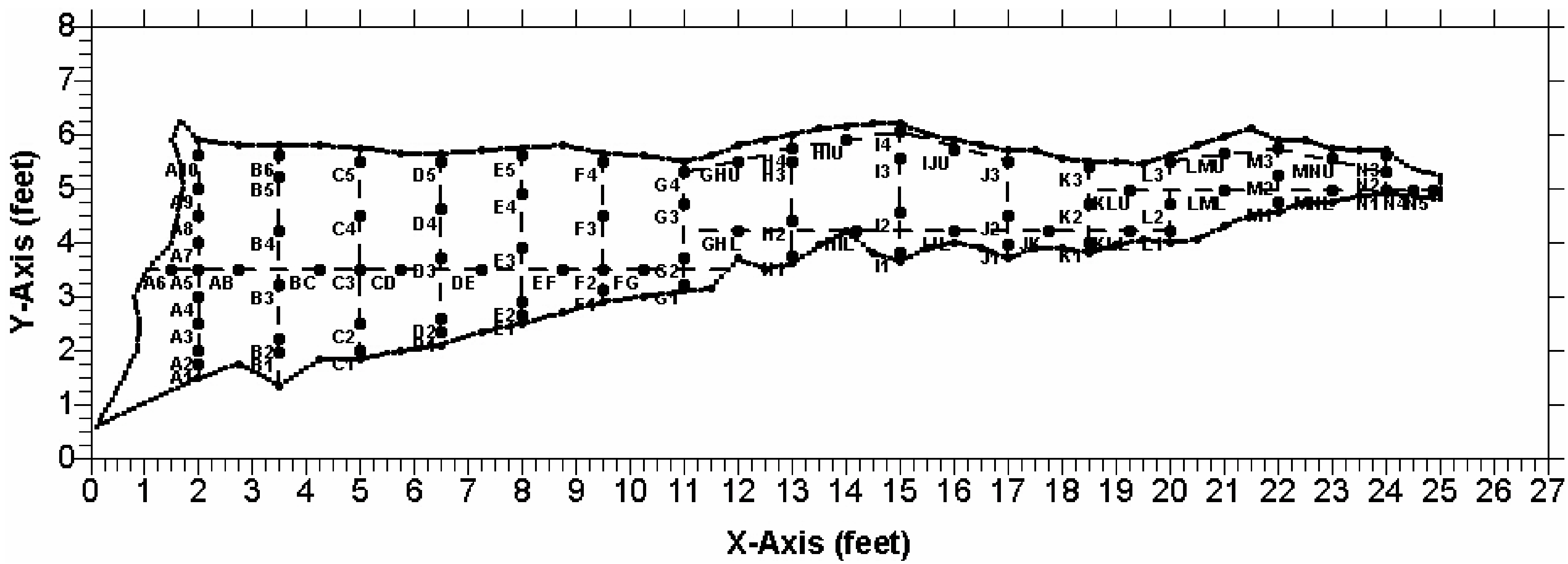

Figure 2A. Discharge measurement cross-section; Catfish Reception Hall Spring Vent 1 (Main Vent), Marion County, Florida, September 21, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located between the 29- and 33-foot depth levels. Support poles are represented by dashed lines. Velocity measurement stations are shown as points along the support poles. See Table 1 for station velocities. Boundary wall of the cross section is shown as the perimeter ring of connected points. X- and Y-axis scales are shown in feet.

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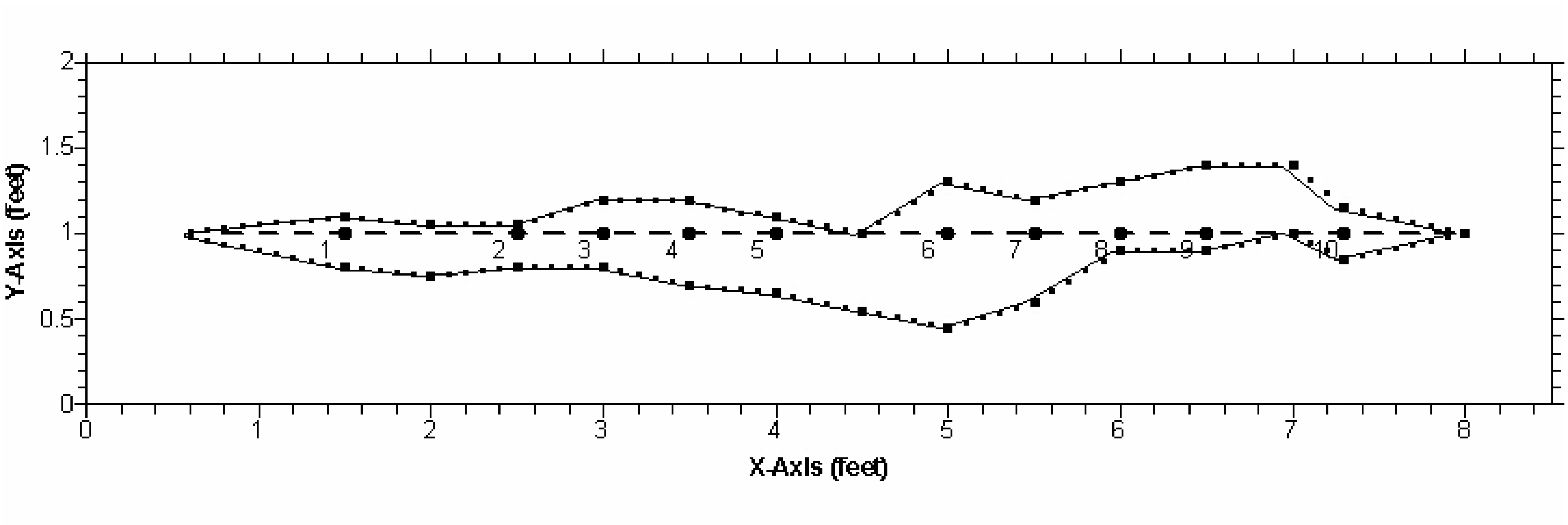

Figure 2B. Discharge measurement cross-section; Catfish Reception Hall Spring Vent 2, Marion County, Florida, September 21, 2006. Cross-section is viewed to the upstream of observer, and is located at the 27-foot depth level. Support poles are represented by dashed lines. Velocity measurement stations are shown as points along the support poles. See Table 1 for station velocities. Boundary wall of the cross section is shown as the perimeter ring of connected points. X- and Y-axis scales are shown in feet.

KARST ENVIRONMENTAL SERVICES, INC. 2007

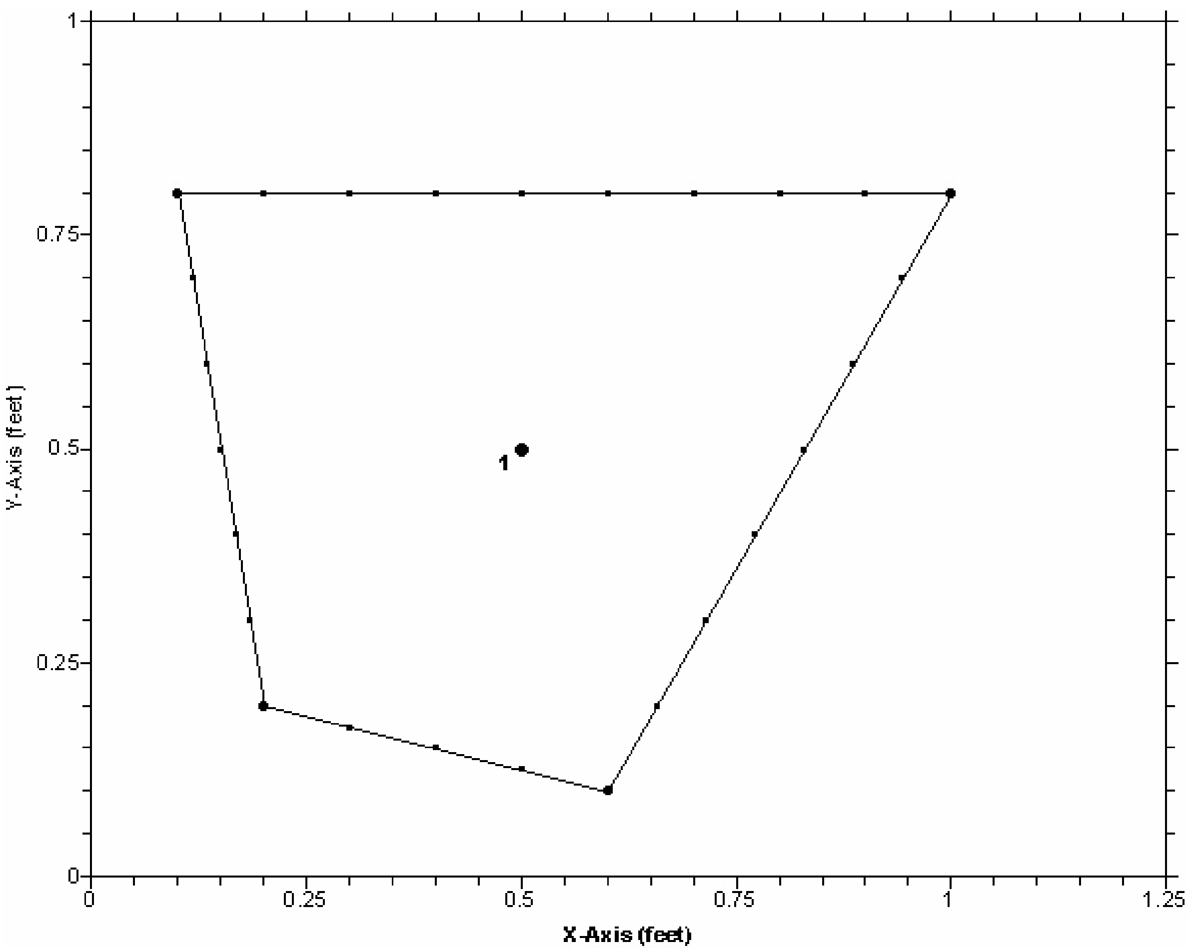

Figure 2C. Discharge measurement cross-section; Catfish Reception Hall Spring Vent 3, Marion County, Florida, September 21, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 27-foot depth levels. The velocity measurement station was hand-held. See Table 1 for station velocities. Boundary wall of the cross section is shown as the perimeter ring of connected points. X- and Y-axis scales are shown in feet.

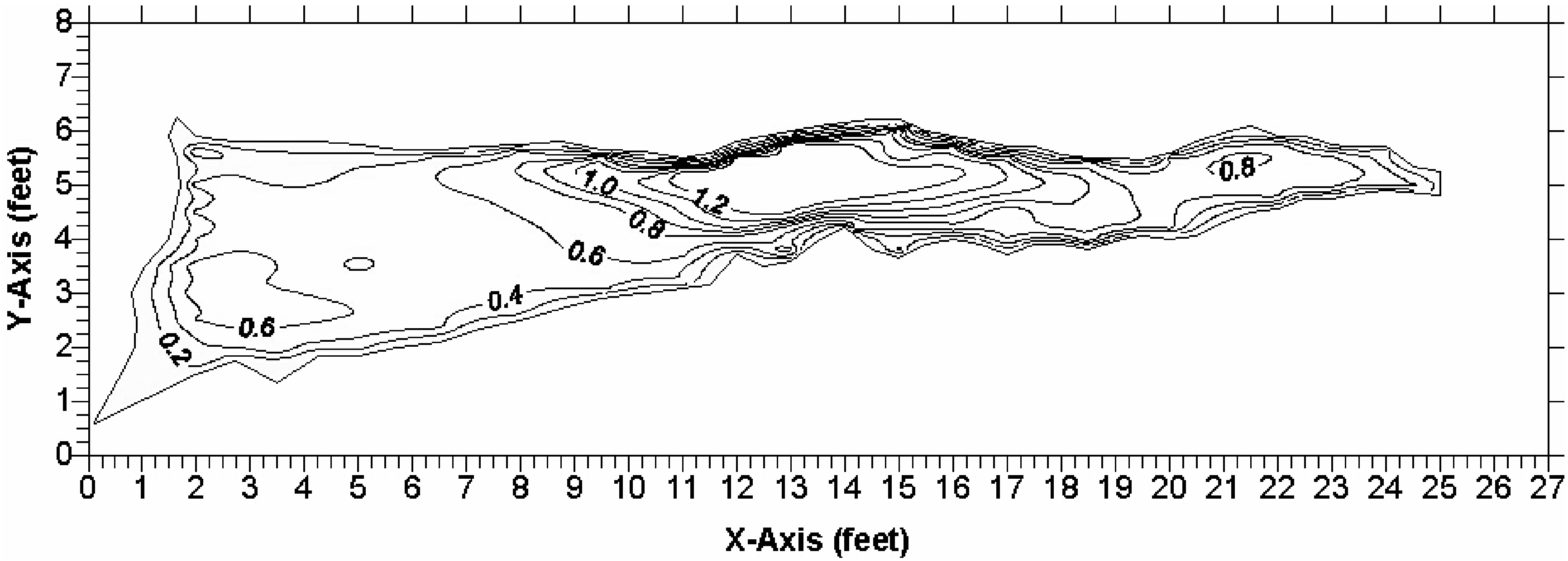

Figure 3A. Discharge measurement cross-section; Catfish Reception Hall Spring Vent 1 (Main Vent), Marion County, Florida, September 21, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

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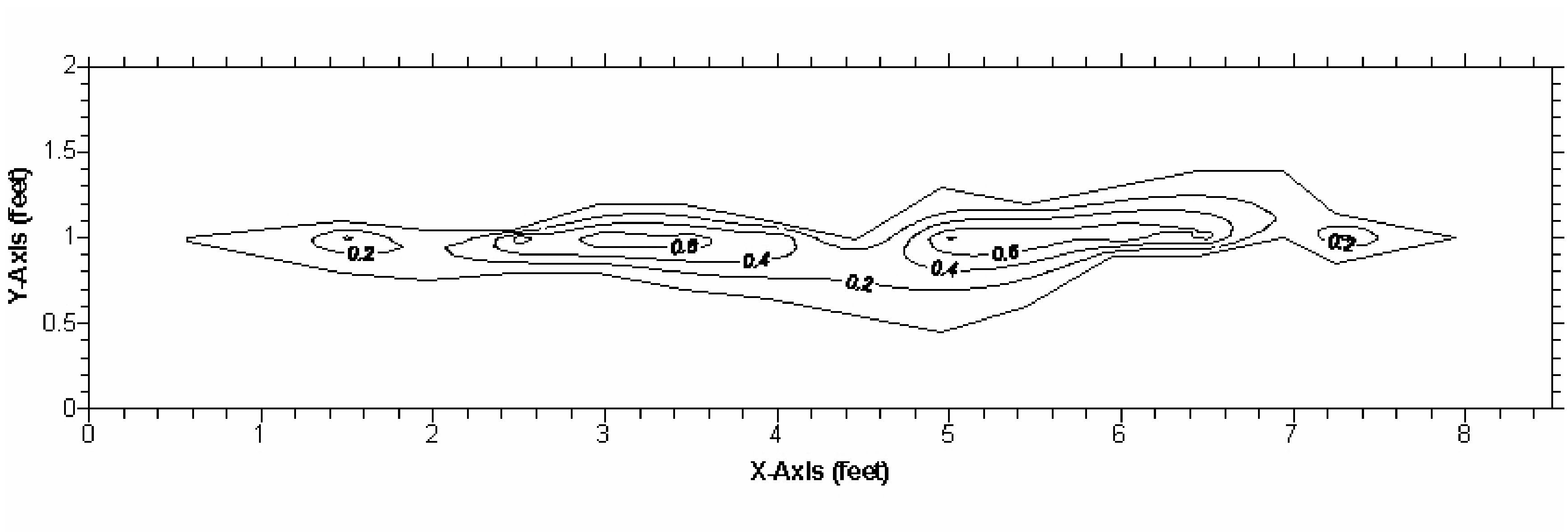

Figure 3B. Discharge measurement cross-section; Catfish Reception Hall Spring Vent 2, Marion County, Florida, September 21, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

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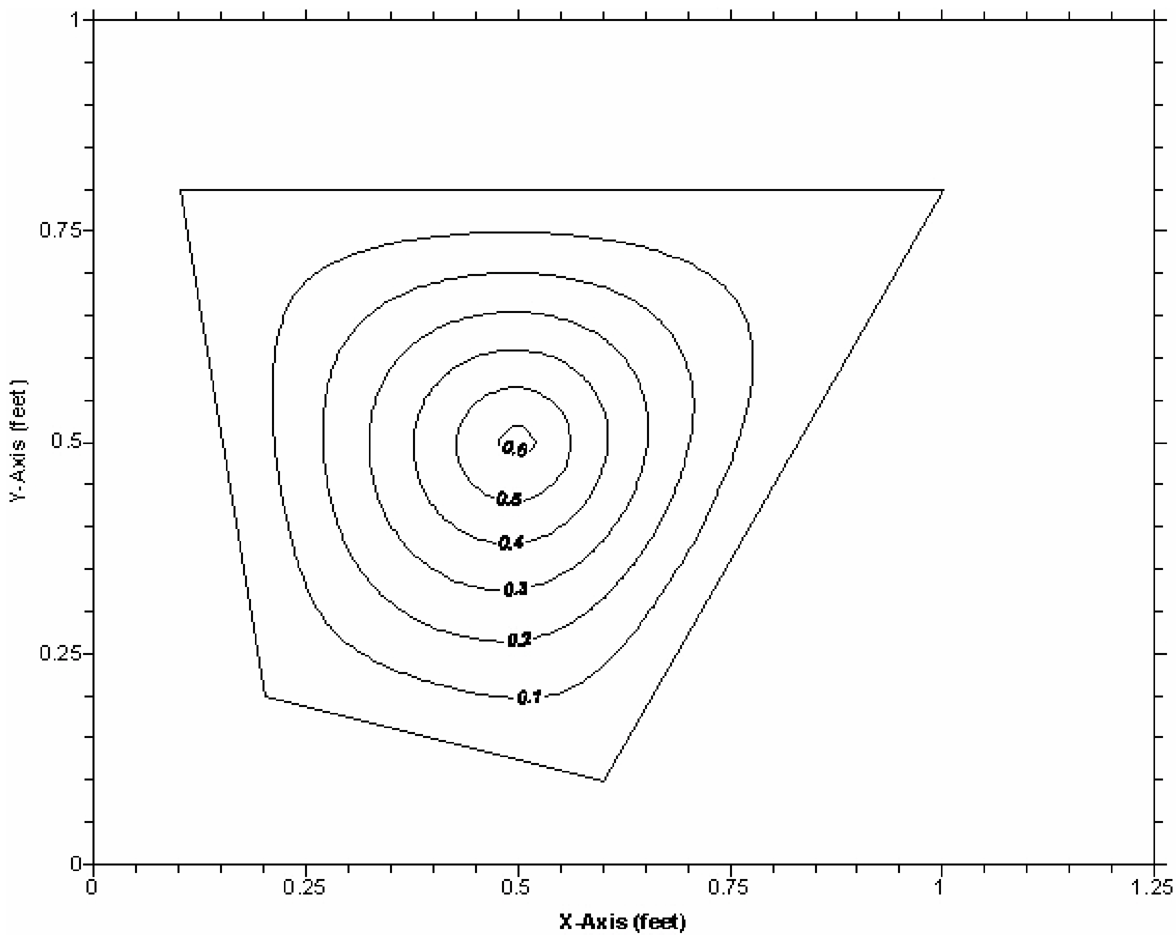

Figure 3C. Discharge measurement cross-section; Catfish Reception Hall Spring Vent 3, Marion County, Florida, September 21, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

TABLE 2A. CATFISH RECEPTION HALL SPRING VENT 1 (MAIN VENT), SEPTEMBER 21, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\CatfishMain\CatfishReceptionHallMain_9-06.3x.bln.grd
Grid Size:	61 rows x 256 columns
X Minimum:	0
X Maximum:	25.5
X Spacing:	0.1
Y Minimum:	0.5
Y Maximum:	6.5
Y Spacing:	0.1
Z Minimum:	-6.5944716354238E-010
Z Maximum:	1.4238157997923

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES
Z Scale Factor: 1
Total Volumes by:
Trapezoidal Rule: 35.620356677853
Simpson's Rule: 35.637719952228
Simpson's 3/8 Rule: 35.612103361508

CUT & FILL VOLUMES
Positive Volume [Cut]: 35.620356677874
Negative Volume [Fill]: 2.1716014128935E-011
Net Volume [Cut-Fill]: 35.620356677853<<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 56.575 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 56.57499999993
Negative Planar Area [Fill]: 6.9664282908436E-011
Blanked Planar Area: 96.425
Total Planar Area: 153

Surface Areas
Positive Surface Area [Cut]: 77.538106682827
Negative Surface Area [Fill]: 1.795449817077E-010

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\CatfishMain\Catfish Reception Hall Main 9-06 SURFER XYZ T3A BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	641
Original Data:	641
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.1	0.6	0
25%-tile:	4.9	3.2	0
Median:	11.2	4.71	0
75%-tile:	18.3	5.7	0
Maximum:	25	6.25	1.36
Midrange:	12.55	3.425	0.68
Range:	24.9	5.65	1.36
Interquartile Range:	13.4	2.5	0
Median Abs. Deviation:	6.7	1.04	0
Mean:	11.672343042122	4.3237952028081	0.082964118564743
Trim Mean (10%):	11.57232610052	4.4023958838822	0.042755632582322
Standard Deviation:	7.5367844373149	1.5324714294778	0.23264392379855
Variance:	56.803119654552	2.3484686821656	0.054123195280385
Coef. of Variation:			2.8041510935478
Coef. of Skewness:			2.9094189276715

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.444	0.030
Y:		1.000	0.036
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	56.803119654552	5.1331624406753	0.052411539812744
Y:		2.3484686821656	0.012985290350491
Z:			0.054123195280385

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.00052714369706637	0.004377054802533	0.057885627942471
Standard Error:	0.0013631362475099	0.0067039840734085	0.027715249904956

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.444	-0.109
B:		1.000	0.791
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.054142539568666	0.027071269784333	0.49862
Residual:	638	34.638825635158	0.054292830149151	
Total:	640	34.692968174727		

Coefficient of Multiple Determination (R^2): 0.0015606199877735

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.1002215326165	0
Median:	0.10198039027186	0
75%-tile:	0.1087978841706	0
Maximum:	1	1.36
Midrange:	0.525	0.68
Range:	0.95	1.36

Interquartile Range:	0.0085763515541032	0
Median Abs. Deviation:	0.0019803902718574	0
Mean:	0.13740918951053	0.059173166926677
Trim Mean (10%):	0.11273951198281	0.021542461005199
Standard Deviation:	0.13358438645032	0.19252514384271
Variance:	0.017844788303308	0.037065931011655
Coef. of Variation:	0.97216486703809	3.2535886423194
Coef. of Skewness:	4.1381448570868	3.7126144280172
Root Mean Square:	0.19164048023643	0.2014134918415
Mean Square:	0.036726073665249	0.040567394695788

Complete Spatial Randomness

Lambda:	4.5562782101859
Clark and Evans:	0.58661192989886
Skellam:	673.94217235663

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	2.9E-006
Y Duplicate Tolerance:	6.7E-007

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	0
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	3
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\CatfishMain\CatfishReceptionHallMain_9-06.3x.grd
Grid Size:	61 rows x 256 columns
Total Nodes:	15616
Filled Nodes:	15616
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	25.5
X Spacing:	0.1
Y Minimum:	0.5
Y Maximum:	6.5
Y Spacing:	0.1

Grid Statistics

Z Minimum:	-0.98679218418089
Z 25%-tile:	-0.6631644757017
Z Median:	-0.22059744433548
Z 75%-tile:	0.46170840092478
Z Maximum:	1.4238157997923
Z Midrange:	0.21851180780573
Z Range:	2.4106079839732
Z Interquartile Range:	1.1248728766265
Z Median Abs. Deviation:	0.53350843329231
Z Mean:	-0.10401250439169
Z Trim Mean (10%):	-0.13001237549711
Z Standard Deviation:	0.63047630077387
Z Variance:	0.3975003658375
Z Coef. of Variation:	-1
Z Coef. of Skewness:	0.44736322288118
Z Root Mean Square:	0.63899840915869
Z Mean Square:	0.40831896690734

**TABLE 2B. CATFISH RECEPTION HALL SPRING VENT 2, SEPTEMBER 21, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT**

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\CatfishSide(2)\CatfishReceptionHallSide_9-06.bln.grd
Grid Size:	41 rows x 171 columns
X Minimum:	0
X Maximum:	8.5
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	2
Y Spacing:	0.05
Z Minimum:	-0.00020313758708324
Z Maximum:	0.82000000027394

LOWER SURFACE

Level Surface defined by Z = 0

VOLUMES

Z Scale Factor:	1
Total Volumes by:	
Trapezoidal Rule:	0.73183215070098
Simpson's Rule:	0.73032506309639
Simpson's 3/8 Rule:	0.73509353441039

CUT & FILL VOLUMES

Positive Volume [Cut]:	0.731832476721
Negative Volume [Fill]:	3.2602002264778E-007
Net Volume [Cut-Fill]:	**0.73183215070098<<<<<<Total Discharge in CFS**

(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS

Planar Areas

Operational Planar Area: 2.484 <<<<Total Cross-section Area in Square Feet

(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)

Positive Planar Area [Cut]:	2.4837446567812
Negative Planar Area [Fill]:	5.3432187693254E-006
Blanked Planar Area:	14.51625
Total Planar Area:	17

Surface Areas

Positive Surface Area [Cut]:	6.2980700226502
Negative Surface Area [Fill]:	1.2245858241398E-005

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\CatfishSide(2)\Catfish Reception Hall Side 9-06 SURFER XYZ T3B BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	160
Original Data:	160
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.5	0.45	0
25%-tile:	2.5	0.8	0
Median:	4.3	1	0
75%-tile:	6.1	1.12	0
Maximum:	8	1.4	0.82
Midrange:	4.25	0.925	0.41
Range:	7.5	0.95	0.82
Interquartile Range:	3.6	0.32	0
Median Abs. Deviation:	1.8	0.16	0
Mean:	4.264375	0.9705625625	0.0406875
Trim Mean (10%):	4.2659722222222	0.97340284722222	0.0061111111111111
Standard Deviation:	2.1443340130155	0.22675209453345	0.16062425826677
Variance:	4.598168359375	0.051416512375309	0.02580015234375
Coef. of Variation:			3.9477544274475
Coef. of Skewness:			3.82252531568

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.170	0.029
Y:		1.000	0.033
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	4.598168359375	0.082541053789062	0.0101494921875
Y:		0.051416512375309	0.0011977357382813
Z:			0.02580015234375

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.0018422168660102	0.020337381291442	0.013092895551246
Standard Error:	0.0060611594289395	0.05731876633169	0.058641262425307

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.170	-0.280
B:		1.000	0.874
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.0068890198536096	0.0034445099268048	0.13122
Residual:	157	4.1211353551464	0.026249269778002	
Total:	159	4.128024375		

Coefficient of Multiple Determination (R^2): 0.0016688418545517

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.03	0
25%-tile:	0.1	0
Median:	0.10198039027186	0
75%-tile:	0.10198039027186	0
Maximum:	0.26	0.82

Midrange:	0.145	0.41
Range:	0.23	0.82
Interquartile Range:	0.0019803902718557	0
Median Abs. Deviation:	0.0014816340606466	0
Mean:	0.10245283435035	0.05125
Trim Mean (10%):	0.10182281431965	0.016875
Standard Deviation:	0.022850770196637	0.17608857856204
Variance:	0.0005221576985795	0.0310071875
Coef. of Variation:	0.22303697444324	3.4358747036496
Coef. of Skewness:	2.5234001103899	3.2772702690313
Root Mean Square:	0.10497019084007	0.18339506536437
Mean Square:	0.011018740965	0.03363375

Complete Spatial Randomness
Lambda: 22.456140350877
Clark and Evans: 0.9710051432107
Skellam: 248.75220465594

Exclusion Filtering
Exclusion Filter String: Not In Use

Duplicate Filtering
Duplicate Points to Keep: First
X Duplicate Tolerance: 8.9E-007
Y Duplicate Tolerance: 1.1E-007
No duplicate data were found.

Breakline Filtering
Breakline Filtering: Not In Use

Gridding Rules
Gridding Method: Kriging
Kriging Type: Point
Polynomial Drift Order: 1
Kriging std. deviation grid: no

Semi-Variogram Model
Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 3
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\CatfishSide(2)\CatfishReceptionHallSide_9-06.grd
Grid Size:	41 rows x 171 columns
Total Nodes:	7011
Filled Nodes:	7011
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	8.5
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	2
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-0.3718666786826
Z 25%-tile:	-0.21212701124653
Z Median:	-0.1648128407893
Z 75%-tile:	-0.067481525958489
Z Maximum:	0.82000000027394
Z Midrange:	0.22406666079567
Z Range:	1.1918666789565
Z Interquartile Range:	0.14464548528804
Z Median Abs. Deviation:	0.070397316230419
Z Mean:	-0.11090534269392
Z Trim Mean (10%):	-0.13242353399369
Z Standard Deviation:	0.19813045093621
Z Variance:	0.039255675588185
Z Coef. of Variation:	-1
Z Coef. of Skewness:	1.8684968288223
Z Root Mean Square:	0.22705873827325
Z Mean Square:	0.05155567062624

TABLE 2C. CATFISH RECEPTION HALL SPRING VENT 3, SEPTEMBER 21, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\CatfishVent\CatfishReceptionHallVent-0906.bln.grd
Grid Size:	51 rows x 56 columns
X Minimum:	0
X Maximum:	1.1
X Spacing:	0.02
Y Minimum:	0
Y Maximum:	1
Y Spacing:	0.02
Z Minimum:	0.0012025577001354
Z Maximum:	0.65

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES
Z Scale Factor: 1
Total Volumes by:

Trapezoidal Rule:	0.073677759681247
Simpson's Rule:	0.073726057764768
Simpson's 3/8 Rule:	0.073662944497755

CUT & FILL VOLUMES
Positive Volume [Cut]: 0.073677759681247
Negative Volume [Fill]: 0
Net Volume [Cut-Fill]: 0.073677759681247<<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 0.391 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 0.3906
Negative Planar Area [Fill]: 0
Blanked Planar Area: 0.7094
Total Planar Area: 1.1

Surface Areas
Positive Surface Area [Cut]: 0.74063315330587
Negative Surface Area [Fill]: 0

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\CatfishVent\Catfish Reception Hall Vent 9-06 SURFER XYZ T3C BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	27
Original Data:	27
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.1	0.1	0
25%-tile:	0.2	0.3	0
Median:	0.5	0.6	0
75%-tile:	0.77142	0.8	0
Maximum:	1	0.8	0.65
Midrange:	0.55	0.45	0.325
Range:	0.9	0.7	0.65
Interquartile Range:	0.57142	0.5	0
Median Abs. Deviation:	0.3	0.2	0
Mean:	0.501848518518520	0.535185185185190	0.024074074074074
Trim Mean (10%):	0.4979964	0.542	0
Standard Deviation:	0.28624296630794	0.2564229776838	0.12275417347538
Variance:	0.081935035760768	0.065752743484225	0.015068587105624
Coef. of Variation:			5.0990195135928
Coef. of Skewness:			4.9029033784546

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.147	-0.001
Y:		1.000	-0.027
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	0.081935035760768	0.010798922496571	-4.4501371742112E-005
Y:		0.065752743484225	-0.00084705075445816
Z:			0.015068587105624

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.0011802961401653	-0.013076209986661	0.030479938067951
Standard Error:	0.08846854601283	0.098756746623893	0.068567770906849

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.147	-0.534
B:		1.000	0.676
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.00029763959590862	0.00014881979795431	0.0087852
Residual:	24	0.40655421225594	0.016939758843998	
Total:	26	0.40685185185185		

Coefficient of Multiple Determination (R^2): 0.00073156750928838

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.1	0
25%-tile:	0.1	0
Median:	0.101378279725	0
75%-tile:	0.10878213272408	0
Maximum:	0.28925562466441	0.65

Midrange:	0.19462781233221	0.325
Range:	0.18925562466441	0.65
Interquartile Range:	0.008782132724083	0
Median Abs. Deviation:	0.0013782797249983	0
Mean:	0.11090629295012	0.024074074074074
Trim Mean (10%):	0.10420857139956	0
Standard Deviation:	0.035425006636166	0.12275417347538
Variance:	0.0012549310951724	0.015068587105624
Coef. of Variation:	0.31941385555188	5.0990195135928
Coef. of Skewness:	4.7098805788202	4.9029033784546
Root Mean Square:	0.11642653009994	0.12509255832442
Mean Square:	0.013555136911111	0.015648148148148

Complete Spatial Randomness

Lambda:	42.857142857143
Clark and Evans:	1.4521042356883
Skellam:	98.553205760183

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	1E-007
Y Duplicate Tolerance:	8.3E-008

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point

Polynomial Drift Order: 2
Kriging std. deviation grid: no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\CatfishVent\CatfishReceptionHallVent-0906.grd
Grid Size:	51 rows x 56 columns
Total Nodes:	2856
Filled Nodes:	2856
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	1.1
X Spacing:	0.02
Y Minimum:	0
Y Maximum:	1
Y Spacing:	0.02

Grid Statistics

Z Minimum:	-0.70729761711412
Z 25%-tile:	-0.14126177389324
Z Median:	-0.042595526568344
Z 75%-tile:	0.073519944338342
Z Maximum:	0.65
Z Midrange:	-0.02864880855706
Z Range:	1.3572976171141
Z Interquartile Range:	0.21478171823158
Z Median Abs. Deviation:	0.10546913702577
Z Mean:	-0.024623024399732
Z Trim Mean (10%):	-0.027847947649028
Z Standard Deviation:	0.20064693385346
Z Variance:	0.040259192064793
Z Coef. of Variation:	-1
Z Coef. of Skewness:	0.3395383816665
Z Root Mean Square:	0.20215213428352
Z Mean Square:	0.040865485395383

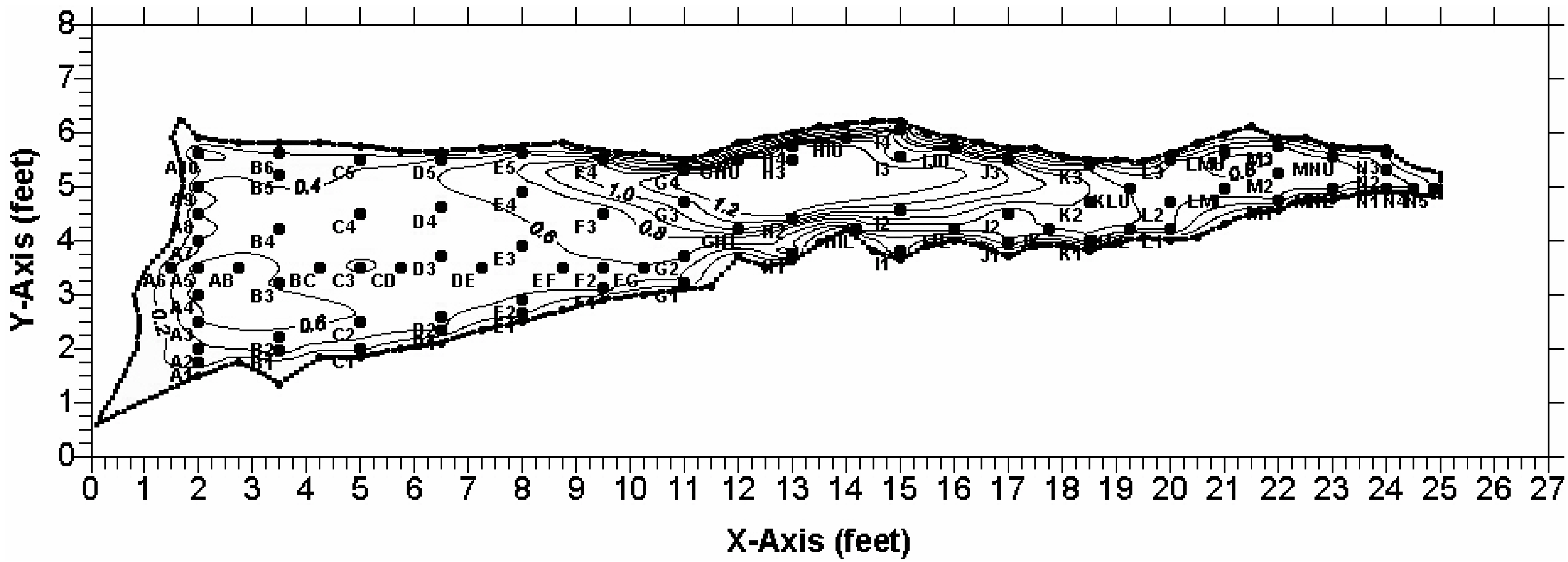

Figure 4A. Discharge measurement cross-section; Catfish Reception Hall Spring Vent 1 (Main Vent), Marion County, Florida, September 21, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (labeled points) are shown. See Table 1 for station velocities. Boundary wall of the cross section is shown as the perimeter ring of connected points. X- and Y-axis scales are shown in feet.

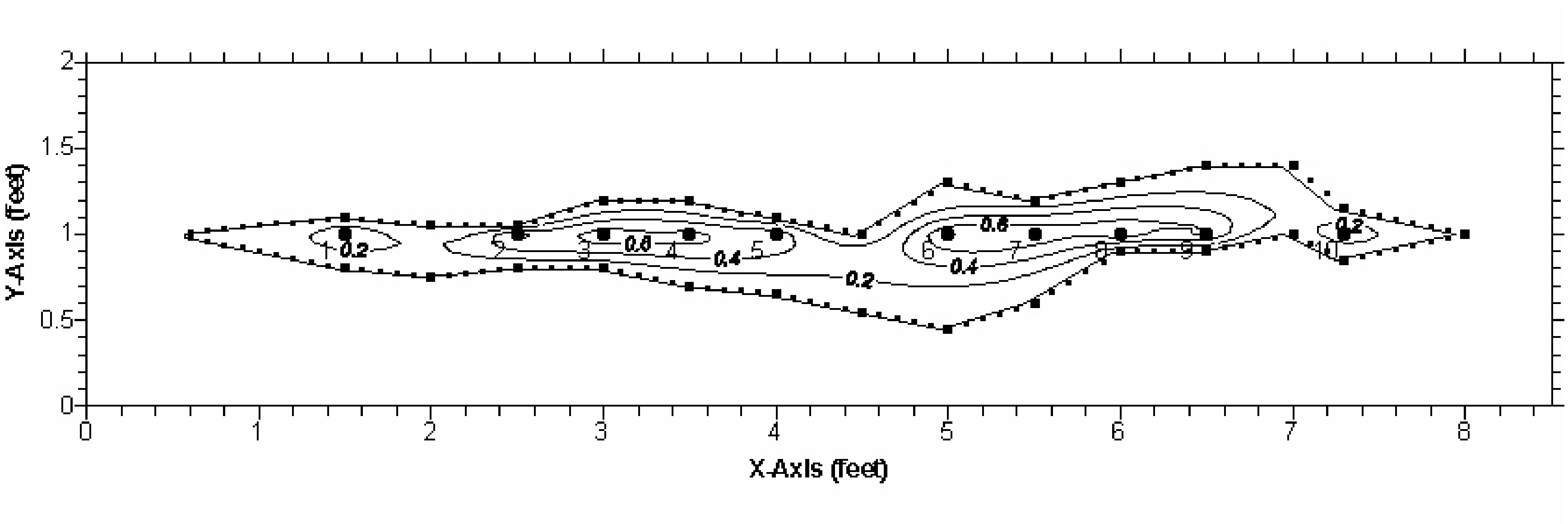

Figure 4B. Discharge measurement cross-section; Catfish Reception Hall Spring Vent 2, Marion County, Florida, September 21, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (labeled points) are shown. See Table 1 for station velocities. Boundary wall of the cross section is shown as the perimeter ring of connected points. X- and Y-axis scales are shown in feet.

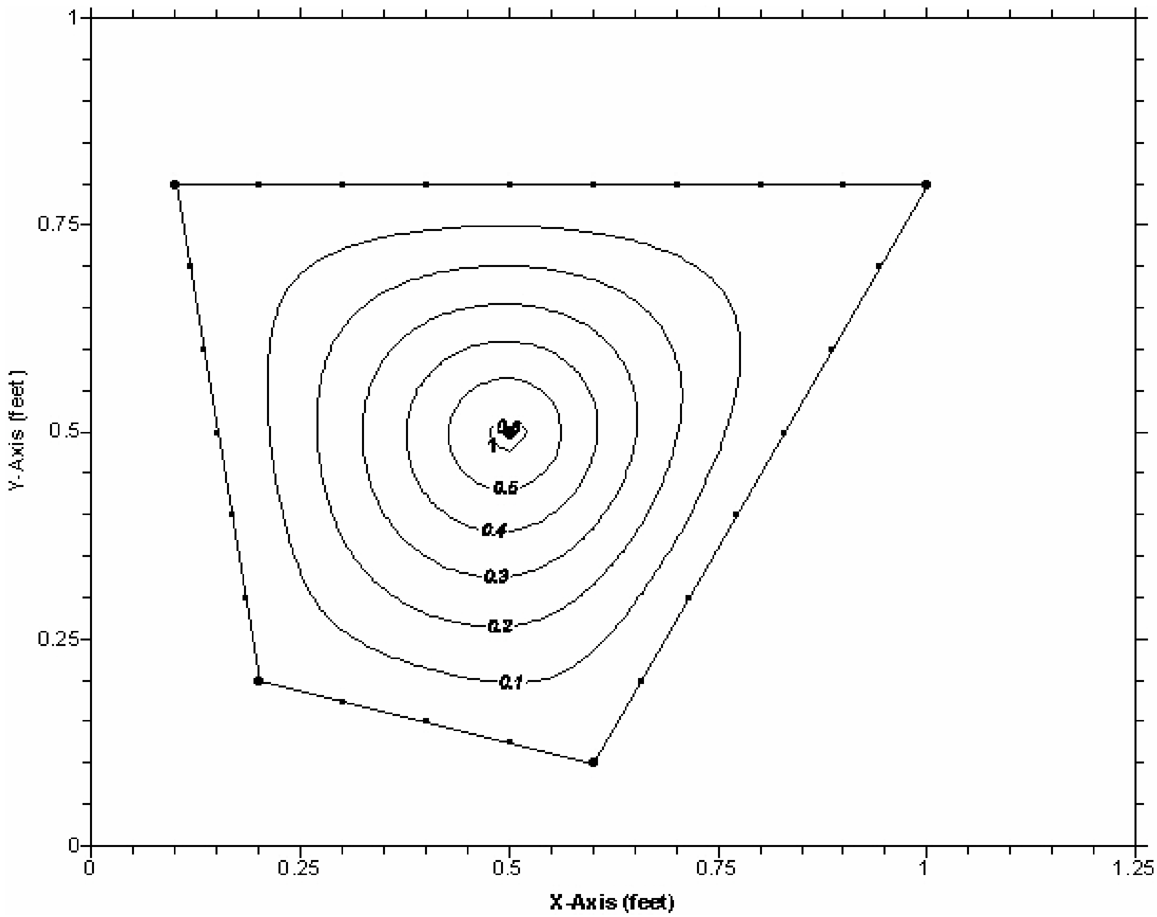

Figure 4C. Discharge measurement cross-section; Catfish Reception Hall Spring Vent 3, Marion County, Florida, September 21, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (labeled points) are shown. See Table 1 for station velocities. Boundary wall of the cross section is shown as the perimeter ring of connected points. X- and Y-axis scales are shown in feet.

Table 3A. Catfish Reception Hall Spring Vent 1 (Main Vent) XYZ Grid Data, September 21, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
2	**1.75**	**0.43**	**A1**	20	17.5
2	**2**	**0.37**	**A2**	20	20
2	**2.5**	**0.6**	**A3**	20	25
2	**3**	**0.72**	**A4**	20	30
2	**3.5**	**0.7**	**A5**	20	35
1.5	**3.5**	**0.39**	**A6**	15	35
2	**4**	**0.41**	**A7**	20	40
2	**4.5**	**0.46**	**A8**	20	45
2	**5**	**0.52**	**A9**	20	50
2	**5.6**	**0.6**	**A10**	20	56
2.75	**3.5**	**0.72**	**AB**	27.5	35
3.5	**1.95**	**0.53**	**B1**	35	19.5
3.5	**2.2**	**0.53**	**B2**	35	22
3.5	**3.2**	**0.55**	**B3**	35	32
3.5	**4.2**	**0.42**	**B4**	35	42
3.5	**5.2**	**0.26**	**B5**	35	52
3.5	**5.6**	**0.22**	**B6**	35	56
4.25	**3.5**	**0.49**	**BC**	42.5	35
5	**2**	**0.3**	**C1**	50	20
5	**2.5**	**0.58**	**C2**	50	25
5	**3.5**	**0.35**	**C3**	50	35
5	**4.5**	**0.4**	**C4**	50	45
5	**5.5**	**0.33**	**C5**	50	55
5.75	**3.5**	**0.48**	**CD**	57.5	35
6.5	**2.35**	**0.44**	**D1**	65	23.5
6.5	**2.6**	**0.44**	**D2**	65	26
6.5	**3.7**	**0.48**	**D3**	65	37
6.5	**4.6**	**0.51**	**D4**	65	46
6.5	**5.5**	**0.5**	**D5**	65	55
7.25	**3.5**	**0.51**	**DE**	72.5	35
8	**2.65**	**0.29**	**E1**	80	26.5
8	**2.9**	**0.35**	**E2**	80	29
8	**3.9**	**0.54**	**E3**	80	39
8	**4.9**	**0.67**	**E4**	80	49
8	**5.6**	**0.67**	**E5**	80	56
8.75	**3.5**	**0.57**	**EF**	87.5	35
9.5	**3.1**	**0.48**	**F1**	95	31
9.5	**3.5**	**0.53**	**F2**	95	35
9.5	**4.5**	**0.7**	**F3**	95	45
9.5	**5.5**	**0.97**	**F4**	95	55
10.25	**3.5**	**0.58**	**FG**	102.5	35

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
11	3.2	0.39	G1	110	32
11	3.7	0.63	G2	110	37
11	4.7	1.05	G3	110	47
11	5.3	1.15	G4	110	53
12	4.2	1.02	GHL	120	42
12	5.5	1.23	GHU	120	55
13	3.75	0.81	H1	130	37.5
13	4.4	1.14	H2	130	44
13	5.5	1.2	H3	130	55
13	5.75	1.36	H4	130	57.5
14.2	4.2	0.75	HIL	142	42
14	5.9	0.98	HIU	140	59
15	3.8	0.45	I1	150	38
15	4.55	1.01	I2	150	45.5
15	5.55	1	I3	150	55.5
15	6.05	1.06	I4	150	60.5
16	4.2	0.74	IJL	160	42
16	5.7	1.02	IJU	160	57
17	3.95	0.61	J1	170	39.5
17	4.5	0.7	J2	170	45
17	5.5	0.95	J3	170	55
17.75	4.2	0.79	JK	177.5	42
18.5	4	0.78	K1	185	40
18.5	4.7	0.88	K2	185	47
18.5	5.4	0.75	K3	185	54
19.25	4.2	0.71	KLL	192.5	42
19.25	4.95	0.79	KLU	192.5	49.5
20	4.2	0.64	L1	200	42
20	4.7	0.64	L2	200	47
20	5.5	0.62	L3	200	55
21	4.95	0.71	LML	210	49.5
21	5.65	0.73	LMU	210	56.5
22	4.75	0.61	M1	220	47.5
22	5.25	0.7	M2	220	52.5
22	5.75	0.69	M3	220	57.5
23	4.95	0.67	MNL	230	49.5
23	5.55	0.58	MNU	230	55.5
24	4.95	0.45	N1	240	49.5
24	5.3	0.41	N2	240	53
24	5.6	0.36	N3	240	56

Table 3A. Catfish Reception Hall Spring Vent 1 XYZ Grid Data, September 21, 2006.

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
24.5	**4.95**	**0.39**	**N4**	245	49.5
24.9	**4.95**	**0.44**	**N5**	249	49.5
2	**5.9**	**0**	**AT**	20	59
2	**1.5**	**0**	**AS**	20	15
3.5	**5.8**	**0**	**BT**	35	58
3.5	**1.35**	**0**	**BS**	35	13.5
5	**5.75**	**0**	**CT**	50	57.5
5	**1.85**	**0**	**CS**	50	18.5
6.5	**5.65**	**0**	**DT**	65	56.5
6.5	**2.1**	**0**	**DS**	65	21
8	**5.75**	**0**	**ET**	80	57.5
8	**2.5**	**0**	**ES**	80	25
9.5	**5.65**	**0**	**FT**	95	56.5
9.5	**2.9**	**0**	**FS**	95	29
11	**5.5**	**0**	**GT**	110	55
11	**3.1**	**0**	**GS**	110	31
13	**6**	**0**	**HT**	130	60
13	**3.6**	**0**	**HS**	130	36
15	**6.2**	**0**	**IT**	150	62
15	**3.65**	**0**	**IS**	150	36.5
17	**5.7**	**0**	**JT**	170	57
17	**3.7**	**0**	**JS**	170	37
18.5	**5.5**	**0**	**KT**	185	55
18.5	**3.8**	**0**	**KS**	185	38
20	**5.6**	**0**	**LT**	200	56
20	**4**	**0**	**LS**	200	40
22	**5.9**	**0**	**MT**	220	59
22	**4.55**	**0**	**MS**	220	45.5
24	**5.7**	**0**	**NT**	240	57
24	**4.9**	**0**	**NS**	240	49
0					
2.75	**1.75**	**0**	**ABS**	27.5	17.5
4.25	**1.85**	**0**	**BCS**	42.5	18.5
5.75	**2**	**0**	**CDS**	57.5	20
7.25	**2.35**	**0**	**DES**	72.5	23.5
8.75	**2.7**	**0**	**EFS**	87.5	27
10.25	**3**	**0**	**FGS**	102.5	30
11.5	**3.15**	**0**	**GHS1**	115	31.5
12	**3.7**	**0**	**GHS2**	120	37
12.5	**3.5**	**0**	**GHS3**	125	35
13.5	**3.95**	**0**	**HIS1**	135	39.5
14	**4.2**	**0**	**HIS2**	140	42
14.5	**3.8**	**0**	**HIS3**	145	38
15.5	**3.9**	**0**	**IJS1**	155	39
16	**4**	**0**	**IJS2**	160	40
16.5	**3.9**	**0**	**IJS3**	165	39
17.5	**3.9**	**0**	**JKS1**	175	39

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
18	**3.9**	**0**	**JKS2**	180	39
19	**3.95**	**0**	**KLS1**	190	39.5
19.5	**4.05**	**0**	**KLS2**	195	40.5
20.5	**4.05**	**0**	**LMS1**	205	40.5
21	**4.3**	**0**	**LMS2**	210	43
21.5	**4.5**	**0**	**LMS3**	215	45
22.5	**4.75**	**0**	**MNS1**	225	47.5
23	**4.75**	**0**	**MNS2**	230	47.5
23.5	**4.85**	**0**	**MNS3**	235	48.5
2.75	**5.8**	**0**	**ABT**	27.5	58
4.25	**5.8**	**0**	**BCT**	42.5	58
5.75	**5.65**	**0**	**CDT**	57.5	56.5
7.25	**5.7**	**0**	**DET**	72.5	57
8.75	**5.8**	**0**	**EFT**	87.5	58
10.25	**5.6**	**0**	**FGT**	102.5	56
11.5	**5.6**	**0**	**GHT1**	115	56
12	**5.8**	**0**	**GHT2**	120	58
12.5	**5.9**	**0**	**GHT3**	125	59
13.5	**6.1**	**0**	**HIT1**	135	61
14	**6.15**	**0**	**HIT2**	140	61.5
14.5	**6.2**	**0**	**HIT3**	145	62
15.5	**6**	**0**	**IJT1**	155	60
16	**5.9**	**0**	**IJT2**	160	59
16.5	**5.8**	**0**	**IJT3**	165	58
17.5	**5.7**	**0**	**JKT1**	175	57
18	**5.55**	**0**	**JKT2**	180	55.5
19	**5.5**	**0**	**KLT1**	190	55
19.5	**5.45**	**0**	**KLT2**	195	54.5
20.5	**5.8**	**0**	**LMT1**	205	58
21	**5.95**	**0**	**LMT2**	210	59.5
21.5	**6.1**	**0**	**LMT3**	215	61
22.5	**5.9**	**0**	**MNT1**	225	59
23	**5.75**	**0**	**MNT2**	230	57.5
23.5	**5.7**	**0**	**MNT3**	235	57
0.1	**0.6**	**0**	**AE1**	1	6
0.6	**1.5**	**0**	**AE2**	6	15
0.85	**2**	**0**	**AE3**	8.5	20
0.9	**2.5**	**0**	**AE4**	9	25
0.8	**3**	**0**	**AE5**	8	30
1.05	**3.5**	**0**	**AE6**	10.5	35
1.5	**4**	**0**	**AE7**	15	40
1.6	**4.5**	**0**	**AE8**	16	45
1.7	**5**	**0**	**AE9**	17	50
1.65	**5.5**	**0**	**AE10**	16.5	55
1.5	**5.9**	**0**	**AE11**	15	59
1.65	**6.25**	**0**	**AE12**	16.5	62.5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
24.5	**4.85**	**0**	**NV1**	245	48.5
25	**4.8**	**0**	**NV2**	250	48
25	**4.95**	**0**	**NV3**	250	49.5
25	**5.25**	**0**	**NV4**	250	52.5
24.5	**5.35**	**0**	**NV5**	245	53.5
0.15666	**0.7**	**0**	**AV1**	1.5666	7
0.21332	**0.8**	**0**	**AV2**	2.1332	8
0.26998	**0.9**	**0**	**AV3**	2.6998	9
0.32661	**1**	**0**	**AV4**	3.2661	10
0.3833	**1.1**	**0**	**AV5**	3.833	11
0.43996	**1.2**	**0**	**AV6**	4.3996	12
0.49662	**1.3**	**0**	**AV7**	4.9662	13
0.55328	**1.4**	**0**	**AV8**	5.5328	14
0.65	**1.6**	**0**	**AV9**	6.5	16
0.7	**1.7**	**0**	**AV10**	7	17
0.75	**1.8**	**0**	**AV11**	7.5	18
0.8	**1.9**	**0**	**AV12**	8	19
0.86	**2.1**	**0**	**AV13**	8.6	21
0.87	**2.2**	**0**	**AV14**	8.7	22
0.88	**2.3**	**0**	**AV15**	8.8	23
0.89	**2.4**	**0**	**AV16**	8.9	24
0.88	**2.6**	**0**	**AV17**	8.8	26
0.86	**2.7**	**0**	**AV18**	8.6	27
0.84	**2.8**	**0**	**AV19**	8.4	28
0.82	**2.9**	**0**	**AV20**	8.2	29
0.85	**3.1**	**0**	**AV21**	8.5	31
0.9	**3.2**	**0**	**AV22**	9	32
0.95	**3.3**	**0**	**AV23**	9.5	33
1	**3.4**	**0**	**AV24**	10	34
1.14	**3.6**	**0**	**AV25**	11.4	36
1.23	**3.7**	**0**	**AV26**	12.3	37
1.32	**3.8**	**0**	**AV27**	13.2	38
1.41	**3.9**	**0**	**AV28**	14.1	39
1.52	**4.1**	**0**	**AV29**	15.2	41
1.54	**4.2**	**0**	**AV30**	15.4	42
1.56	**4.3**	**0**	**AV31**	15.6	43
1.58	**4.4**	**0**	**AV32**	15.8	44
1.62	**4.6**	**0**	**AV33**	16.2	46
1.64	**4.7**	**0**	**AV34**	16.4	47

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
1.66	**4.8**	**0**	**AV35**	16.6	48
1.68	**4.9**	**0**	**AV36**	16.8	49
1.69	**5.1**	**0**	**AV37**	16.9	51
1.68	**5.2**	**0**	**AV38**	16.8	52
1.67	**5.3**	**0**	**AV39**	16.7	53
1.66	**5.4**	**0**	**AV40**	16.6	54
1.6125	**5.6**	**0**	**AV41**	16.125	56
1.575	**5.7**	**0**	**AV42**	15.75	57
1.5375	**5.8**	**0**	**AV43**	15.375	58
1.54286	**6**	**0**	**AV44**	15.4286	60
1.58572	**6.1**	**0**	**AV45**	15.8572	61
1.62858	**6.2**	**0**	**AV46**	16.2858	62
1.7	**6.2**	**0**	**AET1**	17	62
1.8	**6.1**	**0**	**AET2**	18	61
1.9	**6**	**0**	**AET3**	19	60
0.2	**0.64737**	**0**	**AES1**	2	6.4737
0.3	**0.69474**	**0**	**AES2**	3	6.9474
0.4	**0.74211**	**0**	**AES3**	4	7.4211
0.5	**0.78948**	**0**	**AES4**	5	7.8948
0.6	**0.83685**	**0**	**AES5**	6	8.3685
0.7	**0.88422**	**0**	**AES6**	7	8.8422
0.8	**0.93159**	**0**	**AES7**	8	9.3159
0.9	**0.97896**	**0**	**AES8**	9	9.7896
1	**1.02633**	**0**	**AES9**	10	10.2633
1.1	**1.0737**	**0**	**AES10**	11	10.737
1.2	**1.12107**	**0**	**AES11**	12	11.2107
1.3	**1.16844**	**0**	**AES12**	13	11.6844
1.4	**1.21581**	**0**	**AES13**	14	12.1581
1.5	**1.26318**	**0**	**AES14**	15	12.6318
1.6	**1.31055**	**0**	**AES15**	16	13.1055
1.7	**1.35792**	**0**	**AES16**	17	13.5792
1.8	**1.40529**	**0**	**AES17**	18	14.0529
1.9	**1.45266**	**0**	**AES18**	19	14.5266
25	**5.2**	**0**	**NE1**	250	52
25	**5.1**	**0**	**NE2**	250	51
25	**5**	**0**	**NE3**	250	50
25	**4.9**	**0**	**NE4**	250	49
2.1	**5.88667**	**0**	**AT1**	21	58.8667
2.2	**5.87334**	**0**	**AT2**	22	58.7334
2.3	**5.86001**	**0**	**AT3**	23	58.6001
2.4	**5.84668**	**0**	**AT4**	24	58.4668

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
2.5	**5.83335**	**0**	**AT5**	25	58.3335
2.6	**5.82002**	**0**	**AT6**	26	58.2002
2.7	**5.80669**	**0**	**AT7**	27	58.0669
2.8	**5.8**	**0**	**AT8**	28	58
2.9	**5.8**	**0**	**AT9**	29	58
3	**5.8**	**0**	**AT10**	30	58
3.1	**5.8**	**0**	**AT11**	31	58
3.2	**5.8**	**0**	**AT12**	32	58
3.3	**5.8**	**0**	**AT13**	33	58
3.4	**5.8**	**0**	**AT14**	34	58
3.6	**5.8**	**0**	**BT1**	36	58
3.7	**5.8**	**0**	**BT2**	37	58
3.8	**5.8**	**0**	**BT3**	38	58
3.9	**5.8**	**0**	**BT4**	39	58
4	**5.8**	**0**	**BT5**	40	58
4.1	**5.8**	**0**	**BT6**	41	58
4.2	**5.8**	**0**	**BT7**	42	58
4.3	**5.79334**	**0**	**BT8**	43	57.9334
4.4	**5.78668**	**0**	**BT9**	44	57.8668
4.5	**5.78002**	**0**	**BT10**	45	57.8002
4.6	**5.77336**	**0**	**BT11**	46	57.7336
4.7	**5.7667**	**0**	**BT12**	47	57.667
4.8	**5.76004**	**0**	**BT13**	48	57.6004
4.9	**5.75338**	**0**	**BT14**	49	57.5338
5.1	**5.73667**	**0**	**CT1**	51	57.3667
5.2	**5.72334**	**0**	**CT2**	52	57.2334
5.3	**5.71001**	**0**	**CT3**	53	57.1001
5.4	**5.69668**	**0**	**CT4**	54	56.9668
5.5	**5.68335**	**0**	**CT5**	55	56.8335
5.6	**5.67002**	**0**	**CT6**	56	56.7002
5.7	**5.65669**	**0**	**CT7**	57	56.5669
5.8	**5.65**	**0**	**CT8**	58	56.5
5.9	**5.65**	**0**	**CT9**	59	56.5
6	**5.65**	**0**	**CT10**	60	56.5
6.1	**5.65**	**0**	**CT11**	61	56.5
6.2	**5.65**	**0**	**CT12**	62	56.5
6.3	**5.65**	**0**	**CT13**	63	56.5
6.4	**5.65**	**0**	**CT14**	64	56.5
6.6	**5.65666**	**0**	**DT1**	66	56.5666
6.7	**5.66332**	**0**	**DT2**	67	56.6332
6.8	**5.66998**	**0**	**DT3**	68	56.6998
6.9	**5.67664**	**0**	**DT4**	69	56.7664
7	**5.6833**	**0**	**DT5**	70	56.833
7.1	**5.68996**	**0**	**DT6**	71	56.8996
7.2	**5.69662**	**0**	**DT7**	72	56.9662

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
7.3	5.70328	0	DT8	73	57.0328
7.4	5.70994	0	DT9	74	57.0994
7.5	5.7166	0	DT10	75	57.166
7.6	5.72326	0	DT11	76	57.2326
7.7	5.72992	0	DT12	77	57.2992
7.8	5.73658	0	DT13	78	57.3658
7.9	5.74324	0	DT14	79	57.4324
8.1	5.75666	0	ET1	81	57.5666
8.2	5.76332	0	ET2	82	57.6332
8.3	5.76998	0	ET3	83	57.6998
8.4	5.77664	0	ET4	84	57.7664
8.5	5.7833	0	ET5	85	57.833
8.6	5.78996	0	ET6	86	57.8996
8.7	5.79662	0	ET7	87	57.9662
8.8	5.79	0	ET8	88	57.9
8.9	5.77	0	ET9	89	57.7
9	5.75	0	ET10	90	57.5
9.1	5.73	0	ET11	91	57.3
9.2	5.71	0	ET12	92	57.1
9.3	5.69	0	ET13	93	56.9
9.4	5.67	0	ET14	94	56.7
9.6	5.64334	0	FT1	96	56.4334
9.7	5.63668	0	FT2	97	56.3668
9.8	5.63002	0	FT3	98	56.3002
9.9	5.62336	0	FT4	99	56.2336
10	5.6167	0	FT5	100	56.167
10.1	5.61004	0	FT6	101	56.1004
10.2	5.60338	0	FT7	102	56.0338
10.3	5.59333	0	FT8	103	55.9333
10.4	5.58	0	FT9	104	55.8
10.5	5.56667	0	FT10	105	55.6667
10.6	5.55334	0	FT11	106	55.5334
10.7	5.54001	0	FT12	107	55.4001
10.8	5.52668	0	FT13	108	55.2668
10.9	5.51335	0	FT14	109	55.1335
11.1	5.52	0	GT1	111	55.2
11.2	5.54	0	GT2	112	55.4
11.3	5.56	0	GT3	113	55.6
11.4	5.58	0	GT4	114	55.8
11.6	5.64	0	GT5	116	56.4
11.7	5.68	0	GT6	117	56.8
11.8	5.72	0	GT7	118	57.2
11.9	5.76	0	GT8	119	57.6
12.1	5.82	0	GT9	121	58.2
12.2	5.84	0	GT10	122	58.4

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
12.3	**5.86**	**0**	**GT11**	123	58.6
12.4	**5.88**	**0**	**GT12**	124	58.8
12.6	**5.92**	**0**	**GT13**	126	59.2
12.7	**5.94**	**0**	**GT14**	127	59.4
12.8	**5.96**	**0**	**GT15**	128	59.6
12.9	**5.98**	**0**	**GT16**	129	59.8
13.1	**6.02**	**0**	**HT1**	131	60.2
13.2	**6.04**	**0**	**HT2**	132	60.4
13.3	**6.06**	**0**	**HT3**	133	60.6
13.4	**6.08**	**0**	**HT4**	134	60.8
13.6	**6.11**	**0**	**HT5**	136	61.1
13.7	**6.12**	**0**	**HT6**	137	61.2
13.8	**6.13**	**0**	**HT7**	138	61.3
13.9	**6.14**	**0**	**HT8**	139	61.4
14.1	**6.16**	**0**	**HT9**	141	61.6
14.2	**6.17**	**0**	**HT10**	142	61.7
14.3	**6.18**	**0**	**HT11**	143	61.8
14.4	**6.19**	**0**	**HT12**	144	61.9
14.6	**6.2**	**0**	**HT13**	146	62
14.7	**6.2**	**0**	**HT14**	147	62
14.8	**6.2**	**0**	**HT15**	148	62
14.9	**6.2**	**0**	**HT16**	149	62
15.1	**6.16**	**0**	**IT1**	151	61.6
15.2	**6.12**	**0**	**IT2**	152	61.2
15.3	**6.08**	**0**	**IT3**	153	60.8
15.4	**6.04**	**0**	**IT4**	154	60.4
15.6	**5.98**	**0**	**IT5**	156	59.8
15.7	**5.96**	**0**	**IT6**	157	59.6
15.8	**5.94**	**0**	**IT7**	158	59.4
15.9	**5.92**	**0**	**IT8**	159	59.2
16.1	**5.88**	**0**	**IT9**	161	58.8
16.2	**5.86**	**0**	**IT10**	162	58.6
16.3	**5.84**	**0**	**IT11**	163	58.4
16.4	**5.82**	**0**	**IT12**	164	58.2
16.6	**5.78**	**0**	**IT13**	166	57.8
16.7	**5.76**	**0**	**IT14**	167	57.6
16.8	**5.74**	**0**	**IT15**	168	57.4
16.9	**5.72**	**0**	**IT16**	169	57.2
17.1	**5.7**	**0**	**JT1**	171	57
17.2	**5.7**	**0**	**JT2**	172	57
17.3	**5.7**	**0**	**JT3**	173	57
17.4	**5.7**	**0**	**JT4**	174	57
17.6	**5.67**	**0**	**JT5**	176	56.7
17.7	**5.64**	**0**	**JT6**	177	56.4
17.8	**5.61**	**0**	**JT7**	178	56.1

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
17.9	**5.58**	**0**	**JT8**	179	55.8
18.1	**5.54**	**0**	**JT9**	181	55.4
18.2	**5.53**	**0**	**JT10**	182	55.3
18.3	**5.52**	**0**	**JT11**	183	55.2
18.4	**5.51**	**0**	**JT12**	184	55.1
18.6	**5.5**	**0**	**KT1**	186	55
18.7	**5.5**	**0**	**KT2**	187	55
18.8	**5.5**	**0**	**KT3**	188	55
18.9	**5.5**	**0**	**KT4**	189	55
19.1	**5.49**	**0**	**KT5**	191	54.9
19.2	**5.48**	**0**	**KT6**	192	54.8
19.3	**5.47**	**0**	**KT7**	193	54.7
19.4	**5.46**	**0**	**KT8**	194	54.6
19.6	**5.48**	**0**	**KT9**	196	54.8
19.7	**5.51**	**0**	**KT10**	197	55.1
19.8	**5.54**	**0**	**KT11**	198	55.4
19.9	**5.57**	**0**	**KT12**	199	55.7
20.1	**5.64**	**0**	**LT1**	201	56.4
20.2	**5.68**	**0**	**LT2**	202	56.8
20.3	**5.72**	**0**	**LT3**	203	57.2
20.4	**5.76**	**0**	**LT4**	204	57.6
20.6	**5.83**	**0**	**LT5**	206	58.3
20.7	**5.86**	**0**	**LT6**	207	58.6
20.8	**5.89**	**0**	**LT7**	208	58.9
20.9	**5.92**	**0**	**LT8**	209	59.2
21.1	**5.98**	**0**	**LT9**	211	59.8
21.2	**6.01**	**0**	**LT10**	212	60.1
21.3	**6.04**	**0**	**LT11**	213	60.4
21.4	**6.07**	**0**	**LT12**	214	60.7
21.6	**6.06**	**0**	**LT13**	216	60.6
21.7	**6.02**	**0**	**LT14**	217	60.2
21.8	**5.98**	**0**	**LT15**	218	59.8
21.9	**5.94**	**0**	**LT16**	219	59.4
22.1	**5.9**	**0**	**MT1**	221	59
22.2	**5.9**	**0**	**MT2**	222	59
22.3	**5.9**	**0**	**MT3**	223	59
22.4	**5.9**	**0**	**MT4**	224	59
22.6	**5.87**	**0**	**MT5**	226	58.7
22.7	**5.84**	**0**	**MT6**	227	58.4
22.8	**5.81**	**0**	**MT7**	228	58.1
22.9	**5.78**	**0**	**MT8**	229	57.8
23.1	**5.74**	**0**	**MT9**	231	57.4
23.2	**5.73**	**0**	**MT10**	232	57.3
23.3	**5.72**	**0**	**MT11**	233	57.2
23.4	**5.71**	**0**	**MT12**	234	57.1

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
23.6	5.7	0	MT13	236	57
23.7	5.7	0	MT14	237	57
23.8	5.7	0	MT15	238	57
23.9	5.7	0	MT16	239	57
24.1	5.63	0	NT1	241	56.3
24.2	5.56	0	NT2	242	55.6
24.3	5.49	0	NT3	243	54.9
24.4	5.42	0	NT4	244	54.2
24.6	5.33	0	NT5	246	53.3
24.7	5.31	0	NT6	247	53.1
24.8	5.29	0	NT7	248	52.9
24.9	5.27	0	NT8	249	52.7
2.1	1.53333	0	AS1	21	15.3333
2.2	1.56666	0	AS2	22	15.6666
2.3	1.59999	0	AS3	23	15.9999
2.4	1.63332	0	AS4	24	16.3332
2.5	1.66665	0	AS5	25	16.6665
2.6	1.69998	0	AS6	26	16.9998
2.7	1.73331	0	AS7	27	17.3331
2.8	1.72334	0	AS8	28	17.23335
2.9	1.67	0	AS9	29	16.7
3	1.61668	0	AS10	30	16.1668
3.1	1.56335	0	AS11	31	15.6335
3.2	1.51002	0	AS12	32	15.1002
3.3	1.45669	0	AS13	33	14.5669
3.4	1.40336	0	AS14	34	14.0336
3.6	1.41666	0	BS1	36	14.1666
3.7	1.48332	0	BS2	37	14.8332
3.8	1.54998	0	BS3	38	15.4998
3.9	1.61664	0	BS4	39	16.1664
4	1.6833	0	BS5	40	16.833
4.1	1.74996	0	BS6	41	17.4996
4.2	1.81662	0	BS7	42	18.1662
4.3	1.85	0	BS8	43	18.5
4.4	1.85	0	BS9	44	18.5
4.5	1.85	0	BS10	45	18.5
4.6	1.85	0	BS11	46	18.5
4.7	1.85	0	BS12	47	18.5
4.8	1.85	0	BS13	48	18.5
4.9	1.85	0	BS14	49	18.5
5.1	1.87	0	CS1	51	18.7
5.2	1.89	0	CS2	52	18.9
5.3	1.91	0	CS3	53	19.1
5.4	1.93	0	CS4	54	19.3

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
5.5	**1.95**	**0**	**CS5**	55	19.5
5.6	**1.97**	**0**	**CS6**	56	19.7
5.7	**1.99**	**0**	**CS7**	57	19.9
5.8	**2.00667**	**0**	**CS8**	58	20.0667
5.9	**2.02**	**0**	**CS9**	59	20.2
6	**2.03333**	**0**	**CS10**	60	20.3333
6.1	**2.04666**	**0**	**CS11**	61	20.4666
6.2	**2.05999**	**0**	**CS12**	62	20.5999
6.3	**2.07332**	**0**	**CS13**	63	20.7332
6.4	**2.08665**	**0**	**CS14**	64	20.8665
6.6	**2.13333**	**0**	**DS1**	66	21.3333
6.7	**2.16666**	**0**	**DS2**	67	21.6666
6.8	**2.19999**	**0**	**DS3**	68	21.9999
6.9	**2.23332**	**0**	**DS4**	69	22.3332
7	**2.26665**	**0**	**DS5**	70	22.6665
7.1	**2.29998**	**0**	**DS6**	71	22.9998
7.2	**2.33331**	**0**	**DS7**	72	23.3331
7.3	**2.36**	**0**	**DS8**	73	23.6
7.4	**2.38**	**0**	**DS9**	74	23.8
7.5	**2.4**	**0**	**DS10**	75	24
7.6	**2.42**	**0**	**DS11**	76	24.2
7.7	**2.44**	**0**	**DS12**	77	24.4
7.8	**2.46**	**0**	**DS13**	78	24.6
7.9	**2.48**	**0**	**DS14**	79	24.8
8.1	**2.52666**	**0**	**ES1**	81	25.2666
8.2	**2.55332**	**0**	**ES2**	82	25.5332
8.3	**2.57998**	**0**	**ES3**	83	25.7998
8.4	**2.60664**	**0**	**ES4**	84	26.0664
8.5	**2.6333**	**0**	**ES5**	85	26.333
8.6	**2.65996**	**0**	**ES6**	86	26.5996
8.7	**2.68662**	**0**	**ES7**	87	26.8662
8.8	**2.71333**	**0**	**ES8**	88	27.1333
8.9	**2.74**	**0**	**ES9**	89	27.4
9	**2.76667**	**0**	**ES10**	90	27.6667
9.1	**2.79334**	**0**	**ES11**	91	27.9334
9.2	**2.82001**	**0**	**ES12**	92	28.2001
9.3	**2.84668**	**0**	**ES13**	93	28.4668
9.4	**2.87335**	**0**	**ES14**	94	28.7335
9.6	**2.91333**	**0**	**FS1**	96	29.1333
9.7	**2.92666**	**0**	**FS2**	97	29.2666
9.8	**2.93999**	**0**	**FS3**	98	29.3999
9.9	**2.95332**	**0**	**FS4**	99	29.5332
10	**2.96665**	**0**	**FS5**	100	29.6665
10.1	**2.97998**	**0**	**FS6**	101	29.7998
10.2	**2.99331**	**0**	**FS7**	102	29.9331

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
10.3	**3.00667**	**0**	**FS8**	103	30.0667
10.4	**3.02**	**0**	**FS9**	104	30.2
10.5	**3.03333**	**0**	**FS10**	105	30.3333
10.6	**3.04666**	**0**	**FS11**	106	30.4666
10.7	**3.05999**	**0**	**FS12**	107	30.5999
10.8	**3.07332**	**0**	**FS13**	108	30.7332
10.9	**3.08665**	**0**	**FS14**	109	30.8665
11.1	**3.11**	**0**	**GS1**	111	31.1
11.2	**3.12**	**0**	**GS2**	112	31.2
11.3	**3.13**	**0**	**GS3**	113	31.3
11.4	**3.14**	**0**	**GS4**	114	31.4
11.6	**3.26**	**0**	**GS5**	116	32.6
11.7	**3.37**	**0**	**GS6**	117	33.7
11.8	**3.48**	**0**	**GS7**	118	34.8
11.9	**3.59**	**0**	**GS8**	119	35.9
12.1	**3.66**	**0**	**GS9**	121	36.6
12.2	**3.62**	**0**	**GS10**	122	36.2
12.3	**3.58**	**0**	**GS11**	123	35.8
12.4	**3.54**	**0**	**GS12**	124	35.4
12.6	**3.52**	**0**	**GS13**	126	35.2
12.7	**3.54**	**0**	**GS14**	127	35.4
12.8	**3.56**	**0**	**GS15**	128	35.6
12.9	**3.58**	**0**	**GS16**	129	35.8
13.1	**3.67**	**0**	**HS1**	131	36.7
13.2	**3.74**	**0**	**HS2**	132	37.4
13.3	**3.81**	**0**	**HS3**	133	38.1
13.4	**3.88**	**0**	**HS4**	134	38.8
13.6	**4**	**0**	**HS5**	136	40
13.7	**4.05**	**0**	**HS6**	137	40.5
13.8	**4.1**	**0**	**HS7**	138	41
13.9	**4.15**	**0**	**HS8**	139	41.5
14.1	**4.12**	**0**	**HS9**	141	41.2
14.2	**4.04**	**0**	**HS10**	142	40.4
14.3	**3.96**	**0**	**HS11**	143	39.6
14.4	**3.88**	**0**	**HS12**	144	38.8
14.6	**3.77**	**0**	**HS13**	146	37.7
14.7	**3.74**	**0**	**HS14**	147	37.4
14.8	**3.71**	**0**	**HS15**	148	37.1
14.9	**3.68**	**0**	**HS16**	149	36.8
15.1	**3.7**	**0**	**IS1**	151	37
15.2	**3.75**	**0**	**IS2**	152	37.5
15.3	**3.8**	**0**	**IS3**	153	38
15.4	**3.85**	**0**	**IS4**	154	38.5
15.6	**3.92**	**0**	**IS5**	156	39.2
15.7	**3.94**	**0**	**IS6**	157	39.4

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
15.8	**3.96**	**0**	**IS7**	158	39.6
15.9	**3.98**	**0**	**IS8**	159	39.8
16.1	**3.98**	**0**	**IS9**	161	39.8
16.2	**3.96**	**0**	**IS10**	162	39.6
16.3	**3.94**	**0**	**IS11**	163	39.4
16.4	**3.92**	**0**	**IS12**	164	39.2
16.6	**3.86**	**0**	**IS13**	166	38.6
16.7	**3.82**	**0**	**IS14**	167	38.2
16.8	**3.78**	**0**	**IS15**	168	37.8
16.9	**3.74**	**0**	**IS16**	169	37.4
17.1	**3.74**	**0**	**JS1**	171	37.4
17.2	**3.78**	**0**	**JS2**	172	37.8
17.3	**3.82**	**0**	**JS3**	173	38.2
17.4	**3.86**	**0**	**JS4**	174	38.6
17.6	**3.9**	**0**	**JS5**	176	39
17.7	**3.9**	**0**	**JS6**	177	39
17.8	**3.9**	**0**	**JS7**	178	39
17.9	**3.9**	**0**	**JS8**	179	39
18.1	**3.88**	**0**	**JS9**	181	38.8
18.2	**3.86**	**0**	**JS10**	182	38.6
18.3	**3.84**	**0**	**JS11**	183	38.4
18.4	**3.82**	**0**	**JS12**	184	38.2
18.6	**3.83**	**0**	**KS1**	186	38.3
18.7	**3.86**	**0**	**KS2**	187	38.6
18.8	**3.89**	**0**	**KS3**	188	38.9
18.9	**3.92**	**0**	**KS4**	189	39.2
19.1	**3.97**	**0**	**KS5**	191	39.7
19.2	**3.99**	**0**	**KS6**	192	39.9
19.3	**4.01**	**0**	**KS7**	193	40.1
19.4	**4.03**	**0**	**KS8**	194	40.3
19.6	**4.04**	**0**	**KS9**	196	40.4
19.7	**4.03**	**0**	**KS10**	197	40.3
19.8	**4.02**	**0**	**KS11**	198	40.2
19.9	**4.01**	**0**	**KS12**	199	40.1
20.1	**4.01**	**0**	**LS1**	201	40.1
20.2	**4.02**	**0**	**LS2**	202	40.2
20.3	**4.03**	**0**	**LS3**	203	40.3
20.4	**4.04**	**0**	**LS4**	204	40.4
20.6	**4.1**	**0**	**LS5**	206	41
20.7	**4.15**	**0**	**LS6**	207	41.5
20.8	**4.2**	**0**	**LS7**	208	42
20.9	**4.25**	**0**	**LS8**	209	42.5
21.1	**4.34**	**0**	**LS9**	211	43.4
21.2	**4.38**	**0**	**LS10**	212	43.8
21.3	**4.42**	**0**	**LS11**	213	44.2

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
21.4	**4.46**	**0**	**LS12**	214	44.6
21.6	**4.51**	**0**	**LS13**	216	45.1
21.7	**4.52**	**0**	**LS14**	217	45.2
21.8	**4.53**	**0**	**LS15**	218	45.3
21.9	**4.54**	**0**	**LS16**	219	45.4
22.1	**4.59**	**0**	**MS1**	221	45.9
22.2	**4.63**	**0**	**MS2**	222	46.3
22.3	**4.67**	**0**	**MS3**	223	46.7
22.4	**4.71**	**0**	**MS4**	224	47.1
22.6	**4.75**	**0**	**MS5**	226	47.5
22.7	**4.75**	**0**	**MS6**	227	47.5
22.8	**4.75**	**0**	**MS7**	228	47.5
22.9	**4.75**	**0**	**MS8**	229	47.5
23.1	**4.77**	**0**	**MS9**	231	47.7
23.2	**4.79**	**0**	**MS10**	232	47.9
23.3	**4.81**	**0**	**MS11**	233	48.1
23.4	**4.83**	**0**	**MS12**	234	48.3
23.6	**4.86**	**0**	**MS13**	236	48.6
23.7	**4.87**	**0**	**MS14**	237	48.7
23.8	**4.88**	**0**	**MS15**	238	48.8
23.9	**4.89**	**0**	**MS16**	239	48.9
24.1	**4.89**	**0**	**NS1**	241	48.9
24.2	**4.88**	**0**	**NS2**	242	48.8
24.3	**4.87**	**0**	**NS3**	243	48.7
24.4	**4.86**	**0**	**NS4**	244	48.6
24.6	**4.84**	**0**	**NS5**	246	48.4
24.7	**4.83**	**0**	**NS6**	247	48.3
24.8	**4.82**	**0**	**NS7**	248	48.2
24.9	**4.81**	**0**	**NS8**	249	48.1

Table 3B. Catfish Reception Hall Spring Vent 2 XYZ Grid Data, September 21, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
1.5	**1**	**0.43**	**1**	15	10
2.5	**1**	**0.7**	**2**	25	10
3	**1**	**0.74**	**3**	30	10
3.5	**1**	**0.67**	**4**	35	10
4	**1**	**0.56**	**5**	40	10
5	**1**	**0.82**	**6**	50	10
5.5	**1**	**0.73**	**7**	55	10
6	**1**	**0.76**	**8**	60	10
6.5	**1**	**0.65**	**9**	65	10
7.3	**1**	**0.45**	**10**	73	10
0.5	**1**	**0**	**A**	5	10
1.5	**1.1**	**0**	**BT**	15	11
2	**1.05**	**0**	**CT**	20	10.5
2.5	**1.05**	**0**	**DT**	25	10.5
3	**1.2**	**0**	**ET**	30	12
3.5	**1.2**	**0**	**FT**	35	12
4	**1.1**	**0**	**GT**	40	11
4.5	**1**	**0**	**HT**	45	10
5	**1.3**	**0**	**IT**	50	13
5.5	**1.2**	**0**	**JT**	55	12
6	**1.3**	**0**	**KT**	60	13
6.5	**1.4**	**0**	**LT**	65	14
7	**1.4**	**0**	**MT**	70	14
7.3	**1.15**	**0**	**NT**	73	11.5
8	**1**	**0**	**O**	80	10
1.5	**0.8**	**0**	**BS**	15	8
2	**0.75**	**0**	**CS**	20	7.5
2.5	**0.8**	**0**	**DS**	25	8
3	**0.8**	**0**	**ES**	30	8
3.5	**0.7**	**0**	**FS**	35	7
4	**0.65**	**0**	**GS**	40	6.5
4.5	**0.55**	**0**	**HS**	45	5.5
5	**0.45**	**0**	**IS**	50	4.5
5.5	**0.6**	**0**	**JS**	55	6
6	**0.9**	**0**	**KS**	60	9
6.5	**0.9**	**0**	**LS**	65	9
7	**1**	**0**	**MS**	70	10
7.3	**0.85**	**0**	**NS**	73	8.5
0.6	**1.01**	**0**	**AT1**	6	10.1
0.7	**1.02**	**0**	**AT2**	7	10.2
0.8	**1.03**	**0**	**AT3**	8	10.3
0.9	**1.04**	**0**	**AT4**	9	10.4
1	**1.05**	**0**	**AT5**	10	10.5
1.1	**1.06**	**0**	**AT6**	11	10.6

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
1.2	**1.07**	**0**	**AT7**	12	10.7
1.3	**1.08**	**0**	**AT8**	13	10.8
1.4	**1.09**	**0**	**AT9**	14	10.9
1.6	**1.09**	**0**	**BT1**	16	10.9
1.7	**1.08**	**0**	**BT2**	17	10.8
1.8	**1.07**	**0**	**BT3**	18	10.7
1.9	**1.06**	**0**	**BT4**	19	10.6
2.1	**1.05**	**0**	**CT1**	21	10.5
2.2	**1.05**	**0**	**CT2**	22	10.5
2.3	**1.05**	**0**	**CT3**	23	10.5
2.4	**1.05**	**0**	**CT4**	24	10.5
2.6	**1.08**	**0**	**DT1**	26	10.8
2.7	**1.11**	**0**	**DT2**	27	11.1
2.8	**1.14**	**0**	**DT3**	28	11.4
2.9	**1.17**	**0**	**DT4**	29	11.7
3.1	**1.2**	**0**	**ET1**	31	12
3.2	**1.2**	**0**	**ET2**	32	12
3.3	**1.2**	**0**	**ET3**	33	12
3.4	**1.2**	**0**	**ET4**	34	12
	1.18				
3.6	**1.16**	**0**	**FT1**	36	11.8
3.7	**1.14**	**0**	**FT2**	37	11.6
3.8	**1.12**	**0**	**FT3**	38	11.4
3.9	**1.12**	**0**	**FT4**	39	11.2
4.1	**1.08**	**0**	**GT1**	41	10.8
4.2	**1.06**	**0**	**GT2**	42	10.6
4.3	**1.04**	**0**	**GT3**	43	10.4
4.4	**1.02**	**0**	**GT4**	44	10.2
4.6	**1.06**	**0**	**HT1**	46	10.6
4.7	**1.12**	**0**	**HT2**	47	11.2
4.8	**1.18**	**0**	**HT3**	48	11.8
4.9	**1.24**	**0**	**HT4**	49	12.4
5.1	**1.28**	**0**	**IT1**	51	12.8
5.2	**1.26**	**0**	**IT2**	52	12.6
5.3	**1.24**	**0**	**IT3**	53	12.4
5.4	**1.22**	**0**	**IT4**	54	12.2
5.6	**1.22**	**0**	**JT1**	56	12.2
5.7	**1.24**	**0**	**JT2**	57	12.4
5.8	**1.26**	**0**	**JT3**	58	12.6
5.9	**1.28**	**0**	**JT4**	59	12.8

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
6.1	**1.32**	**0**	**KT1**	61	13.2
6.2	**1.34**	**0**	**KT2**	62	13.4
6.3	**1.36**	**0**	**KT3**	63	13.6
6.4	**1.38**	**0**	**KT4**	64	13.8
6.6	**1.4**	**0**	**LT1**	66	14
6.7	**1.4**	**0**	**LT2**	67	14
6.8	**1.4**	**0**	**LT3**	68	14
6.9	**1.4**	**0**	**LT4**	69	14
7.1	**1.31667**	**0**	**MT1**	71	13.1667
7.2	**1.23334**	**0**	**MT2**	72	12.3334
7.4	**1.12857**	**0**	**NT1**	74	11.2857
7.5	**1.10714**	**0**	**NT2**	75	11.0714
7.6	**1.08571**	**0**	**NT3**	76	10.8571
7.7	**1.06428**	**0**	**NT4**	77	10.6428
7.8	**1.04285**	**0**	**NT5**	78	10.4285
7.9	**1.02142**	**0**	**NT6**	79	10.2142
0.6	**0.98**	**0**	**AS1**	6	9.8
0.7	**0.96**	**0**	**AS2**	7	9.6
0.8	**0.94**	**0**	**AS3**	8	9.4
0.9	**0.92**	**0**	**AS4**	9	9.2
1	**0.9**	**0**	**AS5**	10	9
1.1	**0.88**	**0**	**AS6**	11	8.8
1.2	**0.86**	**0**	**AS7**	12	8.6
1.3	**0.84**	**0**	**AS8**	13	8.4
1.4	**0.82**	**0**	**AS9**	14	8.2
1.6	**0.79**	**0**	**BS1**	16	7.9
1.7	**0.78**	**0**	**BS2**	17	7.8
1.8	**0.77**	**0**	**BS3**	18	7.7
1.9	**0.76**	**0**	**BS4**	19	7.6
2.1	**0.76**	**0**	**CS1**	21	7.6
2.2	**0.77**	**0**	**CS2**	22	7.7
2.3	**0.78**	**0**	**CS3**	23	7.8
2.4	**0.79**	**0**	**CS4**	24	7.9
2.6	**0.8**	**0**	**DS1**	26	8
2.7	**0.8**	**0**	**DS2**	27	8
2.8	**0.8**	**0**	**DS3**	28	8
2.9	**0.8**	**0**	**DS4**	29	8
3.1	**0.78**	**0**	**ES1**	31	7.8
3.2	**0.76**	**0**	**ES2**	32	7.6

Table 3B. Catfish Reception Hall Spring Vent 2 XYZ Grid Data, September 21, 2006.

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
3.3	**0.74**	**0**	**ES3**	33	7.4
3.4	**0.72**	**0**	**ES4**	34	7.2
0					
3.6	**0.69**	**0**	**FS1**	36	6.9
3.7	**0.68**	**0**	**FS2**	37	6.8
3.8	**0.67**	**0**	**FS3**	38	6.7
3.9	**0.66**	**0**	**FS4**	39	6.6
4.1	**0.63**	**0**	**GS1**	41	6.3
4.2	**0.61**	**0**	**GS2**	42	6.1
4.3	**0.59**	**0**	**GS3**	43	5.9
4.4	**0.57**	**0**	**GS4**	44	5.7
4.6	**0.53**	**0**	**HS1**	46	5.3
4.7	**0.51**	**0**	**HS2**	47	5.1
4.8	**0.49**	**0**	**HS3**	48	4.9
4.9	**0.47**	**0**	**HS4**	49	4.7
0					
5.1	**0.48**	**0**	**IS1**	51	4.8
5.2	**0.51**	**0**	**IS2**	52	5.1
5.3	**0.54**	**0**	**IS3**	53	5.4
5.4	**0.57**	**0**	**IS4**	54	5.7
5.6	**0.66**	**0**	**JS1**	56	6.6
5.7	**0.72**	**0**	**JS2**	57	7.2
5.8	**0.78**	**0**	**JS3**	58	7.8
5.9	**0.84**	**0**	**JS4**	59	8.4
6.1	**0.9**	**0**	**KS1**	61	9
6.2	**0.9**	**0**	**KS2**	62	9
6.3	**0.9**	**0**	**KS3**	63	9
6.4	**0.9**	**0**	**KS4**	64	9
	0				
6.6	**0.92**	**0**	**LS1**	66	9.2
6.7	**0.94**	**0**	**LS2**	67	9.4
6.8	**0.96**	**0**	**LS3**	68	9.6
6.9	**0.98**	**0**	**LS4**	69	9.8
7.1	**0.95**	**0**	**MS1**	71	9.5
7.2	**0.9**	**0**	**MS2**	72	9
7.4	**0.87143**	**0**	**NS1**	74	8.7143
7.5	**0.89286**	**0**	**NS2**	75	8.9286
7.6	**0.91429**	**0**	**NS3**	76	9.1429
7.7	**0.93572**	**0**	**NS4**	77	9.3572
7.8	**0.95715**	**0**	**NS5**	78	9.5715
7.9	**0.97858**	**0**	**NS6**	79	9.7858

Table 3B. Catfish Reception Hall Spring Vent 2 XYZ Grid Data, September 21, 2006.

Table 3C. Catfish Reception Hall Spring Vent 3 XYZ Grid Data, September 21, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
0.5	**0.5**	**0.65**	**1**	5	5
0.1	**0.8**	**0**	**A**	1	8
0.2	**0.2**	**0**	**B**	2	2
0.6	**0.1**	**0**	**C**	6	1
1	**0.8**	**0**	**D**	10	8
0.11667	**0.7**	**0**	**A1**	1.1667	7
0.13334	**0.6**	**0**	**A2**	1.3334	6
0.15	**0.5**	**0**	**A3**	1.5	5
0.16667	**0.4**	**0**	**A4**	1.6667	4
0.18333	**0.3**	**0**	**A5**	1.8333	3
0.3	**0.175**	**0**	**B1**	3	1.75
0.4	**0.15**	**0**	**B2**	4	1.5
0.5	**0.125**	**0**	**B3**	5	1.25
0.65714	**0.2**	**0**	**C1**	6.5714	2
0.71428	**0.3**	**0**	**C2**	7.1428	3
0.77142	**0.4**	**0**	**C3**	7.7142	4
0.82856	**0.5**	**0**	**C4**	8.2856	5
0.88568	**0.6**	**0**	**C5**	8.8568	6
0.94282	**0.7**	**0**	**C6**	9.4282	7
0.9	**0.8**	**0**	**D1**	9	8
0.8	**0.8**	**0**	**D2**	8	8
0.7	**0.8**	**0**	**D3**	7	8
0.6	**0.8**	**0**	**D4**	6	8
0.5	**0.8**	**0**	**D5**	5	8
0.4	**0.8**	**0**	**D6**	4	8
0.3	**0.8**	**0**	**D7**	3	8
0.2	**0.8**	**0**	**D8**	2	8

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ____________ Time Constant: ____________

SensorSer # N/A

Type of Reading

Velocity:

X FPS

_ CMS

_ ____

Level:

_ IN

_ CM

X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: [signature] Date: 18 Apr 2006

QA Technician: [signature] Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement
4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

Discharge Measurement: Christmas Tree Spring, Marion County, Florida; September 29, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
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Discharge Measurement: Christmas Tree Spring, Marion County, Florida; September 29, 2006

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Results of Discharge Measurements of Christmas Tree Spring, Marion County, Florida; September 29, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Christmas Tree Spring on September 29, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Christmas Tree Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

Christmas Tree Spring is located in a cove on the north side of the Silver River, south of the main stage area. It consists of a cluster of vents within a depression that surround a sunken boat. A second sunken boat lies along the west bank. A line of vents begins at the north end of the cove, at about 15 feet deep, runs for 20 feet to the southeast, and then angles to the south for 18 feet, ending at 13 feet of depth. This vent line accounts for most of the discharge from this basin, and contains debris and considerable aquatic vegetation. West of the vent line, and near the bow of the sunken boat is a roughly circular vent about 15 feet deep. Another vent lies west of the sunken boat at 14 feet of depth. Discharge was also observed near the second sunken boat on the western edge of the basin. See Figure 1.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter.

One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Christmas Tree Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Christmas Tree Spring on September 29, 2006 was 4.18 CFS (cubic feet per second). This result is also expressed as 1878 GPM (gallons per minute) or 2.705 MGD (million gallons per day), see Table 1. Three readings were made at each of six vents, for a total of eighteen (18) readings. Individual point velocity readings ranged from 0.47 to 1.51 feet per second (fps), with an overall average station reading of 1.02 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 14 to 16 feet. The measurements commenced at about 12:42 hours and were completed by 13:20 hours.

UNDERWATER DISCHARGE MEASUREMENT								**PAGE 1 of 2**
Location:	**CHRISTMAS TREE SPRING**			Date:	**September 29, 2006**			
	Silver Springs Group,			Time Start:	12:42			
	Marion County, Florida			Time End:	13:20			
Personnel:	Peter Butt, Mark Long							
Method:	Vent Discharge Capture Device		(0.49' Diameter)					
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe							
Calculation Method: Discharge = V x *pi* x r^2								
Measurement Periods:		60 seconds						
Christmas Tree Spring ESTIMATED Discharge:								
(Combined Vents and Vent Segments)			**Vent 1**	**Vent 2**	**Vent 3**	**Vent 4**	**Vent 5**	**Vent 6**
CFS	**4.18**		**0.226**	**0.155**	**0.123**	**0.272**	**0.425**	**0.090**
MGD	**2.705**		**0.146**	**0.100**	**0.079**	**0.176**	**0.275**	**0.058**
GPM	**1878**		**102**	**69**	**55**	**122**	**191**	**40**
		(Multiplier:)					(1.5)	
			Vent Segment	**Vent Segment**	**Vent Segment**			
			V1-V2	**V2-V3**	**V3-V4**			
		CFS	**0.762**	**0.555**	**1.577**			
		MGD	**0.493**	**0.358**	**1.019**			
		GPM	**342**	**249**	**708**			
		(Length:)	(8')	(8')	(16')			
		(Multiplier:)	(4)	(4)	(8)			
Christmas Tree Spring Measured Discharge:			**Vent 1**	**Vent 2**	**Vent 3**	**Vent 4**	**Vent 5**	**Vent 6**
CFS	**4.04**		**0.226**	**0.155**	**0.123**	**0.272**	**0.284**	**0.090**
MGD	**2.613**		**0.146**	**0.100**	**0.079**	**0.176**	**0.183**	**0.058**
GPM	**1815**	All Vents:	**102**	**69**	**55**	**122**	**127**	**40**
Avg. Point Velocity (ft/sec):		1.02	1.20	0.82	0.65	1.44	1.50	0.48
Vent Depth (feet deep):			14	14	14	14	16	14

Table 1. Page 1 of 2. Discharge of Christmas Tree Spring, Marion County, Florida on September 29, 2006. Data record and calculation of discharge measurement.

UNDERWATER DISCHARGE MEASUREMENT					**PAGE 2 of 2**	
Location:	**CHRISTMAS TREE SPRING**			Date:	**September 29, 2006**	
	Silver Springs Group, Marion County, Florida					
Velocity Readings:		(All velocity readings in feet per second.)				
Vent 1		**Vent 2**		**Vent 3**		
North Vent (under log)		East of Vent 1		East of Vent 1 (at 'angle')		
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity	
1	1.19	1	0.82	1	0.71	
2	1.2	2	0.82	2	0.63	
3	1.21	3	0.82	3	0.61	
Average:	1.20	Average:	0.82	Average:	0.65	
Discharge:	**0.226**	**Discharge:**	**0.155**	**Discharge:**	**0.123**	
Vent 4		**Vent 5**		**Vent 6**		
South Vent (end)		West Vent		Far West Vent (near barge)		
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity	
1	1.44	1	1.5	1	0.48	
2	1.44	2	1.51	2	0.47	
3	1.44	3	1.5	3	0.48	
Average:	1.44	Average:	1.50	Average:	0.48	
Discharge:	**0.272**	Discharge:	0.284	**Discharge:**	**0.090**	
		Multiplier:	1.5			
		Est. Discharge:	**0.425**			
Vent Segment V1-V2		**Vent Segment V2-V3**		**Vent Segment V3-V4**		
Vent Line in dense vegetation		Vent Line in dense vegetation		Vent Line in dense vegetation		
V1/V2 PV Avg:	1.01	V2/V3 PV Avg:	0.74	V3/V4 PV Avg:	1.05	
Length:	8'	Length:	8'	Length:	16'	
Multiplier:	4	Multiplier:	4	Multiplier:	8	
Est. Discharge:	**0.762**	**Est. Discharge:**	**0.555**	**Est. Discharge:**	**1.577**	
Segment Estimated Discharges Calculation:						
Averaged End Point Velocity X Multiplier X VDCD X-section Area.						
Multiplier based on segment length.						

Table 1. Page 2 of 2. Discharge of Christmas Tree Spring, Marion County, Florida on September 29, 2006. Data record and calculation of discharge measurement.

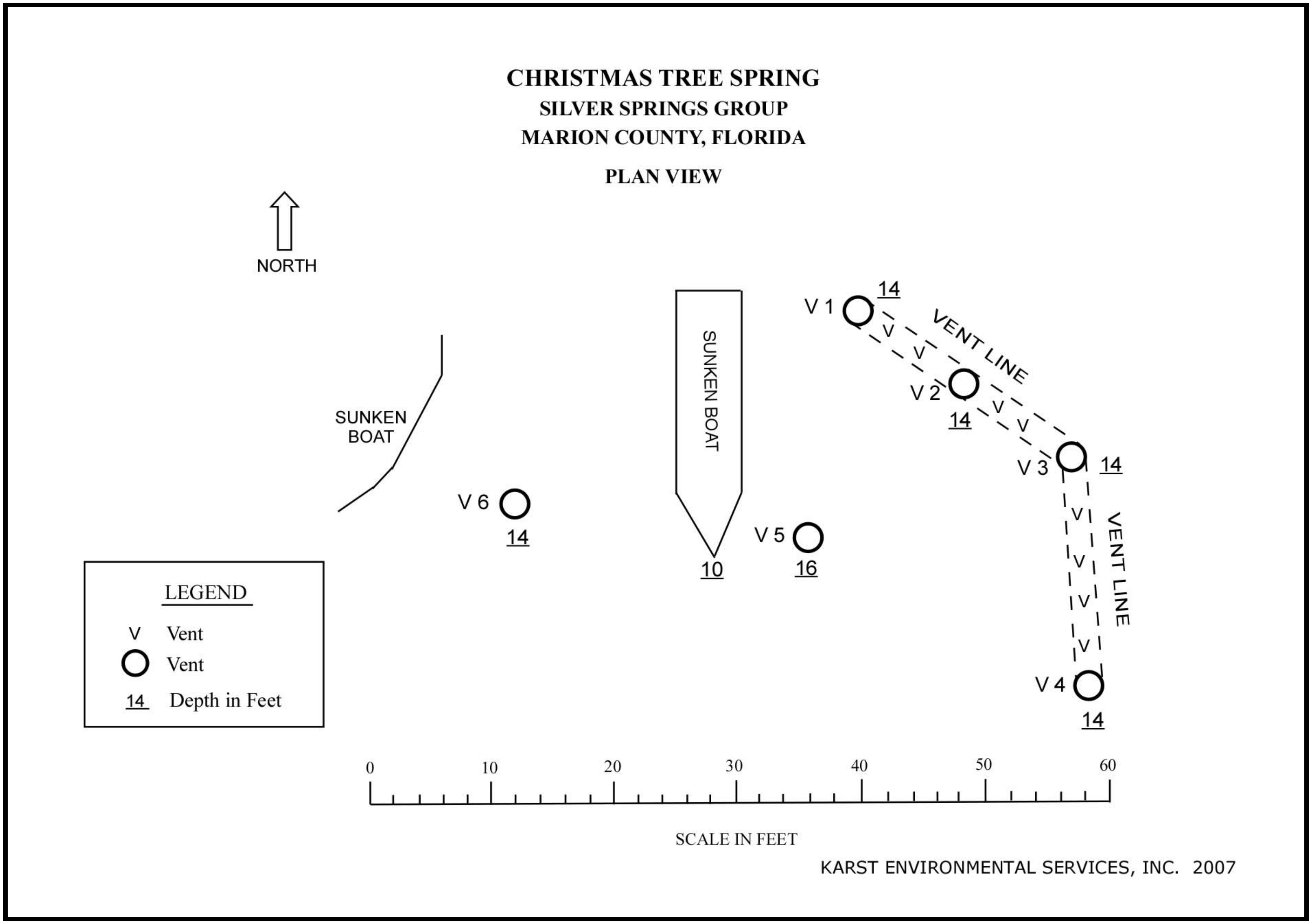

Figure 1. Map of Christmas Tree Spring.

CALIBRATION CERTIFICATE

Model: 2ØØØ-21 Serial Number: 2ØØ2679

Unit Gain Ratio: ____________ Time Constant: ________

SensorSer # N/A

Type of Reading

Velocity:

X FPS

_ CMS

_ ____

Level:

_ IN

_ CM

X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.ØØ	N/A
Measured:	Ø.ØØ	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: [signature] Date: 18 Apr 2006

QA Technician: [signature] Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY

A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

P/N 101001 301

Discharge Measurement:
Devil's Kitchen Spring A,
Marion County, Florida;
September 28, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Devil's Kitchen Spring A,
Marion County, Florida; September 28, 2006

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Results of Discharge Measurements of Devil's Kitchen Spring A, Marion County, Florida; September 28, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Devil's Kitchen Spring A on September 28, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Devil's Kitchen Spring A, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida.

SITE DESCRIPTION

Devil's Kitchen Spring A is located approximately 90 feet northeast of Ladies Parlor Spring. Water flows from vents beneath a 26 foot long linear limestone ledge, at a depth of 20 feet, at the bottom of a bowl-shaped depression. There are vents at each end of the ledge (Upstream and Downstream Vents) and several smaller vents between these (Middle Vents). See Figure 1.

(The depression extends to the northwest with a low saddle separating the deeper Devil's Kitchen Spring A basin and the slightly shallower Devil's Kitchen B basin. Devil's Kitchen Spring B is located approximately 60 feet northwest of Devil's Kitchen Spring A. It discharges from a roughly circular vent, about 15 feet deep, at the bottom of a sediment-sided depression. There is one small vent located between the two springs, and it was tabulated with Spring B.)

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring openings there are suitable locations for discharge measurements that lends themselves to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter.

One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

Pete Butt positioned the sensor, and recorded positional data, while Tom Morris read the velocity readings, after taking meter reset cues from Butt. During all measurements, the sensor handler completely removed himself from the cross section of the flow. The meter operator was also positioned outside the cross-section. This eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. Seventeen (17) station readings were taken.

The approximate depth for the measurement grids was 20 feet. Telescoping aluminum poles with 1, 0.5, 0.25 and 0.1 foot interval markings were positioned horizontally to allow for a grid of velocity measurements. As all sensor-support poles were positioned at right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was positioned on the poles with a quick release clamp. Spring vent dimensions and positions were measured with a metal tape. Two hand-held readings were made in two smaller Middle Vents.

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figures 2(AB). Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Tables 3A and 3B. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift, an anisotropy ratio of 1 at an angle of 0°, and a variogram slope of 1.0. The results of the contour processing are illustrated in Figures 3(AB) and 4(AB).

During this measurement, one negative velocity was measured in the Upstream Vent. Negative velocity stations typically represent slight back eddies near walls. In order to incorporate any negative values, calculations were made using a Surfer 8 “blanking file” operation to define the measurement cross-section boundary. The total discharge is shown on Tables 2A and 2B as the **Net Volume (Cut-Fill)**, and has been calculated as the Positive Volume (Cut) less that portion of the Negative Volume (Fill) lying within the measurement cross-section boundary walls that define the plane of measurement.

The software also calculates the total cross-sectional area of the measurement location within the passage, and is presented on Tables 2A and 2B as the **Operational Planar Area**. The Operational Planar Area is the sum of the Positive (Cut) and that portion of the Negative (Fill) Planar areas lying within the measurement cross-section boundary walls that define the plane of measurement.

RESULTS AND DISCUSSION

This measurement is the first one performed at Devil's Kitchen Spring A applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated total discharge of Devil's Kitchen Spring A (all vents) on September 28, 2006 was 1.51 CFS (cubic feet per second). This result is also expressed as 678 GPM (gallons per minute) or 0.976 MGD (million gallons per day), see Table 1. A total of seventeen (17) readings were made, see Figures 2(AB), 3(AB) and 4(AB). The total cross-sectional area was calculated as 3.16 square feet. The point velocity readings ranged from -0.04 to 1.81 feet per second (fps), with an overall average station reading of 0.94 fps. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 15:21 hours and were completed by 15:55 hours. The results for each of the individual vents are detailed below.

The estimated discharge of Devil's Kitchen Spring A Upstream Vent on September 28, 2006 was 0.835 CFS. This result is also expressed as 375 GPM or 0.54 MGD, see Table 1. Ten (10) readings were made, see Figures 2A, 3A and 4A. The total cross-sectional area was calculated as 1.979 square feet. The point velocity readings ranged from -0.04 to 0.94 feet per second (fps), with an overall average station reading of 0.68 fps.

The estimated discharge of Devil's Kitchen Spring A Downstream Vent on September 28, 2006 was 0.362 CFS. This result is also expressed as 162 GPM or 0.234 MGD, see Table 1. Five (5) readings were made, see Figures 2B, 3B and 4B. The total cross-sectional area was calculated as 0.79 square feet. The point velocity readings ranged from 0.71 to 1.81 feet per second (fps), with an overall average station reading of 1.41 fps.

The estimated discharge of Devil's Kitchen Spring A Middle Vents on September 28, 2006 was 0.313 CFS. This result is also expressed as 0.202 GPM or 141 MGD, see Table 1. Two (2) readings were made, see Table 1. The total cross-sectional areas were calculated as 0.39 square feet. The point velocity readings were 0.42 and 1.25 feet per second (fps).

UNDERWATER DISCHARGE MEASUREMENT						
Location:	**DEVIL'S KITCHEN SPRING A**			Date:	**September 28, 2006**	
	Silver Springs Group,			Time Start:	15:21	
	Marion County, Florida			Time End:	15:55	
Personnel:	Peter Butt, Tom Morris					
Method:	Grid within irregular conduit					
Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles					
Msmt. Periods:	60 seconds					
Analysis Method: Surfer 8 with kriging						
Devil's Kitchen Spring A Total Discharge:			**U/S Vent:**	**D/S Vent:**	**Middle Vents:**	
CFS	**1.51**		**0.835**	**0.362**	**0.313**	
MGD	**0.976**		**0.540**	**0.234**	**0.202**	
GPM	**678**	All Vents:	**375**	**162**	**141**	
Total Cross-sectional Area (sq/ft):		3.16	1.979	0.79	0.39	
Avg. Station Point Velocity (ft/sec):		0.94	0.68	1.41	0.84	
Cross-section Depth (feet deep):			20	20	20	
Velocity Reading by Station:		(All velocity readings in feet per second.)				
Station #	Point Velocity	Station #	Point Velocity	Station #	Point Velocity	
UPSTREAM VENT		**DOWNSTREAM VENT**		**Middle U/S Vent**		
1	0.37	1	1.81	6	0.42	
2	0.81	2	1.27			
3	0.91	3	1.57	**Middle D/S Vent**		
4	-0.04	4	0.71	7	1.25	
5	0.61	5	1.69			
6	0.74					
7	0.94					
8	0.93					
9	0.81					
10	0.7					
Handheld Middle Vent Readings Calculations						
Station #	**Point Velocity**	**X-Sec Area**	**Discharge:**		**Mid U/S Vent:**	**Mid D/S Vent:**
		(in Sq. Ft.)		**CFS**	0.0882	0.225
6	0.42	0.21	0.0882	**MGD**	0.057	0.145
Middle/Upstream		(0.3' x 0.7')		**GPM**	**40**	101
7	1.25	0.18	0.225			
Middle/Downstream		(0.3' x 0.6')				

Table 1. Discharge of Devil’s Kitchen Spring A, Marion County, Florida on September 28, 2006. Data record and calculation of discharge measurement.

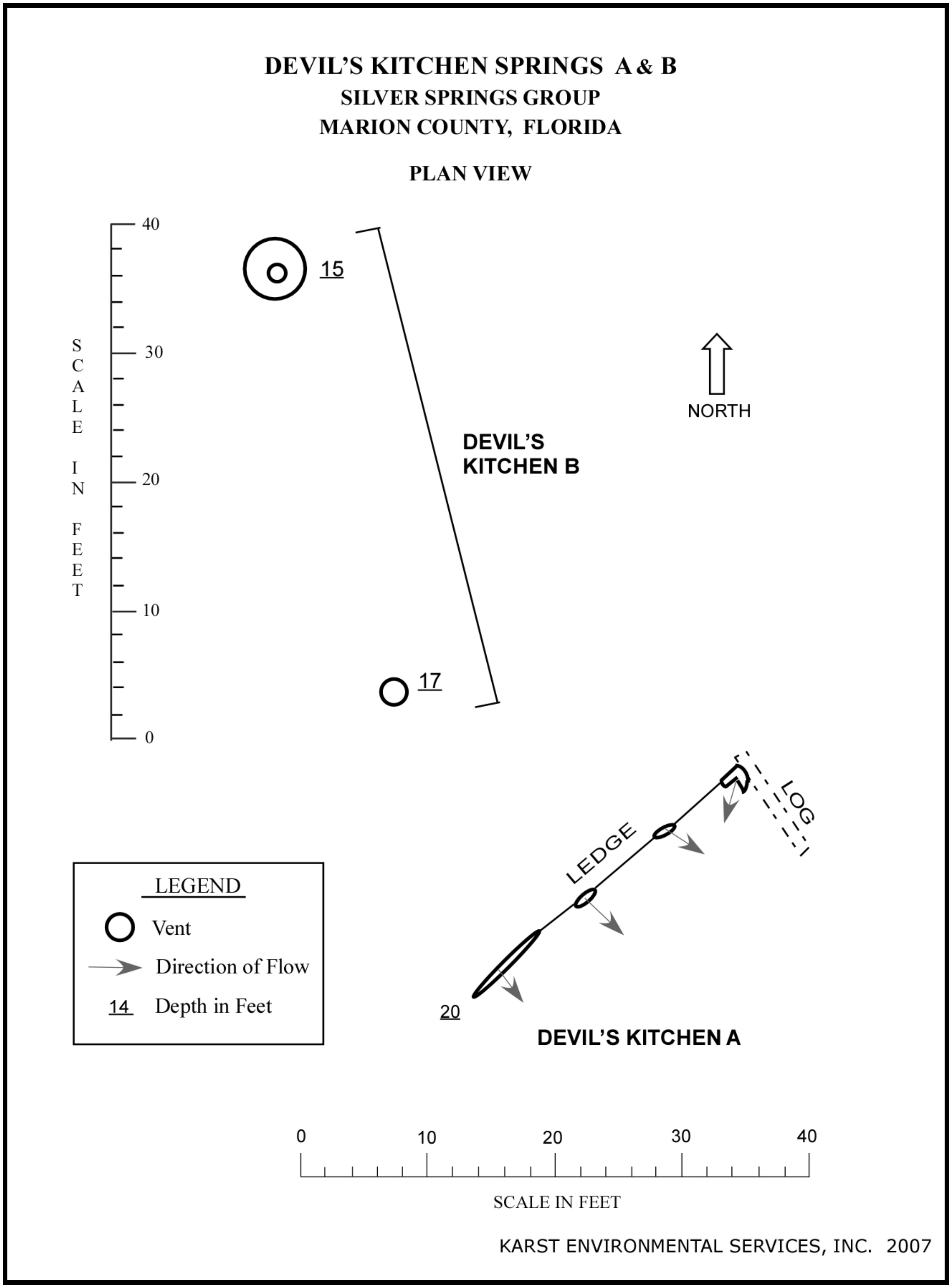

Figure 1. Map of Devil's Kitchen Spring A.

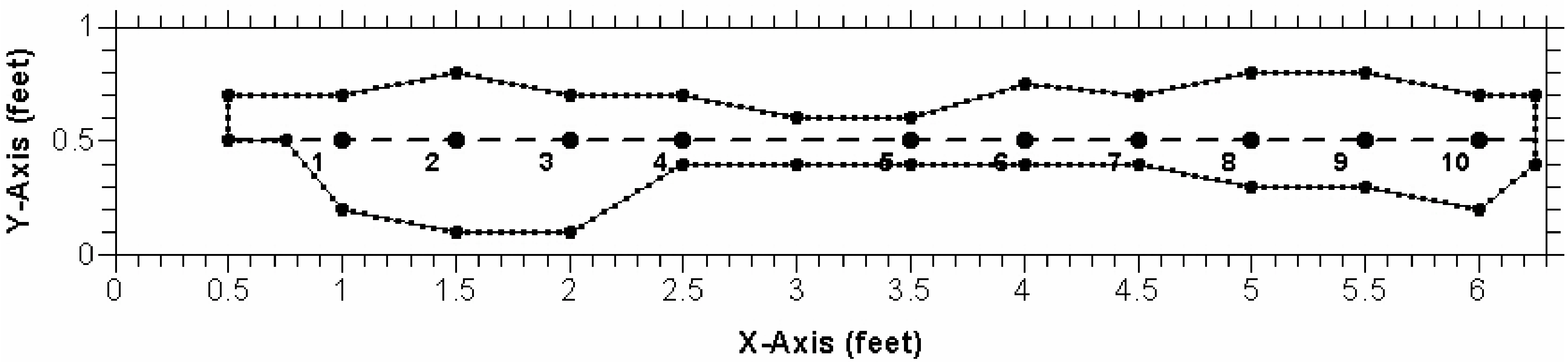

Figure 2A. Discharge measurement cross-section; Devil's Kitchen Spring A Upstream Vent, Marion County, Florida, September 28, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 20-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

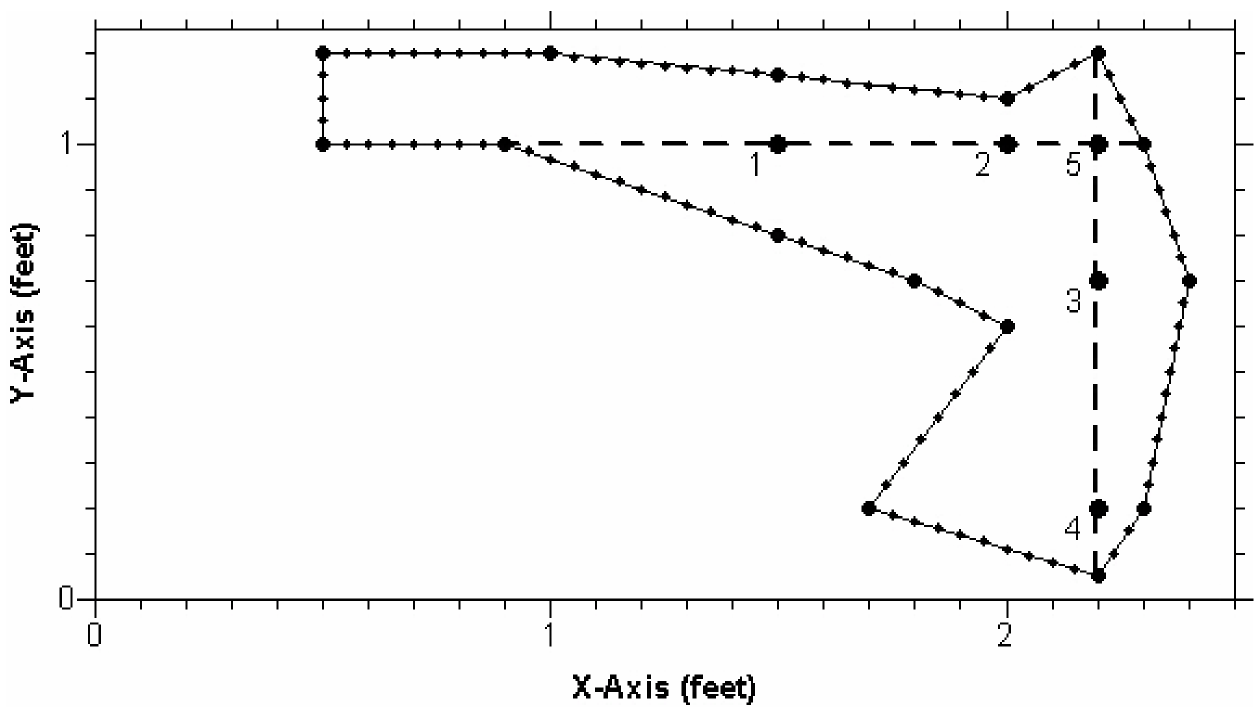

Figure 2B. Discharge measurement cross-section; Devil's Kitchen Spring A Downstream Vent, Marion County, Florida, September 28, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 20-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

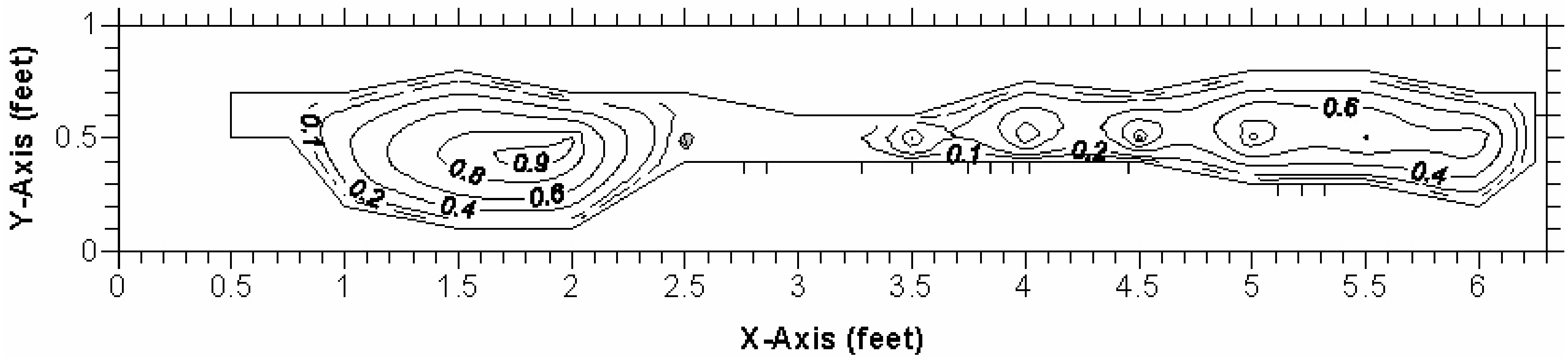

Figure 3A. Discharge measurement cross-section; Devil's Kitchen Spring A Upstream Vent, Marion County, Florida, September 28, 2006 measurement. Flow contour velocities are shown in feet per second. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

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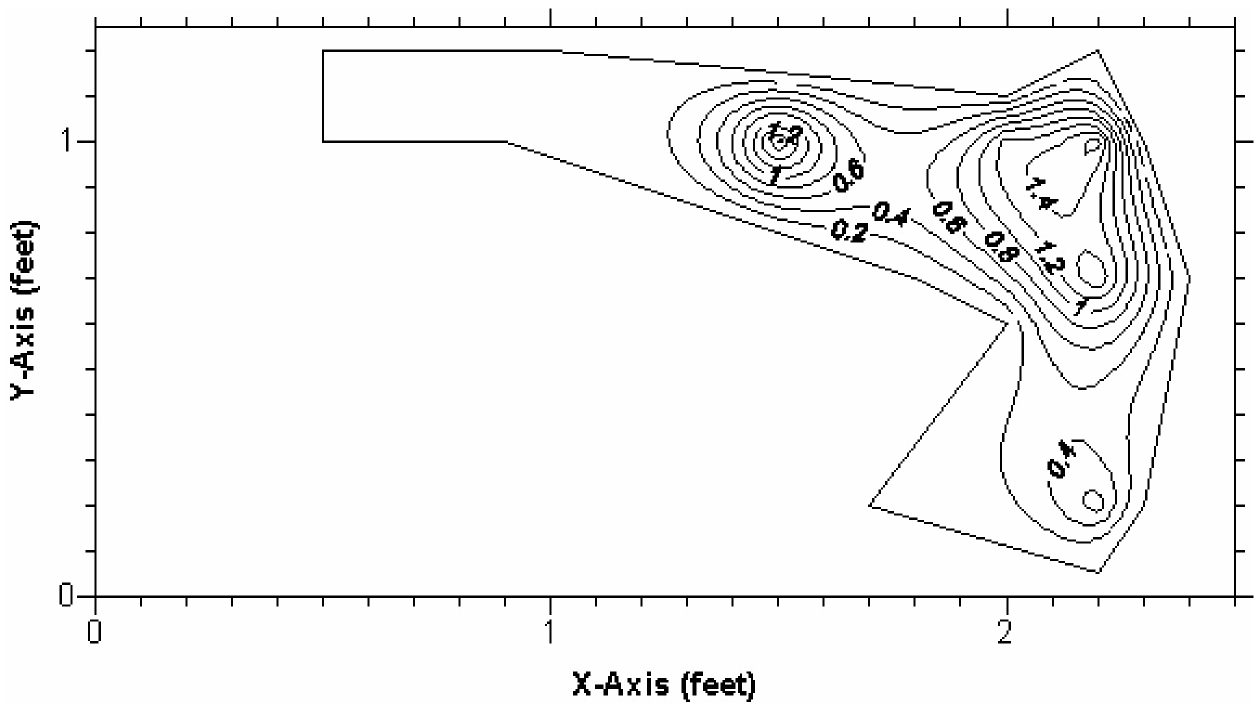

Figure 3B. Discharge measurement cross-section; Devil's Kitchen Spring A Downstream Vent, Marion County, Florida, September 28, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

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TABLE 2A. DEVIL’S KITCHEN SPRING A, UPSTREAM VENT, SEPTEMBER 28, 2006. SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\DevilsKitchen_1_US\Devil'sKitchen_1_US_9-06.bln.grd
Grid Size:	19 rows x 119 columns
X Minimum:	0.4
X Maximum:	6.3
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	0.9
Y Spacing:	0.05
Z Minimum:	-0.039999998457619
Z Maximum:	0.94000000028401

LOWER SURFACE

Level Surface defined by Z = 0

VOLUMES

Z Scale Factor:	1
Total Volumes by:	
Trapezoidal Rule:	0.8345491603032
Simpson's Rule:	0.83757118089679
Simpson's 3/8 Rule:	0.83478378571318

CUT & FILL VOLUMES

Positive Volume [Cut]:	0.83458749910691
Negative Volume [Fill]:	3.8338803705738E-005
Net Volume [Cut-Fill]:	**0.8345491603032<<<<<<Total Discharge in CFS**

(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS

Planar Areas

Operational Planar Area: 1.979 <<<<Total Cross-section Area in Square Feet

(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)

Positive Planar Area [Cut]:	1.9758745910505
Negative Planar Area [Fill]:	0.0028754089494666
Blanked Planar Area:	3.33125
Total Planar Area:	5.31

Surface Areas

Positive Surface Area [Cut]:	5.4691394940791
Negative Surface Area [Fill]:	0.0051227823875163

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\DevilsKitchen_1_US\Devil's Kitchen 1 US 9-06 SURFER XYZ T3A BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	251
Original Data:	251
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.5	0.1	-0.04
25%-tile:	1.9	0.36	0
Median:	3.4	0.5	0
75%-tile:	4.9	0.7	0
Maximum:	6.25	0.8	0.94
Midrange:	3.375	0.45	0.45
Range:	5.75	0.7	0.98
Interquartile Range:	3	0.34	0
Median Abs. Deviation:	1.5	0.2	0
Mean:	3.3949202191235	0.51314741035857	0.027011952191235
Trim Mean (10%):	3.3954844713656	0.51977973568282	0
Standard Deviation:	1.7287545134656	0.21197105291565	0.14467794932363
Variance:	2.9885921678277	0.04493172727417	0.020931709020492
Coef. of Variation:			5.3560715752554
Coef. of Skewness:			5.32350567317

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.066	0.046
Y:		1.000	-0.012
Z:			1.000

Table 2A. Devil’s Kitchen Spring A Upstream, September 28, 2006.

Inter-Variable Covariance

	X	Y	Z
X:	2.9885921678277	0.024172049907938	0.01162327057507
Y:		0.04493172727417	-0.00035513722004413
Z:			0.020931709020492

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.0039704165111376	-0.010039906174851	0.0186846567531
Standard Error:	0.0053195356917998	0.043384090470125	0.029204772045708

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.066	-0.568
B:		1.000	0.721
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.012478407213052	0.0062392036065262	0.29521
Residual:	248	5.2413805569304	0.021134599019881	
Total:	250	5.2538589641434		

Coefficient of Multiple Determination (R^2): 0.0023750936784209

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.05	0
Median:	0.05	0
75%-tile:	0.050990195135928	0
Maximum:	0.29427877939124	0.94

Midrange:	0.17213938969562	0.47
Range:	0.24427877939124	0.94
Interquartile Range:	0.00099019513592785	0
Median Abs. Deviation:	2.2204460492503E-016	0
Mean:	0.055929360518832	0.027330677290837
Trim Mean (10%):	0.051202578274467	0
Standard Deviation:	0.02627674616512	0.14461807860879
Variance:	0.00069046738902617	0.020914388660497
Coef. of Variation:	0.46982025042594	5.2914194942865
Coef. of Skewness:	6.2036643859355	5.3239076068281
Root Mean Square:	0.061794504262691	0.14717796907715
Mean Square:	0.0038185607570717	0.021661354581673

Complete Spatial Randomness
Lambda: 62.360248447205
Clark and Evans: 0.88333160160242
Skellam: 375.54426282221

Exclusion Filtering
Exclusion Filter String: Not In Use

Duplicate Filtering
Duplicate Points to Keep: First
X Duplicate Tolerance: 6.8E-007
Y Duplicate Tolerance: 8.3E-008
No duplicate data were found.

Breakline Filtering
Breakline Filtering: Not In Use

Gridding Rules
Gridding Method: Kriging
Kriging Type: Point

Polynomial Drift Order: 2
Kriging std. deviation grid: no

Semi-Variogram Model
Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 1
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\DevilsKitchen_1_US\Devil'sKitchen_1_US_9-06.grd
Grid Size:	19 rows x 119 columns
Total Nodes:	2261
Filled Nodes:	2261
Blanked Nodes:	0

Grid Geometry

X Minimum:	0.4
X Maximum:	6.3
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	0.9
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-2.2167705865747
Z 25%-tile:	-0.65170021190854
Z Median:	-0.12219709295333
Z 75%-tile:	0.23647685235408
Z Maximum:	0.94000000028401
Z Midrange:	-0.63838529314533
Z Range:	3.1567705868587
Z Interquartile Range:	0.88817706426262
Z Median Abs. Deviation:	0.44407971640074
Z Mean:	-0.24160530344016
Z Trim Mean (10%):	-0.20980536955367
Z Standard Deviation:	0.67141916704771
Z Variance:	0.45080369787904
Z Coef. of Variation:	-1
Z Coef. of Skewness:	-0.65488297469124
Z Root Mean Square:	0.7135662691926
Z Mean Square:	0.50917682052945

TABLE 2B. DEVIL'S KITCHEN SPRING A, DOWNSTREAM VENT, SEPTEMBER 28, 2006. SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\DevilsKitchen_1_DS\Devil's Kitchen_1_DS_9-06.bln.grd
Grid Size:	51 rows x 83 columns
X Minimum:	0.45
X Maximum:	2.5
X Spacing:	0.025
Y Minimum:	0
Y Maximum:	1.25
Y Spacing:	0.025
Z Minimum:	-0.0021994340998188
Z Maximum:	1.8099999992163

LOWER SURFACE

Level Surface defined by Z = 0

VOLUMES

Z Scale Factor: 1

Total Volumes by:

Trapezoidal Rule:	0.36229367794045
Simpson's Rule:	0.36221858155177
Simpson's 3/8 Rule:	0.36240598541292

CUT & FILL VOLUMES

Positive Volume [Cut]:	0.362306885294
Negative Volume [Fill]:	1.3207353559033E-005
Net Volume [Cut-Fill]:	**0.36229367794044<<<<<<Total Discharge in CFS**

(The Net Volume value is used due to the presence of negative velocity values. Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS

Planar Areas

Operational Planar Area: 0.791 <<<<Total Cross-section Area in Square Feet

(Calculated using blanking file due to the presence of negative velocity values; Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area]. Please refer to report text.)

Positive Planar Area [Cut]:	0.78312166453988
Negative Planar Area [Fill]:	0.0084408354601214
Blanked Planar Area:	1.7709375
Total Planar Area:	2.5625

Surface Areas

Positive Surface Area [Cut]:	3.548024973059
Negative Surface Area [Fill]:	0.0084454324786012

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\DevilsKitchen_1_DS\Devil's Kitchen 1 DS 9-06 SURFER XYZ T3B BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	114
Original Data:	114
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.5	0.05	0
25%-tile:	1.1	0.55	0
Median:	1.75	0.95	0
75%-tile:	2.15	1.135	0
Maximum:	2.4	1.2	1.81
Midrange:	1.45	0.625	0.905
Range:	1.9	1.15	1.81
Interquartile Range:	1.05	0.585	0
Median Abs. Deviation:	0.475	0.22	0
Mean:	1.6065786842105	0.81219192982456	0.061842105263158
Trim Mean (10%):	1.6223715865385	0.828845	0
Standard Deviation:	0.59014182073154	0.36503802191564	0.3002646954771
Variance:	0.34826736857634	0.13325275744408	0.090158887349954
Coef. of Variation:			4.8553440119701
Coef. of Skewness:			4.8924686379338

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.547	0.132
Y:		1.000	0.023
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	0.34826736857634	-0.1178187989615	0.023356318213296
Y:		0.13325275744408	0.0025004113573407
Z:			0.090158887349954

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.10474254385166	0.11137519672224	-0.19689306897934
Standard Error:	0.056806671668093	0.091836988574452	0.14874985986379

Inter-Parameter Correlations

	A	B	C
A:	1.000	-0.547	-0.888
B:		1.000	0.837
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.31063677502872	0.15531838751436	1.7297
Residual:	111	9.967476382866	0.089797084530324	
Total:	113	10.278113157895		

Coefficient of Multiple Determination (R^2): 0.030223132422911

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.050249378105604	0
Median:	0.052201532544553	0
75%-tile:	0.052704100646914	0
Maximum:	0.19002119783066	1.81

Midrange:	0.12001059891533	0.905
Range:	0.14002119783066	1.81
Interquartile Range:	0.0024547225413094	0
Median Abs. Deviation:	0.0019521544389481	0
Mean:	0.055619191719095	0.061842105263158
Trim Mean (10%):	0.052664383425515	0
Standard Deviation:	0.017052490570696	0.3002646954771
Variance:	0.00029078743466368	0.090158887349954
Coef. of Variation:	0.30659364229563	4.8553440119701
Coef. of Skewness:	6.034975528559	4.8924686379338
Root Mean Square:	0.058174581409316	0.30656701279383
Mean Square:	0.0033842819221491	0.0939833333333333

Complete Spatial Randomness

Lambda:	52.173913043478
Clark and Evans:	0.8034916611653
Skellam:	126.47499292907

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	2.2E-007
Y Duplicate Tolerance:	1.3E-007

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point

Polynomial Drift Order: 1
Kriging std. deviation grid: no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\DevilsKitchen_1_DS\Devil's Kitchen_1_DS_9-06.grd
Grid Size:	51 rows x 83 columns
Total Nodes:	4233
Filled Nodes:	4233
Blanked Nodes:	0

Grid Geometry

X Minimum:	0.45
X Maximum:	2.5
X Spacing:	0.025
Y Minimum:	0
Y Maximum:	1.25
Y Spacing:	0.025

Grid Statistics

Z Minimum:	-0.87191986995473
Z 25%-tile:	-0.097036151680639
Z Median:	8.0514572786683E-010
Z 75%-tile:	0.14466911502255
Z Maximum:	1.8099999992163
Z Midrange:	0.46904006463078
Z Range:	2.681919869171
Z Interquartile Range:	0.24170526670319
Z Median Abs. Deviation:	0.11606356255849
Z Mean:	0.081875401544725
Z Trim Mean (10%):	0.049885620566584
Z Standard Deviation:	0.36479367304436
Z Variance:	0.13307442389319
Z Coef. of Variation:	4.4554733920308
Z Coef. of Skewness:	1.6821035450455
Z Root Mean Square:	0.37386896805071
Z Mean Square:	0.1397780052713

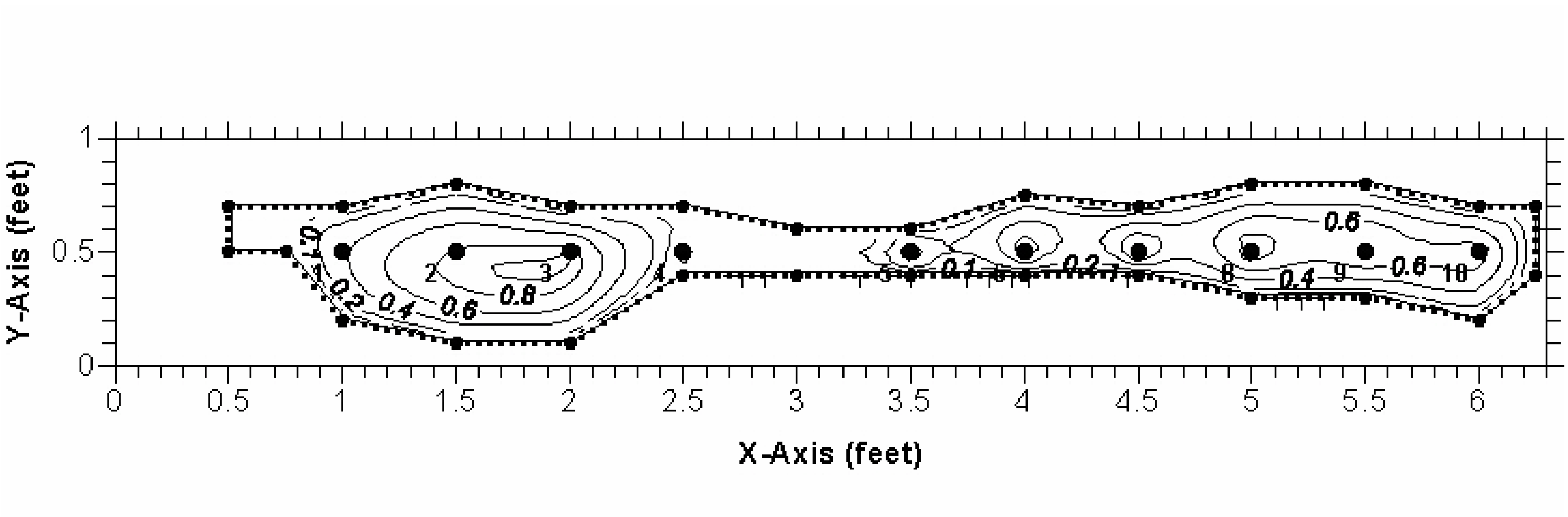

Figure 4A. Discharge measurement cross-section; Devil's Kitchen Spring A Upstream Vent, Marion County, Florida, September 28, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. See Table 1 for station velocities. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

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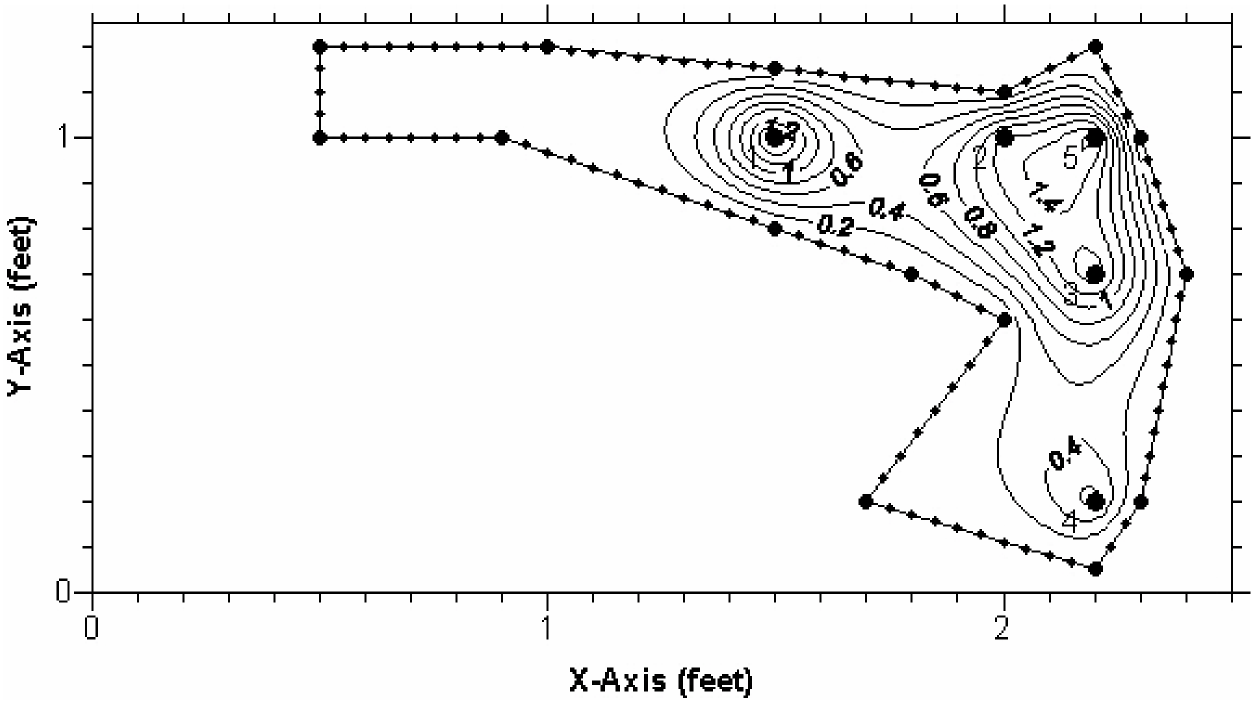

Figure 4B. Discharge measurement cross-section; Devil's Kitchen Spring A Downstream Vent, Marion County, Florida, September 28, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

KARST ENVIRONMENTAL SERVICES, INC. 2007

Table 3A. Devil's Kitchen 1 Upstream XYZ Grid Data, September 28, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
1	**0.5**	**0.37**	**1**	20	10
1.5	**0.5**	**0.81**	**2**	30	10
2	**0.5**	**0.91**	**3**	40	10
2.5	**0.5**	**-0.04**	**4**	50	10
3.5	**0.5**	**0.61**	**5**	70	10
4	**0.5**	**0.74**	**6**	80	10
4.5	**0.5**	**0.94**	**7**	90	10
5	**0.5**	**0.93**	**8**	100	10
5.5	**0.5**	**0.81**	**9**	110	10
6	**0.5**	**0.7**	**10**	120	10
0.5	**0.7**	**0**	**AT**	10	14
1	**0.7**	**0**	**BT**	20	14
1.5	**0.8**	**0**	**CT**	30	16
2	**0.7**	**0**	**DT**	40	14
2.5	**0.7**	**0**	**ET**	50	14
3	**0.6**	**0**	**FT**	60	12
3.5	**0.6**	**0**	**GT**	70	12
4	**0.75**	**0**	**HT**	80	15
4.5	**0.7**	**0**	**IT**	90	14
5	**0.8**	**0**	**JT**	100	16
5.5	**0.8**	**0**	**KT**	110	16
6	**0.7**	**0**	**LT**	120	14
6.25	**0.7**	**0**	**MT**	125	14
0.5	**0.5**	**0**	**AS**	10	10
0.75	**0.5**	**0**	**ABS**	15	10
1	**0.2**	**0**	**BS**	20	4
1.5	**0.1**	**0**	**CS**	30	2
2	**0.1**	**0**	**DS**	40	2
2.5	**0.4**	**0**	**ES**	50	8
3	**0.4**	**0**	**FS**	60	8
3.5	**0.4**	**0**	**GS**	70	8
4	**0.4**	**0**	**HS**	80	8
4.5	**0.4**	**0**	**IS**	90	8
5	**0.3**	**0**	**JS**	100	6
5.5	**0.3**	**0**	**KS**	110	6
6	**0.2**	**0**	**LS**	120	4
6.25	**0.4**	**0**	**MS**	125	8
0.55	**0.7**	**0**	**AT1**	11	14
0.6	**0.7**	**0**	**AT2**	12	14
0.65	**0.7**	**0**	**AT3**	13	14
0.7	**0.7**	**0**	**AT4**	14	14
0.75	**0.7**	**0**	**AT5**	15	14
0.8	**0.7**	**0**	**AT6**	16	14
0.85	**0.7**	**0**	**AT7**	17	14

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
0.9	**0.7**	**0**	**AT8**	18	14
0.95	**0.7**	**0**	**AT9**	19	14
0.5	**0.55**	**0**	**AV1**	10	11
0.5	**0.6**	**0**	**AV2**	10	12
0.5	**0.65**	**0**	**AV3**	10	13
1.05	**0.71**	**0**	**BT1**	21	14.2
1.1	**0.72**	**0**	**BT2**	22	14.4
1.15	**0.73**	**0**	**BT3**	23	14.6
1.2	**0.74**	**0**	**BT4**	24	14.8
1.25	**0.75**	**0**	**BT5**	25	15
1.3	**0.76**	**0**	**BT5**	26	15.2
1.35	**0.77**	**0**	**BT6**	27	15.4
1.4	**0.78**	**0**	**BT8**	28	15.6
1.45	**0.79**	**0**	**BT9**	29	15.8
1.55	**0.79**	**0**	**CT1**	31	15.8
1.6	**0.78**	**0**	**CT2**	32	15.6
1.65	**0.77**	**0**	**CT3**	33	15.4
1.7	**0.76**	**0**	**CT4**	34	15.2
1.75	**0.75**	**0**	**CT5**	35	15
1.8	**0.74**	**0**	**CT6**	36	14.8
1.85	**0.73**	**0**	**CT7**	37	14.6
1.9	**0.72**	**0**	**CT8**	38	14.4
1.95	**0.71**	**0**	**CT9**	39	14.2
2.05	**0.7**	**0**	**DT1**	41	14
2.1	**0.7**	**0**	**DT2**	42	14
2.15	**0.7**	**0**	**DT3**	43	14
2.2	**0.7**	**0**	**DT4**	44	14
2.25	**0.7**	**0**	**DT5**	45	14
2.3	**0.7**	**0**	**DT6**	46	14
2.35	**0.7**	**0**	**DT7**	47	14
2.4	**0.7**	**0**	**DT8**	48	14
2.45	**0.7**	**0**	**DT9**	49	14
2.55	**0.69**	**0**	**ET1**	51	13.8
2.6	**0.68**	**0**	**ET2**	52	13.6
2.65	**0.67**	**0**	**ET3**	53	13.4
2.7	**0.66**	**0**	**ET4**	54	13.2
2.75	**0.65**	**0**	**ET5**	55	13
2.8	**0.64**	**0**	**ET6**	56	12.8
2.85	**0.63**	**0**	**ET7**	57	12.6
2.9	**0.62**	**0**	**ET8**	58	12.4
2.95	**0.61**	**0**	**ET9**	59	12.2
3.05	**0.6**	**0**	**FT1**	61	12
3.1	**0.6**	**0**	**FT2**	62	12

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
3.15	0.6	0	FT3	63	12
3.2	0.6	0	FT4	64	12
3.25	0.6	0	FT5	65	12
3.3	0.6	0	FT6	66	12
3.35	0.6	0	FT7	67	12
3.4	0.6	0	FT8	68	12
3.45	0.6	0	FT9	69	12
3.55	0.615	0	GT1	71	12.3
3.6	0.63	0	GT2	72	12.6
3.65	0.645	0	GT3	73	12.9
3.7	0.66	0	GT4	74	13.2
3.75	0.675	0	GT5	75	13.5
3.8	0.69	0	GT6	76	13.8
3.85	0.705	0	GT7	77	14.1
3.9	0.72	0	GT8	78	14.4
3.95	0.735	0	GT9	79	14.7
4.05	0.745	0	HT1	81	14.9
4.1	0.74	0	HT2	82	14.8
4.15	0.735	0	HT3	83	14.7
4.2	0.73	0	HT4	84	14.6
4.25	0.725	0	HT5	85	14.5
4.3	0.72	0	HT6	86	14.4
4.35	0.715	0	HT7	87	14.3
4.4	0.71	0	HT8	88	14.2
4.45	0.705	0	HT9	89	14.1
4.55	0.71	0	IT1	91	14.2
4.6	0.72	0	IT2	92	14.4
4.65	0.73	0	IT3	93	14.6
4.7	0.74	0	IT4	94	14.8
4.75	0.75	0	IT5	95	15
4.8	0.76	0	IT6	96	15.2
4.85	0.77	0	IT7	97	15.4
4.9	0.78	0	IT8	98	15.6
4.95	0.79	0	IT9	99	15.8
5.05	0.8	0	JT1	101	16
5.1	0.8	0	JT1	102	16
5.15	0.8	0	JT3	103	16
5.2	0.8	0	JT4	104	16
5.25	0.8	0	JT5	105	16
5.3	0.8	0	JT6	106	16
5.35	0.8	0	JT7	107	16
5.4	0.8	0	JT8	108	16
5.45	0.8	0	JT9	109	16
5.55	0.79	0	KT1	111	15.8

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
5.6	**0.78**	**0**	**KT2**	112	15.6
5.65	**0.77**	**0**	**KT3**	113	15.4
5.7	**0.76**	**0**	**KT4**	114	15.2
5.75	**0.75**	**0**	**KT5**	115	15
5.8	**0.74**	**0**	**KT6**	116	14.8
5.85	**0.73**	**0**	**KT7**	117	14.6
5.9	**0.72**	**0**	**KT8**	118	14.4
5.95	**0.71**	**0**	**KT9**	119	14.2
6.05	**0.7**	**0**	**LT1**	121	14
6.1	**0.7**	**0**	**LT2**	122	14
6.15	**0.7**	**0**	**LT3**	123	14
6.2	**0.7**	**0**	**LT4**	124	14
6.25	**0.65**	**0**	**MV1**	125	13
6.25	**0.6**	**0**	**MV2**	125	12
6.25	**0.55**	**0**	**MV3**	125	11
6.25	**0.5**	**0**	**MV4**	125	10
6.25	**0.45**	**0**	**MV5**	125	9
0.55	**0.5**	**0**	**AS1**	11	10
0.6	**0.5**	**0**	**AS2**	12	10
0.65	**0.5**	**0**	**AS3**	13	10
0.7	**0.5**	**0**	**AS4**	14	10
0.79167	**0.45**	**0**	**ABS1**	15.8333	9
0.83333	**0.4**	**0**	**ABS2**	16.6666	8
0.875	**0.35**	**0**	**ABS3**	17.4999	7
0.91666	**0.3**	**0**	**ABS4**	18.3332	6
0.95833	**0.25**	**0**	**ABS5**	19.1665	5
1.05	**0.19**	**0**	**BS1**	21	3.8
1.1	**0.18**	**0**	**BS2**	22	3.6
1.15	**0.17**	**0**	**BS3**	23	3.4
1.2	**0.16**	**0**	**BS4**	24	3.2
1.25	**0.15**	**0**	**BS5**	25	3
1.3	**0.14**	**0**	**BS6**	26	2.8
1.35	**0.13**	**0**	**BS7**	27	2.6
1.4	**0.12**	**0**	**BS8**	28	2.4
1.45	**0.11**	**0**	**BS9**	29	2.2
1.55	**0.1**	**0**	**CS1**	31	2
1.6	**0.1**	**0**	**CS2**	32	2
1.65	**0.1**	**0**	**CS3**	33	2
1.7	**0.1**	**0**	**CS4**	34	2
1.75	**0.1**	**0**	**CS5**	35	2
1.8	**0.1**	**0**	**CS6**	36	2
1.85	**0.1**	**0**	**CS7**	37	2
1.9	**0.1**	**0**	**CS8**	38	2

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
1.95	**0.1**	**0**	**CS9**	39	2
2.05	**0.13**	**0**	**DS1**	41	2.6
2.1	**0.16**	**0**	**DS2**	42	3.2
2.15	**0.19**	**0**	**DS3**	43	3.8
2.2	**0.22**	**0**	**DS4**	44	4.4
2.25	**0.25**	**0**	**DS5**	45	5
2.3	**0.28**	**0**	**DS6**	46	5.6
2.35	**0.31**	**0**	**DS7**	47	6.2
2.4	**0.34**	**0**	**DS8**	48	6.8
2.45	**0.37**	**0**	**DS9**	49	7.4
2.55	**0.4**	**0**	**ES1**	51	8
2.6	**0.4**	**0**	**ES2**	52	8
2.65	**0.4**	**0**	**ES3**	53	8
2.7	**0.4**	**0**	**ES4**	54	8
2.75	**0.4**	**0**	**ES5**	55	8
2.8	**0.4**	**0**	**ES6**	56	8
2.85	**0.4**	**0**	**ES7**	57	8
2.9	**0.4**	**0**	**ES8**	58	8
2.95	**0.4**	**0**	**ES9**	59	8
3.05	**0.4**	**0**	**FS1**	61	8
3.1	**0.4**	**0**	**FS2**	62	8
3.15	**0.4**	**0**	**FS3**	63	8
3.2	**0.4**	**0**	**FS4**	64	8
3.25	**0.4**	**0**	**FS5**	65	8
3.3	**0.4**	**0**	**FS6**	66	8
3.35	**0.4**	**0**	**FS7**	67	8
3.4	**0.4**	**0**	**FS8**	68	8
3.45	**0.4**	**0**	**FS9**	69	8
3.55	**0.4**	**0**	**GS1**	71	8
3.6	**0.4**	**0**	**GS2**	72	8
3.65	**0.4**	**0**	**GS2**	73	8
3.7	**0.4**	**0**	**GS4**	74	8
3.75	**0.4**	**0**	**GS5**	75	8
3.8	**0.4**	**0**	**GS6**	76	8
3.85	**0.4**	**0**	**GS7**	77	8
3.9	**0.4**	**0**	**GS8**	78	8
3.95	**0.4**	**0**	**GS9**	79	8
4.05	**0.4**	**0**	**HS1**	81	8
4.1	**0.4**	**0**	**HS2**	82	8
4.15	**0.4**	**0**	**HS3**	83	8
4.2	**0.4**	**0**	**HS4**	84	8
4.25	**0.4**	**0**	**HS5**	85	8
4.3	**0.4**	**0**	**HS6**	86	8
4.35	**0.4**	**0**	**HS7**	87	8

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
4.4	0.4	0	HS8	88	8
4.45	0.4	0	HS9	89	8
4.55	0.39	0	IS1	91	7.8
4.6	0.38	0	IS2	92	7.6
4.65	0.37	0	IS3	93	7.4
4.7	0.36	0	IS4	94	7.2
4.75	0.35	0	IS5	95	7
4.8	0.34	0	IS6	96	6.8
4.85	0.33	0	IS8	97	6.6
4.9	0.32	0	IS8	98	6.4
4.95	0.31	0	IS9	99	6.2
5.05	0.3	0	JS1	101	6
5.1	0.3	0	JS2	102	6
5.15	0.3	0	JS3	103	6
5.2	0.3	0	JS4	104	6
5.25	0.3	0	JS5	105	6
5.3	0.3	0	JS6	106	6
5.35	0.3	0	JS7	107	6
5.4	0.3	0	JS8	108	6
5.45	0.3	0	JS9	109	6
5.55	0.29	0	KS1	111	5.8
5.6	0.28	0	KS2	112	5.6
5.65	0.27	0	KS3	113	5.4
5.7	0.26	0	KS4	114	5.2
5.75	0.25	0	KS5	115	5
5.8	0.24	0	KS6	116	4.8
5.85	0.23	0	KS7	117	4.6
5.9	0.22	0	KS8	118	4.4
5.95	0.21	0	KS9	119	4.2
6.05	0.24	0	LS1	121	4.8
6.1	0.28	0	LS1	122	5.6
6.15	0.32	0	LS3	123	6.4
6.2	0.36	0	LS4	124	7.2

Table 3B. Devil's Kitchen 1 Downstream XYZ Grid Data, September 28, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
1.5	1	1.81	1	30	20
2	1	1.27	2	40	20
2.2	0.7	1.57	3	44	14
2.2	0.2	0.71	4	44	4
2.2	1	1.69	5	44	20
0.5	1.2	0	A	10	24
1	1.2	0	B	20	24
1.5	1.15	0	C	30	23
2	1.1	0	D	40	22
2.2	1.2	0	E	44	24
2.3	1	0	F	46	20
2.4	0.7	0	G	48	14
2.3	0.2	0	H	46	4
2.2	0.05	0	I	44	1
1.7	0.2	0	J	34	4
2	0.6	0	K	40	12
1.8	0.7	0	L	36	14
1.5	0.8	0	M	30	16
0.9	1	0	N	18	20
0.5	1	0	O	10	20
0.55	1.2	0	A1	11	24
0.6	1.2	0	A2	12	24
0.65	1.2	0	A3	13	24
0.7	1.2	0	A4	14	24
0.75	1.2	0	A5	15	24
0.8	1.2	0	A6	16	24
0.85	1.2	0	A7	17	24
0.9	1.2	0	A8	18	24
0.95	1.2	0	A9	19	24
1.05	1.19	0	B1	21	23.9
1.1	1.185	0	B2	22	23.8
1.15	1.18	0	B3	23	23.7
1.2	1.175	0	B4	24	23.6
1.25	1.17	0	B5	25	23.5
1.3	1.165	0	B6	26	23.4
1.35	1.16	0	B7	27	23.3
1.4	1.16	0	B8	28	23.2
1.45	1.155	0	B9	29	23.1
1.55	1.145	0	C1	31	22.9
1.6	1.14	0	C2	32	22.8
1.65	1.135	0	C3	33	22.7
1.7	1.13	0	C4	34	22.6
1.75	1.125	0	C5	35	22.5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
1.8	**1.12**	**0**	**C6**	36	22.4
1.85	**1.115**	**0**	**C7**	37	22.3
1.9	**1.11**	**0**	**C8**	38	22.2
1.95	**1.105**	**0**	**C9**	39	22.1
2.05	**1.125**	**0**	**D1**	41	22.5
2.1	**1.15**	**0**	**D2**	42	23
2.15	**1.175**	**0**	**D3**	43	23.5
2.225	**1.15**	**0**	**E1**	44.5	23
2.25	**1.1**	**0**	**E2**	45	22
2.275	**1.05**	**0**	**E3**	45.5	21
2.31667	**0.95**	**0**	**F1**	46.3333	19
2.33333	**0.9**	**0**	**F2**	46.6666	18
2.35	**0.85**	**0**	**F3**	46.9999	17
2.36666	**0.8**	**0**	**F4**	47.3332	16
2.38333	**0.75**	**0**	**F5**	47.6665	15
2.39	**0.65**	**0**	**G1**	47.8	13
2.38	**0.6**	**0**	**G2**	47.6	12
2.37	**0.55**	**0**	**G3**	47.4	11
2.36	**0.5**	**0**	**G4**	47.2	10
2.35	**0.45**	**0**	**G5**	47	9
2.34	**0.4**	**0**	**G6**	46.8	8
2.33	**0.35**	**0**	**G7**	46.6	7
2.32	**0.3**	**0**	**G8**	46.4	6
2.31	**0.25**	**0**	**G9**	46.2	5
2.26667	**0.15**	**0**	**H1**	45.3333	3
2.23333	**0.1**	**0**	**H2**	44.6666	2
2.15	**0.065**	**0**	**I1**	43	1.3
2.1	**0.08**	**0**	**I2**	42	1.6
2.05	**0.095**	**0**	**I3**	41	1.9
2	**0.11**	**0**	**I4**	40	2.2
1.95	**0.125**	**0**	**I5**	39	2.5
1.9	**0.14**	**0**	**I6**	38	2.8
1.85	**0.155**	**0**	**I7**	37	3.1
1.8	**0.17**	**0**	**I8**	36	3.4
1.75	**0.185**	**0**	**I9**	35	3.7
1.7375	**0.25**	**0**	**J1**	34.75	5
1.775	**0.3**	**0**	**J2**	35.5	6
1.8125	**0.35**	**0**	**J3**	36.25	7
1.85	**0.4**	**0**	**J4**	37	8
1.8875	**0.45**	**0**	**J5**	37.75	9
1.925	**0.5**	**0**	**J6**	38.5	10
1.9625	**0.55**	**0**	**J7**	39.25	11

Table 3B. Devil's Kitchen Spring A D/S XYZ Grid Data, September 28, 2006.

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
1.95	**0.625**	**0**	**K1**	39	12.5
1.9	**0.65**	**0**	**K2**	38	13
1.85	**0.675**	**0**	**K3**	37	13.5
1.75	**0.71667**	**0**	**L1**	35	14.3333
1.7	**0.73333**	**0**	**L2**	34	14.6666
1.65	**0.75**	**0**	**L3**	33	14.9999
1.6	**0.76666**	**0**	**L4**	32	15.3332
1.55	**0.78333**	**0**	**L5**	31	15.6665
1.45	**0.81667**	**0**	**M1**	29	16.3333
1.4	**0.83333**	**0**	**M2**	28	16.6666
1.35	**0.85**	**0**	**M3**	27	16.9999
1.3	**0.86667**	**0**	**M4**	26	17.3333
1.25	**0.88333**	**0**	**M5**	25	17.6666
1.2	**0.9**	**0**	**M6**	24	17.9999
1.15	**0.91666**	**0**	**M7**	23	18.3331
1.1	**0.93332**	**0**	**M8**	22	18.6664
1.05	**0.94999**	**0**	**M9**	21	18.9997
1	**0.96665**	**0**	**M10**	20	19.333
0.95	**0.98332**	**0**	**M11**	19	19.6663
0.85	**1**	**0**	**N1**	17	20
0.8	**1**	**0**	**N2**	16	20
0.75	**1**	**0**	**N3**	15	20
0.7	**1**	**0**	**N4**	14	20
0.65	**1**	**0**	**N5**	13	20
0.6	**1**	**0**	**N6**	12	20
0.55	**1**	**0**	**N7**	11	20
0.5	**1.05**	**0**	**O1**	10	21
0.5	**1.1**	**0**	**O2**	10	22
0.5	**1.15**	**0**	**O3**	10	23

CALIBRATION CERTIFICATE

Model: 2ØØØ-21 Serial Number: 2ØØ2679

Unit Gain Ratio: ______ Time Constant: ______

Sensor Ser # N/A

Type of Reading

Velocity:
- X FPS
- _ CMS
- _ ______

Level:
- _ IN
- _ CM
- X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.ØØ	N/A
Measured:	Ø.ØØ	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ______

Calibration Technician: Stan Culski Date: 18 Apr 2006

QA Technician: [signature] Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement
4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

P/N 101001 301

Discharge Measurement: Devil's Kitchen Spring B, Marion County, Florida; September 28, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556   (386) 454-3541 FAX

Discharge Measurement: Devil's Kitchen Spring B, Marion County, Florida; September 28, 2006

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Results of Discharge Measurements of Devil's Kitchen Spring B, Marion County, Florida; September 28, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Devil's Kitchen Spring B on September 28, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Devil's Kitchen Spring B, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

Devil's Kitchen Spring B is located approximately 60 feet northwest of Devil's Kitchen Spring A. It discharges from a roughly circular vent, about 15 feet deep, at the bottom of a sediment-sided depression.

The depression extends to the southeast with a low saddle separating the deeper Devil's Kitchen Spring A basin and the slightly shallower Devil's Kitchen B basin. There is one small vent located between the two springs, and is included in this measurement. See Figure 1.

(Devil's Kitchen Spring A is located approximately 90 feet northeast of Ladies Parlor Spring. Water flows from vents beneath a 26 foot long linear limestone ledge, at a depth of 20 feet, at the bottom of a bowl-shaped depression. There are vents at each end of the ledge and several smaller vents between these.)

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Devil's Kitchen Spring B applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Devil's Kitchen Spring B on September 28, 2006 was 0.24 CFS (cubic feet per second). This result is also expressed as 109 GPM (gallons per minute) or 0.157 MGD (million gallons per day), see Table 1. Three readings were made at each of two vents, for a total of six (6) readings. Individual point velocity readings ranged from 0.23 to 1.02 feet per second (fps), with an overall average station reading of 0.62 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 15 and 17 feet. The measurements commenced at about 15:58 hours and were completed by 16:08 hours.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**DEVIL'S KITCHEN SPRING B**			Date:	**September 28, 2006**
	Silver Springs Group,			Time Start:	15:58
	Marion County, Florida			Time End:	16:08
Personnel:	Peter Butt, Tom Morris				
Method:	Vent Discharge Capture Device		(0.49' Diameter)		
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe.				
Calculation Method: Discharge = V x *pi* x r^2					
Measurement Periods:		60 seconds			
Devil's Kitchen Spring B Total Discharge:			**Main Vent:**	**Small Vent:**	
CFS	**0.24**		**0.198**	**0.045**	
MGD	**0.157**		**0.128**	**0.029**	
GPM	**109**	All Vents:	**89**	**20**	
Avg. Point Velocity (ft/sec):		0.62	1.01	0.23	
Vent Depth (feet deep):			15	17	
Velocity Readings:		(All velocity readings in feet per second.)			
Main Vent		**Small Vent**			
Reading #	Point Velocity	Reading #	Point Velocity		
1	1	1	0.23		
2	1	2	0.23		
3	1.02	3	0.23		
Average:	1.01	Average:	0.23		
Discharge:	0.190	Discharge:	0.043		

Table 1. Discharge of Devil's Kitchen Spring B, Marion County, Florida on September 28, 2006. Data record and calculation of discharge measurement.

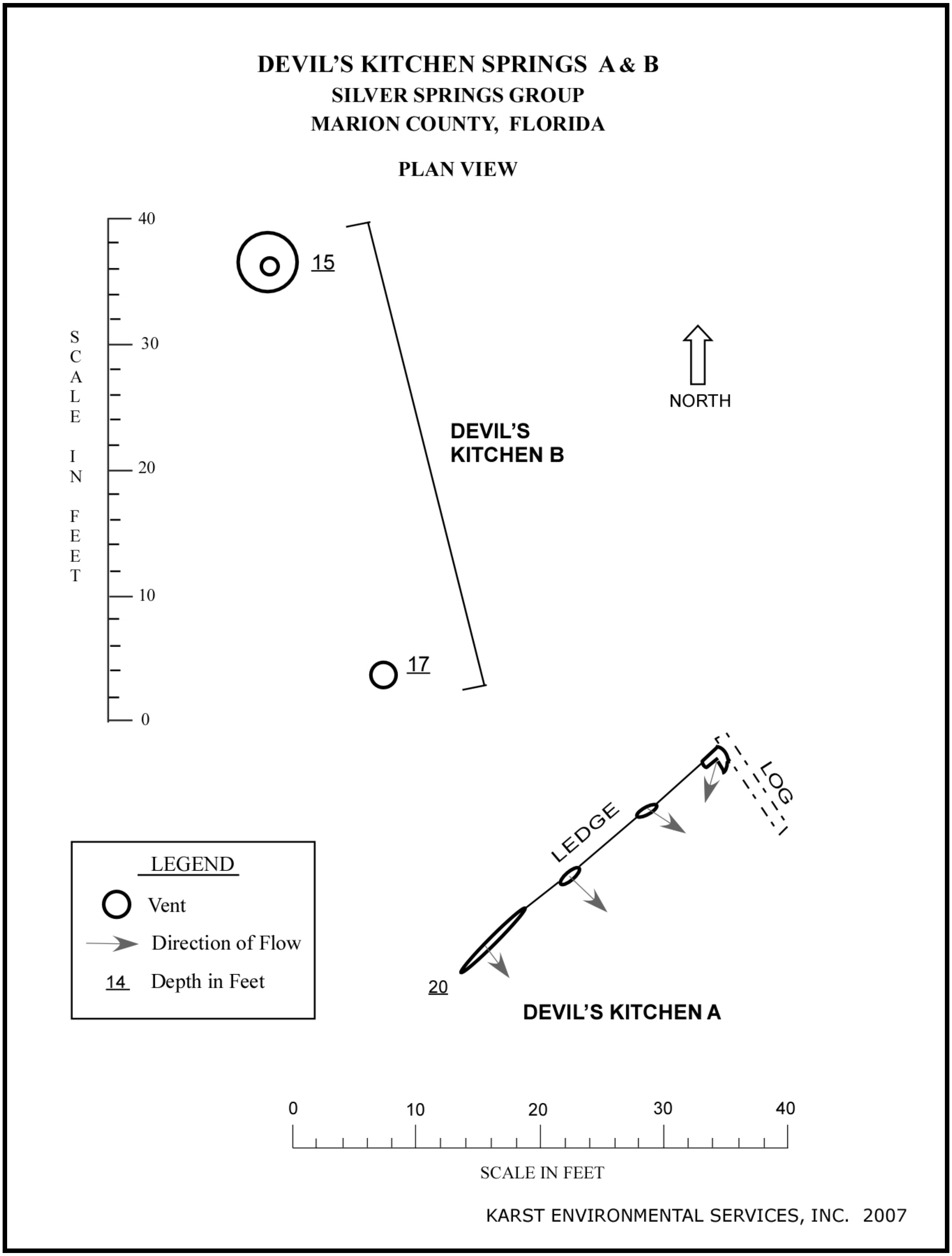

Figure 1. Map of Devil's Kitchen Spring B.

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ____________ Time Constant: ____________

SensorSer # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ______

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: [signature] Date: 18 Apr 2006

QA Technician: [signature] Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

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Discharge Measurement: Garden of Eden Springs Group, Marion County, Florida; September 29, 2006

Prepared for:

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INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Garden of Eden Springs Group on September 29, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Garden of Eden Springs Group, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

The Garden of Eden Spring Group is located in a cove about 240 feet east of Christmas Tree Spring. Garden of Eden is in the same cove as the jungle boat docks. A linear depression about 24 feet long and 15 feet deep contains a line of vents. This vent line accounts for most of the discharge from this group, and contains debris. About 30 feet west of this vent line, there is a roughly circular vent about 4 feet in diameter and 14 feet deep.

Two additional vents lie east of the vent line in a shallow swampy extension of the cove. The first of these, about 70 feet east, is about 2 feet tin diameter and about 8 feet deep. The second vent is 110 feet to the east, and is about 3 feet in diameter and 5 feet deep. Both of these vents gently discharge through detrital sediments and are beneath fallen tree limbs.

Another line of vents, about 17 feet long and 15 feet deep, lies 110 feet southwest of the main vent line. This vent line lies within a depression at the edge of the strong flow of the Silver River. The vents discharge through sand and gravel sediments. See Figure 1.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Garden of Eden Springs Group applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Garden of Eden Springs Group on September 29, 2006 was 2.559 cubic feet per second). This result is also expressed as 1149 (gallons per minute) or 1.654 million gallons per day), see Table 1. Three readings were made at each of twelve, for a total of thirty-six (36) readings. Individual point velocity readings ranged from 0.25 to 0.67 feet per second (fps), with an overall average station reading of 1.12 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 14 to 16 feet. The measurements commenced at about 11:04 hours and were completed by 12:25 hours.

UNDERWATER DISCHARGE MEASUREMENT					**PAGE 1 of 4**
Location:	**GARDEN OF EDEN SPRINGS GROUP**			Date:	**September 29, 2006**
	Silver Springs Group,			Time Start:	11:04
	Marion County, Florida			Time End:	12:25
Personnel:	Peter Butt, Mark Long				
Method:	Vent Discharge Capture Device		(0.49' Diameter)		
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe				
Calculation Method: Discharge = V x *pi* x r^2					
Measurement Periods:		60 seconds			
Garden of Eden Springs Group Total ESTIMATED Discharge:					
			Long Vent	**Round Vent**	**River Vent**
CFS	**2.559**		**1.470**	**0.612**	**0.477**
MGD	**1.654**		**0.950**	**0.396**	**0.308**
GPM	**1149**		**660**	**275**	**214**
		(Multiplier:)	(2.5)	(2)	n/a
Garden of Eden Springs Group Total Measured Discharge:					
CFS	**1.371**		**0.588**	**0.306**	**0.477**
MGD	**0.886**		**0.380**	**0.198**	**0.308**
GPM	**615**	All Vents:	**264**	**137**	**214**
Avg. Point Velocity (ft/sec):		0.65	0.62	0.81	0.51

Table 1. Page 1 of 4. Discharge of Garden of Eden Springs Group, Marion County, Florida on September 29, 2006. Data record and calculation of discharge measurement.

UNDERWATER DISCHARGE MEASUREMENT							**PAGE 2 of 4**
Location:	**GARDEN OF EDEN SPRINGS GROUP**			Date:	**September 29, 2006**		
	Silver Springs Group, Marion County, Florida						
Garden of Eden Long Vent ESTIMATED Discharge							
			Vent 1	**Vent 2**	**Vent 3**	**Vent 4**	**Vent 5**
CFS	**1.470**		**0.379**	**0.314**	**0.288**	**0.269**	**0.220**
MGD	**0.950**		**0.245**	**0.203**	**0.186**	**0.174**	**0.142**
GPM	**660**		**170**	**141**	**129**	**121**	**99**
		(Multiplier:)	(2.5)	(2.5)	(2.5)	(2.5)	(2.5)
Garden of Eden Long Vent Measured Discharge							
			Vent 1	**Vent 2**	**Vent 3**	**Vent 4**	**Vent 5**
CFS	**0.588**		**0.152**	**0.126**	**0.115**	**0.108**	**0.088**
MGD	**0.380**		**0.098**	**0.081**	**0.074**	**0.069**	**0.057**
GPM	**264**	All Vents:	**68**	**56**	**52**	**48**	**40**
Avg. Point Velocity (ft/sec):		0.62	0.80	0.67	0.61	0.57	0.47
Vent Depth (feet deep):			16	16	16	16	16
Velocity Readings:		(All velocity readings in feet per second.)					
Vent 1		**Vent 2**		**Vent 3**		**Vent 4**	
North End Vent		North End Vent		Middle-North Vent		Middle-South Vent	
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity
1	0.81	1	0.67	1	0.63	1	0.56
2	0.79	2	0.67	2	0.6	2	0.58
3	0.81	3	0.66	3	0.6	3	0.57
Average:	0.80	Average:	0.67	Average:	0.61	Average:	0.57
Discharge:	0.152	Discharge:	0.126	Discharge:	0.115	Discharge:	0.108
Multiplier:	2.5	Multiplier:	2.5	Multiplier:	2.5	Multiplier:	2.5
Est. Discharge:	**0.379**	**Est. Discharge:**	**0.314**	**Est. Discharge:**	**0.288**	**Est. Discharge:**	**0.269**
Vent 5							
South End Vent							
Reading #	Point Velocity						
1	0.48						
2	0.45						
3	0.47						
Average:	0.47						
Discharge:	0.088						
Multiplier:	2.5						
Est. Discharge:	**0.220**						

Table 1. Page 2 of 4. Discharge of Garden of Eden Springs Group, Marion County, Florida on September 29, 2006. Data record and calculation of discharge measurement.

UNDERWATER DISCHARGE MEASUREMENT					**PAGE 3 of 4**
Location:	**GARDEN OF EDEN SPRINGS GROUP**			Date:	**September 29, 2006**
	Silver Springs Group, Marion County, Florida				
Garden of Eden Round Vent ESTIMATED Discharge:					
			Vent 6	**Vent 7**	
CFS	**0.612**		**0.415**	**0.197**	
MGD	**0.396**		**0.268**	**0.128**	
GPM	**275**		**186**	**89**	
		(Multiplier)	(2)	(2)	
Garden of Eden Round Vent Measured Discharge:					
CFS	**0.306**		**0.208**	**0.099**	
MGD	**0.198**		**0.134**	**0.064**	
GPM	**137**	All Vents:	**93**	**44**	
Avg. Point Velocity (ft/sec):		0.81	1.10	0.52	
Vent Depth (feet deep):			14	14	
Velocity Readings:		(All velocity readings in feet per second.)			
Vent 6		**Vent 7**			
Round Vent South (Main)		Round Vent North			
Reading #	Point Velocity	Reading #	Point Velocity		
1	1.12	1	0.52		
2	1.09	2	0.53		
3	1.09	3	0.52		
Average:	1.10	Average:	0.52		
Discharge:	0.208	Discharge:	0.099		
Multiplier:	2	Multiplier:	2		
Est. Discharge:	**0.415**	**Est. Discharge:**	**0.197**		

Table 1. Page 3 of 4. Discharge of Garden of Eden Springs Group, Marion County, Florida on September 29, 2006. Data record and calculation of discharge measurement.

UNDERWATER DISCHARGE MEASUREMENT							**PAGE 4 of 4**
Location:	**GARDEN OF EDEN SPRINGS GROUP**			Date:	**September 29, 2006**		
	Silver Springs Group, Marion County, Florida						
Garden of Eden River Vent			**Vent 1**	**Vent 2**	**Vent 3**	**Vent 4**	**Vent 5**
CFS	**0.477**		**0.075**	**0.126**	**0.048**	**0.113**	**0.115**
MGD	**0.308**		**0.048**	**0.082**	**0.031**	**0.073**	**0.074**
GPM	**214**	All Vents:	**34**	**57**	**21**	**51**	**52**
Avg. Point Velocity (ft/sec):		0.51	0.40	0.67	0.25	0.60	0.61
Vent Depth (feet deep):			14	14	15	15	15
Velocity Readings:		(All velocity readings in feet per second.)					
Vent 1		**Vent 2**		**Vent 3**		**Vent 4**	
Downstream Vent		Middle Downstream Vent		Middle Vent		Middle Upstream Vent	
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity
1	0.41	1	0.67	1	0.25	1	0.6
2	0.39	2	0.67	2	0.26	2	0.59
3	0.39	3	0.67	3	0.25	3	0.6
Average:	0.40	Average:	0.67	Average:	0.25	Average:	0.60
Discharge:	**0.075**	**Discharge:**	**0.126**	**Discharge:**	**0.048**	**Discharge:**	**0.113**
Vent 5							
Upstream Vent							
Reading #	Point Velocity						
1	0.61						
2	0.61						
3	0.61						
Average:	0.61						
Discharge:	**0.115**						

Table 1. Page 4 of 4. Discharge of Garden of Eden Springs Group, Marion County, Florida on September 29, 2006. Data record and calculation of discharge measurement.

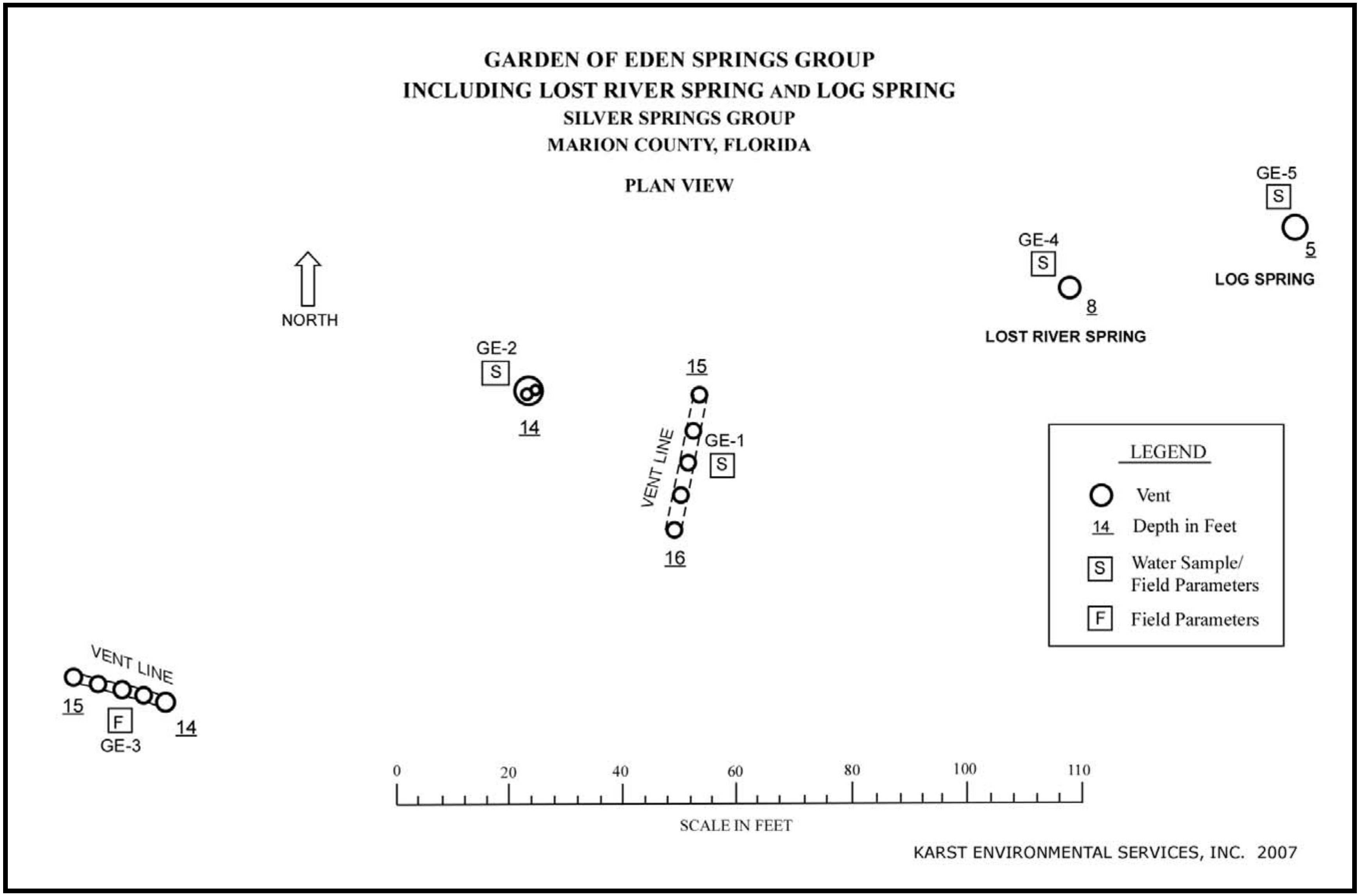

Figure 1. Map of Garden of Eden Springs Group.

CALIBRATION CERTIFICATE

Model: 2ØØØ-21 Serial Number: 2ØØ2679

Unit Gain Ratio: ____________ Time Constant: ____________

SensorSer # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ______

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.ØØ	N/A
Measured:	Ø.ØØ	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: Stan Cieslski Date: 18 Apr 2006

QA Technician: [signature] Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement
4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

P/N 101001 301

Discharge Measurement:
Geyser Springs Group,
Marion County, Florida;
September 29 & 30, 2006

Prepared for:

St. Johns River Water Management District

4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.

5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Geyser Springs Group, Marion County, Florida; September 29 and 30, 2006

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Results of Discharge Measurements of Geyser Springs Group, Marion County, Florida; September 29 and 30, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurements made at Geyser Springs Group on September 29 and 30, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Geyser Springs Group, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida.

SITE DESCRIPTION

The Geyser Spring Group is located in the western side of a large cove on the south side of the Silver River, east and downstream of Alligator Hole. There is a small peninsula of land between Alligator Hole Spring and Geyser Spring.

The Geyser Spring Group encompasses a number of vents of varying description. The large basin containing this spring group is dominated by a linear outcrop of limestone about 3 feet high and 26 feet long, at about 16 feet of depth. There are vents all along the base of this outcrop, with the largest vent on the northern side of its eastern end. Numerous other vents can be observed on the bottom of the basin around this outcrop, discharging through the filamentous algae that covers the bottom.

On the north side of the basin, about 35 to 40 feet north of the outcrop, there is a group of five large vents formed within the thick peaty deposits that overly the limestone. These vents lie along the bottom of the north slope of the basin, at about 18 to 21 feet deep.

About 30 to 40 feet west of the outcrop, there are several vents at about 15 feet of depth discharging through the algae covering the bottom. About 30 feet south of the outcrop, another vent discharges from the bottom of a conical depression at about 18 feet deep. See Figure 1.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

Cross-Section Measurements

Pete Butt positioned the sensor, and recorded positional data, while Mark Long read the velocity readings, after taking meter reset cues from Butt. During all measurements, the sensor handler completely removed himself from the cross section of the flow. The meter operator was also positioned outside the cross-section. This eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. Fifty-two (52) station readings were taken.

The approximate depth for the measurement grids was 18 to 21 feet. Telescoping aluminum poles with 1, 0.5, 0.25 and 0.1 foot interval markings were positioned horizontally to allow for a grid of velocity measurements. As all sensor-support poles were positioned at right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was positioned on the poles with a quick release clamp. Spring vent dimensions and positions were measured with a metal tape. Two hand-held readings were made in two small vents,

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figures 2(A, BL, BU, C & D). Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Tables 3A, 3BL, 3BU, 3C & 3D. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used for all five vents was point Kriging with linear drift, an anisotropy ratio of 1 at an angle of 0°, and a variogram slope of 1.0. The results of the contour processing are illustrated in Figures 3(A, BL, BU, C & D) and 4(A, BL, BU, C & D).

During this measurement, one negative velocity was measured in Vent A. Negative velocity stations typically represent slight back eddies near walls. In order to incorporate any negative values, calculations were made using a Surfer 8 “blanking file” operation to define the measurement cross-section boundary. The total discharge is shown on Tables 2A, 2BL, 2BU, 2C and 2D as the **Net Volume (Cut-Fill)**, and has been calculated as the Positive Volume (Cut) less that portion of the Negative Volume (Fill) lying within the measurement cross-section boundary walls that define the plane of measurement.

The software also calculates the total cross-sectional area of the measurement location within the passage, and is presented on Tables 2A, 2BL, 2BU, 2C and 2D as the **Operational Planar Area**. The Operational Planar Area is the sum of the Positive (Cut) and that portion of the Negative (Fill) Planar areas lying within the measurement cross-section boundary walls that define the plane of measurement.

VDCD Measurements

This spring also has small, scattered vents discharging through a mixed bottom of either detritus, sediments, or a thick algal layer. Direct measurements of the vent cross-sections at these locations were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1B.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1B, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Geyser Springs Group applying the methods and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated total discharge of Geyser Springs Group (all vents) on September 29 and 30, 2006 was 6.06 CFS (cubic feet per second). This result is also expressed as 3.919 GPM (gallons per minute) or 2722 MGD (million gallons per day), see Tables 1A and 1B. The small vent measurements were performed between 16:09 and 16:28 hours on September 29 and 11:03 and the cross-sectional vent measurements between 11:03 and 12:40 hours on September 30. The results for each of the individual vents are detailed below. Individual point velocity measurement periods of 60 seconds were used. A total of fifty-two (52) cross-sectional readings were made, see Figures 2(A,BL,BU,C,D), 3(A,BL,BU,C,D) and 4(A,BL,BU,C,D). The total cross-sectional area was calculated as 21.25 square feet. The point velocity readings ranged from -0.53 to 1.06 feet per second (fps), with an overall average station reading of 0.44 fps.

The estimated discharge of Geyser Springs Group Vent A on September 30, 2006 was 1.576 CFS. This result is also expressed as 707 GPM or 1.019 MGD, see Table 1A. Fifteen (15) readings were made, see Figures 2A, 3A and 4A. The total cross-sectional area was calculated as 8.28 square feet. The point velocity readings ranged from -0.53 to 0.44 feet per second (fps), with an overall average station reading of 0.22 fps.
The estimated discharge of Geyser Springs Group Vent B Upper on September 30, 2006 was 0.2 CFS. This result is also expressed as 90 GPM or 0.129 MGD, see Table 1A. Thirteen (13) readings were made, see Figures 2BU, 3BU and 4BU. The total cross-sectional area was

calculated as 2.14 square feet. The point velocity readings ranged from 0.17 to 0.61 feet per second (fps), with an overall average station reading of 0.41 fps.

The estimated discharge of Geyser Springs Group Vent B Lower on September 30, 2006 was 1.584 CFS. This result is also expressed as 711 GPM or 1.024 MGD, see Table 1A. Eight (8) readings were made, see Figures 2BL, 3BL and 4BL. The total cross-sectional area was calculated as 5.39 square feet. The point velocity readings ranged from 0.01 to 0.36 feet per second (fps), with an overall average station reading of 0.17 fps.

The estimated discharge of Geyser Springs Group Vent C on September 30, 2006 was 0.321 CFS. This result is also expressed as 144 GPM or 0.207 MGD, see Table 1A. Five (5) readings were made, see Figures 2C, 3C and 4C. The total cross-sectional area was calculated as 0.82 square feet. The point velocity readings ranged from 0.55 to 1.06 feet per second (fps), with an overall average station reading of 0.8 fps.

The estimated discharge of Geyser Springs Group Vent D on September 30, 2006 was 1.683 CFS. This result is also expressed as 755 GPM or 1.088 MGD, see Table 1A. Eleven (11) readings were made, see Figures 2D, 3D and 4D. The total cross-sectional area was calculated as 4.62 square feet. The point velocity readings ranged from 0.03 to 1.04 feet per second (fps), with an overall average station reading of 0.57 fps.

The estimated discharge of Geyser Springs Group Miscellaneous Vents on September 29, 2006 was 0.7 CFS. This result is also expressed as 316 GPM or 0.456 MGD, see Table 1B. Three readings were made at each of three vents, for a total of nine (9) readings. Individual point velocity readings ranged from 0.24 to 1.13 feet per second (fps), with an overall average station reading of 0.56 fps. The approximate depth for the measurements was 15 to 18 feet. The measurements commenced at about 16:09 hours and were completed by 16:28 hours.

UNDERWATER DISCHARGE MEASUREMENT								
Location:	**GEYSER SPRINGS GROUP**			Date:	**September 30, 2006**		**September 29, 2006**	
	Silver Springs Group,			Time Start:	11:03		16:09	
	Marion County, Florida			Time End:	12:40		16:28	
Personnel:	Peter Butt, Mark Long				(X-Sec. Vents)		(Small Vents)	
Method:	Grid within irregular conduit							
Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles							
Msmt. Periods:		60 seconds						(From
Analysis Method: Surfer 8 with kriging								Table 1B)
Geyser Spring Total Discharge:			**Vent A:**	**Vent B Upper:**	**Vent B Lower:**	**Vent C:**	**Vent D:**	**Small Vents:**
CFS	**6.06**		**1.576**	**0.2**	**1.584**	**0.321**	**1.683**	**0.7**
MGD	**3.919**		**1.019**	**0.129**	**1.024**	**0.207**	**1.088**	**0.456**
GPM	**2722**	X-Sec. Vents:	**707**	**90**	**711**	**144**	**755**	**316**
Total Cross-sectional Area (sq/ft):		21.25	8.28	2.14	5.39	0.82	4.62	n/a
Avg. Station Point Velocity (ft/sec):		0.44	0.22	0.17	0.41	0.80	0.57	(0.56)
Cross-section Depth (feet deep):			19-21	18-19	19	20	20-21	18-21
Velocity Reading by Station:		(All velocity readings in feet per second.)						
Station #	Point Velocity	Station #	Point Velocity	Station #	Point Velocity	Station #	Point Velocity	
VENT A		**VENT B Upper**		**VENT B Lower**		**VENT C**		
1	0.44	1	0.01	1	0.39	1	0.83	
2	0.39	2	0.07	2	0.58	2	0.76	
3	0.31	3	0.06	3	0.6	3	0.79	
4	0.1	4	0.16	4	0.53	4	0.55	
5	0.2	5	0.35	5	0.61	5	1.06	
6	0.33	6	0.26	6	0.21			
7	0.24	7	0.36	7	0.54	**VENT D**		
8	0.42	8	0.12	8	0.26	1	0.46	
9	-0.53			9	0.29	2	0.76	
10	0.23			10	0.24	3	0.77	
11	0.09			11	0.17	4	1.04	
12	0.21			12	0.4	5	0.84	
13	0.15			13	0.53	6	0.08	
14	0.34					7	0.03	
15	0.36					8	0.63	
						9	0.65	
						10	0.78	
						11	0.27	

Table 1A. Discharge of Geyser Springs Group, Marion County, Florida on September 29 & 30, 2006. Data record and calculation of discharge measurement.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**GEYSER SPRINGS GROUP SMALL VENTS**			Date:	**September 29, 2006**
	Silver Springs Group,			Time Start:	16:09
	Marion County, Florida			Time End:	16:28
Personnel:	Peter Butt, Mark Long				
Method:	Vent Discharge Capture Device		(0.49' Diameter		
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe.				
Calculation Method: Discharge = V x *pi* x r^2					
Measurement Periods:		60 seconds			
Geyser Springs Group Small Vents ESTIMATED Discharge:					
All Small Vents:			**Vent 1:**	**Vent 2:**	**Vent 3:**
CFS	**0.70**		**0.092**	**0.198**	**0.415**
MGD	**0.456**		**0.059**	**0.128**	**0.268**
GPM	**316**		**41**	**89**	**186**
		(Multipliers:)	(2)	(3)	(2)
Geyser Springs Group Small Vents Measured Discharge:					
CFS	**0.32**		**0.046**	**0.066**	**0.208**
MGD	**0.206**		**0.030**	**0.043**	**0.134**
GPM	**143**	All Vents:	**21**	**30**	**93**
Avg. Point Velocity (ft/sec):		0.56	0.24	0.35	1.10
Vent Depth (feet deep):			15	15	18
Velocity Readings:		(All velocity readings in feet per second.)			
Vent 1		**Vent 2**		**Vent 3**	
West Vent		West Vent		South Vent	
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity
1	0.25	1	0.35	1	1.13
2	0.24	2	0.35	2	1.11
3	0.24	3	0.35	3	1.06
Average:	0.24	Average:	0.35	Average:	1.10
Discharge:	0.046	Discharge:	0.066	Discharge:	0.208
Multiplier:	2	Multiplier:	3	Multiplier:	2
Est. Discharge:	**0.092**	**Est. Discharge:**	**0.198**	**Est. Discharge:**	**0.415**

Table 1B. Discharge of Geyser Springs Group Small Vents, Marion County, Florida on September 29, 2006. Data record and calculation of discharge measurement.

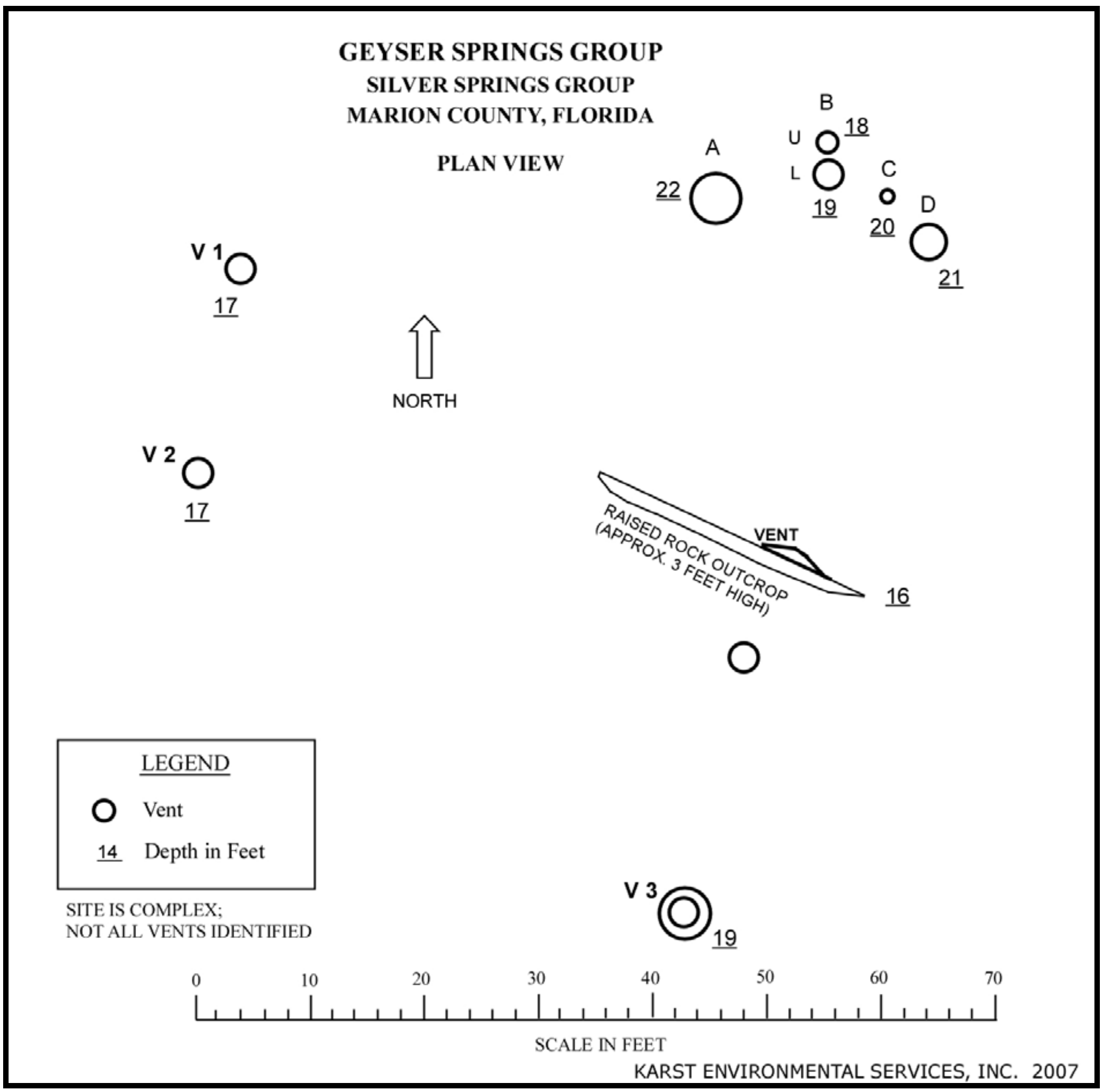

Figure 1. Map of Geyser Springs Group.

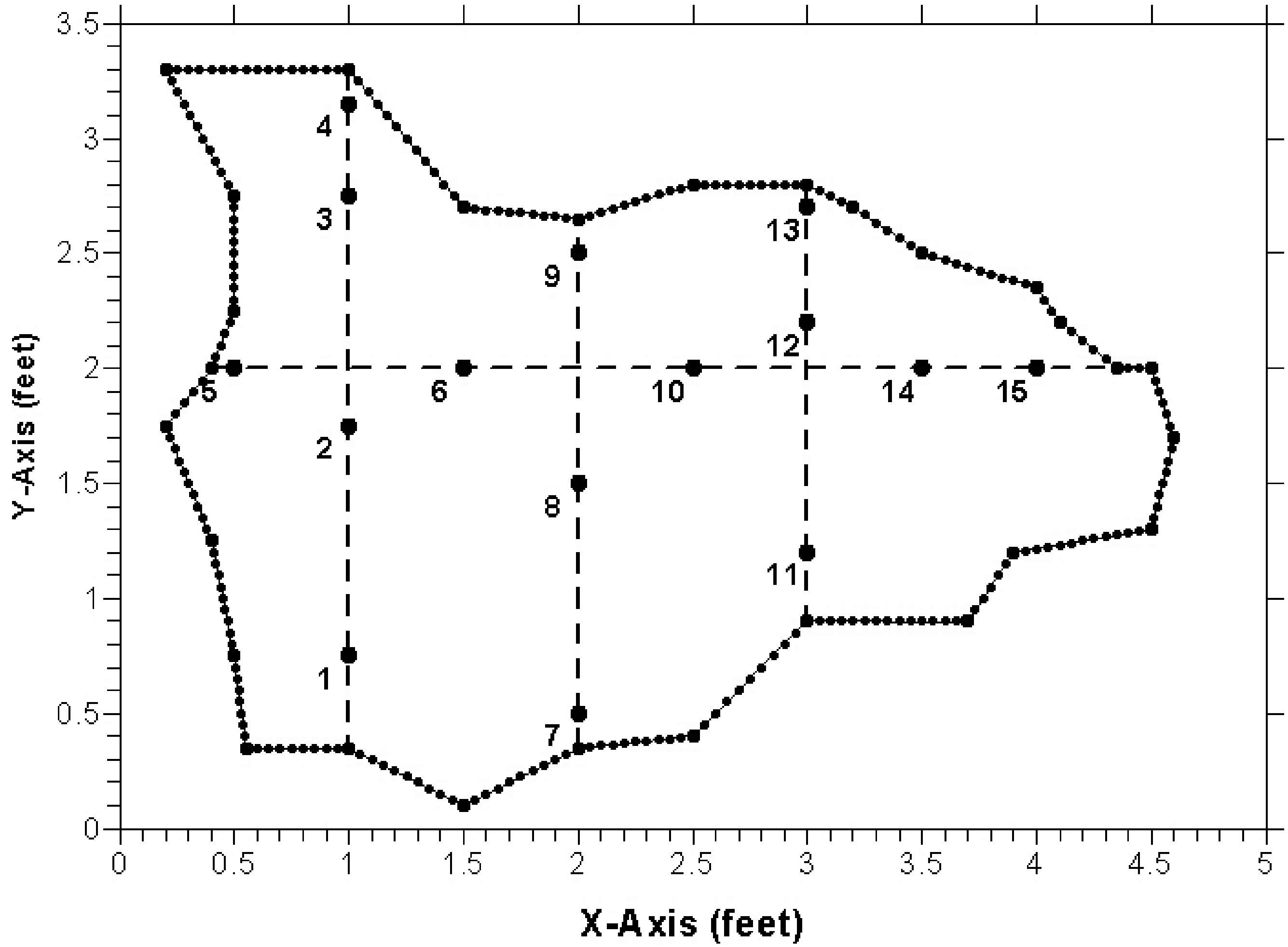

Figure 2A. Discharge measurement cross-section; Geyser Springs Group Vent A, Marion County, Florida, September 30, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 19 to 21-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

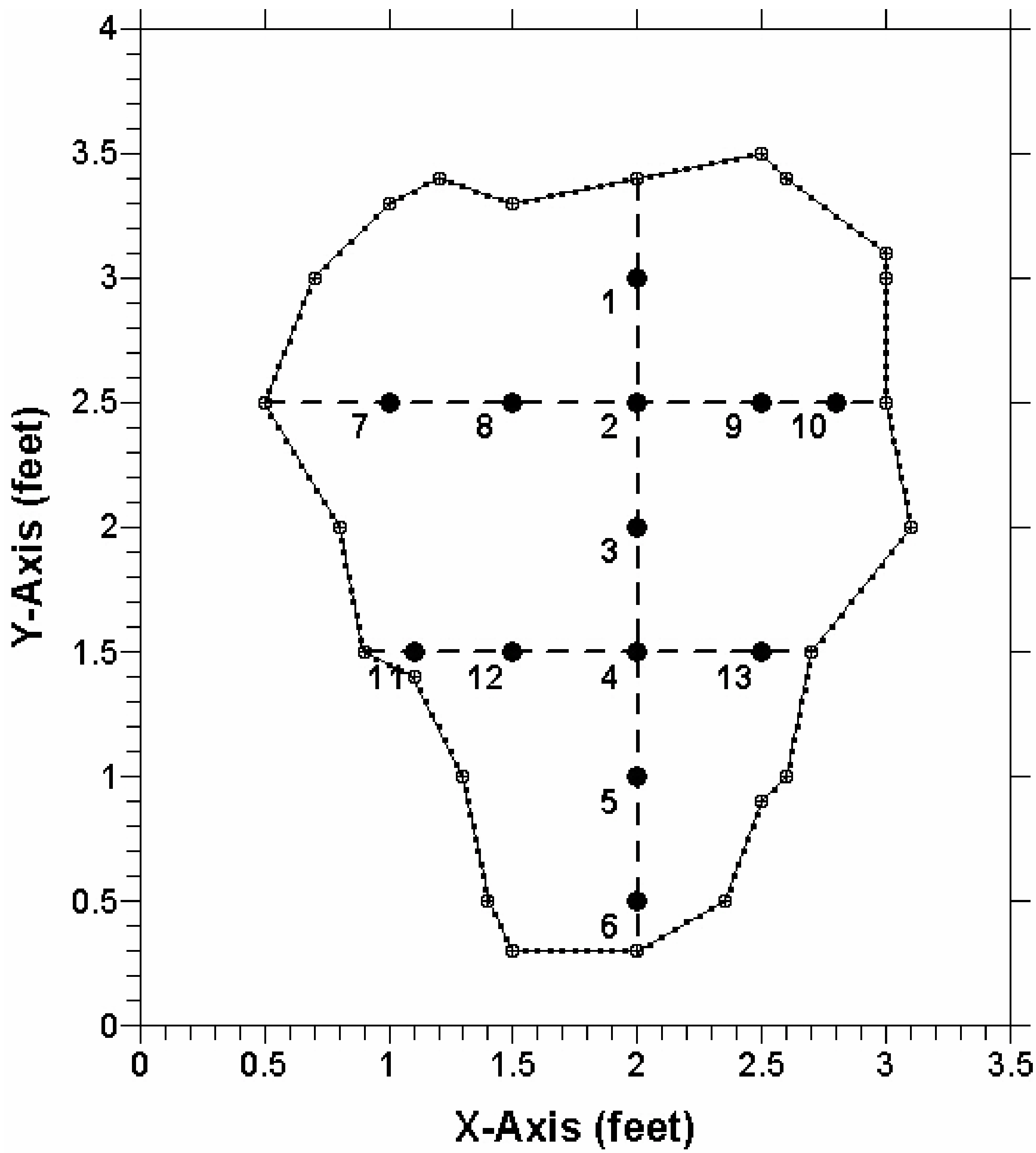

Figure 2BU. Discharge measurement cross-section; Geyser Springs Group Vent B Upper, Marion County, Florida, September 30, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 18 to 20-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

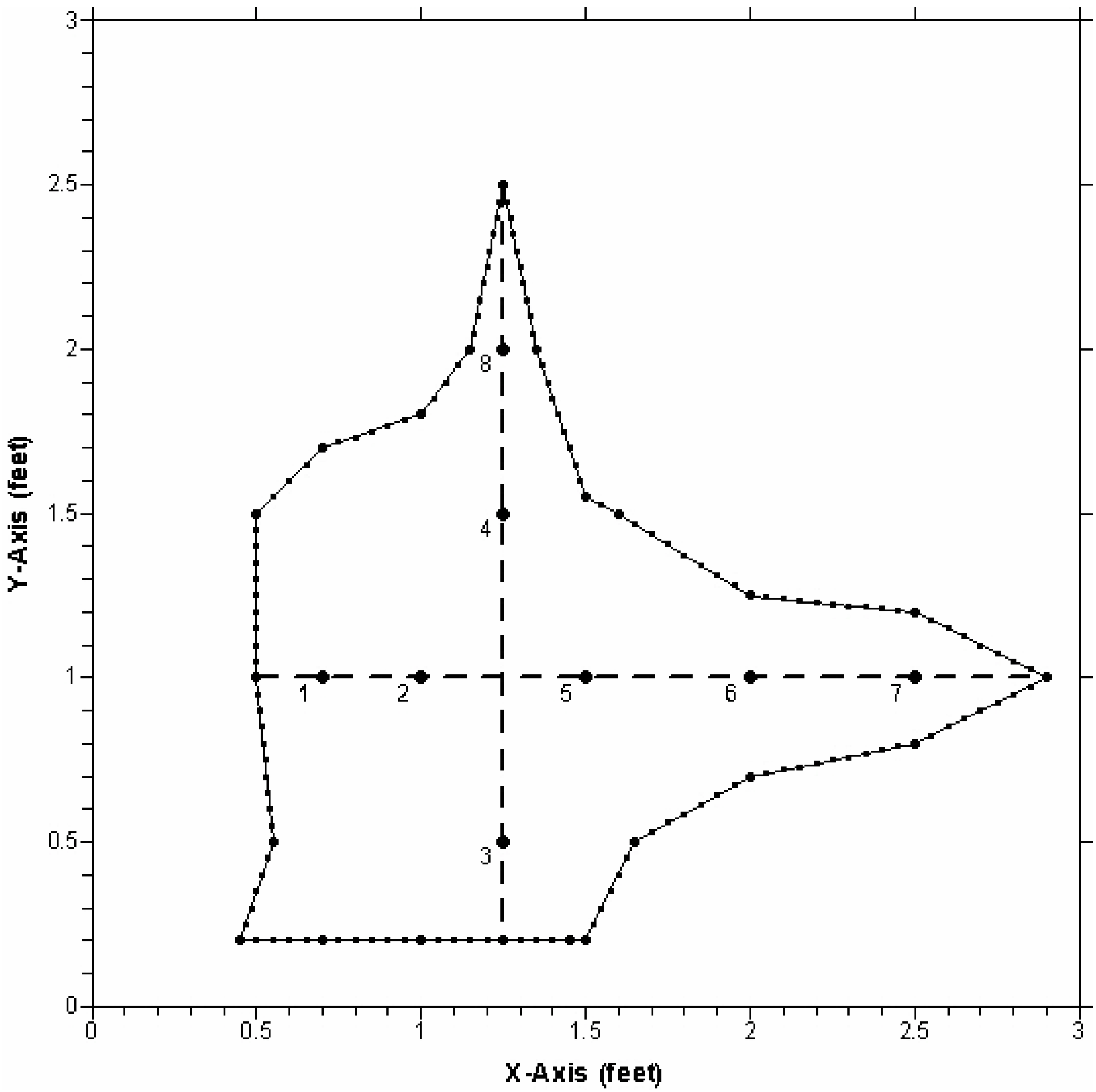

Figure 2BL. Discharge measurement cross-section; Geyser Springs Group Vent B Lower, Marion County, Florida, September 30, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 19-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

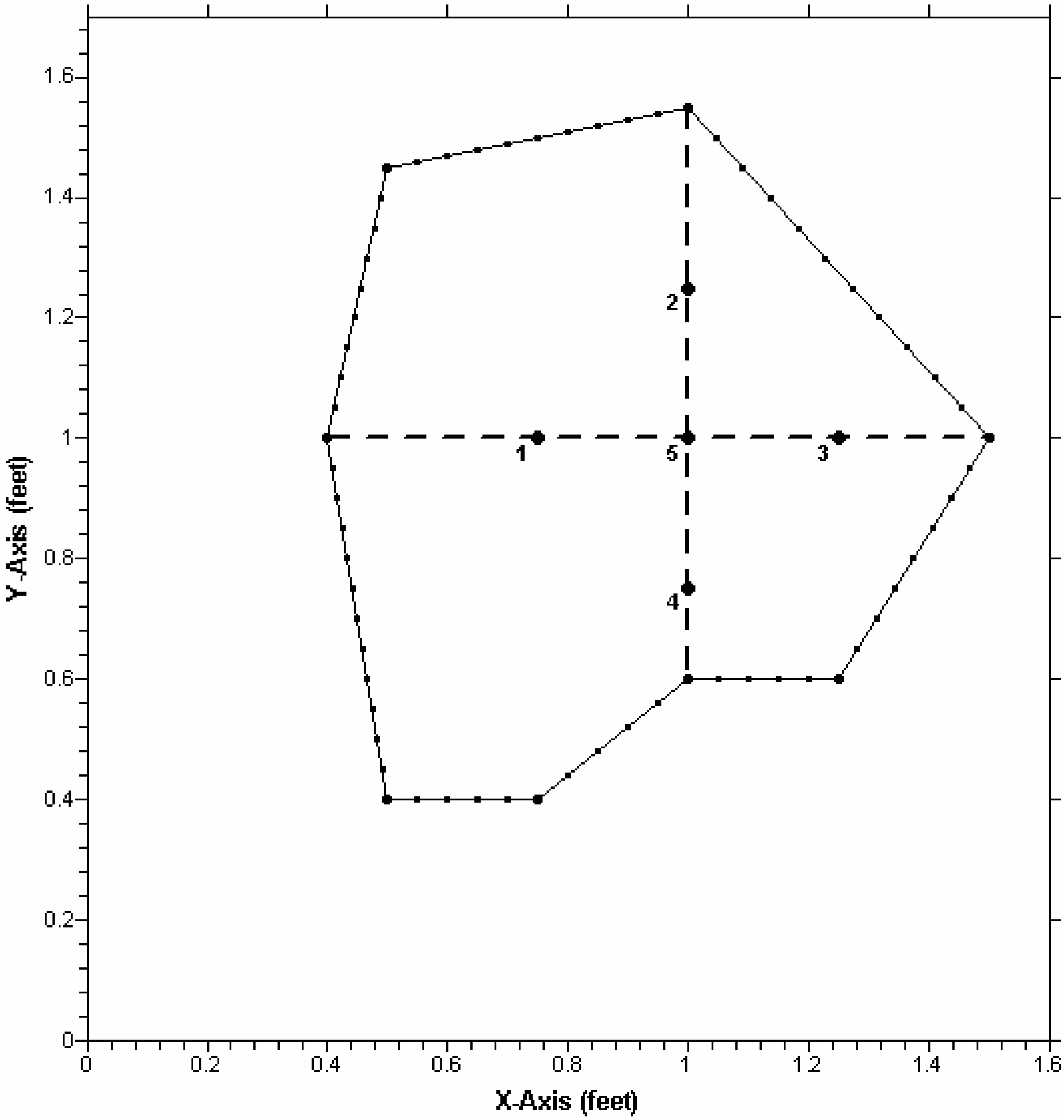

Figure 2C. Discharge measurement cross-section; Geyser Springs Group Vent C, Marion County, Florida, September 30, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 20-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

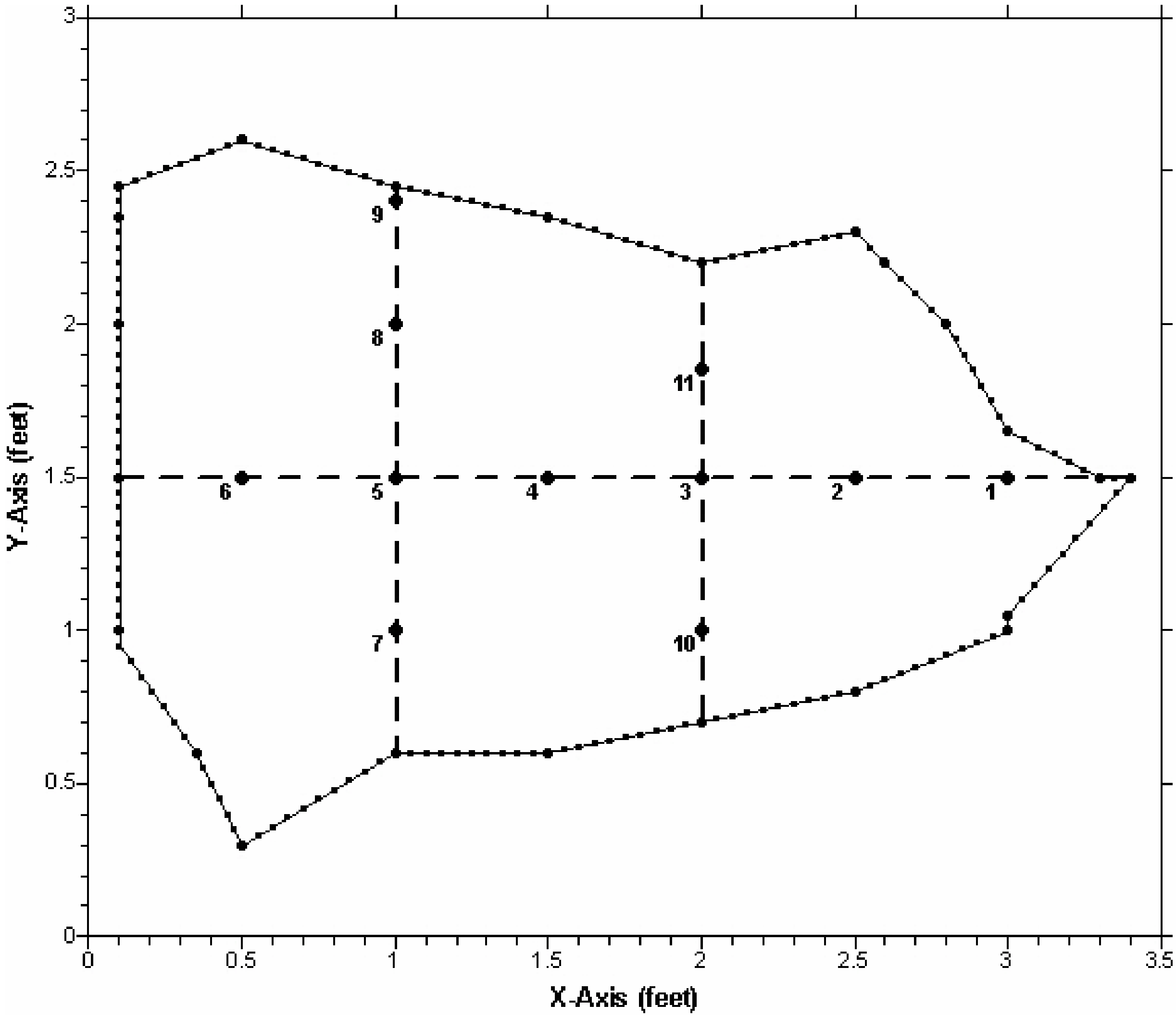

Figure 2D. Discharge measurement cross-section; Geyser Springs Group Vent D, Marion County, Florida, September 30, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 20 to 21-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

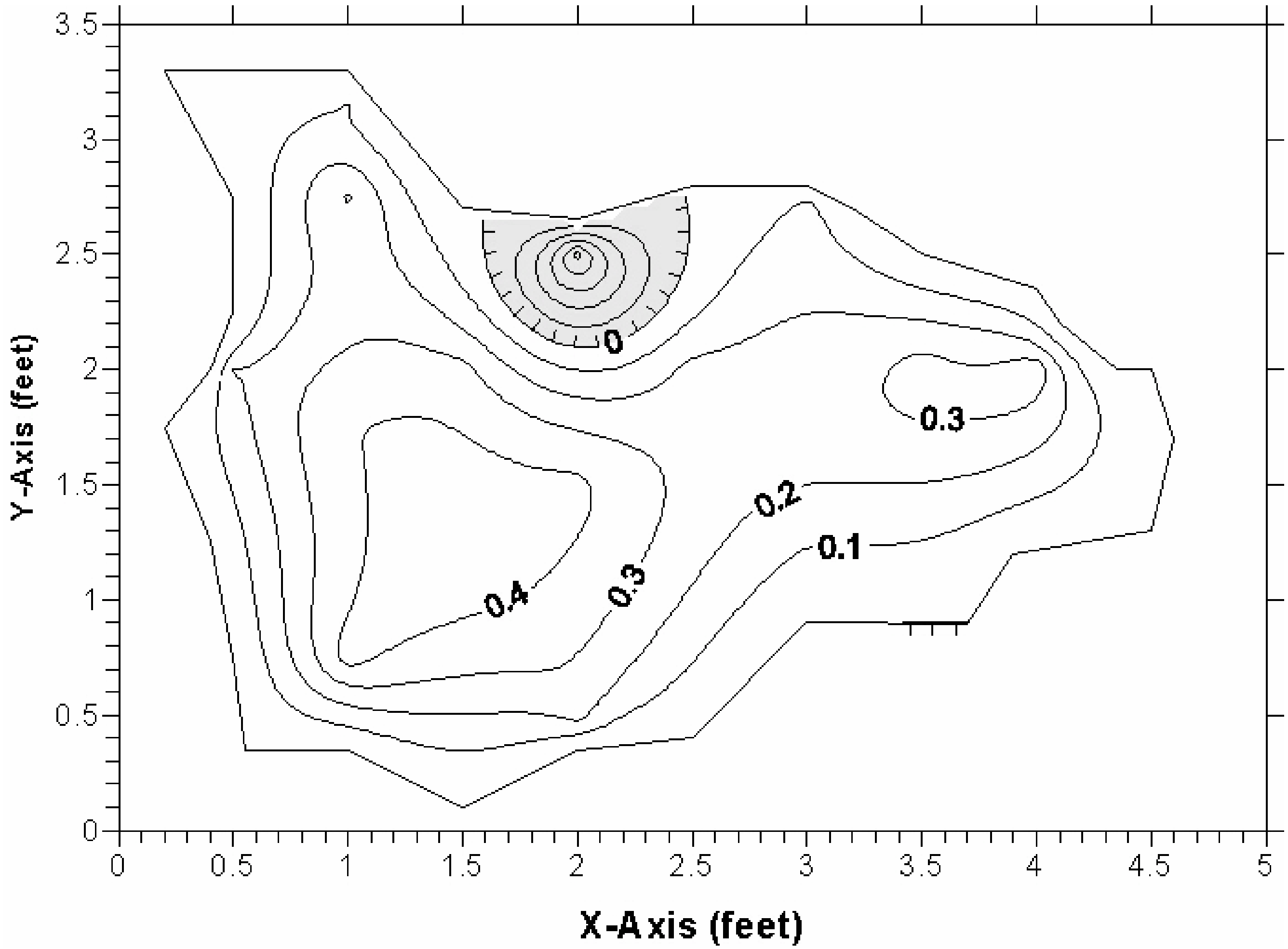

Figure 3A. Discharge measurement cross-section; Geyser Springs Group Vent A, Marion County, Florida, September 30, 2006 measurement. Flow contour velocities are shown in feet per second. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

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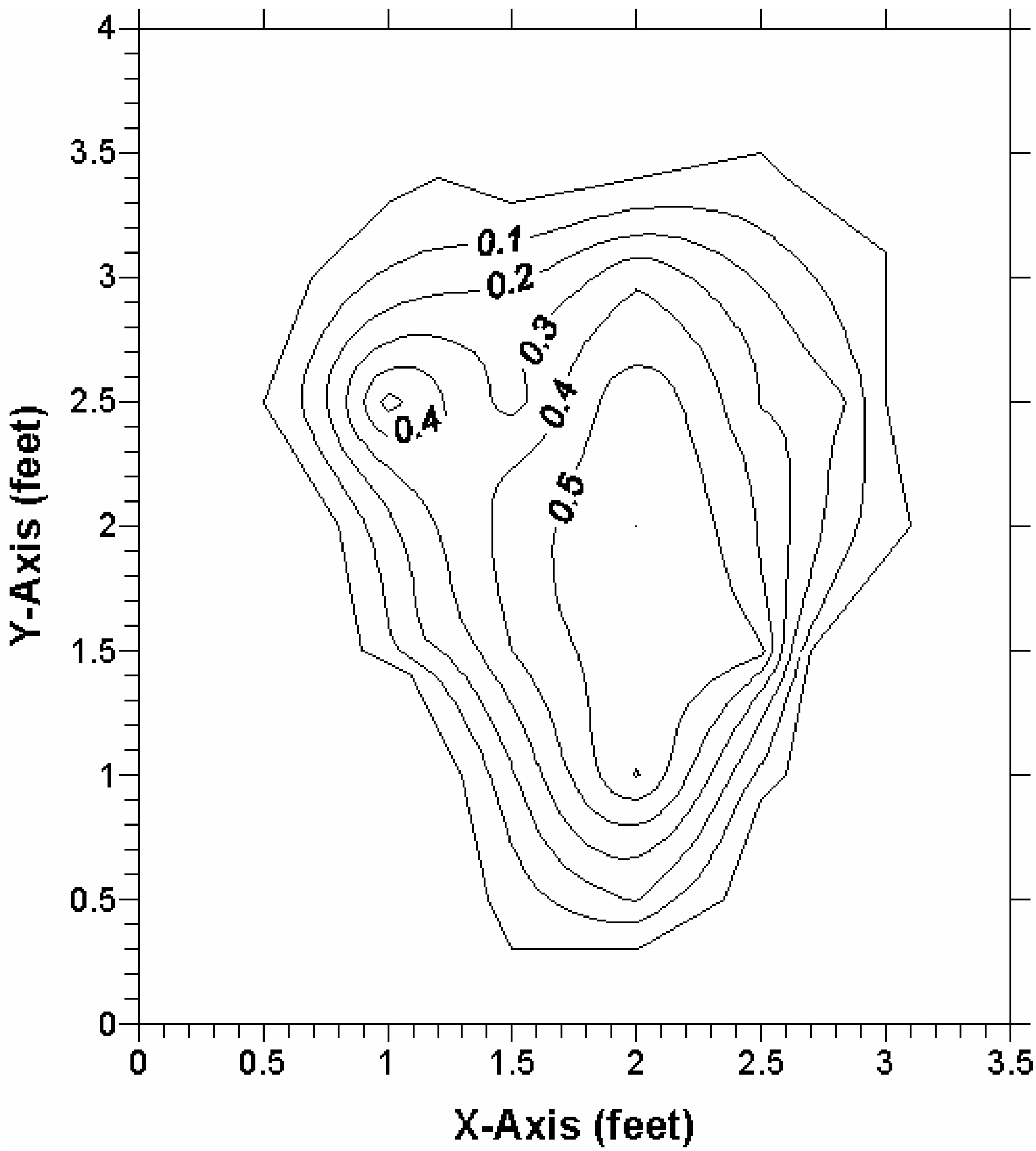

Figure 3BU. Discharge measurement cross-section; Geyser Springs Group Vent B Upper, Marion County, Florida, September 30, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

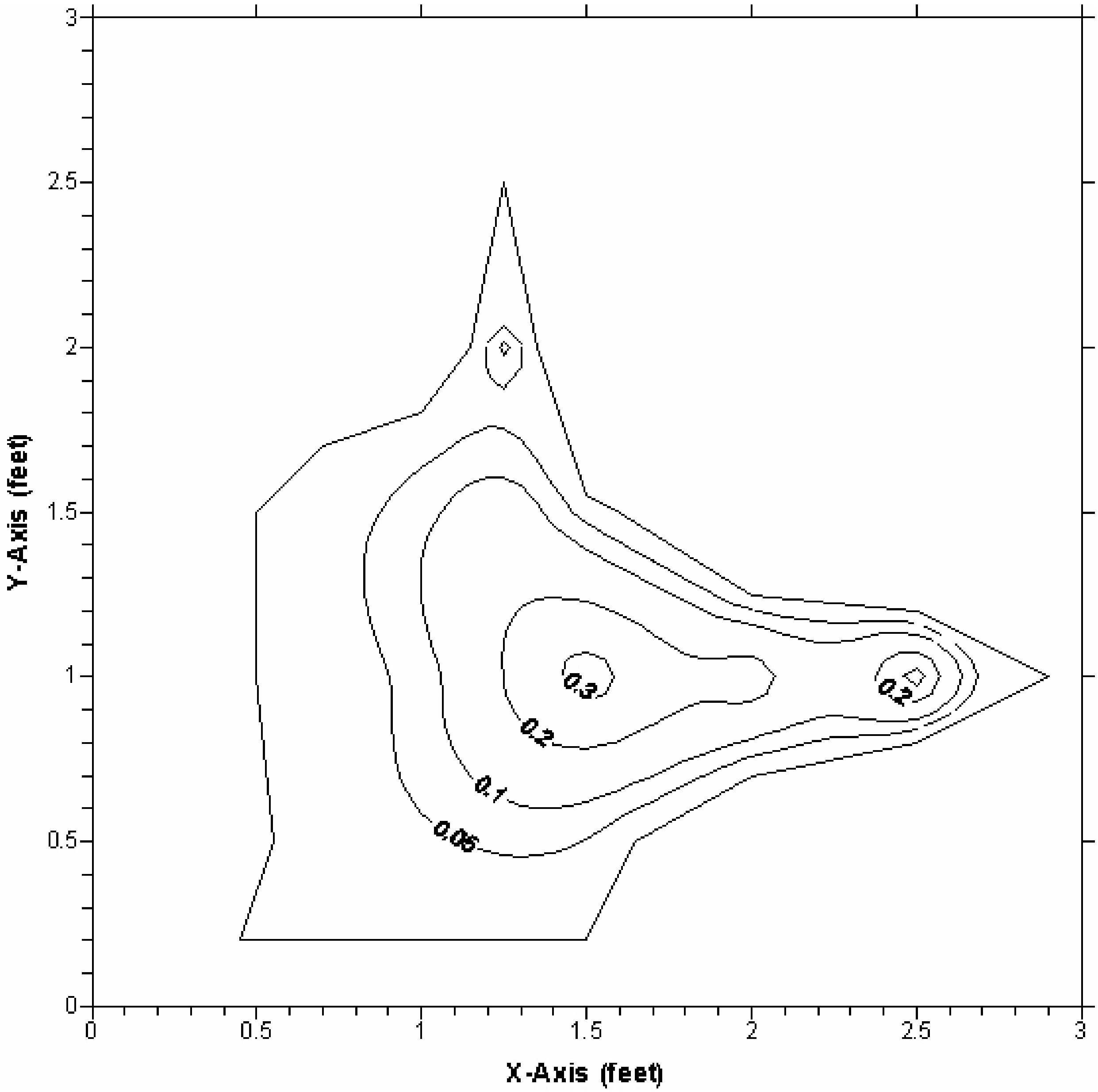

Figure 3BL. Discharge measurement cross-section; Geyser Springs Group Vent B Lower, Marion County, Florida, September 30, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

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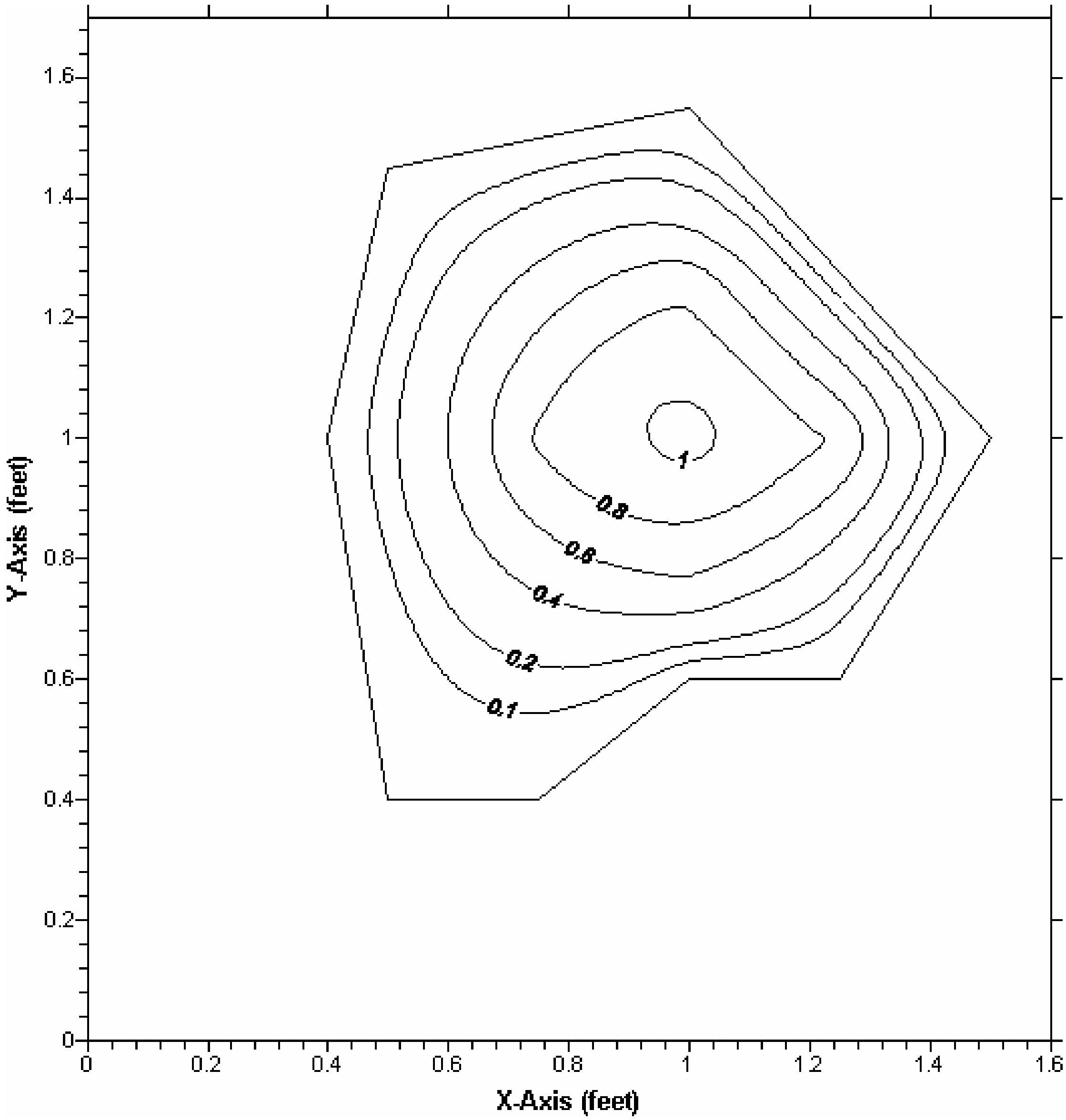

Figure 3C. Discharge measurement cross-section; Geyser Springs Group Vent C, Marion County, Florida, September 30, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

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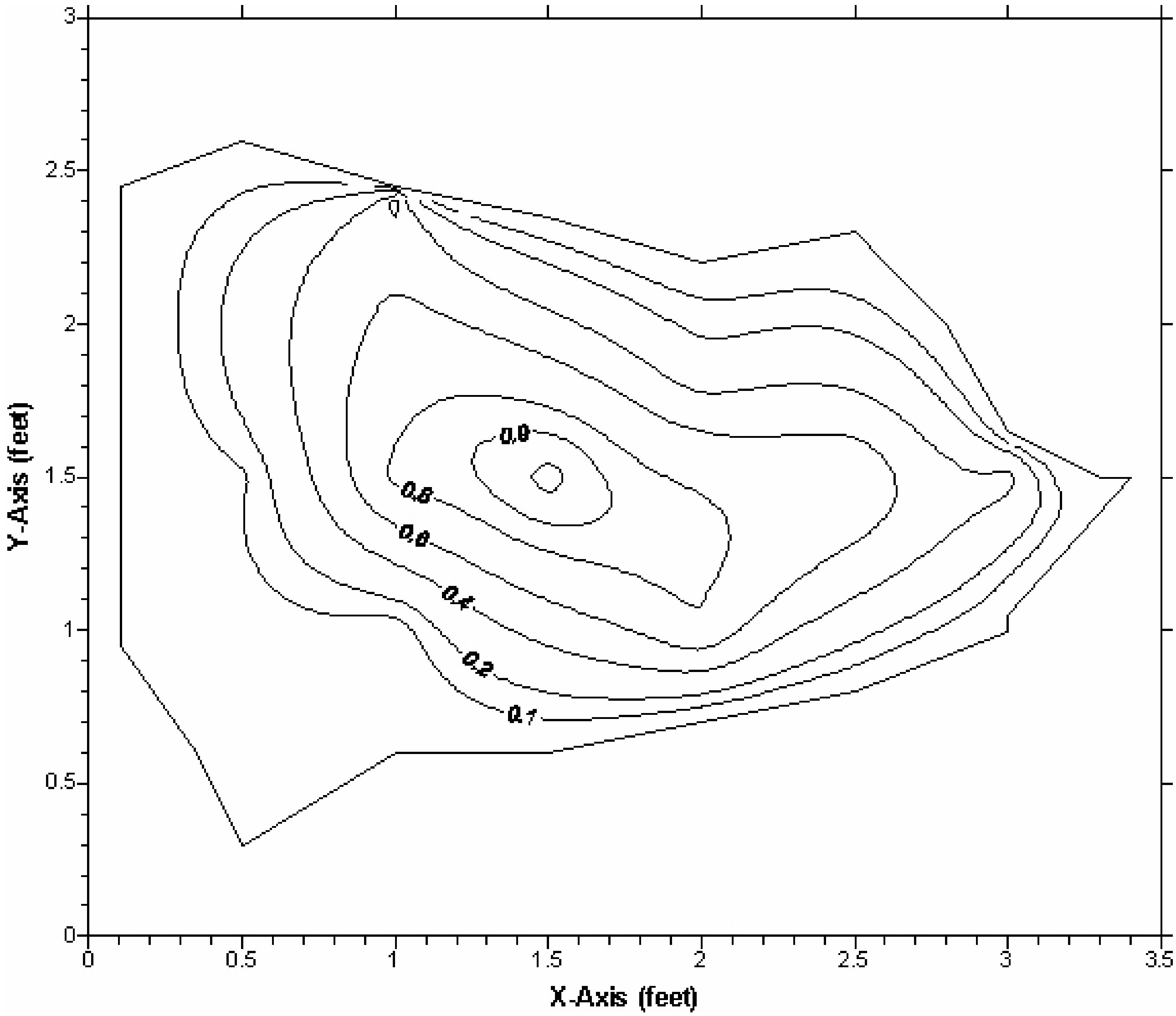

Figure 3D. Discharge measurement cross-section; Geyser Springs Group Vent D, Marion County, Florida, September 30, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

KARST ENVIRONMENTAL SERVICES, INC. 2007

TABLE 2A. GEYSER SPRINGS GROUP, VENT A, SEPTEMBER 30, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_A\Geyser_Vent_A_9-06.bln.grd
Grid Size:	71 rows x 101 columns
X Minimum:	0
X Maximum:	5
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	3.5
Y Spacing:	0.05
Z Minimum:	-0.5300000002622
Z Maximum:	0.44651694257247

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES
Z Scale Factor: 1
Total Volumes by:
Trapezoidal Rule: 1.5755136003306
Simpson's Rule: 1.5756338953435
Simpson's 3/8 Rule: 1.5754395882871

CUT & FILL VOLUMES
Positive Volume [Cut]: 1.6290435254362
Negative Volume [Fill]: 0.053529925105566
Net Volume [Cut-Fill]: 1.5755136003306 <<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 8.28 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 7.8597272106182
Negative Planar Area [Fill]: 0.41527278938182
Blanked Planar Area: 9.225
Total Planar Area: 17.5

Surface Areas
Positive Surface Area [Cut]: 8.8593874031864
Negative Surface Area [Fill]: 0.65247574906328

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_A\Geyser Vent A 9-06 SURFER XYZ T3A BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	258
Original Data:	258
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.2	0.1	-0.53
25%-tile:	0.5375	0.9	0
Median:	1.95	1.9	0
75%-tile:	3.35	2.7	0
Maximum:	4.6	3.3	0.44
Midrange:	2.4	1.7	-0.045
Range:	4.4	3.2	0.97
Interquartile Range:	2.8125	1.8	0
Median Abs. Deviation:	1.4125	0.9	0
Mean:	2.0725764341085	1.769573120155	0.012713178294574
Trim Mean (10%):	2.0389045726496	1.7728626709402	0.00081196581196581
Standard Deviation:	1.4393965772601	1.012466824136	0.074882356705117
Variance:	2.0718625066282	1.025089069976	0.0056073673457124
Coef. of Variation:			5.8901365944879
Coef. of Skewness:			1.9758765408185

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.097	-0.005
Y:		1.000	-0.016
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	2.0718625066282	-0.14103021877686	-0.00057383993750376
Y:		1.025089069976	-0.0011790691244517
Z:			0.0056073673457124

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-0.00035862066997249	-0.0011995498849915	0.015579138276709
Standard Error:	0.0032727236619922	0.0046527423171716	0.012107401397244

Inter-Parameter Correlations

	A	B	C
A:	1.000	-0.097	-0.626
B:		1.000	0.734
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.00041799691863309	0.00020899845931655	0.036849
Residual:	255	1.4462827782752	0.0056716971697065	
Total:	257	1.4467007751938		

Coefficient of Multiple Determination (R^2): 0.00028893114996575

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.05	0
Median:	0.052201532544552	0
75%-tile:	0.056955470544979	0
Maximum:	0.70710678118655	0.53

Midrange:	0.37855339059327	0.265
Range:	0.65710678118655	0.53
Interquartile Range:	0.006955470544979	0
Median Abs. Deviation:	0.0022015325445526	0
Mean:	0.070935697064093	0.012209302325581
Trim Mean (10%):	0.054640177246354	0.0005982905982906
Standard Deviation:	0.083635808076405	0.061089611953756
Variance:	0.0069949483925933	0.0037319406886605
Coef. of Variation:	1.1790369523096	5.0035301219267
Coef. of Skewness:	5.3813088304613	5.925215557905
Root Mean Square:	0.10966686605608	0.062297734725574
Mean Square:	0.012026821510562	0.003881007751938

Complete Spatial Randomness

Lambda: 18.323863636364
Clark and Evans: 0.60730011312083
Skellam: 357.24609571494

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 5.2E-007
Y Duplicate Tolerance: 3.8E-007
No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point
Polynomial Drift Order: 1
Kriging std. deviation grid: no

Semi-Variogram Model

Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 1
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_A\Geyser_Vent_A_9-06.grd
Grid Size:	71 rows x 101 columns
Total Nodes:	7171
Filled Nodes:	7171
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	5
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	3.5
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-0.5300000002622
Z 25%-tile:	-0.07971588178555
Z Median:	-0.0071902918605128
Z 75%-tile:	0.17845647968758
Z Maximum:	0.44651694257247
Z Midrange:	-0.041741528844863
Z Range:	0.97651694283467
Z Interquartile Range:	0.25817236147313
Z Median Abs. Deviation:	0.098336854431382
Z Mean:	0.049755561733246
Z Trim Mean (10%):	0.041593290558128
Z Standard Deviation:	0.16690863656794
Z Variance:	0.027858492960968
Z Coef. of Variation:	3.3545724488608
Z Coef. of Skewness:	0.71298051338966
Z Root Mean Square:	0.17416689950837
Z Mean Square:	0.030334108884359

TABLE 2B(U). GEYSER SPRINGS GROUP, VENT B UPPER, SEPTEMBER 30, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_BU\Geyser_Vent_BU_9-06.bln.grd
Grid Size:	61 rows x 61 columns
X Minimum:	0
X Maximum:	3
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	3
Y Spacing:	0.05
Z Minimum:	-1.9054065339419E-009
Z Maximum:	0.35999999913212

LOWER SURFACE

Level Surface defined by Z = 0

VOLUMES

Z Scale Factor: 1

Total Volumes by:

Trapezoidal Rule:	0.19985692106969
Simpson's Rule:	0.19974981921935
Simpson's 3/8 Rule:	0.19998590399039

CUT & FILL VOLUMES

Positive Volume [Cut]:	0.19985692107422
Negative Volume [Fill]:	4.5287054924879E-012
Net Volume [Cut-Fill]:	**0.19985692106969 <<<<<<Total Discharge in CFS**

(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS

Planar Areas

Operational Planar Area: 2.14 <<<<Total Cross-section Area in Square Feet

(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)

Positive Planar Area [Cut]:	2.14375
Negative Planar Area [Fill]:	7.0528941581705E-018
Blanked Planar Area:	6.85625
Total Planar Area:	9

Surface Areas

Positive Surface Area [Cut]:	2.4478130435977
Negative Surface Area [Fill]:	1.1262859755052E-017

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_BU\Geyser Vent BU 9-06 SURFER XYZ T3B Upper BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	157
Original Data:	157
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.45	0.2	0
25%-tile:	0.8	0.6	0
Median:	1.31	1.075	0
75%-tile:	1.95	1.65	0
Maximum:	2.9	2.5	0.36
Midrange:	1.675	1.35	0.18
Range:	2.45	2.3	0.36
Interquartile Range:	1.15	1.05	0
Median Abs. Deviation:	0.59	0.525	0
Mean:	1.4186300636943	1.126592388535	0.0088535031847134
Trim Mean (10%):	1.3959784965035	1.1089161188811	6.993006993007E-005
Standard Deviation:	0.709863046854	0.66203433052775	0.04761801501501
Variance:	0.50390554528885	0.43828945479732	0.0022674753539697
Coef. of Variation:			5.378437667163
Coef. of Skewness:			6.1307486390296

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.003	0.090
Y:		1.000	-0.001
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	0.50390554528885	0.0012827238275549	0.0030261414742992
Y:		0.43828945479732	-3.7983567284677E-005
Z:			0.0022674753539697

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.0060056397737444	-0.00010423966176253	0.00045115765948667
Standard Error:	0.0053838151069798	0.0057727692044199	0.01072215052142

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.003	-0.711
B:		1.000	0.605
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.0028539263739378	0.0014269631869689	0.62228
Residual:	154	0.35313970419931	0.0022931149623332	
Total:	156	0.35599363057325		

Coefficient of Multiple Determination (R^2): 0.0080167905513989

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.02	0
25%-tile:	0.050249378105604	0
Median:	0.050990195135928	0
75%-tile:	0.055901699437495	0
Maximum:	0.4770105475773	0.36

Midrange:	0.24850527378865	0.18
Range:	0.4570105475773	0.36
Interquartile Range:	0.0056523213318903	0
Median Abs. Deviation:	0.00099019513592785	0
Mean:	0.062756138216994	0.0087898089171975
Trim Mean (10%):	0.053297753429381	6.993006993007E-005
Standard Deviation:	0.051158168998328	0.047542810992132
Variance:	0.0026171582552615	0.0022603188770336
Coef. of Variation:	0.81518988344114	5.4088560331628
Coef. of Skewness:	5.4818051280421	6.1582867328558
Root Mean Square:	0.080965987545215	0.048348522395564
Mean Square:	0.006555491139172	0.0023375796178344

Complete Spatial Randomness

Lambda:	27.861579414374
Clark and Evans:	0.66250486611138
Skellam:	180.17332259924

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	2.9E-007
Y Duplicate Tolerance:	2.7E-007

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	1
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_BU\Geyser_Vent_BU_9-06.grd
Grid Size:	61 rows x 61 columns
Total Nodes:	3721
Filled Nodes:	3721
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	3
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	3
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-0.13093348676141
Z 25%-tile:	-0.079360846378159
Z Median:	-0.01219014680448
Z 75%-tile:	1.3390852870998E-009
Z Maximum:	0.35999999913212
Z Midrange:	0.11453325618535
Z Range:	0.49093348589354
Z Interquartile Range:	0.079360847717244
Z Median Abs. Deviation:	0.041149375777078
Z Mean:	-0.016175827589535
Z Trim Mean (10%):	-0.02315512867045
Z Standard Deviation:	0.07987902576432
Z Variance:	0.0063806587570569
Z Coef. of Variation:	-1
Z Coef. of Skewness:	1.2647909491083
Z Root Mean Square:	0.081500405859501
Z Mean Square:	0.0066423161552633

TABLE 2B(L). GEYSER SPRINGS GROUP, VENT B LOWER, SEPTEMBER 30, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_BL\Geyser_Vent_BL_9-06.bln.grd
Grid Size:	81 rows x 71 columns
X Minimum:	0
X Maximum:	3.5
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	4
Y Spacing:	0.05
Z Minimum:	-1.927751569486E-009
Z Maximum:	0.61000000037419

LOWER SURFACE

Level Surface defined by Z = 0

VOLUMES

Z Scale Factor: 1

Total Volumes by:

Trapezoidal Rule:	1.5844231016445
Simpson's Rule:	1.5843335206557
Simpson's 3/8 Rule:	1.5846051838843

CUT & FILL VOLUMES

Positive Volume [Cut]: 1.5844231016653
Negative Volume [Fill]: 2.0790231951731E-011
Net Volume [Cut-Fill]: 1.5844231016445 <<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS

Planar Areas

Operational Planar Area: 5.39 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 5.3924999991292
Negative Planar Area [Fill]: 8.7082175107482E-010
Blanked Planar Area: 8.6075
Total Planar Area: 14

Surface Areas

Positive Surface Area [Cut]: 6.6653471641368
Negative Surface Area [Fill]: 1.030662966842E-009

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_BL\Geyser Vent BL 9-06 SURFER XYZ T3B Lower BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	184
Original Data:	184
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.5	0.3	0
25%-tile:	1.15	1.1	0
Median:	1.9	2.05	0
75%-tile:	2.65	3.05	0
Maximum:	3.1	3.5	0.61
Midrange:	1.8	1.9	0.305
Range:	2.6	3.2	0.61
Interquartile Range:	1.5	1.95	0
Median Abs. Deviation:	0.75	1	0
Mean:	1.8648269293478	2.0092394293478	0.029076086956522
Trim Mean (10%):	1.8708925	2.0230726204819	0.0053012048192771
Standard Deviation:	0.82718438382107	1.0607247329431	0.11327014013215
Variance:	0.68423400483745	1.1251369590773	0.012830124645558
Coef. of Variation:			3.8956459409937
Coef. of Skewness:			4.0244567515591

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.014	0.018
Y:		1.000	-0.020
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	0.68423400483745	0.012165669318628	0.0016422604782018
Y:		1.1251369590773	-0.0024153855815808
Z:			0.012830124645558

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.0024387824886283	-0.0021731176663887	0.028894493396826
Standard Error:	0.010175573473071	0.0079352118527437	0.02601390437717

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.014	-0.721
B:		1.000	0.603
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.0017027421041043	0.00085137105205213	0.065322
Residual:	181	2.3590401926785	0.013033371230268	
Total:	183	2.3607429347826		

Coefficient of Multiple Determination (R^2): 0.00072127383249421

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.050990195135928	0
Median:	0.052704100646914	0
75%-tile:	0.058309518948453	0

Maximum:	0.5	0.54
Midrange:	0.275	0.27
Range:	0.45	0.54
Interquartile Range:	0.0073193238125251	0
Median Abs. Deviation:	0.0027041006469135	0
Mean:	0.07599684339297	0.016521739130435
Trim Mean (10%):	0.057295562163537	0.0013253012048193
Standard Deviation:	0.087344080302385	0.074109712773767
Variance:	0.0076289883638696	0.0054922495274102
Coef. of Variation:	1.1493119503759	4.4855878784122
Coef. of Skewness:	4.1187194179348	5.2811217814352
Root Mean Square:	0.11577784144458	0.07592902864718
Mean Square:	0.013404508569565	0.0057652173913043

Complete Spatial Randomness

Lambda:	22.115384615385
Clark and Evans:	0.71478066762577
Skellam:	342.72286903585

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 3E-007
Y Duplicate Tolerance: 3.8E-007
No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point
Polynomial Drift Order: 1
Kriging std. deviation grid: no

Semi-Variogram Model

Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 1
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_BL\Geyser_Vent_BL_9-06.grd
Grid Size:	81 rows x 71 columns
Total Nodes:	5751
Filled Nodes:	5751
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	3.5
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	4
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-0.34171924854028
Z 25%-tile:	-0.15023084809837
Z Median:	-0.066224672493005
Z 75%-tile:	0.19440943250605
Z Maximum:	0.61000000037419
Z Midrange:	0.13414037591696
Z Range:	0.95171924891446
Z Interquartile Range:	0.34464028060442
Z Median Abs. Deviation:	0.12238619456149
Z Mean:	0.024549986585448
Z Trim Mean (10%):	0.012579268010808
Z Standard Deviation:	0.24129063769018
Z Variance:	0.058221171836932
Z Coef. of Variation:	9.8285445839388
Z Coef. of Skewness:	0.82245798729235
Z Root Mean Square:	0.24253633475889
Z Mean Square:	0.058823873678277

TABLE 2C. GEYSER SPRINGS GROUP, VENT C, SEPTEMBER 30, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_C\Geyser_Vent_C_9-06.bln.grd
Grid Size:	69 rows x 65 columns
X Minimum:	0
X Maximum:	1.6
X Spacing:	0.025
Y Minimum:	0
Y Maximum:	1.7
Y Spacing:	0.025
Z Minimum:	-1.3503103080126E-009
Z Maximum:	1.0599999968131

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES
Z Scale Factor: 1
Total Volumes by:
Trapezoidal Rule: 0.32148228538414
Simpson's Rule: 0.32148029291413
Simpson's 3/8 Rule: 0.32151520130326

CUT & FILL VOLUMES
Positive Volume [Cut]: 0.32148228538493
Negative Volume [Fill]: 7.9281079130205E-013
Net Volume [Cut-Fill]: 0.32148228538414 <<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 0.82 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 0.8196875
Negative Planar Area [Fill]: 3.3786686758949E-018
Blanked Planar Area: 1.9003125
Total Planar Area: 2.72

Surface Areas
Positive Surface Area [Cut]: 2.0589030319955
Negative Surface Area [Fill]: 7.456068009908E-018

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_C\Geyser Vent C 9-06 SURFER XYZ T3C BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	70
Original Data:	70
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.4	0.4	0
25%-tile:	0.48333	0.6	0
Median:	0.85	1	0
75%-tile:	1.18182	1.3	0
Maximum:	1.5	1.55	1.06
Midrange:	0.95	0.975	0.53
Range:	1.1	1.15	1.06
Interquartile Range:	0.69849	0.7	0
Median Abs. Deviation:	0.36112	0.4	0
Mean:	0.85464107142857	0.96214285714286	0.057
Trim Mean (10%):	0.84659609375	0.96140625	0.02046875
Standard Deviation:	0.3562931183088	0.37798674525946	0.21007719669547
Variance:	0.12694478615421	0.14287397959184	0.044132428571429
Coef. of Variation:			3.6855648543065
Coef. of Skewness:			3.5747569996417

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.045	0.109
Y:		1.000	0.037
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	0.12694478615421	0.0060866619897959	0.0081426017857143
Y:		0.14287397959184	0.0029078571428571
Z:			0.044132428571429

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.063296299575166	0.017656076840197	-0.014083285503345
Standard Error:	0.07164262200625	0.067530868525308	0.090891442276611

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.045	-0.641
B:		1.000	0.684
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.039671653777312	0.019835826888656	0.4358
Residual:	67	3.0495983462227	0.045516393227204	
Total:	69	3.08927		

Coefficient of Multiple Determination (R^2): 0.012841756718355

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.050689961777456	0
Median:	0.051219450407047	0
75%-tile:	0.064031242374328	0
Maximum:	0.25	0.79

Midrange:	0.15	0.395
Range:	0.2	0.79
Interquartile Range:	0.013341280596872	0
Median Abs. Deviation:	0.0012194504070473	0
Mean:	0.066044395320757	0.037571428571429
Trim Mean (10%):	0.058912306810746	0.00828125
Standard Deviation:	0.041208590426389	0.14872251932744
Variance:	0.0016981479249299	0.022118387755102
Coef. of Variation:	0.62395287633798	3.9583940505403
Coef. of Skewness:	3.5205673760657	4.1661984884886
Root Mean Square:	0.077846066555827	0.15339491516996
Mean Square:	0.0060600100782143	0.02353

Complete Spatial Randomness

Lambda: 55.335968379447
Clark and Evans: 0.98258407516029
Skellam: 147.48870734822

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 1.3E-007
Y Duplicate Tolerance: 1.3E-007
No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point
Polynomial Drift Order: 1
Kriging std. deviation grid: no

Semi-Variogram Model

Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 1
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_C\Geyser_Vent_C_9-06.grd
Grid Size:	69 rows x 65 columns
Total Nodes:	4485
Filled Nodes:	4485
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	1.6
X Spacing:	0.025
Y Minimum:	0
Y Maximum:	1.7
Y Spacing:	0.025

Grid Statistics

Z Minimum:	-0.44711523250258
Z 25%-tile:	-0.15807341730339
Z Median:	-0.085294141159168
Z 75%-tile:	0.070066669512005
Z Maximum:	1.0599999968131
Z Midrange:	0.30644238215524
Z Range:	1.5071152293156
Z Interquartile Range:	0.22814008681539
Z Median Abs. Deviation:	0.091272102443869
Z Mean:	0.016170425325832
Z Trim Mean (10%):	-0.011457911947425
Z Standard Deviation:	0.29852945517153
Z Variance:	0.089119835605008
Z Coef. of Variation:	18.461447312374
Z Coef. of Skewness:	1.5757359881958
Z Root Mean Square:	0.29896708558005
Z Mean Square:	0.089381318260226

TABLE 2D. GEYSER SPRINGS GROUP, VENT D, SEPTEMBER 30, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_D\Geyser_Vent_D_9-06.bln.grd
Grid Size:	61 rows x 71 columns
X Minimum:	0
X Maximum:	3.5
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	3
Y Spacing:	0.05
Z Minimum:	-1.3449608093907E-009
Z Maximum:	1.0399999980003

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES
Z Scale Factor: 1
Total Volumes by:
Trapezoidal Rule: 1.6828187454261
Simpson's Rule: 1.6823001350709
Simpson's 3/8 Rule: 1.6824713497665

CUT & FILL VOLUMES
Positive Volume [Cut]: 1.6828187454307
Negative Volume [Fill]: 4.6302506469873E-012
Net Volume [Cut-Fill]: 1.682818745426 <<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 4.62 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 4.6237499998559
Negative Planar Area [Fill]: 1.4412154077208E-010
Blanked Planar Area: 5.87625
Total Planar Area: 10.5

Surface Areas
Positive Surface Area [Cut]: 6.925795774864
Negative Surface Area [Fill]: 1.5307341981236E-010

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_D\Geyser Vent D 9-06 SURFER XYZ T3D BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	183
Original Data:	183
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.099995	0.3	0
25%-tile:	0.4	0.76	0
Median:	1.4	1.5	0
75%-tile:	2.45	2.25	0
Maximum:	3.4	2.6	1.04
Midrange:	1.7499975	1.45	0.52
Range:	3.300005	2.3	1.04
Interquartile Range:	2.05	1.49	0
Median Abs. Deviation:	1	0.75	0
Mean:	1.46516453555191	1.503825136612	0.03448087431694
Trim Mean (10%):	1.4398152424242	1.507196969697	0.00066666666666667
Standard Deviation:	1.0723770083162	0.73040398341304	0.1561092108102
Variance:	1.1499924479652	0.53348997898564	0.024370085699782
Coef. of Variation:			4.5274145131958
Coef. of Skewness:			4.6840149182031

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.060	0.047
Y:		1.000	0.027
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	1.1499924479652	-0.046891107512915	0.0077858567260892
Y:		0.53348997898564	0.0030894174206456
Z:			0.024370085699782

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.007031682825096	0.0064090066368162	0.014540276735433
Standard Error:	0.010853233625846	0.015934686105977	0.031744139351613

Inter-Parameter Correlations

	A	B	C
A:	1.000	-0.060	-0.546
B:		1.000	0.785
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.013642242234334	0.0068211211171669	0.27615
Residual:	180	4.4460834408258	0.024700463560143	
Total:	182	4.4597256830601		

Coefficient of Multiple Determination (R^2): 0.0030589868534185

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.05	0
Median:	0.052201532544552	0
75%-tile:	0.055901699437495	0
Maximum:	0.5	0.78

Midrange:	0.275	0.39
Range:	0.45	0.78
Interquartile Range:	0.0059016994374945	0
Median Abs. Deviation:	0.0022015325445524	0
Mean:	0.071667838362829	0.023060109289617
Trim Mean (10%):	0.054369306915191	0.00078787878787879
Standard Deviation:	0.079019581885201	0.10725808563144
Variance:	0.006244094321312	0.011504296933321
Coef. of Variation:	1.1025807906352	4.651239258425
Coef. of Skewness:	4.3762152082884	5.2009602304154
Root Mean Square:	0.10667883284379	0.10970900406881
Mean Square:	0.011380373376913	0.01203606557377

Complete Spatial Randomness

Lambda: 24.110635405493
Clark and Evans: 0.703815179292
Skellam: 315.49764721575

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 3.9E-007
Y Duplicate Tolerance: 2.7E-007
No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point
Polynomial Drift Order: 1
Kriging std. deviation grid: no

Semi-Variogram Model

Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 1
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Geyser_D\Geyser_Vent_D_9-06.grd
Grid Size:	61 rows x 71 columns
Total Nodes:	4331
Filled Nodes:	4331
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	3.5
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	3
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-0.39917967762178
Z 25%-tile:	-0.19268725024338
Z Median:	-0.014682822293365
Z 75%-tile:	0.22997337669654
Z Maximum:	1.0399999980003
Z Midrange:	0.32041016018927
Z Range:	1.4391796756221
Z Interquartile Range:	0.42266062693992
Z Median Abs. Deviation:	0.19474436383401
Z Mean:	0.060346854061225
Z Trim Mean (10%):	0.0394891888478
Z Standard Deviation:	0.33240723939151
Z Variance:	0.11049457279988
Z Coef. of Variation:	5.5082778474958
Z Coef. of Skewness:	0.9528661930389
Z Root Mean Square:	0.33784066598764
Z Mean Square:	0.11413631559497

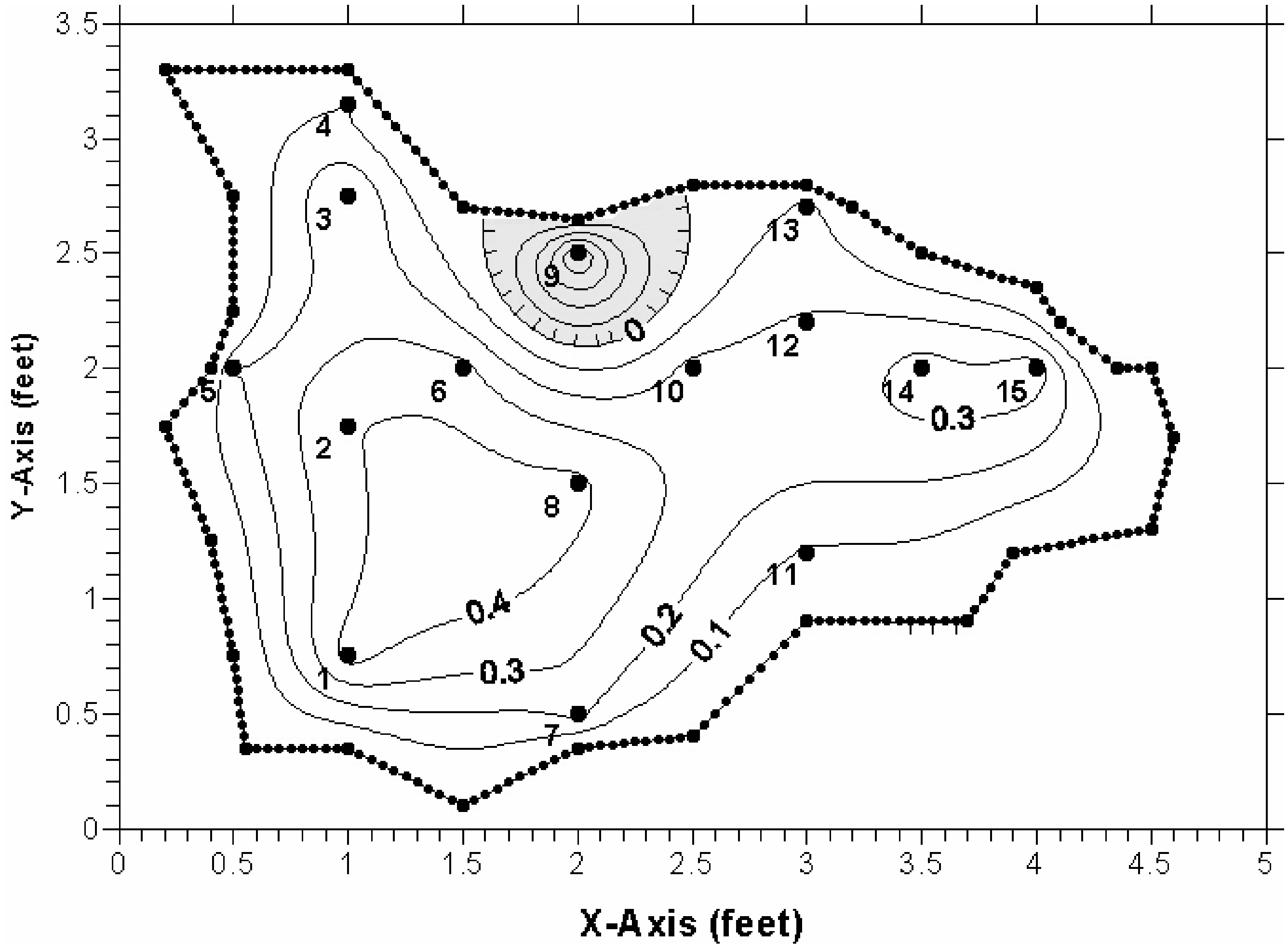

Figure 4A. Discharge measurement cross-section; Geyser Springs Group Vent A, Marion County, Florida, September 30, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. See Table 1 for station velocities. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

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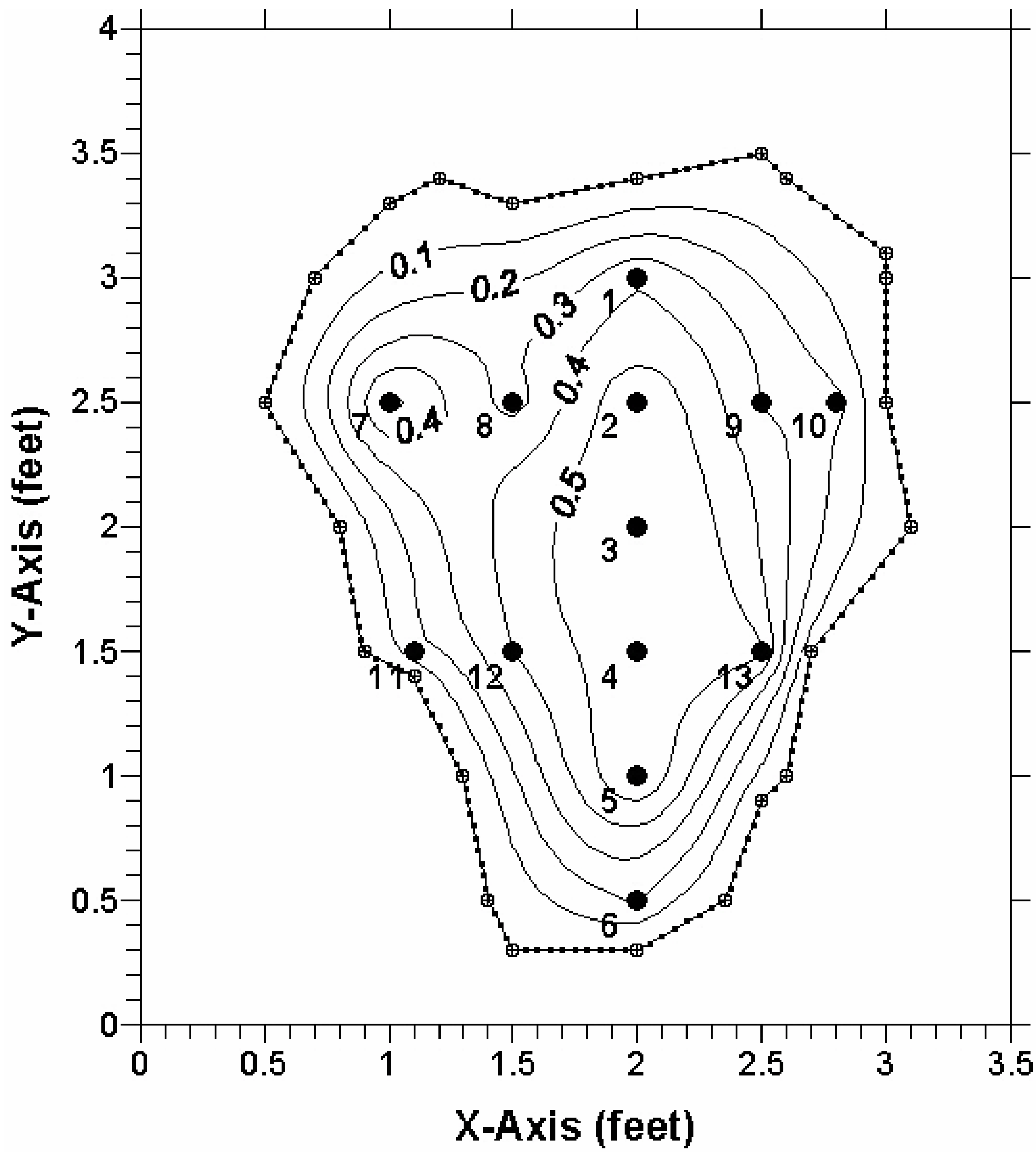

Figure 4BU. Discharge measurement cross-section; Geyser Springs Group Vent B Upper, Marion County, Florida, September 30, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

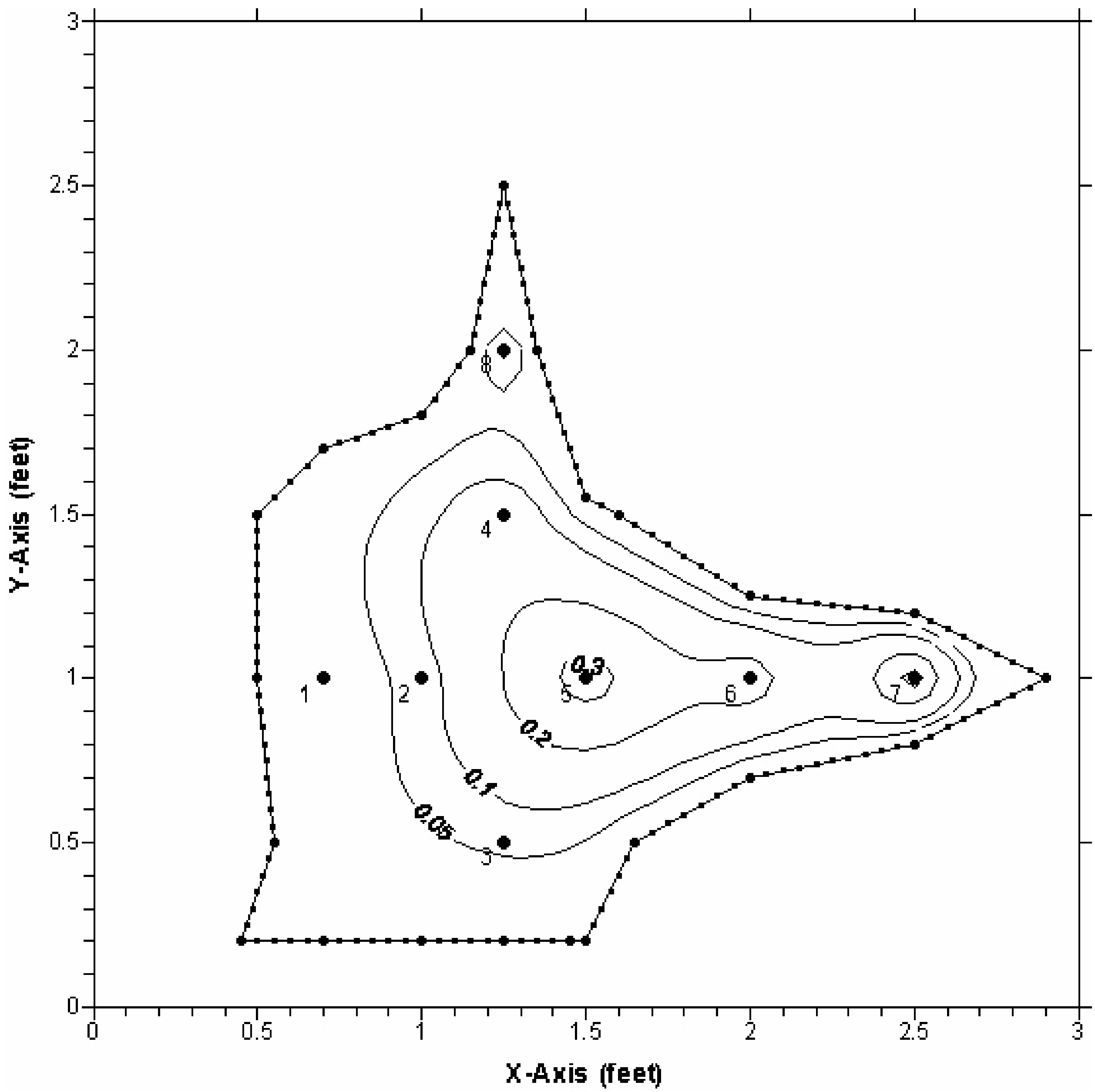

Figure 4BL. Discharge measurement cross-section; Geyser Springs Group Vent B Lower, Marion County, Florida, September 30, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

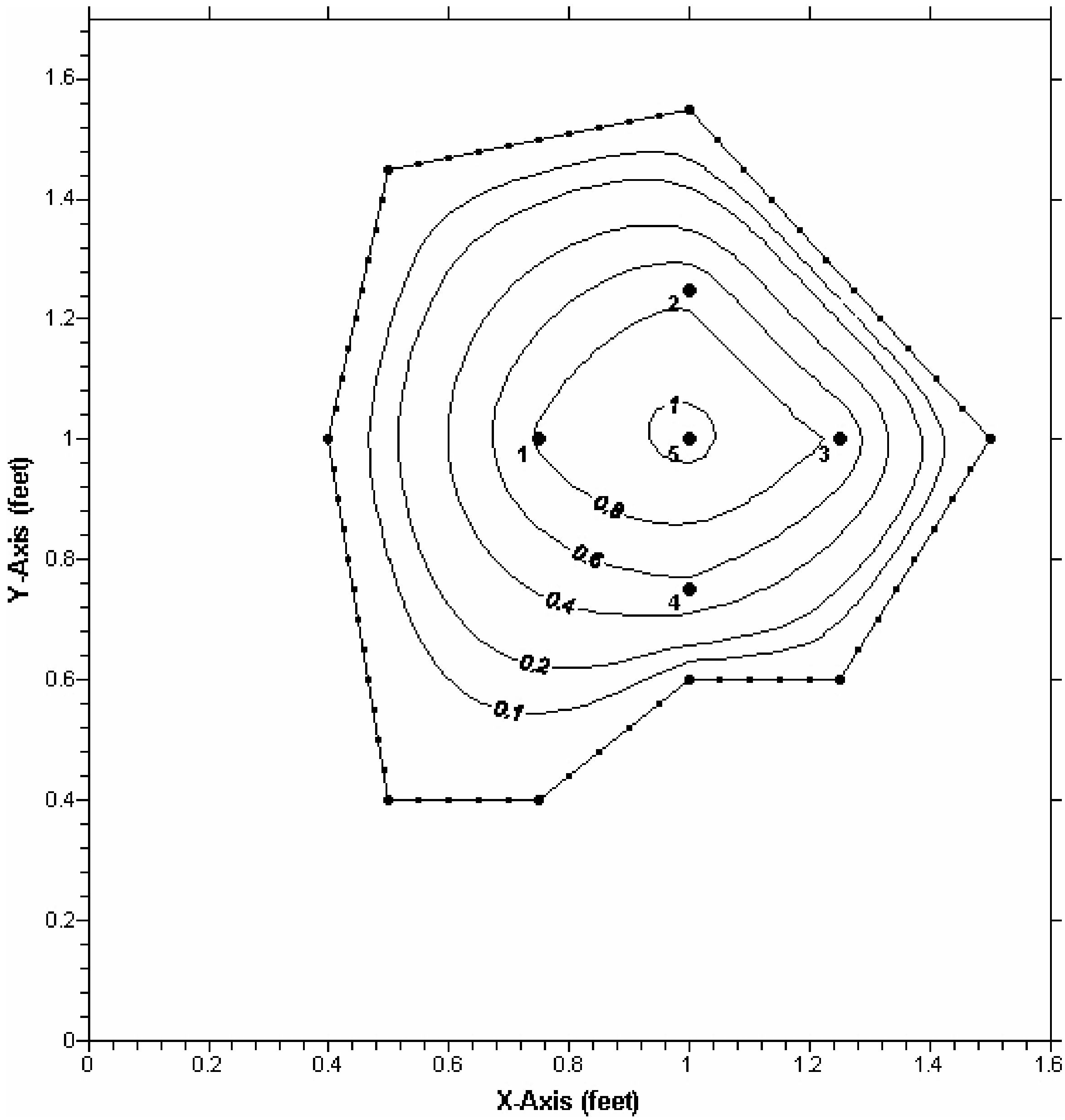

Figure 4C. Discharge measurement cross-section; Geyser Springs Group Vent C, Marion County, Florida, September 30, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

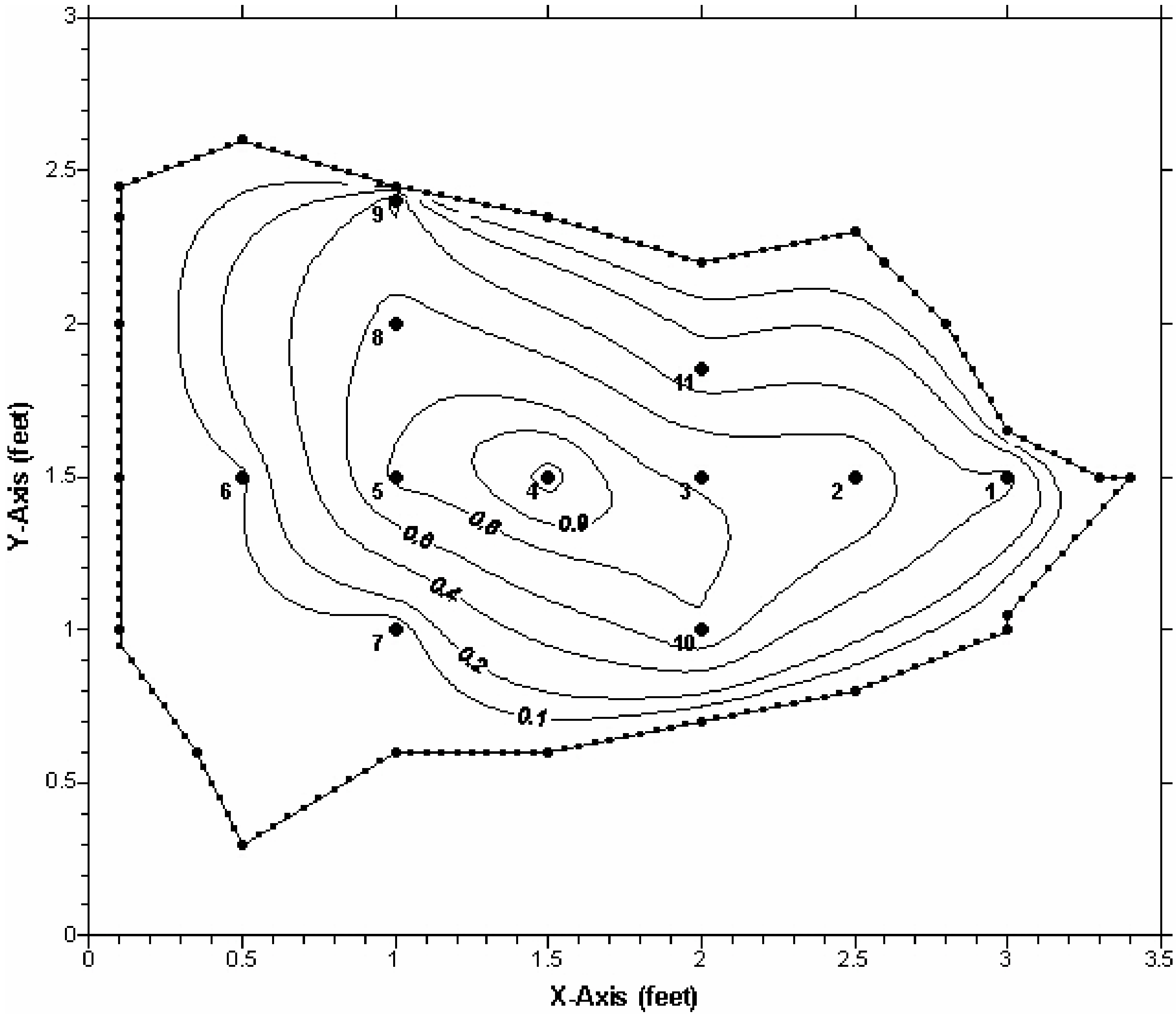

Figure 4D. Discharge measurement cross-section; Geyser Springs Group Vent D, Marion County, Florida, September 30, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

Table 3A. Geyser Springs Group Vent A XYZ Grid Data, September 30, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
1	**0.75**	**0.44**	**1**	20	15
1	**1.75**	**0.39**	**2**	20	35
1	**2.75**	**0.31**	**3**	20	55
1	**3.15**	**0.1**	**4**	20	63
0.5	**2**	**0.2**	**5**	10	40
1.5	**2**	**0.33**	**6**	30	40
2	**0.5**	**0.24**	**7**	40	10
2	**1.5**	**0.42**	**8**	40	30
2	**2.5**	**-0.53**	**9**	40	50
2.5	**2**	**0.23**	**10**	50	40
3	**1.2**	**0.09**	**11**	60	24
3	**2.2**	**0.21**	**12**	60	44
3	**2.7**	**0.15**	**13**	60	54
3.5	**2**	**0.34**	**14**	70	40
4	**2**	**0.36**	**15**	80	40
0.2	**3.3**	**0**	**A**	4	66
1	**3.3**	**0**	**B**	20	66
1.5	**2.7**	**0**	**C**	30	54
2	**2.65**	**0**	**D**	40	53
2.5	**2.8**	**0**	**E**	50	56
3	**2.8**	**0**	**F**	60	56
3.2	**2.7**	**0**	**G**	64	54
3.5	**2.5**	**0**	**H**	70	50
4	**2.35**	**0**	**I**	80	47
4.1	**2.2**	**0**	**J**	82	44
4.35	**2**	**0**	**K**	87	40
4.5	**2**	**0**	**L**	90	40
4.6	**1.7**	**0**	**M**	92	34
4.5	**1.3**	**0**	**N**	90	26
3.9	**1.2**	**0**	**O**	78	24
3.7	**0.9**	**0**	**P**	74	18
3	**0.9**	**0**	**Q**	60	18
2.5	**0.4**	**0**	**R**	50	8
2	**0.35**	**0**	**S**	40	7
1.5	**0.1**	**0**	**T**	30	2
1	**0.35**	**0**	**U**	20	7
0.55	**0.35**	**0**	**V**	11	7
0.5	**0.75**	**0**	**W**	10	15
0.4	**1.25**	**0**	**X**	8	25
0.2	**1.75**	**0**	**Y**	4	35
0.4	**2**	**0**	**Z**	8	40
0.5	**2.25**	**0**	**AA**	10	45
0.5	**2.75**	**0**	**BB**	10	55
0.25	**3.3**	**0**	**A1**	5	66
0.3	**3.3**	**0**	**A2**	6	66

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
0.35	3.3	0	A3	7	66
0.4	3.3	0	A4	8	66
0.45	3.3	0	A5	9	66
0.5	3.3	0	A6	10	66
0.55	3.3	0	A7	11	66
0.6	3.3	0	A8	12	66
0.65	3.3	0	A9	13	66
0.7	3.3	0	A10	14	66
0.75	3.3	0	A11	15	66
0.8	3.3	0	A12	16	66
0.85	3.3	0	A13	17	66
0.9	3.3	0	A14	18	66
0.95	3.3	0	A15	19	66
1.04167	3.25	0	B1	20.8333	65
1.08333	3.2	0	B2	21.6666	64
1.125	3.15	0	B3	22.4999	63
1.16666	3.1	0	B4	23.3332	62
1.20833	3.05	0	B5	24.1665	61
1.24999	3	0	B6	24.9998	60
1.29166	2.95	0	B7	25.8331	59
1.33332	2.9	0	B8	26.6664	58
1.37499	2.85	0	B9	27.4997	57
1.41665	2.8	0	B10	28.333	56
1.45832	2.75	0	B11	29.1663	55
1.55	2.695	0	C1	31	53.9
1.6	2.69	0	C2	32	53.8
1.65	2.685	0	C3	33	53.7
1.7	2.68	0	C4	34	53.6
1.75	2.675	0	C5	35	53.5
1.8	2.67	0	C6	36	53.4
1.85	2.665	0	C7	37	53.3
1.9	2.66	0	C8	38	53.2
1.95	2.655	0	C9	39	53.1
2.05	2.665	0	D1	41	53.3
2.1	2.68	0	D2	42	53.6
2.15	2.695	0	D3	43	53.9
2.2	2.71	0	D4	44	54.2
2.25	2.725	0	D5	45	54.5
2.3	2.74	0	D6	46	54.8
2.35	2.755	0	D7	47	55.1
2.4	2.77	0	D8	48	55.4
2.45	2.785	0	D9	49	55.7
2.55	2.8	0	E1	51	56
2.6	2.8	0	E2	52	56
2.65	2.8	0	E3	53	56

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
2.7	**2.8**	**0**	**E4**	54	56
2.75	**2.8**	**0**	**E5**	55	56
2.8	**2.8**	**0**	**E6**	56	56
2.85	**2.8**	**0**	**E7**	57	56
2.9	**2.8**	**0**	**E8**	58	56
2.95	**2.8**	**0**	**E9**	59	56
3.05	**2.775**	**0**	**F1**	61	55.5
3.1	**2.75**	**0**	**F2**	62	55
3.15	**2.725**	**0**	**F3**	63	54.5
3.25	**2.66667**	**0**	**G1**	65	53.3333
3.3	**2.63333**	**0**	**G2**	66	52.6666
3.35	**2.6**	**0**	**G3**	67	51.9999
3.4	**2.56666**	**0**	**G4**	68	51.3332
3.45	**2.53333**	**0**	**G5**	69	50.6665
3.55	**2.485**	**0**	**H1**	71	49.7
3.6	**2.47**	**0**	**H2**	72	49.4
3.65	**2.455**	**0**	**H3**	73	49.1
3.7	**2.44**	**0**	**H4**	74	48.8
3.75	**2.425**	**0**	**H5**	75	48.5
3.8	**2.41**	**0**	**H6**	76	48.2
3.85	**2.395**	**0**	**H7**	77	47.9
3.9	**2.38**	**0**	**H8**	78	47.6
3.95	**2.365**	**0**	**H9**	79	47.3
4.03334	**2.3**	**0**	**I1**	80.6667	46
4.06667	**2.25**	**0**	**I2**	81.3334	45
4.15	**2.16**	**0**	**J1**	83	43.2
4.2	**2.12**	**0**	**J2**	84	42.4
4.25	**2.08**	**0**	**J3**	85	41.6
4.3	**2.04**	**0**	**J4**	86	40.8
4.4	**2**	**0**	**K1**	88	40
4.45	**2**	**0**	**K2**	89	40
4.51667	**1.95**	**0**	**L1**	90.3333	39
4.53333	**1.9**	**0**	**L2**	90.6666	38
4.55	**1.85**	**0**	**L3**	90.9999	37
4.56666	**1.8**	**0**	**L4**	91.3332	36
4.58333	**1.75**	**0**	**L5**	91.6665	35
4.5875	**1.65**	**0**	**M1**	91.75	33
4.575	**1.6**	**0**	**M2**	91.5	32
4.5625	**1.55**	**0**	**M3**	91.25	31
4.55	**1.5**	**0**	**M4**	91	30
4.5375	**1.45**	**0**	**M5**	90.75	29

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
4.525	**1.4**	**0**	**M6**	90.5	28
4.5125	**1.35**	**0**	**M7**	90.25	27
4.45	**1.29167**	**0**	**N1**	89	25.8333
4.4	**1.28333**	**0**	**N2**	88	25.6666
4.35	**1.275**	**0**	**N3**	87	25.4999
4.3	**1.26666**	**0**	**N4**	86	25.3332
4.25	**1.25833**	**0**	**N5**	85	25.1665
4.2	**1.24999**	**0**	**N6**	84	24.9998
4.15	**1.24166**	**0**	**N7**	83	24.8331
4.1	**1.23332**	**0**	**N8**	82	24.6664
4.05	**1.22499**	**0**	**N9**	81	24.4997
4	**1.21665**	**0**	**N10**	80	24.333
3.95	**1.20832**	**0**	**N11**	79	24.1663
3.86667	**1.15**	**0**	**O1**	77.3333	23
3.83333	**1.1**	**0**	**O2**	76.6666	22
3.8	**1.05**	**0**	**O3**	75.9999	21
3.76666	**1**	**0**	**O4**	75.3332	20
3.73333	**0.95**	**0**	**O5**	74.6665	19
3.65	**0.9**	**0**	**P1**	73	18
3.6	**0.9**	**0**	**P2**	72	18
3.55	**0.9**	**0**	**P3**	71	18
3.5	**0.9**	**0**	**P4**	70	18
3.45	**0.9**	**0**	**P5**	69	18
3.4	**0.9**	**0**	**P6**	68	18
3.35	**0.9**	**0**	**P7**	67	18
3.3	**0.9**	**0**	**P8**	66	18
3.25	**0.9**	**0**	**P9**	65	18
3.2	**0.9**	**0**	**P10**	64	18
3.15	**0.9**	**0**	**P11**	63	18
3.1	**0.9**	**0**	**P12**	62	18
3.05	**0.9**	**0**	**P13**	61	18
2.95	**0.85**	**0**	**Q1**	59	17
2.9	**0.8**	**0**	**Q2**	58	16
2.85	**0.75**	**0**	**Q3**	57	15
2.8	**0.7**	**0**	**Q4**	56	14
2.75	**0.65**	**0**	**Q5**	55	13
2.7	**0.6**	**0**	**Q6**	54	12
2.65	**0.55**	**0**	**Q7**	53	11
2.6	**0.5**	**0**	**Q8**	52	10
2.55	**0.45**	**0**	**Q9**	51	9
2.45	**0.395**	**0**	**R1**	49	7.9
2.4	**0.39**	**0**	**R2**	48	7.8
2.35	**0.385**	**0**	**R3**	47	7.7
2.3	**0.38**	**0**	**R4**	46	7.6

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
2.25	**0.375**	**0**	**R5**	45	7.5
2.2	**0.37**	**0**	**R6**	44	7.4
2.15	**0.365**	**0**	**R7**	43	7.3
2.1	**0.36**	**0**	**R8**	42	7.2
2.05	**0.355**	**0**	**R9**	41	7.1
1.95	**0.325**	**0**	**S1**	39	6.5
1.9	**0.3**	**0**	**S2**	38	6
1.85	**0.275**	**0**	**S3**	37	5.5
1.8	**0.25**	**0**	**S4**	36	5
1.75	**0.225**	**0**	**S5**	35	4.5
1.7	**0.2**	**0**	**S6**	34	4
1.65	**0.175**	**0**	**S7**	33	3.5
1.6	**0.15**	**0**	**S8**	32	3
1.55	**0.125**	**0**	**S9**	31	2.5
1.45	**0.125**	**0**	**T1**	29	2.5
1.4	**0.15**	**0**	**T2**	28	3
1.35	**0.175**	**0**	**T3**	27	3.5
1.3	**0.2**	**0**	**T4**	26	4
1.25	**0.225**	**0**	**T5**	25	4.5
1.2	**0.25**	**0**	**T6**	24	5
1.15	**0.275**	**0**	**T7**	23	5.5
1.1	**0.3**	**0**	**T8**	22	6
1.05	**0.325**	**0**	**T9**	21	6.5
0.95	**0.35**	**0**	**U1**	19	7
0.9	**0.35**	**0**	**U2**	18	7
0.85	**0.35**	**0**	**U3**	17	7
0.8	**0.35**	**0**	**U4**	16	7
0.75	**0.35**	**0**	**U5**	15	7
0.7	**0.35**	**0**	**U6**	14	7
0.65	**0.35**	**0**	**U7**	13	7
0.6	**0.35**	**0**	**U8**	12	7
0.54375	**0.4**	**0**	**V1**	10.875	8
0.5375	**0.45**	**0**	**V2**	10.75	9
0.53125	**0.5**	**0**	**V3**	10.625	10
0.525	**0.55**	**0**	**V4**	10.5	11
0.51875	**0.6**	**0**	**V5**	10.375	12
0.5125	**0.65**	**0**	**V6**	10.25	13
0.50625	**0.7**	**0**	**V7**	10.125	14
0.49	**0.8**	**0**	**W1**	9.8	16
0.48	**0.85**	**0**	**W2**	9.6	17
0.47	**0.9**	**0**	**W3**	9.4	18
0.46	**0.95**	**0**	**W4**	9.2	19
0.45	**1**	**0**	**W5**	9	20
0.44	**1.05**	**0**	**W6**	8.8	21

Table 3A. Geyser Springs Group Vent A, XYZ Grid Data, September 30, 2006.

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
0.43	**1.1**	**0**	**W7**	8.6	22
0.42	**1.15**	**0**	**W8**	8.4	23
0.41	**1.2**	**0**	**W9**	8.2	24
0.38	**1.3**	**0**	**X1**	7.6	26
0.36	**1.35**	**0**	**X2**	7.2	27
0.34	**1.4**	**0**	**X3**	6.8	28
0.32	**1.45**	**0**	**X4**	6.4	29
0.3	**1.5**	**0**	**X5**	6	30
0.28	**1.55**	**0**	**X6**	5.6	31
0.26	**1.6**	**0**	**X7**	5.2	32
0.24	**1.65**	**0**	**X8**	4.8	33
0.22	**1.7**	**0**	**X9**	4.4	34
0.24	**1.8**	**0**	**Y1**	4.8	36
0.28	**1.85**	**0**	**Y2**	5.6	37
0.32	**1.9**	**0**	**Y3**	6.4	38
0.36	**1.95**	**0**	**Y4**	7.2	39
0.42	**2.05**	**0**	**Z1**	8.4	41
0.44	**2.1**	**0**	**Z2**	8.8	42
0.46	**2.15**	**0**	**Z3**	9.2	43
0.48	**2.2**	**0**	**Z4**	9.6	44
0.5	**2.3**	**0**	**AA1**	10	46
0.5	**2.35**	**0**	**AA2**	10	47
0.5	**2.4**	**0**	**AA3**	10	48
0.5	**2.45**	**0**	**AA4**	10	49
0.5	**2.5**	**0**	**AA5**	10	50
0.5	**2.55**	**0**	**AA6**	10	51
0.5	**2.6**	**0**	**AA7**	10	52
0.5	**2.65**	**0**	**AA8**	10	53
0.5	**2.7**	**0**	**AA9**	10	54
0.47273	**2.8**	**0**	**BB1**	9.4545	56
0.44545	**2.85**	**0**	**BB2**	8.909	57
0.41818	**2.9**	**0**	**BB3**	8.3635	58
0.3909	**2.95**	**0**	**BB4**	7.818	59
0.36363	**3**	**0**	**BB5**	7.2725	60
0.33635	**3.05**	**0**	**BB6**	6.727	61
0.30908	**3.1**	**0**	**BB7**	6.1815	62
0.2818	**3.15**	**0**	**BB8**	5.636	63
0.25453	**3.2**	**0**	**BB9**	5.0905	64
0.22725	**3.25**	**0**	**BB10**	4.545	65

Table 3B Upper. Geyser Springs Group Vent B Upper XYZ Grid Data, September 30, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
0.7	**1**	**0.01**	**1**	14	20
1	**1**	**0.07**	**2**	20	20
1.25	**0.5**	**0.06**	**3**	25	10
1.25	**1.5**	**0.16**	**4**	25	30
1.5	**1**	**0.35**	**5**	30	20
2	**1**	**0.26**	**6**	40	20
2.5	**1**	**0.36**	**7**	50	20
1.25	**2**	**0.12**	**8**	25	40
0.5	**1.5**	**0**	**A**	10	30
0.7	**1.7**	**0**	**B**	14	34
1	**1.8**	**0**	**C**	20	36
1.15	**2**	**0**	**D**	23	40
1.25	**2.5**	**0**	**E**	25	50
1.35	**2**	**0**	**F**	27	40
1.5	**1.55**	**0**	**G**	30	31
1.6	**1.5**	**0**	**H**	32	30
2	**1.25**	**0**	**I**	40	25
2.5	**1.2**	**0**	**J**	50	24
2.9	**1**	**0**	**K**	58	20
2.5	**0.8**	**0**	**L**	50	16
2	**0.7**	**0**	**M**	40	14
1.65	**0.5**	**0**	**N**	33	10
1.5	**0.2**	**0**	**O**	30	4
1.45	**0.2**	**0**	**P**	29	4
1.25	**0.2**	**0**	**Q**	25	4
1	**0.2**	**0**	**R**	20	4
0.7	**0.2**	**0**	**S**	14	4
0.45	**0.2**	**0**	**T**	9	4
0.55	**0.5**	**0**	**U**	11	10
0.5	**1**	**0**	**V**	10	20
0.55	**1.55**	**0**	**A1**	11	31
0.6	**1.6**	**0**	**A2**	12	32
0.65	**1.65**	**0**	**A3**	13	33
0.75	**1.71667**	**0**	**B1**	15	34.3333
0.8	**1.73333**	**0**	**B2**	16	34.6666
0.85	**1.75**	**0**	**B3**	17	34.9999
0.9	**1.76666**	**0**	**B4**	18	35.3332
0.95	**1.78333**	**0**	**B5**	19	35.6665
1.0375	**1.85**	**0**	**C1**	20.75	37
1.075	**1.9**	**0**	**C2**	21.5	38
1.1125	**1.95**	**0**	**C3**	22.25	39
1.16	**2.05**	**0**	**D1**	23.2	41

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
1.17	2.1	0	D2	23.4	42
1.18	2.15	0	D3	23.6	43
1.19	2.2	0	D4	23.8	44
1.2	2.25	0	D5	24	45
1.21	2.3	0	D6	24.2	46
1.22	2.35	0	D7	24.4	47
1.23	2.4	0	D8	24.6	48
1.24	2.45	0	D9	24.8	49
1.26	2.45	0	E1	25.2	49
1.27	2.4	0	E2	25.4	48
1.28	2.35	0	E3	25.6	47
1.29	2.3	0	E4	25.8	46
1.3	2.25	0	E5	26	45
1.31	2.2	0	E6	26.2	44
1.32	2.15	0	E7	26.4	43
1.33	2.1	0	E8	26.6	42
1.34	2.05	0	E9	26.8	41
1.36667	1.95	0	F1	27.3333	39
1.38333	1.9	0	F2	27.6666	38
1.4	1.85	0	F3	27.9999	37
1.41666	1.8	0	F4	28.3332	36
1.43333	1.75	0	F5	28.6665	35
1.44999	1.7	0	F6	28.9998	34
1.46666	1.65	0	F7	29.3331	33
1.48332	1.6	0	F8	29.6664	32
1.55	1.525	0	G1	31	30.5
1.65	1.46875	0	H1	33	29.375
1.7	1.4375	0	H2	34	28.75
1.75	1.40625	0	H3	35	28.125
1.8	1.375	0	H4	36	27.5
1.85	1.34375	0	H5	37	26.875
1.9	1.3125	0	H6	38	26.25
1.95	1.28125	0	H7	39	25.625
2.05	1.245	0	I1	41	24.9
2.1	1.24	0	I2	42	24.8
2.15	1.235	0	I3	43	24.7
2.2	1.23	0	I4	44	24.6
2.25	1.225	0	I5	45	24.5
2.3	1.22	0	I6	46	24.4
2.35	1.215	0	I7	47	24.3
2.4	1.21	0	I8	48	24.2
2.45	1.205	0	I9	49	24.1
2.55	1.175	0	J1	51	23.5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
2.6	1.15	0	J2	52	23
2.65	1.125	0	J3	53	22.5
2.7	1.1	0	J4	54	22
2.75	1.075	0	J5	55	21.5
2.8	1.05	0	J6	56	21
2.85	1.025	0	J7	57	20.5
		0			
2.85	0.975	0	K1	57	19.5
2.8	0.95	0	K2	56	19
2.75	0.925	0	K3	55	18.5
2.7	0.9	0	K4	54	18
2.65	0.875	0	K5	53	17.5
2.6	0.85	0	K6	52	17
2.55	0.825	0	K7	51	16.5
2.45	0.79	0	L1	49	15.8
2.4	0.78	0	L2	48	15.6
2.35	0.77	0	L3	47	15.4
2.3	0.76	0	L4	46	15.2
2.25	0.75	0	L5	45	15
2.2	0.74	0	L6	44	14.8
2.15	0.73	0	L7	43	14.6
2.1	0.72	0	L8	42	14.4
2.05	0.71	0	L9	41	14.2
1.95	0.67143	0	M1	39	13.4286
1.9	0.64286	0	M2	38	12.8572
1.85	0.61429	0	M3	37	12.2858
1.8	0.58572	0	M4	36	11.7144
1.75	0.55715	0	M5	35	11.143
1.7	0.52858	0	M6	34	10.5716
1.625	0.45	0	N1	32.5	9
1.6	0.4	0	N2	32	8
1.575	0.35	0	N3	31.5	7
1.55	0.3	0	N4	31	6
1.525	0.25	0	N5	30.5	5
1.4	0.2	0	P1	28	4
1.35	0.2	0	P2	27	4
1.3	0.2	0	P3	26	4
		0			
1.2	0.2	0	Q1	24	4
1.15	0.2	0	Q2	23	4
1.1	0.2	0	Q3	22	4
1.05	0.2	0	Q4	21	4
0.95	0.2	0	R1	19	4
0.9	0.2	0	R2	18	4

Table 3BU. Geyser Springs Group Vent B Upper, XYZ Grid Data, September 30, 2006. Page 3 of 4

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
0.85	**0.2**	**0**	**R3**	17	4
0.8	**0.2**	**0**	**R4**	16	4
0.75	**0.2**	**0**	**R5**	15	4
0.65	**0.2**	**0**	**S1**	13	4
0.6	**0.2**	**0**	**S2**	12	4
0.55	**0.2**	**0**	**S3**	11	4
0.5	**0.2**	**0**	**S4**	10	4
0.46667	**0.25**	**0**	**T1**	9.3333	5
0.48333	**0.3**	**0**	**T2**	9.6666	6
0.5	**0.35**	**0**	**T3**	10	7
0.51666	**0.4**	**0**	**T4**	10.3332	8
0.53333	**0.45**	**0**	**T5**	10.6665	9
0.545	**0.55**	**0**	**U1**	10.9	11
0.54	**0.6**	**0**	**U2**	10.8	12
0.535	**0.65**	**0**	**U3**	10.7	13
0.53	**0.7**	**0**	**U4**	10.6	14
0.525	**0.75**	**0**	**U5**	10.5	15
0.52	**0.8**	**0**	**U6**	10.4	16
0.515	**0.85**	**0**	**U7**	10.3	17
0.51	**0.9**	**0**	**U8**	10.2	18
0.505	**0.95**	**0**	**U9**	10.1	19
0.5	**1.05**	**0**	**V1**	10	21
0.5	**1.1**	**0**	**V2**	10	22
0.5	**1.15**	**0**	**V3**	10	23
0.5	**1.2**	**0**	**V4**	10	24
0.5	**1.25**	**0**	**V5**	10	25
0.5	**1.3**	**0**	**V6**	10	26
0.5	**1.35**	**0**	**V7**	10	27
0.5	**1.4**	**0**	**V8**	10	28
0.5	**1.45**	**0**	**V9**	10	29

Table 3B Lower. Geyser Springs Group Vent B Lower XYZ Grid Data, September 30, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
2	**3**	**0.39**	**1**	40	60
2	**2.5**	**0.58**	**2**	40	50
2	**2**	**0.6**	**3**	40	40
2	**1.5**	**0.53**	**4**	40	30
2	**1**	**0.61**	**5**	40	20
2	**0.5**	**0.21**	**6**	40	10
1	**2.5**	**0.54**	**7**	20	50
1.5	**2.5**	**0.26**	**8**	30	50
2.5	**2.5**	**0.29**	**9**	50	50
2.8	**2.5**	**0.24**	**10**	56	50
1.1	**1.5**	**0.17**	**11**	22	30
1.5	**1.5**	**0.4**	**12**	30	30
2.5	**1.5**	**0.53**	**13**	50	30
0.5	**2.5**	**0**	**A**	10	50
0.7	**3**	**0**	**B**	14	60
1	**3.3**	**0**	**C**	20	66
1.2	**3.4**	**0**	**D**	24	68
1.5	**3.3**	**0**	**E**	30	66
2	**3.4**	**0**	**F**	40	68
2.5	**3.5**	**0**	**G**	50	70
2.6	**3.4**	**0**	**H**	52	68
3	**3.1**	**0**	**I**	60	62
3	**3**	**0**	**J**	60	60
3	**2.5**	**0**	**K**	60	50
3.1	**2**	**0**	**L**	62	40
2.7	**1.5**	**0**	**M**	54	30
2.6	**1**	**0**	**N**	52	20
2.5	**0.9**	**0**	**O**	50	18
2.35	**0.5**	**0**	**P**	47	10
2	**0.3**	**0**	**Q**	40	6
1.5	**0.3**	**0**	**R**	30	6
1.4	**0.5**	**0**	**S**	28	10
1.3	**1**	**0**	**T**	26	20
1.1	**1.4**	**0**	**U**	22	28
0.9	**1.5**	**0**	**V**	18	30
0.8	**2**	**0**	**W**	16	40
0.52	**2.55**	**0**	**A1**	10.4	51
0.54	**2.6**	**0**	**A2**	10.8	52
0.56	**2.65**	**0**	**A3**	11.2	53
0.58	**2.7**	**0**	**A4**	11.6	54
0.6	**2.75**	**0**	**A5**	12	55
0.62	**2.8**	**0**	**A6**	12.4	56
0.64	**2.85**	**0**	**A7**	12.8	57
0.66	**2.9**	**0**	**A8**	13.2	58
0.68	**2.95**	**0**	**A9**	13.6	59

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
0.75	**3.05**	**0**	**B1**	15	61
0.8	**3.1**	**0**	**B2**	16	62
0.85	**3.15**	**0**	**B3**	17	63
0.9	**3.2**	**0**	**B4**	18	64
0.95	**3.25**	**0**	**B5**	19	65
1.05	**3.325**	**0**	**C1**	21	66.5
1.1	**3.35**	**0**	**C2**	22	67
1.15	**3.375**	**0**	**C3**	23	67.5
1.25	**3.38334**	**0**	**D1**	25	67.6667
1.3	**3.36667**	**0**	**D2**	26	67.3334
1.35	**3.35001**	**0**	**D3**	27	67.0001
1.4	**3.33334**	**0**	**D4**	28	66.6668
1.45	**3.31668**	**0**	**D5**	29	66.3335
1.55	**3.31**	**0**	**E1**	31	66.2
1.6	**3.32**	**0**	**E2**	32	66.4
1.65	**3.33**	**0**	**E3**	33	66.6
1.7	**3.34**	**0**	**E4**	34	66.8
1.75	**3.35**	**0**	**E5**	35	67
1.8	**3.36**	**0**	**E6**	36	67.2
1.85	**3.37**	**0**	**E7**	37	67.4
1.9	**3.38**	**0**	**E8**	38	67.6
1.95	**3.39**	**0**	**E9**	39	67.8
2.05	**3.41**	**0**	**F1**	41	68.2
2.1	**3.42**	**0**	**F2**	42	68.4
2.15	**3.43**	**0**	**F3**	43	68.6
2.2	**3.44**	**0**	**F4**	44	68.8
2.25	**3.45**	**0**	**F5**	45	69
2.3	**3.46**	**0**	**F6**	46	69.2
2.35	**3.47**	**0**	**F7**	47	69.4
2.4	**3.48**	**0**	**F8**	48	69.6
2.45	**3.49**	**0**	**F9**	49	69.8
2.55	**3.45**	**0**	**G1**	51	69
2.65	**3.3625**	**0**	**H1**	53	67.25
2.7	**3.325**	**0**	**H2**	54	66.5
2.75	**3.2875**	**0**	**H3**	55	65.75
2.8	**3.25**	**0**	**H4**	56	65
2.85	**3.2125**	**0**	**H5**	57	64.25
2.9	**3.175**	**0**	**H6**	58	63.5
2.95	**3.1375**	**0**	**H7**	59	62.75
3	**3.05**	**0**	**I1**	60	61

Table 3BL. Geyser Springs Group Vent B Lower, XYZ Grid Data, September 30, 2006. Page 2 of 5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
3	2.95	0	J1	60	59
3	2.9	0	J2	60	58
3	2.85	0	J3	60	57
3	2.8	0	J4	60	56
3	2.75	0	J5	60	55
3	2.7	0	J6	60	54
3	2.65	0	J7	60	53
3	2.6	0	J8	60	52
3	2.55	0	J9	60	51
3.01	2.45	0	K1	60.2	49
3.02	2.4	0	K2	60.4	48
3.03	2.35	0	K3	60.6	47
3.04	2.3	0	K4	60.8	46
3.05	2.25	0	K5	61	45
3.06	2.2	0	K6	61.2	44
3.07	2.15	0	K7	61.4	43
3.08	2.1	0	K8	61.6	42
3.09	2.05	0	K9	61.8	41
3.06	1.95	0	L1	61.2	39
3.02	1.9	0	L2	60.4	38
2.98	1.85	0	L3	59.6	37
2.94	1.8	0	L4	58.8	36
2.9	1.75	0	L5	58	35
2.86	1.7	0	L6	57.2	34
2.82	1.65	0	L7	56.4	33
2.78	1.6	0	L8	55.6	32
2.74	1.55	0	L9	54.8	31
2.69	1.45	0	M1	53.8	29
2.68	1.4	0	M2	53.6	28
2.67	1.35	0	M3	53.4	27
2.66	1.3	0	M4	53.2	26
2.65	1.25	0	M5	53	25
2.64	1.2	0	M6	52.8	24
2.63	1.15	0	M7	52.6	23
2.62	1.1	0	M8	52.4	22
2.61	1.05	0	M9	52.2	21
2.55	0.95	0	N1	51	19
2.48135	0.85	0	O1	49.627	17
2.4627	0.8	0	O2	49.254	16
2.44441	0.75	0	O3	48.8881	15
2.4254	0.7	0	O4	48.508	14
2.40675	0.65	0	O5	48.135	13
2.3881	0.6	0	O6	47.762	12
2.36945	0.55	0	O7	47.389	11

Table 3BL. Geyser Springs Group Vent B Lower, XYZ Grid Data, September 30, 2006.

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
2.3	**0.47143**	**0**	**P1**	46	9.4286
2.25	**0.44286**	**0**	**P2**	45	8.8572
2.2	**0.41429**	**0**	**P3**	44	8.2858
2.15	**0.38572**	**0**	**P4**	43	7.7144
2.1	**0.35715**	**0**	**P5**	42	7.143
2.05	**0.32858**	**0**	**P6**	41	6.5716
1.95	**0.3**	**0**	**Q1**	39	6
1.9	**0.3**	**0**	**Q2**	38	6
1.85	**0.3**	**0**	**Q3**	37	6
1.8	**0.3**	**0**	**Q4**	36	6
1.75	**0.3**	**0**	**Q5**	35	6
1.7	**0.3**	**0**	**Q6**	34	6
1.65	**0.3**	**0**	**Q7**	33	6
1.6	**0.3**	**0**	**Q8**	32	6
1.55	**0.3**	**0**	**Q9**	31	6
1.475	**0.35**	**0**	**R1**	29.5	7
1.45	**0.4**	**0**	**R2**	29	8
1.425	**0.45**	**0**	**R3**	28.5	9
1.39	**0.55**	**0**	**S1**	27.8	11
1.38	**0.6**	**0**	**S2**	27.6	12
1.37	**0.65**	**0**	**S3**	27.4	13
1.36	**0.7**	**0**	**S4**	27.2	14
1.35	**0.75**	**0**	**S5**	27	15
1.34	**0.8**	**0**	**S6**	26.8	16
1.33	**0.85**	**0**	**S7**	26.6	17
1.32	**0.9**	**0**	**S8**	26.4	18
1.31	**0.95**	**0**	**S9**	26.2	19
1.275	**1.05**	**0**	**T1**	25.5	21
1.25	**1.1**	**0**	**T2**	25	22
1.225	**1.15**	**0**	**T3**	24.5	23
1.2	**1.2**	**0**	**T4**	24	24
1.175	**1.25**	**0**	**T5**	23.5	25
1.15	**1.3**	**0**	**T6**	23	26
1.125	**1.35**	**0**	**T7**	22.5	27
1.05	**1.425**	**0**	**U1**	21	28.5
1	**1.45**	**0**	**U2**	20	29
0.95	**1.475**	**0**	**U3**	19	29.5
0.89	**1.55**	**0**	**V1**	17.8	31
0.88	**1.6**	**0**	**V2**	17.6	32
0.87	**1.65**	**0**	**V3**	17.4	33
0.86	**1.7**	**0**	**V4**	17.2	34
0.85	**1.75**	**0**	**V5**	17	35

Table 3BL. Geyser Springs Group Vent B Lower, XYZ Grid Data, September 30, 2006. Page 4 of 5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
0.84	**1.8**	**0**	**V6**	16.8	36
0.83	**1.85**	**0**	**V7**	16.6	37
0.82	**1.9**	**0**	**V8**	16.4	38
0.81	**1.95**	**0**	**V9**	16.2	39
0.77	**2.05**	**0**	**W1**	15.4	41
0.74	**2.1**	**0**	**W2**	14.8	42
0.71	**2.15**	**0**	**W3**	14.2	43
0.68	**2.2**	**0**	**W4**	13.6	44
0.65	**2.25**	**0**	**W5**	13	45
0.62	**2.3**	**0**	**W6**	12.4	46
0.59	**2.35**	**0**	**W7**	11.8	47
0.56	**2.4**	**0**	**W8**	11.2	48
0.53	**2.45**	**0**	**W9**	10.6	49

Table 3C. Geyser Springs Group Vent C XYZ Grid Data, September 30, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
0.75	**1**	**0.83**	**1**	15	20
1	**1.25**	**0.76**	**2**	20	25
1.25	**1**	**0.79**	**3**	25	20
1	**0.75**	**0.55**	**4**	20	15
1	**1**	**1.06**	**5**	20	20
0.5	**1.45**	**0**	**A**	10	29
1	**1.55**	**0**	**B**	20	31
1.5	**1**	**0**	**C**	30	20
1.25	**0.6**	**0**	**D**	25	12
1	**0.6**	**0**	**E**	20	12
0.75	**0.4**	**0**	**F**	15	8
0.5	**0.4**	**0**	**G**	10	8
0.4	**1**	**0**	**H**	8	20
0.55	**1.46**	**0**	**A1**	11	29.2
0.6	**1.47**	**0**	**A2**	12	29.4
0.65	**1.48**	**0**	**A3**	13	29.6
0.7	**1.49**	**0**	**A4**	14	29.8
0.75	**1.5**	**0**	**A5**	15	30
0.8	**1.51**	**0**	**A6**	16	30.2
0.85	**1.52**	**0**	**A7**	17	30.4
0.9	**1.53**	**0**	**A8**	18	30.6
0.95	**1.54**	**0**	**A9**	19	30.8
1.04546	**1.5**	**0**	**B1**	20.9091	30
1.09091	**1.45**	**0**	**B2**	21.8182	29
1.13637	**1.4**	**0**	**B3**	22.7273	28
1.18182	**1.35**	**0**	**B4**	23.6364	27
1.22728	**1.3**	**0**	**B5**	24.5455	26
1.27273	**1.25**	**0**	**B6**	25.4546	25
1.31819	**1.2**	**0**	**B7**	26.3637	24
1.36364	**1.15**	**0**	**B8**	27.2728	23
1.4091	**1.1**	**0**	**B9**	28.1819	22
1.45455	**1.05**	**0**	**B10**	29.091	21
1.46875	**0.95**	**0**	**C1**	29.375	19
1.4375	**0.9**	**0**	**C2**	28.75	18
1.40625	**0.85**	**0**	**C3**	28.125	17
1.375	**0.8**	**0**	**C4**	27.5	16
1.34375	**0.75**	**0**	**C5**	26.875	15
1.3125	**0.7**	**0**	**C6**	26.25	14
1.28125	**0.65**	**0**	**C7**	25.625	13
1.2	**0.6**	**0**	**D1**	24	12
1.15	**0.6**	**0**	**D2**	23	12
1.1	**0.6**	**0**	**D3**	22	12

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
1.05	**0.6**	**0**	**D4**	21	12
0.95	**0.56**	**0**	**E1**	19	11.2
0.9	**0.52**	**0**	**E2**	18	10.4
0.85	**0.48**	**0**	**E3**	17	9.6
0.8	**0.44**	**0**	**E4**	16	8.8
0.7	**0.4**	**0**	**F1**	14	8
0.65	**0.4**	**0**	**F2**	13	8
0.6	**0.4**	**0**	**F3**	12	8
0.55	**0.4**	**0**	**F4**	11	8
0.49167	**0.45**	**0**	**G1**	9.8333	9
0.48333	**0.5**	**0**	**G2**	9.6666	10
0.475	**0.55**	**0**	**G3**	9.4999	11
0.46666	**0.6**	**0**	**G4**	9.3332	12
0.45833	**0.65**	**0**	**G5**	9.1665	13
0.44999	**0.7**	**0**	**G6**	8.9998	14
0.44166	**0.75**	**0**	**G7**	8.8331	15
0.43332	**0.8**	**0**	**G8**	8.6664	16
0.42499	**0.85**	**0**	**G9**	8.4997	17
0.41665	**0.9**	**0**	**G10**	8.333	18
0.40832	**0.95**	**0**	**G11**	8.1663	19
0.41111	**1.05**	**0**	**H1**	8.2222	21
0.42222	**1.1**	**0**	**H2**	8.4444	22
0.43333	**1.15**	**0**	**H3**	8.6666	23
0.44444	**1.2**	**0**	**H4**	8.8888	24
0.45555	**1.25**	**0**	**H5**	9.111	25
0.46666	**1.3**	**0**	**H6**	9.3332	26
0.47777	**1.35**	**0**	**H7**	9.5554	27
0.48888	**1.4**	**0**	**H8**	9.7776	28

Table 3D. Geyser Springs Group Vent D XYZ Grid Data, September 30, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
3	**1.5**	**0.46**	**1**	60	30
2.5	**1.5**	**0.76**	**2**	50	30
2	**1.5**	**0.77**	**3**	40	30
1.5	**1.5**	**1.04**	**4**	30	30
1	**1.5**	**0.84**	**5**	20	30
0.5	**1.5**	**0.08**	**6**	10	30
1	**1**	**0.03**	**7**	20	20
1	**2**	**0.63**	**8**	20	40
1	**2.4**	**0.65**	**9**	20	48
2	**1**	**0.78**	**10**	40	20
2	**1.85**	**0.27**	**11**	40	37
0.1	**2.45**	**0**	**A**	2	49
0.5	**2.6**	**0**	**B**	10	52
1	**2.45**	**0**	**C**	20	49
1.5	**2.35**	**0**	**D**	30	47
2	**2.2**	**0**	**E**	40	44
2.5	**2.3**	**0**	**F**	50	46
2.6	**2.2**	**0**	**G**	52	44
2.8	**2**	**0**	**H**	56	40
3	**1.65**	**0**	**I**	60	33
3.3	**1.5**	**0**	**J**	66	30
3.4	**1.5**	**0**	**K**	68	30
3	**1.05**	**0**	**L**	60	21
3	**1**	**0**	**M**	60	20
2.5	**0.8**	**0**	**N**	50	16
2	**0.7**	**0**	**O**	40	14
1.5	**0.6**	**0**	**P**	30	12
1	**0.6**	**0**	**Q**	20	12
0.5	**0.3**	**0**	**R**	10	6
0.35	**0.6**	**0**	**S**	7	12
0.1	**1**	**0**	**T**	2	20
0.1	**1.5**	**0**	**U**	2	30
0.1	**2**	**0**	**V**	2	40
0.1	**2.35**	**0**	**W**	2	47
0.15	**2.46875**	**0**	**A1**	3	49.375
0.2	**2.4875**	**0**	**A2**	4	49.75
0.25	**2.50625**	**0**	**A3**	5	50.125
0.3	**2.525**	**0**	**A4**	6	50.5
0.35	**2.54375**	**0**	**A5**	7	50.875
0.4	**2.5625**	**0**	**A6**	8	51.25
0.45	**2.58125**	**0**	**A7**	9	51.625
0.55	**2.585**	**0**	**B1**	11	51.7
0.6	**2.57**	**0**	**B2**	12	51.4
0.65	**2.555**	**0**	**B3**	13	51.1

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
0.7	**2.54**	**0**	**B4**	14	50.8
0.75	**2.525**	**0**	**B5**	15	50.5
0.8	**2.51**	**0**	**B6**	16	50.2
0.85	**2.495**	**0**	**B7**	17	49.9
0.9	**2.48**	**0**	**B8**	18	49.6
0.95	**2.465**	**0**	**B9**	19	49.3
1.05	**2.44**	**0**	**C1**	21	48.8
1.1	**2.43**	**0**	**C2**	22	48.6
1.15	**2.42**	**0**	**C3**	23	48.4
1.2	**2.41**	**0**	**C4**	24	48.2
1.25	**2.4**	**0**	**C5**	25	48
1.3	**2.39**	**0**	**C6**	26	47.8
1.35	**2.38**	**0**	**C7**	27	47.6
1.4	**2.37**	**0**	**C8**	28	47.4
1.45	**2.36**	**0**	**C9**	29	47.2
1.55	**2.335**	**0**	**D1**	31	46.7
1.6	**2.32**	**0**	**D2**	32	46.4
1.65	**2.305**	**0**	**D3**	33	46.1
1.7	**2.29**	**0**	**D4**	34	45.8
1.75	**2.275**	**0**	**D5**	35	45.5
1.8	**2.26**	**0**	**D6**	36	45.2
1.85	**2.245**	**0**	**D7**	37	44.9
1.9	**2.23**	**0**	**D8**	38	44.6
1.95	**2.215**	**0**	**D9**	39	44.3
2.05	**2.21**	**0**	**E1**	41	44.2
2.1	**2.22**	**0**	**E2**	42	44.4
2.15	**2.23**	**0**	**E3**	43	44.6
2.2	**2.24**	**0**	**E4**	44	44.8
2.25	**2.25**	**0**	**E5**	45	45
2.3	**2.26**	**0**	**E6**	46	45.2
2.35	**2.27**	**0**	**E7**	47	45.4
2.4	**2.28**	**0**	**E8**	48	45.6
2.45	**2.29**	**0**	**E9**	49	45.8
2.55	**2.25**	**0**	**F1**	51	45
2.65	**2.15**	**0**	**G1**	53	43
2.7	**2.1**	**0**	**G2**	54	42
2.75	**2.05**	**0**	**G3**	55	41
2.82857	**1.95**	**0**	**H1**	56.5714	39
2.85714	**1.9**	**0**	**H2**	57.1428	38
2.88571	**1.85**	**0**	**H3**	57.7142	37
2.91428	**1.8**	**0**	**H4**	58.2856	36
2.94285	**1.75**	**0**	**H5**	58.857	35
2.97142	**1.7**	**0**	**H6**	59.4284	34

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
3.05	**1.625**	**0**	**I1**	61	32.5
3.1	**1.6**	**0**	**I2**	62	32
3.15	**1.575**	**0**	**I3**	63	31.5
3.2	**1.55**	**0**	**I4**	64	31
3.25	**1.525**	**0**	**I5**	65	30.5
3.35	**1.5**	**0**	**J1**	67	30
3.35556	**1.45**	**0**	**K1**	67.1112	29
3.31112	**1.4**	**0**	**K2**	66.2224	28
3.26668	**1.35**	**0**	**K3**	65.3336	27
3.22224	**1.3**	**0**	**K4**	64.4448	26
3.1778	**1.25**	**0**	**K5**	63.556	25
3.13336	**1.2**	**0**	**K6**	62.6672	24
3.08892	**1.15**	**0**	**K7**	61.7784	23
3.04448	**1.1**	**0**	**K8**	60.8896	22
2.95	**0.98**	**0**	**M1**	59	19.6
2.9	**0.96**	**0**	**M2**	58	19.2
2.85	**0.94**	**0**	**M3**	57	18.8
2.8	**0.92**	**0**	**M4**	56	18.4
2.75	**0.9**	**0**	**M5**	55	18
2.7	**0.88**	**0**	**M6**	54	17.6
2.65	**0.86**	**0**	**M7**	53	17.2
2.6	**0.84**	**0**	**M8**	52	16.8
2.55	**0.82**	**0**	**M9**	51	16.4
2.45	**0.79**	**0**	**N1**	49	15.8
2.4	**0.78**	**0**	**N2**	48	15.6
2.35	**0.77**	**0**	**N3**	47	15.4
2.3	**0.76**	**0**	**N4**	46	15.2
2.25	**0.75**	**0**	**N5**	45	15
2.2	**0.74**	**0**	**N6**	44	14.8
2.15	**0.73**	**0**	**N7**	43	14.6
2.1	**0.72**	**0**	**N8**	42	14.4
2.05	**0.71**	**0**	**N9**	41	14.2
1.95	**0.69**	**0**	**O1**	39	13.8
1.9	**0.68**	**0**	**O2**	38	13.6
1.85	**0.67**	**0**	**O3**	37	13.4
1.8	**0.66**	**0**	**O4**	36	13.2
1.75	**0.65**	**0**	**O5**	35	13
1.7	**0.64**	**0**	**O6**	34	12.8
1.65	**0.63**	**0**	**O7**	33	12.6
1.6	**0.62**	**0**	**O8**	32	12.4
1.55	**0.61**	**0**	**O9**	31	12.2
1.45	**0.6**	**0**	**P1**	29	12

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
1.4	0.6	0	P2	28	12
1.35	0.6	0	P3	27	12
1.3	0.6	0	P4	26	12
1.25	0.6	0	P5	25	12
1.2	0.6	0	P6	24	12
1.15	0.6	0	P7	23	12
1.1	0.6	0	P8	22	12
1.05	0.6	0	P9	21	12
0.95	0.57	0	Q1	19	11.4
0.9	0.54	0	Q2	18	10.8
0.85	0.51	0	Q3	17	10.2
0.8	0.48	0	Q4	16	9.6
0.75	0.45	0	Q5	15	9
0.7	0.42	0	Q6	14	8.4
0.65	0.39	0	Q7	13	7.8
0.6	0.36	0	Q8	12	7.2
0.55	0.33	0	Q9	11	6.6
0.475	0.35	0	R1	9.5	7
0.45	0.4	0	R2	9	8
0.425	0.45	0	R3	8.5	9
0.4	0.5	0	R4	8	10
0.375	0.55	0	R5	7.5	11
0.31429	0.65	0	S1	6.2857	13
0.27857	0.7	0	S2	5.5714	14
0.24286	0.75	0	S3	4.8571	15
0.20714	0.8	0	S4	4.1428	16
0.17143	0.85	0	S5	3.4285	17
0.13571	0.9	0	S6	2.7142	18
0.1	0.95	0	S7	1.9999	19
0.1	1.05	0	T1	2	21
0.1	1.1	0	T2	2	22
0.1	1.15	0	T3	2	23
0.1	1.2	0	T4	2	24
0.1	1.25	0	T5	2	25
0.1	1.3	0	T6	2	26
0.1	1.35	0	T7	2	27
0.1	1.4	0	T8	2	28
0.1	1.45	0	T9	2	29
0.1	1.55	0	U1	2	31
0.1	1.6	0	U2	2	32
0.1	1.65	0	U3	2	33
0.1	1.7	0	U4	2	34
0.1	1.75	0	U5	2	35
0.1	1.8	0	U6	2	36

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
0.1	**1.85**	**0**	**U7**	2	37
0.1	**1.9**	**0**	**U8**	2	38
0.1	**1.95**	**0**	**U9**	2	39
0.1	**2.05**	**0**	**V1**	2	41
0.1	**2.1**	**0**	**V2**	2	42
0.1	**2.15**	**0**	**V3**	2	43
0.1	**2.2**	**0**	**V4**	2	44
0.1	**2.25**	**0**	**V5**	2	45
0.1	**2.3**	**0**	**V6**	2	46
0.1	**2.4**	**0**	**W1**	2	48

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ________ Time Constant: ________

SensorSer # N/A

Type of Reading

Velocity:

X FPS

_ CMS

_ ______

Level:

_ IN

_ CM

X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ________

Calibration Technician: Stan Cielsk Date: 18 Apr 2006

QA Technician: B Hall Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

P/N 101001 301

Discharge Measurement: Indian Cave Spring, Marion County, Florida; September 28, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
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High Springs, Florida 32643
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LIST OF CONTENTS

Results of Discharge Measurements of Indian Cave Spring, Marion County, Florida; September 28, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Indian Cave Spring on September 28, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Indian Cave Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Tom Morris, both of KES. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida.

SITE DESCRIPTION

Indian Cave Spring is located within a small cove on the south side of the Silver River, about 250 feet southeast of the Garden of Eden Spring Group. The main vent, about 11 feet long, lies within a sediment-sided basin, about 17 feet deep. The main vent discharges from a rocky opening at its southeastern end, and has additional smaller vents discharging through detritus at its western end. There is an additional vent about 40 feet to the south in the bottom of a conical basin formed in soft sediment, and about 15 feet deep. (This additional vent is not shown on the map.) See Figure 1.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

Cross-Section Measurement

Pete Butt positioned the sensor, and recorded positional data, while Tom Morris read the velocity readings, after taking meter reset cues from Butt. During all measurements, the sensor handler completely removed himself from the cross section of the flow. The meter operator was also positioned outside the cross-section. This eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. Thirty-one station readings were taken along the measurement cross-section, along with three hand-held readings.

The approximate depth for the measurement grid was 17 feet. Telescoping aluminum poles with 1, 0.5, 0.25 and 0.1 foot interval markings were positioned horizontally to allow for a grid of velocity measurements. As all sensor-support poles were positioned at right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was positioned on the poles with a quick release clamp. Spring vent dimensions and positions were measured with a metal tape. Three hand-held readings were made in each of three small vents, and vertical and horizontal measurements were made.

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figure 2. Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Table 3. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift, an anisotropy ratio of 1 at an angle of 0°, and a variogram slope of 1.0. The results of the contour processing are illustrated in Figures 3 and 4.

During this measurement, no negative velocities were measured. However, in order to incorporate one or more negative values that have been typical in other measurements, calculations were made using a Surfer 8 “blanking file” operation to define the measurement cross-section boundary. The total discharge is shown on Table 2 as the **Net Volume (Cut-Fill)**, and has been calculated as the Positive Volume (Cut) less that portion of the Negative Volume (Fill) lying within the measurement cross-section boundary walls that define the plane of measurement.

The software also calculates the total cross-sectional area of the measurement location within the passage, and is presented on Table 2 as the **Operational Planar Area**. The Operational Planar Area is the sum of the Positive (Cut) and that portion of the Negative (Fill) Planar areas lying within the measurement cross-section boundary walls that define the plane of measurement.

VDCD Measurements

This spring also has a small vent discharging through a mixed bottom of detritus and sediments. Direct measurements of the vent cross-sections at this vent were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1A.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

RESULTS AND DISCUSSION

This measurement is the first one performed at Indian Cave Spring applying the methods and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated total discharge of Indian Cave Spring (all vents) on September 28, 2006 was 4.31 CFS (cubic feet per second). This result is also expressed as 1934 GPM (gallons per minute) or 2.786 MGD (million gallons per day), see Tables 1A and 1B. A total of thirty-one (31) cross-section and 4 miscellaneous vent readings were made, see Figures 2(AB), 3(AB) and 4(AB). The total cross-sectional area was calculated as 11.64 square feet. The point velocity readings ranged from 0.13 to 0.76 feet per second (fps), with an overall average station reading of 0.46 fps. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 11:43 hours and were completed by 12:40 hours. The results for each of the individual vents are detailed below.

The estimated discharge of Indian Cave Spring Main Vent on September 28, 2006 was 3.9 CFS. This result is also expressed as 1750 GPM or 2.521 MGD, see Table 1A. Thirty-one (31) readings were made, see Figures 2A, 3A and 4A. The total cross-sectional area was calculated as 10.29 square feet. The point velocity readings ranged from 0.13 to 0.76 feet per second (fps), with an overall average station reading of 0.46 fps.

The estimated discharge of Indian Cave Spring Miscellaneous Vents hand-held readings on September 28, 2006 was 0.41 CFS. This result is also expressed as 183 GPM or 0.263 MGD, see Table 1B. One VDCD measurement was made at Vent 2, with three readings taken. Individual point velocity readings ranged from 0.85 to 0.89 feet per second (fps), with an overall average station reading of 0.87 fps. The approximate depth for this measurement was 11 feet. Three (3) hand-held readings were made. The total cross-sectional areas for these were calculated as 0.32, 0.28 and 0.75 square feet. The point velocity readings were 0.11, 0.29 and 0.17 feet per second (fps). The approximate depth for these measurements was 15 feet.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**INDIAN CAVE SPRING**			Date:	**September 28, 2006**
	Silver Springs Group,			Time Start:	11:43
	Marion County, Florida			Time End:	12:40
Personnel:	Peter Butt, Tom Morris				
Indian Cave Spring Total Discharge:				**Misc. Vents**	
(Total from below and Table 1B)				**From Table 1B:**	
CFS	**4.31**			**CFS**	**0.41**
MGD	**2.786**			**MGD**	**0.263**
GPM	**1934**			**GPM**	**183**
Method:	Grid within irregular conduit				
Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles				
Msmt. Periods:		60 seconds			
Analysis Method:	Surfer 8 with kriging				
Indian Cave Spring Discharge:					
CFS	**3.90**				
MGD	**2.521**				
GPM	**1750**				
Total Cross-sectional Area (sq/ft):		10.29			
Avg. Station Point Velocity (ft/sec):		0.46			
Cross-section Depth (feet deep):		17			
Velocity Reading by Station:		(All velocity readings in feet per second.)			
Station #	Point Velocity	Station #	Point Velocity		
1	0.69	17	0.14		
2	0.62	18	0.5		
3	0.76	19	0.4		
4	0.67	20	0.33		
5	0.52	21	0.47		
6	0.69	22	0.42		
7	0.51	23	0.16		
8	0.52	24	0.51		
9	0.45	25	0.13		
10	0.73	26	0.8		
11	0.62	27	0.65		
12	0.04	28	0.53		
13	0.72	29	0.16		
14	0.41	30	0.51		
15	0.18	31	0.34		
16	0.15				

Table 1A. Discharge of Indian Cave Spring, Marion County, Florida on September 28, 2006. Data record and calculation of discharge measurement.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**INDIAN CAVE SPRING: MISCELLANEOUS VENTS**				
	Silver Springs Group,		Date:	**September 28, 2006**	
	Marion County, Florida			Time Start:	11:43
Personnel:	Peter Butt, Tom Morris			Time End:	12:40
Method:	Vent Discharge Capture Device		(0.49' Diameter)		
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe and handheld.				
Calculation Method: Discharge = V x *pi* x r^2					
Measurement Periods:		60 seconds			
Indian Cave Spring Misc. Vents					
Total Discharge:		**Vent 2**	**Station 32**	**Station 33**	**Station 34**
CFS	**0.41**	**0.163**	**0.035**	**0.081**	**0.128**
MGD	**0.263**	**0.106**	**0.023**	**0.052**	**0.082**
GPM	**183**	**73**	**16**	**36**	**57**
Vent Depth (feet deep):		11	15	15	15
VDCD Velocity Readings:		(All velocity readings in feet per second.)			
Vent 2					
Reading #	Point Velocity				
1	0.85				
2	0.86				
3	0.89				
Average:	0.87				
Discharge:	**0.163**				
Misc. Vents Handheld Readings					
Station #	**Point Velocity**	**X-Sec Area**	**Discharge:**		
		(in Sq. Ft.)			
32	0.11	0.32	**0.0352**		
33	0.29	0.28	**0.0812**		
34	0.17	0.75	**0.1275**		

Table 1B. Discharge of Indian Cave Spring, Miscellaneous Vents, Marion County, Florida on September 28, 2006. Data record and calculation of discharge measurement.

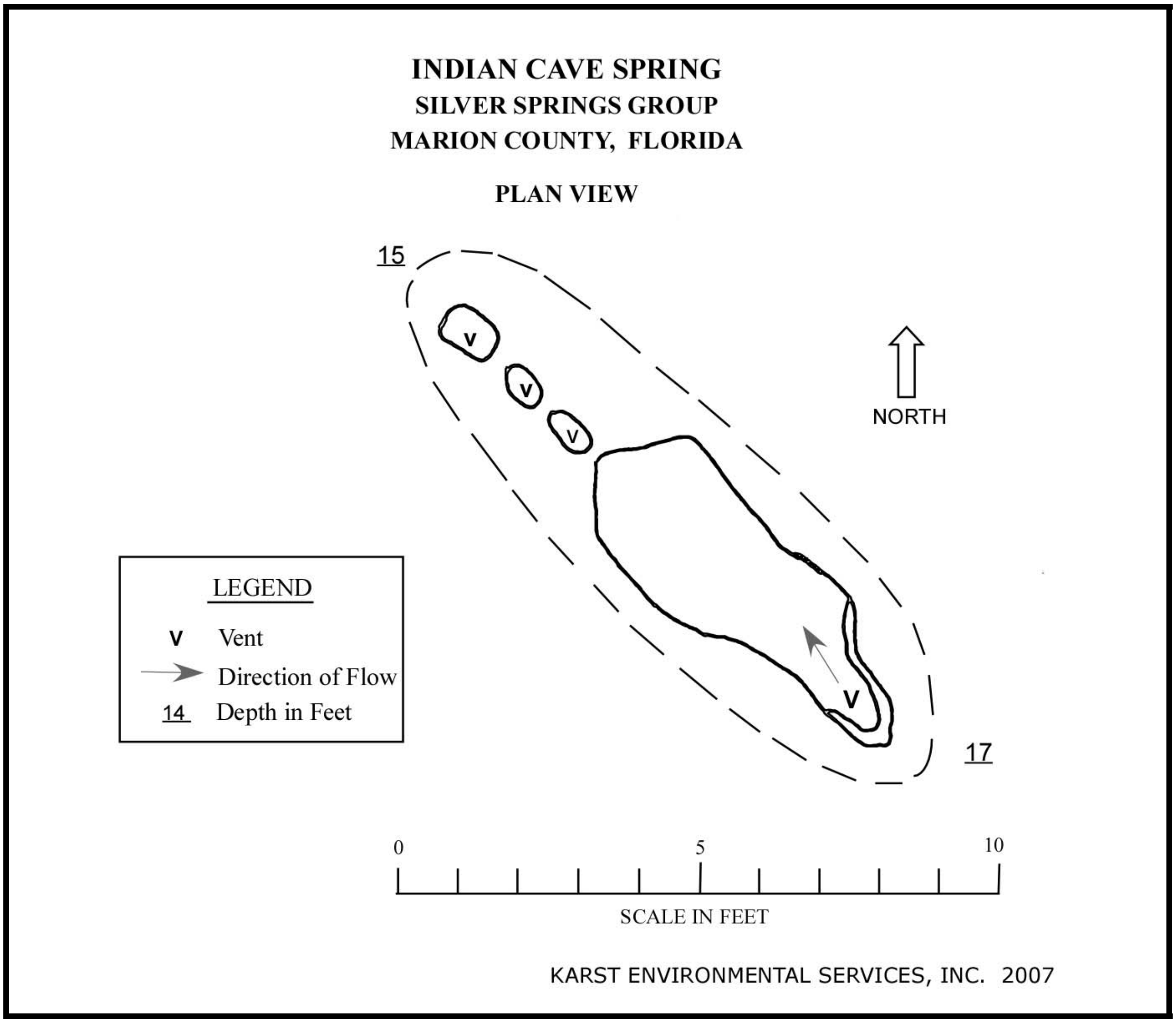

Figure 1. Map of Indian Cave Spring.

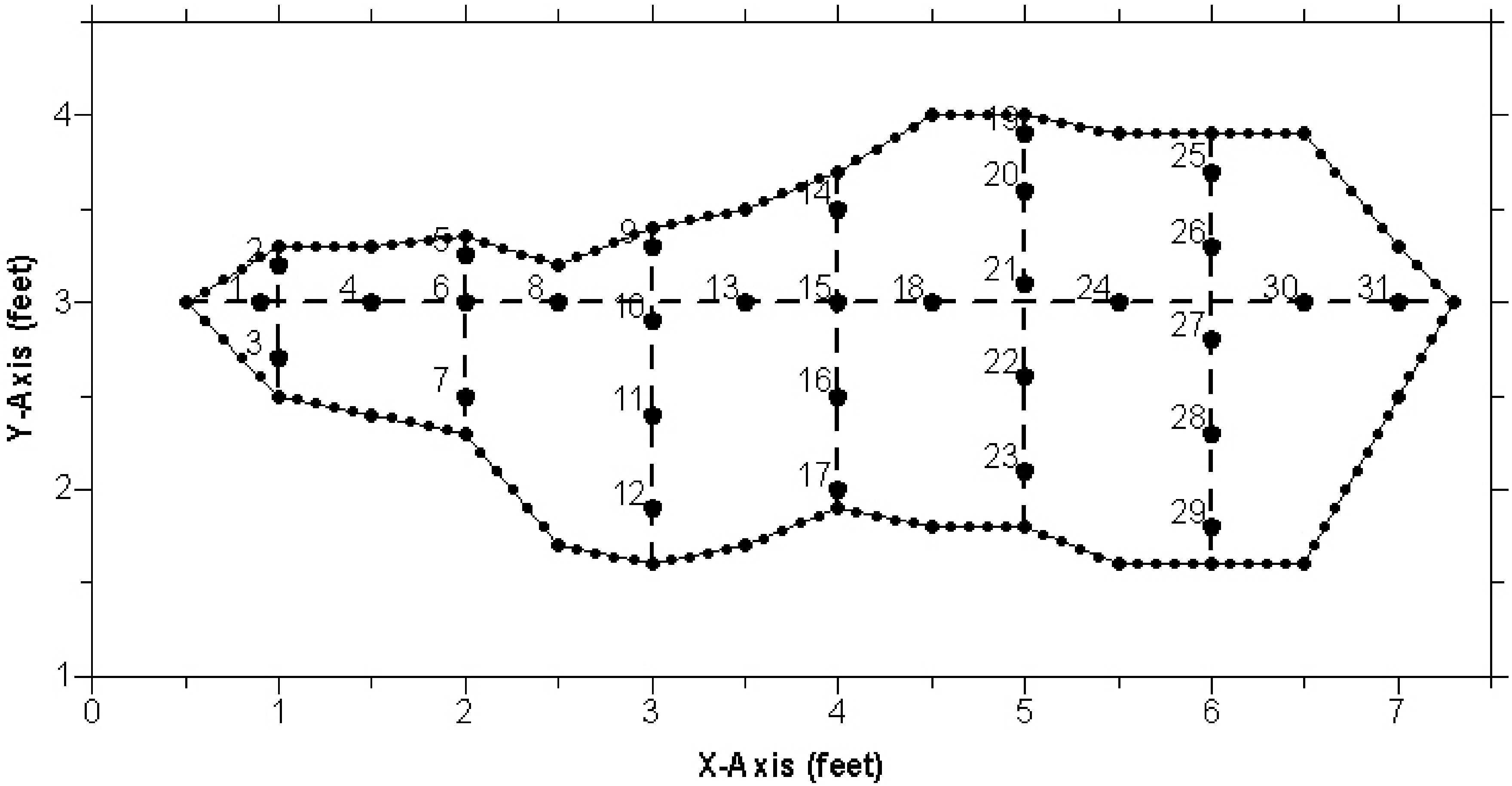

Figure 2. Discharge measurement cross-section; Indian Cave Spring, Marion County, Florida, September 28, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 17-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1A for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

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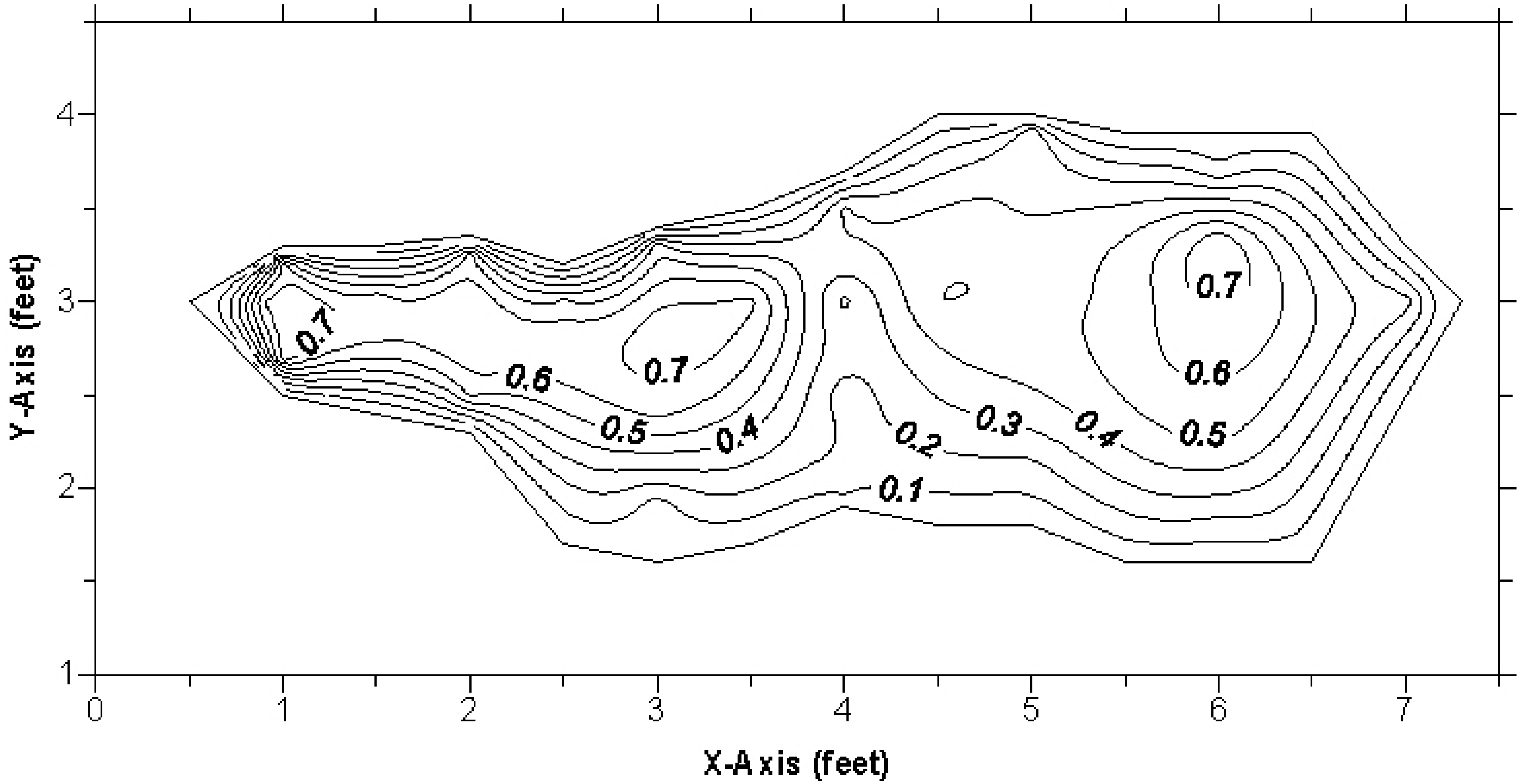

Figure 3. Discharge measurement cross-section; Indian Cave Spring, Marion County, Florida, September 28, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

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TABLE 2. INDIAN CAVE SPRING, SEPTEMBER 28, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\IndianCave\IndianCave_9-06.bln.grd
Grid Size:	71 rows x 151 columns
X Minimum:	0
X Maximum:	7.5
X Spacing:	0.05
Y Minimum:	1
Y Maximum:	4.5
Y Spacing:	0.05
Z Minimum:	-0.00099237264110141
Z Maximum:	0.79999999910804

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES
Z Scale Factor: 1
Total Volumes by:

Trapezoidal Rule:	3.9009458401774
Simpson's Rule:	3.9014972621891
Simpson's 3/8 Rule:	3.9012446249881

CUT & FILL VOLUMES
Positive Volume [Cut]: 3.900946736763
Negative Volume [Fill]: 8.9658560387483E-007
Net Volume [Cut-Fill]: 3.9009458401774<<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 10.29 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 10.287494327203
Negative Planar Area [Fill]: 5.6727972423821E-006
Blanked Planar Area: 15.9625
Total Planar Area: 26.25

Surface Areas
Positive Surface Area [Cut]: 13.973011181825
Negative Surface Area [Fill]: 6.6216656540163E-006

GRIDDING REPORT

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\IndianCave\Indian Cave 9-06 SURFER XYZ BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	175
Original Data:	175
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.5	1.6	0
25%-tile:	2.3	1.88	0
Median:	4	3	0
75%-tile:	5.8	3.4	0
Maximum:	7.3	4	0.8
Midrange:	3.9	2.8	0.4
Range:	6.8	2.4	0.8
Interquartile Range:	3.5	1.52	0
Median Abs. Deviation:	1.75001	0.7	0
Mean:	4.0205677142857	2.7748571428571	0.081885714285714
Trim Mean (10%):	4.030184591195	2.7727044025157	0.054213836477987
Standard Deviation:	1.9734295441679	0.80971378163106	0.19765016301227
Variance:	3.8944241657948	0.65563640816326	0.039065586938776
Coef. of Variation:			2.4137319279237
Coef. of Skewness:			2.2937862181651

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.002	-0.074
Y:		1.000	0.092
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	3.8944241657948	-0.0036715831836735	-0.028792773404082
Y:		0.65563640816326	0.014653126530612
Z:			0.039065586938776

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-0.0073723009676423	0.022308185348231	0.049624522078495
Standard Error:	0.0075839367017246	0.018483524780985	0.06157515204671

Inter-Parameter Correlations

	A	B	C
A:	1.000	-0.002	-0.497
B:		1.000	0.834
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.094351889415696	0.047175944707848	1.2035
Residual:	172	6.74212582487	0.039198405958547	
Total:	174	6.8364777142857		

Coefficient of Multiple Determination (R^2): 0.013801242885431

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.1	0
25%-tile:	0.1	0
Median:	0.10440306508911	0
75%-tile:	0.11661903789691	0
Maximum:	0.50990195135928	0.76

Midrange:	0.30495097567964	0.38
Range:	0.40990195135928	0.76
Interquartile Range:	0.016619037896906	0
Median Abs. Deviation:	0.0044030650891055	0
Mean:	0.14494185912647	0.0708
Trim Mean (10%):	0.12927624777216	0.044150943396226
Standard Deviation:	0.10341226735101	0.17349002441474
Variance:	0.010694097038676	0.030098788571429
Coef. of Variation:	0.71347413351979	2.4504240736546
Coef. of Skewness:	2.7584504549624	2.5569866059782
Root Mean Square:	0.17805122736368	0.18738043807033
Mean Square:	0.031702239565714	0.035111428571429

Complete Spatial Randomness

Lambda:	10.723039215686
Clark and Evans:	0.94925473117842
Skellam:	373.78834429975

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 8.1E-007
Y Duplicate Tolerance: 2.8E-007
No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point

Polynomial Drift Order: 2
Kriging std. deviation grid: no

Semi-Variogram Model

Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 1
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\IndianCave\IndianCave_9-06.grd
Grid Size:	71 rows x 151 columns
Total Nodes:	10721
Filled Nodes:	10721
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	7.5
X Spacing:	0.05
Y Minimum:	1
Y Maximum:	4.5
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-2.8131387348556
Z 25%-tile:	-0.72473240724118
Z Median:	-0.17962918752979
Z 75%-tile:	0.28631636883304
Z Maximum:	0.79999999910804
Z Midrange:	-1.0065693678738
Z Range:	3.6131387339637
Z Interquartile Range:	1.0110487760742
Z Median Abs. Deviation:	0.49855343220606
Z Mean:	-0.28078853274951
Z Trim Mean (10%):	-0.24290013893576
Z Standard Deviation:	0.68472961544247
Z Variance:	0.46885464626399
Z Coef. of Variation:	-1
Z Coef. of Skewness:	-0.70486773374004
Z Root Mean Square:	0.74006543385542
Z Mean Square:	0.54769684638761

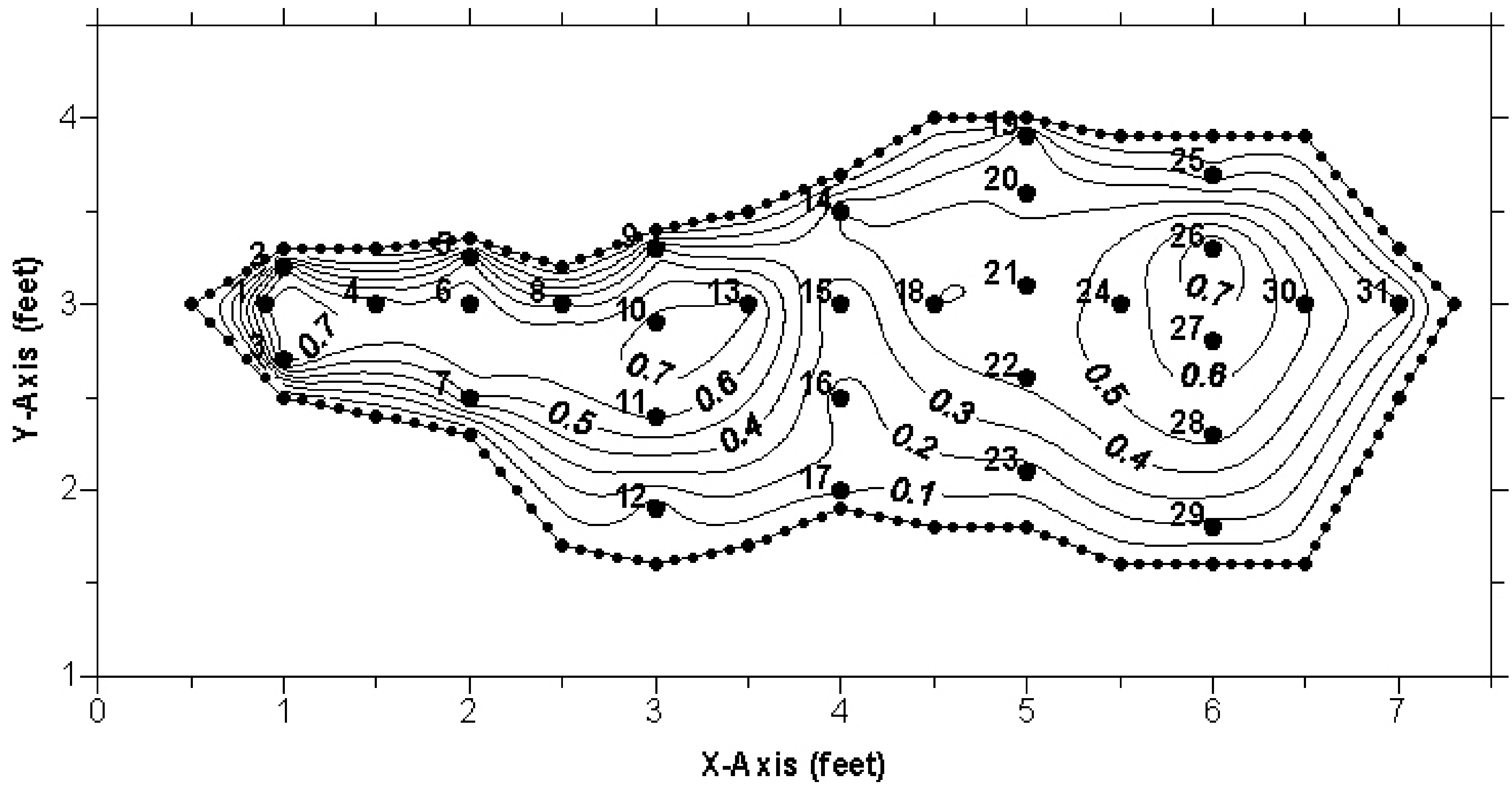

Figure 4. Discharge measurement cross-section; Indian Cave Spring, Marion County, Florida, September 28, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. See Table 1A for station velocities. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

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Table 3. Indian Cave Spring XYZ Grid Data, September 28, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
0.9	**3**	**0.69**	**1**	9	30
1	**3.2**	**0.62**	**2**	10	32
1	**2.7**	**0.76**	**3**	10	27
1.5	**3**	**0.67**	**4**	15	30
2	**3.25**	**0.52**	**5**	20	32.5
2	**3**	**0.69**	**6**	20	30
2	**2.5**	**0.51**	**7**	20	25
2.5	**3**	**0.52**	**8**	25	30
3	**3.3**	**0.45**	**9**	30	33
3	**2.9**	**0.73**	**10**	30	29
3	**2.4**	**0.62**	**11**	30	24
3	**1.9**	**0.04**	**12**	30	19
3.5	**3**	**0.72**	**13**	35	30
4	**3.5**	**0.41**	**14**	40	35
4	**3**	**0.18**	**15**	40	30
4	**2.5**	**0.15**	**16**	40	25
4	**2**	**0.14**	**17**	40	20
4.5	**3**	**0.5**	**18**	45	30
5	**3.9**	**0.4**	**19**	50	39
5	**3.6**	**0.33**	**20**	50	36
5	**3.1**	**0.47**	**21**	50	31
5	**2.6**	**0.42**	**22**	50	26
5	**2.1**	**0.16**	**23**	50	21
5.5	**3**	**0.51**	**24**	55	30
6	**3.7**	**0.13**	**25**	60	37
6	**3.3**	**0.8**	**26**	60	33
6	**2.8**	**0.65**	**27**	60	28
6	**2.3**	**0.53**	**28**	60	23
6	**1.8**	**0.16**	**29**	60	18
6.5	**3**	**0.51**	**30**	65	30
7	**3**	**0.34**	**31**	70	30
0.5	**3**	**0**	**AE**	5	30
1	**3.3**	**0**	**AT**	10	33
1.5	**3.3**	**0**	**ABT**	15	33
2	**3.35**	**0**	**BT**	20	33.5
2.5	**3.2**	**0**	**BCT**	25	32
3	**3.4**	**0**	**CT**	30	34
3.5	**3.5**	**0**	**CDT**	35	35
4	**3.7**	**0**	**DT**	40	37
4.5	**4**	**0**	**DET**	45	40
5	**4**	**0**	**ET**	50	40
5.5	**3.9**	**0**	**EFT**	55	39
6	**3.9**	**0**	**FT**	60	39
6.5	**3.9**	**0**	**FT1**	65	39
7	**3.3**	**0**	**FT2**	70	33
7.3	**3**	**0**	**FE**	73	30
1	**2.5**	**0**	**AS**	10	25

1.5	**2.4**	**0**	**ABS**	15	24
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
2	**2.3**	**0**	**BS**	20	23
2.5	**1.7**	**0**	**BCS**	25	17
3	**1.6**	**0**	**CS**	30	16
3.5	**1.7**	**0**	**CDS**	35	17
4	**1.9**	**0**	**DS**	40	19
4.5	**1.8**	**0**	**DES**	45	18
5	**1.8**	**0**	**ES**	50	18
5.5	**1.6**	**0**	**EFS**	55	16
6	**1.6**	**0**	**FS**	60	16
6.5	**1.6**	**0**	**FS1**	65	16
7	**2.5**	**0**	**FS2**	70	25
0.6	**3.06**	**0**	**AET1**	6	30.6
0.7	**3.12**	**0**	**AET2**	7	31.2
0.8	**3.18**	**0**	**AET3**	8	31.8
0.9	**3.24**	**0**	**AET4**	9	32.4
1.1	**3.3**	**0**	**AT1**	11	33
1.2	**3.3**	**0**	**AT2**	12	33
1.3	**3.3**	**0**	**AT3**	13	33
1.4	**3.3**	**0**	**AT4**	14	33
1.6	**3.31**	**0**	**AT5**	16	33.1
1.7	**3.32**	**0**	**AT6**	17	33.2
1.8	**3.33**	**0**	**AT7**	18	33.3
1.9	**3.34**	**0**	**AT8**	19	33.4
2.1	**3.32**	**0**	**BT1**	21	33.2
2.2	**3.29**	**0**	**BT2**	22	32.9
2.3	**3.26**	**0**	**BT3**	23	32.6
2.4	**3.23**	**0**	**BT4**	24	32.3
2.6	**3.24**	**0**	**BT5**	26	32.4
2.7	**3.28**	**0**	**BT6**	27	32.8
2.8	**3.32**	**0**	**BT7**	28	33.2
2.9	**3.36**	**0**	**BT8**	29	33.6
3.1	**3.42**	**0**	**CT1**	31	34.2
3.2	**3.44**	**0**	**CT2**	32	34.4
3.3	**3.46**	**0**	**CT3**	33	34.6
3.4	**3.48**	**0**	**CT4**	34	34.8
3.6	**3.54**	**0**	**CT5**	36	35.4
3.7	**3.58**	**0**	**CT6**	37	35.8
3.8	**3.62**	**0**	**CT7**	38	36.2
3.9	**3.66**	**0**	**CT8**	39	36.6
4.1	**3.76**	**0**	**DT1**	41	37.6
4.2	**3.82**	**0**	**DT2**	42	38.2
4.3	**3.88**	**0**	**DT3**	43	38.8
4.4	**3.94**	**0**	**DT4**	44	39.4

4.6	**4**	**0**	**DT5**	46	40
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
4.7	**4**	**0**	**DT6**	47	40
4.8	**4**	**0**	**DT7**	48	40
4.9	**4**	**0**	**DT8**	49	40
5.1	**3.98**	**0**	**ET1**	51	39.8
5.2	**3.96**	**0**	**ET2**	52	39.6
5.3	**3.94**	**0**	**ET3**	53	39.4
5.4	**3.92**	**0**	**ET4**	54	39.2
5.6	**3.9**	**0**	**ET5**	56	39
5.7	**3.9**	**0**	**ET6**	57	39
5.8	**3.9**	**0**	**ET7**	58	39
5.9	**3.9**	**0**	**ET8**	59	39
6.1	**3.9**	**0**	**FT1**	61	39
6.2	**3.9**	**0**	**FT2**	62	39
6.3	**3.9**	**0**	**FT3**	63	39
6.4	**3.9**	**0**	**FT4**	64	39
6.58333	**3.8**	**0**	**FT5**	65.8333	38
6.66666	**3.7**	**0**	**FT6**	66.6666	37
6.74999	**3.6**	**0**	**FT7**	67.4999	36
6.83332	**3.5**	**0**	**FT8**	68.3332	35
6.91665	**3.4**	**0**	**FT9**	69.1665	34
7.1	**3.2**	**0**	**FT10**	71	32
7.2	**3.1**	**0**	**FT11**	72	31
0.6	**2.9**	**0**	**AES1**	6	29
0.7	**2.8**	**0**	**AES2**	7	28
0.8	**2.7**	**0**	**AES3**	8	27
0.9	**2.6**	**0**	**AES4**	9	26
1.1	**2.48**	**0**	**AS1**	11	24.8
1.2	**2.46**	**0**	**AS2**	12	24.6
1.3	**2.44**	**0**	**AS3**	13	24.4
1.4	**2.42**	**0**	**AS4**	14	24.2
1.6	**2.38**	**0**	**AS5**	16	23.8
1.7	**2.36**	**0**	**AS6**	17	23.6
1.8	**2.34**	**0**	**AS7**	18	23.4
1.9	**2.32**	**0**	**AS8**	19	23.2
2.08333	**2.2**	**0**	**BS1**	20.8333	22
2.16666	**2.1**	**0**	**BS2**	21.6666	21
2.24999	**2**	**0**	**BS3**	22.4999	20
2.33332	**1.9**	**0**	**BS4**	23.3332	19
2.41665	**1.8**	**0**	**BS5**	24.1665	18
2.6	**1.68**	**0**	**BS6**	26	16.8
2.7	**1.66**	**0**	**BS7**	27	16.6
2.8	**1.64**	**0**	**BS8**	28	16.4
2.9	**1.62**	**0**	**BS9**	29	16.2

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
3.1	1.62	0	CS1	31	16.2
3.2	1.64	0	CS2	32	16.4
3.3	1.66	0	CS3	33	16.6
3.4	1.68	0	CS4	34	16.8
3.6	1.74	0	CS5	36	17.4
3.7	1.78	0	CS6	37	17.8
3.8	1.82	0	CS7	38	18.2
3.9	1.86	0	CS8	39	18.6
4.1	1.88	0	DS1	41	18.8
4.2	1.86	0	DS2	42	18.6
4.3	1.84	0	DS3	43	18.4
4.4	1.82	0	DS4	44	18.2
4.6	1.8	0	DS5	46	18
4.7	1.8	0	DS6	47	18
4.8	1.8	0	DS7	48	18
4.9	1.8	0	DS8	49	18
5.1	1.76	0	ES1	51	17.6
5.2	1.72	0	ES2	52	17.2
5.3	1.68	0	ES3	53	16.8
5.4	1.64	0	ES4	54	16.4
5.6	1.6	0	ES5	56	16
5.7	1.6	0	ES6	57	16
5.8	1.6	0	ES7	58	16
5.9	1.6	0	ES8	59	16
6.1	1.6	0	FS1	61	16
6.2	1.6	0	FS2	62	16
6.3	1.6	0	FS3	63	16
6.4	1.6	0	FS4	64	16
6.55555	1.7	0	FS5	65.5555	17
6.6111	1.8	0	FS6	66.111	18
6.66665	1.9	0	FS7	66.6665	19
6.7222	2	0	FS8	67.222	20
6.77775	2.1	0	FS9	67.7775	21
6.8333	2.2	0	FS10	68.333	22
6.8885	2.3	0	FS11	68.885	23
6.9444	2.4	0	FS12	69.444	24
7.06	2.6	0	FS13	70.6	26
7.12	2.7	0	FS14	71.2	27
7.18	2.8	0	FS15	71.8	28
7.24	2.9	0	FS16	72.4	29

CALIBRATION CERTIFICATE

Model: 2ØØØ-21 Serial Number: 2ØØ2679

Unit Gain Ratio: ________ Time Constant: ________

Sensor Ser # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ______

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.ØØ	N/A
Measured:	Ø.ØØ	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ________

Calibration Technician: Stan Cuthski Date: 18 Apr 2006

QA Technician: [signature] Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement
4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

Discharge Measurement:
Jacob's Well Spring,
Marion County, Florida;
September 21, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Jacob’s Well Spring,
Marion County, Florida; September 21, 2006

LIST OF CONTENTS

Results of Discharge Measurements of Jacobs's Well Spring, Marion County, Florida; September 22, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Jacob's Well Spring on September 21, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Jacob's Well Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Tom Morris, both of KES. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida.

SITE DESCRIPTION

Jacob's Well Spring is located on the south side of the upper Silver River, approximately 500 feet downstream from Mammoth Spring. The spring is in a large, sandy-bottomed depression shared with Catfish Reception Hall Spring to the southeast, and is about 22 feet deep. Water discharges horizontally from a narrow 10 foot long rocky vent beneath a limestone ledge. The ledge is at the bottom of the relatively steep western wall of the depression. See Figure 1.

Since the orifice of this spring is located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

Pete Butt positioned the sensor, and recorded positional data, while Tom Morris read the velocity readings, after taking meter reset cues from Butt. During all measurements, the sensor handler completely removed himself from the cross section of the flow. The meter operator was also positioned outside the cross-section. This eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. Twenty-six station readings were taken.

Velocity measurements were taken at the same location and approximate position as those taken on March 25, 2005. The approximate depth for the measurement grid was 21 to 22 feet. Telescoping aluminum poles with 1, 0.5, 0.25 and 0.1 foot interval markings were positioned horizontally to allow for a grid of velocity measurements. As all sensor-support poles were positioned at right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was positioned on the poles with a quick release clamp. Spring vent dimensions and positions were measured with a metal tape.

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figure 2. Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Table 3. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift, an anisotropy ratio of 3 at an angle of 0°, and a variogram slope of 1.0. The results of the contour processing are illustrated in Figures 3 and 4.

During this measurement, no negative velocities were measured. However, in order to incorporate one or more negative values that have been typical in other measurements, calculations were made using a Surfer 8 “blanking file” operation to define the measurement cross-section boundary. The total discharge is shown on Table 2 as the **Net Volume (Cut-Fill)**, and has been calculated as the Positive Volume (Cut) less that portion of the Negative Volume (Fill) lying within the measurement cross-section boundary walls that define the plane of measurement.

The software also calculates the total cross-sectional area of the measurement location within the passage, and is presented on Table 2 as the **Operational Planar Area**. The Operational Planar Area is the sum of the Positive (Cut) and that portion of the Negative (Fill) Planar areas lying within the measurement cross-section boundary walls that define the plane of measurement.

RESULTS AND DISCUSSION

This measurement is the second one performed at Jacob’s Well Spring applying the method and data processing used at other spring sites by KES. This spring is referred to as “Catfish Reception Hall Spring Vent #3” for the March 25, 2005 measurement. Based on KES’ experience at other springs, the estimate of discharge for these initial measurements should be considered to be a minimum value.

The estimated discharge of Jacob's Well Spring on September 21, 2006 was 2.57 CFS (cubic feet per second). This result is also expressed as 1153 GPM (gallons per minute) or 1.661 MGD (million gallons per day), see Table 1. Twenty-six (26) readings were made, see Figures 2, 3 and 4. The point velocity readings ranged from 0.16 to 0.94 feet per second (fps), with an overall average station reading of 0.48 fps. The total cross-sectional area was calculated as 8.831 square feet. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 18:01 hours and were completed by 18:39 hours.

	UNDERWATER DISCHARGE MEASUREMENT						
	Location:	**JACOB'S WELL SPRING**			Date:	**September 21, 2006**	
		Silver Springs Group,			Time Start:	18:01	
		Marion County, Florida			Time End:	18:39	
	Personnel:	Peter Butt, Tom Morris					
	Method:	Grid within irregular conduit					
	Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles					
	Msmt. Periods:		60 seconds				
	Analysis Method: Surfer 8 with kriging						
	Jacob's Well Spring Total Discharge:						
	CFS	**2.57**					
	MGD	**1.661**					
	GPM	**1153**					
	Total Cross-sectional Area (sq/ft):		8.831				
	Avg. Station Point Velocity (ft/sec):		0.48				
	Cross-section Depth (feet deep):		21-22				
	Velocity Reading by Station:		(All velocity readings in feet per second.)				
	Station #	Point Velocity					
	1	0.22					
	2	0.4					
	3	0.55					
	4	0.69					
	5	0.16					
	6	0.94					
	7	0.89					
	8	0.21					
	9	0.53					
	10	0.29					
	11	0.45					
	12	0.58					
	13	0.76					
	14	0.89					
	15	0.5					
	16	0.57					
	17	0.51					
	18	0.22					
	19	0.42					
	20	0.44					
	21	0.36					
	22	0.48					
	23	0.65					
	24	0.4					
	25	0.17					
	26	0.16					

Table 1. Discharge of Jacob's Well Spring, Marion County, Florida on September 21, 2006. Data record and calculation of discharge measurement.

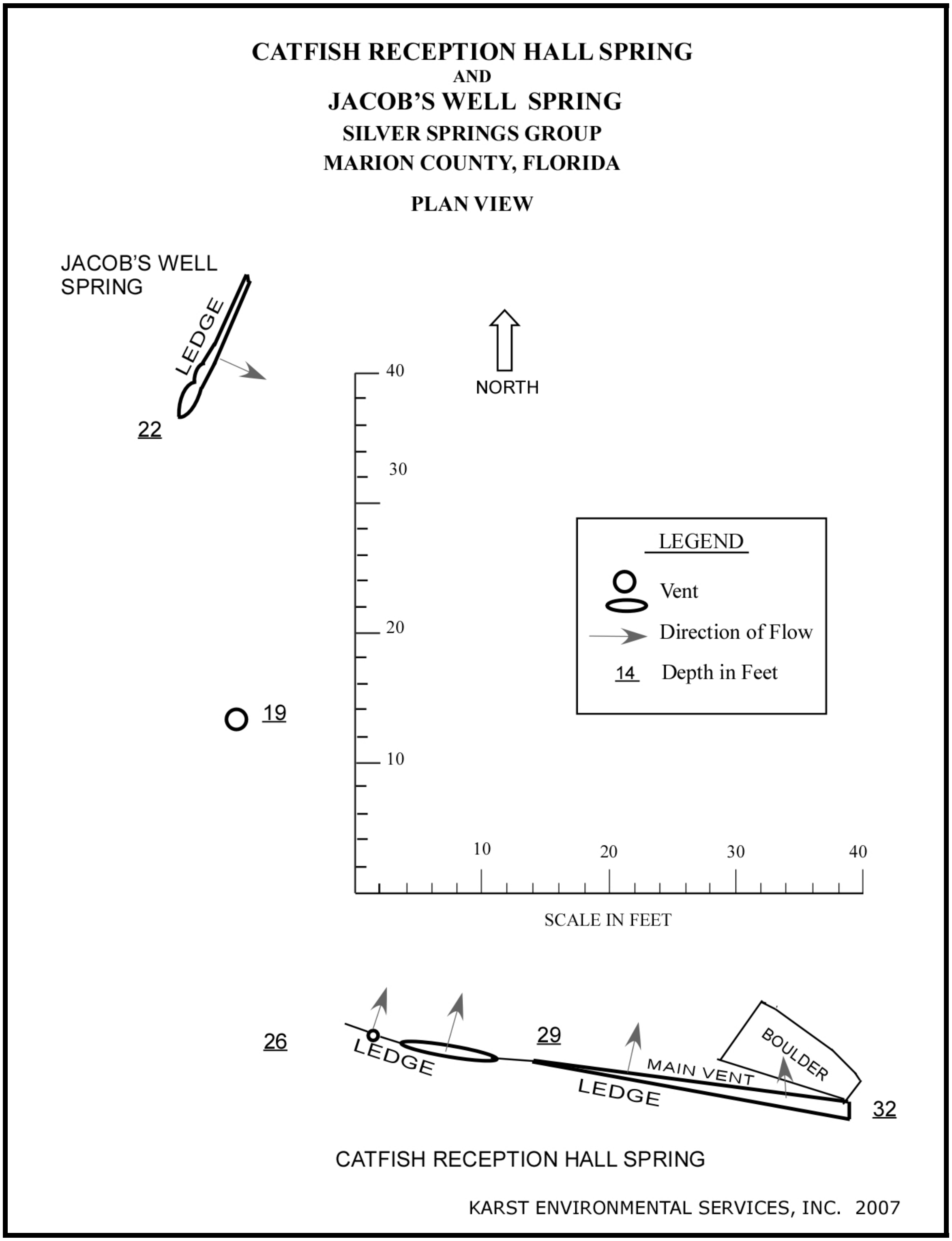

Figure 1. Map of Jacob's Well Spring.

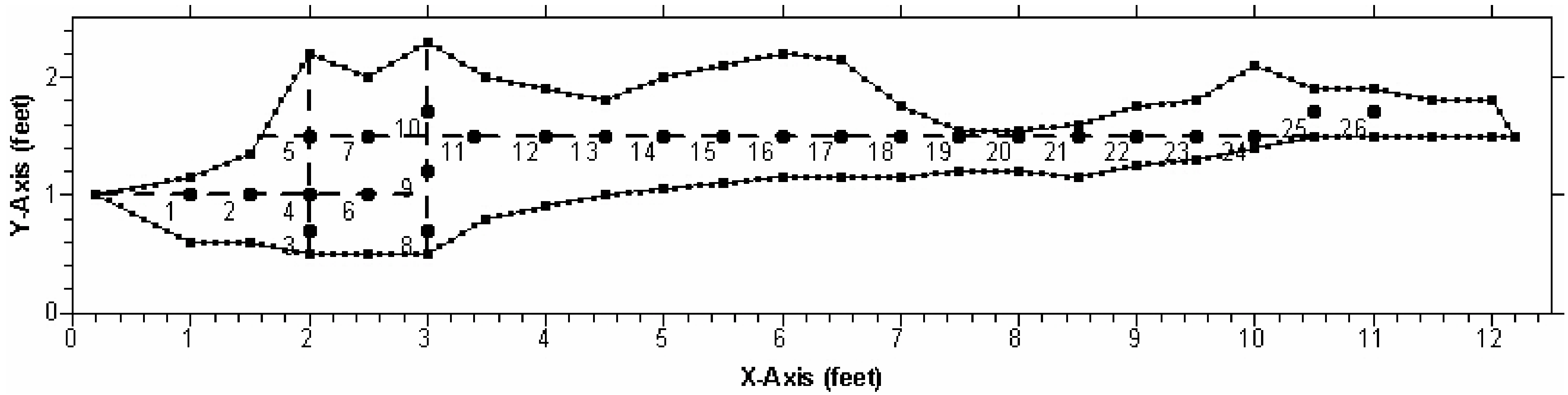

Figure 2. Discharge measurement cross-section; Jacob's Well Spring, Marion County, Florida, September 21, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 21 to 22-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

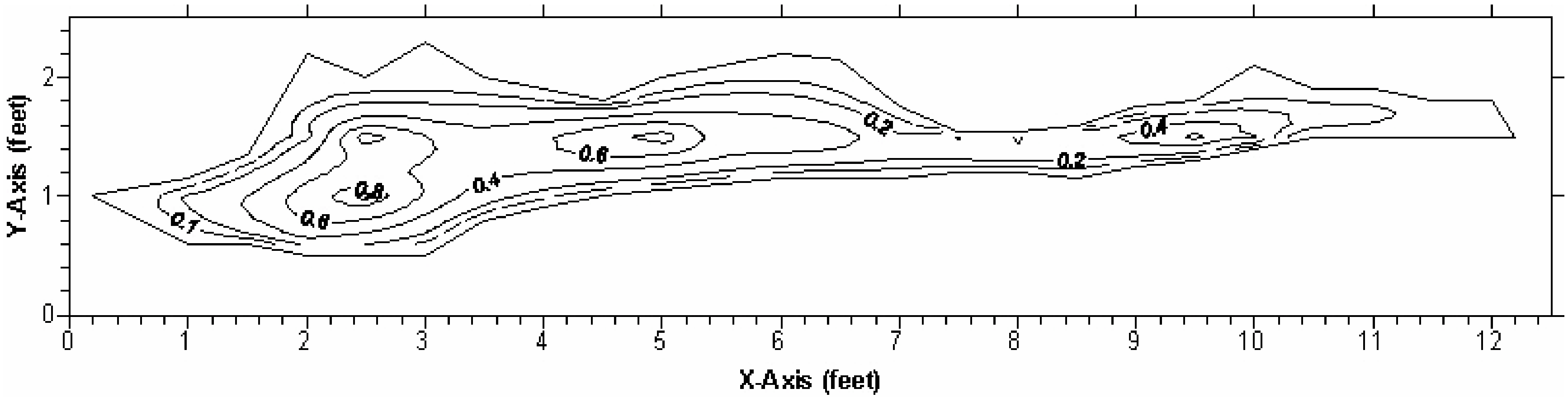

Figure 3. Discharge measurement cross-section; Jacob's Well Spring, Marion County, Florida, September 21, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

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TABLE 2. JACOB'S WELL SPRING, SEPTEMBER 21, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\JacobsWell(CRH3)\JacobsWell-0906.bln.grd
Grid Size:	26 rows x 126 columns
X Minimum:	0
X Maximum:	12.5
X Spacing:	0.1
Y Minimum:	0
Y Maximum:	2.5
Y Spacing:	0.1
Z Minimum:	-1.4926044289432E-009
Z Maximum:	0.93999999893634

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES
Z Scale Factor: 1
Total Volumes by:
Trapezoidal Rule: 2.5701866471267
Simpson's Rule: 2.5806130412344
Simpson's 3/8 Rule: 2.5656673358512

CUT & FILL VOLUMES
Positive Volume [Cut]: 2.5701866471563
Negative Volume [Fill]: 2.967538545994E-011
Net Volume [Cut-Fill]: 2.5701866471267<<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 8.831 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 7.8149999989839
Negative Planar Area [Fill]: 1.0160794168321E-009
Blanked Planar Area: 23.435
Total Planar Area: 31.25

Surface Areas
Positive Surface Area [Cut]: 12.504904628616
Negative Surface Area [Fill]: 1.1300707258449E-009

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\JacobsWell(CRH3)\Jacobs Well 9-06 SURFER XYZ T3 BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	270
Original Data:	270
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.2	0.5	0
25%-tile:	3	1.12	0
Median:	6	1.5	0
75%-tile:	9.1	1.84	0
Maximum:	12.2	2.3	0.94
Midrange:	6.2	1.4	0.47
Range:	12	1.8	0.94
Interquartile Range:	6.1	0.72	0
Median Abs. Deviation:	3	0.36	0
Mean:	6.0883446296296	1.4343518518519	0.046074074074074
Trim Mean (10%):	6.074397704918	1.4431762295082	0.015983606557377
Standard Deviation:	3.4607455343828	0.47552351394162	0.1573300201925
Variance:	11.976759653751	0.22612261231139	0.024752735253772
Coef. of Variation:			3.4147190877793
Coef. of Skewness:			3.6989557962157

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.366	-0.095
Y:		1.000	-0.047
Z:			1.000

Table 2. Jacob's Well Spring, September 21, 2006.

Inter-Variable Covariance

	X	Y	Z
X:	11.976759653751	0.60294697985254	-0.051625952565158
Y:		0.22612261231139	-0.0035234705075446
Z:			0.024752735253772

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-0.0040727798781188	-0.0047222176035993	0.077643883137253
Standard Error:	0.0029763726491654	0.021661322841594	0.031193099747327

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.366	-0.216
B:		1.000	0.783
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.061262928518198	0.030631464259099	1.2351
Residual:	267	6.6219755900003	0.024801406704121	
Total:	269	6.6832385185185		

Coefficient of Multiple Determination (R^2): 0.0091666530153675

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.1	0
Median:	0.10198039027186	0
75%-tile:	0.10770329614269	0
Maximum:	0.5	0.89

Midrange:	0.275	0.445
Range:	0.45	0.89
Interquartile Range:	0.0077032961426897	0
Median Abs. Deviation:	0.0019803902718557	0
Mean:	0.12112571262197	0.043518518518519
Trim Mean (10%):	0.10798232182241	0.016680327868852
Standard Deviation:	0.070191460296006	0.14346450596534
Variance:	0.0049268410984857	0.020582064471879
Coef. of Variation:	0.57949265087149	3.2966312009057
Coef. of Skewness:	3.9484878383673	3.6999240390784
Root Mean Square:	0.13999385471036	0.1499197316097
Mean Square:	0.019598279356667	0.022475925925926

Complete Spatial Randomness
Lambda: 12.5
Clark and Evans: 0.8564881277105
Skellam: 415.59622053685

Exclusion Filtering
Exclusion Filter String: Not In Use

Duplicate Filtering
Duplicate Points to Keep: First
X Duplicate Tolerance: 1.4E-006
Y Duplicate Tolerance: 2.1E-007
No duplicate data were found.

Breakline Filtering
Breakline Filtering: Not In Use

Gridding Rules
Gridding Method: Kriging
Kriging Type: Point

Polynomial Drift Order: 1
Kriging std. deviation grid: no

Semi-Variogram Model
Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 3
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\JacobsWell(CRH3)\JacobsWell-0906.grd
Grid Size:	26 rows x 126 columns
Total Nodes:	3276
Filled Nodes:	3276
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	12.5
X Spacing:	0.1
Y Minimum:	0
Y Maximum:	2.5
Y Spacing:	0.1

Grid Statistics

Z Minimum:	-0.50769800581695
Z 25%-tile:	-0.27272544777595
Z Median:	-0.077083669936039
Z 75%-tile:	0.015920966823845
Z Maximum:	0.93999999893634
Z Midrange:	0.21615099655969
Z Range:	1.4476980047533
Z Interquartile Range:	0.28864641459979
Z Median Abs. Deviation:	0.15469473481763
Z Mean:	-0.066143090002099
Z Trim Mean (10%):	-0.082184134719625
Z Standard Deviation:	0.27930234638628
Z Variance:	0.078009800696884
Z Coef. of Variation:	-1
Z Coef. of Skewness:	0.82775381549849
Z Root Mean Square:	0.28702736638152
Z Mean Square:	0.08238470905191

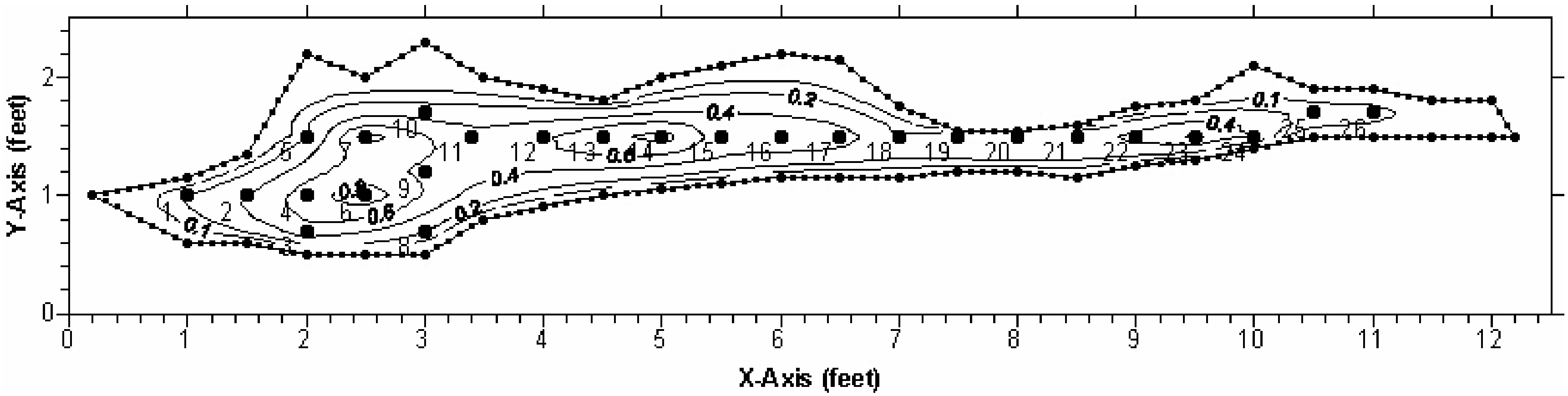

Figure 4. Discharge measurement cross-section; Jacob's Well Spring, Marion County, Florida, September 21, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. See Table 1 for station velocities. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

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Table 3. Jacob's Well Spring XYZ Grid Data, September 21, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
1	**1**	**0.22**	**1**	10	10
1.5	**1**	**0.4**	**2**	15	10
2	**0.7**	**0.55**	**3**	20	7
2	**1**	**0.69**	**4**	20	10
2	**1.5**	**0.16**	**5**	20	15
2.5	**1**	**0.94**	**6**	25	10
2.5	**1.5**	**0.89**	**7**	25	15
3	**0.7**	**0.21**	**8**	30	7
3	**1.2**	**0.53**	**9**	30	12
3	**1.7**	**0.29**	**10**	30	17
3.4	**1.5**	**0.45**	**11**	34	15
4	**1.5**	**0.58**	**12**	40	15
4.5	**1.5**	**0.76**	**13**	45	15
5	**1.5**	**0.89**	**14**	50	15
5.5	**1.5**	**0.5**	**15**	55	15
6	**1.5**	**0.57**	**16**	60	15
6.5	**1.5**	**0.51**	**17**	65	15
7	**1.5**	**0.22**	**18**	70	15
7.5	**1.5**	**0.42**	**19**	75	15
8	**1.5**	**0.44**	**20**	80	15
8.5	**1.5**	**0.36**	**21**	85	15
9	**1.5**	**0.48**	**22**	90	15
9.5	**1.5**	**0.65**	**23**	95	15
10	**1.5**	**0.4**	**24**	100	15
10.5	**1.7**	**0.17**	**25**	105	17
11	**1.7**	**0.16**	**26**	110	17
0.2	**1**	**0**	**A**	2	10
1	**1.15**	**0**	**BT**	10	11.5
1.5	**1.35**	**0**	**CT**	15	13.5
2	**2.2**	**0**	**DT**	20	22
2.5	**2**	**0**	**ET**	25	20
3	**2.3**	**0**	**FT**	30	23
3.5	**2**	**0**	**GT**	35	20
4	**1.9**	**0**	**HT**	40	19
4.5	**1.8**	**0**	**IT**	45	18
5	**2**	**0**	**JT**	50	20
5.5	**2.1**	**0**	**KT**	55	21
6	**2.2**	**0**	**LT**	60	22
6.5	**2.15**	**0**	**MT**	65	21.5
7	**1.75**	**0**	**NT**	70	17.5
7.5	**1.55**	**0**	**OT**	75	15.5
8	**1.55**	**0**	**PT**	80	15.5
8.5	**1.6**	**0**	**QT**	85	16
9	**1.75**	**0**	**RT**	90	17.5
9.5	**1.8**	**0**	**ST**	95	18
10	**2.1**	**0**	**TT**	100	21

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
10.5	1.9	0	UT	105	19
11	1.9	0	VT	110	19
11.5	1.8	0	WT	115	18
12	1.8	0	XT	120	18
12.2	1.5	0	Y	122	15
1	0.6	0	BS	10	6
1.5	0.6	0	CS	15	6
2	0.5	0	DS	20	5
2.5	0.5	0	ES	25	5
3	0.5	0	FS	30	5
3.5	0.8	0	GS	35	8
4	0.9	0	HS	40	9
4.5	1	0	IS	45	10
5	1.05	0	JS	50	10.5
5.5	1.1	0	KS	55	11
6	1.15	0	LS	60	11.5
6.5	1.15	0	MS	65	11.5
7	1.15	0	NS	70	11.5
7.5	1.2	0	OS	75	12
8	1.2	0	PS	80	12
8.5	1.15	0	QS	85	11.5
9	1.25	0	RS	90	12.5
9.5	1.3	0	SS	95	13
10	1.4	0	TS	100	14
10.5	1.5	0	US	105	15
11	1.5	0	VS	110	15
11.5	1.5	0	WS	115	15
12	1.5	0	XS	120	15
0.3	1.01875	0	AT1	3	10.1875
0.4	1.0375	0	AT2	4	10.375
0.5	1.05625	0	AT3	5	10.5625
0.6	1.075	0	AT4	6	10.75
0.7	1.09375	0	AT5	7	10.9375
0.8	1.1125	0	AT6	8	11.125
0.9	1.13125	0	AT7	9	11.3125
1.1	1.19	0	BT1	11	11.9
1.2	1.23	0	BT2	12	12.3
1.3	1.27	0	BT3	13	12.7
1.4	1.31	0	BT4	14	13.1
1.58826	1.5	0	CT1	15.8826	15
1.64708	1.6	0	CT2	16.4708	16
1.7059	1.7	0	CT3	17.059	17
1.76472	1.8	0	CT4	17.6472	18
1.82354	1.9	0	CT5	18.2354	19
1.88236	2	0	CT6	18.8236	20

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
1.94118	**2.1**	**0**	**CT7**	19.4118	21
2.1	**2.16**	**0**	**DT1**	21	21.6
2.2	**2.12**	**0**	**DT2**	22	21.2
2.3	**2.08**	**0**	**DT3**	23	20.8
2.4	**2.04**	**0**	**DT4**	24	20.4
2.6	**2.06**	**0**	**ET1**	26	20.6
2.7	**2.12**	**0**	**ET2**	27	21.2
2.8	**2.18**	**0**	**ET3**	28	21.8
2.9	**2.24**	**0**	**ET4**	29	22.4
3.1	**2.24**	**0**	**FT1**	31	22.4
3.2	**2.18**	**0**	**FT2**	32	21.8
3.3	**2.12**	**0**	**FT3**	33	21.2
3.4	**2.06**	**0**	**FT4**	34	20.6
3.6	**1.98**	**0**	**GT1**	36	19.8
3.7	**1.96**	**0**	**GT2**	37	19.6
3.8	**1.94**	**0**	**GT3**	38	19.4
3.9	**1.92**	**0**	**GT4**	39	19.2
4.1	**1.88**	**0**	**HT1**	41	18.8
4.2	**1.86**	**0**	**HT2**	42	18.6
4.3	**1.84**	**0**	**HT3**	43	18.4
4.4	**1.82**	**0**	**HT4**	44	18.2
4.6	**1.84**	**0**	**IT1**	46	18.4
4.7	**1.88**	**0**	**IT2**	47	18.8
4.8	**1.92**	**0**	**IT3**	48	19.2
4.9	**1.96**	**0**	**IT4**	49	19.6
5.1	**2.02**	**0**	**JT1**	51	20.2
5.2	**2.04**	**0**	**JT2**	52	20.4
5.3	**2.06**	**0**	**JT3**	53	20.6
5.4	**2.08**	**0**	**JT4**	54	20.8
5.6	**2.12**	**0**	**KT1**	56	21.2
5.7	**2.14**	**0**	**KT2**	57	21.4
5.8	**2.16**	**0**	**KT3**	58	21.6
5.9	**2.18**	**0**	**KT4**	59	21.8
6.1	**2.19**	**0**	**LT1**	61	21.9
6.2	**2.18**	**0**	**LT2**	62	21.8
6.3	**2.17**	**0**	**LT3**	63	21.7
6.4	**2.16**	**0**	**LT4**	64	21.6
6.6	**2.07**	**0**	**MT1**	66	20.7
6.7	**1.99**	**0**	**MT2**	67	19.9

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
6.8	**1.91**	**0**	**MT3**	68	19.1
6.9	**1.83**	**0**	**MT4**	69	18.3
7.1	**1.71**	**0**	**NT1**	71	17.1
7.2	**1.67**	**0**	**NT2**	72	16.7
7.3	**1.63**	**0**	**NT3**	73	16.3
7.4	**1.59**	**0**	**NT4**	74	15.9
7.6	**1.55**	**0**	**OT1**	76	15.5
7.7	**1.55**	**0**	**OT2**	77	15.5
7.8	**1.55**	**0**	**OT3**	78	15.5
7.9	**1.55**	**0**	**OT4**	79	15.5
8.1	**1.56**	**0**	**PT1**	81	15.6
8.2	**1.57**	**0**	**PT2**	82	15.7
8.3	**1.58**	**0**	**PT3**	83	15.8
8.4	**1.59**	**0**	**PT4**	84	15.9
8.6	**1.63**	**0**	**QT1**	86	16.3
8.7	**1.66**	**0**	**QT2**	87	16.6
8.8	**1.69**	**0**	**QT3**	88	16.9
8.9	**1.72**	**0**	**QT4**	89	17.2
9.1	**1.76**	**0**	**RT1**	91	17.6
9.2	**1.77**	**0**	**RT2**	92	17.7
9.3	**1.78**	**0**	**RT3**	93	17.8
9.4	**1.79**	**0**	**RT4**	94	17.9
9.6	**1.86**	**0**	**ST1**	96	18.6
9.7	**1.92**	**0**	**ST2**	97	19.2
9.8	**1.98**	**0**	**ST3**	98	19.8
9.9	**2.04**	**0**	**ST4**	99	20.4
10.1	**2.06**	**0**	**TT1**	101	20.6
10.2	**2.02**	**0**	**TT2**	102	20.2
10.3	**1.98**	**0**	**TT3**	103	19.8
10.4	**1.94**	**0**	**TT4**	104	19.4
10.6	**1.9**	**0**	**UT1**	106	19
10.7	**1.9**	**0**	**UT2**	107	19
10.8	**1.9**	**0**	**UT3**	108	19
10.9	**1.9**	**0**	**UT4**	109	19
11.1	**1.88**	**0**	**VT1**	111	18.8
11.2	**1.86**	**0**	**VT2**	112	18.6
11.3	**1.84**	**0**	**VT3**	113	18.4
11.4	**1.82**	**0**	**VT4**	114	18.2
11.6	**1.8**	**0**	**WT1**	116	18

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
11.7	**1.8**	**0**	**WT2**	117	18
11.8	**1.8**	**0**	**WT3**	118	18
11.9	**1.8**	**0**	**WT4**	119	18
12.0667	**1.7**	**0**	**XT1**	120.6667	17
12.1333	**1.6**	**0**	**XT2**	121.3334	16
0.3	**0.95**	**0**	**AS1**	3	9.5
0.4	**0.9**	**0**	**AS2**	4	9
0.5	**0.85**	**0**	**AS3**	5	8.5
0.6	**0.8**	**0**	**AS4**	6	8
0.7	**0.75**	**0**	**AS5**	7	7.5
0.8	**0.7**	**0**	**AS6**	8	7
0.9	**0.65**	**0**	**AS7**	9	6.5
1.1	**0.6**	**0**	**BS1**	11	6
1.2	**0.6**	**0**	**BS2**	12	6
1.3	**0.6**	**0**	**BS3**	13	6
1.4	**0.6**	**0**	**BS4**	14	6
1.6	**0.58**	**0**	**CS1**	16	5.8
1.7	**0.56**	**0**	**CS2**	17	5.6
1.8	**0.54**	**0**	**CS3**	18	5.4
1.9	**0.52**	**0**	**CS4**	19	5.2
2.1	**0.5**	**0**	**DS1**	21	5
2.2	**0.5**	**0**	**DS2**	22	5
2.3	**0.5**	**0**	**DS3**	23	5
2.4	**0.5**	**0**	**DS4**	24	5
2.6	**0.5**	**0**	**ES1**	26	5
2.7	**0.5**	**0**	**ES2**	27	5
2.8	**0.5**	**0**	**ES3**	28	5
2.9	**0.5**	**0**	**ES4**	29	5
3.1	**0.56**	**0**	**FS1**	31	5.6
3.2	**0.62**	**0**	**FS2**	32	6.2
3.3	**0.68**	**0**	**FS3**	33	6.8
3.4	**0.74**	**0**	**FS4**	34	7.4
3.6	**0.82**	**0**	**GS1**	36	8.2
3.7	**0.84**	**0**	**GS2**	37	8.4
3.8	**0.86**	**0**	**GS3**	38	8.6
3.9	**0.88**	**0**	**GS4**	39	8.8
4.1	**0.92**	**0**	**HS1**	41	9.2
4.2	**0.94**	**0**	**HS2**	42	9.4
4.3	**0.96**	**0**	**HS3**	43	9.6
4.4	**0.98**	**0**	**HS4**	44	9.8

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
4.6	**1.01**	**0**	**IS1**	46	10.1
4.7	**1.02**	**0**	**IS2**	47	10.2
4.8	**1.03**	**0**	**IS3**	48	10.3
4.9	**1.04**	**0**	**IS4**	49	10.4
5.1	**1.06**	**0**	**JS1**	51	10.6
5.2	**1.07**	**0**	**JS2**	52	10.7
5.3	**1.08**	**0**	**JS3**	53	10.8
5.4	**1.09**	**0**	**JS4**	54	10.9
5.6	**1.11**	**0**	**KS1**	56	11.1
5.7	**1.12**	**0**	**KS2**	57	11.2
5.8	**1.13**	**0**	**KS3**	58	11.3
5.9	**1.14**	**0**	**KS4**	59	11.4
6.1	**1.15**	**0**	**LS1**	61	11.5
6.2	**1.15**	**0**	**LS2**	62	11.5
6.3	**1.15**	**0**	**LS3**	63	11.5
6.4	**1.15**	**0**	**LS4**	64	11.5
6.6	**1.15**	**0**	**MS1**	66	11.5
6.7	**1.15**	**0**	**MS2**	67	11.5
6.8	**1.15**	**0**	**MS3**	68	11.5
6.9	**1.15**	**0**	**MS4**	69	11.5
7.1	**1.16**	**0**	**NS1**	71	11.6
7.2	**1.17**	**0**	**NS2**	72	11.7
7.3	**1.18**	**0**	**NS3**	73	11.8
7.4	**1.19**	**0**	**NS4**	74	11.9
7.6	**1.2**	**0**	**OS1**	76	12
7.7	**1.2**	**0**	**OS2**	77	12
7.8	**1.2**	**0**	**OS3**	78	12
7.9	**1.2**	**0**	**OS4**	79	12
8.1	**1.19**	**0**	**PS1**	81	11.9
8.2	**1.18**	**0**	**PS2**	82	11.8
8.3	**1.17**	**0**	**PS3**	83	11.7
8.4	**1.16**	**0**	**PS4**	84	11.6
8.6	**1.17**	**0**	**QS1**	86	11.7
8.7	**1.19**	**0**	**QS2**	87	11.9
8.8	**1.21**	**0**	**QS3**	88	12.1
8.9	**1.23**	**0**	**QS4**	89	12.3
9.1	**1.26**	**0**	**RS1**	91	12.6
9.2	**1.27**	**0**	**RS2**	92	12.7
9.3	**1.28**	**0**	**RS3**	93	12.8

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
9.4	**1.29**	**0**	**RS4**	94	12.9
9.6	**1.32**	**0**	**SS1**	96	13.2
9.7	**1.34**	**0**	**SS2**	97	13.4
9.8	**1.36**	**0**	**SS3**	98	13.6
9.9	**1.38**	**0**	**SS4**	99	13.8
10.1	**1.42**	**0**	**TS1**	101	14.2
10.2	**1.44**	**0**	**TS2**	102	14.4
10.3	**1.46**	**0**	**TS3**	103	14.6
10.4	**1.48**	**0**	**TS4**	104	14.8
10.6	**1.5**	**0**	**US1**	106	15
10.7	**1.5**	**0**	**US2**	107	15
10.8	**1.5**	**0**	**US3**	108	15
10.9	**1.5**	**0**	**US4**	109	15
11.1	**1.5**	**0**	**VS1**	111	15
11.2	**1.5**	**0**	**VS2**	112	15
11.3	**1.5**	**0**	**VS3**	113	15
11.4	**1.5**	**0**	**VS4**	114	15
11.6	**1.5**	**0**	**WS1**	116	15
11.7	**1.5**	**0**	**WS2**	117	15
11.8	**1.5**	**0**	**WS3**	118	15
11.9	**1.5**	**0**	**WS4**	119	15
12.1	**1.5**	**0**	**XS1**	121	15

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ______ Time Constant: ______

SensorSer # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ______

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ______

Calibration Technician: [signature] Date: 18 Apr 2006

QA Technician: [signature] Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

P/N 101001 301

Discharge Measurement:
Ladies Parlor Spring,
Marion County, Florida;
September 22, 2006

Prepared for:

St. Johns River Water Management District

4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.

5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Ladies Parlor Spring, Marion County, Florida; September 22, 2006

LIST OF CONTENTS

Results of Discharge Measurements of Ladies Parlor Spring, Marion County, Florida; September 22, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Ladies Parlor Spring on September 22, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Ladies Parlor Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida.

SITE DESCRIPTION

Ladies Parlor Spring is located in the south side of a cove on the south side of the Silver River, approximately 60 feet southeast of Bridal Chamber Spring. Water discharges from a long vent beneath a ledge on the bottom of the southwest side of a large depression. The long vent is composed of two sections, one about 14 feet long (the South Vent), separated by about 5 feet of rock from the narrower vent that is about five feet wide (the North Vent). There is a strong flow moving the sand and shell fragments as water exits the vent. South of the long vent and also along the ledge are several very small vents (Misc. Vents), mostly obscured by algae. See Figure 1.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

Pete Butt positioned the sensor, and recorded positional data, while Tom Morris read the velocity readings, after taking meter reset cues from Butt. During all measurements, the sensor handler completely removed himself from the cross section of the flow. The meter operator was also positioned outside the cross-section. This eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. Fifty-eight (58) station readings were taken.

The approximate depth for the measurement grids was 20 to 22 and 21 feet. Telescoping aluminum poles with 1, 0.5, 0.25 and 0.1 foot interval markings were positioned horizontally to allow for a grid of velocity measurements. As all sensor-support poles were positioned at right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was positioned on the poles with a quick release clamp. Spring vent dimensions and positions were measured with a metal tape. Two hand-held readings were made in two small vents,

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figures 2(AB). Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Tables 3A and 3B. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift. An anisotropy ratio of 1 at an angle of 0°, and a variogram slope of 1.0 was used for the North Vent calculation. An anisotropy ratio of 3 at an angle of 0°, and a variogram slope of 1.0 was used for the South Vent calculation. The results of the contour processing are illustrated in Figures 3(AB) and 4(AB).

During this measurement, four negative velocities were measured in the North Vent. Negative velocity stations typically represent slight back eddies near walls. In order to incorporate any negative values, calculations were made using a Surfer 8 “blanking file” operation to define the measurement cross-section boundary. The total discharge is shown on Tables 2A and 2B as the **Net Volume (Cut-Fill)**, and has been calculated as the Positive Volume (Cut) less that portion of the Negative Volume (Fill) lying within the measurement cross-section boundary walls that define the plane of measurement.

The software also calculates the total cross-sectional area of the measurement location within the passage, and is presented on Tables 2A and 2B as the **Operational Planar Area**. The Operational Planar Area is the sum of the Positive (Cut) and that portion of the Negative (Fill) Planar areas lying within the measurement cross-section boundary walls that define the plane of measurement.

RESULTS AND DISCUSSION

This measurement is the first one performed at Ladies Parlor Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated total discharge of Ladies Parlor Spring (all vents) on September 22, 2006 was 9.56 CFS (cubic feet per second). This result is also expressed as 4292 GPM (gallons per minute) or 6.18 MGD (million gallons per day), see Table 1. A total of fifty-eight (58) readings were made, see Figures 2(AB), 3(AB) and 4(AB). The total cross-sectional area was calculated as 13.7 square feet. The point velocity readings ranged from -0.16 to 1.54 feet per second (fps), with an overall average station reading of 0.89 fps. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 14:32 hours and were completed by 16:03 hours. The results for each of the individual vents are detailed below.

The estimated discharge of Ladies Parlor Spring North Vent on September 22, 2006 was 3.079 CFS. This result is also expressed as 1382 GPM or 1.99 MGD, see Table 1. Twenty-three (23) readings were made, see Figures 2A, 3A and 4A. The total cross-sectional area was calculated as 6.055 square feet. The point velocity readings ranged from -0.16 to 1.41 feet per second (fps), with an overall average station reading of 0.60 fps.

The estimated discharge of Ladies Parlor Spring South Vent on September 22, 2006 was 6.09 CFS. This result is also expressed as 2733 GPM or 3.936 MGD, see Table 1. Thirty-three (33) readings were made, see Figures 2B, 3B and 4B. The total cross-sectional area was calculated as 7.64 square feet. The point velocity readings ranged from 0.04 to 1.54 feet per second (fps), with an overall average station reading of 0.94 fps.

The estimated discharge of Ladies Parlor Spring Miscellaneous Vents on September 22, 2006 was 0.3927 CFS. This result is also expressed as 176 GPM or 0.254 MGD, see Table 1. Two (2) readings were made, see Table 1. The total cross-sectional areas were calculated as 0.09 and 0.25 square feet. The point velocity readings were 1.03 and 1.2 feet per second (fps).

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**LADIES PARLOR SPRING**		Date:	**September 22, 2006**	
	Silver Springs Group,		Time Start:	14:32	
	Marion County, Florida		Time End:	16:03	
Personnel:	Peter Butt, Tom Morris				
Method:	Grid within irregular conduit				
Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles				
Msmt. Periods:	60 seconds				
Analysis Method: Surfer 8 with kriging					
Ladies Parlor Spring Total Discharge:			**North Vent:**	**South Vent:**	**Misc. Vents:**
CFS	**9.56**		**3.079**	**6.09**	**0.3927**
MGD	**6.180**		**1.990**	**3.936**	**0.254**
GPM	**4292**	All Vents:	**1382**	**2733**	**176**
Total Cross-sectional Area (sq/ft):		13.70	6.055	7.64	0.34
Avg. Station Point Velocity (ft/sec):		0.89	0.60	0.94	1.12
Cross-Section Depth (Depth in feet):			20-22	21	21
Velocity Reading by Station:		(All velocity readings in feet per second.)			
Station #	Point Velocity	Station #	Point Velocity		
NORTH VENT		**SOUTH VENT**		**SOUTH VENT (cont'd)**	
1	-0.16	1	0.81	24	0.94
2	0.13	2	0.84	25	1.19
3	1.08	3	1.05	26	0.04
4	1.25	4	0.24	27	0.62
5	0.13	5	0.42	28	1.31
6	1.25	6	0.61	29	0.68
7	1.41	7	0.56	30	1.4
8	-0.06	8	0.46	31	1.51
9	-0.03	9	0.89	32	1.44
10	0.32	10	0.99	33	1.03
11	1.39	11	0.68		
12	0.64	12	1.2	Station #	Point Velocity
13	0.07	13	1.11	**MISC. VENTS**	
14	1.11	14	1.51	34	1.03
15	0.55	15	0.08	35	1.2
16	0.19	16	1.23		
17	1.11	17	1.54		
18	0.84	18	1.44		
19	0.59	19	1.52		
20	-0.02	20	0.59		
21	1.01	21	1.11		
22	0.77	22	1.49		
23	0.27	23	1.31		
Misc. Vents Handheld Readings					
Station #	**Point Velocity**	**X-Sec Area**	**Discharge:**		
		(in Sq. Ft.)			
34	1.03	0.09	**0.0927**		
35	1.2	0.25	**0.3**		
Misc. Vents Total:	1.115	0.34	**0.3927**		

Table 1. Discharge of Ladies Parlor Spring, Marion County, Florida on September 22, 2006. Data record and calculation of discharge measurement.

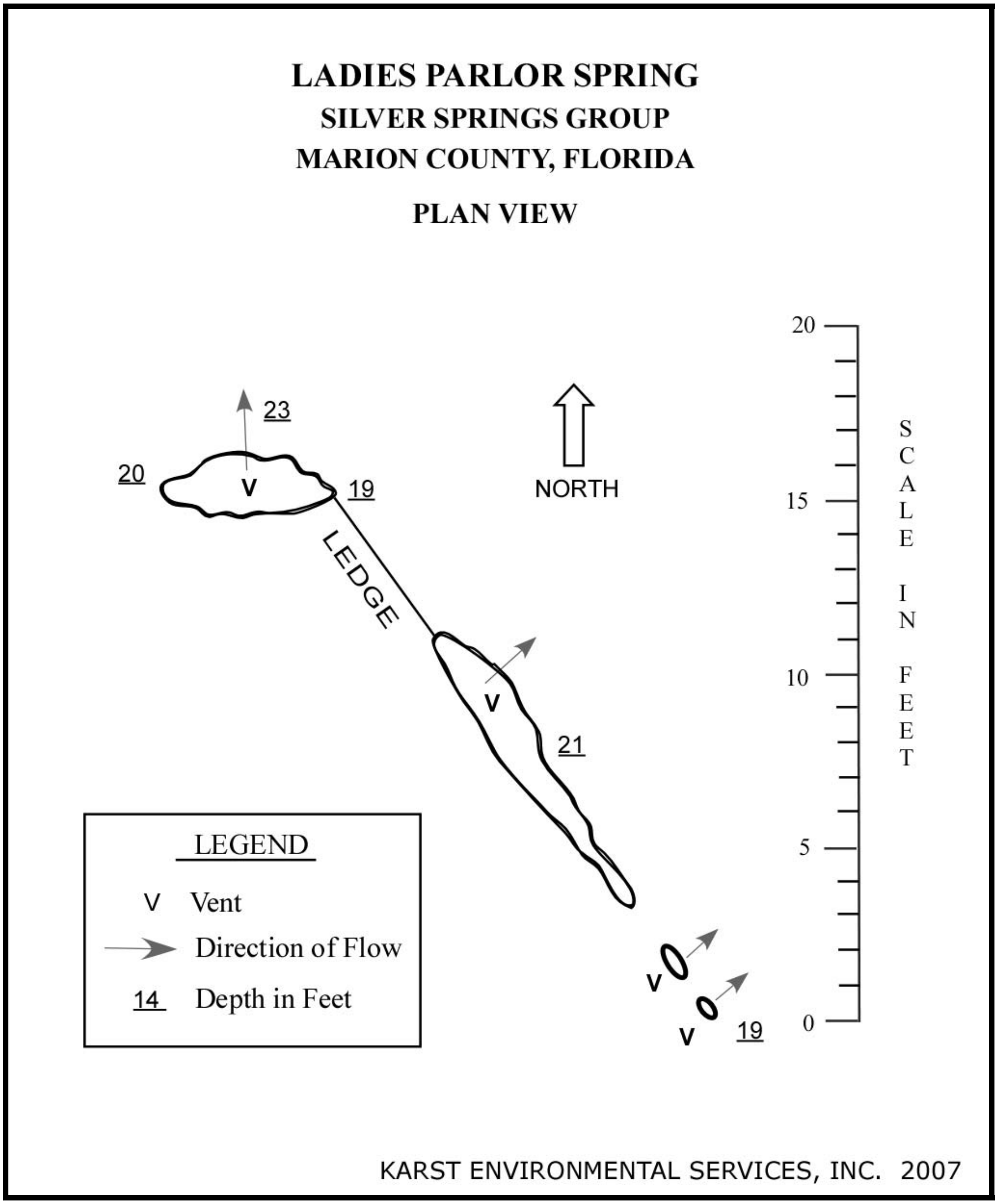

Figure 1. Map of Ladies Parlor Spring.

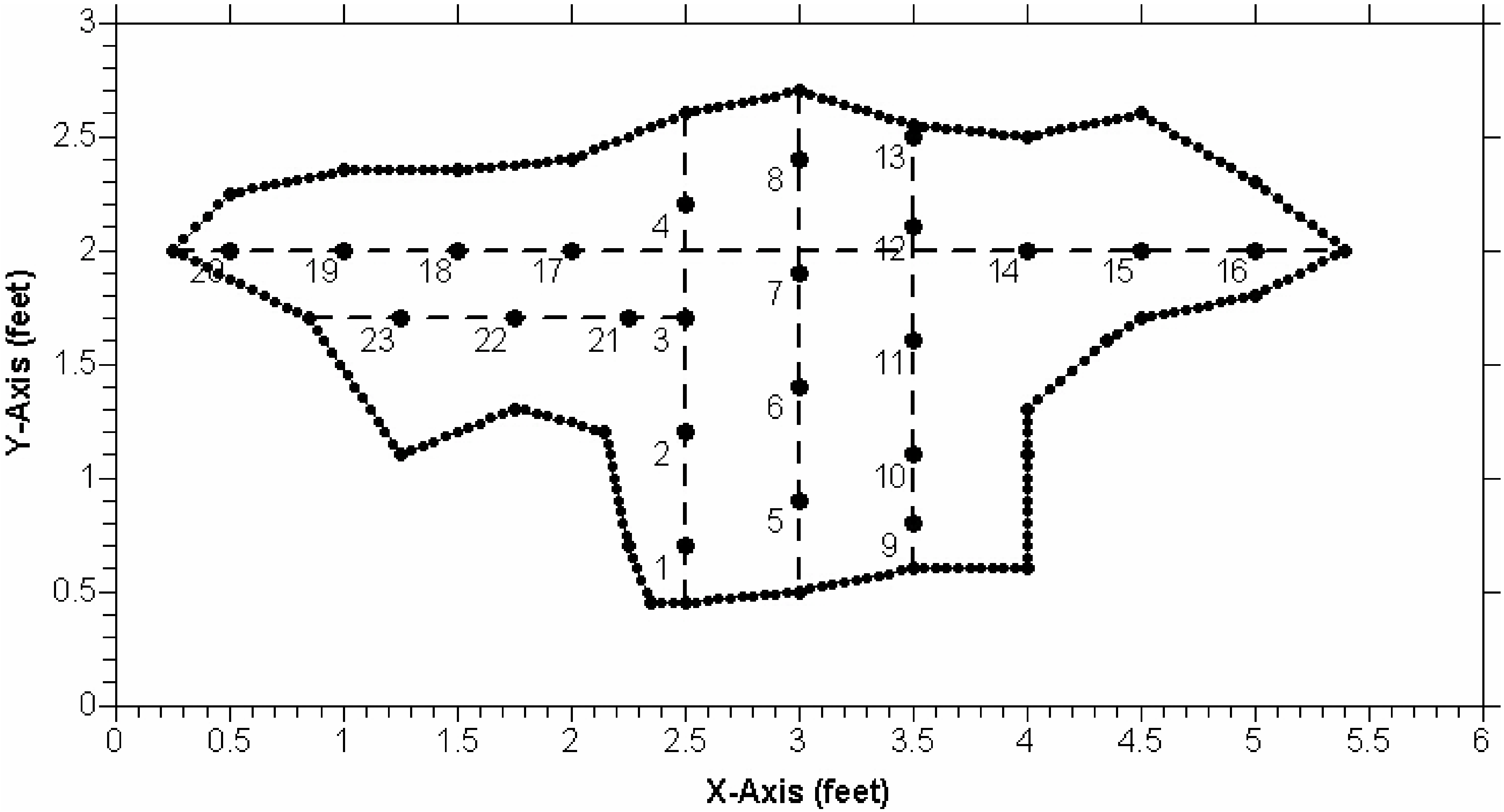

Figure 2A. Discharge measurement cross-section; Ladies Parlor Spring North Vent, Marion County, Florida, September 22, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 20 to 22-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

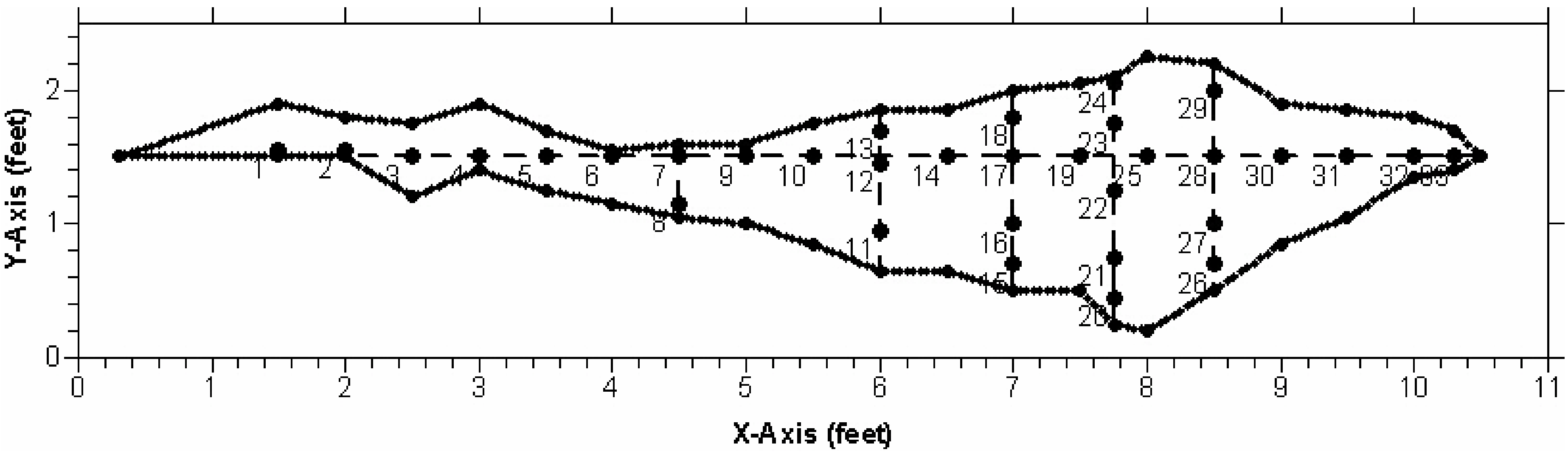

Figure 2B. Discharge measurement cross-section; Ladies Parlor Spring South Vent, Marion County, Florida, September 22, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 21-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

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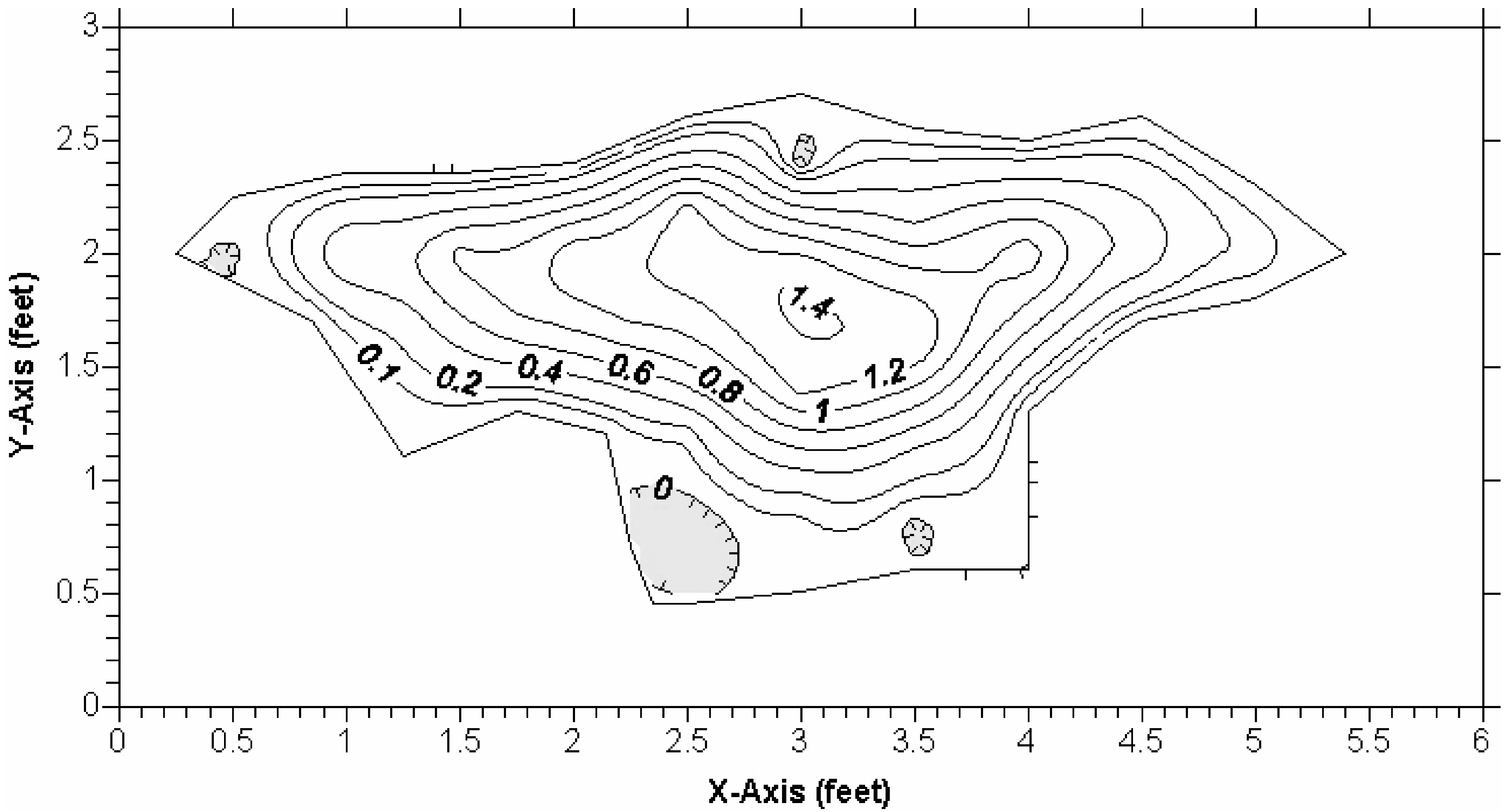

Figure 3A. Discharge measurement cross-section; Ladies Parlor Spring North Vent, Marion County, Florida, September 22, 2006 measurement. Flow contour velocities are shown in feet per second. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

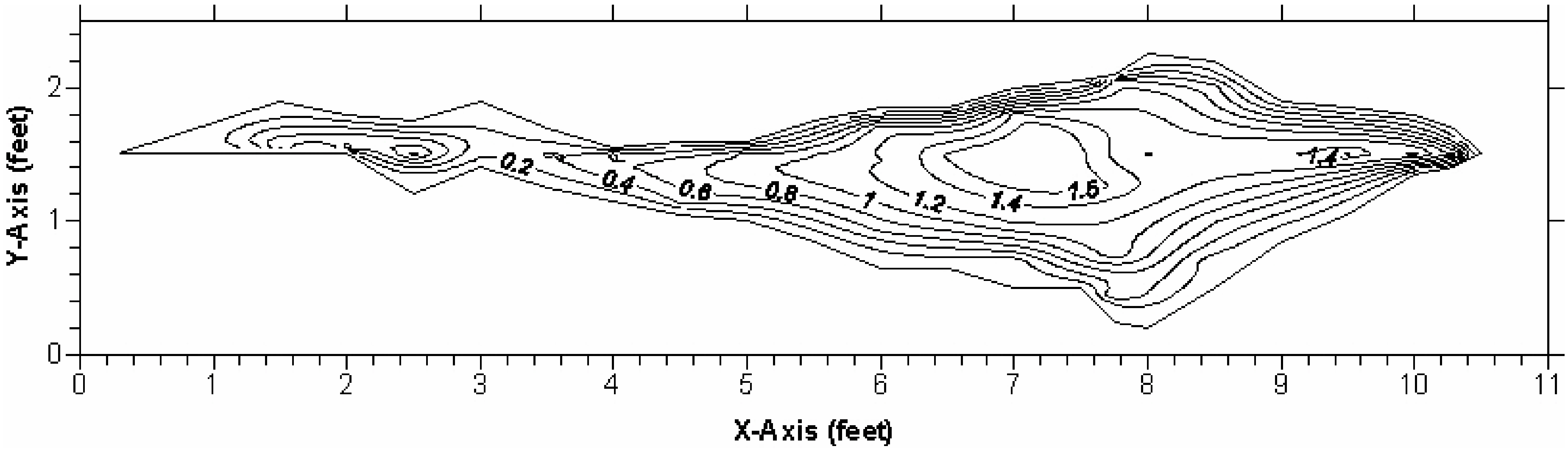

Figure 3B. Discharge measurement cross-section; Ladies Parlor Spring South Vent, Marion County, Florida, September 22, 2006 measurement. Flow contour velocities are shown in feet per second. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

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TABLE 2A. LADIES PARLOR SPRING, NORTH VENT, SEPTEMBER 22, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE
Grid File Name: Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\LadiesNorth\LadiesParlorNorth9-06.bln.grd
Grid Size: 61 rows x 121 columns
X Minimum: 0
X Maximum: 6
X Spacing: 0.05
Y Minimum: 0
Y Maximum: 3
Y Spacing: 0.05
Z Minimum: -0.16000000030727
Z Maximum: 1.4281510419231

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES
Z Scale Factor: 1
Total Volumes by:
Trapezoidal Rule: 3.0785561564418
Simpson's Rule: 3.0783625424388
Simpson's 3/8 Rule: 3.0787120169365

CUT & FILL VOLUMES
Positive Volume [Cut]: 3.0859348616188
Negative Volume [Fill]: 0.0073787051769583
Net Volume [Cut-Fill]: 3.0785561564418<<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 6.055 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 5.8402980261255
Negative Planar Area [Fill]: 0.2147019738745
Blanked Planar Area: 11.945
Total Planar Area: 18

Surface Areas
Positive Surface Area [Cut]: 10.935003351861
Negative Surface Area [Fill]: 0.25096376781654

GRIDDING REPORT

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\LadiesNorth\Ladies Parlor North 9-06 SURFER XYZ T3A BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	256
Original Data:	256
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.25	0.45	-0.16
25%-tile:	1.65	1.15	0
Median:	2.85	1.825	0
75%-tile:	4	2.375	0
Maximum:	5.4	2.7	1.41
Midrange:	2.825	1.575	0.625
Range:	5.15	2.25	1.57
Interquartile Range:	2.35	1.225	0
Median Abs. Deviation:	1.15	0.610715	0
Mean:	2.8257816796875	1.715976640625	0.0540625
Trim Mean (10%):	2.8260780603448	1.7316380172414	0.0071551724137931
Standard Deviation:	1.4192381972877	0.72692885131078	0.23037821314905
Variance:	2.0142370606403	0.52842555486801	0.05307412109375
Coef. of Variation:			4.2613311102715
Coef. of Skewness:			4.4467973116959

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.003	-0.011
Y:		1.000	0.037
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	2.0142370606403	0.0027913287673614	-0.0035989001831054
Y:		0.52842555486801	0.0061675128662109
Z:			0.05307412109375

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-0.0018029187327191	0.011681012298273	0.039112810482194
Standard Error:	0.010197786200439	0.019909909583777	0.046923209622549

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.003	-0.612
B:		1.000	0.726
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.020104017458502	0.010052008729251	0.18745
Residual:	253	13.566870982541	0.053623995978425	
Total:	255	13.586975		

Coefficient of Multiple Determination (R^2): 0.0014796536726167

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.050249378105604	0
Median:	0.050990195135928	0
75%-tile:	0.055901699437495	0
Maximum:	0.5	1.47

Midrange:	0.275	0.735
Range:	0.45	1.47
Interquartile Range:	0.0056523213318911	0
Median Abs. Deviation:	0.00099019513592803	0
Mean:	0.077796607650957	0.0402734375
Trim Mean (10%):	0.061815878669274	0.0047413793103448
Standard Deviation:	0.085436795378833	0.18199502975887
Variance:	0.0072994460046046	0.033122190856934
Coef. of Variation:	1.0982072092675	4.5189842500749
Coef. of Skewness:	3.5615461085497	5.5420214711515
Root Mean Square:	0.11554980816341	0.18639780209273
Mean Square:	0.013351758166602	0.034744140625

Complete Spatial Randomness

Lambda: 22.092772384035
Clark and Evans: 0.73133400028201
Skellam: 474.4697285736

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 6.1E-007
Y Duplicate Tolerance: 2.6E-007
No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point
Polynomial Drift Order: 2
Kriging std. deviation grid: no

Semi-Variogram Model

Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 1
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\LadiesNorth\LadiesParlorNorth9-06.grd
Grid Size:	61 rows x 121 columns
Total Nodes:	7381
Filled Nodes:	7381
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	6
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	3
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-1.7690810013035
Z 25%-tile:	-0.45930599807493
Z Median:	-0.1388425652188
Z 75%-tile:	0.11831861372189
Z Maximum:	1.4281510419231
Z Midrange:	-0.17046497969022
Z Range:	3.1972320432266
Z Interquartile Range:	0.57762461179681
Z Median Abs. Deviation:	0.29406549179321
Z Mean:	-0.10801586070138
Z Trim Mean (10%):	-0.12286034254903
Z Standard Deviation:	0.56557176502299
Z Variance:	0.31987142139122
Z Coef. of Variation:	-1
Z Coef. of Skewness:	0.47314027808224
Z Root Mean Square:	0.57579410170153
Z Mean Square:	0.33153884755427

TABLE 2B. LADIES PARLOR SPRING, SOUTH VENT, SEPTEMBER 22, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\LadiesSouth\LadiesParlorSouth9-06.bln.grd
Grid Size:	51 rows x 221 columns
X Minimum:	0
X Maximum:	11
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	2.5
Y Spacing:	0.05
Z Minimum:	-9.5319174775454E-010
Z Maximum:	1.5638836154687

LOWER SURFACE

Level Surface defined by Z = 0

VOLUMES

Z Scale Factor: 1

Total Volumes by:

Trapezoidal Rule:	6.0906172652304
Simpson's Rule:	6.0922790619635
Simpson's 3/8 Rule:	6.0894454132164

CUT & FILL VOLUMES

Positive Volume [Cut]: 6.0906172652416
Negative Volume [Fill]: 1.1153894435556E-011
Net Volume [Cut-Fill]: 6.0906172652304<<<<<<Total Discharge in CFS
(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS

Planar Areas

Operational Planar Area: 7.644 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)
Positive Planar Area [Cut]: 7.643749999963
Negative Planar Area [Fill]: 3.6986072321774E-011
Blanked Planar Area: 19.85625
Total Planar Area: 27.5

Surface Areas

Positive Surface Area [Cut]: 20.553678325726
Negative Surface Area [Fill]: 2.5496363751931E-010

GRIDDING REPORT

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\LadiesSouth\Ladies Parlor South 9-06 SURFER XYZ T3B BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	441
Original Data:	441
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.3	0.2	0
25%-tile:	3	1.08	0
Median:	5.55	1.5	0
75%-tile:	7.95	1.81	0
Maximum:	10.5	2.25	1.54
Midrange:	5.4	1.225	0.77
Range:	10.2	2.05	1.54
Interquartile Range:	4.95	0.73	0
Median Abs. Deviation:	2.5	0.33	0
Mean:	5.484693877551	1.416215	0.072199546485261
Trim Mean (10%):	5.4931989924433	1.4336418513854	0.012544080604534
Standard Deviation:	2.9150322665291	0.49696437602005	0.27975356194211
Variance:	8.4974131149058	0.24697359103299	0.078262055419296
Coef. of Variation:			3.8747274125775
Coef. of Skewness:			3.9852892232753

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.149	0.126
Y:		1.000	0.019
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	8.4974131149058	-0.21602225056689	0.10282618353464
Y:		0.24697359103299	0.0026036607709751
Z:			0.078262055419296

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	0.012650178887602	0.021607091114595	-0.027783098752354
Standard Error:	0.0045970577517285	0.026964853667592	0.050564644146572

Inter-Parameter Correlations

	A	B	C
A:	1.000	-0.149	-0.611
B:		1.000	0.830
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.59844897383469	0.29922448691734	3.8644
Residual:	438	33.915117466075	0.0774317750367	
Total:	440	34.513566439909		

Coefficient of Multiple Determination (R^2): 0.017339528642357

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.016665	0
25%-tile:	0.050249378105603	0
Median:	0.052201532544552	0
75%-tile:	0.053851648071345	0
Maximum:	0.5	1.51

Midrange:	0.2583325	0.755
Range:	0.483335	1.51
Interquartile Range:	0.0036022699657415	0
Median Abs. Deviation:	0.0019521544389482	0
Mean:	0.064776671992442	0.059886621315193
Trim Mean (10%):	0.053726236920891	0.011335012594458
Standard Deviation:	0.054351142980664	0.23384246849203
Variance:	0.0029540467433046	0.054682300070444
Coef. of Variation:	0.8390542661254	3.9047530709952
Coef. of Skewness:	4.7987233249983	4.2941011276605
Root Mean Square:	0.084558050933788	0.24138912047355
Mean Square:	0.0071500639777211	0.058268707482993

Complete Spatial Randomness

Lambda:	21.090387374462
Clark and Evans:	0.59496429776504
Skellam:	417.84281848706

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 1.2E-006
Y Duplicate Tolerance: 2.4E-007
No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point
Polynomial Drift Order: 2
Kriging std. deviation grid: no

Semi-Variogram Model

Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 3
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\LadiesSouth\LadiesParlorSouth9-06.grd
Grid Size:	51 rows x 221 columns
Total Nodes:	11271
Filled Nodes:	11271
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	11
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	2.5
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-3.6728564406162
Z 25%-tile:	-0.97821314517684
Z Median:	-0.41998271189097
Z 75%-tile:	0.13994638583107
Z Maximum:	1.5638836154687
Z Midrange:	-1.0544864125738
Z Range:	5.2367400560849
Z Interquartile Range:	1.1181595310079
Z Median Abs. Deviation:	0.55906907056478
Z Mean:	-0.39213211670544
Z Trim Mean (10%):	-0.37737736468936
Z Standard Deviation:	0.94748089879929
Z Variance:	0.89772005358951
Z Coef. of Variation:	-1
Z Coef. of Skewness:	-0.076871166658746
Z Root Mean Square:	1.0254207187986
Z Mean Square:	1.0514876505414

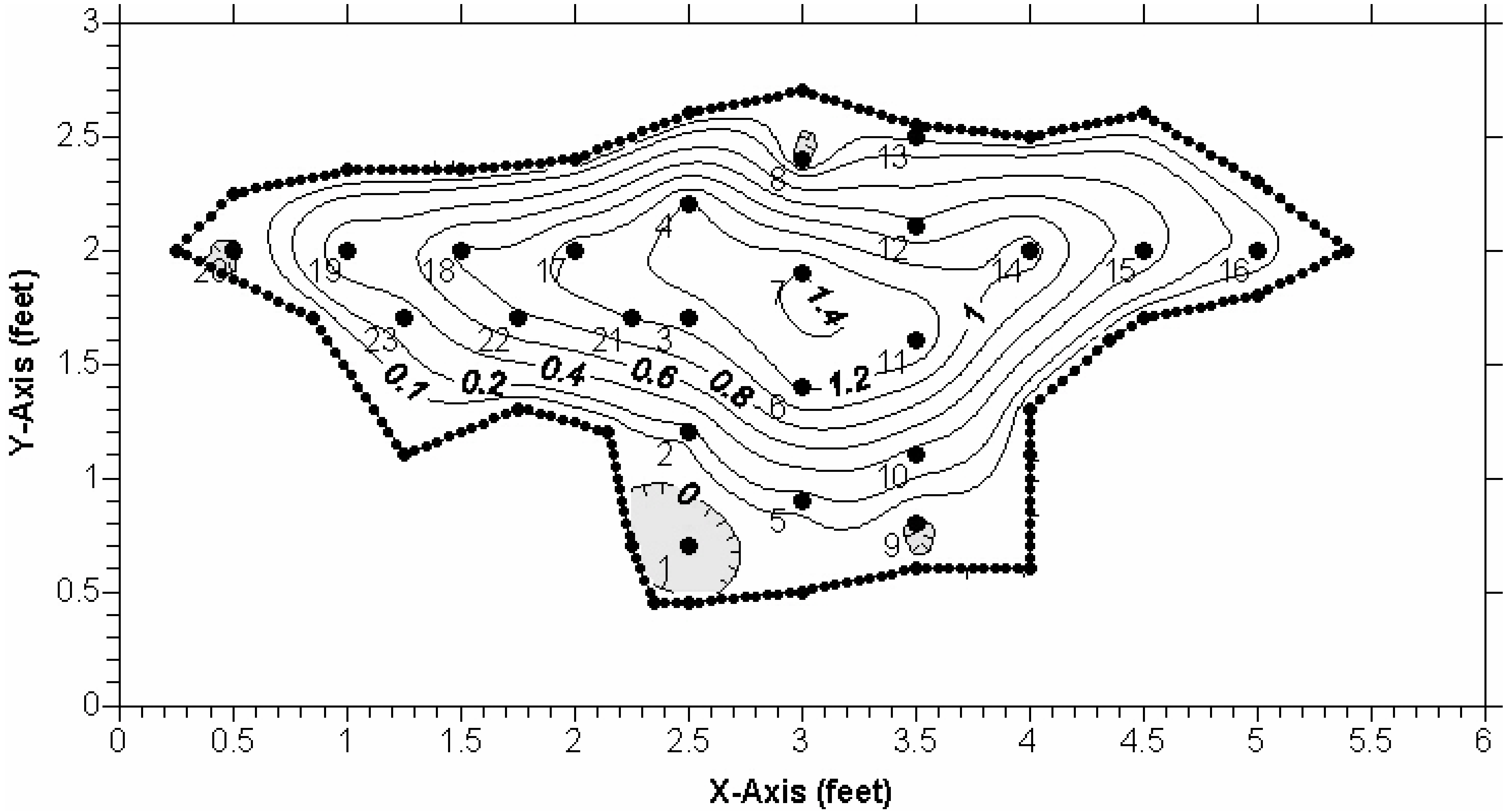

Figure 4A. Discharge measurement cross-section; Ladies Parlor Spring North Vent, Marion County, Florida, September 22, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. See Table 1 for station velocities. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

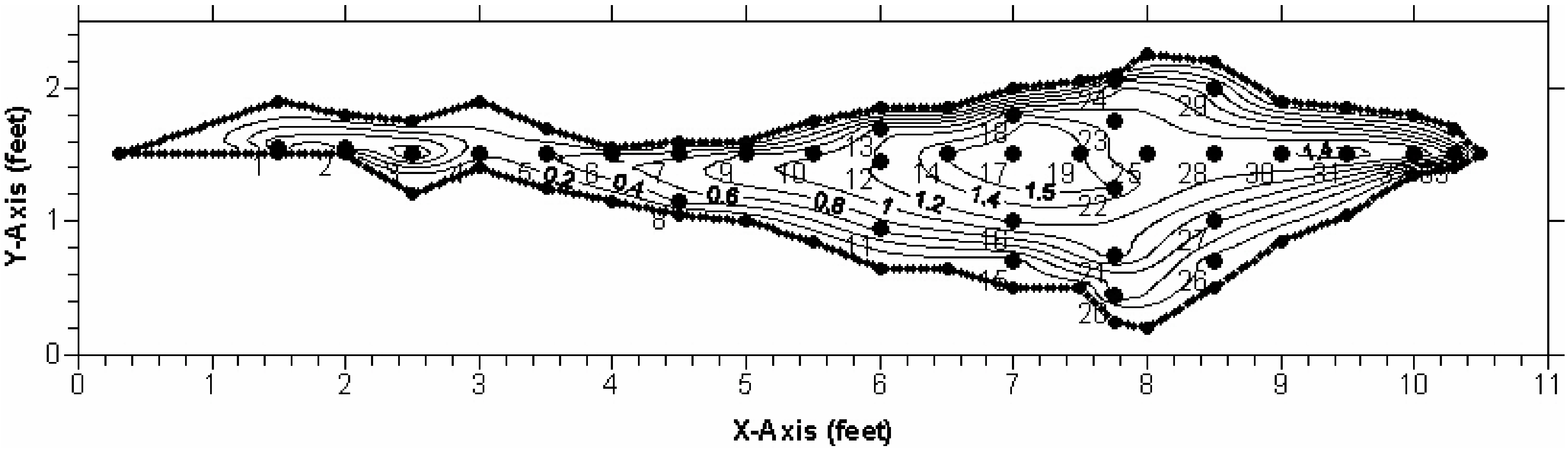

Figure 4B. Discharge measurement cross-section; Ladies Parlor Spring South Vent, Marion County, Florida, September 22, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

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Table 3A. Ladies Parlor Spring North Vent XYZ Grid Data, September 22, 2006.						
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**	
2.5	**0.7**	**-0.16**	**1**	50	14	
2.5	**1.2**	**0.13**	**2**	50	24	
2.5	**1.7**	**1.08**	**3**	50	34	
2.5	**2.2**	**1.25**	**4**	50	44	
3	**0.9**	**0.13**	**5**	60	18	
3	**1.4**	**1.25**	**6**	60	28	
3	**1.9**	**1.41**	**7**	60	38	
3	**2.4**	**-0.06**	**8**	60	48	
3.5	**0.8**	**-0.03**	**9**	70	16	
3.5	**1.1**	**0.32**	**10**	70	22	
3.5	**1.6**	**1.39**	**11**	70	32	
3.5	**2.1**	**0.64**	**12**	70	42	
3.5	**2.5**	**0.07**	**13**	70	50	
4	**2**	**1.11**	**14**	80	40	
4.5	**2**	**0.55**	**15**	90	40	
5	**2**	**0.19**	**16**	100	40	
2	**2**	**1.11**	**17**	40	40	
1.5	**2**	**0.84**	**18**	30	40	
1	**2**	**0.59**	**19**	20	40	
0.5	**2**	**-0.02**	**20**	10	40	
2.25	**1.7**	**1.01**	**21**	45	34	
1.75	**1.7**	**0.77**	**22**	35	34	
1.25	**1.7**	**0.27**	**23**	25	34	
0.25	**2**	**0**	**LE**	5	40	
0.5	**2.25**	**0**	**A**	10	45	
1	**2.35**	**0**	**B**	20	47	
1.5	**2.35**	**0**	**C**	30	47	
2	**2.4**	**0**	**D**	40	48	
2.5	**2.6**	**0**	**E**	50	52	
3	**2.7**	**0**	**F**	60	54	
3.5	**2.55**	**0**	**G**	70	51	
4	**2.5**	**0**	**H**	80	50	
4.5	**2.6**	**0**	**I**	90	52	
5	**2.3**	**0**	**J**	100	46	
5.4	**2**	**0**	**RE**	108	40	
5	**1.8**	**0**	**K**	100	36	
4.5	**1.7**	**0**	**L**	90	34	
4.35	**1.6**	**0**	**M**	87	32	
4	**1.3**	**0**	**N**	80	26	
4	**1.1**	**0**	**O**	80	22	
4	**0.6**	**0**	**P**	80	12	
3.5	**0.6**	**0**	**Q**	70	12	
3	**0.5**	**0**	**R**	60	10	
2.5	**0.45**	**0**	**S**	50	9	
2.35	**0.45**	**0**	**T**	47	9	
2.25	**0.7**	**0**	**U**	45	14	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
2.15	1.2	0	V	43	24	
1.75	1.3	0	W	35	26	
1.25	1.1	0	X	25	22	
0.85	1.7	0	Y	17	34	
0.3	2.05	0	LE1	6	41	
0.35	2.1	0	LE2	7	42	
0.4	2.15	0	LE3	8	43	
0.45	2.2	0	LE4	9	44	
0.55	2.26	0	A1	11	45.2	
0.6	2.27	0	A2	12	45.4	
0.65	2.28	0	A3	13	45.6	
0.7	2.29	0	A4	14	45.8	
0.75	2.3	0	A5	15	46	
0.8	2.31	0	A6	16	46.2	
0.85	2.32	0	A7	17	46.4	
0.9	2.33	0	A8	18	46.6	
0.95	2.34	0	A9	19	46.8	
1.05	2.35	0	B1	21	47	
1.1	2.35	0	B2	22	47	
1.15	2.35	0	B3	23	47	
1.2	2.35	0	B4	24	47	
1.25	2.35	0	B5	25	47	
1.3	2.35	0	B6	26	47	
1.35	2.35	0	B7	27	47	
1.4	2.35	0	B8	28	47	
1.45	2.35	0	B9	29	47	
1.55	2.355	0	C1	31	47.1	
1.6	2.36	0	C2	32	47.2	
1.65	2.365	0	C3	33	47.3	
1.7	2.37	0	C4	34	47.4	
1.75	2.375	0	C5	35	47.5	
1.8	2.38	0	C6	36	47.6	
1.85	2.385	0	C7	37	47.7	
1.9	2.39	0	C8	38	47.8	
1.95	2.395	0	C9	39	47.9	
2.05	2.42	0	D1	41	48.4	
2.1	2.44	0	D2	42	48.8	
2.15	2.46	0	D3	43	49.2	
2.2	2.48	0	D4	44	49.6	
2.25	2.5	0	D5	45	50	
2.3	2.52	0	D6	46	50.4	
2.35	2.54	0	D7	47	50.8	
2.4	2.56	0	D8	48	51.2	
2.45	2.58	0	D9	49	51.6	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
2.55	**2.61**	**0**	**E1**	51	52.2	
2.6	**2.62**	**0**	**E2**	52	52.4	
2.65	**2.63**	**0**	**E3**	53	52.6	
2.7	**2.64**	**0**	**E4**	54	52.8	
2.75	**2.65**	**0**	**E5**	55	53	
2.8	**2.66**	**0**	**E6**	56	53.2	
2.85	**2.67**	**0**	**E7**	57	53.4	
2.9	**2.68**	**0**	**E8**	58	53.6	
2.95	**2.69**	**0**	**E9**	59	53.8	
3.05	**2.685**	**0**	**F1**	61	53.7	
3.1	**2.67**	**0**	**F2**	62	53.4	
3.15	**2.655**	**0**	**F3**	63	53.1	
3.2	**2.64**	**0**	**F4**	64	52.8	
3.25	**2.625**	**0**	**F5**	65	52.5	
3.3	**2.61**	**0**	**F6**	66	52.2	
3.35	**2.595**	**0**	**F7**	67	51.9	
3.4	**2.58**	**0**	**F8**	68	51.6	
3.45	**2.565**	**0**	**F9**	69	51.3	
3.55	**2.545**	**0**	**G1**	71	50.9	
3.6	**2.54**	**0**	**G2**	72	50.8	
3.65	**2.535**	**0**	**G3**	73	50.7	
3.7	**2.53**	**0**	**G4**	74	50.6	
3.75	**2.525**	**0**	**G5**	75	50.5	
3.8	**2.52**	**0**	**G6**	76	50.4	
3.85	**2.515**	**0**	**G7**	77	50.3	
3.9	**2.51**	**0**	**G8**	78	50.2	
3.95	**2.505**	**0**	**G9**	79	50.1	
4.05	**2.51**	**0**	**H1**	81	50.2	
4.1	**2.52**	**0**	**H2**	82	50.4	
4.15	**2.53**	**0**	**H3**	83	50.6	
4.2	**2.54**	**0**	**H4**	84	50.8	
4.25	**2.55**	**0**	**H5**	85	51	
4.3	**2.56**		**H6**	86	51.2	
4.35	**2.57**	**0**	**H7**	87	51.4	
4.4	**2.58**	**0**	**H8**	88	51.6	
4.45	**2.59**	**0**	**H9**	89	51.8	
4.55	**2.57**	**0**	**I1**	91	51.4	
4.6	**2.54**	**0**	**I2**	92	50.8	
4.65	**2.51**	**0**	**I3**	93	50.2	
4.7	**2.48**	**0**	**I4**	94	49.6	
4.75	**2.45**	**0**	**I5**	95	49	
4.8	**2.42**	**0**	**I6**	96	48.4	
4.85	**2.39**	**0**	**I7**	97	47.8	
4.9	**2.36**	**0**	**I8**	98	47.2	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
4.95	**2.33**	**0**	**I9**	99	46.6	
5.05	**2.2625**	**0**	**J1**	101	45.25	
5.1	**2.225**	**0**	**J2**	102	44.5	
5.15	**2.1875**	**0**	**J3**	103	43.75	
5.2	**2.15**	**0**	**J4**	104	43	
5.25	**2.1125**	**0**	**J5**	105	42.25	
5.3	**2.075**	**0**	**J6**	106	41.5	
5.35	**2.0375**	**0**	**J7**	107	40.75	
5.35	**1.975**	**0**	**RE1**	107	39.5	
5.3	**1.95**	**0**	**RE2**	106	39	
5.25	**1.925**	**0**	**RE3**	105	38.5	
5.2	**1.9**	**0**	**RE4**	104	38	
5.15	**1.875**	**0**	**RE5**	103	37.5	
5.1	**1.85**	**0**	**RE6**	102	37	
5.05	**1.825**	**0**	**RE7**	101	36.5	
4.95	**1.79**	**0**	**K1**	99	35.8	
4.9	**1.78**	**0**	**K2**	98	35.6	
4.85	**1.77**	**0**	**K3**	97	35.4	
4.8	**1.76**	**0**	**K4**	96	35.2	
4.75	**1.75**	**0**	**K5**	95	35	
4.7	**1.74**	**0**	**K6**	94	34.8	
4.65	**1.73**	**0**	**K7**	93	34.6	
4.6	**1.72**	**0**	**K8**	92	34.4	
4.55	**1.71**	**0**	**K9**	91	34.2	
4.45	**1.66667**	**0**	**L1**	89	33.3333	
4.4	**1.63333**	**0**	**L2**	88	32.6666	
4.3	**1.55715**	**0**	**M1**	86	31.1429	
4.25	**1.51429**	**0**	**M2**	85	30.2858	
4.2	**1.47144**	**0**	**M3**	84	29.4287	
4.15	**1.42858**	**0**	**M4**	83	28.5716	
4.1	**1.38573**	**0**	**M5**	82	27.7145	
4.05	**1.34287**	**0**	**M6**	81	26.8574	
4	**1.25**	**0**	**N1**	80	25	
4	**1.2**	**0**	**N2**	80	24	
4	**1.15**	**0**	**N3**	80	23	
4	**1.05**	**0**	**O1**	80	21	
4	**1**	**0**	**O2**	80	20	
4	**0.95**	**0**	**O3**	80	19	
4	**0.9**	**0**	**O4**	80	18	
4	**0.85**	**0**	**O5**	80	17	
4	**0.8**	**0**	**O6**	80	16	

4	**0.75**	**0**	**O7**	80	15	
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**	
4	**0.7**	**0**	**O8**	80	14	
4	**0.65**	**0**	**O9**	80	13	
3.95	**0.6**	**0**	**P1**	79	12	
3.9	**0.6**	**0**	**P2**	78	12	
3.85	**0.6**	**0**	**P3**	77	12	
3.8	**0.6**	**0**	**P4**	76	12	
3.75	**0.6**	**0**	**P5**	75	12	
3.7	**0.6**	**0**	**P6**	74	12	
3.65	**0.6**	**0**	**P7**	73	12	
3.6	**0.6**	**0**	**P8**	72	12	
3.55	**0.6**	**0**	**P9**	71	12	
3.45	**0.59**	**0**	**Q1**	69	11.8	
3.4	**0.58**	**0**	**Q2**	68	11.6	
3.35	**0.57**	**0**	**Q3**	67	11.4	
3.3	**0.56**	**0**	**Q4**	66	11.2	
3.25	**0.55**	**0**	**Q5**	65	11	
3.2	**0.54**	**0**	**Q6**	64	10.8	
3.15	**0.53**	**0**	**Q7**	63	10.6	
3.1	**0.52**	**0**	**Q8**	62	10.4	
3.05	**0.51**	**0**	**Q9**	61	10.2	
2.95	**0.495**	**0**	**R1**	59	9.9	
2.9	**0.49**	**0**	**R2**	58	9.8	
2.85	**0.485**	**0**	**R3**	57	9.7	
2.8	**0.48**	**0**	**R4**	56	9.6	
2.75	**0.475**	**0**	**R5**	55	9.5	
2.7	**0.47**	**0**	**R6**	54	9.4	
2.65	**0.465**	**0**	**R7**	53	9.3	
2.6	**0.46**	**0**	**R8**	52	9.2	
2.55	**0.455**	**0**	**R9**	51	9.1	
2.45	**0.45**	**0**	**S1**	49	9	
2.4	**0.45**	**0**	**S2**	48	9	
2.33	**0.5**	**0**	**T1**	46.6	10	
2.31	**0.55**	**0**	**T2**	46.2	11	
2.29	**0.6**	**0**	**T3**	45.8	12	
2.27	**0.65**	**0**	**T4**	45.4	13	
2.24	**0.75**	**0**	**U1**	44.8	15	
2.23	**0.8**	**0**	**U2**	44.6	16	
2.22	**0.85**	**0**	**U3**	44.4	17	
2.21	**0.9**	**0**	**U4**	44.2	18	
2.2	**0.95**		**U5**	44	19	
2.19	**1**	**0**	**U6**	43.8	20	
2.18	**1.05**	**0**	**U7**	43.6	21	

2.17	**1.1**	**0**	**U8**	43.4	22	
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**	
2.16	**1.15**	**0**	**U9**	43.2	23	
2.1	**1.2125**	**0**	**V1**	42	24.25	
2.05	**1.225**	**0**	**V2**	41	24.5	
2	**1.2375**	**0**	**V3**	40	24.75	
1.95	**1.25**	**0**	**V4**	39	25	
1.9	**1.2625**	**0**	**V5**	38	25.25	
1.85	**1.275**	**0**	**V6**	37	25.5	
1.8	**1.2875**	**0**	**V7**	36	25.75	
1.7	**1.28**	**0**	**W1**	34	25.6	
1.65	**1.26**	**0**	**W2**	33	25.2	
1.6	**1.24**	**0**	**W3**	32	24.8	
1.55	**1.22**	**0**	**W4**	31	24.4	
1.5	**1.2**	**0**	**W5**	30	24	
1.45	**1.18**	**0**	**W6**	29	23.6	
1.4	**1.16**	**0**	**W7**	28	23.2	
1.35	**1.14**	**0**	**W8**	27	22.8	
1.3	**1.12**	**0**	**W9**	26	22.4	
1.21669	**1.15**	**0**	**X1**	24.3337	23	
1.18335	**1.2**	**0**	**X2**	23.667	24	
1.15002	**1.25**	**0**	**X3**	23.0003	25	
1.11668	**1.3**	**0**	**X4**	22.3336	26	
1.08335	**1.35**	**0**	**X5**	21.6669	27	
1.05001	**1.4**	**0**	**X6**	21.0002	28	
1.01668	**1.45**	**0**	**X7**	20.3335	29	
0.98334	**1.5**	**0**	**X8**	19.6668	30	
0.95001	**1.55**	**0**	**X9**	19.0001	31	
0.91667	**1.6**	**0**	**X10**	18.3334	32	
0.88334	**1.65**	**0**	**X11**	17.6667	33	
0.8	**1.725**	**0**	**Y1**	16	34.5	
0.75	**1.75**	**0**	**Y2**	15	35	
0.7	**1.775**	**0**	**Y3**	14	35.5	
0.65	**1.8**	**0**	**Y4**	13	36	
0.6	**1.825**	**0**	**Y5**	12	36.5	
0.55	**1.85**	**0**	**Y6**	11	37	
0.5	**1.875**	**0**	**Y7**	10	37.5	
0.45	**1.9**	**0**	**Y8**	9	38	
0.4	**1.925**	**0**	**Y9**	8	38.5	
0.35	**1.95**	**0**	**Y10**	7	39	
0.3	**1.975**	**0**	**Y11**	6	39.5	

Table 3B. Ladies Parlor Spring South Vent XYZ Grid Data, September 22, 2006.						
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**	
1.5	**1.55**	**0.81**	**1**	30	31	
2	**1.55**	**0.84**	**2**	40	31	
2.5	**1.5**	**1.05**	**3**	50	30	
3	**1.5**	**0.24**	**4**	60	30	
3.5	**1.5**	**0.42**	**5**	70	30	
4	**1.5**	**0.61**	**6**	80	30	
4.5	**1.5**	**0.56**	**7**	90	30	
4.5	**1.15**	**0.46**	**8**	90	23	
5	**1.5**	**0.89**	**9**	100	30	
5.5	**1.5**	**0.99**	**10**	110	30	
6	**0.95**	**0.68**	**11**	120	19	
6	**1.45**	**1.2**	**12**	120	29	
6	**1.7**	**1.11**	**13**	120	34	
6.5	**1.5**	**1.51**	**14**	130	30	
7	**0.7**	**0.08**	**15**	140	14	
7	**1**	**1.23**	**16**	140	20	
7	**1.5**	**1.54**	**17**	140	30	
7	**1.8**	**1.44**	**18**	140	36	
7.5	**1.5**	**1.52**	**19**	150	30	
7.75	**0.45**	**0.59**	**20**	155	9	
7.75	**0.75**	**1.11**	**21**	155	15	
7.75	**1.25**	**1.49**	**22**	155	25	
7.75	**1.75**	**1.31**	**23**	155	35	
7.75	**2.05**	**0.94**	**24**	155	41	
8	**1.5**	**1.19**	**25**	160	30	
8.5	**0.7**	**0.04**	**26**	170	14	
8.5	**1**	**0.62**	**27**	170	20	
8.5	**1.5**	**1.31**	**28**	170	30	
8.5	**2**	**0.68**	**29**	170	40	
9	**1.5**	**1.4**	**30**	180	30	
9.5	**1.5**	**1.51**	**31**	190	30	
10	**1.5**	**1.44**	**32**	200	30	
10.3	**1.5**	**1.03**	**33**	206	30	
0.3	**1.5**	**0**	**A**	6	30	
1.5	**1.9**	**0**	**BT**	30	38	
2	**1.8**	**0**	**CT**	40	36	
2.5	**1.75**	**0**	**DT**	50	35	
3	**1.9**	**0**	**ET**	60	38	
3.5	**1.7**	**0**	**FT**	70	34	
4	**1.55**	**0**	**GT**	80	31	
4.5	**1.6**	**0**	**HT**	90	32	
5	**1.6**	**0**	**IT**	100	32	
5.5	**1.75**	**0**	**JT**	110	35	
6	**1.85**	**0**	**KT**	120	37	
6.5	**1.85**	**0**	**LT**	130	37	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
7	**2**	**0**	**MT**	140	40	
7.5	**2.05**	**0**	**NT**	150	41	
7.75	**2.1**	**0**	**OT**	155	42	
8	**2.25**	**0**	**PT**	160	45	
8.5	**2.2**	**0**	**QT**	170	44	
9	**1.9**	**0**	**RT**	180	38	
9.5	**1.85**	**0**	**ST**	190	37	
10	**1.8**	**0**	**TT**	200	36	
10.3	**1.7**	**0**	**UT**	206	34	
10.5	**1.5**	**0**	**V**	210	30	
1.5	**1.5**	**0**	**BS**	30	30	
2	**1.5**	**0**	**CS**	40	30	
2.5	**1.2**	**0**	**DS**	50	24	
3	**1.4**	**0**	**ES**	60	28	
3.5	**1.25**	**0**	**FS**	70	25	
4	**1.15**	**0**	**GS**	80	23	
4.5	**1.05**	**0**	**HS**	90	21	
5	**1**	**0**	**IS**	100	20	
5.5	**0.85**	**0**	**JS**	110	17	
6	**0.65**	**0**	**KS**	120	13	
6.5	**0.65**	**0**	**LS**	130	13	
7	**0.5**	**0**	**MS**	140	10	
7.5	**0.5**	**0**	**NS**	150	10	
7.75	**0.25**	**0**	**OS**	155	5	
8	**0.2**	**0**	**PS**	160	4	
8.5	**0.5**	**0**	**QS**	170	10	
9	**0.85**	**0**	**RS**	180	17	
9.5	**1.05**	**0**	**SS**	190	21	
10	**1.35**	**0**	**TS**	200	27	
10.3	**1.4**	**0**	**US**	206	28	
0.35	**1.51667**	**0**	**AT1**	7	30.3333	
0.4	**1.53333**	**0**	**AT2**	8	30.6666	
0.45	**1.55**	**0**	**AT3**	9	30.9999	
0.5	**1.56666**	**0**	**AT4**	10	31.3332	
0.55	**1.58333**	**0**	**AT5**	11	31.6665	
0.6	**1.59999**	**0**	**AT6**	12	31.9998	
0.65	**1.61666**	**0**	**AT7**	13	32.3331	
0.7	**1.63332**	**0**	**AT8**	14	32.6664	
0.75	**1.64999**	**0**	**AT9**	15	32.9997	
0.8	**1.66665**	**0**	**AT10**	16	33.333	
0.85	**1.68332**	**0**	**AT11**	17	33.6663	
0.9	**1.69998**	**0**	**AT12**	18	33.9996	
0.95	**1.71665**	**0**	**AT13**	19	34.3329	
1	**1.73331**	**0**	**AT14**	20	34.6662	
1.05	**1.74998**	**0**	**AT15**	21	34.9995	
1.1	**1.76664**	**0**	**AT16**	22	35.3328	
1.15	**1.78331**	**0**	**AT17**	23	35.6661	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
1.2	**1.79997**	**0**	**AT18**	24	35.9994	
1.25	**1.81664**	**0**	**AT19**	25	36.3327	
1.3	**1.8333**	**0**	**AT20**	26	36.666	
1.35	**1.84997**	**0**	**AT21**	27	36.9993	
1.4	**1.86663**	**0**	**AT22**	28	37.3326	
1.45	**1.8833**	**0**	**AT23**	29	37.6659	
1.55	**1.89**	**0**	**BT1**	31	37.8	
1.6	**1.88**	**0**	**BT2**	32	37.6	
1.65	**1.87**	**0**	**BT3**	33	37.4	
1.7	**1.86**	**0**	**BT4**	34	37.2	
1.75	**1.85**	**0**	**BT5**	35	37	
1.8	**1.84**	**0**	**BT6**	36	36.8	
1.85	**1.83**	**0**	**BT7**	37	36.6	
1.9	**1.82**	**0**	**BT8**	38	36.4	
1.95	**1.81**	**0**	**BT9**	39	36.2	
2.05	**1.795**	**0**	**CT1**	41	35.9	
2.1	**1.79**	**0**	**CT2**	42	35.8	
2.15	**1.785**	**0**	**CT3**	43	35.7	
2.2	**1.78**	**0**	**CT4**	44	35.6	
2.25	**1.775**	**0**	**CT5**	45	35.5	
2.3	**1.77**	**0**	**CT6**	46	35.4	
2.35	**1.765**	**0**	**CT7**	47	35.3	
2.4	**1.76**	**0**	**CT8**	48	35.2	
2.45	**1.755**	**0**	**CT9**	49	35.1	
2.55	**1.765**	**0**	**DT1**	51	35.3	
2.6	**1.78**	**0**	**DT2**	52	35.6	
2.65	**1.795**	**0**	**DT3**	53	35.9	
2.7	**1.81**	**0**	**DT4**	54	36.2	
2.75	**1.825**	**0**	**DT5**	55	36.5	
2.8	**1.84**	**0**	**DT6**	56	36.8	
2.85	**1.855**	**0**	**DT7**	57	37.1	
2.9	**1.87**	**0**	**DT8**	58	37.4	
2.95	**1.885**	**0**	**DT9**	59	37.7	
3.05	**1.88**	**0**	**ET1**	61	37.6	
3.1	**1.86**	**0**	**ET2**	62	37.2	
3.15	**1.84**	**0**	**ET3**	63	36.8	
3.2	**1.82**	**0**	**ET4**	64	36.4	
3.25	**1.8**	**0**	**ET5**	65	36	
3.3	**1.78**	**0**	**ET6**	66	35.6	
3.35	**1.76**	**0**	**ET7**	67	35.2	
3.4	**1.74**	**0**	**ET8**	68	34.8	
3.45	**1.72**	**0**	**ET9**	69	34.4	
3.55	**1.685**	**0**	**FT1**	71	33.7	
3.6	**1.67**	**0**	**FT2**	72	33.4	

Table 3B. Ladies Parlor Spring XYZ Grid Data, September 22, 2006.

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
3.65	1.655	0	FT3	73	33.1	
3.7	1.64	0	FT4	74	32.8	
3.75	1.625	0	FT5	75	32.5	
3.8	1.61	0	FT6	76	32.2	
3.85	1.595	0	FT7	77	31.9	
3.9	1.58	0	FT8	78	31.6	
3.95	1.565	0	FT9	79	31.3	
4.05	1.555	0	GT1	81	31.1	
4.1	1.56	0	GT2	82	31.2	
4.15	1.565	0	GT3	83	31.3	
4.2	1.57	0	GT4	84	31.4	
4.25	1.575	0	GT5	85	31.5	
4.3	1.58	0	GT6	86	31.6	
4.35	1.585	0	GT7	87	31.7	
4.4	1.59	0	GT8	88	31.8	
4.45	1.595	0	GT9	89	31.9	
4.55	1.6	0	HT1	91	32	
4.6	1.6	0	HT2	92	32	
4.65	1.6	0	HT3	93	32	
4.7	1.6	0	HT4	94	32	
4.75	1.6	0	HT5	95	32	
4.8	1.6	0	HT6	96	32	
4.85	1.6	0	HT7	97	32	
4.9	1.6	0	HT8	98	32	
4.95	1.6	0	HT9	99	32	
5.05	1.615	0	IT1	101	32.3	
5.1	1.63	0	IT2	102	32.6	
5.15	1.645	0	IT3	103	32.9	
5.2	1.66	0	IT4	104	33.2	
5.25	1.675	0	IT5	105	33.5	
5.3	1.69	0	IT6	106	33.8	
5.35	1.705	0	IT7	107	34.1	
5.4	1.72	0	IT8	108	34.4	
5.45	1.735	0	IT9	109	34.7	
5.55	1.76	0	JT1	111	35.2	
5.6	1.77	0	JT2	112	35.4	
5.65	1.78	0	JT3	113	35.6	
5.7	1.79	0	JT4	114	35.8	
5.75	1.8	0	JT5	115	36	
5.8	1.81	0	JT6	116	36.2	
5.85	1.82	0	JT7	117	36.4	
5.9	1.83	0	JT8	118	36.6	
5.95	1.84	0	JT9	119	36.8	
6.05	1.85	0	KT1	121	37	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
6.1	1.85	0	KT2	122	37	
6.15	1.85	0	KT3	123	37	
6.2	1.85	0	KT4	124	37	
6.25	1.85	0	KT5	125	37	
6.3	1.85	0	KT6	126	37	
6.35	1.85	0	KT7	127	37	
6.4	1.85	0	KT8	128	37	
6.45	1.85	0	KT9	129	37	
6.55	1.865	0	LT1	131	37.3	
6.6	1.88	0	LT2	132	37.6	
6.65	1.895	0	LT3	133	37.9	
6.7	1.91	0	LT4	134	38.2	
6.75	1.925	0	LT5	135	38.5	
6.8	1.94	0	LT6	136	38.8	
6.85	1.955	0	LT7	137	39.1	
6.9	1.97	0	LT8	138	39.4	
6.95	1.985	0	LT9	139	39.7	
7.05	2.005	0	MT1	141	40.1	
7.1	2.01	0	MT2	142	40.2	
7.15	2.015	0	MT3	143	40.3	
7.2	2.02	0	MT4	144	40.4	
7.25	2.025	0	MT5	145	40.5	
7.3	2.03	0	MT6	146	40.6	
7.35	2.035	0	MT7	147	40.7	
7.4	2.04	0	MT8	148	40.8	
7.45	2.045	0	MT9	149	40.9	
7.55	2.06	0	NT1	151	41.2	
7.6	2.07	0	NT2	152	41.4	
7.65	2.08	0	NT3	153	41.6	
7.7	2.09	0	NT4	154	41.8	
7.8	2.13	0	OT1	156	42.6	
7.85	2.16	0	OT2	157	43.2	
7.9	2.19	0	OT3	158	43.8	
7.95	2.22	0	OT4	159	44.4	
	0					
8.05	2.245	0	PT1	161	44.9	
8.1	2.24	0	PT2	162	44.8	
8.15	2.235	0	PT3	163	44.7	
8.2	2.23	0	PT4	164	44.6	
8.25	2.225	0	PT5	165	44.5	
8.3	2.22	0	PT6	166	44.4	
8.35	2.215	0	PT7	167	44.3	
8.4	2.21	0	PT8	168	44.2	
8.45	2.205	0	PT9	169	44.1	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
8.55	2.17	0	QT1	171	43.4	
8.6	2.14	0	QT2	172	42.8	
8.65	2.11	0	QT3	173	42.2	
8.7	2.08	0	QT4	174	41.6	
8.75	2.05	0	QT5	175	41	
8.8	2.02	0	QT6	176	40.4	
8.85	1.99	0	QT7	177	39.8	
8.9	1.96	0	QT8	178	39.2	
8.95	1.93	0	QT9	179	38.6	
9.05	1.895	0	RT1	181	37.9	
9.1	1.89	0	RT2	182	37.8	
9.15	1.885	0	RT3	183	37.7	
9.2	1.88	0	RT4	184	37.6	
9.25	1.875	0	RT5	185	37.5	
9.3	1.87	0	RT6	186	37.4	
9.35	1.865	0	RT7	187	37.3	
9.4	1.86	0	RT8	188	37.2	
9.45	1.855	0	RT9	189	37.1	
9.55	1.845	0	ST1	191	36.9	
9.6	1.84	0	ST2	192	36.8	
9.65	1.835	0	ST3	193	36.7	
9.7	1.83	0	ST4	194	36.6	
9.75	1.825	0	ST5	195	36.5	
9.8	1.82	0	ST6	196	36.4	
9.85	1.815	0	ST7	197	36.3	
9.9	1.81	0	ST8	198	36.2	
9.95	1.805	0	ST9	199	36.1	
10.05	1.78335	0	TT1	201	35.667	
10.1	1.7667	0	TT2	202	35.334	
10.15	1.75005	0	TT3	203	35.001	
10.2	1.7334	0	TT4	204	34.668	
10.25	1.71775	0	TT5	205	34.355	
10.35	1.65	0	UT1	207	33	
10.4	1.6	0	UT2	208	32	
10.45	1.55	0	UT3	209	31	
0.35	1.5	0	AS1	7	30	
0.4	1.5	0	AS2	8	30	
0.45	1.5	0	AS3	9	30	
0.5	1.5	0	AS4	10	30	
0.55	1.5	0	AS5	11	30	
0.6	1.5	0	AS6	12	30	
0.65	1.5	0	AS7	13	30	
0.7	1.5	0	AS8	14	30	
0.75	1.5	0	AS9	15	30	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
0.8	1.5	0	AS10	16	30	
0.85	1.5	0	AS11	17	30	
0.9	1.5	0	AS12	18	30	
0.95	1.5	0	AS13	19	30	
1	1.5	0	AS14	20	30	
1.05	1.5	0	AS15	21	30	
1.1	1.5	0	AS16	22	30	
1.15	1.5	0	AS17	23	30	
1.2	1.5	0	AS18	24	30	
1.25	1.5	0	AS19	25	30	
1.3	1.5	0	AS20	26	30	
1.35	1.5	0	AS21	27	30	
1.4	1.5	0	AS22	28	30	
1.45	1.5	0	AS23	29	30	
1.55	1.5	0	BS1	31	30	
1.6	1.5	0	BS2	32	30	
1.65	1.5	0	BS3	33	30	
1.7	1.5	0	BS4	34	30	
1.75	1.5	0	BS5	35	30	
1.8	1.5	0	BS6	36	30	
1.85	1.5	0	BS7	37	30	
1.9	1.5	0	BS8	38	30	
1.95	1.5	0	BS9	39	30	
2.05	1.47	0	CS1	41	29.4	
2.1	1.44	0	CS2	42	28.8	
2.15	1.41	0	CS3	43	28.2	
2.2	1.38	0	CS4	44	27.6	
2.25	1.35	0	CS5	45	27	
2.3	1.32	0	CS6	46	26.4	
2.35	1.29	0	CS7	47	25.8	
2.4	1.26	0	CS8	48	25.2	
2.45	1.23	0	CS9	49	24.6	
2.55	1.22	0	DS1	51	24.4	
2.6	1.24	0	DS2	52	24.8	
2.65	1.26	0	DS3	53	25.2	
2.7	1.28	0	DS4	54	25.6	
2.75	1.3	0	DS5	55	26	
2.8	1.32	0	DS6	56	26.4	
2.85	1.34	0	DS7	57	26.8	
2.9	1.36	0	DS8	58	27.2	
2.95	1.38	0	DS9	59	27.6	
3.05	1.385	0	ES1	61	27.7	
3.1	1.37	0	ES2	62	27.4	
3.15	1.355	0	ES3	63	27.1	
3.2	1.34	0	ES4	64	26.8	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
3.25	1.325	0	ES5	65	26.5	
3.3	1.31	0	ES6	66	26.2	
3.35	1.295	0	ES7	67	25.9	
3.4	1.28	0	ES8	68	25.6	
3.45	1.265	0	ES9	69	25.3	
3.55	1.24	0	FS1	71	24.8	
3.6	1.23	0	FS2	72	24.6	
3.65	1.22	0	FS3	73	24.4	
3.7	1.21	0	FS4	74	24.2	
3.75	1.2	0	FS5	75	24	
3.8	1.19	0	FS6	76	23.8	
3.85	1.18	0	FS7	77	23.6	
3.9	1.17	0	FS8	78	23.4	
3.95	1.16	0	FS9	79	23.2	
4.05	1.14	0	GS1	81	22.8	
4.1	1.13	0	GS2	82	22.6	
4.15	1.12	0	GS3	83	22.4	
4.2	1.11	0	GS4	84	22.2	
4.25	1.1	0	GS5	85	22	
4.3	1.09	0	GS6	86	21.8	
4.35	1.08	0	GS7	87	21.6	
4.4	1.07	0	GS8	88	21.4	
4.45	1.06	0	GS9	89	21.2	
4.55	1.045	0	HS1	91	20.9	
4.6	1.04	0	HS2	92	20.8	
4.65	1.035	0	HS3	93	20.7	
4.7	1.03	0	HS4	94	20.6	
4.75	1.025	0	HS5	95	20.5	
4.8	1.02	0	HS6	96	20.4	
4.85	1.015	0	HS7	97	20.3	
4.9	1.01	0	HS8	98	20.2	
4.95	1.005	0	HS9	99	20.1	
5.05	0.985	0	IS1	101	19.7	
5.1	0.97	0	IS2	102	19.4	
5.15	0.955	0	IS3	103	19.1	
5.2	0.94	0	IS4	104	18.8	
5.25	0.925	0	IS5	105	18.5	
5.3	0.91	0	IS6	106	18.2	
5.35	0.895	0	IS7	107	17.9	
5.4	0.88	0	IS8	108	17.6	
5.45	0.865	0	IS9	109	17.3	
5.55	0.83	0	JS1	111	16.6	
5.6	0.81	0	JS2	112	16.2	
5.65	0.79	0	JS3	113	15.8	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
5.7	0.77	0	JS4	114	15.4	
5.75	0.75	0	JS5	115	15	
5.8	0.73	0	JS6	116	14.6	
5.85	0.71	0	JS7	117	14.2	
5.9	0.69	0	JS8	118	13.8	
5.95	0.67	0	JS9	119	13.4	
6.05	0.65	0	KS1	121	13	
6.1	0.65	0	KS2	122	13	
6.15	0.65	0	KS3	123	13	
6.2	0.65	0	KS4	124	13	
6.25	0.65	0	KS5	125	13	
6.3	0.65	0	KS6	126	13	
6.35	0.65	0	KS7	127	13	
6.4	0.65	0	KS8	128	13	
6.45	0.65	0	KS9	129	13	
6.55	0.635	0	LS1	131	12.7	
6.6	0.62	0	LS2	132	12.4	
6.65	0.605	0	LS3	133	12.1	
6.7	0.59	0	LS4	134	11.8	
6.75	0.575	0	LS5	135	11.5	
6.8	0.56	0	LS6	136	11.2	
6.85	0.545	0	LS7	137	10.9	
6.9	0.53	0	LS8	138	10.6	
6.95	0.515	0	LS9	139	10.3	
7.05	0.5	0	MS1	141	10	
7.1	0.5	0	MS2	142	10	
7.15	0.5	0	MS3	143	10	
7.2	0.5	0	MS4	144	10	
7.25	0.5	0	MS5	145	10	
7.3	0.5	0	MS6	146	10	
7.35	0.5	0	MS7	147	10	
7.4	0.5	0	MS8	148	10	
7.45	0.5	0	MS9	149	10	
7.55	0.45	0	NS1	151	9	
7.6	0.4	0	NS2	152	8	
7.65	0.35	0	NS3	153	7	
7.7	0.3	0	NS4	154	6	
7.8	0.24	0	OS1	156	4.8	
7.85	0.23	0	OS2	157	4.6	
7.9	0.22	0	OS3	158	4.4	
7.95	0.21	0	OS4	159	4.2	
8.05	0.23	0	PS1	161	4.6	
8.1	0.26	0	PS2	162	5.2	

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot	
8.15	0.29	0	PS3	163	5.8	
8.2	0.32	0	PS4	164	6.4	
8.25	0.35	0	PS5	165	7	
8.3	0.38	0	PS6	166	7.6	
8.35	0.41	0	PS7	167	8.2	
8.4	0.44	0	PS8	168	8.8	
8.45	0.47	0	PS9	169	9.4	
8.55	0.535	0	QS1	171	10.7	
8.6	0.57	0	QS2	172	11.4	
8.65	0.605	0	QS3	173	12.1	
8.7	0.64	0	QS4	174	12.8	
8.75	0.675	0	QS5	175	13.5	
8.8	0.71	0	QS6	176	14.2	
8.85	0.745	0	QS7	177	14.9	
8.9	0.78	0	QS8	178	15.6	
8.95	0.815	0	QS9	179	16.3	
9.05	0.87	0	RS1	181	17.4	
9.1	0.89	0	RS2	182	17.8	
9.15	0.91	0	RS3	183	18.2	
9.2	0.93	0	RS4	184	18.6	
9.25	0.95	0	RS5	185	19	
9.3	0.97	0	RS6	186	19.4	
9.35	0.99	0	RS7	187	19.8	
9.4	1.01	0	RS8	188	20.2	
9.45	1.03	0	RS9	189	20.6	
9.55	1.08	0	SS1	191	21.6	
9.6	1.11	0	SS2	192	22.2	
9.65	1.14	0	SS3	193	22.8	
9.7	1.17	0	SS4	194	23.4	
9.75	1.2	0	SS5	195	24	
9.8	1.23	0	SS6	196	24.6	
9.85	1.26	0	SS7	197	25.2	
9.9	1.29	0	SS8	198	25.8	
9.95	1.32	0	SS9	199	26.4	
10.05	1.35834	0	TS1	201	27.1667	
10.1	1.36667	0	TS2	202	27.3334	
10.15	1.37501	0	TS3	203	27.5001	
10.2	1.38334	0	TS4	204	27.6668	
10.25	1.39168	0	TS5	205	27.8335	
10.35	1.425	0	US1	207	28.5	
10.4	1.45	0	US2	208	29	
10.45	1.475	0	US3	209	29.5	

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ____ Time Constant: ____

SensorSer # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ____

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____

Calibration Technician: [signature] Date: 18 Apr 2006

QA Technician: [signature] Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement
4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

P/N 101001 301

Discharge Measurement: Mammoth Spring, Silver Springs Group, Marion County, Florida; September 19, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

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High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Mammoth Spring, Marion County, Florida; September 19, 2006

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Results of Discharge Measurements of Mammoth Spring, Marion County, Florida; September 19, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a discharge measurement at the Mammoth Spring in Marion County, Florida. This report documents the results of the measurement made at the site on September 19, 2006. A summary of the results and collected data for that measurement are presented in Table 1.

PURPOSE and SCOPE OF WORK

The purpose of this work was to obtain accurate discharge measurements of the Mammoth Spring, the headspring and major source of groundwater discharge into the Silver River. A discharge measurement was to be made at the vent of Mammoth Spring during September, 2006.

SITE DESCRIPTION

Mammoth Spring is the largest spring of the Silver Springs Group, and is the headspring of the Silver River. The spring lies within a spring pool surrounded by the Silver Springs theme park. Mammoth Spring's vent is a wide, oval-shaped opening about 69 feet across, with floor to ceiling heights that vary from under 2 to over 6 feet. The depth of this vent ranges between 25 and 34 feet deep. The rock that comprises the ceiling of this vent is solid and self-supported, with the floor beneath composed of a layer of boulders and rubble. See Figure 1.

A large cavern with a complex network of cave passages lies inside of this vent. These cave passages supply waters of varying characteristics to the cavern, where some mixing occurs before these waters exit the vent. The inside of the cavern is a complex structure of breakdown boulders, bedding planes, and small passageways. It was determined during prior investigations that discharge measurements of individual water sources within the cavern would be problematic, if not impossible. The outer edge of this spring vent provided the best location for an underwater discharge measurement with an appropriately adapted instrument.

PERSONNEL

Fieldwork for this discharge measurement was conducted by KES personnel Peter Butt, Tom Morris and Jytka Hyniova. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech-HAI of Orlando, Florida.

METHODS

<u>Instrumentation</u>

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter.

One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

Field Operations

Velocity measurements were taken just inside the ceiling edge of the vent. At the measurement site, the floor of the vent was 32 feet deep, and the ceiling was 26 feet deep.

A positioning grid of telescoping aluminum poles with 0.5-foot interval markings that provided support for the sensor was set up by Pete Butt. Butt also recorded measurements of the grid and surrounding walls. Seventeen poles were positioned vertically to provide the primary positioning grid for velocity measurements. Eight horizontal poles were used as a spacing reference, and fastened to the vertical poles for support. Conduit dimensions around the grid were measured with a collapsible steel tape. As all sensor-support poles were positioned at roughly right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was attached to the poles with a low-profile metal spring clamp. Most measurement stations were set using one-foot intervals on the vertical poles. Velocity stations and boundary points are identified with alpha-numeric labels, based on the letter assigned to identify each vertical pole. See Figure 2.

Tom Morris positioned the sensor and recorded positional data. Jytka Hyniova took the velocity readings after taking reset cues from Morris, and also recorded positional data. During all measurements, the sensor handler was able to move away from the measurement cross-section, and remove himself from the cross section of the flow. The meter operator was also positioned downstream and away from the cross-section. This minimized or eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in the "Fixed Point Averaging" mode. Fixed Point Averaging is an average of velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. One-hundred and thirty-eight (138) station readings were made.

Data Processing

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figure 1. Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Table 3. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift, an anisotropy ratio of 3 at an angle of 0°, and a variogram slope of 1.0. The anisotropy ratio used was selected due to the extremely elongated horizontal aspect of the measurement cross-section. The results of the contour processing are illustrated in Figures 3 and 4.

During this measurement, eight negative velocities were measured. These negative velocity stations represent slight back eddies near walls. In order to incorporate these negative values, calculations were made using a Surfer 8 "blanking file" operation to define the measurement cross-section boundary. The blanking file operation also assists in the elimination of artifacts present in the contouring process that would create inaccuracies in the flow calculations.

The total discharge is shown on Table 2 as the **Net Volume (Cut-Fill)**, and has been calculated as the Positive Volume (Cut) less that portion of the Negative Volume (Fill) lying within the measurement cross-section boundary walls that define the plane of measurement.

The software also calculates the total cross-sectional area of the measurement location within the passage, and is presented on page 1 of Table 2 as the **Operational Planar Area**. The Operational Planar Area is the sum of the Positive (Cut) and that portion of the Negative (Fill) Planar areas lying within the measurement cross-section boundary walls that define the plane of measurement.

RESULTS AND DISCUSSION

This measurement is the second one performed at Mammoth Spring applying the method and data processing used at other spring sites by KES. This measurement also represents the largest cross-section and amount of discharge measured to date by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. Based on results of the prior measurement performed here, additional velocity station readings close to the boundary walls of the cross-section were made to provide the additional data needed for Surfer to more accurately account for the higher flows present near the boundary edge and adjust the contours more appropriately. Due to the extremely elongated cross-section, a high anisotropy ratio setting was used to minimize a "bull's eye" or "curtain" effect that occurs in the contouring and has the unwanted effect of lowering the actual discharge value.

The estimated discharge of Mammoth Spring on September 19, 2006 was 240.07 CFS (cubic feet per second). This result is also expressed as 107,750 GPM (gallons per minute) or 155.16 MGD (million gallons per day), see Table 1. One-hundred and thirty-eight (138) readings were made, see Figures 2, 3 and 4. The point velocity readings ranged from -0.39 to 1.16 feet per second (fps), with an overall average station reading of 0.71 fps. The total cross-sectional area was calculated as 308.16 square feet. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 13:40 hours and were completed by 17:50 hours.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	SILVER SPRINGS MAIN SPRING			Marion County, Florida	
Personnel:	Peter Butt, Tom Morris, Jytka Hyniova				
Method:	Grid within irregular conduit/cross-section				
Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles				
Analysis Method: Surfer 8 with kriging					
Silver Springs Main Spring Total Discharge:			**Date:**	**September 19, 2006**	
CFS	**240.07**		Time Start:	13:40	
MGD	**155.160**		Time End:	17:50	
GPM	**107750**				
Total Cross-sectional Area:		308.16	square feet		
Avg. Station Point Velocity:		0.71	feet/second		
Cross-section Depth:		26-32	feet deep		
Msmt. Periods:		60 seconds			
Velocity Reading by Station:		(All velocity readings in feet per second.)			
Station #	Point Velocity	Station #	Point Velocity	Station #	Point Velocity
A1	0.18	F7	0.92	L1	0.68
A2	0.25	FG	0.95	L2	0.8
A3	0.59	G1	0.03	L3	0.91
A4	0.47	G2	0.81	L4	1
A5	0.53	G3	1	L5	0.99
AH1	-0.07	G4	1.01	L6	1
AH2	-0.03	G5	0.92	L7	1.03
AB	0.35	G6	1.09	L8	0.88
B1	-0.39	GH	0.93	LM	0.89
B2	-0.4	H1	0.2	M1	-0.07
B3	-0.04	H2	0.77	M2	0.26
B4	0.11	H3	0.85	M3	0.68
B5	0.27	H4	0.88	M4	0.78
B6	0.83	H5	1	M5	0.91
B7	0.85	H6	1.08	M6	0.96
B8	0.5	H7	1.04	M7	1.04
BC	0.68	HI	0.98	M8	1.07
C1	0.56	I1	0.07	MN	0.91
C2	0.81	I2	0.39	N1	0.05
C3	0.93	I3	0.92	N2	0.53
C4	0.91	I4	0.86	N3	0.76
C5	1.16	I5	0.96	N4	0.99
C6	0.96	I6	0.97	N5	0.98
CD	0.99	I7	0.96	N6	0.97
D1	0.65	I8	0.72	N7	1.02
D2	0.76	IJ	0.85	N8	0.88
D3	0.86	J1	0.22	NO	0.79
D4	0.96	J2	0.39	O1	0.31
D5	1.07	J3	0.59	O2	0.66
D6	1.02	J4	0.72	O3	0.92
D7	1.01	J5	1.16	O4	0.95
DE	1.05	J6	0.85	O5	0.9
E1	0.32	J7	0.99	OP	0.9
E2	0.69	J8	1.01	P1	0.52
E3	0.86	J9	0.98	P2	0.76
E4	0.78	JK	0.83	P3	0.9
E5	0.84	K1	-0.02	P4	0.6
E6	1	K2	0.38	P5	0.84
E7	0.95	K3	0.71	PQ	0.42
EF	0.89	K4	0.71	Q1	0.2
F1	-0.02	K5	0.87	Q2	0.27
F2	0.76	K6	0.94	Q3	0.4
F3	0.92	K7	1.01	Q4	0.32
F4	0.93	K8	1.03	Q5	0.34
F5	1.07	K9	1.14	QH1	0.25
F6	0.99	KL	0.9	QH2	0.2

Table 1. Discharge of Mammoth Spring, Marion County, Florida on September 19, 2006. Data record and calculation of discharge measurement.

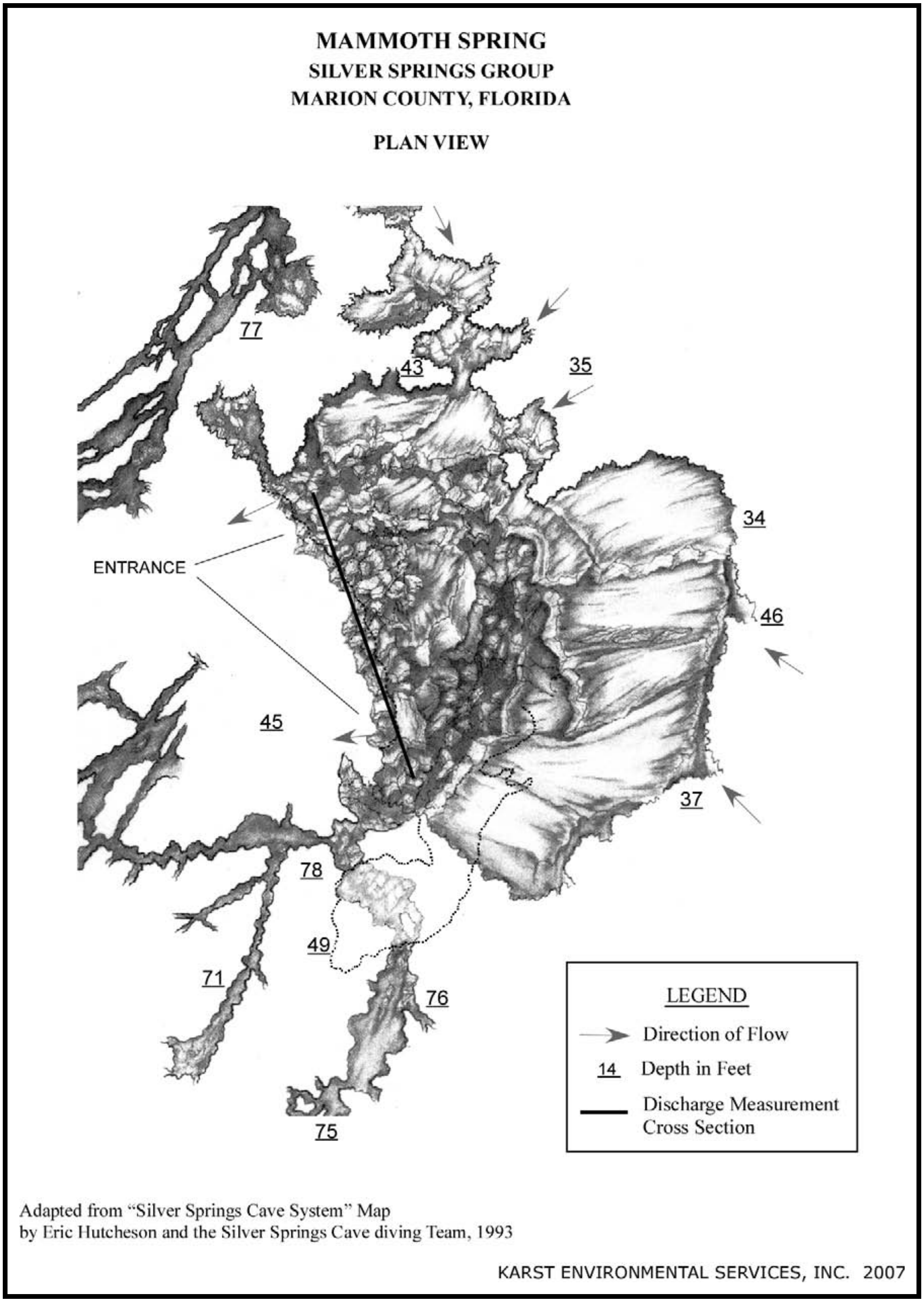

Figure 1. Map of Mammoth Spring.

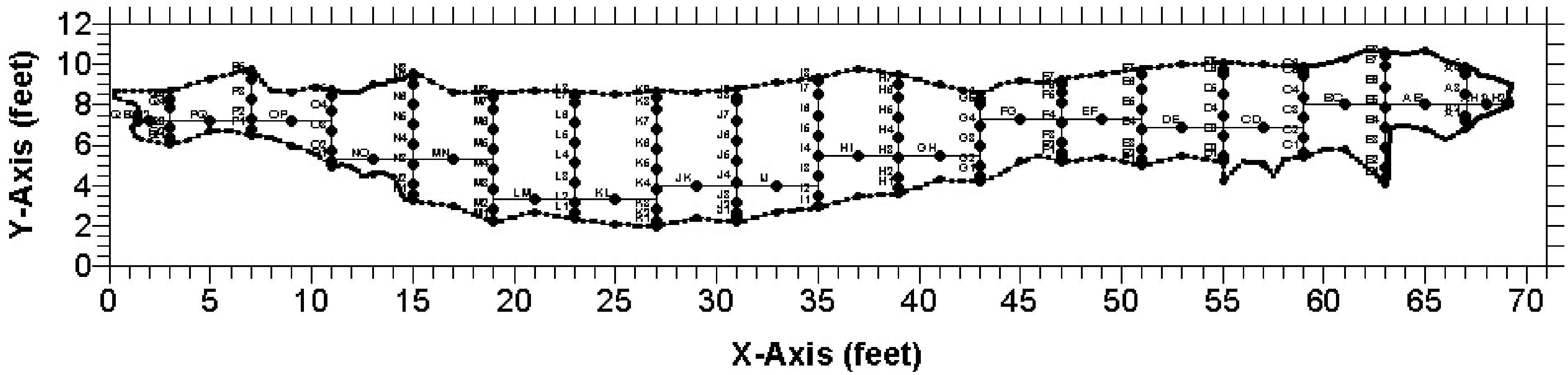

Figure 2. Discharge measurement cross-section; Mammoth Spring, Marion County, Florida, September 19, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located between the 26- and 32-foot depth levels. Support poles are represented by dashed lines. Velocity measurement stations are shown as points along the support poles. See Table 1 for station velocities. Boundary wall of the cross section is shown as the perimeter ring of connected points. X- and Y-axis scales are shown in feet.

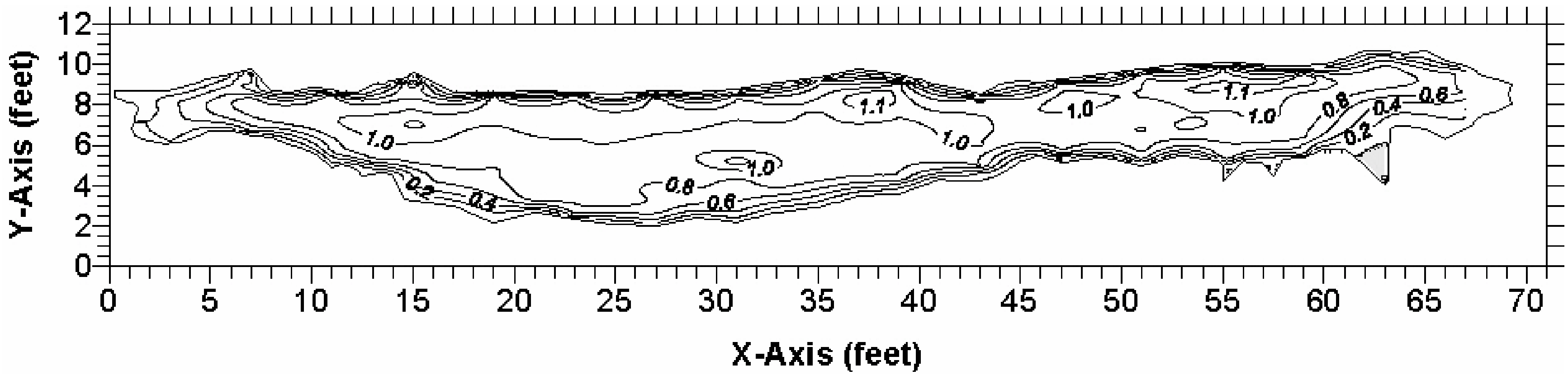

Figure 3. Discharge measurement cross-section; Mammoth Spring, Marion County, Florida, September 19, 2006 measurement. Flow contour velocities are shown in feet per second. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

TABLE 2. MAMMOTH SPRING, SEPTEMBER 19, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\SS_Main\SilverSpringMain-0906.bln.grd
Grid Size:	61 rows x 351 columns
X Minimum:	0
X Maximum:	70
X Spacing:	0.2
Y Minimum:	0
Y Maximum:	12
Y Spacing:	0.2
Z Minimum:	-0.39000000071826
Z Maximum:	1.1600000013049

LOWER SURFACE

Level Surface defined by Z = 0

VOLUMES

Z Scale Factor:	1
Total Volumes by:	
Trapezoidal Rule:	240.06792644883
Simpson's Rule:	240.00517156312
Simpson's 3/8 Rule:	239.94186683411

CUT & FILL VOLUMES

Positive Volume [Cut]:	240.15113319567
Negative Volume [Fill]:	0.083206746841645
Net Volume [Cut-Fill]:	**240.06792644883<<<<<<Total Discharge in CFS**

(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS

Planar Areas

Operational Planar Area: 308.16 <<<<Total Cross-section Area in Square Feet

(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)

Positive Planar Area [Cut]:	306.68517561951
Negative Planar Area [Fill]:	1.474824380489
Blanked Planar Area:	531.84
Total Planar Area:	840

Surface Areas

Positive Surface Area [Cut]:	349.2420271661
Negative Surface Area [Fill]:	1.6275387805188

GRIDDING REPORT

Data Source

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\SS_Main\Silver Spring Main 9-06 SURFER XYZ T3 BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	750
Original Data:	750
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.3	2	-0.4
25%-tile:	17.2	5.01	0
Median:	37.2	7.25	0
75%-tile:	57.3334	9	0
Maximum:	69.3	10.7	1.16
Midrange:	34.8	6.35	0.38
Range:	69	8.7	1.56
Interquartile Range:	40.1334	3.99	0
Median Abs. Deviation:	20	1.99	0
Mean:	37.098293613333	6.89148464	0.13104
Trim Mean (10%):	37.301583150888	6.9555524852071	0.090976331360947
Standard Deviation:	21.485960669933	2.4746796394004	0.31325897443915
Variance:	461.6465059099	6.124039317663	0.098131185066667
Coef. of Variation:			2.3905599392487
Coef. of Skewness:			2.078037077697

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.172	-0.052
Y:		1.000	-0.003
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	461.6465059099	9.1257214708366	-0.3513203950912
Y:		6.124039317663	-0.0020914805589333
Z:			0.098131185066667

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-0.00077715760043612	0.0008165596238364	0.1542439127395
Standard Error:	0.00054072917911662	0.004694783797712	0.036843060637724

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.172	-0.394
B:		1.000	0.785
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.20349262249117	0.10174631124558	1.0356
Residual:	747	73.394896177509	0.098252873062261	
Total:	749	73.5983888		

Coefficient of Multiple Determination (R^2): 0.0027649059416797

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.05	0
25%-tile:	0.200249843945	0
Median:	0.20223748416157	0
75%-tile:	0.25	0
Maximum:	2.0155644370746	1.14

Midrange:	1.0327822185373	0.57
Range:	1.9655644370746	1.14
Interquartile Range:	0.049750156054996	0
Median Abs. Deviation:	0.013169108123813	0
Mean:	0.28909959535923	0.07332
Trim Mean (10%):	0.24958089885178	0.031701183431953
Standard Deviation:	0.27084799622358	0.21272277170063
Variance:	0.073358637058327	0.0452509776
Coef. of Variation:	0.93686743451516	2.9012925763862
Coef. of Skewness:	3.2902711963084	3.331410372399
Root Mean Square:	0.39615301727388	0.22500399996445
Mean Square:	0.1569372130952	0.0506268

Complete Spatial Randomness

Lambda:	1.2493753123438
Clark and Evans:	0.64628479648316
Skellam:	923.97450475025

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 8.2E-006
Y Duplicate Tolerance: 1E-006
No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point
Polynomial Drift Order: 2
Kriging std. deviation grid: no

Semi-Variogram Model

Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 3
Variogram Slope: 1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\SS_Main\SilverSpringMain-0906.grd
Grid Size:	61 rows x 351 columns
Total Nodes:	21411
Filled Nodes:	21411
Blanked Nodes:	0

Grid Geometry

X Minimum:	0
X Maximum:	70
X Spacing:	0.2
Y Minimum:	0
Y Maximum:	12
Y Spacing:	0.2

Grid Statistics

Z Minimum:	-4.0870627657804
Z 25%-tile:	-1.4759114144108
Z Median:	-0.31733645004242
Z 75%-tile:	0.7104002992699
Z Maximum:	1.1600000013049
Z Midrange:	-1.4635313822378
Z Range:	5.2470627670853
Z Interquartile Range:	2.1863117136807
Z Median Abs. Deviation:	1.0777507785677
Z Mean:	-0.53115562257292
Z Trim Mean (10%):	-0.4690794712427
Z Standard Deviation:	1.2764266925575
Z Variance:	1.6292651014732
Z Coef. of Variation:	-1
Z Coef. of Skewness:	-0.52088718331664
Z Root Mean Square:	1.3825307941829
Z Mean Square:	1.911391396864

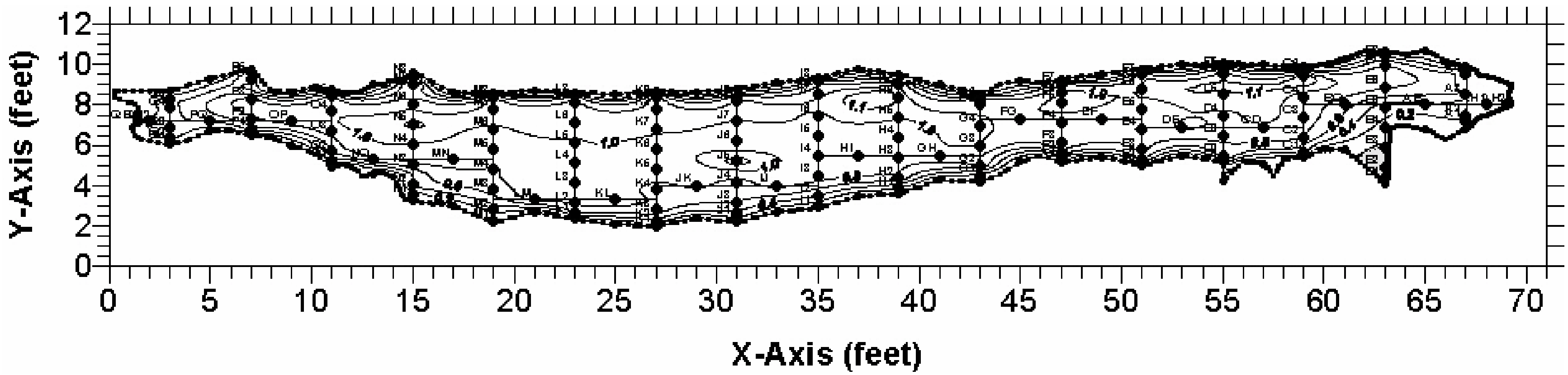

Figure 4. Discharge measurement cross-section; Mammoth Spring, Marion County, Florida, September 19, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (labeled points) are shown. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. See Table 1 for station velocities. Boundary wall of the cross section is shown as the perimeter ring of connected points. X- and Y-axis scales are shown in feet.

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Table 3. Mammoth Spring XYZ Grid Data, September 19, 2006.					
(Minor boundary points have been edited for processing in Surfer.)					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
67	**7.25**	**0.18**	**A1**	670	72.5
67	**7.5**	**0.25**	**A2**	670	75
67	**8.5**	**0.59**	**A3**	670	85
67	**9.5**	**0.47**	**A4**	670	95
67	**9.7**	**0.53**	**A5**	670	97
68	**8**	**-0.07**	**AH1**	680	80
69	**8**	**-0.03**	**AH2**	690	80
65	**8**	**0.35**	**AB**	650	80
63	**4.4**	**-0.39**	**B1**	630	44
63	**4.9**	**-0.4**	**B2**	630	49
63	**5.9**	**-0.04**	**B3**	630	59
63	**6.9**	**0.11**	**B4**	630	69
63	**7.9**	**0.27**	**B5**	630	79
63	**8.9**	**0.83**	**B6**	630	89
63	**9.9**	**0.85**	**B7**	630	99
63	**10.4**	**0.5**	**B8**	630	104
61	**8**	**0.68**	**BC**	610	80
59	**5.65**	**0.56**	**C1**	590	56.5
59	**6.4**	**0.81**	**C2**	590	64
59	**7.4**	**0.93**	**C3**	590	74
59	**8.4**	**0.91**	**C4**	590	84
59	**9.4**	**1.16**	**C5**	590	94
59	**9.7**	**0.96**	**C6**	590	97
57	**6.9**	**0.99**	**CD**	570	69
55	**5.25**	**0.65**	**D1**	550	52.5
55	**5.5**	**0.76**	**D2**	550	55
55	**6.5**	**0.86**	**D3**	550	65
55	**7.5**	**0.96**	**D4**	550	75
55	**8.5**	**1.07**	**D5**	550	85
55	**9.5**	**1.02**	**D6**	550	95
55	**9.8**	**1.01**	**D7**	550	98
53	**6.9**	**1.05**	**DE**	530	69
51	**5.05**	**0.32**	**E1**	510	50.5
51	**5.3**	**0.69**	**E2**	510	53
51	**5.8**	**0.86**	**E3**	510	58
51	**6.8**	**0.78**	**E4**	510	68
51	**7.8**	**0.84**	**E5**	510	78
51	**8.8**	**1**	**E6**	510	88
51	**9.5**	**0.95**	**E7**	510	95
49	**7.3**	**0.89**	**EF**	490	73

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
47	**5.4**	**-0.02**	**F1**	470	54
47	**5.65**	**0.76**	**F2**	470	56.5
47	**6.15**	**0.92**	**F3**	470	61.5
47	**7.15**	**0.93**	**F4**	470	71.5
47	**8.15**	**1.07**	**F5**	470	81.5
47	**8.65**	**0.99**	**F6**	470	86.5
47	**9.05**	**0.92**	**F7**	470	90.5
45	**7.3**	**0.95**	**FG**	450	73
43	**4.5**	**0.03**	**G1**	430	45
43	**5**	**0.81**	**G2**	430	50
43	**6**	**1**	**G3**	430	60
43	**7**	**1.01**	**G4**	430	70
43	**8**	**0.92**	**G5**	430	80
43	**8.3**	**1.09**	**G6**	430	83
41	**5.5**	**0.93**	**GH**	410	55
39	**3.9**	**0.2**	**H1**	390	39
39	**4.4**	**0.77**	**H2**	390	44
39	**5.4**	**0.85**	**H3**	390	54
39	**6.4**	**0.88**	**H4**	390	64
39	**7.4**	**1**	**H5**	390	74
39	**8.4**	**1.08**	**H6**	390	84
39	**9**	**1.04**	**H7**	390	90
37	**5.5**	**0.98**	**HI**	370	55
35	**3**	**0.07**	**I1**	350	30
35	**3.5**	**0.39**	**I2**	350	35
35	**4.5**	**0.92**	**I3**	350	45
35	**5.5**	**0.86**	**I4**	350	55
35	**6.5**	**0.96**	**I5**	350	65
35	**7.5**	**0.97**	**I6**	350	75
35	**8.5**	**0.96**	**I7**	350	85
35	**9.2**	**0.72**	**I8**	350	92
33	**4**	**0.85**	**IJ**	330	40
31	**2.45**	**0.22**	**J1**	310	24.5
31	**2.7**	**0.39**	**J2**	310	27
31	**3.2**	**0.59**	**J3**	310	32
31	**4.2**	**0.72**	**J4**	310	42
31	**5.2**	**1.16**	**J5**	310	52
31	**6.2**	**0.85**	**J6**	310	62
31	**7.2**	**0.99**	**J7**	310	72
31	**8.2**	**1.01**	**J8**	310	82
31	**8.4**	**0.98**	**J9**	310	84
29	**4**	**0.83**	**JK**	290	40
27	**2.05**	**-0.02**	**K1**	270	20.5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
27	**2.3**	**0.38**	**K2**	270	23
27	**2.8**	**0.71**	**K3**	270	28
27	**3.8**	**0.71**	**K4**	270	38
27	**4.8**	**0.87**	**K5**	270	48
27	**5.8**	**0.94**	**K6**	270	58
27	**6.8**	**1.01**	**K7**	270	68
27	**7.8**	**1.03**	**K8**	270	78
27	**8.4**	**1.14**	**K9**	270	84
25	**3.3**	**0.9**	**KL**	250	33
23	**2.65**	**0.68**	**L1**	230	26.5
23	**3.15**	**0.8**	**L2**	230	31.5
23	**4.15**	**0.91**	**L3**	230	41.5
23	**5.15**	**1**	**L4**	230	51.5
23	**6.15**	**0.99**	**L5**	230	61.5
23	**7.15**	**1**	**L6**	230	71.5
23	**8.15**	**1.03**	**L7**	230	81.5
23	**8.45**	**0.88**	**L8**	230	84.5
21	**3.3**	**0.89**	**LM**	210	33
19	**2.3**	**-0.07**	**M1**	190	23
19	**2.8**	**0.26**	**M2**	190	28
19	**3.8**	**0.68**	**M3**	190	38
19	**4.8**	**0.78**	**M4**	190	48
19	**5.8**	**0.91**	**M5**	190	58
19	**6.8**	**0.96**	**M6**	190	68
19	**7.8**	**1.04**	**M7**	190	78
19	**8.4**	**1.07**	**M8**	190	84
17	**5.3**	**0.91**	**MN**	170	53
15	**3.55**	**0.05**	**N1**	150	35.5
15	**4.05**	**0.53**	**N2**	150	40.5
15	**5.05**	**0.76**	**N3**	150	50.5
15	**6.05**	**0.99**	**N4**	150	60.5
15	**7.05**	**0.98**	**N5**	150	70.5
15	**8.05**	**0.97**	**N6**	150	80.5
15	**9.05**	**1.02**	**N7**	150	90.5
15	**9.45**	**0.88**	**N8**	150	94.5
13	**5.3**	**0.79**	**NO**	130	53
11	**5.25**	**0.31**	**O1**	110	52.5
11	**5.7**	**0.66**	**O2**	110	57
11	**6.7**	**0.92**	**O3**	110	67
11	**7.7**	**0.95**	**O4**	110	77
11	**8.45**	**0.9**	**O5**	110	84.5
9	**7.2**	**0.9**	**OP**	90	72
7	**6.8**	**0.52**	**P1**	70	68
7	**7.3**	**0.76**	**P2**	70	73

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
7	**8.3**	**0.9**	**P3**	70	83
7	**9.3**	**0.6**	**P4**	70	93
7	**9.6**	**0.84**	**P5**	70	96
5	**7.2**	**0.42**	**PQ**	50	72
3	**6.15**	**0.2**	**Q1**	30	61.5
3	**6.35**	**0.27**	**Q2**	30	63.5
3	**6.85**	**0.4**	**Q3**	30	68.5
3	**7.85**	**0.32**	**Q4**	30	78.5
3	**8.25**	**0.34**	**Q5**	30	82.5
1.4	**7.2**	**0.25**	**QH1**	14	72
2	**7.2**	**0.2**	**QH2**	20	72
67	**9.9**	**0**	**AT**	670	99
67	**6.8**	**0**	**AS**	670	68
63	**10.65**	**0**	**BT**	630	106.5
63	**4.1**	**0**	**BS**	630	41
59	**9.9**	**0**	**CT**	590	99
59	**5.4**	**0**	**CS**	590	54
55	**10.1**	**0**	**DT**	550	101
55	**4.25**	**0**	**DS**	550	42.5
51	**9.8**	**0**	**ET**	510	98
51	**5**	**0**	**ES**	510	50
47	**9.25**	**0**	**FT**	470	92.5
47	**5.15**	**0**	**FS**	470	51.5
43	**8.55**	**0**	**GT**	430	85.5
43	**4.2**	**0**	**GS**	430	42
39	**9.5**	**0**	**HT**	390	95
39	**3.6**	**0**	**HS**	390	36
35	**9.35**	**0**	**IT**	350	93.5
35	**2.9**	**0**	**IS**	350	29
31	**8.8**	**0**	**JT**	310	88
31	**2.2**	**0**	**JS**	310	22
27	**8.7**	**0**	**KT**	270	87
27	**2**	**0**	**KS**	270	20
23	**8.65**	**0**	**LT**	230	86.5
23	**2.35**	**0**	**LS**	230	23.5
19	**8.6**	**0**	**MT**	190	86
19	**2.2**	**0**	**MS**	190	22
15	**9.6**	**0**	**NT**	150	96
15	**3.25**	**0**	**NS**	150	32.5
11	**8.75**	**0**	**OT**	110	87.5
11	**4.9**	**0**	**OS**	110	49
7	**9.8**	**0**	**PT**	70	98
7	**6.5**	**0**	**PS**	70	65
3	**8.7**	**0**	**QT**	30	87
3	**6.05**	**0**	**QS**	30	60.5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
65	**10.7**	**0**	**ABT**	650	107
65	**6.8**	**0**	**ABS**	650	68
61	**10.3**	**0**	**BCT**	610	103
61	**5.8**	**0**	**BCS**	610	58
57	**10**	**0**	**CDT**	570	100
57	**5.1**	**0**	**CDS**	570	51
53	**10**	**0**	**DET**	530	100
53	**5.5**	**0**	**DES**	530	55
49	**9.5**	**0**	**EFT**	490	95
49	**5.4**	**0**	**EFS**	490	54
45	**9.2**	**0**	**FGT**	450	92
45	**5.2**	**0**	**FGS**	450	52
41	**9**	**0**	**GHT**	410	90
41	**4.3**	**0**	**GHS**	410	43
37	**9.8**	**0**	**HIT**	370	98
37	**3.5**	**0**	**HIS**	370	35
33	**9.1**	**0**	**IJT**	330	91
33	**2.7**	**0**	**IJS**	330	27
29	**8.6**	**0**	**JKT**	290	86
29	**2.4**	**0**	**JKS**	290	24
25	**8.5**	**0**	**KLT**	250	85
25	**2.1**	**0**	**KLS**	250	21
21	**8.7**	**0**	**LMT**	210	87
21	**2.7**	**0**	**LMS**	210	27
17	**8.6**	**0**	**MNT**	170	86
17	**3**	**0**	**MNS**	170	30
13	**9**	**0**	**NOT**	130	90
13	**4.55**	**0**	**NOS**	130	45.5
9	**8.65**	**0**	**OPT**	90	86.5
9	**6**	**0**	**OPS**	90	60
5	**9.3**	**0**	**PQT**	50	93
5	**6.7**	**0**	**PQS**	50	67
64	**10.5**	**0**	**ABTA**	640	105
66	**10.2**	**0**	**ABTB**	660	102
63.2	**4.4**	**0**	**ABSA**	632	44
63.15	**4.9**	**0**	**ABSB**	631.5	49
63.15	**5.4**	**0**	**ABSC**	631.5	54
63.2	**5.9**	**0**	**ABSD**	632	59
63.25	**6.4**	**0**	**ABSE**	632.5	64
63.3	**6.9**	**0**	**ABSF**	633	69
64	**7**	**0**	**ABSG**	640	70
66	**6.3**	**0**	**ABSH**	660	63
60	**10**	**0**	**BCTA**	600	100
62	**10.7**	**0**	**BCTB**	620	107
60	**5.8**	**0**	**BCSA**	600	58
62	**5**	**0**	**BCSB**	620	50
56	**5.2**	**0**	**CDSA**	560	52

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
57.5	**4.5**	**0**	**CDSB**	575	45
58	**5.3**	**0**	**CDSC**	580	53
44	**9**	**0**	**FGTA**	440	90
46	**9.1**	**0**	**FGTB**	460	91
44	**4.6**	**0**	**FGSA**	440	46
46	**5.5**	**0**	**FGSB**	460	55
11.5	**8.6**	**0**	**NOTA**	115	86
12	**8.6**	**0**	**NOTB**	120	86
12.5	**8.7**	**0**	**NOTC**	125	87
13.5	**9**	**0**	**NOTD**	135	90
14	**9.2**	**0**	**NOTE**	140	92
14.5	**9.3**	**0**	**NOTF**	145	93
11.5	**5.05**	**0**	**NOSA**	115	50.5
12	**4.9**	**0**	**NOSB**	120	49
12.5	**4.5**	**0**	**NOSC**	125	45
13.5	**4.65**	**0**	**NOSD**	135	46.5
14	**4.5**	**0**	**NOSE**	140	45
14.5	**3.5**	**0**	**NOSF**	145	35
7.9	**8.8**	**0**	**OPTA**	79	88
8	**8.7**	**0**	**OPTB**	80	87
10	**8.9**	**0**	**OPTC**	100	89
8	**6.35**	**0**	**OPSA**	80	63.5
10	**5.65**	**0**	**OPSB**	100	56.5
4	**6.3**	**0**	**PQSA**	40	63
6	**6.7**	**0**	**PQSB**	60	67
67.3	**7**	**0**	**AV1**	673	70
67.5	**7.3**	**0**	**AV2**	675	73
67.9	**7.5**	**0**	**AV3**	679	75
68	**7.5**	**0**	**AV4**	680	75
68.5	**7.7**	**0**	**AV5**	685	77
69	**7.9**	**0**	**AV6**	690	79
69.3	**8**	**0**	**AV7**	693	80
69.1	**8.5**	**0**	**AV8**	691	85
69.3	**9**	**0**	**AV9**	693	90
69	**9.1**	**0**	**AV10**	690	91
68.5	**9.3**	**0**	**AV11**	685	93
68	**9.4**	**0**	**AV12**	680	94
67.6	**9.5**	**0**	**AV13**	676	95
67.5	**9.7**	**0**	**AV14**	675	97
1.45	**6.35**	**0**	**QV1**	14.5	63.5
1.1	**6.85**	**0**	**QV2**	11	68.5
1.25	**7.2**	**0**	**QV3**	12.5	72
1.25	**7.35**	**0**	**QV4**	12.5	73.5
1.4	**7.85**	**0**	**QV5**	14	78.5
1.3	**8.05**	**0**	**QV6**	13	80.5
0.3	**8.35**	**0**	**QV7**	3	83.5

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
0.3	**8.7**	**0**	**QV8**	3	87
67.1	**6.86667**	**0**	**AE1**	671	68.6667
67.2	**6.93334**	**0**	**AE2**	672	69.3334
67.3667	**7.1**	**0**	**AE3**	673.6667	71
67.4333	**7.2**	**0**	**AE4**	674.3334	72
67.6	**7.35**	**0**	**AE5**	676	73.5
67.7	**7.4**	**0**	**AE6**	677	74
67.8	**7.45**	**0**	**AE7**	678	74.5
68.1	**7.54**	**0**	**AE8**	681	75.4
68.2	**7.58**	**0**	**AE9**	682	75.8
68.3	**7.62**	**0**	**AE10**	683	76.2
68.4	**7.66**	**0**	**AE11**	684	76.6
68.6	**7.74**	**0**	**AE12**	686	77.4
68.7	**7.78**	**0**	**AE13**	687	77.8
68.8	**7.82**	**0**	**AE14**	688	78.2
68.9	**7.86**	**0**	**AE15**	689	78.6
69.1	**7.9333**	**0**	**AE16**	691	79.333
69.2	**7.96666**	**0**	**AE17**	692	79.6666
69.26	**8.1**	**0**	**AE18**	692.6	81
69.22	**8.2**	**0**	**AE19**	692.2	82
69.18	**8.3**	**0**	**AE20**	691.8	83
69.14	**8.4**	**0**	**AE21**	691.4	84
69.14	**8.6**	**0**	**AE22**	691.4	86
69.18	**8.7**	**0**	**AE23**	691.8	87
69.22	**8.8**	**0**	**AE24**	692.2	88
69.26	**8.9**	**0**	**AE25**	692.6	89
69.2	**9.03333**	**0**	**AE26**	692	90.3333
69.1	**9.06666**	**0**	**AE27**	691	90.6666
68.9	**9.14**	**0**	**AE28**	689	91.4
68.8	**9.18**	**0**	**AE29**	688	91.8
68.7	**9.22**	**0**	**AE30**	687	92.2
68.6	**9.26**	**0**	**AE31**	686	92.6
68.4	**9.32**	**0**	**AE32**	684	93.2
68.3	**9.34**	**0**	**AE33**	683	93.4
68.2	**9.36**	**0**	**AE34**	682	93.6
68.1	**9.38**	**0**	**AE35**	681	93.8
67.9	**9.425**	**0**	**AE36**	679	94.25
67.8	**9.45**	**0**	**AE37**	678	94.5
67.7	**9.475**	**0**	**AE38**	677	94.75
67.55	**9.6**	**0**	**AE39**	675.5	96
67.4	**9.74**	**0**	**AE40**	674	97.4
67.3	**9.78**	**0**	**AE41**	673	97.8
67.2	**9.82**	**0**	**AE42**	672	98.2
67.1	**9.86**	**0**	**AE43**	671	98.6
2.8	**6.09**	**0**	**QE1**	28	60.9
2.4	**6.17**	**0**	**QE3**	24	61.7

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
2	6.25	0	QE5	20	62.5
1.6	6.33	0	QE7	16	63.3
1.3	6.5	0	QE8	13	65
1.15	6.7	0	QE9	11.5	67
1.15	7	0	QE10	11.5	70
1.35	7.5	0	QE11	13.5	75
1.45	7.7	0	QE12	14.5	77
1.1	8.1	0	QE13	11	81
0.9	8.15	0	QE14	9	81.5
0.5	8.25	0	QE16	5	82.5
0.3	8.5	0	QE17	3	85
0.4	8.7	0	QE18	4	87
0.8	8.7	0	QE20	8	87
1.2	8.7	0	QE22	12	87
1.6	8.7	0	QE24	16	87
2	8.7	0	QE26	20	87
2.4	8.7	0	QE28	24	87
2.8	8.7	0	QE30	28	87
66.8	6.7	0	ABS1	668	67
66.6	6.6	0	ABS2	666	66
66.4	6.5	0	ABS3	664	65
66.2	6.4	0	ABS4	662	64
65.8	6.4	0	ABS5	658	64
65.6	6.5	0	ABS6	656	65
65.4	6.6	0	ABS7	654	66
65.2	6.7	0	ABS8	652	67
64.8	6.84	0	ABS9	648	68.4
64.6	6.88	0	ABS10	646	68.8
64.4	6.92	0	ABS11	644	69.2
64.2	6.96	0	ABS12	642	69.6
63.8	6.97142	0	ABS13	638	69.7142
63.6	6.94284	0	ABS14	636	69.4284
63.4	6.91426	0	ABS15	634	69.1426
63.28	6.8	0	ABS16	632.8	68
63.26	6.6	0	ABS17	632.6	66
63.23	6.2	0	ABS18	632.3	62
63.21	6	0	ABS19	632.1	60
63.18	5.7	0	ABS20	631.8	57
63.16	5.5	0	ABS21	631.6	55
63.15	5.2	0	ABS22	631.5	52
63.15	5	0	ABS23	631.5	50
63.17	4.7	0	ABS24	631.7	47
63.19	4.5	0	ABS25	631.9	45
63.1	4.25	0	ABS26	631	42.5
62.8	4.28	0	BCS1	628	42.8
62.6	4.46	0	BCS2	626	44.6

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
62.4	**4.64**	**0**	**BCS3**	624	46.4
62.2	**4.82**	**0**	**BCS4**	622	48.2
61.8	**5.16**	**0**	**BCS5**	618	51.6
61.6	**5.32**	**0**	**BCS6**	616	53.2
61.4	**5.48**	**0**	**BCS7**	614	54.8
61.2	**5.64**	**0**	**BCS8**	612	56.4
60.8	**5.8**	**0**	**BCS9**	608	58
60.4	**5.8**	**0**	**BCS11**	604	58
60.2	**5.8**	**0**	**BCS12**	602	58
59.8	**5.72**	**0**	**BCS13**	598	57.2
59.4	**5.56**	**0**	**BCS15**	594	55.6
59.2	**5.48**	**0**	**BCS16**	592	54.8
58.8	**5.38**	**0**	**CDS1**	588	53.8
58.6	**5.36**	**0**	**CDS2**	586	53.6
58.2	**5.32**	**0**	**CDS4**	582	53.2
57.875	**5.1**	**0**	**CDS5**	578.75	51
57.75	**4.9**	**0**	**CDS6**	577.5	49
57.625	**4.7**	**0**	**CDS7**	576.25	47
57.3334	**4.7**	**0**	**CDS8**	573.334	47
57.1668	**4.9**	**0**	**CDS9**	571.668	49
56.8	**5.12**	**0**	**CDS10**	568	51.2
56.6	**5.14**	**0**	**CDS11**	566	51.4
56.4	**5.16**	**0**	**CDS12**	564	51.6
56.2	**5.18**	**0**	**CDS13**	562	51.8
55.8	**5.01**	**0**	**CDS14**	558	50.1
55.6	**4.82**	**0**	**CDS15**	556	48.2
55.4	**4.63**	**0**	**CDS16**	554	46.3
55.2	**4.44**	**0**	**CDS17**	552	44.4
55.1	**4.3**	**0**	**CDS18**	551	43
55	**4.4**	**0**	**DES1**	550	44
55	**4.6**	**0**	**DES2**	550	46
55	**5**	**0**	**DES4**	550	50
54.8	**5.23**	**0**	**DES5**	548	52.3
54.6	**5.26**	**0**	**DES6**	546	52.6
54.2	**5.32**	**0**	**DES8**	542	53.2
54	**5.35**	**0**	**DES9**	540	53.5
53.6	**5.41**	**0**	**DES11**	536	54.1
53.2	**5.47**	**0**	**DES13**	532	54.7
52.8	**5.45**	**0**	**DES14**	528	54.5
52.4	**5.35**	**0**	**DES16**	524	53.5
52	**5.25**	**0**	**DES18**	520	52.5
51.8	**5.2**	**0**	**DES19**	518	52
51.4	**5.1**	**0**	**DES21**	514	51
51.2	**5.05**	**0**	**DES22**	512	50.5
50.8	**5.04**	**0**	**EFS1**	508	50.4

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
50.6	**5.08**	**0**	**EFS2**	506	50.8
50.2	**5.16**	**0**	**EFS4**	502	51.6
50	**5.2**	**0**	**EFS5**	500	52
49.6	**5.28**	**0**	**EFS7**	496	52.8
49.2	**5.36**	**0**	**EFS9**	492	53.6
48.8	**5.375**	**0**	**EFS10**	488	53.75
48.4	**5.325**	**0**	**EFS12**	484	53.25
48	**5.275**	**0**	**EFS14**	480	52.75
47.8	**5.25**	**0**	**EFS15**	478	52.5
47.4	**5.2**	**0**	**EFS17**	474	52
47.2	**5.175**	**0**	**EFS18**	472	51.75
46.8	**5.22**	**0**	**FGS1**	468	52.2
46.4	**5.36**	**0**	**FGS3**	464	53.6
45.8	**5.44**	**0**	**FGS5**	458	54.4
45.4	**5.32**	**0**	**FGS7**	454	53.2
45.2	**5.26**	**0**	**FGS8**	452	52.6
44.8	**5.08**	**0**	**FGS9**	448	50.8
44.4	**4.84**	**0**	**FGS11**	444	48.4
44.2	**4.72**	**0**	**FGS12**	442	47.2
43.6	**4.44**	**0**	**FGS14**	436	44.4
43.2	**4.28**	**0**	**FGS16**	432	42.8
42.8	**4.21**	**0**	**GHS1**	428	42.1
42.6	**4.22**	**0**	**GHS2**	426	42.2
42.2	**4.24**	**0**	**GHS4**	422	42.4
42	**4.25**	**0**	**GHS5**	420	42.5
41.6	**4.27**	**0**	**GHS7**	416	42.7
41.2	**4.29**	**0**	**GHS9**	412	42.9
40.8	**4.23**	**0**	**GHS10**	408	42.3
40.4	**4.09**	**0**	**GHS12**	404	40.9
40	**3.95**	**0**	**GHS14**	400	39.5
39.8	**3.88**	**0**	**GHS15**	398	38.8
39.4	**3.74**	**0**	**GHS17**	394	37.4
39.2	**3.67**	**0**	**GHS18**	392	36.7
38.8	**3.59**	**0**	**HIS1**	388	35.9
38.6	**3.58**	**0**	**HIS2**	386	35.8
38.2	**3.56**	**0**	**HIS4**	382	35.6
38	**3.55**	**0**	**HIS5**	380	35.5
37.6	**3.53**	**0**	**HIS7**	376	35.3
37.2	**3.51**	**0**	**HIS9**	372	35.1
36.8	**3.44**	**0**	**HIS10**	368	34.4
36.4	**3.32**	**0**	**HIS12**	364	33.2
36	**3.2**	**0**	**HIS14**	360	32
35.8	**3.14**	**0**	**HIS15**	358	31.4
35.4	**3.02**	**0**	**HIS17**	354	30.2

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
35.2	**2.96**	**0**	**HIS18**	352	29.6
34.8	**2.88**	**0**	**IJS1**	348	28.8
34.6	**2.86**	**0**	**IJS2**	346	28.6
34.2	**2.82**	**0**	**IJS4**	342	28.2
34	**2.8**	**0**	**IJS5**	340	28
33.8	**2.78**	**0**	**IJS6**	338	27.8
33.6	**2.76**	**0**	**IJS7**	336	27.6
33.2	**2.72**	**0**	**IJS9**	332	27.2
32.8	**2.65**	**0**	**IJS10**	328	26.5
32.4	**2.55**	**0**	**IJS12**	324	25.5
32	**2.45**	**0**	**IJS14**	320	24.5
31.8	**2.4**	**0**	**IJS15**	318	24
31.4	**2.3**	**0**	**IJS17**	314	23
31.2	**2.25**	**0**	**IJS18**	312	22.5
30.8	**2.22**	**0**	**JKS1**	308	22.2
30.6	**2.24**	**0**	**JKS2**	306	22.4
30.2	**2.28**	**0**	**JKS4**	302	22.8
30	**2.3**	**0**	**JKS5**	300	23
29.6	**2.34**	**0**	**JKS7**	296	23.4
29.2	**2.38**	**0**	**JKS9**	292	23.8
28.8	**2.36**	**0**	**JKS10**	288	23.6
28.4	**2.28**	**0**	**JKS12**	284	22.8
28	**2.2**	**0**	**JKS14**	280	22
27.8	**2.16**	**0**	**JKS15**	278	21.6
27.4	**2.08**	**0**	**JKS17**	274	20.8
27.2	**2.04**	**0**	**JKS18**	272	20.4
26.8	**2.01**	**0**	**KLS1**	268	20.1
26.6	**2.02**	**0**	**KLS2**	266	20.2
26.2	**2.04**	**0**	**KLS4**	262	20.4
26	**2.05**	**0**	**KLS5**	260	20.5
25.6	**2.07**	**0**	**KLS7**	256	20.7
25.2	**2.09**	**0**	**KLS9**	252	20.9
24.8	**2.125**	**0**	**KLS10**	248	21.25
24.4	**2.175**	**0**	**KLS12**	244	21.75
24	**2.225**	**0**	**KLS14**	240	22.25
23.8	**2.25**	**0**	**KLS15**	238	22.5
23.4	**2.3**	**0**	**KLS17**	234	23
23.2	**2.325**	**0**	**KLS18**	232	23.25
22.8	**2.385**	**0**	**LMS1**	228	23.85
22.6	**2.42**	**0**	**LMS2**	226	24.2
22.2	**2.49**	**0**	**LMS4**	222	24.9
22	**2.525**	**0**	**LMS5**	220	25.25
21.6	**2.595**	**0**	**LMS7**	216	25.95
21.2	**2.665**	**0**	**LMS9**	212	26.65

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
20.8	**2.65**	**0**	**LMS10**	208	26.5
20.4	**2.55**	**0**	**LMS12**	204	25.5
20	**2.45**	**0**	**LMS14**	200	24.5
19.8	**2.4**	**0**	**LMS15**	198	24
19.4	**2.3**	**0**	**LMS17**	194	23
19.2	**2.25**	**0**	**LMS18**	192	22.5
18.8	**2.28**	**0**	**MNS1**	188	22.8
18.6	**2.36**	**0**	**MNS2**	186	23.6
18.2	**2.52**	**0**	**MNS4**	182	25.2
18	**2.6**	**0**	**MNS5**	180	26
17.6	**2.76**	**0**	**MNS7**	176	27.6
17.2	**2.92**	**0**	**MNS9**	172	29.2
16.8	**3.025**	**0**	**MNS10**	168	30.25
16.4	**3.075**	**0**	**MNS12**	164	30.75
16	**3.125**	**0**	**MNS14**	160	31.25
15.8	**3.15**	**0**	**MNS15**	158	31.5
15.4	**3.2**	**0**	**MNS17**	154	32
15.2	**3.225**	**0**	**MNS18**	152	32.25
14.8	**3.31**	**0**	**NOS1**	148	33.1
14.6	**3.37**	**0**	**NOS2**	146	33.7
14.45	**3.6**	**0**	**NOS3**	144.5	36
14.35	**3.8**	**0**	**NOS4**	143.5	38
14.25	**4**	**0**	**NOS5**	142.5	40
14.15	**4.2**	**0**	**NOS6**	141.5	42
14.05	**4.4**	**0**	**NOS7**	140.5	44
13.9	**4.53**	**0**	**NOS8**	139	45.3
13.7	**4.59**	**0**	**NSO9**	137	45.9
13.3	**4.63**	**0**	**NOS10**	133	46.3
13.1	**4.59**	**0**	**NOS11**	131	45.9
12.9	**4.54**	**0**	**NOS12**	129	45.4
12.7	**4.52**	**0**	**NOS13**	127	45.2
12.3	**4.7**	**0**	**NOS14**	123	47
12.1	**4.8**	**0**	**NOS15**	121	48
11.9	**4.96**	**0**	**NOS16**	119	49.6
11.7	**5.02**	**0**	**NOS17**	117	50.2
11.3	**4.99**	**0**	**NOS18**	113	49.9
11.1	**4.93**	**0**	**NOS19**	111	49.3
10.8	**5.06**	**0**	**OPS1**	108	50.6
10.4	**5.38**	**0**	**OPS3**	104	53.8
10.2	**5.54**	**0**	**OPS4**	102	55.4
9.8	**5.72**	**0**	**OPS5**	98	57.2
9.4	**5.86**	**0**	**OPS7**	94	58.6
9.2	**5.93**	**0**	**OPS8**	92	59.3
8.8	**6.07**	**0**	**OPS9**	88	60.7
8.4	**6.21**	**0**	**OPS11**	84	62.1

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
8.2	**6.28**	**0**	**OPS12**	82	62.8
7.8	**6.38**	**0**	**OPS13**	78	63.8
7.4	**6.44**	**0**	**OPS15**	74	64.4
7.2	**6.47**	**0**	**OPS16**	72	64.7
6.8	**6.54**	**0**	**PQS1**	68	65.4
6.4	**6.62**	**0**	**PQS3**	64	66.2
5.8	**6.7**	**0**	**PQS5**	58	67
5.4	**6.7**	**0**	**PQS7**	54	67
5.2	**6.7**	**0**	**PQS8**	52	67
4.8	**6.62**	**0**	**PQS9**	48	66.2
4.4	**6.46**	**0**	**PQS11**	44	64.6
3.8	**6.25**	**0**	**PQS13**	38	62.5
3.4	**6.15**	**0**	**PQS15**	34	61.5
3.2	**6.1**	**0**	**PQS16**	32	61
66.8	**9.96**	**0**	**ABT1**	668	99.6
66.6	**10.02**	**0**	**ABT2**	666	100.2
66.4	**10.08**	**0**	**ABT3**	664	100.8
66.2	**10.14**	**0**	**ABT4**	662	101.4
65.8	**10.3**	**0**	**ABT5**	658	103
65.6	**10.4**	**0**	**ABT6**	656	104
65.4	**10.5**	**0**	**ABT7**	654	105
65.2	**10.6**	**0**	**ABT8**	652	106
64.8	**10.66**	**0**	**ABT9**	648	106.6
64.6	**10.62**	**0**	**ABT10**	646	106.2
64.4	**10.58**	**0**	**ABT11**	644	105.8
64.2	**10.54**	**0**	**ABT12**	642	105.4
63.8	**10.53**	**0**	**ABT13**	638	105.3
63.6	**10.56**	**0**	**ABT14**	636	105.6
63.4	**10.59**	**0**	**ABT15**	634	105.9
63.2	**10.62**	**0**	**ABT16**	632	106.2
62.8	**10.66**	**0**	**BCT1**	628	106.6
62.4	**10.68**	**0**	**BCT3**	624	106.8
62.2	**10.69**	**0**	**BCT4**	622	106.9
61.8	**10.62**	**0**	**BCT5**	618	106.2
61.6	**10.54**	**0**	**BCT6**	616	105.4
61.4	**10.46**	**0**	**BCT7**	614	104.6
61.2	**10.38**	**0**	**BCT8**	612	103.8
60.8	**10.24**	**0**	**BCT9**	608	102.4
60.6	**10.18**	**0**	**BCT10**	606	101.8
60.4	**10.12**	**0**	**BCT11**	604	101.2
60.2	**10.06**	**0**	**BCT12**	602	100.6
59.8	**9.98**	**0**	**BCT13**	598	99.8
59.6	**9.96**	**0**	**BCT14**	596	99.6
59.4	**9.94**	**0**	**BCT15**	594	99.4
59.2	**9.92**	**0**	**BCT16**	592	99.2

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
58.8	**9.91**	**0**	**CDT1**	588	99.1
58.6	**9.92**	**0**	**CDT2**	586	99.2
58.2	**9.94**		**CDT4**	582	99.4
58	**9.95**	**0**	**CDT5**	580	99.5
57.6	**9.97**	**0**	**CDT7**	576	99.7
57.2	**9.99**	**0**	**CDT9**	572	99.9
56.8	**10.01**	**0**	**CDT10**	568	100.1
56.4	**10.03**	**0**	**CDT12**	564	100.3
56	**10.05**	**0**	**CDT14**	560	100.5
55.8	**10.06**	**0**	**CDT15**	558	100.6
55.4	**10.08**	**0**	**CDT17**	554	100.8
55.2	**10.09**	**0**	**CDT18**	552	100.9
		0			
54.8	**10.09**	**0**	**DET1**	548	100.9
54.6	**10.08**	**0**	**DET2**	546	100.8
54.2	**10.06**	**0**	**DET4**	542	100.6
54	**10.05**	**0**	**DET5**	540	100.5
53.6	**10.03**	**0**	**DET7**	536	100.3
53.2	**10.01**	**0**	**DET9**	532	100.1
52.8	**9.98**	**0**	**DET10**	528	99.8
52.4	**9.94**	**0**	**DET12**	524	99.4
52	**9.9**	**0**	**DET14**	520	99
51.8	**9.88**	**0**	**DET15**	518	98.8
51.4	**9.84**	**0**	**DET17**	514	98.4
51.2	**9.82**	**0**	**DET18**	512	98.2
50.8	**9.77**	**0**	**EFT1**	508	97.7
50.6	**9.74**	**0**	**EFT2**	506	97.4
50.2	**9.68**	**0**	**EFT4**	502	96.8
49.8	**9.62**	**0**	**EFT6**	498	96.2
49.6	**9.59**	**0**	**EFT7**	496	95.9
49.2	**9.53**	**0**	**EFT9**	492	95.3
48.8	**9.485**	**0**	**EFT10**	488	94.85
48.4	**9.45**	**0**	**EFT12**	484	94.5
48	**9.4**	**0**	**EFT14**	480	94
47.8	**9.375**	**0**	**EFT15**	478	93.75
47.4	**9.325**	**0**	**EFT17**	474	93.25
47.2	**9.3**	**0**	**EFT18**	472	93
46.8	**9.22**	**0**	**FGT1**	468	92.2
46.4	**9.16**	**0**	**FGT3**	464	91.6
45.8	**9.12**	**0**	**FGT5**	458	91.2
45.4	**9.16**	**0**	**FGT7**	454	91.6
45.2	**9.18**	**0**	**FGT8**	452	91.8
44.8	**9.16**	**0**	**FGT9**	448	91.6
44.4	**9.08**	**0**	**FGT11**	444	90.8
43.8	**8.91**	**0**	**FGT13**	438	89.1

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
43.6	8.82	0	FGT14	436	88.2
43.2	8.64	0	FGT16	432	86.4
42.8	8.595	0	GHT1	428	85.95
42.6	8.64	0	GHT2	426	86.4
42.2	8.73	0	GHT4	422	87.3
42	8.775	0	GHT5	420	87.75
41.6	8.865	0	GHT7	416	88.65
41.2	8.955	0	GHT9	412	89.55
40.8	9.05	0	GHT10	408	90.5
40.4	9.15	0	GHT12	404	91.5
40	9.25	0	GHT14	400	92.5
39.8	9.3	0	GHT15	398	93
39.4	9.4	0	GHT17	394	94
39.2	9.45	0	GHT18	392	94.5
38.8	9.53	0	HIT1	388	95.3
38.6	9.56	0	HIT2	386	95.6
38.2	9.62	0	HIT4	382	96.2
38	9.65	0	HIT5	380	96.5
37.6	9.71	0	HIT7	376	97.1
37.2	9.77	0	HIT9	372	97.7
36.8	9.755	0	HIT10	368	97.55
36.4	9.665	0	HIT12	364	96.65
36	9.575	0	HIT14	360	95.75
35.8	9.53	0	HIT15	358	95.3
35.4	9.44	0	HIT17	354	94.4
35.2	9.395	0	HIT18	352	93.95
34.8	9.325	0	IJT1	348	93.25
34.6	9.3	0	IJT2	346	93
34.2	9.25	0	IJT4	342	92.5
34	9.225	0	IJT5	340	92.25
33.6	9.175	0	IJT7	336	91.75
33.2	9.125	0	IJT9	332	91.25
32.8	9.07	0	IJT10	328	90.7
32.4	9.01	0	IJT12	324	90.1
32	8.95	0	IJT14	320	89.5
31.8	8.92	0	IJT15	318	89.2
31.4	8.86	0	IJT17	314	88.6
31.2	8.83	0	IJT18	312	88.3
30.8	8.78	0	JKT1	308	87.8
30.6	8.76	0	JKT2	306	87.6
30.2	8.72	0	JKT4	302	87.2
30	8.7	0	JKT5	300	87
29.6	8.66	0	JHT7	296	86.6
29.2	8.62	0	JKT9	292	86.2

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
28.8	**8.61**	**0**	**JKT10**	288	86.1
28.4	**8.63**	**0**	**JKT12**	284	86.3
28	**8.65**	**0**	**JKT14**	280	86.5
27.8	**8.66**	**0**	**JKT15**	278	86.6
27.4	**8.68**	**0**	**JKT17**	274	86.8
27.2	**8.69**	**0**	**JKT18**	272	86.9
26.8	**8.68**	**0**	**KLT1**	268	86.8
26.6	**8.66**	**0**	**KLT2**	266	86.6
26.2	**8.62**	**0**	**KLT4**	262	86.2
26	**8.6**	**0**	**KLT5**	260	86
25.6	**8.56**	**0**	**KLT7**	256	85.6
25.2	**8.52**	**0**	**KLT9**	252	85.2
24.8	**8.515**	**0**	**KLT10**	248	85.15
24.4	**8.545**	**0**	**KLT12**	244	85.45
24	**8.575**	**0**	**KLT14**	240	85.75
23.8	**8.59**	**0**	**KLT15**	238	85.9
23.4	**8.62**	**0**	**KLT17**	234	86.2
23.2	**8.635**	**0**	**KLT18**	232	86.35
22.8	**8.655**	**0**	**LMT1**	228	86.55
22.6	**8.66**	**0**	**LMT2**	226	86.6
22.2	**8.67**	**0**	**LMT4**	222	86.7
22	**8.675**	**0**	**LMT5**	220	86.75
21.6	**8.685**	**0**	**LMT7**	216	86.85
21.2	**8.695**	**0**	**LMT9**	212	86.95
20.8	**8.69**	**0**	**LMT10**	208	86.9
20.4	**8.67**	**0**	**LMT12**	204	86.7
20	**8.65**	**0**	**LMT14**	200	86.5
19.8	**8.64**	**0**	**LMT15**	198	86.4
19.4	**8.62**	**0**	**LMT17**	194	86.2
19.2	**8.61**	**0**	**LMT18**	192	86.1
18.8	**8.6**	**0**	**NMT1**	188	86
18.6	**8.6**	**0**	**NMT2**	186	86
18.2	**8.6**	**0**	**NMT4**	182	86
18	**8.6**	**0**	**NMT5**	180	86
17.6	**8.6**	**0**	**NMT7**	176	86
17.2	**8.6**	**0**	**NMT9**	172	86
16.8	**8.7**	**0**	**NMT10**	168	87
16.4	**8.9**	**0**	**NMT12**	164	89
16	**9.1**	**0**	**NMT14**	160	91
15.8	**9.2**	**0**	**NMT15**	158	92
15.4	**9.4**	**0**	**NMT17**	154	94
15.2	**9.5**	**0**	**NMT18**	152	95
14.8	**9.48**	**0**	**NOT1**	148	94.8
14.6	**9.36**	**0**	**NOT2**	146	93.6

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
14.3	**9.26**	**0**	**NOT3**	143	92.6
14.1	**9.22**	**0**	**NOT4**	141	92.2
13.8	**9.18**	**0**	**NOT5**	138	91.8
13.6	**9.04**	**0**	**NOT6**	136	90.4
13.3	**9**	**0**	**NOT7**	133	90
13.1	**9**	**0**	**NOT8**	131	90
12.8	**8.88**	**0**	**NOT9**	128	88.8
12.6	**8.76**	**0**	**NOT10**	126	87.6
12.3	**8.64**	**0**	**NOT11**	123	86.4
12.1	**8.62**	**0**	**NOT12**	121	86.2
11.8	**8.6**	**0**	**NOT13**	118	86
11.6	**8.6**	**0**	**NOT14**	116	86
11.3	**8.66**	**0**	**NOT15**	113	86.6
11.1	**8.72**	**0**	**NOT16**	111	87.2
10.8	**8.78**	**0**	**OPT1**	108	87.8
10.4	**8.84**	**0**	**OPT3**	104	88.4
10.2	**8.87**	**0**	**OPT4**	102	88.7
9.6	**8.8**	**0**	**OPT6**	96	88
9.2	**8.7**	**0**	**OPT8**	92	87
8.8	**8.66**	**0**	**OPT9**	88	86.6
8.4	**8.68**	**0**	**OPT11**	84	86.8
8.2	**8.69**	**0**	**OPT12**	82	86.9
7.72	**9**	**0**	**OPT13**	77.2	90
7.54	**9.2**	**0**	**OPT15**	75.4	92
7.36	**9.4**	**0**	**OPT15**	73.6	94
7.18	**9.6**	**0**	**OPT16**	71.8	96
7.09	**9.7**	**0**	**OPT17**	70.9	97
6.8	**9.75**	**0**	**PQT1**	68	97.5
6.6	**9.7**	**0**	**PTQ2**	66	97
6.2	**9.6**	**0**	**PQT4**	62	96
6	**9.55**	**0**	**PQT5**	60	95.5
5.6	**9.45**	**0**	**PQT7**	56	94.5
5.2	**9.35**	**0**	**PQT9**	52	93.5
4.8	**9.24**	**0**	**PQT10**	48	92.4
4.4	**9.12**	**0**	**PQT12**	44	91.2
4	**9**	**0**	**PQT14**	40	90
3.8	**8.94**	**0**	**PQT15**	38	89.4
3.4	**8.82**	**0**	**PQT17**	34	88.2
3.2	**8.76**	**0**	**PQT18**	32	87.6

CALIBRATION CERTIFICATE

Model: 2ØØØ-21 Serial Number: 2ØØ2679

Unit Gain Ratio: ____________ Time Constant: ____________

SensorSer # N/A

Type of Reading

Velocity:

- X FPS
- _ CMS
- _ ____

Level:

- _ IN
- _ CM
- X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.ØØ	N/A
Measured:	Ø.ØØ	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: ____________ Date: 18 Apr 2006

QA Technician: ____________ Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

Discharge Measurement:
Mastodon Bone Spring,
Marion County, Florida;
September 28, 2006

Prepared for:

St. Johns River Water Management District

4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.

5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Mastodon Bone Spring, Marion County, Florida; September 28, 2006

LIST OF CONTENTS

Results of Discharge Measurements of Mastodon Bone Spring, Marion County, Florida; September 28, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Mastodon Bone Spring on September 28, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Mastodon Bone Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Tom Morris, both of KES. Data management and report preparation was performed by Peter Butt. Data processing using Surfer 8 contouring software was performed by W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida.

SITE DESCRIPTION

Mastodon Bone Spring is located within the Silver River, on the north side, and opposite from a peninsula on the south side that is immediately upstream of the Geyser Spring Group. This spring discharges vigorously from two 4-foot long linear cracks that form a roughly triangular vent in the limestone, at the bottom of a conical basin. This spring is rocky, with little sediment around it, and is about 12 feet deep. See Figure 1.

Since the orifice of this spring is located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

Pete Butt positioned the sensor, and recorded positional data, while Tom Morris read the velocity readings, after taking meter reset cues from Butt. During all measurements, the sensor handler completely removed himself from the cross section of the flow. The meter operator was also positioned outside the cross-section. This eliminated the possibility of interference with flow while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each station. Thirteen station readings were taken.

The approximate depth for the measurement grid was 13 feet. Telescoping aluminum poles with 1, 0.5, 0.25 and 0.1 foot interval markings were positioned horizontally to allow for a grid of velocity measurements. As all sensor-support poles were positioned at right angles to the main flow path, no angle coefficient corrections for velocity readings were made. The flowmeter sensor was positioned on the poles with a quick release clamp. Spring vent dimensions and positions were measured with a metal tape.

Field measurements of the velocity measurement stations and vent boundaries were plotted on grid paper and assigned X- and Y-axis values. See Figure 2. Values for the Z-axis were the point velocities, and zero values were assigned to the cross-section boundary points. See Table 3. The X, Y and Z data was processed using the Surfer v.8 (by Golden Software, Inc.) contouring program. The gridding method used was point Kriging with linear drift, an anisotropy ratio of 1 at an angle of 0°, and a variogram slope of 1.0. The results of the contour processing are illustrated in Figures 3 and 4.

During this measurement, one negative velocity was measured. Negative velocity stations typically represent slight back eddies near walls. In order to incorporate any negative values, calculations were made using a Surfer 8 “blanking file” operation to define the measurement cross-section boundary. The total discharge is shown on Table 2 as the **Net Volume (Cut-Fill)**, and has been calculated as the Positive Volume (Cut) less that portion of the Negative Volume (Fill) lying within the measurement cross-section boundary walls that define the plane of measurement.

The software also calculates the total cross-sectional area of the measurement location within the passage, and is presented on Table 2 as the **Operational Planar Area**. The Operational Planar Area is the sum of the Positive (Cut) and that portion of the Negative (Fill) Planar areas lying within the measurement cross-section boundary walls that define the plane of measurement.

RESULTS AND DISCUSSION

This measurement is the first one performed at Mastodon Bone Spring applying the method and data processing used at other spring sites by KES. Based on KES’ experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Mastodon Bone Spring on September 28, 2006 was 1.45 CFS (cubic feet per second). This result is also expressed as 650 GPM (gallons per minute) or 0.936 MGD (million gallons per day), see Table 1. Thirteen (13) readings were made, see Figures 2, 3 and 4. The point velocity readings ranged from -0.01 to 1.4 feet per second (fps), with an overall average station reading of 0.79 fps. The total cross-sectional area was calculated as 2.755 square feet. Individual point velocity measurement periods of 60 seconds were used. The measurements commenced at about 13:51 hours and were completed by 14:11 hours.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**MASTODON BONE SPRING**			Date:	**September 28, 2006**
	Silver Springs Group,			Time Start:	13:51
	Marion County, Florida			Time End:	14:11
Personnel:	Peter Butt, Tom Morris				
Method:	Grid within irregular conduit				
Instrument:	MMB2000 FLO-MATE in U/W case, sensor on support poles				
	Msmt. Periods:	60 seconds			
Analysis Method: Surfer 8 with kriging					
Mastodon Bone Spring Total Discharge:					
CFS	**1.45**				
MGD	**0.936**				
GPM	**650**				
Total Cross-sectional Area (sq/ft):		2.755			
Avg. Station Point Velocity (ft/sec):		0.79			
Cross-section Depth (feet deep):		13			
Velocity Reading by Station:		(All velocity readings in feet per second.)			
Station #	Point Velocity				
1	0.58				
2	1.21				
3	1.4				
4	1.19				
5	1.3				
6	0.55				
7	0.08				
8	1.02				
9	0.43				
10	0.34				
11	-0.01				
12	1.08				
13	1.05				

Table 1. Discharge of Mastodon Bone Spring, Marion County, Florida on September 28, 2006. Data record and calculation of discharge measurement.

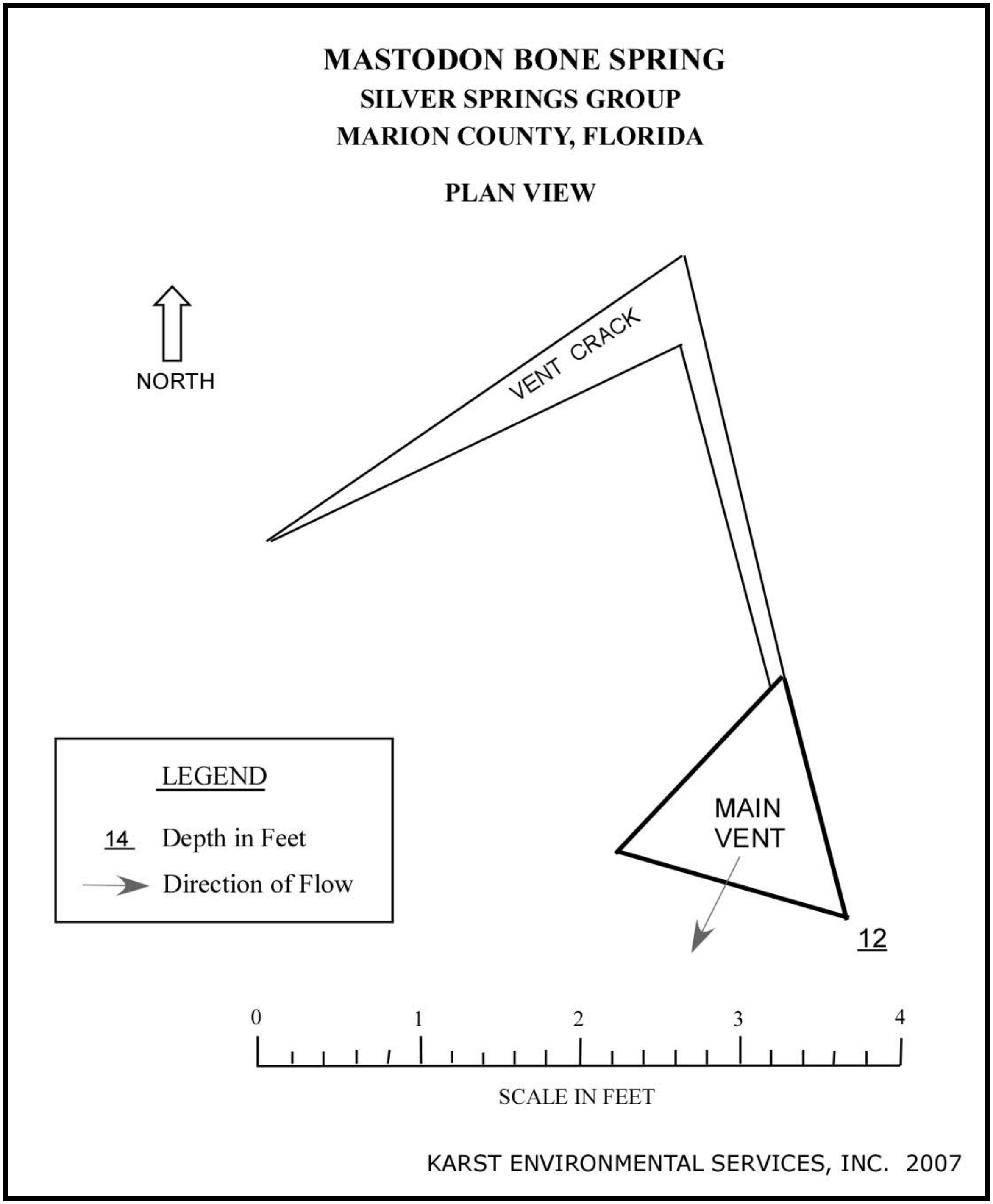

Figure 1. Map of Mastodon Bone Spring.

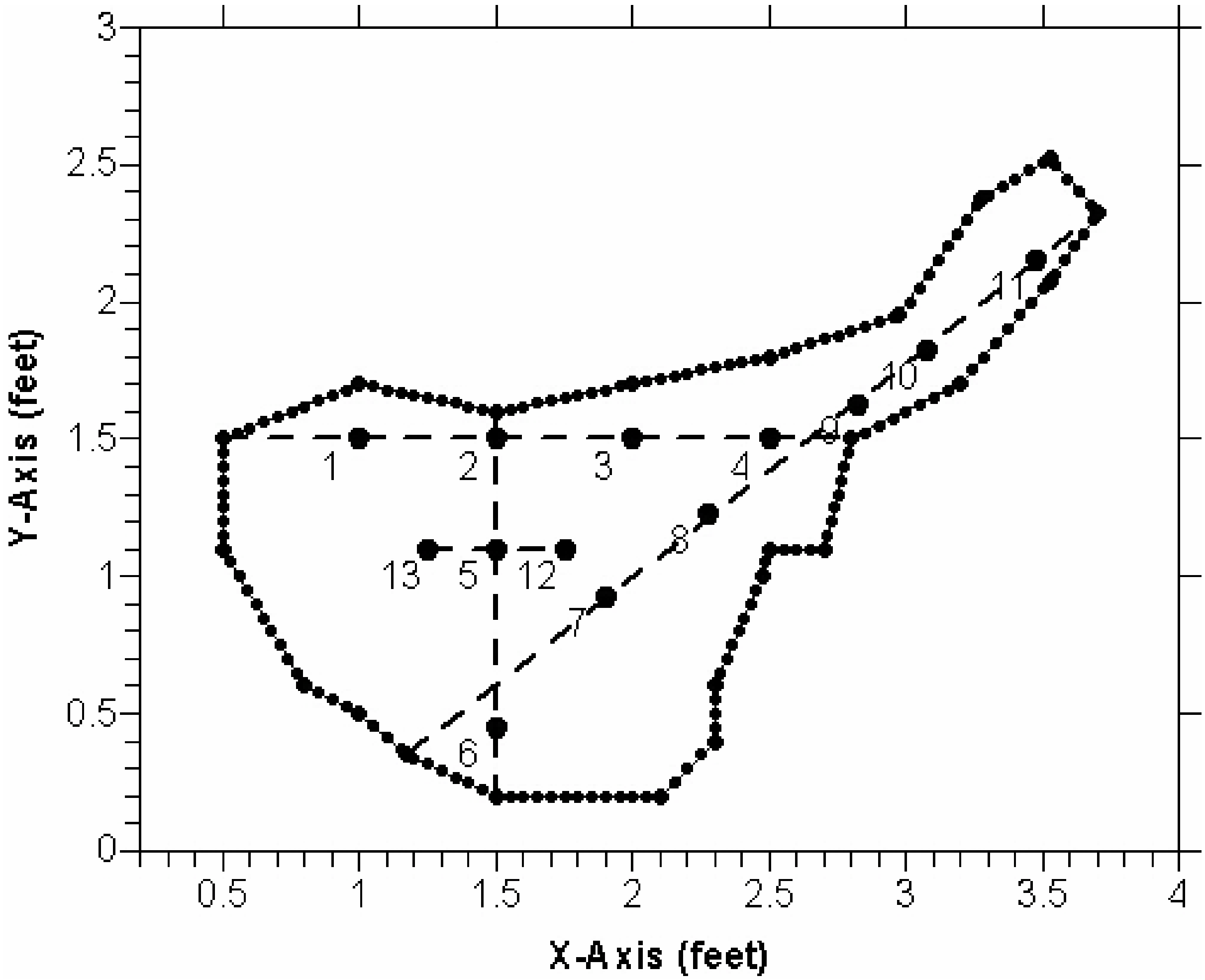

Figure 2. Discharge measurement cross-section; Mastodon Bone Spring, Marion County, Florida, September 28, 2006 measurement. Cross-section is viewed to the upstream of observer, and is located at the 13-foot depth level. Velocity measurement stations are shown as numbered points. See Table 1 for station velocities. Boundary of cross section is shown as connected points. Support poles represented by dashed lines. X- and Y-axis scales are shown in feet.

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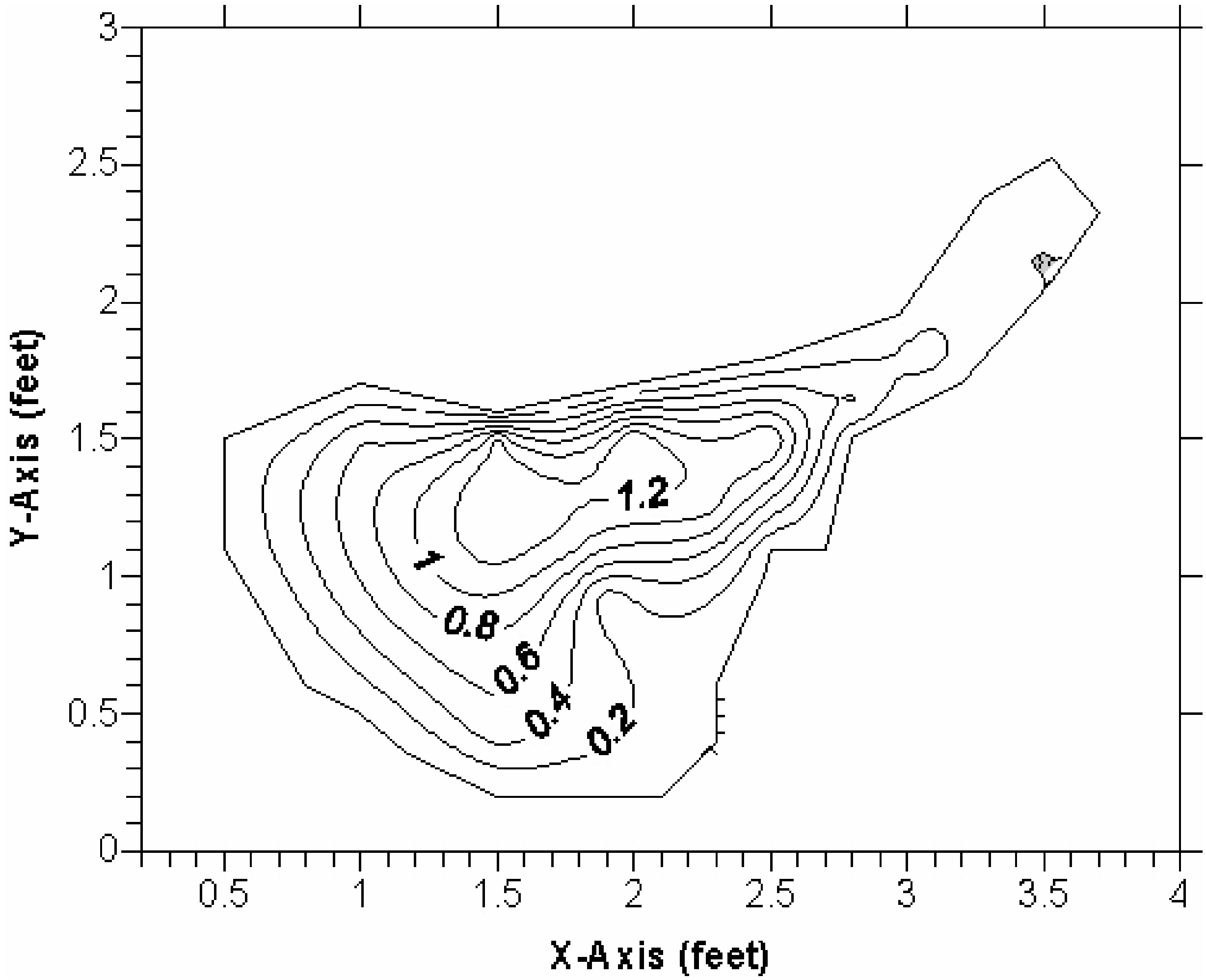

Figure 3. Discharge measurement cross-section; Mastodon Bone Spring, Marion County, Florida, September 28, 2006 measurement. Flow contour velocities are shown in feet per second. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. Outer boundary of cross section represents the zero-value contour. X- and Y-axis scales are shown in feet.

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TABLE 2. MASTODON BONE SPRING, SEPTEMBER 28, 2006.
SURFER 8 GRID VOLUME COMPUTATIONS AND GRIDDING REPORT

UPPER SURFACE

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Mastodon\MastodonBone9-06.bln.grd
Grid Size:	61 rows x 77 columns
X Minimum:	0.2
X Maximum:	4
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	3
Y Spacing:	0.05
Z Minimum:	-0.0053314706106041
Z Maximum:	1.3999999994555

LOWER SURFACE
Level Surface defined by Z = 0

VOLUMES

Z Scale Factor:	1
Total Volumes by:	
Trapezoidal Rule:	1.4484001312717
Simpson's Rule:	1.4484344157176
Simpson's 3/8 Rule:	1.4481101368109

CUT & FILL VOLUMES

Positive Volume [Cut]:	1.4484105979796
Negative Volume [Fill]:	1.0466707929344E-005
Net Volume [Cut-Fill]:	**1.4484001312717<<<<<<Total Discharge in CFS**

(The Net Volume value is used due to the presence of negative velocity values.
Positive Vol. Cut - Negative Vol. Fill = Net Volume. Please refer to report text.)

AREAS
Planar Areas
Operational Planar Area: 2.755 <<<<Total Cross-section Area in Square Feet
(Calculated using blanking file due to the presence of negative velocity values;
Operational Planar Area = [P.P.A.Cut + N.P.A.Fill] = [Total Planar Area - Blanked Planar Area].
Please refer to report text.)

Positive Planar Area [Cut]:	2.7524732324001
Negative Planar Area [Fill]:	0.0025267675999065
Blanked Planar Area:	8.645
Total Planar Area:	11.4

Surface Areas

Positive Surface Area [Cut]:	6.3480024831556
Negative Surface Area [Fill]:	0.0025780922979023

GRIDDING REPORT

Source Data File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Mastodon\Mastodon Bone 9-06 SURFER XYZ BLF.xls
X Column:	A
Y Column:	B
Z Column:	C

Data Counts

Active Data:	180
Original Data:	180
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Univariate Statistics

	X	Y	Z
Minimum:	0.5	0.2	-0.01
25%-tile:	1.25	0.85	0
Median:	2.25	1.56	0
75%-tile:	2.9	1.8	0
Maximum:	3.7	2.525	1.4
Midrange:	2.1	1.3625	0.695
Range:	3.2	2.325	1.41
Interquartile Range:	1.65	0.95	0
Median Abs. Deviation:	0.8	0.46	0
Mean:	2.0955461111111	1.3554890277778	0.056777777777778
Trim Mean (10%):	2.0989290123457	1.3584137345679	0.0052469135802469
Standard Deviation:	0.96111683233586	0.662839371143	0.23810748169578
Variance:	0.92374556539932	0.43935603193725	0.056695172839506
Coef. of Variation:			4.1936738459139
Coef. of Skewness:			4.3564652474141

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.537	-0.062
Y:		1.000	-0.023
Z:			1.000

Inter-Variable Covariance

	X	Y	Z
X:	0.92374556539932	0.3420298516865	-0.014283229197531
Y:		0.43935603193725	-0.0035630436882716
Z:			0.056695172839506

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-0.017505373312558	0.0055178861181211	0.085981660656816
Standard Error:	0.022027249301177	0.031939502985335	0.046671237632284

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.537	-0.491
B:		1.000	0.397
C:			1.000

ANOVA Table

Source	df	Sum of Squares	Mean Square	F
Regression:	2	0.041467102183052	0.020733551091526	0.36107
Residual:	177	10.163664008928	0.057421830558916	
Total:	179	10.205131111111		

Coefficient of Multiple Determination (R^2): 0.0040633581020731

Nearest Neighbor Statistics

	Separation	|Delta Z|
Minimum:	0.026215493510518	0
25%-tile:	0.05	0
Median:	0.052433997558836	0
75%-tile:	0.058309518948453	0
Maximum:	0.29181543824822	1.4

Midrange:	0.15901546587937	0.7
Range:	0.2655999447377	1.4
Interquartile Range:	0.0083095189484529	0
Median Abs. Deviation:	0.0024339975588357	0
Mean:	0.062478953425028	0.0511111111111111
Trim Mean (10%):	0.054759521334596	0.0050617283950617
Standard Deviation:	0.042327369337395	0.21680479927265
Variance:	0.0017916061950243	0.047004320987654
Coef. of Variation:	0.6774660428361	4.2418330292475
Coef. of Skewness:	3.7545817160282	4.6050132072048
Root Mean Square:	0.075466719924157	0.22274798914169
Mean Square:	0.0056952258161111	0.049616666666667

Complete Spatial Randomness

Lambda:	24.193548387097
Clark and Evans:	0.61462967773314
Skellam:	155.83424154181

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	3.8E-007
Y Duplicate Tolerance:	2.7E-007

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	2
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	Y:\2. PROJECTS\KARST ENVIRONMENTAL\Silver Springs\Sep 06\Mastodon\MastodonBone9-06.grd
Grid Size:	61 rows x 77 columns
Total Nodes:	4697
Filled Nodes:	4697
Blanked Nodes:	0

Grid Geometry

X Minimum:	0.2
X Maximum:	4
X Spacing:	0.05
Y Minimum:	0
Y Maximum:	3
Y Spacing:	0.05

Grid Statistics

Z Minimum:	-5.1976118875018
Z 25%-tile:	-1.1348827250522
Z Median:	-0.33514151066706
Z 75%-tile:	0.0047985274453725
Z Maximum:	1.3999999994555
Z Midrange:	-1.8988059440232
Z Range:	6.5976118869573
Z Interquartile Range:	1.1396812524976
Z Median Abs. Deviation:	0.50008688602946
Z Mean:	-0.62399978464546
Z Trim Mean (10%):	-0.55840322772702
Z Standard Deviation:	1.0966081740578
Z Variance:	1.2025494874104
Z Coef. of Variation:	-1
Z Coef. of Skewness:	-1.0696522801176
Z Root Mean Square:	1.261715189196
Z Mean Square:	1.5919252186479

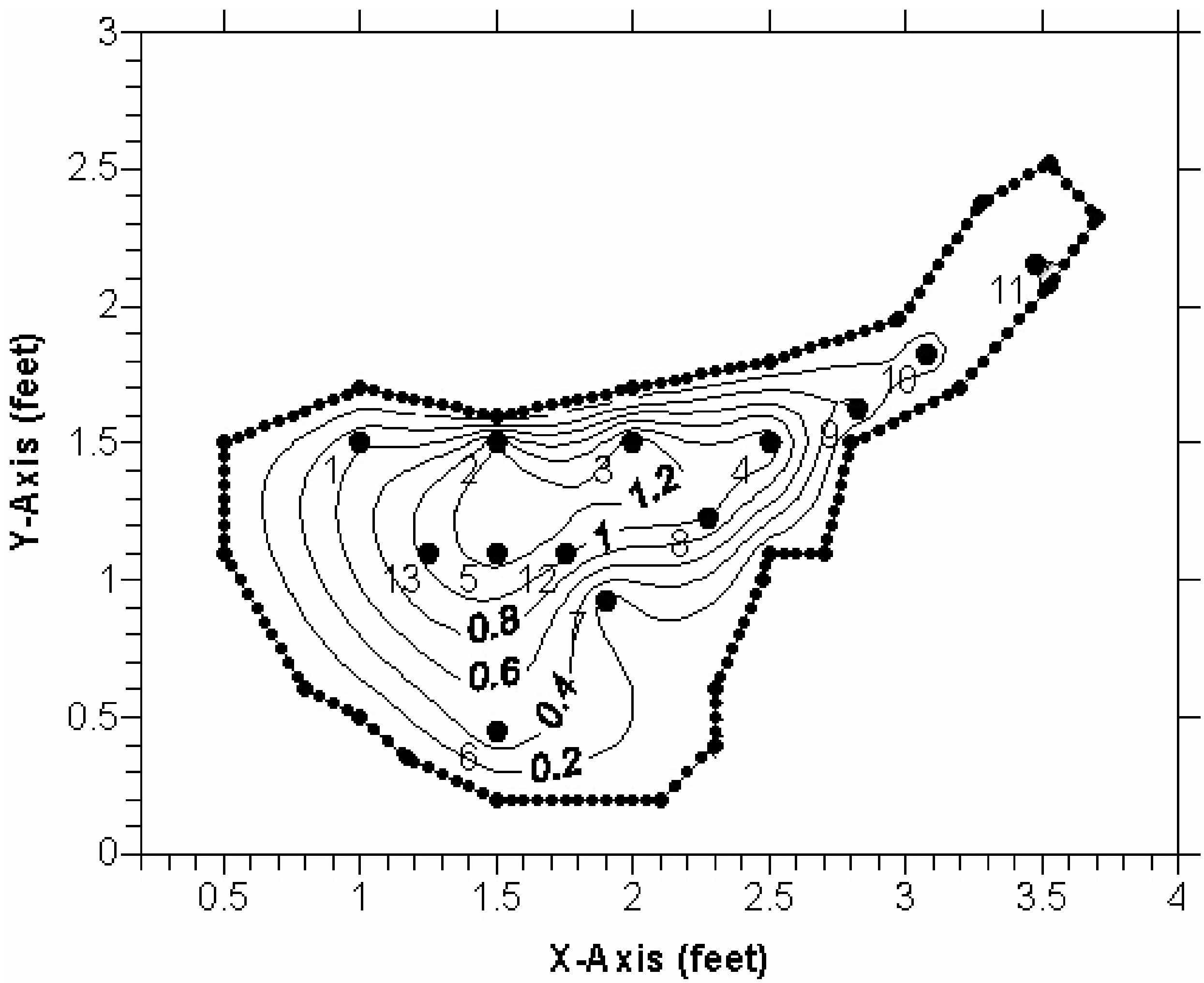

Figure 4. Discharge measurement cross-section; Mastodon Bone Spring, Marion County, Florida, September 28, 2006 measurement. Relationship of flow contours (velocities shown in feet per second) and velocity measurement stations (numbered points) are shown. Areas with negative velocities (reverse flow) are shaded and delineated by hatched lines. See Table 1 for station velocities. Boundary of cross section is shown as connected points. X- and Y-axis scales are shown in feet.

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Table 3. Mastodon Bone Spring XYZ Grid Data, September 28, 2006.					
X	**Y**	**Z (Velocity)**	**Station Name**	**X Plot**	**Y Plot**
1	1.5	0.58	1	20	30
1.5	1.5	1.21	2	30	30
2	1.5	1.4	3	40	30
2.5	1.5	1.19	4	50	30
1.5	1.1	1.3	5	30	22
1.5	0.45	0.55	6	30	9
1.9	0.925	0.08	7	38	18.5
2.275	1.225	1.02	8	45.5	24.5
2.825	1.625	0.43	9	56.5	32.5
3.075	1.825	0.34	10	61.5	36.5
3.475	2.15	-0.01	11	69.5	43
1.75	1.1	1.08	12	35	22
1.25	1.1	1.05	13	25	22
0.5	1.5	0	A	10	30
0.5	1.1	0	B	10	22
0.8	0.6	0	C	16	12
1	0.5	0	D	20	10
1.175	0.35	0	E	23.5	7
1.5	0.2	0	F	30	4
2.1	0.2	0	G	42	4
2.3	0.4	0	H	46	8
2.3	0.6	0	I	46	12
2.475	1	0	J	49.5	20
2.5	1.1	0	K	50	22
2.7	1.1	0	L	54	22
2.8	1.5	0	M	56	30
3.2	1.7	0	N	64	34
3.525	2.075	0	O	70.5	41.5
3.7	2.325	0	P	74	46.5
3.525	2.525	0	Q	70.5	50.5
3.275	2.375	0	R	65.5	47.5
2.975	1.95	0	S	59.5	39
2.5	1.8	0	T	50	36
2	1.7	0	U	40	34
1.5	1.6	0	V	30	32
1	1.7	0	W	20	34
0.5	1.45	0	A1	10	29
0.5	1.4	0	A2	10	28
0.5	1.35	0	A3	10	27
0.5	1.3	0	A4	10	26
0.5	1.25	0	A5	10	25
0.5	1.2	0	A6	10	24
0.5	1.15	0	A7	10	23

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
0.53	**1.05**	**0**	**B1**	10.6	21
0.56	**1**	**0**	**B2**	11.2	20
0.59	**0.95**	**0**	**B3**	11.8	19
0.62	**0.9**	**0**	**B4**	12.4	18
0.65	**0.85**	**0**	**B5**	13	17
0.68	**0.8**	**0**	**B6**	13.6	16
0.71	**0.75**	**0**	**B7**	14.2	15
0.74	**0.7**	**0**	**B8**	14.8	14
0.77	**0.65**	**0**	**B9**	15.4	13
0.85	**0.575**	**0**	**C1**	17	11.5
0.9	**0.55**	**0**	**C2**	18	11
0.95	**0.525**	**0**	**C3**	19	10.5
1.05	**0.45715**	**0**	**D1**	21	9.143
1.1	**0.4143**	**0**	**D2**	22	8.286
1.15	**0.37145**	**0**	**D3**	23	7.429
1.2	**0.33845**	**0**	**E1**	24	6.769
1.25	**0.31538**	**0**	**E2**	25	6.3075
1.3	**0.2923**	**0**	**E3**	26	5.846
1.35	**0.26923**	**0**	**E4**	27	5.3845
1.4	**0.24615**	**0**	**E5**	28	4.923
1.45	**0.22308**	**0**	**E6**	29	4.4615
1.55	**0.2**	**0**	**F1**	31	4
1.6	**0.2**	**0**	**F2**	32	4
1.65	**0.2**	**0**	**F3**	33	4
1.7	**0.2**	**0**	**F4**	34	4
1.75	**0.2**	**0**	**F5**	35	4
1.8	**0.2**	**0**	**F6**	36	4
1.85	**0.2**	**0**	**F7**	37	4
1.9	**0.2**	**0**	**F8**	38	4
1.95	**0.2**	**0**	**F9**	39	4
2	**0.2**	**0**	**F10**	40	4
2.05	**0.2**	**0**	**F11**	41	4
2.15	**0.25**	**0**	**G1**	43	5
2.2	**0.3**	**0**	**G2**	44	6
2.25	**0.35**	**0**	**G3**	45	7
2.3	**0.45**	**0**	**H1**	46	9
2.3	**0.5**	**0**	**H2**	46	10
2.3	**0.55**	**0**	**H3**	46	11
2.32188	**0.65**	**0**	**I1**	46.4375	13
2.34375	**0.7**	**0**	**I2**	46.875	14
2.36563	**0.75**	**0**	**I3**	47.3125	15
2.3875	**0.8**	**0**	**I4**	47.75	16

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
2.40938	0.85	0	I5	48.1875	17
2.43125	0.9	0	I6	48.625	18
2.45313	0.95	0	I7	49.0625	19
2.4875	1.05	0	J1	49.75	21
	0				
2.55	1.1	0	K1	51	22
2.6	1.1	0	K2	52	22
2.65	1.1	0	K3	53	22
2.7125	1.15	0	L1	54.25	23
2.725	1.2	0	L2	54.5	24
2.7375	1.25	0	L3	54.75	25
2.75	1.3	0	L4	55	26
2.7625	1.35	0	L5	55.25	27
2.775	1.4	0	L6	55.5	28
2.7875	1.45	0	L7	55.75	29
0					
2.85	1.525	0	M1	57	30.5
2.9	1.55	0	M2	58	31
2.95	1.575	0	M3	59	31.5
3	1.6	0	M4	60	32
3.05	1.625	0	M5	61	32.5
3.1	1.65	0	M6	62	33
3.15	1.675	0	M7	63	33.5
3.24334	1.75	0	N1	64.8667	35
3.28667	1.8	0	N2	65.7334	36
3.33001	1.85	0	N3	66.6001	37
3.37334	1.9	0	N4	67.4668	38
3.41668	1.95	0	N5	68.3335	39
3.46001	2	0	N6	69.2002	40
3.50335	2.05	0	N7	70.0669	41
3.5425	2.1	0	O1	70.85	42
3.5775	2.15	0	O2	71.55	43
3.6125	2.2	0	O3	72.25	44
3.6475	2.25	0	O4	72.95	45
3.6825	2.3	0	O5	73.65	46
3.67813	2.35	0	P1	73.5625	47
3.63438	2.4	0	P2	72.6875	48
3.59063	2.45	0	P3	71.8125	49
3.54868	2.5	0	P4	70.9735	50
3.5	2.51	0	Q1	70	50.2
3.45	2.48	0	Q2	69	49.6
3.4	2.45	0	Q3	68	49
3.35	2.42	0	Q4	67	48.4

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
3.3	**2.39**	**0**	**Q5**	66	47.8
3.25736	**2.35**	**0**	**R1**	65.1472	47
3.22207	**2.3**	**0**	**R2**	64.4413	46
3.18677	**2.25**	**0**	**R3**	63.7354	45
3.15148	**2.2**	**0**	**R4**	63.0295	44
3.11618	**2.15**	**0**	**R5**	62.3236	43
3.08089	**2.1**	**0**	**R6**	61.6177	42
3.04559	**2.05**	**0**	**R7**	60.9118	41
3.0103	**2**	**0**	**R8**	60.2059	40
2.95	**1.94211**	**0**	**S1**	59	38.8422
2.9	**1.92632**	**0**	**S2**	58	38.5264
2.85	**1.91053**	**0**	**S3**	57	38.2106
2.8	**1.89474**	**0**	**S4**	56	37.8948
2.75	**1.87895**	**0**	**S5**	55	37.579
2.7	**1.86316**	**0**	**S6**	54	37.2632
2.65	**1.84737**	**0**	**S7**	53	36.9474
2.6	**1.83158**	**0**	**S8**	52	36.6316
2.55	**1.81579**	**0**	**S9**	51	36.3158
2.45	**1.79**	**0**	**T1**	49	35.8
2.4	**1.78**	**0**	**T2**	48	35.6
2.35	**1.77**	**0**	**T3**	47	35.4
2.3	**1.76**	**0**	**T4**	46	35.2
2.25	**1.75**	**0**	**T5**	45	35
2.2	**1.74**	**0**	**T6**	44	34.8
2.15	**1.73**	**0**	**T7**	43	34.6
2.1	**1.72**	**0**	**T8**	42	34.4
2.05	**1.71**	**0**	**T9**	41	34.2
1.95	**1.69**	**0**	**U1**	39	33.8
1.9	**1.68**	**0**	**U2**	38	33.6
1.85	**1.67**	**0**	**U3**	37	33.4
1.8	**1.66**	**0**	**U4**	36	33.2
1.75	**1.65**	**0**	**U5**	35	33
1.7	**1.64**	**0**	**U6**	34	32.8
1.65	**1.63**	**0**	**U7**	33	32.6
1.6	**1.62**	**0**	**U8**	32	32.4
1.55	**1.61**	**0**	**U9**	31	32.2
1.45	**1.61**	**0**	**V1**	29	32.2
1.4	**1.62**	**0**	**V2**	28	32.4
1.35	**1.63**	**0**	**V3**	27	32.6
1.3	**1.64**	**0**	**V4**	26	32.8
1.25	**1.65**	**0**	**V5**	25	33
1.2	**1.66**	**0**	**V6**	24	33.2
1.15	**1.67**	**0**	**V7**	23	33.4

X	Y	Z (Velocity)	Station Name	X Plot	Y Plot
1.1	**1.68**	**0**	**V8**	22	33.6
1.05	**1.69**	**0**	**V9**	21	33.8
0.95	**1.68**	**0**	**W1**	19	33.6
0.9	**1.66**	**0**	**W2**	18	33.2
0.85	**1.64**	**0**	**W3**	17	32.8
0.8	**1.62**	**0**	**W4**	16	32.4
0.75	**1.6**	**0**	**W5**	15	32
0.7	**1.58**	**0**	**W6**	14	31.6
0.65	**1.56**	**0**	**W7**	13	31.2
0.6	**1.54**	**0**	**W8**	12	30.8
0.55	**1.52**	**0**	**W9**	11	30.4

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ______ Time Constant: ______

SensorSer # N/A

Type of Reading

Velocity:

X FPS

_ CMS

_ ______

Level:

_ IN

_ CM

X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ______

Calibration Technician: Stan Cielecki Date: 18 Apr 2006

QA Technician: B Hall Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY

A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452

(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

P/N 101001 301

Discharge Measurement:
No Name Cove Spring,
Marion County, Florida;
September 29, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: No Name Cove Spring, Marion County, Florida; September 29, 2006

LIST OF CONTENTS

Results of Discharge Measurements of No Name Cove Spring, Marion County, Florida; September 29, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at No Name Cove Spring on September 29, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of No Name Cove Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

No Name Cove Spring is a line of six vents spread along the bottom of linear depression located in a small cove along the south side of the Silver River, about 450 feet east of First Fisherman's Paradise. The vents discharge vertically through soft bottom sediments, from between 10 to 14 feet deep. See Figure 1. Three of these vents were suitable for attempts at measurement.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the first one performed at No Name Cove Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of No Name Cove Spring on September 29, 2006 was 0.24 CFS (cubic feet per second). This result is also expressed as 106 GPM (gallons per minute) or 0.153 MGD (million gallons per day), see Table 1. Three readings were made at each of three vents, for a total of nine (9) readings. Individual point velocity readings ranged from 0.07 to 0.41 feet per second (fps), with an overall average station reading of 0.20 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 10 to 14 feet. The measurements commenced at about 16:53 hours and were completed by 17:11 hours.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**NO NAME COVE SPRING**		Date:	**September 29, 2006**	
	Silver Springs Group,		Time Start:	16:53	
	Marion County, Florida		Time End:	17:11	
Personnel:	Peter Butt, Mark Long				
Method:	Vent Discharge Capture Device		(0.49' Diameter)		
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe.				
Calculation Method: Discharge = V x *pi* x r^2					
Measurement Periods:		60 seconds			
No Name Cove Spring ESTIMATED Discharge:			**Vent 1:**	**Vent 2:**	**Vent 3:**
CFS	**0.24**		**0.153**	**0.040**	**0.044**
MGD	**0.153**		**0.099**	**0.026**	**0.028**
GPM	**106**		**69**	**18**	**20**
		(Multipliers:)	(2)	(3)	(2)
No Name Cove Spring Measured Discharge:					
CFS	**0.11**		**0.077**	**0.013**	**0.022**
MGD	**0.072**		**0.050**	**0.009**	**0.014**
GPM	**50**	All Vents:	**34**	**6**	**10**
Avg. Point Velocity (ft/sec):		0.20	0.41	0.07	0.12
Vent Depth (feet deep):			14	12	10
Velocity Readings:		(All velocity readings in feet per second.)			
Vent 1 (Middle)		**Vent 2 (North)**		**Vent 3 (South)**	
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity
1	0.41	1	0.07	1	0.11
2	0.41	2	0.07	2	0.12
3	0.4	3	0.07	3	0.12
Average:	0.41	Average:	0.07	Average:	0.12
Discharge:	0.077	Discharge:	0.013	Discharge:	0.022
Multiplier:	2	Multiplier:	3	Multiplier:	2
Est. Discharge:	**0.153**	**Est. Discharge:**	**0.040**	**Est. Discharge:**	**0.044**

Table 1. Discharge of No Name Cove Spring, Marion County, Florida on September 29, 2006. Data record and calculation of discharge measurement.

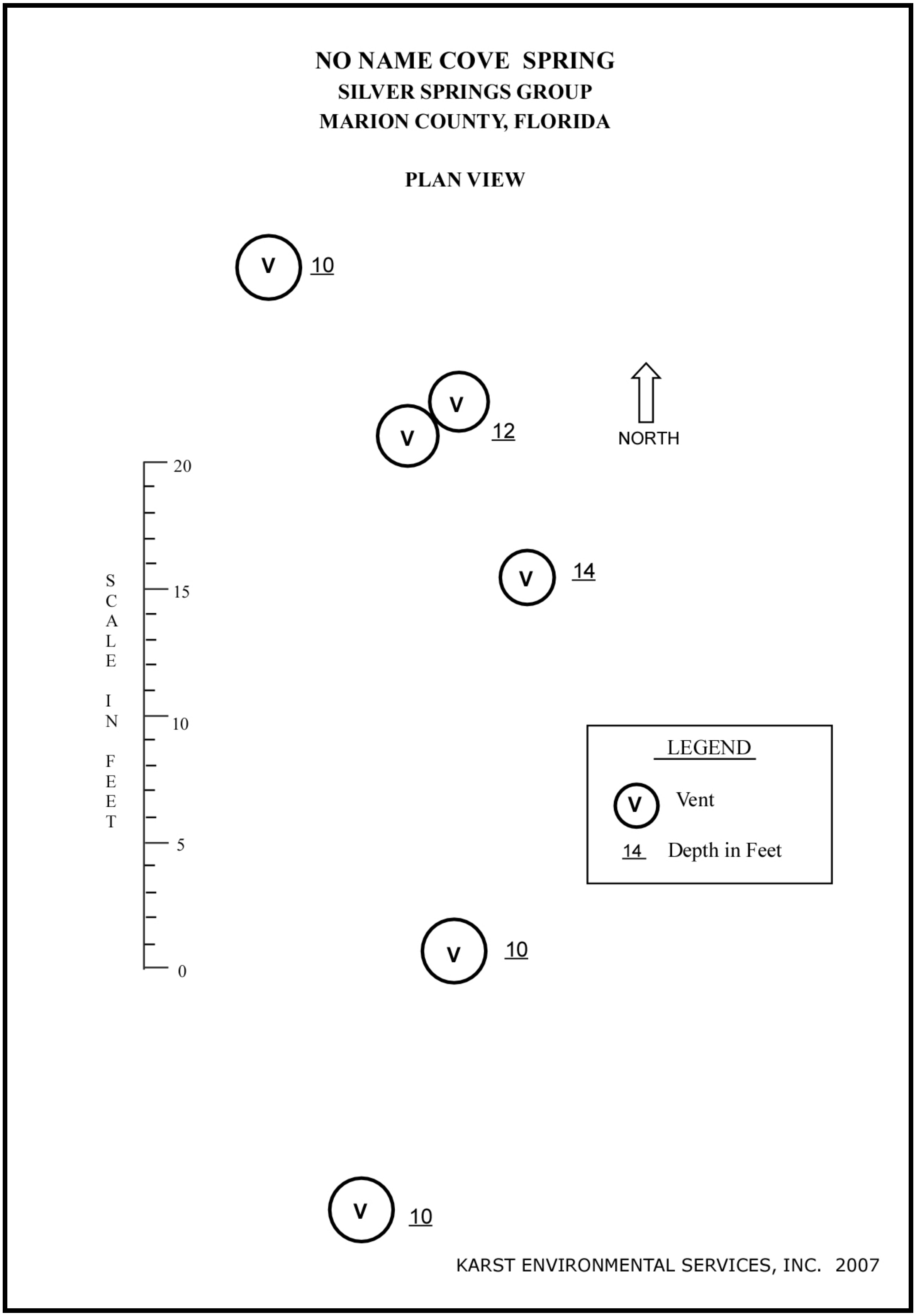

Figure 1. Map of No Name Cove Spring.

CALIBRATION CERTIFICATE

Model: 2ØØØ-21 Serial Number: 2ØØ2679

Unit Gain Ratio: ____________ Time Constant: ____________

Sensor Ser # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ______

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.ØØ	N/A
Measured:	Ø.ØØ	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: Stan Cinkoski Date: 18 Apr 2006

QA Technician: ______ Date: 4/18/06

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P/N 101001 301

Discharge Measurement:
Oscar Spring,
Marion County, Florida;
September 28, 2006

Prepared for:

St. Johns River Water Management District

4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.

5779 NE County Road 340
High Springs, Florida 32643
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Discharge Measurement: Oscar Spring, Marion County, Florida; September 28, 2006

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Results of Discharge Measurements of Oscar Spring, Marion County, Florida; September 28, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Oscar Spring on September 28, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Oscar Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

Oscar Spring is a group of spring vents in a shallow depression on the north side of the center of the river channel, about 140 feet northeast of Jacob's Well Spring. There are three small vents in the depression, one of which discharges from a marl ledge, and a line of vents about 8 feet long about ten feet to the southwest of the marl ledge. The deepest part of the depression is about 17 feet deep. See Figure 1. The line of vents was not measured.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as “Estimated Discharge”, and are presented along with the original “Measured Discharge” value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Oscar Spring applying the method and data processing used at other spring sites by KES. Based on KES’ experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Oscar Spring on September 28, 2006 was 0.46 (cubic feet per second). This result is also expressed as 205 GPM (gallons per minute) or 0.295 MGD (million gallons per day), see Table 1. A single reading was made at each of three vents, for a total of three (3) readings. (A minimum number of readings were taken here due to tour boat traffic in the channel.) Individual point velocity readings ranged from 0.28 to 0.5 feet per second (fps), with an overall average station reading of 0.40 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 15 to 17 feet. The measurements commenced at about 14:30 hours and were completed by 14:41 hours.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**OSCAR SPRING**		Date:	**September 28, 2006**	
	Silver Springs Group,		Time Start:	14:30	
	Marion County, Florida		Time End:	14:41	
Personnel:	Peter Butt, Tom Morris				
Method:	Vent Discharge Capture Device		(0.49' Diameter)		
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe.				
Calculation Method: Discharge = V x *pi* x r^2					
Measurement Periods:		60 seconds			
Oscar Spring ESTIMATED Discharge:			**Vent 1**	**Vent 2**	**Vent 3**
CFS	**0.46**		**0.162**	**0.106**	**0.189**
MGD	**0.295**		**0.105**	**0.068**	**0.122**
GPM	**205**		**73**	**47**	**85**
		(Multipliers:)	(2)	(2)	(2)
Oscar Spring Measured Discharge:					
CFS	**0.23**		**0.081**	**0.053**	**0.094**
MGD	**0.148**		**0.052**	**0.034**	**0.061**
GPM	**102**	All Vents:	**36**	**24**	**42**
Avg. Point Velocity (ft/sec):		0.40	0.43	0.28	0.50
Vent Depth (feet deep):			15	17	17
Velocity Readings:		(All velocity readings in feet per second.)			
Vent 1 (near tag)		**Vent 2**		**Vent 3**	
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity
1	0.43	1	0.28	1	0.5
Average:	0.43	Average:	0.28	Average:	0.50
Discharge:	0.081	Discharge:	0.053	Discharge:	0.094
Multiplier	2	Multiplier	2	Multiplier	2
Est. Discharge:	**0.162**	**Est. Discharge:**	**0.106**	**Est. Discharge:**	**0.189**

Table 1. Discharge of Oscar Spring, Marion County, Florida on September 28, 2006. Data record and calculation of discharge measurement.

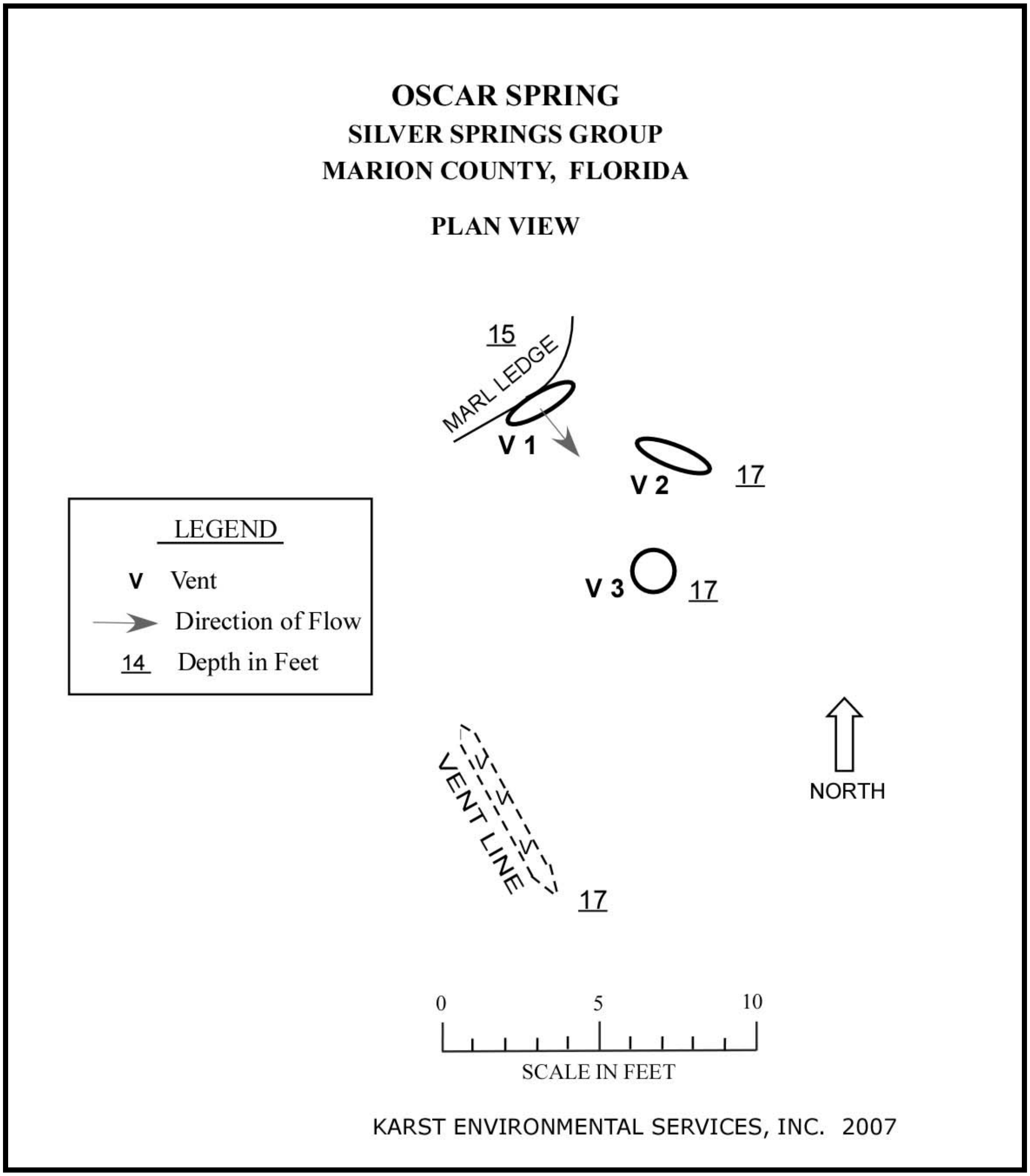

Figure 1. Map of Oscar Spring.

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ______ Time Constant: ______

SensorSer # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ____

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ______

Calibration Technician: Stan Cwalski Date: 18 Apr 2006

QA Technician: B Hall Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

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P/N 101001 301

Discharge Measurement: Raccoon Island Spring, Marion County, Florida; September 28, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Raccoon Island Spring, Marion County, Florida; September 28, 2006

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Results of Discharge Measurements of Raccoon Island Spring, Marion County, Florida; September 28, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Raccoon Island Spring on September 28, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Raccoon Island Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

Raccoon Island Spring is located in Gar Cove northeast of a forested island. Discharge is primarily from three vent clusters, with each cluster located in the bottom of three broad, low relief depressions. The vents discharge through a layer of sediment and filamentous algae. The "central" vent cluster comprises an area of about six feet in diameter, and is 12 feet deep. A second vent cluster lies 25 feet to the southwest in 14 feet of water, and a third vent cluster lies 35 feet to the north (towards the bank) in 10 feet of water. See Figure 1.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Raccoon Island Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Raccoon Island Spring on September 29, 2006 was 0.52 CFS (cubic feet per second). This result is also expressed as 235 GPM (gallons per minute) or 0.338 MGD (million gallons per day), see Table 1. Three readings were made at each of three vents, for a total of nine (9) readings. Individual point velocity readings ranged from 0.31 to 0.49 feet per second (fps), with an overall average station reading of 0.38 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 10 to 14 feet. The measurements commenced at about 17:12 hours and were completed by 17:35 hours.

	UNDERWATER DISCHARGE MEASUREMENT					
	Location:	**RACOON ISLAND SPRING**		Date:	**September 28, 2006**	
		Silver Springs Group,		Time Start:	17:12	
		Marion County, Florida		Time End:	17:35	
	Personnel:	Peter Butt, Tom Morris				
	Method:	Vent Discharge Capture Device		(0.49' Diameter)		
	Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe.				
	Calculation Method: Discharge = V x *pi* x r^2					
	Measurement Periods:		60 seconds			
	Raccoon Island Spring ESTIMATED Discharge:			**North Vent:**	**South Vent:**	**Middle Vent:**
	CFS	**0.52**		**0.128**	**0.277**	**0.117**
	MGD	**0.338**		**0.083**	**0.179**	**0.076**
	GPM	**235**		**58**	**124**	**52**
			(Multiplier:)	(2)	(3)	(2)
	Raccoon Island Spring Measured Discharge:					
	CFS	**0.22**		**0.064**	**0.092**	**0.058**
	MGD	**0.139**		**0.041**	**0.060**	**0.038**
	GPM	**97**	All Vents:	**29**	**41**	**26**
	Avg. Point Velocity (ft/sec):		0.38	0.34	0.49	0.31
	Vent Depth (feet deep):			10	14	12
	Velocity Readings:		(All velocity readings in feet per second.)			
	North Vent (tag)		**South Vent**		**MiddleVent**	
	Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity
	1	0.34	1	0.48	1	0.31
	2	0.34	2	0.5	2	0.31
	3	0.34	3	0.49	3	0.31
	Average:	0.34	Average:	0.49	Average:	0.31
	Discharge:	0.064	Discharge:	0.092	Discharge:	0.058
	Multiplier:	2	Multiplier:	3	Multiplier:	2
	Est. Discharge:	**0.128**	**Est. Discharge:**	**0.277**	**Est. Discharge:**	**0.117**

Table 1. Discharge of Raccoon Island Spring, Marion County, Florida on September 28, 2006. Data record and calculation of discharge measurement.

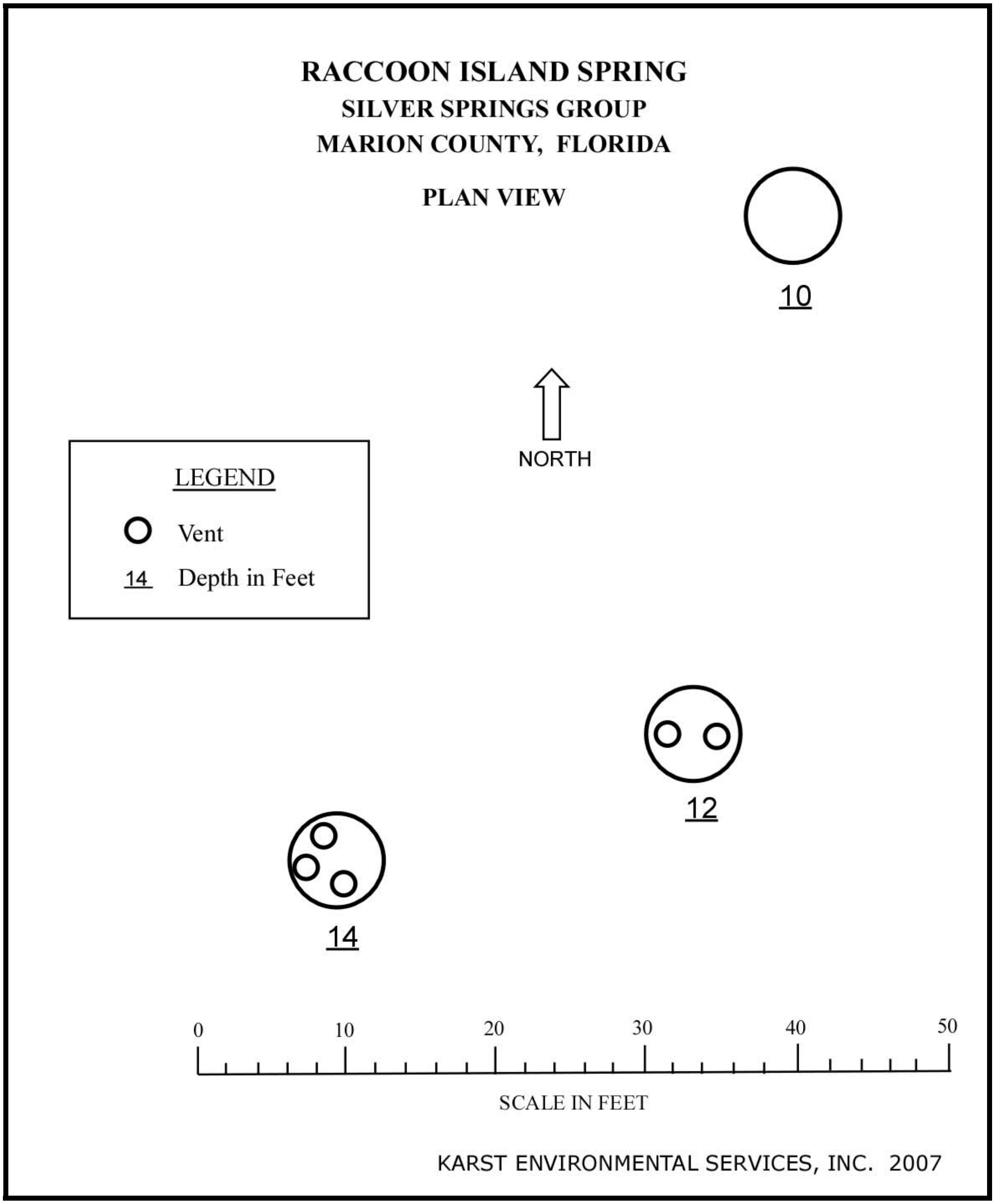

Figure 1. Map of Raccoon Island Spring.

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ______ Time Constant: ______

SensorSer # N/A

Type of Reading

Velocity:

X FPS
_ CMS
_ ______

Level:

_ IN
_ CM
X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ______

Calibration Technician: [signature] Date: 18 Apr 2006

QA Technician: [signature] Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

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P/N 101001 301

Discharge Measurement:
Shipwreck Spring,
Marion County, Florida;
September 30, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
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High Springs, Florida 32643
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Discharge Measurement: Shipwreck Spring, Marion County, Florida; September 30, 2006

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Results of Discharge Measurements of Shipwreck Spring, Marion County, Florida; September 30, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Shipwreck Spring on September 30, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Shipwreck Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

The main vent of the Shipwreck Springs Group is located at the bow of a sunken boat on the bottom of a large, 20 foot deep depression north of the main river channel, and east of the eastern tip of a forested island. The main vent discharges from rock through a layer of sediment and algae. Another similar but smaller vent lies about 15 feet to the east. Discharging from the algae-covered bottom of the western side of the basin, and about 20 to 30 feet from the stern section of the sunken boat, are numerous small vents. See Figure 1.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

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It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Shipwreck Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Shipwreck Spring on September 30, 2006 was 0.90 CFS (cubic feet per second). This result is also expressed as 404 GPM (gallons per minute) or 0.352 MGD (million gallons per day), see Table 1. Three readings were made at each of five vents, for a total of fifteen (15) readings. Individual point velocity readings ranged from 0.15 to 0.1.61 feet per second (fps), with an overall average station reading of 0.58 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 17 to 20 feet. The measurements commenced at about 15:17 hours and were completed by 16:00 hours.

UNDERWATER DISCHARGE MEASUREMENT							
Location:	**SHIPWRECK SPRINGS GROUP**		Date:	**September 30, 2006**			
	Silver Springs Group,		Time Start:	15:17			
	Marion County, Florida		Time End:	16:00			
Personnel:	Peter Butt, Mark Long		Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe			
Calculation Method: Discharge = V x *pi* x r^2			Method:	Vent Discharge Capture Device		(0.49' Diameter)	
Measurement Periods:		60 seconds					
Shipwreck Springs Group ESTIMATED Discharge:			**Vent 1**	**Vent 2**	**Vent 3**	**Vent 4**	**Vent 5**
CFS	**0.90**		**0.140**	**0.455**	**0.085**	**0.087**	**0.134**
MGD	**0.582**		**0.091**	**0.294**	**0.055**	**0.056**	**0.087**
GPM	**404**		**63**	**204**	**38**	**39**	**60**
		(Multiplier:)	n/a	(1.5)	(3)	(3)	(3)
Shipwreck Springs Group Measured Discharge:			**Vent 1**	**Vent 2**	**Vent 3**	**Vent 4**	**Vent 5**
CFS	**0.55**		**0.140**	**0.303**	**0.028**	**0.029**	**0.045**
MGD	**0.352**		**0.091**	**0.196**	**0.018**	**0.019**	**0.029**
GPM	**245**	All Vents:	**63**	**136**	**13**	**13**	**20**
Avg. Point Velocity (ft/sec):		0.58	0.74	1.61	0.15	0.15	0.24
Vent Depth (feet deep):			20	20	17	17	17
Velocity Readings:		(All velocity readings in feet per second.)					
Vent 1		**Vent 2**		**Vent 3**			
Vent East of Wreck Bow		Main Vent at Wreck Bow		West of Wreck Stern A			
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity		
1	0.72	1	1.61	1	0.15		
2	0.76	2	1.6	2	0.15		
3	0.75	3	1.61	3	0.15		
Average:	0.74	Average:	1.61	Average:	0.15		
Discharge:	0.140	Discharge:	0.303	Discharge:	0.028		
		Multiplier:	1.5	Multiplier:	3		
Est. Discharge:	n/a	**Est. Discharge:**	**0.455**	**Est. Discharge:**	**0.085**		
Vent 4		**Vent 5**					
West of Wreck Stern B		West of Wreck Stern C					
Reading #	Point Velocity	Reading #	Point Velocity				
1	0.15	1	0.23				
2	0.16	2	0.24				
3	0.15	3	0.24				
Average:	0.15	Average:	0.24				
Discharge:	0.029	Discharge:	0.045				
Multiplier:	3	Multiplier:	3				
Est. Discharge:	**0.087**	**Est. Discharge:**	**0.134**				

Table 1. Discharge of Shipwreck Spring, Marion County, Florida on September 30, 2006. Data record and calculation of discharge measurement.

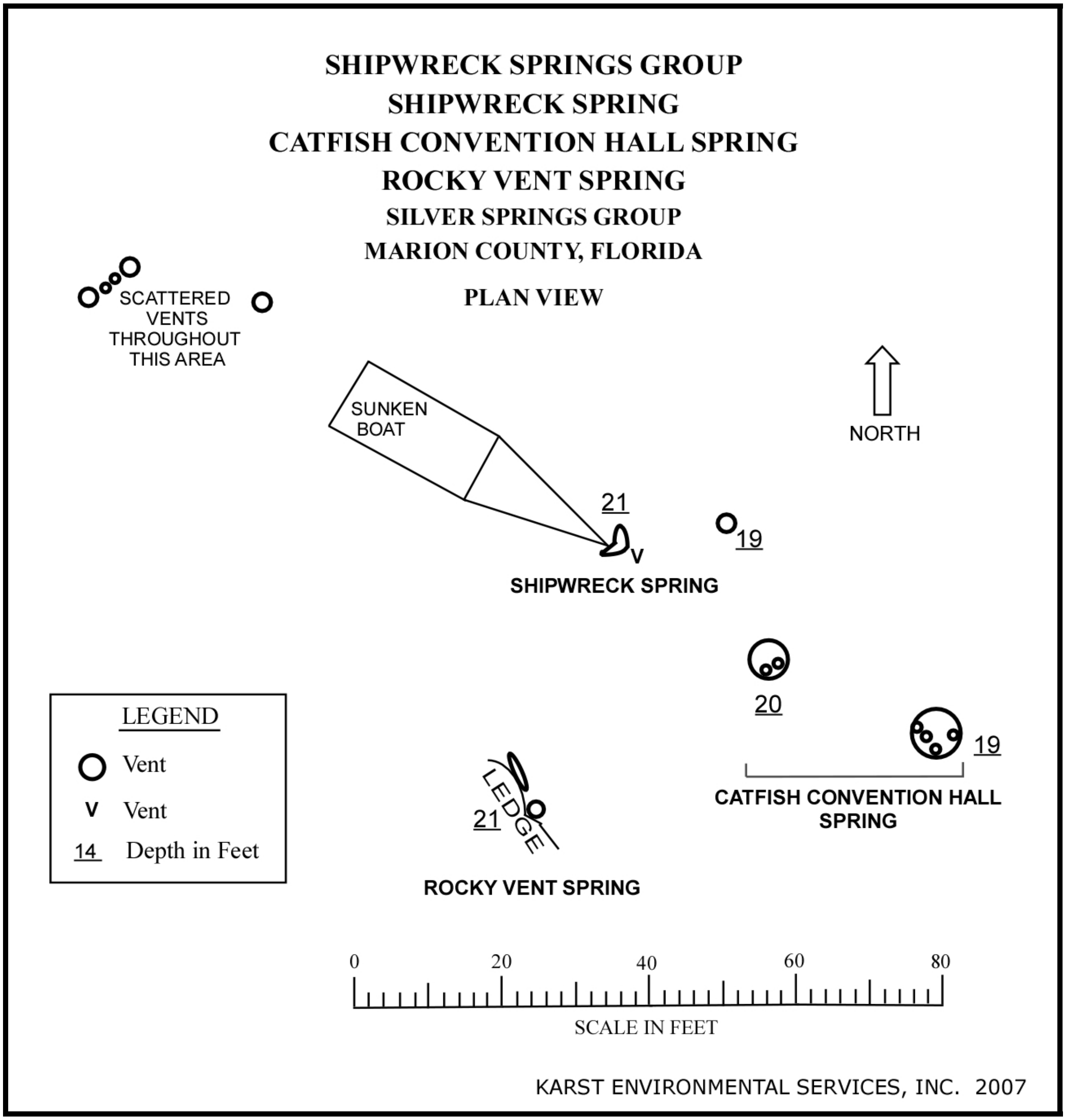

Figure 1. Map of Shipwreck Spring.

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ______ Time Constant: ______

SensorSer # N/A

Type of Reading

Velocity:

X FPS

_ CMS

_ ______

Level:

_ IN

_ CM

X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ______

Calibration Technician: Stan Cinkoski Date: 18 Apr 2006

QA Technician: B Hall Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY

A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

P/N 101001 301

Discharge Measurement: Timber Spring, Marion County, Florida; September 30, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Marion County, Florida; September 30, 2006

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Results of Discharge Measurements of Timber Spring, Marion County, Florida; September 30, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Timber Spring on September 30, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Timber Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

Timber Spring lies in the north side of the Silver River, about 800 feet downstream of the Shipwreck Springs Group. It is the most downstream of the springs in the Silver River. It has at least 6 vents about 14 feet deep in a 20 foot long roughly oval depression with a bottom of detritus, sand, and pebbles. A few fallen branches and logs lay across some of the spring vents. See Figure 1.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as “Estimated Discharge”, and are presented along with the original “Measured Discharge” value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Timber Spring applying the method and data processing used at other spring sites by KES. Based on KES’ experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Timber Spring on September 30, 2006 was 2.33 CFS (cubic feet per second). This result is also expressed as 1047 GPM (gallons per minute) or 1.508 MGD (million gallons per day), see Table 1. Three readings were made at each of six vents, for a total of eighteen (18) readings. Individual point velocity readings ranged from 0.25 to 0.97 feet per second (fps), with an overall average station reading of 0.68 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 14 feet. The measurements commenced at about 15:47 hours and were completed by 18:16 hours.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**TIMBER SPRING**		Date:	**September 30, 2006**	
	Silver Springs Group,		Time Start:	15:47	
	Marion County, Florida		Time End:	18:16	
Personnel:	Peter Butt, Mark Long				
Method:	Vent Discharge Capture Device	(0.49' Diameter)			
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe.				
Calculation Method: Discharge = V x *pi* x r^2					
Measurement Periods:	60 seconds				
Timber Spring Total Discharge:			**Vent 1**	**Vent 2**	**Vent 3**
CFS	**2.33**		**0.170**	**0.180**	**0.050**
MGD	**1.508**		**0.110**	**0.116**	**0.033**
GPM	**1047**	All Vents:	**76**	**81**	**23**
Avg. Point Velocity (ft/sec):		0.68	0.90	0.95	0.27
Vent Depth (feet deep):			14	14	14
			Vent 4	**Vent 5**	**Vent 6**
		CFS	**0.727**	**0.787**	**0.420**
		MGD	**0.470**	**0.508**	**0.271**
		GPM	**326**	**353**	**189**
	Avg. Point Velocity (ft/sec):		0.73	0.79	0.42
	Vent Depth (feet deep):		14	14	14
Velocity Readings:		(All velocity readings in feet per second.)			
Vent 1		**Vent 2**		**Vent 3**	
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity
1	0.9	1	0.87	1	0.28
2	0.9	2	0.97	2	0.27
3	0.9	3	1.02	3	0.25
Average:	0.90	Average:	0.95	Average:	0.27
Discharge:	0.170	Discharge:	0.180	Discharge:	0.050
Vent 4		**Vent 5**		**Vent 6**	
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity
1	0.73	1	0.8	1	0.41
2	0.74	2	0.8	2	0.43
3	0.71	3	0.76	3	0.42
Average:	0.73	Average:	0.79	Average:	0.42
Discharge:	0.137	Discharge:	0.148	Discharge:	0.079

Table 1. Discharge of Timber Spring, Marion County, Florida on September 30, 2006. Data record and calculation of discharge measurement.

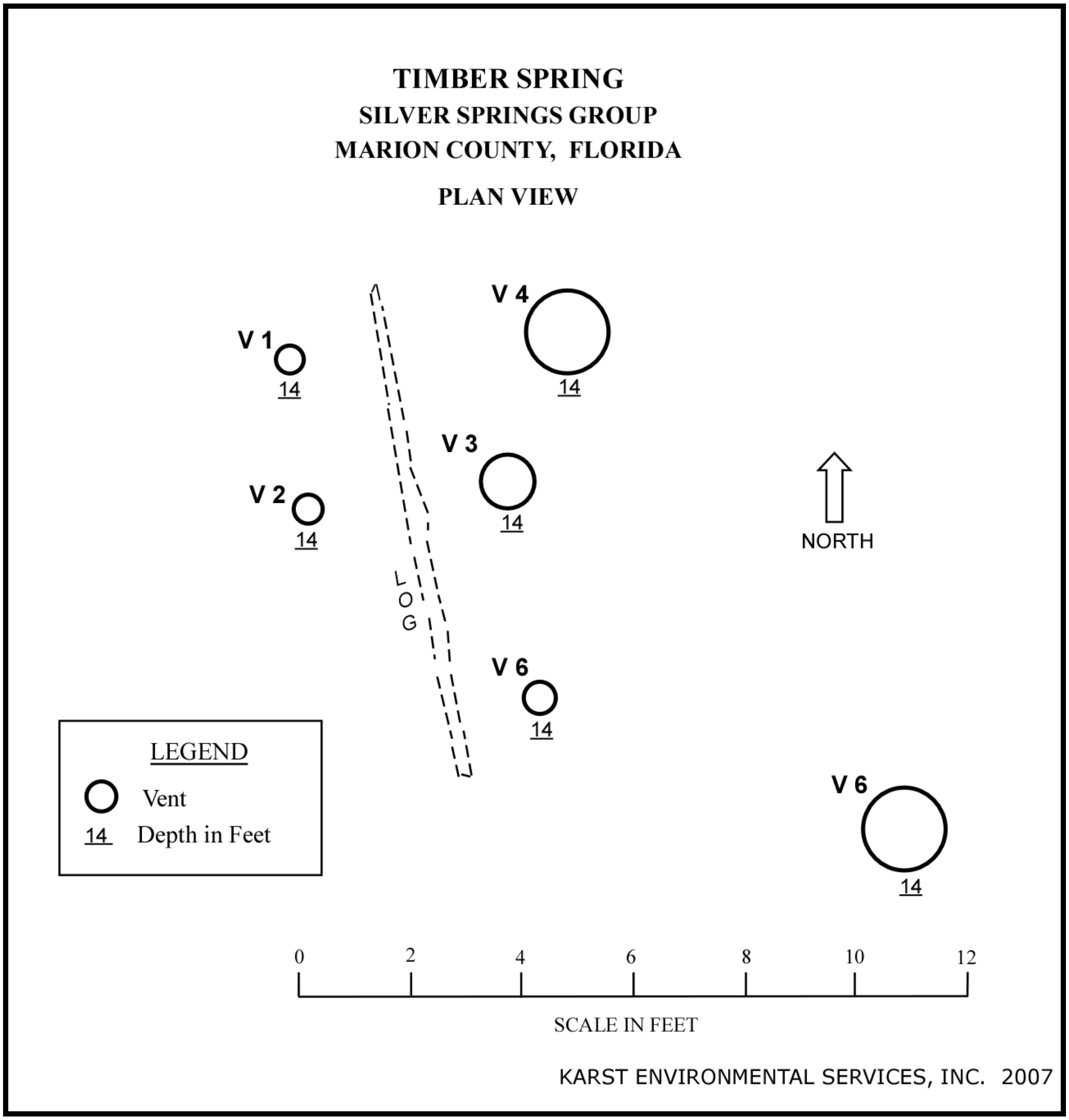

Figure 1. Map of Timber Spring.

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ____________ Time Constant: ____________

SensorSer # N/A

Type of Reading

Velocity:
- X FPS
- _ CMS
- _ ______

Level:
- _ IN
- _ CM
- X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: Stan Cumbski Date: 18 Apr 2006

QA Technician: B Hall Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
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P/N 101001 301

Discharge Measurement:
Turtle Nook Spring,
Marion County, Florida;
September 28, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
5779 NE County Road 340
High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Turtle Nook Spring, Marion County, Florida; September 30, 2006

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Results of Discharge Measurements of Turtle Nook Spring, Marion County, Florida; September 30, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Turtle Nook Spring on September 30, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Turtle Nook Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

Turtle Nook Spring is located on the northwest side of a forested island in the river, approximately 100 feet northeast of Second Fisherman's Paradise. Water discharges from three vents along a line about 10 feet long at the bottom of a small, conical basin. The vents are between 15 and 18 feet deep. See Figure 1.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter. One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as “Estimated Discharge”, and are presented along with the original “Measured Discharge” value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Turtle Nook Spring applying the method and data processing used at other spring sites by KES. Based on KES’ experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Turtle Nook Spring on September 30, 2006 was 0.63 CFS (cubic feet per second). This result is also expressed as 283 GPM (gallons per minute) or 0.408 MGD (million gallons per day), see Table 1. Three readings were made at each of two vents, for a total of six (6) readings. Individual point velocity readings ranged from 0.79 to 1.05 feet per second (fps), with an overall average station reading of 0.94 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 15 to 18 feet. The measurements commenced at about 13:15 hours and were completed by 13:26 hours.

UNDERWATER DISCHARGE MEASUREMENT				
Location:	**TURTLE NOOK SPRING**		Date:	**September 30, 2006**
	Silver Springs Group,		Time Start:	13:15
	Marion County, Florida		Time End:	13:26
Personnel:	Peter Butt, Mark Long			
Method:	Vent Discharge Capture Device		(0.49' Diameter)	
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe.			
Calculation Method: Discharge = V x *pi* x r^2				
Measurement Periods:		60 seconds		
Turtle Nook Spring ESTIMATED Discharge:			**North Vent:**	**South Vent:**
CFS	**0.63**		**0.389**	**0.242**
MGD	**0.408**		**0.251**	**0.157**
GPM	**283**		**174**	**109**
		(Multipliers:)	(2)	(1.5)
Turtle Nook Spring Measured Discharge:				
CFS	**0.36**		**0.194**	**0.162**
MGD	**0.230**		**0.126**	**0.104**
GPM	**160**	All Vents:	**87**	**73**
Avg. Point Velocity (ft/sec):		0.94	1.03	0.86
Vent Depth (feet deep):			18	15
Velocity Readings:		(All velocity readings in feet per second.)		
North Vent:		**South Vent:**		
Reading #	Point Velocity	Reading #	Point Velocity	
1	1.02	1	0.91	
2	1.02	2	0.87	
3	1.05	3	0.79	
Average:	1.03	Average:	0.86	
Discharge:	0.194	Discharge:	0.162	
Multiplier:	2	Multiplier:	1.5	
Est. Discharge:	**0.389**	**Est. Discharge:**	**0.242**	

Table 1. Discharge of Turtle Nook Spring, Marion County, Florida on September 30, 2006. Data record and calculation of discharge measurement.

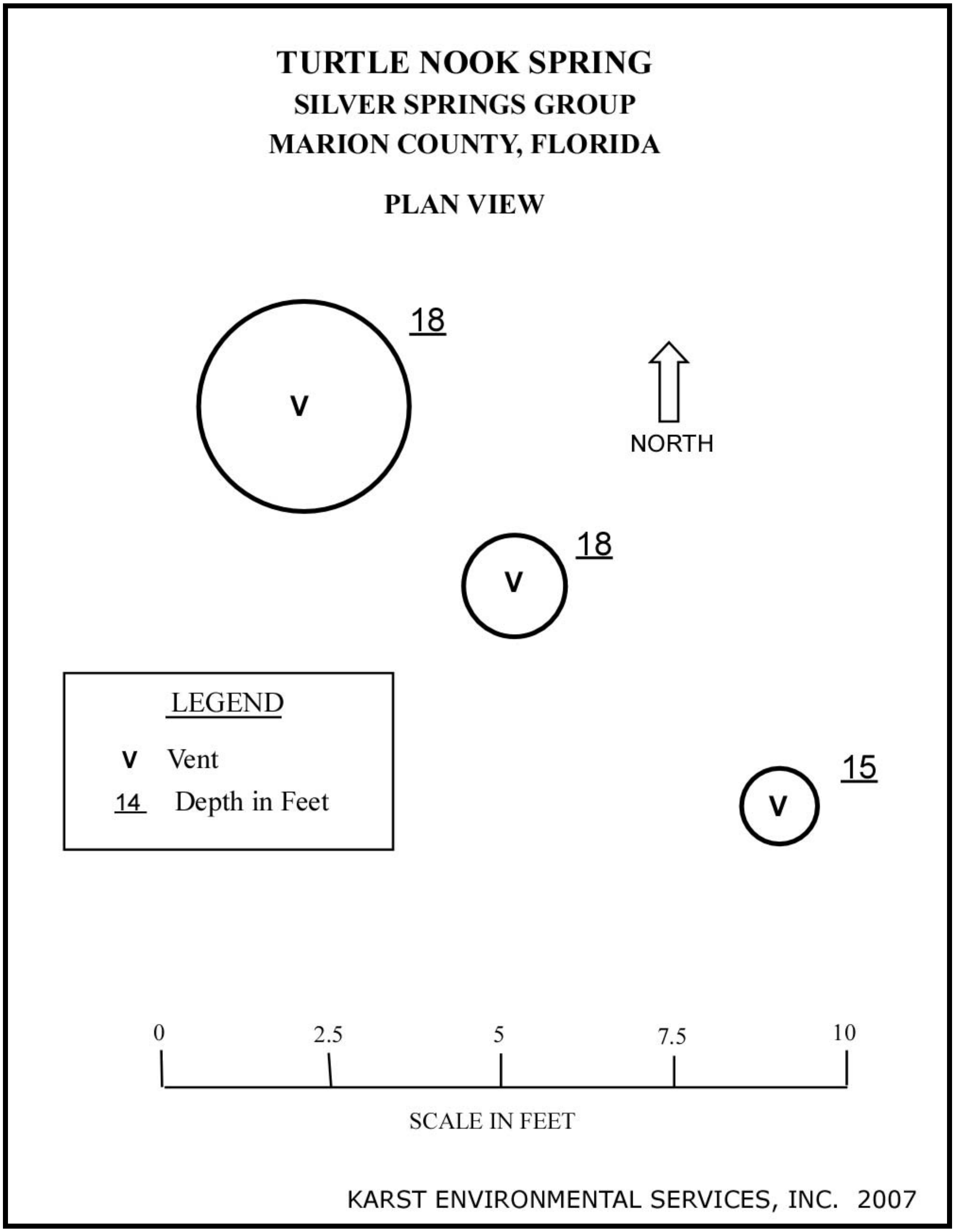

Figure 1. Map of Turtle Nook Spring.

CALIBRATION CERTIFICATE

Model: 2ØØØ-21 Serial Number: 2ØØ2679

Unit Gain Ratio: ____________ Time Constant: ____________

Sensor Ser # N/A

Type of Reading

Velocity:

X FPS

_ CMS

_ ______

Level:

_ IN

_ CM

X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.ØØ	N/A
Measured:	Ø.ØØ	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ____________

Calibration Technician: [signature] Date: 18 Apr 2006

QA Technician: [signature] Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

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P/N 101001 301

Discharge Measurement: Turtle Nook Run Spring, Marion County, Florida; September 29, 2006

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

Karst Environmental Services, Inc.
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High Springs, Florida 32643
(386) 454-3556 (386) 454-3541 FAX

Discharge Measurement: Turtle Nook Run Spring, Marion County, Florida; September 29, 2006

LIST OF CONTENTS

Results of Discharge Measurements of Turtle Nook Run Spring, Marion County, Florida; September 29, 2006

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) contracted with Karst Environmental Services, Inc. (KES) to conduct a series of discharge measurements at the Silver Springs Group in Marion County, Florida. This report documents the results of the measurement made at Turtle Nook Run Spring on September 29, 2006.

PURPOSE and SCOPE OF WORK

The purpose of this work is to obtain an initial discharge measurement of Turtle Nook Run Spring, which is among the many sources of groundwater discharging into the Silver River. A program of discharge measurements was to be made of the springs in the Silver Springs Group during September of 2006.

PERSONNEL

Fieldwork for this discharge measurement was conducted by Peter Butt and Mark Long, both of KES. Data management and report preparation was performed by Peter Butt. W. Bruce Lafrenz, P.G., of Tetra Tech HAI of Orlando, Florida provided oversight.

SITE DESCRIPTION

Turtle Nook Run Spring is located about 30 feet southwest of Turtle Nook Spring, at the west side of the entrance to the cove. Water discharges from several rocky vents and one detrital vent cluster.

The main vent discharges from along a rock outcrop, 18 feet deep, and beneath a ledge on the south side of a basin about 25 feet in diameter. Several smaller vents also discharge through sediment and algae to the north of the main vent. The top of the limestone outcrop in the basin is 13 feet below the water surface. The basin is just north of and out of the main channel of the Silver River. See Figure 1.

Since the vents of this spring are located on the bottom of the river, its discharge cannot be measured by conventional discharge measurement methods. However, at the spring opening there is a suitable location for a discharge measurement that lends itself to the application of an appropriately adapted instrument.

METHODS

The instrument used for this discharge measurement was a Marsh-McBirney Model 2000 Flo-Mate electronic flowmeter (Serial Number 2002679) that has been adapted for fully submersible use. In order to operate and read the meter at depth, the unit has been placed within an underwater housing with a transparent lid. The sensor wire is routed through a sealing gland on the housing lid. There are two housing controls that allow for direct operation of the flow meter.

One operates the on/off/reset buttons, and the other operates the time interval selector buttons that control the measurement period.

The flowmeter used was factory calibrated while in its underwater housing in the method normally used for this unit on April 18, 2006. A copy of the Calibration Certificate is included with this report.

This spring consists of small, scattered vents discharging through a mixed bottom of either detritus, sediments, a thick algal layer, sand or pebbles. Direct measurements of the vent cross-sections at this site were not practical. To accomplish measurements of these vents, a device was designed and employed to capture and concentrate the vent discharge for effective measurement. This device is referred to herein as the Vent Discharge Capture Device (VDCD).

The VDCD is constructed of an inverted heavy-duty plastic tub that has a plastic flange connecting it to a short length of plastic pipe. The tub dimensions are 2.23 feet inside diameter on its bottom, a height of 1.05 feet, and a top inside diameter of 1.8 feet. The top side of the tub has a 0.5 foot hole to which a flange is attached. A 0.49 foot inside diameter plastic discharge pipe is attached to the flange and extends upward for 2.05 feet. This minimum pipe length was chosen to minimize turbulence at the sensor placement location at its upper end.

A section of half-inch PVC pipe is inserted through holes on opposite sides of the discharge pipe near its top for positioning the flow sensor. The sensor has a spring clip that attaches it to the half-inch PVC pipe, and it is positioned facing downward in the center of the discharge pipe.

To install the VDCD over a spring vent for a measurement, the open end of the tub is centered over a vent and pushed down onto the bottom, often into the sediment or detritus. Belts of weights are placed around the flange area of the tub to securely hold it in place. Sediments were sometimes arranged around the bottom circumference of the tub to provide a more effective seal. The discharge pipe is kept in a vertical position. The sensor is positioned at a right angle to the main flow path within the discharge pipe, so no angle coefficient corrections for velocity readings are necessary.

Once in place, the installation is checked for leakage around its bottom circumference. The condition of nearby vents is monitored for changes in flow, or the formation of new vents. A few minutes are allowed to let debris clear and for conditions to stabilize. The sensor is monitored for debris accumulation and cleaned off as needed.

Once the VDCD and sensor are positioned, and positional data recorded, velocity readings are made. During all measurements, the sensor handler moved away from the discharge pipe, eliminating the possibility of interference while the measurements were taken. The flowmeter was operated in its Fixed Point Averaging mode. Fixed Point Averaging is an average of measured velocities over a fixed period of time. Averaging periods of 60 seconds were used. The flowmeter was reset between each reading. A record and the calculated results of these measurements are presented in Table 1.

To measure the discharge, a series of three readings are typically taken at each vent installation, and the average velocity determined. The discharge (Q) is calculated by multiplying the averaged velocity by the area of the pipe ($Q = V \times pi \times r^2$). For purposes of this calculation, it is assumed that the measured velocity is representative of velocities over the entire cross-section. This assumption is based on direct observations of the uniformity of flow exiting the pipe. In addition, the plastic pipe is smooth sided and relatively short in length.

It was often impractical or impossible to capture and quantify all of a spring's discharge at its various vents using this device. The reasons include; leakage, large size of vents, backpressure effects at adjacent vents, vents formed on long, narrow fissures and the presence of small vents too numerous and scattered to effectively measure. To better estimate the actual discharge, a multiplier was applied to the measurement results of some individual vents and lines of vents in order to account for water that would be otherwise missed at and beyond the measurement locations. While applying this multiplier to a measured discharge adds some element of subjectivity to that measurement, it is felt that this method provides a more accurate description in a difficult measurement situation. When used, these multipliers and resulting values are included in Table 1, and identified therein as "Estimated Discharge", and are presented along with the original "Measured Discharge" value.

RESULTS AND DISCUSSION

This measurement is the first one performed at Turtle Nook Run Spring applying the method and data processing used at other spring sites by KES. Based on KES' experience at other springs, the estimate of discharge for this initial measurement should be considered to be a minimum value. The data from this measurement will also provide a guide for the planning and improvements for any future measurements of this type here.

The estimated discharge of Turtle Nook Run Spring on September 29, 2006 was 0.64 CFS (cubic feet per second). This result is also expressed as 287 GPM (gallons per minute) or 0.413 MGD (million gallons per day), see Table 1. Three readings were made at each of three vents, for a total of nine (9) readings. Individual point velocity readings ranged from 0.33 to 0.67 feet per second (fps), with an overall average station reading of 0.51 fps. Individual point velocity measurement periods of 60 seconds were used. The approximate depth for the measurements was 15 to 18 feet. The measurements commenced at about 17:24 hours and were completed by 17:42 hours.

UNDERWATER DISCHARGE MEASUREMENT					
Location:	**TURTLE NOOK RUN SPRING**		Date:	**September 29, 2006**	
	Silver Springs Group,		Time Start:	17:24	
	Marion County, Florida		Time End:	17:42	
Personnel:	Peter Butt, Mark Long				
Method:	Vent Discharge Capture Device		(0.49' Diameter)		
Instrument:	MMB2000 FLO-MATE in U/W case, sensor in vertical pipe.				
Calculation Method: Discharge = V x *pi* x r^2					
Measurement Periods:		60 seconds			
Turtle Nook Run Spring ESTIMATED Discharge:			**Vent 1:**	**Vent 2:**	**Vent 3:**
CFS	**0.64**		**0.200**	**0.189**	**0.250**
MGD	**0.413**		**0.129**	**0.122**	**0.162**
GPM	**287**		**90**	**85**	**112**
		(Multipliers:)	(2)	(3)	(2)
Turtle Nook Run Spring Measured Discharge:					
CFS	**0.29**		**0.100**	**0.063**	**0.125**
MGD	**0.186**		**0.065**	**0.041**	**0.081**
GPM	**129**	All Vents:	**45**	**28**	**56**
Avg. Point Velocity (ft/sec):		0.51	0.53	0.33	0.66
Vent Depth (feet deep):			15	15	18
Velocity Readings:		(All velocity readings in feet per second.)			
Vent 1		**Vent 2**		**Vent 3**	
Main Vent (tag)		North Vent		West Vent	
Reading #	Point Velocity	Reading #	Point Velocity	Reading #	Point Velocity
1	0.53	1	0.34	1	0.65
2	0.53	2	0.33	2	0.67
3	0.53	3	0.33	3	0.67
Average:	0.53	Average:	0.33	Average:	0.66
Discharge:	0.100	Discharge:	0.063	Discharge:	0.125
Multiplier:	2	Multiplier:	3	Multiplier:	2
Est. Discharge:	**0.200**	**Est. Discharge:**	**0.189**	**Est. Discharge:**	**0.250**

Table 1. Discharge of Turtle Nook Run Spring, Marion County, Florida on September 29, 2006. Data record and calculation of discharge measurement.

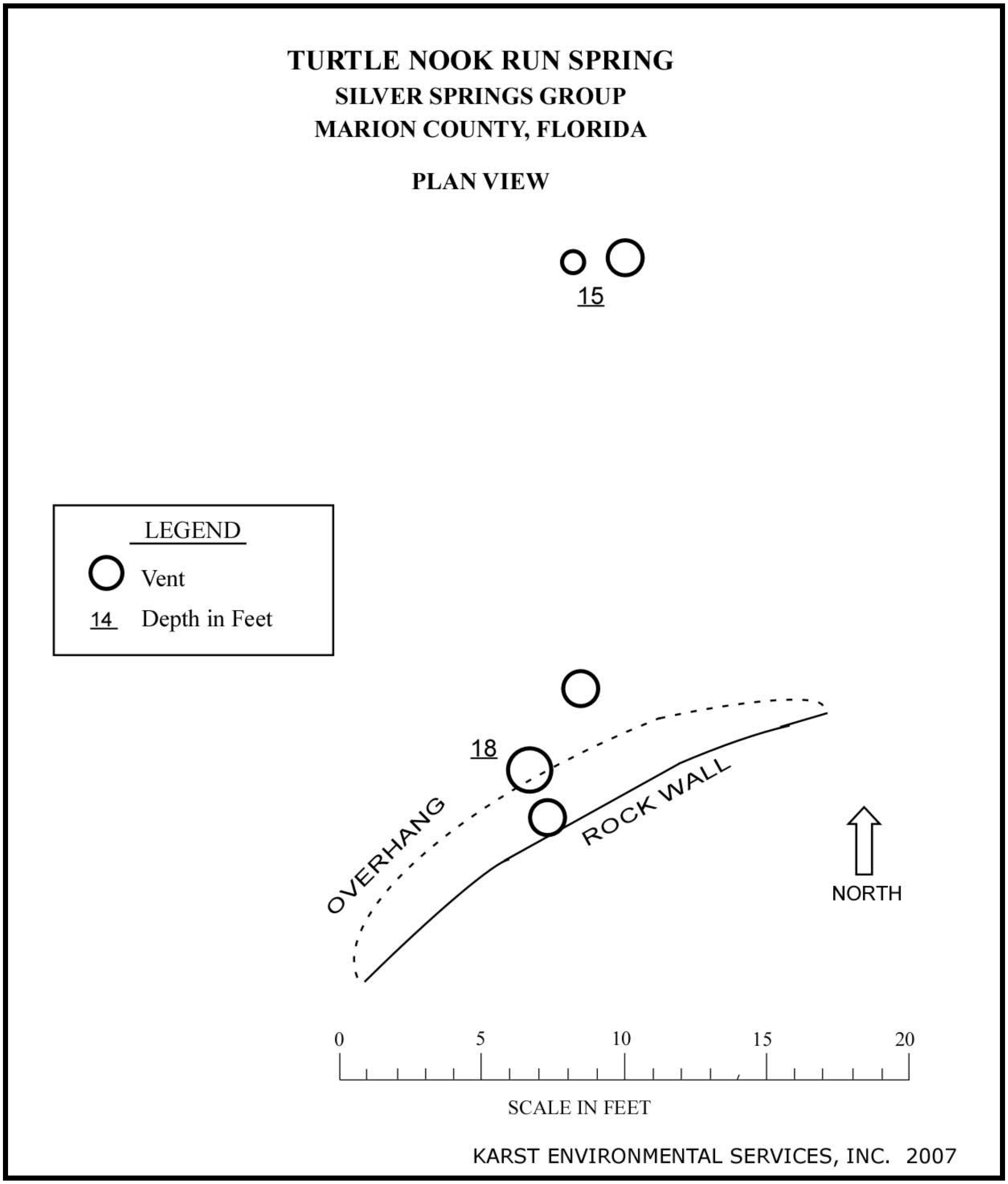

Figure 1. Map of Turtle Nook Run Spring.

CALIBRATION CERTIFICATE

Model: 2000-21 Serial Number: 2002679

Unit Gain Ratio: ______ Time Constant: ______

SensorSer # N/A

Type of Reading

Velocity:

X FPS

_ CMS

_ ______

Level:

_ IN

_ CM

X N/A

	Static Velocity	Dynamic Velocity	Level
Standard:	Zero	2.00	N/A
Measured:	0.00	1.98	N/A

X Factory Calibration TOW TANK

_ Field Profile Calibration;
Site Coefficient or Velocity Multiplier: ______

Calibration Technician: Stan Cwalski Date: 18 Apr 2006

QA Technician: B Hall Date: 4/18/06

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results show above. Velocity calibration is traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, MD. For Product information, service, or calibration, please contact the Customer Service Department.

MARSH McBIRNEY
A Higher Level of Flow Measurement

4539 Metropolitan Ct., Frederick, MD 21704-9452
(301) 874-5599 _ (800)-368-2723 _ FAX (301) 874-2172

P/N 101001 301

SUMMARY of DISCHARGE MEASUREMENTS

Silver River Springs Group, Marion County, Florida; September, 2006

Spring/Vent Name	Abbrev.	Number of Vents	Depth (in feet)	Method	Date	Time	Discharge CFS	Discharge MGD	Discharge GPM	Number of PV Stations	X-sectional Area	Highest PV Reading	Lowest PV Reading	Negative PV Stations	Number of VDCD Msmnts	Multiplier Used?
Mammoth	**ME, MW**	1	40	Grid XSec	9/19/2006	13:40-17:50	**240.07**	**155.16**	**107750**	138	308.16	1.16	-0.39	8	n/a	n/a
Jacobs Well	**JW**	1	22	Grid XSec	9/21/2006	18:01-18:39	**2.57**	**1.661**	**1153**	26	8.831	0.94	0.16	none	n/a	n/a
Catfish Reception Hall	**CR**	3	27-33	Grid XSec	9/21/2006	14:17-17:29	**36.43**	**23.543**	**16349**	62	59.54	1.29	0.13	none	n/a	n/a
Bridal Chamber	**BC**	1	25	Grid XSec	9/22/2006	12:18-13:10	**4.61**	**2.98**	**2069**	31	12.72	1.25	-0.03	3	n/a	n/a
Oscar	**OS**	3	15-17	VDCD	9/28/2006	14:30-14:41	**0.46**	**0.295**	**205**	n/a	n/a	0.5	0.28	n/a	3	yes
Devils Kitchen B	**DK-2**	1	15-17	VDCD	9/28/2006	15:58-16:08	**0.24**	**0.157**	**109**	n/a	n/a	1.02	0.23	n/a	2	no
Ladies Parlor	**LP**	4	20-22	Grid XSec	9/22/2006	14:32-16:03	**9.56**	**6.18**	**4292**	35	13.7	1.54	-0.016	4	n/a	n/a
Devils Kitchen A	**DK-1**	4	20	Grid XSec	9/28/2006	15:21-15:55	**1.51**	**0.976**	**678**	17	3.16	1.81	-0.04	1	n/a	n/a
Alligator Hole	**AH**	2	15-18	VDCD	9/28/2006	16:35-17:00	**0.77**	**0.498**	**346**	n/a	n/a	1.85	0.93	n/a	3	no
Mastodon Bone	**MB**	1	13	Grid XSec	9/28/2006	13:51-14:11	**1.448**	**0.936**	**650**	13	2.755	1.21	-0.01	1	n/a	n/a
Geyser	**GY**	5	18-21	Grid XSec	9/30/2006	11:03-12:40	**5.36**	**3.467**	**2408**	52	21.25	1.06	-0.53	1	n/a	n/a
		3	15-18	VDCD	9/29/2006	16:09-16:28	**0.7**	**0.456**	**316**	n/a	n/a	1.13	0.24	n/a	3	yes
Blue Grotto	**BG**	2	26	Grid XSec	9/29/2006	14:34-15:51	**6.28**	**4.058**	**2818**	40	8.95	1.87	-0.1	3	n/a	n/a
Christmas Tree	**CT**	5	18	VDCD	9/29/2006	12:42-13:20	**4.18**	**2.705**	**1878**	n/a	n/a	1.51	0.47	n/a	6	yes
Garden of Eden	**GE**	3	16	VDCD	9/29/2006	11:04-12:25	**2.559**	**1.654**	**1149**	n/a	n/a	1.12	0.25	n/a	12	yes
Indian Cave	**IC**	4	15-17	Grid XSec	9/28/2006	11:43-12:40	**4.31**	**2.786**	**1934**	34	11.64	0.8	0.11	none	n/a	n/a
		1	11	VDCD						n/a	n/a	0.89	0.85	n/a	1	no
First Fishermans Paradise	**FP-1**	5	18	No Discharge Measurement Performed Due to Absence of Suitable Cross-sections.												
No Name Cove	**NN**	3	15-18	VDCD	9/29/2006	16:53-17:11	**0.24**	**0.153**	**106**	n/a	n/a	*0.07*	*0.41*	n/a	3	yes
Turtle Meadows	**TM**	3	15	No Discharge Measurement Performed Due to Absence of Suitable Cross-sections.												
Second Fishermans Paradise	**FP-2**	1	24	Grid XSec	9/22/2006	17:01-17:24	**0.56**	**0.365**	**253**	14	1.205	1.09	-0.07	2	n/a	n/a
Catfish Hotel	**CH**	3	29	No Discharge Measurement Performed Due to Absence of Suitable Cross-sections.												
Turtle Nook	**TN**	2	15-18	VDCD	9/30/2006	13:15-13:26	**0.63**	**0.408**	**283**	n/a	n/a	0.79	1.05	n/a	2	yes
Turtle Nook Run	**TR**	3	15-18	VDCD	9/29/2006	17:24-17:42	**0.64**	**0.186**	**287**	n/a	n/a	0.33	0.67	n/a	3	yes
Raccoon Island	**RI**	3	10-14	VDCD	9/28/2006	17:12-17:35	**0.52**	**0.338**	**235**	n/a	n/a	0.5	0.31	n/a	3	yes
Rocky vent	**RV**	1	21	No Discharge Measurement Performed Due to Absence of Suitable Cross-sections.												
Shipwreck	**SW**	5	17-20	VDCD	9/30/2006	15:17-16:00	**0.9**	**0.582**	**404**	n/a	n/a	1.61	0.15	n/a	5	yes

Catfish Convention Hall	**CC**	2	19	VDCD	9/30/2006	15:00-15:16	**0.32**	**0.204**	**142**	n/a	n/a	0.75	0.42	n/a	3	no
Timber	**TB**	6	14	VDCD	9/30/2006	15:47-18:16	**2.33**	**1.508**	**1047**	n/a	n/a	1.02	0.25	n/a	6	no
Total Measured (Estimated) Discharge:							**327.197**	**211.256**	**146861**							
							Discharge	**Discharge**	**Discharge**							
							CFS	**MGD**	**GPM**							

Appendix 6
Cluster Analysis Report

Multivariate Statistical Analysis of Water Quality Data for Silver Springs, Marion County, Florida

FINAL REPORT

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

Prepared by:

INTERA, Inc.
Niwot, Colorado

May 4, 2007

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Executive Summary

Strong spatial gradients and geochemical clusters are identified in waters entering Silver Springs. Three basic water types are identified that differ in their concentrations of sulfate, dissolved oxygen, Ca, Mg, alkalinity, Na, Cl and nitrate. One group of analytes associated with sulfate weathering and potential anthropogenic pollution or deep brines includes nitrate, sulfate, Na, Cl, and dissolved oxygen, and has strong north-south gradients and weak east-west gradients. Concentrations of these solutes are highest in the southern vents and decrease with distance north. A second group of solutes associated with carbonate weathering includes alkalinity (HCO_3), Mg, Ca, and TDS and has strong east-west gradients with weak north-south gradients. Nitrate is correlated with Na and Cl, suggesting an anthropogenic source or deep brine high in NO3. The southern vents have the highest nitrate concentrations, suggesting they should be targeted for nitrate control. Future geochemical analysis using groundwater wells could identify the flow paths that contribute to the geochemistry of the springs and may suggest mitigation strategies for nitrate contamination.

I. Introduction

The District has a contract with FDEP to perform multivariate statistical analysis on water quality data from 34 samples collected at Silver Springs. Silver Springs consists of 30 different vent groups and 61 vents. In September 2006, the District collected 34 different samples for water quality from 30 vent groups and measured the field parameters of temperature, pH, DO, and conductivity from 61 vents. The District would like to group these vents into a small number of sets of similar vents. The discrete sets of identified vents will then be the focus of sampling in the future for additional parameters of waste water constituents and isotopes. The water quality parameters available are:

- Temperature
- pH
- DO
- Field Conductivity
- Lab Conductivity
- Alkalinity
- NOx-total
- P-total
- TOC
- Ca-T
- Mg-T
- Na-T
- K-T
- Chloride
- Sulfate
- TDS
- PO4-T

The objective of the multivariate statistical analyses is to identify the discrete vent groups or vents that represent the data collected at Silver Springs. To achieve this objective, cluster analysis and principal component analysis are performed using SPLUS™ on water quality data collected from 34 samples collected at Silver Springs. Measurements included major ions and field parameters of temperature, pH, DO, and conductivity measured at different vents. A larger number of springs were also sampled for field parameters but were not analyzed for major ions. Here we include only the 34 vents with both major ion data and field parameter data. As detailed below, cluster analysis is performed to reveal which observations are most similar to each other and which observations are most different from each other. Another analysis method used in this report is principal component analysis which reveals the data attributes that can be used to provide a concise summary of the available measurements and can be easily used for subsequent analyses.

Multivariate statistics are used to simplify large volumes of data into simpler groups or components that describe most of the essential characteristics of the data. It has been used to identify clusters and factors in geochemical data (Salman and Ruka'h 1999, Suk and Lee 1999, Meng and Maynard 2001, Güler et al. 2002, Thyne et al. 2004, Ji-Hoon Kim et al. 2005), precipitation (Gong and Richman 1995, Domroes et al. 1998), climate (Fovell 1997), watershed properties (Mather and Doornkamp 1970, Wolock et al. 2004), and streamflow (Pegg and Pierce 2002).

This Report summarizes the results of the statistical analyses performed on these data. Training has also been provided to District staff on the utilized methods and software.

II. Cluster Analysis

Cluster analysis is a widely-used classification technique with the major advantage that no number of groups needs to be specified prior to the analysis (Johnson and Wichern, 1988). Instead, grouping is done on the basis of similarities and differences between the available measurements. The idea is to assign the data into groups where the inter-variance within each group is minimized and the intra-variance between different groups (clusters) is maximized. Variations of cluster analysis have been developed which require a prior specification of the number of groups (clusters). These variations are developed solely to reduce the computational burden of the classical clustering algorithms which can be significant when dealing with a large number of observations (e.g., above 1000). None of these methods will be used in this report as the number of observations is not large enough to necessitate the use of efficient computational algorithms.

One of the most powerful clustering algorithms is hierarchical cluster analysis (HCA) which has two variations: agglomerative and divisive. The agglomerative version (bottom-up) starts with each object in a class by itself. Then, in small steps, we add objects that are close enough to each other and form small groups (clusters) of objects. The process continues with clusters joining other similar clusters and more objects are grouped together into larger and larger clusters. Finally, in the last step, all objects are joined together. Divisive algorithms (top-down) operate in an opposite way where all objects start in the one cluster. Then smaller clusters break out of the large cluster to minimize the within-cluster variance. The process continues with smaller and smaller clusters forming until each object is in a separate cluster. Typically, the two HCA methods generate similar or identical results.

Geochemical data can be grouped for purposes of identifying spatial patterns in water chemistry and associate the patterns with other landscape variables such as hydrological flowpaths or land use. Geochemical facies or groups can be generated using hierarchical cluster analysis (HCA) on observed concentrations of major ions (Thyne et al. 2004). The results of HCA depend on the algorithm used and are typically sensitive to the dataset (Güler et al. 2002). The "agnes" algorithm ("agglomerative nesting") performs HCA in SPLUS™ and has several options:

Option	SPLUS™ Code	Option Recommended
Standardize variables	stand	True
Distance metric	metric	Euclidean
Method	method	Ward

We recommend standardizing the concentrations (stand = true), which gives all variables equal weight and prevents constituents with high concentrations (e.g., HCO3) from dominating the cluster structure. We use Euclidean distance, which is the most commonly used distance measure. Clusters may be aggregated using several different methods; here we follow Güler et al (2002) and Mathes and Rasmussen (2006) and use Ward distancing (also called incremental sum of squares method), which calculates the sum of squared errors as the sum of the Euclidean distances from each sample to the center of its cluster. Clusters are formed to minimize the sum of squared errors at each iteration. In the first iteration of HCA, the number of clusters equals the number of samples. The algorithm then iteratively forms clusters until all samples are included in a single cluster. The results of the clustering may be viewed in a dendrogram (Figure 1) which shows the sample numbers that form each cluster, and the Euclidean distance between each successive cluster. An arbitrary Euclidean distance is selected to distinguish vent groups; any clusters below the threshold are considered a distinct vent group.

One key methodological note is the importance of filling data gaps (Güler et al. 2002). Most statistical packages fill missing data with the average of the other samples for a given constituent, which could lead to erroneous groupings. The recommended method to fill gaps is multiple regression with other constituents as independent variables (Güler et al. 2002). There were no data gaps in the Silver Springs water quality data.

From a mathematical point of view, clusters are not unique. That is, few vents can change cluster designation depending on the numerical algorithm used during the cluster analysis. However, in practical terms, these are typically the border line measurements that have enough noise in their data to make them swing one way or the other. There are always some core vents that will not change cluster designation regardless of the numerical algorithm. These core vents are identified below in the results discussion. Further distinction by physical location (e.g., north and south banks), geochemical signature, or some other physical feature(s) must be used to solidify the uniqueness conclusion.

HCA has seven steps:

1. Export data into a text file for import to S-plus
2. Load data into SPLUS™
3. Standardize the concentration values
4. Run HCA in SPLUS™
5. Determine threshold height for clusters from the dendrogram
6. Calculate constituent means for each cluster (in Excel or SPLUS™)
7. Map clusters to examine spatial associations

III. Cluster Analysis Results

HCA on the Silver Springs water samples reveals five distinct groups (Figure 1, 2). Groups 4 and 5 consists of only one vent each and are distinguished from the other groups due to anomalously high TOC or P concentrations: Lost River (LR1, Group 4) had TOC of 33 mg/L and Catfish Convention Hall 1 (CC1, Group 5) had Total P of 2.1 mg/L.

When the two outlier samples are included in the HCA, the three main clusters show 11 vents each in clusters 1 and 2, and 10 vents in cluster 3 (Figure 1, A). When these two outliers are excluded from the HCA (Figure 1, B), few vents change clusters. When the two outlier samples are excluded, cluster one has 15 springs; cluster two has 10 springs; and cluster three has 7 springs (Table 1 and figure 1B). Vent 22 (No Name Cove) moves from cluster 2 to cluster 1. This illustrates the fact that few samples are borderline and can move between clusters without having a significant impact on the overall statistics. The remainder of this discussion will focus on Groups 1-3 each containing multiple vents. The names of the vents in each group are listed in Table 1.

Group 1 is located in the south and western part of the Silver River and has the highest TDS, DO, Ca, Mg, HCO3, SO4, NO3, and phosphorus (Figure 1). Group 2, which includes vents in the northern part of the springs, has lower concentrations of most solutes than Group 1, and particularly low DO, SO4 and P concentrations. Group 3 is intermediate between Groups 1 and 2.

The clusters show continuous rather than discrete changes from one group to the next as shown on the map (Figure 2) and Figures 3-12. This suggests that water from many of the vents represent a mixture of different source waters, rather than distinct end-members. A few vents within each cluster can be singled out as "end-members" corresponding to each of the three groups (highlighted in red in Table 1). The rest of the samples can be viewed as mixtures of these three waters.

Table 1. Geochemical groups with names and abbreviation. Red indicates samples that may be considered distinct geochemical end-members. The numbers correspond to Figure 1B, except for the 2 outlier springs, whose numbers correspond to Figure 1A.

Abbreviation	Number	Name
		Group 1
ME	1	Mammoth East
JW	3	Jacobs Well
CR1	4	Catfish Reception Hall 1
BC	5	Bridal Chamber
OS1	6	Oscar
DK21	7	Devils Kitchen B
LP1	8	Ladies Parlor
DK11	9	Devils Kitchen A1
AH1	10	Alligator Hole 1
GY1	12	Geyser 1
BG	13	Blue Grotto
IC1	20	IndianCave1
FP11	21	First Fisherman's Paradise 1 middle
FP15	22	First Fisherman's Paradise 5
NN	23	No Name Cove
		Group 2
MW	2	Mammoth West
MB1	11	Mastodon Bone
CT1	14	Christmas Tree Central
CT3	15	Christmas Tree North
GE1	16	Garden of Eden 1
GE2	17	Garden of Eden 2
L1	19	Log
TM1	24	Turtle Meadows 1
TN1	27	Turtle Nook
RI1	29	Raccoon Island 1 inland
		Group 3
FP2	25	Second Fisherman's Paradise
CH1	26	Catfish Hotel 1
TR1	28	Turtle Nook Run
RV1	30	Rocky Vent
SW1	31	Shipwreck 1
CC2	33	Catfish Convention Hall 2
TB1	34	Timber 1
	Outliers (number corresponds to Figure 1A)	
LR-1	18	Lost River 1
CC-1	32	Catfish Convention Hall 1

All water samples are Ca-HCO3 type (Figure 3), and Ca+HCO3 accounts for 73-88% of total dissolved solids. Groups 1 and 2 have proportionately more Ca, sulfate and Mg than Group 3, suggesting more weathering of gypsum ($CaSO_4$) and dolomite($CaMg(CO_3)_2$) in waters draining from the south, and dominantly carbonate weathering in waters draining from the north. This could also suggest that Group 1 and 2 are from a deeper source than Group 3. Group 2 has a slightly higher proportion of Na than the other two groups.

All samples fall on a single lithology, Eocene limerock (Eo). Consistent with the geology the spatial geochemical patterns suggest that carbonate weathering dominates though sulfate minerals are weathering in waters draining from the south. Alternatively, waters on the south (Group 1) are from a deeper source. Gypsum is present in the middle confining unit of the Floridan aquifer system.

Land use differs over the region and may contribute to the observed spatial patterns in vent geochemistry. The sampled vents are located within the boundaries of Silver Springs Park. Residential areas are located to the west of the springs, and forested areas, with some regenerating forest, are located to the east (Figure 13). More data, in particular chemical data from wells in the residential and forested areas, information on fertilization patterns on different land cover types, and the management of wastewater from the sewage treatment plant would be required to establish groundwater pathways and solute sources.

The solutes show contrasting behavior with latitude and longitude (Table 2). One group of solutes includes nitrate, sulfate, Mg, Cl, Na, and dissolved oxygen. This group shows the strongest gradients north-south, and weaker or no gradients east-west (Figures 4, 5, 8, 9, 10, 11). A second group indicates carbonate and dolomite weathering, and includes Ca, bicarbonate, and TDS. This group shows the strongest gradients east-west and weaker or no gradients north-south (Figures 6, 7, 12). Bicarbonate in particular shows strong east-west gradients but no north-south gradients (Figure 7). No solute has a significant correlation with depth.

The pollutant of most concern, nitrate, decreases from south to north, has no east-west gradient, and has highest concentrations in Group 1 (Figure 5). Nitrate is strongly associated with Na and Cl (Figure 14), which suggests anthropogenic origin of all three solutes. The results suggest that nitrate control strategies should focus on the springshed contributing water to vents in the southern part of the springs.

The north-south pattern found in the clusters suggests that two different baseflow regimes exist on the two sides of the river (Figure 2). This result should be verified using local hydrogeologic knowledge about the Silver Springs system (e.g. Toth and Katz, 2006).

Table 2. Correlations between water parameters and latitude, longitude, and depth at the Silver Springs sampling locations. The correlation coefficients for longitude are negative for parameters that decrease from west to east. Correlations greater than 0.6 are highlighted in red.

	Lat	Long	Depth
Temp_C	-0.65	0.30	-0.18
pH	-0.12	0.49	-0.05
DO	-0.73	-0.03	0.15
Field_Cond	-0.53	-0.80	0.34
Lab_Cond	-0.52	-0.86	0.28
Alkalinity	-0.01	-0.91	0.36
NOx_total	-0.61	0.07	0.00
P_total	-0.01	0.10	-0.14
TOC	0.10	-0.12	-0.01
Ca_T	-0.36	-0.86	0.20
Mg_T	-0.73	-0.59	0.30
Na_T	-0.62	0.12	0.33
K_	-0.05	0.52	-0.44
Chloride	-0.68	-0.03	0.34
Sulfate	-0.87	-0.43	0.13
TDS	-0.59	-0.81	0.27
PO4_T	-0.13	-0.07	-0.13

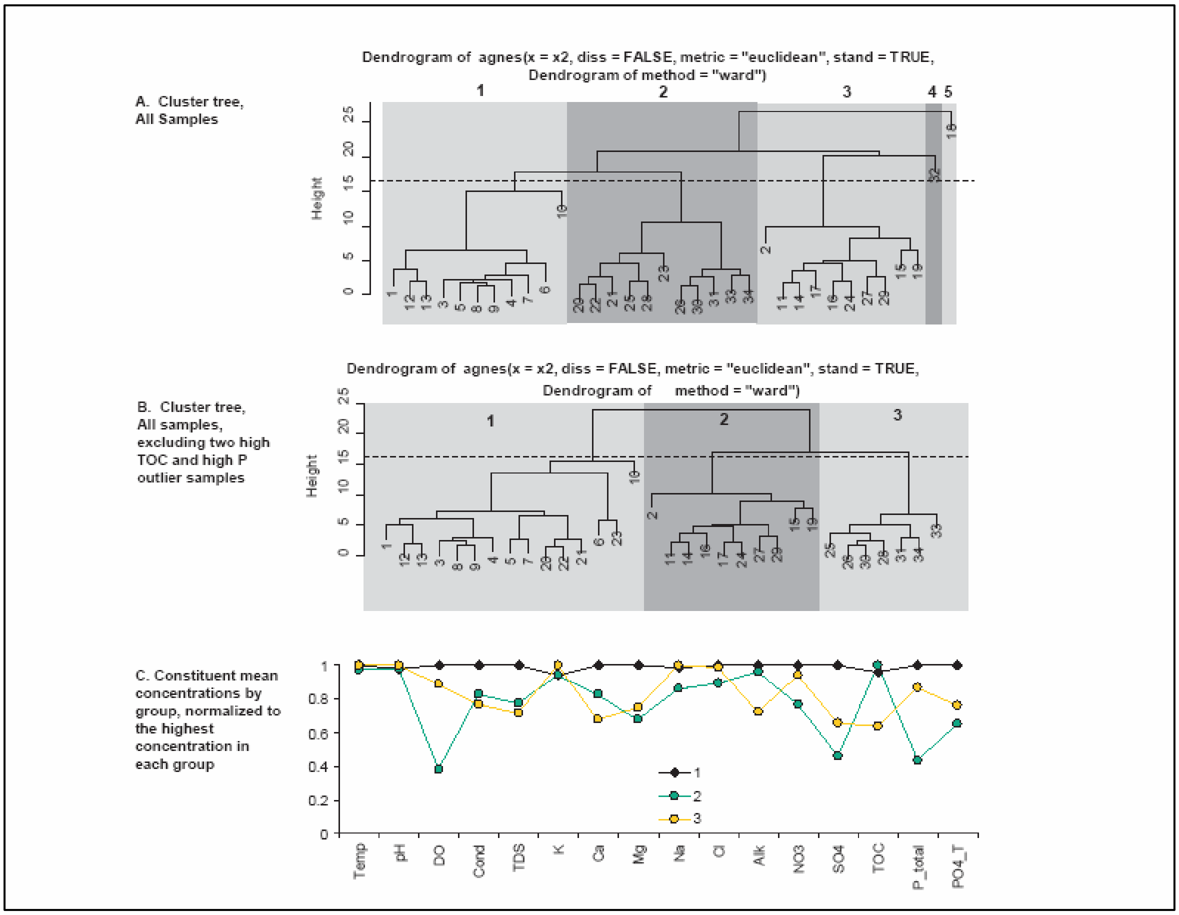
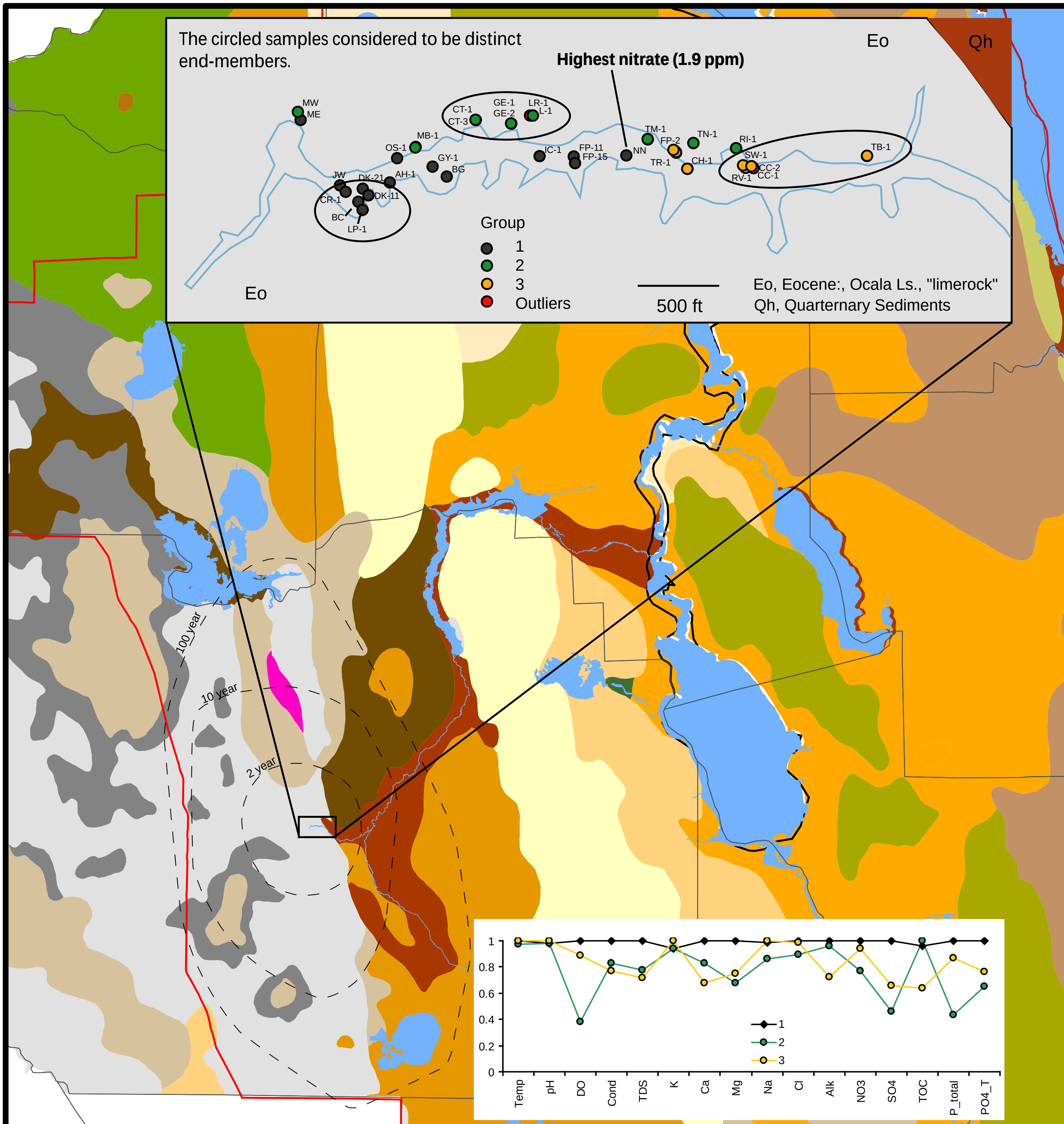
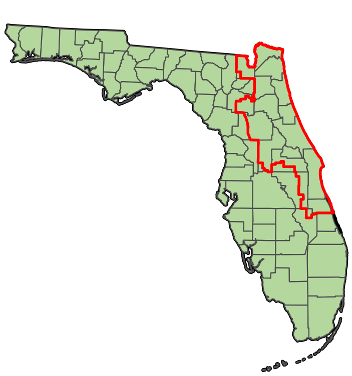


Figure 1. Groups formed by Hierarchical Cluster Analysis (HCA) on the Silver Springs water samples and Mean Concentrations.





0 5 10 20 Miles

Projection: Universal Transverse Mercator Zone 17N
Datum: North American Datum 1983 HARN

Capture Zone | SJRWMD Boundary | Water

Geology

- Qh: Holocene undifferentiated sediments
- Qd: Quaternary sand dunes
- Qftg: Fort Thompson Group
- QPp: preglacial Pleistocene sediments
- PQt: Clayey sand and clays
- Pu: Undifferentiated sand
- Mh3: Hawthorne Formation (Statenville type)
- Mh4: Hawthorne Formation: Groveland Park facies
- Mh5: Hawthorne Formation (Interlachen facies)
- Mh1: Hawthorne Formation (Devils Millhopper type)
- Mt: Tampa Formation
- Eo: Ocala Limestone
- Ea: Avon Park Formation

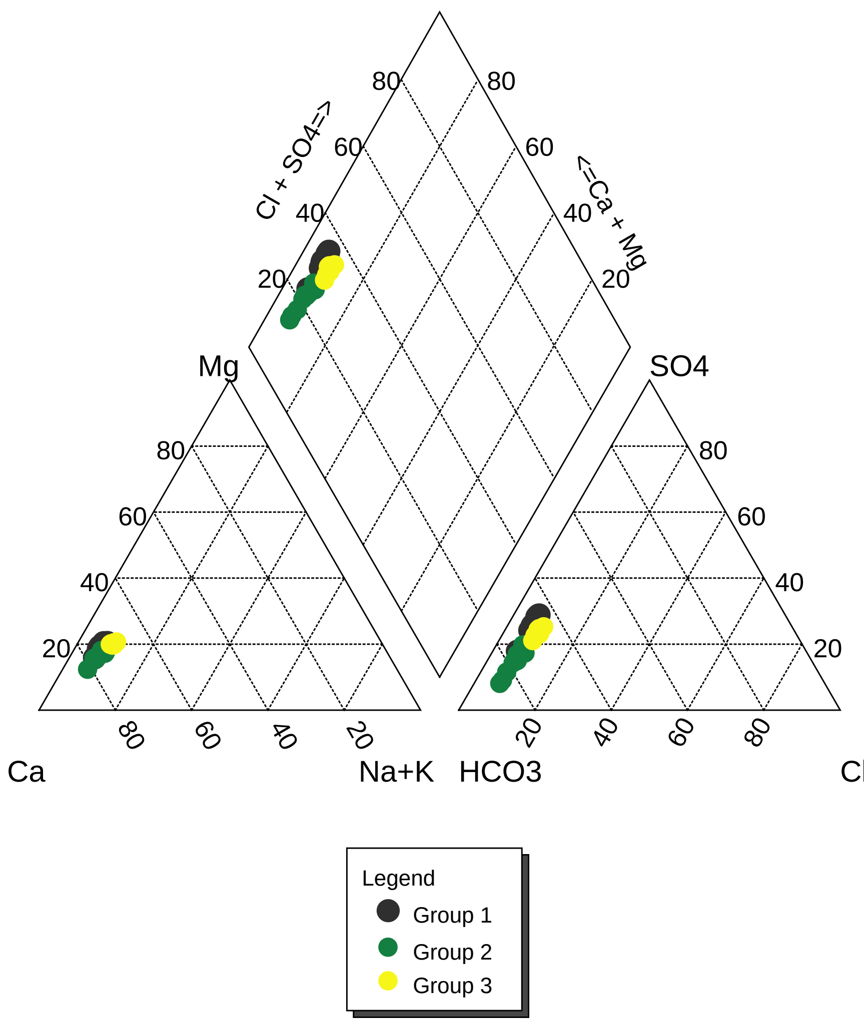
Silver Springs Clusters Locations and Mean Concentrations with SJRWMD Geology and Springs Capture Zones

Date: 3/15/2007 | SJR_Geology.mxd

INTERA

Figure 2

Piper Plot

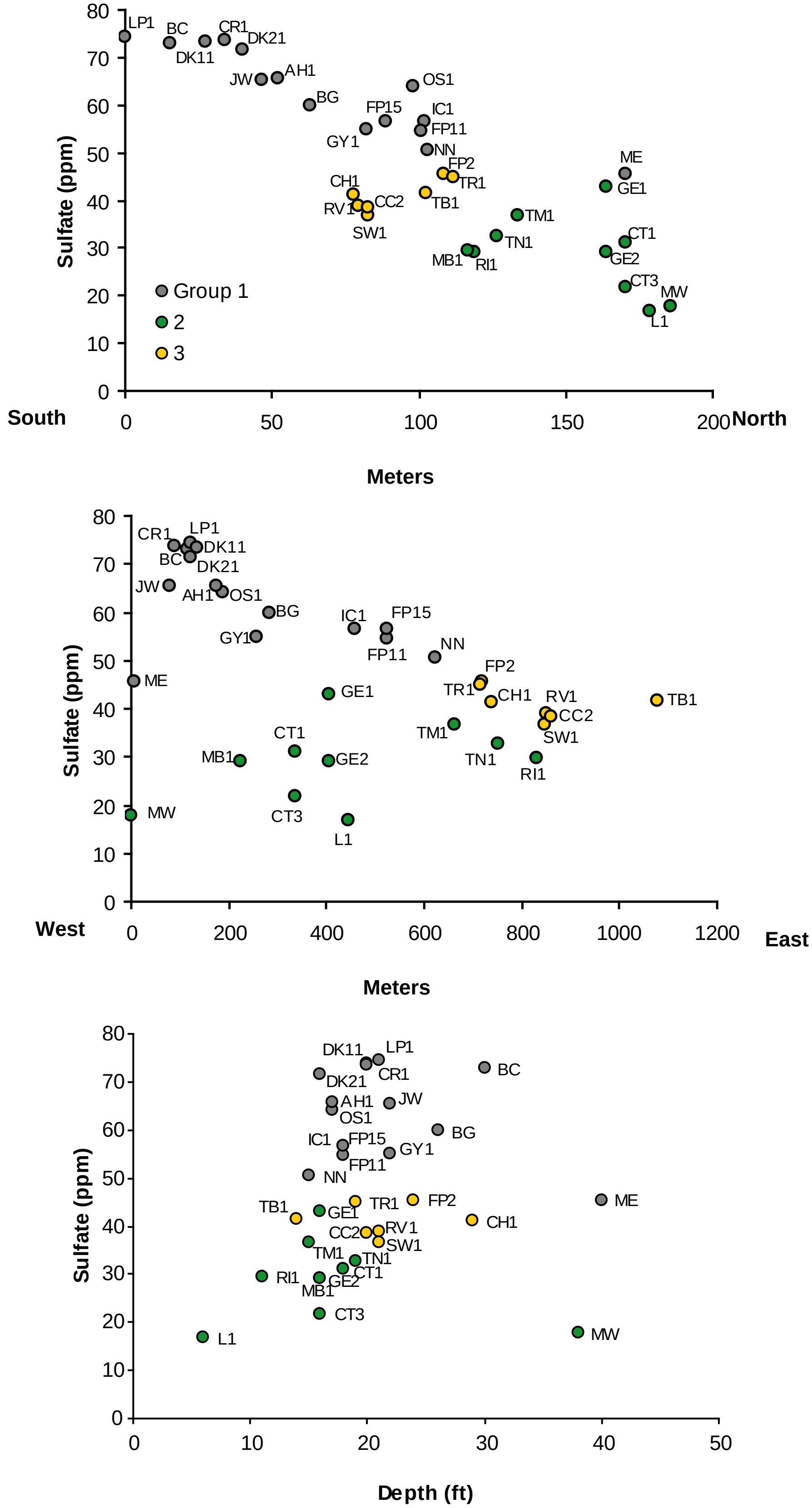


Date: February 19, 2007	Piper diagram of water samples taken from vents in Silver Springs
File: Figure3.pdf	

INTERA

St. Johns River Water Management District
Palatka, Florida

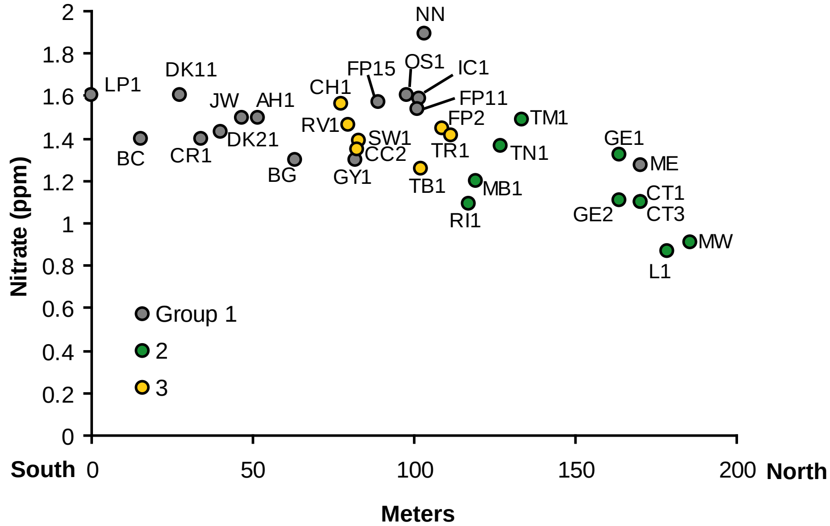
Figure 3

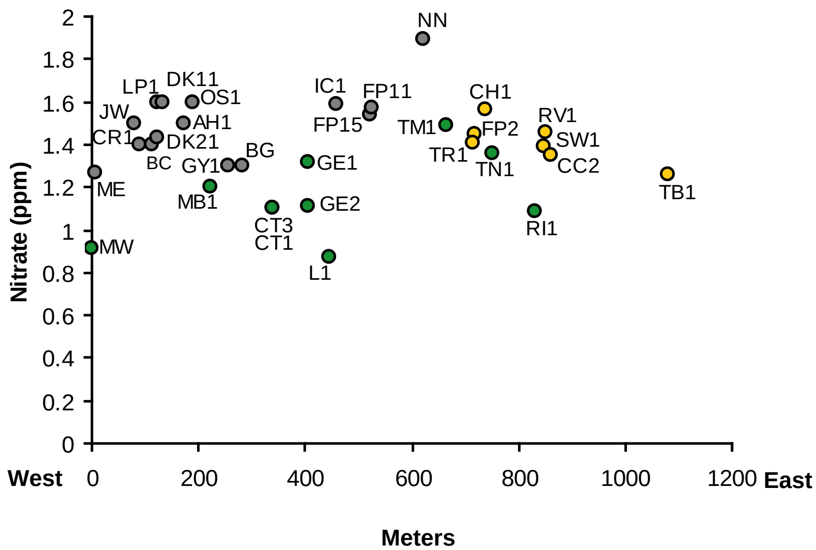


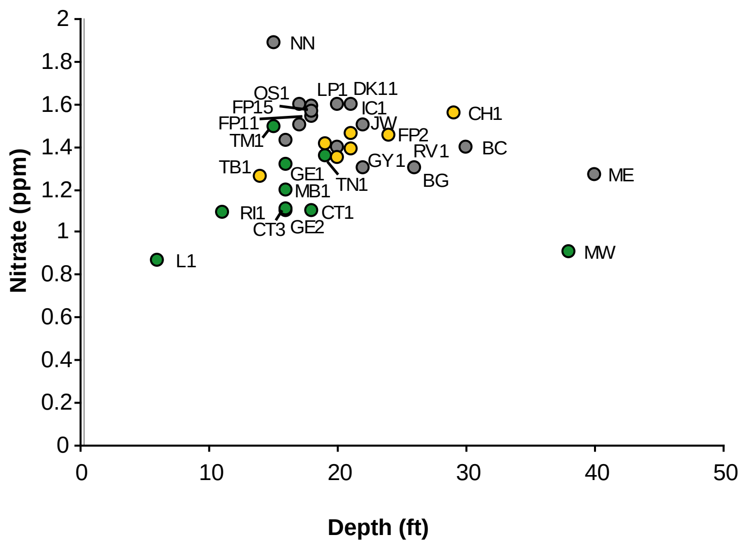
Date: February 14, 2007	Spatial variability of Sulfate concentrations in water samples taken from vents in Silver Springs
File: Figure4.pdf	

St. Johns River Water Management District
Palatka, Florida

Figure 4





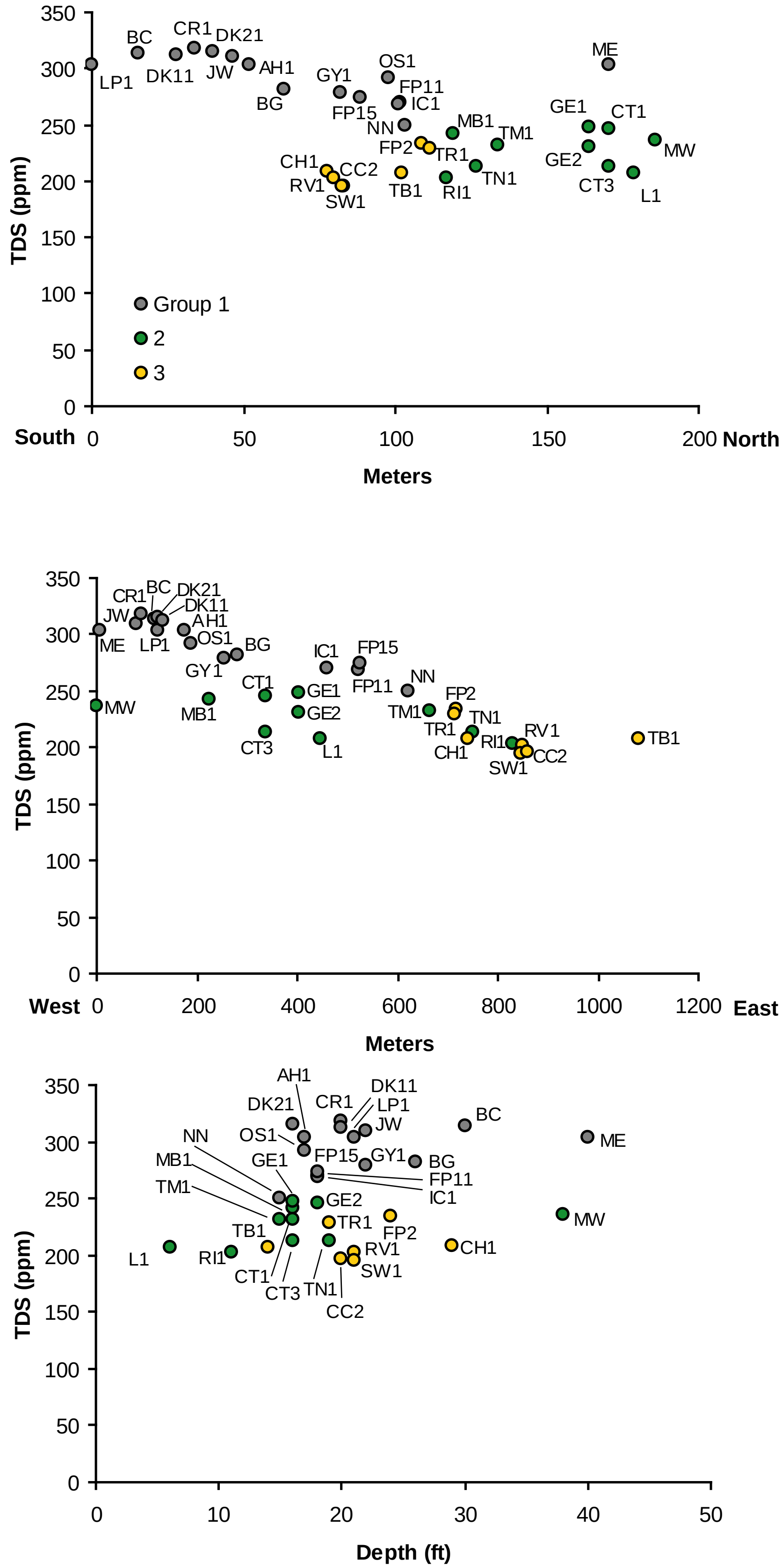


Date: February 14, 2007	Spatial variability of Nitrate concentrations in water samples taken from vents in Silver Springs
File: Figure5.pdf	

INTERA

St. Johns River Water Management District
Palatka, Florida

Figure 5

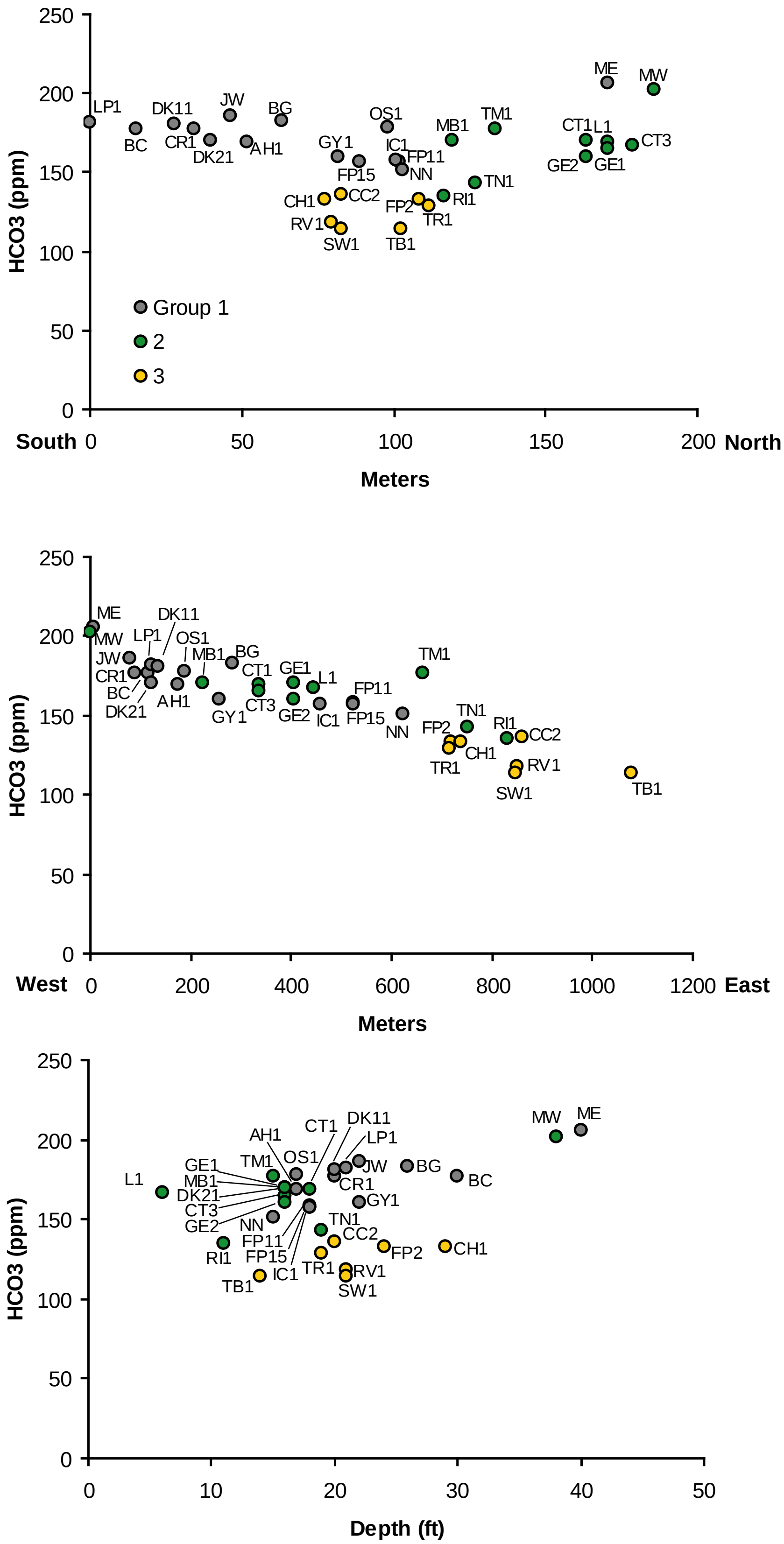


Date: February 14, 2007	Spatial variability of Total Dissolved Solid (TDS) concentrations in water samples taken from vents in Silver Springs
File: Figure6.pdf	

INTERA

St. Johns River Water Management District
Palatka, Florida

Figure 6

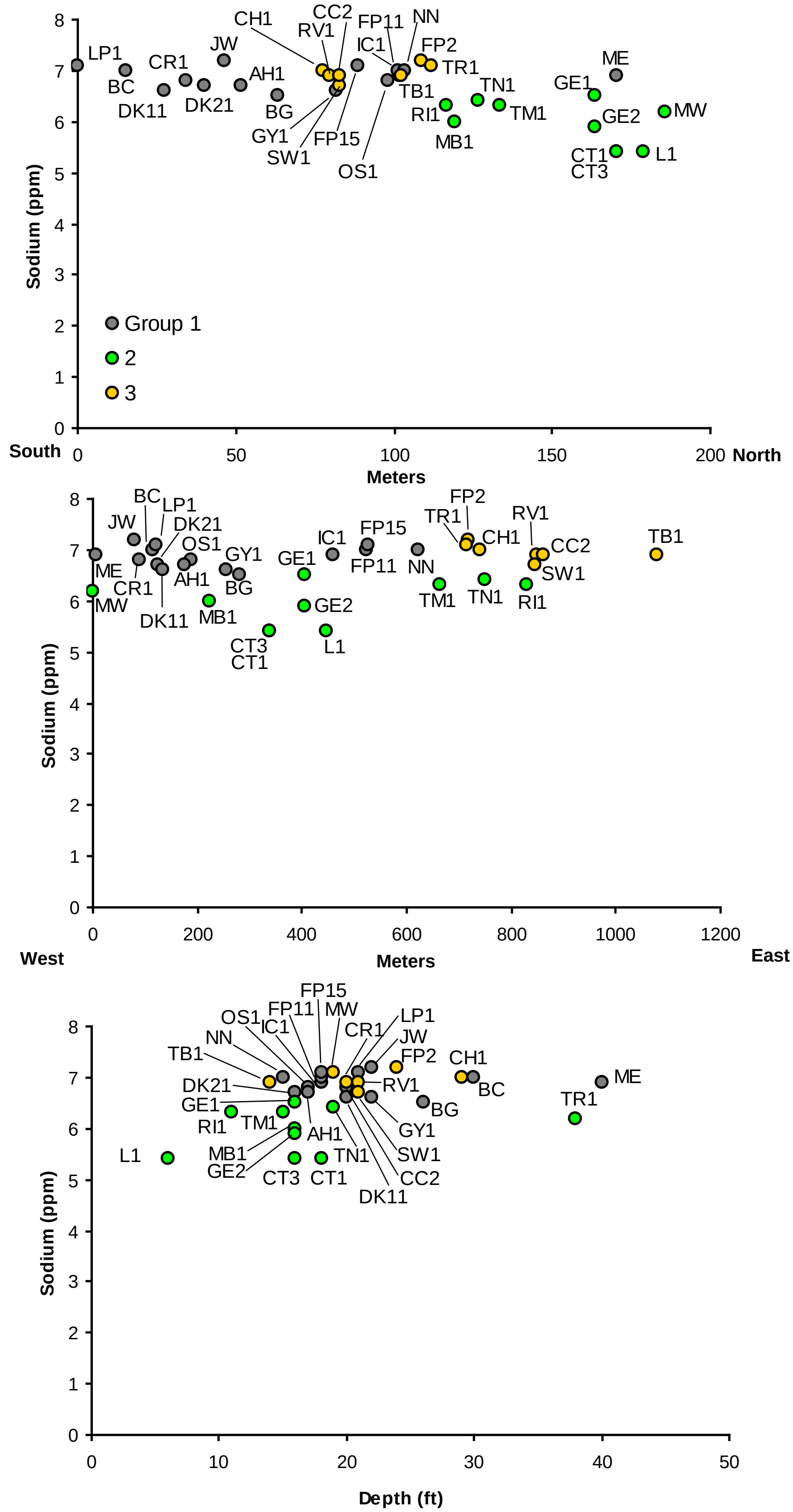


Date: February 14, 2007	Spatial variability of Alkalinity (HCO3) concentrations in water samples taken from vents in Silver Springs
File: Figure7.pdf	

INTERA

St. Johns River Water Management District
Palatka, Florida

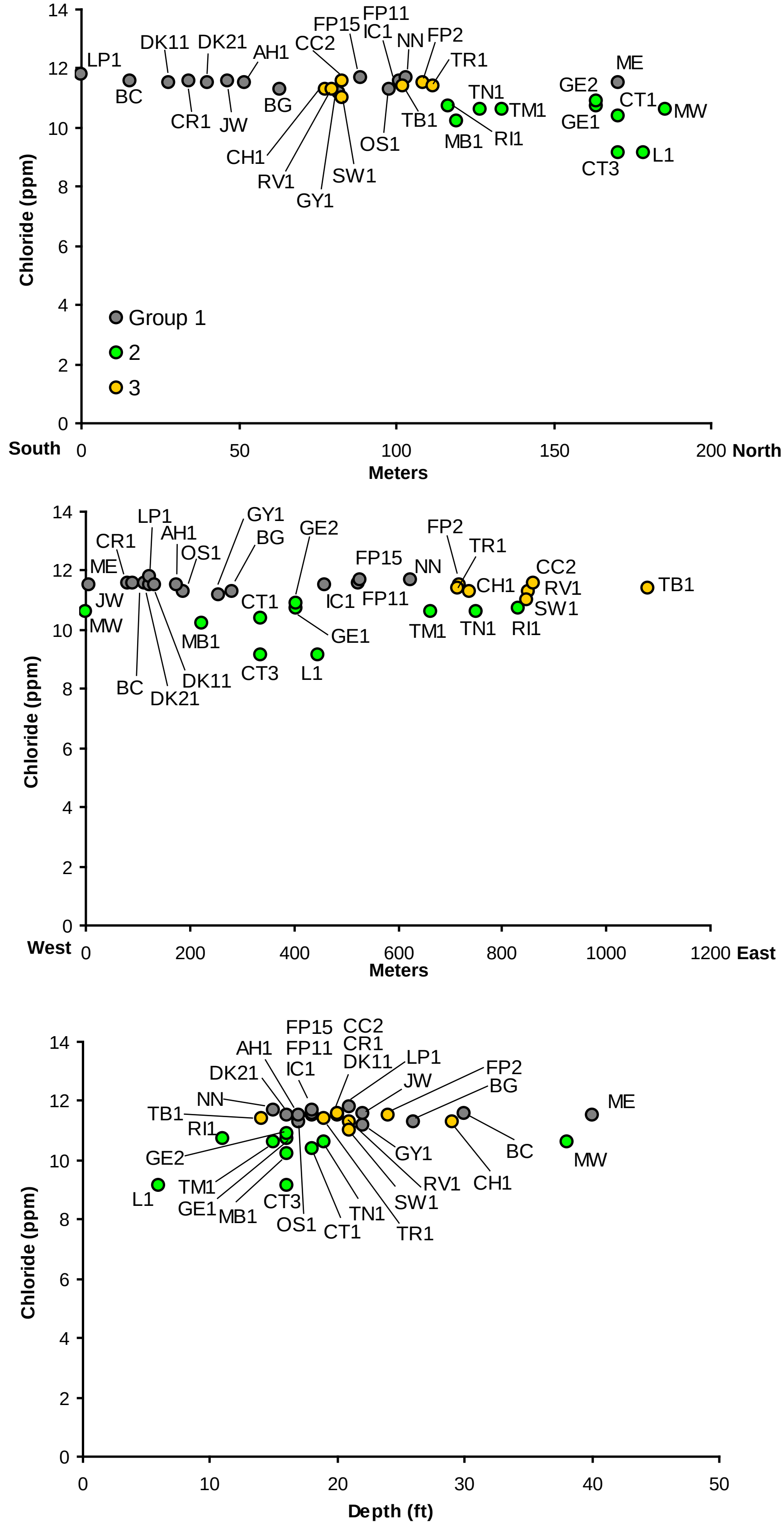
Figure 7



Date: February 14, 2007	Spatial variability of Sodium (Na) concentrations in water samples taken from vents in Silver Springs
File: Figure8.pdf	

St. Johns River Water Management District
Palatka, Florida

Figure 8



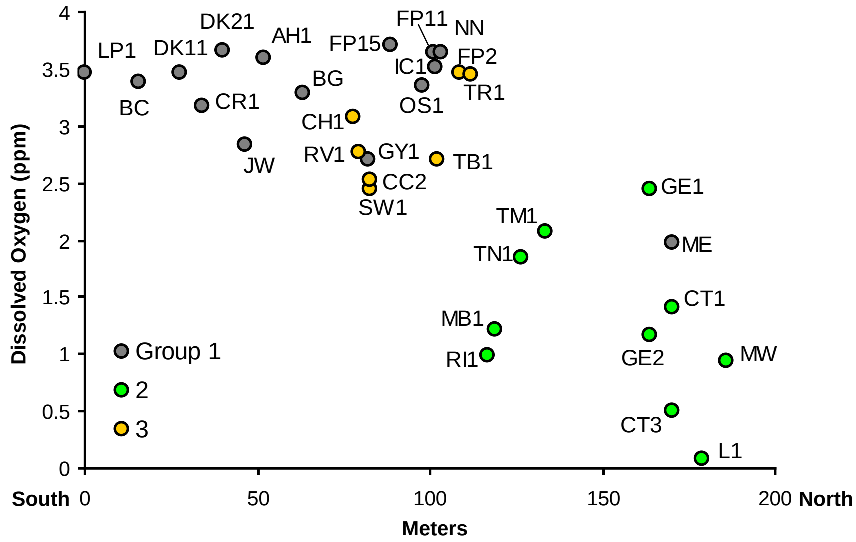
Date: February 15, 2007

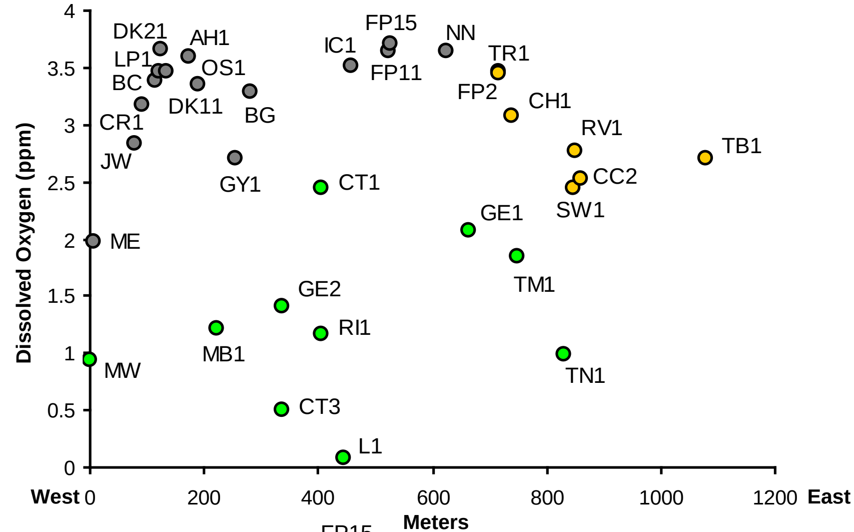
File: Figure8.pdf

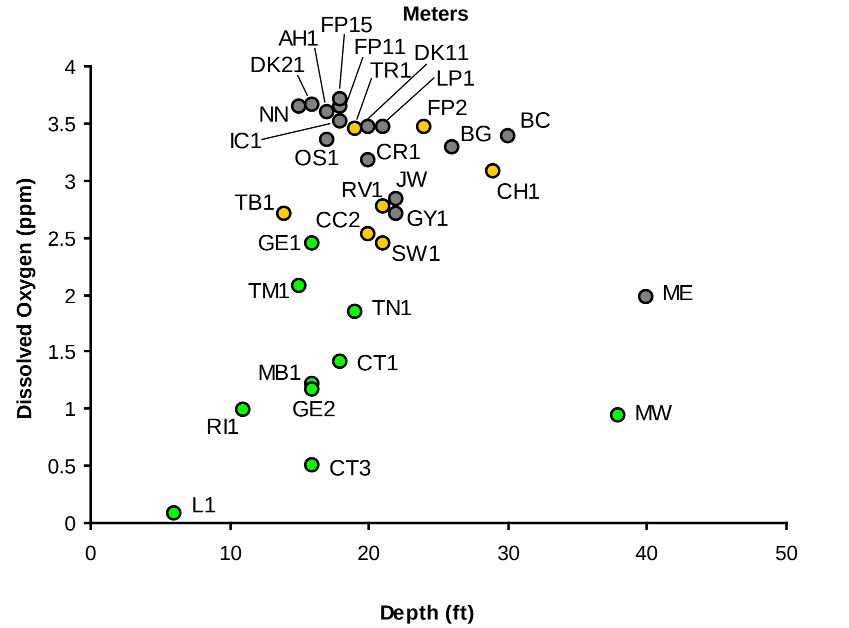
Spatial variability of Chloride (Cl) concentrations in water samples taken from vents in Silver Springs

St. Johns River Water Management District
Palatka, Florida

Figure 9







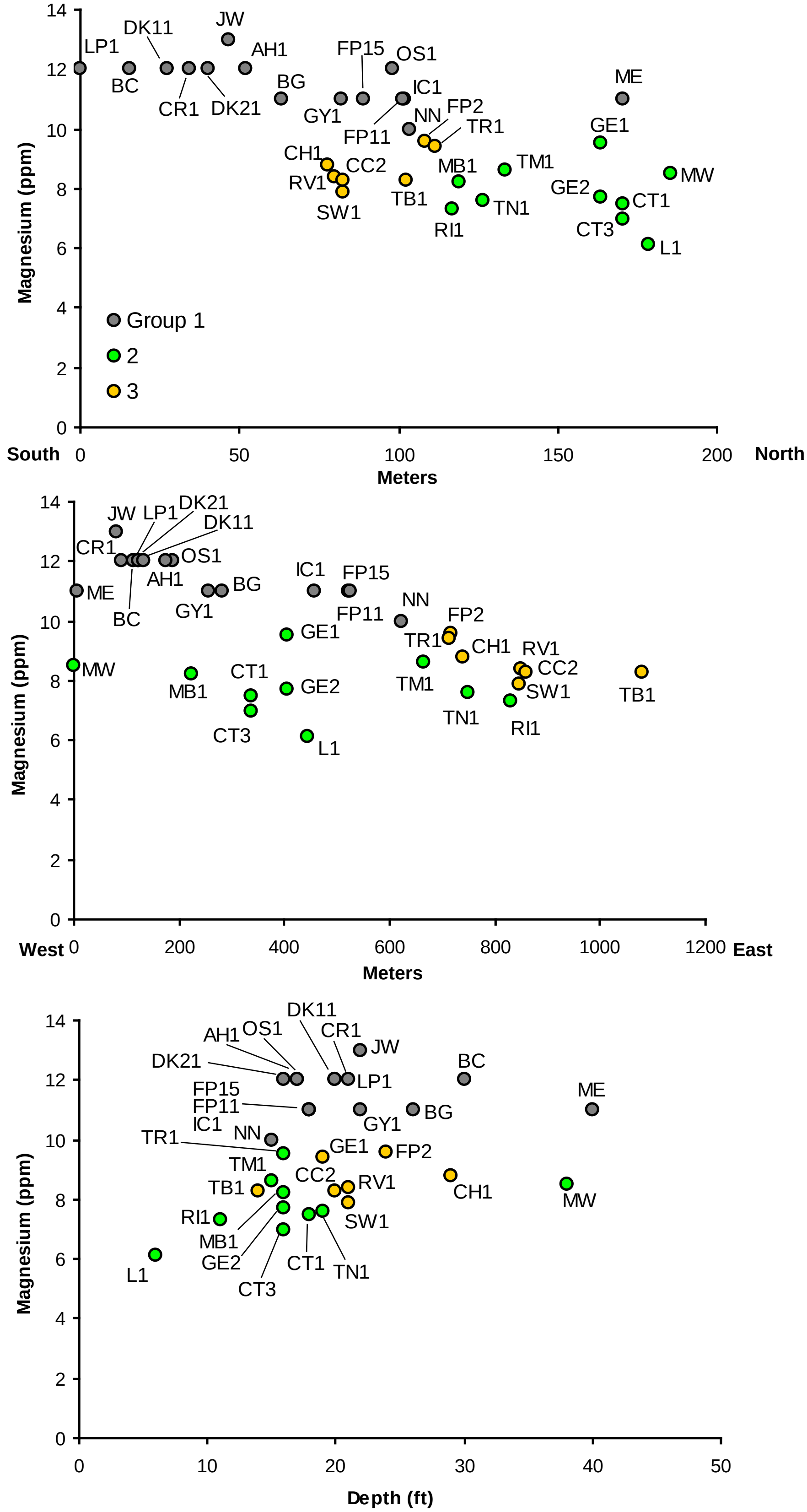
Date: February 17, 2007

File: Figure10.pdf

Spatial variability of Dissolved Oxygen (DO) concentrations in water samples taken from vents in Silver Springs

St. Johns River Water Management District
Palatka, Florida

Figure 10

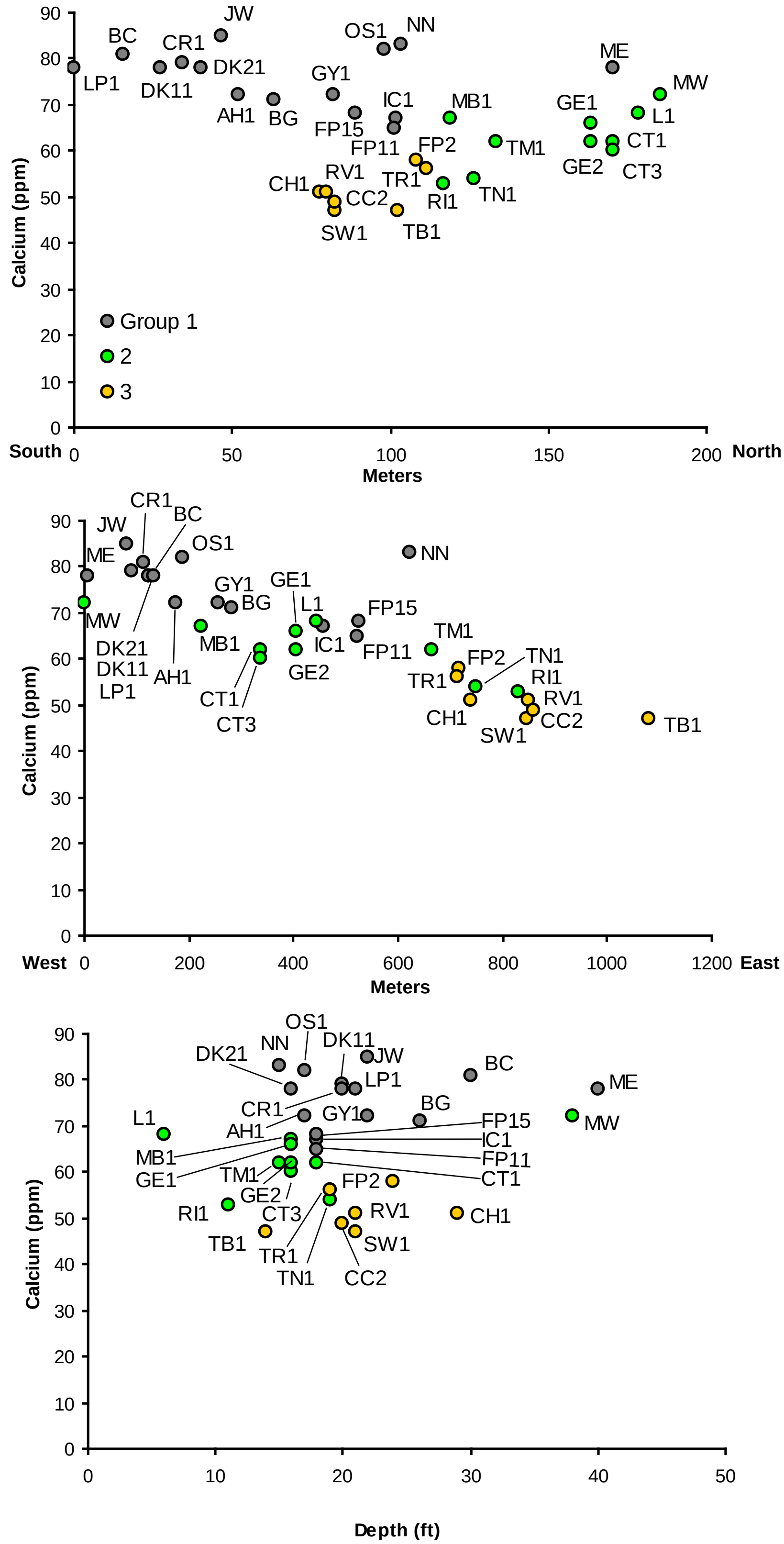


Date: February 17, 2007	Spatial variability of Magnesium (Mg) concentrations in water samples taken from vents in Silver Springs
File: Figure11.pdf	

INTERA

St. Johns River Water Management District
Palatka, Florida

Figure 11

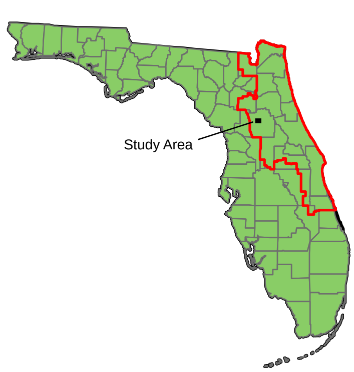


Date: February 17, 2007	Spatial variability of Calcium (Ca) concentrations in water samples taken from vents in Silver Springs
File: Figure12.pdf	

INTERA

St. Johns River Water Management District
Palatka, Florida

Figure 12



0 0.1 0.2 0.4 Miles

Projection: Universal Transverse Mercator Zone 17N
Datum: North American Datum 1983 HARN

Residential	Mixed Upland Nonforested
Commercial and Services	Pine Flatwoods
Government/Institutional	Upland Mixed Coniferous/Hardwoods
Parks and Zoos	Forest Regeneration
Other Recreational	Water
Horse Farms	Wetlands
Herbaceous Upland Nonforested	Roads and Highways
Sewage Treatment Plant	

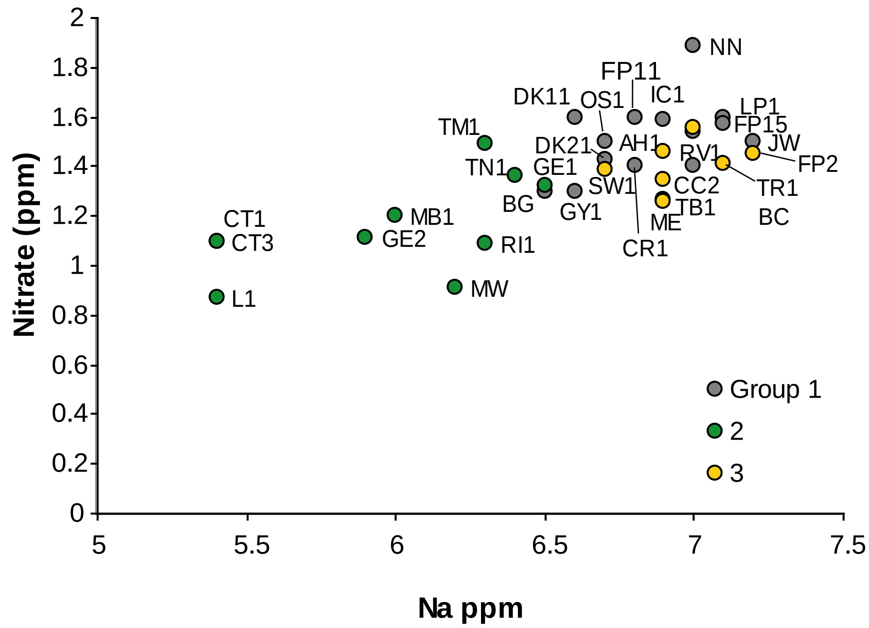
Land Cover Map
of the Silver Springs Area

Date: 2/20/2007

SJR_LandUse.mxd

INTERA

Figure 13



Date: April 30, 2007	Nitrate verses Sodium concentrations by group in water samples taken from vents in Silver Springs	
File: Figure14.pdf		
INTERA	St. Johns River Water Management District Palatka, Florida	Figure 14

IV. Principal Components Analysis

Principal component analysis (PCA) attempts to explain the variance-covariance structure of the data through the construction of few uncorrelated (orthogonal) linear combinations of the data (Johnson and Wichern, 1988). These few linear combinations (principal components or PCs) can then be used for data reduction. For example the PCs can be used as explanatory variables in regression analysis where, being uncorrelated, the resulting regression coefficients are unambiguous. Another common use for PCs is for data interpretation where the weights calculated for the linear combinations can be used to understand which data attributes are most relevant for a given application.

Computationally, PCs are obtained using the eigenvectors and eigenvalues of the correlation matrix (or the variance-covariance matrix). The first principal component direction is defined as the eigenvector corresponding to the largest absolute eigenvalue. The second PC is the eigenvector corresponding to the second largest eigenvalue, and so on. The process of obtaining the eigenvectors and eigenvalues can be computationally intensive but several efficient algorithms have been developed for this purpose such as singular value decomposition (Horn and Johnson, 1991).

Principal component analysis is often used to understand the major underlying components that contribute to the overall variability in the water quality measurements. PCA can lead to significant reductions in the efforts required to monitor a natural system by highlighting redundant or correlated measurements. It has been used in geochemical analysis to identify major water types (Melloul and Collin, 1992) and estimate susceptibility of aquifers to pollution (Abu-Jaber et al., 1997). PCA may be performed using either the covariance or correlation matrix; due to the large differences among parameter ranges (e.g. compare TDS and P-Total), we used the correlation matrix.

The correlation matrix (Table 3) shows high correlations among several variables, particularly between TDS, conductivity, alkalinity, Ca, Mg, and SO4, and between Na, Cl, DO, and temperature.

Table 3. Correlation coefficient matrix for the Silver Springs data. Excludes two samples with anomalous TOC or TP values. Values in red are greater than 0.60.

	T	pH	DO	Con field	Con lab	Alk	HCO3	NOx	TP	TOC	Ca	Mg	Na	K	Cl	SO4	TDS
T	1.00																
pH	0.13	1.00															
DO	0.77	0.12	1.00														
Cond.f	0.20	-0.39	0.55	1.00													
Cond.l	0.12	-0.35	0.47	0.96	1.00												
Alk	-0.41	-0.51	-0.10	0.70	0.77	1.00											
HCO3	-0.41	-0.51	-0.10	0.70	0.77	1.00	1.00										
NOx	0.76	-0.02	0.86	0.44	0.33	-0.12	-0.12	1.00									
TP	0.20	-0.13	0.19	-0.03	-0.02	-0.04	-0.04	0.39	1.00								
TOC	-0.14	0.02	-0.16	0.05	0.03	0.19	0.19	-0.09	0.14	1.00							
Ca	-0.02	-0.43	0.29	0.85	0.91	0.81	0.81	0.28	0.20	0.29	1.00						
Mg	0.48	-0.18	0.78	0.89	0.88	0.46	0.46	0.63	0.09	-0.07	0.74	1.00					
Na	0.70	0.29	0.85	0.33	0.27	-0.20	-0.20	0.75	0.18	-0.10	0.14	0.65	1.00				
K	0.46	0.28	0.18	-0.27	-0.33	-0.51	-0.51	0.35	0.11	0.28	-0.28	-0.17	0.18	1.00			
Cl	0.66	0.27	0.88	0.49	0.43	-0.06	-0.06	0.73	0.19	-0.14	0.26	0.74	0.90	0.13	1.00		
SO4	0.66	-0.07	0.84	0.80	0.78	0.27	0.27	0.69	0.09	-0.06	0.62	0.94	0.65	0.01	0.76	1.00	
TDS	0.25	-0.32	0.54	0.96	0.98	0.70	0.70	0.39	-0.03	0.08	0.87	0.92	0.34	-0.26	0.51	0.85	1.00
PO4	0.09	-0.12	0.15	0.06	0.10	0.01	0.01	0.14	0.18	-0.14	0.08	0.17	0.06	-0.15	0.14	0.15	0.14

The correlation matrix may be further simplified by finding its principal components or eigenvectors. First, the eigenvalues and eigenvectors of the correlation matrix are found in SPLUS™. The eigenvalues explain the percent of the total variation in the data explained by each factor or eigenvector. For the Silver Springs data, the first three components accounted for 78% of the variance in the data. Selection of the final components used to model the data is qualitative and depends on the component's eigenvalue and interpretability.

Table 4. Principal components results, showing eigenvalues and the total percent of the variance explained by each additional factor. Red highlights the components selected for further analysis.

	Eigenvalue	Cumulative percent explained
Factor 1	7.80	0.43
2	4.71	0.70
3	1.45	0.78
4	1.30	0.85
5	0.85	0.89
6	0.74	0.94
7	0.35	0.95
8	0.29	0.97
9	0.17	0.98
10	0.12	0.99
11	0.11	0.99
12	0.06	1.00
13	0.03	1.00
14	0.03	1.00
15	0.01	1.00
16	0.01	1.00
17	0.00	1.00
18	0.00	1.00

For the Silver Springs data, the first three eigenvectors correspond to the following principal components:

- Component 1: TDS-Ca-Mg-SO_4 component,
- Component 2: inverse alkalinity-Na-Cl-Temperature component,
- Component 3: organic constituents component.

The above designations are somewhat subjective and based on the absolute values of the factor loadings shown in Table 5. For example, component 1 has factor loadings values above 0.27 for TDS and related constituents (e.g., conductivity). Component 2 has the largest (negative) factors associated with alkalinity and the largest (positive) factors associated with temperature, Na, and Cl. Component 3 has a large factor associated with TOC with two smaller factors associated with phosphorous and potassium.

Table 5. First three components in the PCA with values of the factor loadings. Red highlights the constituents with the largest influence on each component.			
	Component 1	Component 2	Component 3
	TDS factor	Na-Cl/Temp	Organic factor
Temp.C	0.162	0.357	0.046
pH	-0.089	0.244	-0.070
DO	0.272	0.275	-0.056
Field.Cond	0.332	-0.131	-0.010
Lab.Cond	0.326	-0.170	-0.035
Alkalinity	0.189	-0.375	0.049
Alk.as.HCO3	0.189	-0.375	0.049
NOx.total	0.233	0.277	0.136
P.total	0.052	0.093	0.395
TOC	0.000	-0.088	0.692
Ca	0.287	-0.221	0.216
Mg	0.352	0.028	-0.079
Na	0.213	0.309	-0.053
K	-0.054	0.273	0.471
Cl	0.255	0.264	-0.087
SO4	0.333	0.109	-0.038
TDS	0.336	-0.125	-0.013
PO4.T	0.060	0.022	-0.207

PCA suggests that at least three distinct water types mix to yield the observed chemistry:

- water high in TDS which contains mostly Ca-Mg sulfates,
- water high in temperature, Na, Cl, NO_3, and low in alkalinity; and
- water high in TOC, K and P.

The correlation of NOx with warm water suggests that NOx are coming from deep sources. For example, at Mammoth spring the warmer vent (23.4 degrees versus 22.0 degrees C) has the higher NOx (1.23 mg/l versus 0.91 mg/l). It is also worth noting that NOx showed a high loading factor (> 0.13) for the top three components, indicating that NOx variability is fairly large and cannot be easily explained by its correlation with temperature and dissolved oxygen.

The analysis also suggests that some constituents, mainly SO4, Ca, Mg, alkalinity and TDS can be predicted using field conductivity, but that other constituents such as TOC, P, and K do not relate to conductivity and need to be measured in each sample.

Based on these results, further analysis is suggested as follows:

1. Principal component analysis can be conducted within each of the three clusters described in Section III above. This analysis can highlight further distinctions between the vents within Silver Springs. Results of this analysis are listed in Appendix A.

2. Regression may be used to understand how well field parameters (conductivity and pH) predict the value of different constituents or to evaluate the correlations between the principal components at Silver Springs and those upstream within the springshed.

3. Hydrogeologic interpretation may be used to attempt to distinguish between the three clusters in terms of the likely groundwater pathlines leading to each cluster. Lines of evidence could include geochemical data from wells, tritium dating of vent water, and information on hydraulic heads and flows. This analysis will depend on modeling results (indicating the different possible capture zones for the spring vents) and expertise with the local hydrogeologic regime.

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APPENDIX A. Principal Components Analysis for Each Cluster

A.1 Group 1

The first four components account for 88% of the variance in Group 1. The first component is dominated by TDS, FieldCond, Alkalinity, and Mg. The second component is Cl, K, and SO4 dominated. The third is Na, Ca and DO dominated.

	Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6
pH		0.331	0.374	-0.493	0.220	-0.313
DO	-0.229	0.314	0.382	0.326	-0.163	0.164
Field.Cond	0.389	0.239	0.178		0.239	0.213
Alkalinity	0.385		-0.276	-0.212	0.164	0.281
Nox.total	-0.304	0.271	-0.175	0.449		
Ca	0.219	0.167	-0.450	0.403	0.404	-0.261
Mg	0.361	0.254			-0.376	-0.478
Na	-0.141	0.289	-0.468	-0.307	-0.402	-0.291
K	-0.253	0.385		-0.160	0.536	
Cl	-0.130	0.410	-0.294	-0.188	-0.240	0.587
SO4	0.271	0.363	0.252	0.262	-0.147	
TDS	0.440	0.184				0.112

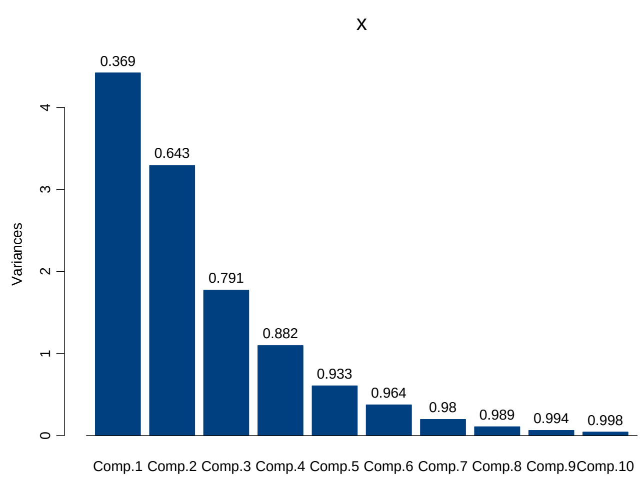


Figure A1. Variance Explained by Each Principal Component for Group 1

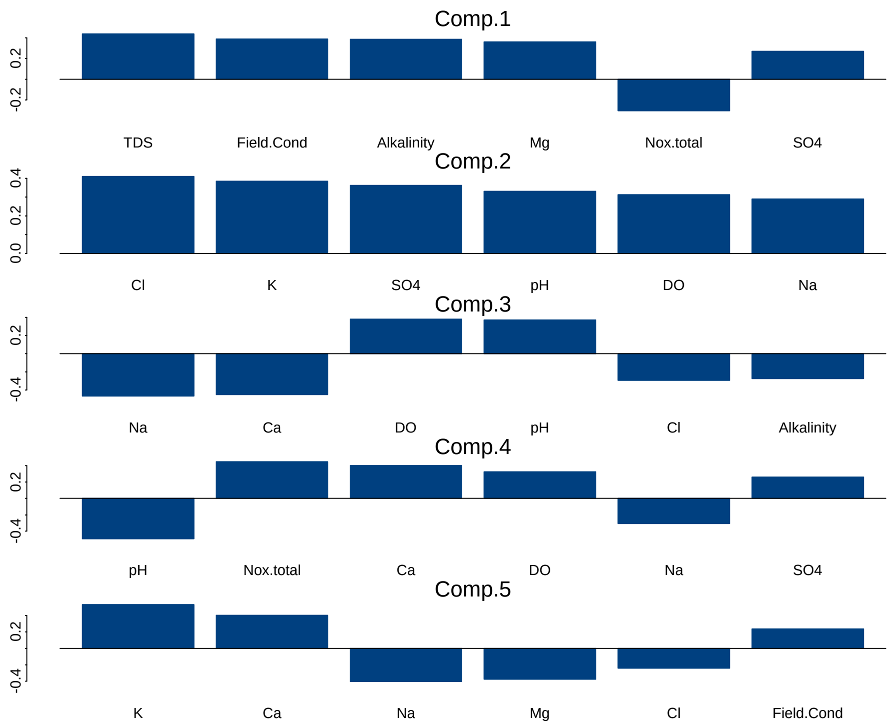


Figure A2. Loadings for each constituent – Group 1

A.2 Group 2

Most (87%) of the variance in Group 2 is explained by the first 3 components. The first component is a DO-Mg-SO4 component. The second PC is Alk-Ca-K, and the third is pH-Cl-Na.

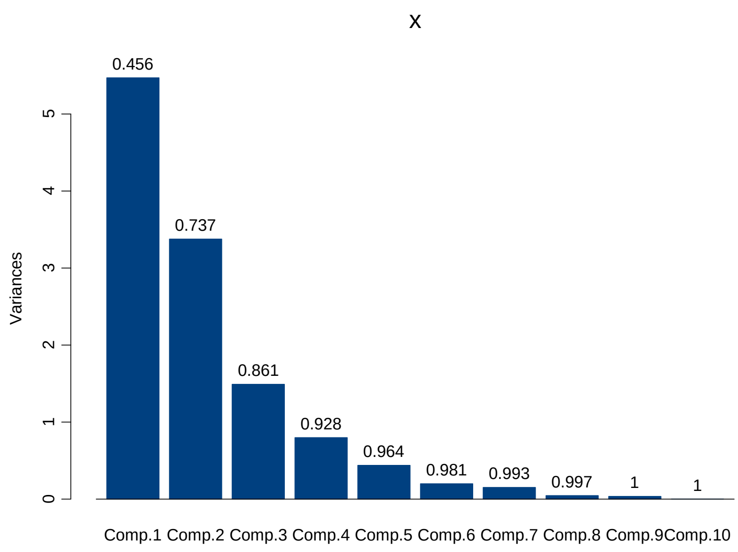


Figure A3. Variance Explained by Each Principal Component for Group 2

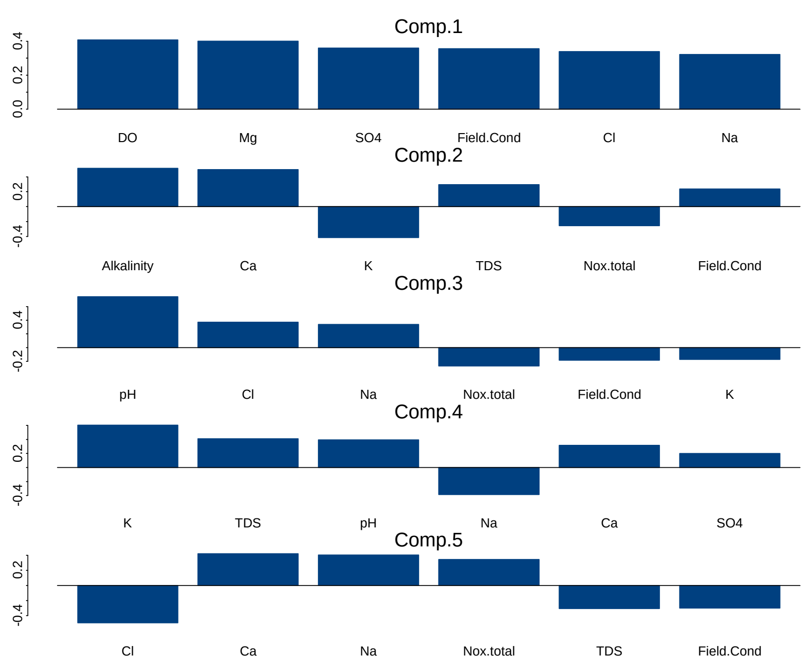


Figure A4. Loadings for each constituent – Group 2

A.3 Group 3

More than 92% of the variance in Group 3 is explained by the first three components. PC1 is Mg-Na-Ca dominated, PC2 is K-Cl-NOx dominated, and PC3 is Alk-NOx-Cl dominated.

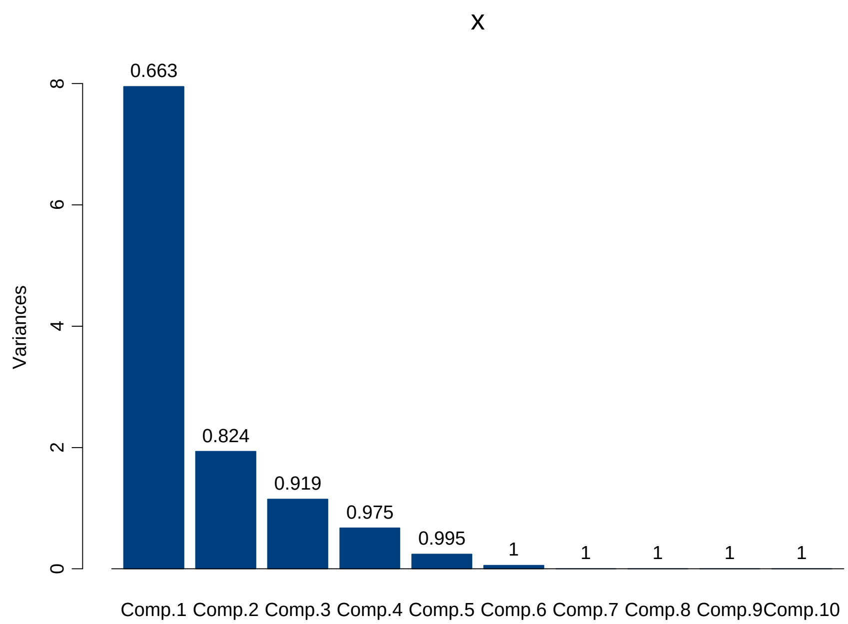


Figure A5. Variance Explained by Each Principal Component for Group 3

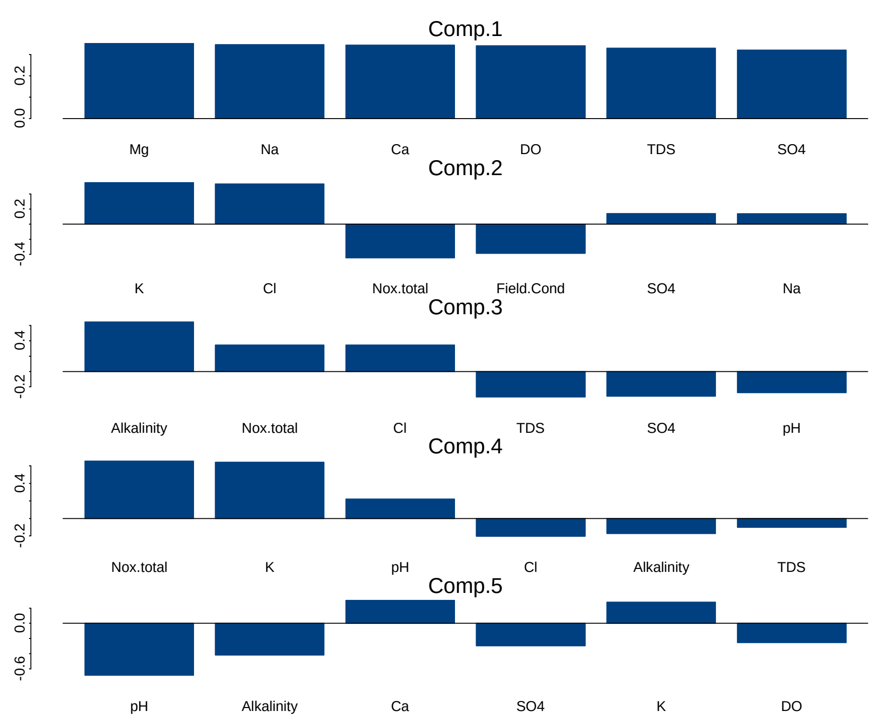


Figure A6. Loadings for each constituent – Group 3

APPENDIX B. HCA and PCA Using SPLUS™

Two scripts were written for multivariate analysis, including cluster analysis and principal components analysis (PCA). This appendix provides details of these scripts and user instructions.

The scripts Cluster_Analysis.ssc and Principal_Components_Analysis.ssc implement cluster analysis and PCA in SPlus for applications in SJRWMD. The scripts include an example of both analyses using geochemical data from Silver Springs.

B.1 Cluster_Analysis.ssc

This script loads geochemical data, generates clusters using Hierarchical Cluster Analysis (HCA) and produces various plots of the clusters, including Piper Diagrams.

User Input

The first section of the scrip is similar to the Trend Analysis scripts, where the workspace is cleared, and the user defines the path and file names.

The main difference in the User Input section is in the designation of variable columns. There is no time variable in the analysis, and more than one response variable. The location of each sample is designated in an x and y coordinate corresponding to the column names in the Excel sheet:

```
x.coord.label <- "Long.min"
y.coord.label <- "Lat.min"
```

The constituents in the Excel sheet need to be assigned:

```
#  The constituent.list is a list of the names of the columns in the Excel
#  spreadsheet.
#  They do not need to be in the same order as the colunms in the Excel sheet.
#  The user can alter the constituent.list to see the effect of excluding
#  different constituents
#  The names in constituent.abb.list need to be in the same order as the names
#  in constituent.list
#  The names in constituent.abb.list should not change for constituents
#  involved in the charge balance:
#   ("Alk","NOx""Ca","Mg","Na","K","Cl","SO4","TDS").  All other constituents
#   may have arbitrary labels in constituent.abb.list

constituent.list <- c("pH","DO","Field.Cond","Alkalinity","Nox.total",
       "Ca","Mg","Na","K","Cl","SO4","TDS")
constituent.abb.list <- c("pH","DO","Cond","Alk","NOx"
       "Ca","Mg","Na","K","Cl","SO4","TDS")
```

The constituent.list contains the labels of the columns in the Excel spreadsheet of the variables to be included in the analysis. This list can change to test the effect of including/excluding certain constituents on the final cluster resutls. The list does not need to be chemical analytes; for example, annual groundwater levels (or precipitation) for a sequence of months or years could be used:

```
constituent.list <-
   c("X1980","X1981","X1982","X1983","X1984","X1985","X1986","X1987","X1988")
constituent.abb.list <- c("80","81","82","83","84","85","86","87","88")
```

The list constituent.abb.list is used both for plotting, and, if a charge balance and Piper diagram are performed, to link the names in the Excel sheet with labels used by the USGS SPLUS™ scripts. The order in constituent.abb.list needs to match the order in constituent.list. For elements involved in the charge balance and Piper Diagrams, the names in constituent.abb.list should not change: Ca, Mg, Na, K, Cl, NOx, Alk, SO4. For all other constituents, the names in constituent.abb.list can be arbitrary. If new analytes (e.g. heavy metals, etc) are included in constituent list, then the user can add to constituent.abb.list with arbitrary abbreviations.

Other user input includes:

```
exclude.samples <- NULL          #  Names of specific samples or stations to
                                 #  be excluded from the analysis.  Can be used
                                 #  to test the sensitivity of the clustering
                                 #  to outlier samples.

threshhold.height <- 12          # Defines the threshold separation height that
                                 # separates groups
```

The threshhold.height is the single most important parameter in the clustering algorithm. It is a user-defined value that determines the maximum distance groups can be apart and still be in the same cluster. The cluster tree diagram (Figure A1) can be used to visualize how many clusters will be generated by a given threshold height. The lower the threshold.height, the more clusters will be generated. The user can experiment with different values and determine which yields a clustering that provides insight.

The charge balance and Piper Diagram options are:

```
# charge balance options
charge.bal.flag <- 1             # Option 1 means a charge balance will be conducted
                                 # Option 0 means no charge balance
charge.bal.tolerance <- 0.1      # The error tolerance for the charge balance,
                                 #  computed as
                          # (sum.cations-sum.anions)/(sum.cations+sum.anions)

# Piper Diagram option
piper.diag.flag <- 1             # Option 1 means piper diagrams will be generated
                                 # Option 0 means no piper diagrams
```

If the analysis does not include all the constituents required for a mass balance (e.g. if the analysis is to be done on heavy metals or well levels), the user should set the charge.bal.flag and piper.diag.flag to 0. Otherwise an error will result.

The graphics formatting options include:

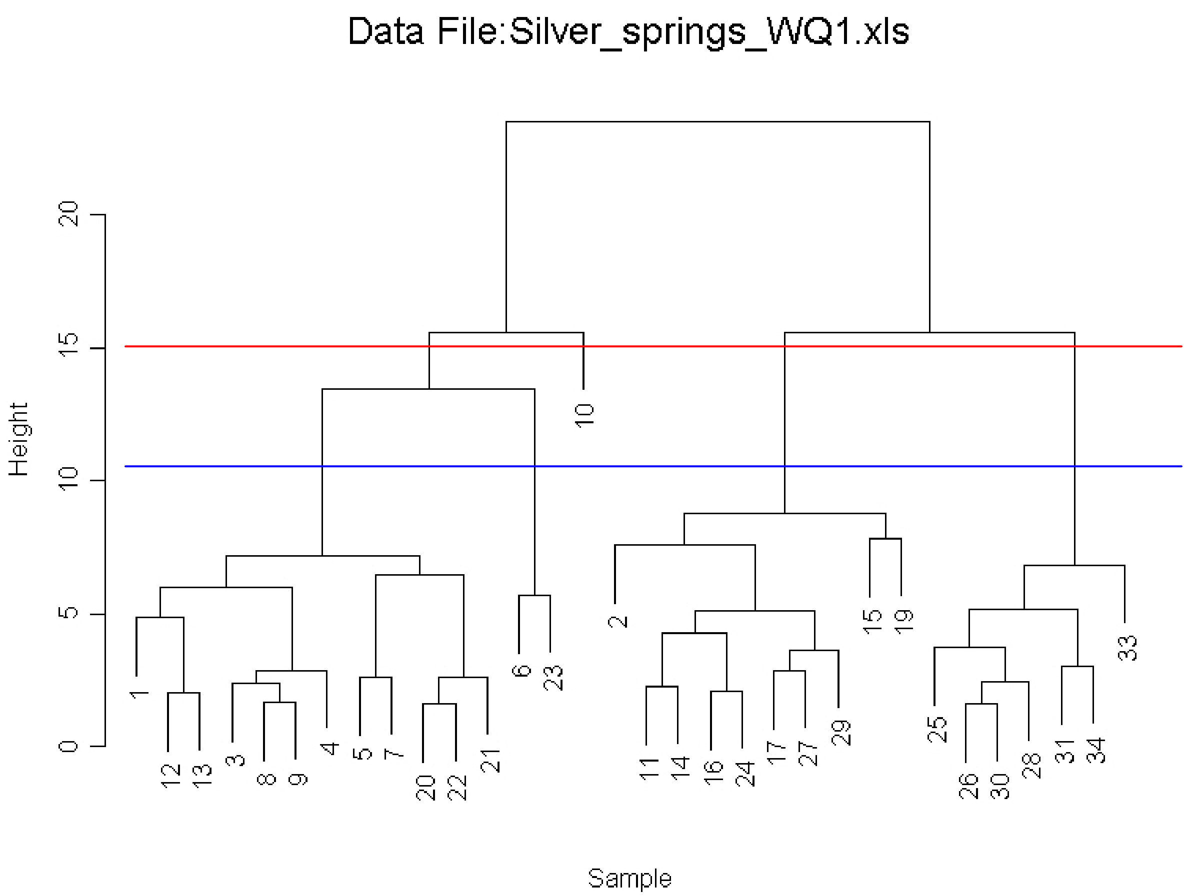
```
# Graphics Formatting Options
chart.make.jpeg   <- 0       # option 1 creates JPEG files. Zero will not generate
   JPEGs
                             # When option 1 is used, the file names will be:
                             # ClusterAnalysis01.jpg,
                             # ClusterAnalysis02.jpg, ClusterAnalysis03.jpg,
                             # and so on
chart.size.width  <- 8    # chart width for outer margins in inches
chart.size.height <- 5    # chart height for outer margins in inches
legend.font.size  <- 1       # Legend font size
legend.location.x <- 1       # Legend X location within the chart - Value
                             # ranges from zero to one
legend.location.y <- 0       # Legend Y location within the chart - Value
                             # ranges from zero to one
#  Zoomed map parameters
#  Note:  These parameters may not be necessary if the large map (Fig 3)
#  produces acceptable detail
map.x.min           <- -8.2033      # lower limit for x coordinate in the
                                    # zoomed clusters map(longitude)
map.x.max           <- -8.202       # upper limit for x coordinate in the
                                    # zoomed clusters map (longitude)
map.y.min           <-  2.9125      # lower limit for y coordinate in the
                                    # zoomed clusters map (latitude)
map.y.max           <-  2.91262     # upper limit for y coordinate in the
                                    # zoomed clusters map (latitude)
# End of Graphics Options
```

The variables map.x.min(max) and map.y.min(max) allow the user to define the corners of a location to be zoomed for mapping. For example, in some applications, a certain region will have a high density of points that are not visually distinguished on the regional plot.   The values map.x.min(max) and map.y.min(max) correspond to values in the x.coord.label and y.coord.label.

Output

The output consists of five figures:

Figure B1. Tree diagram of hierarchical clustering



The threshold height determines the number of clusters. For example, a threshold of 15.55 (red line) would yield four clusters, while a threshold of 11 (blue line) would yield five clusters.

Figure B2. Normalized constituent plot by cluster. This allows the user to identify which constituents differ the most from cluster to cluster.

In this example from Silver Springs, DO, Mg, and SO4 show the largest differences among groups, while pH, K and Cl show the smallest differences.

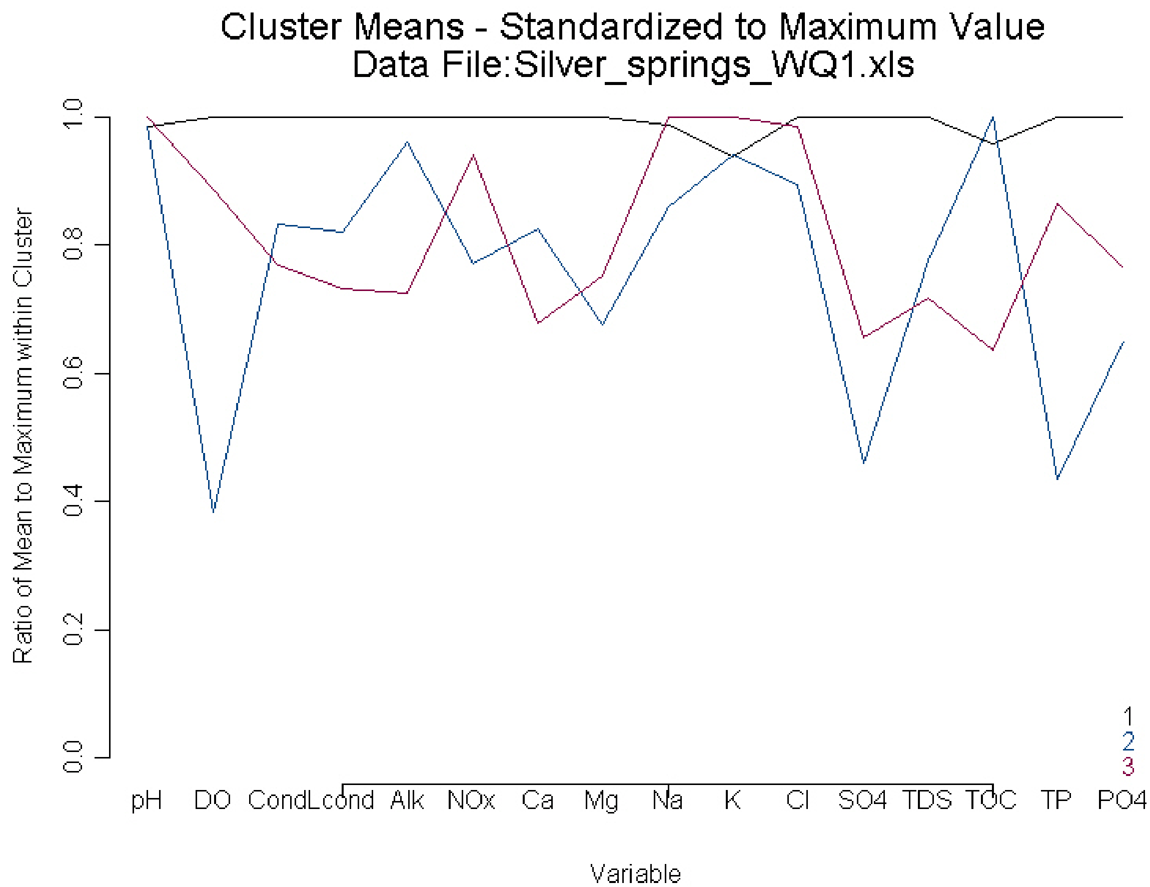


Figure B3. Map of groups with labels. Note that this map is not geometrically correct, but has been fitted to the x and y data. The scales on the x and y axis may therefore be different. Production of a "true" map, as in Figure A2 of the report, needs to be done in a GIS or other mapping software.

In this example, the three clusters form geographically distinct groups. This is a good indication that the algorithm has identified meaningful clusters that correspond to different flowpaths and/or groundwater sources.

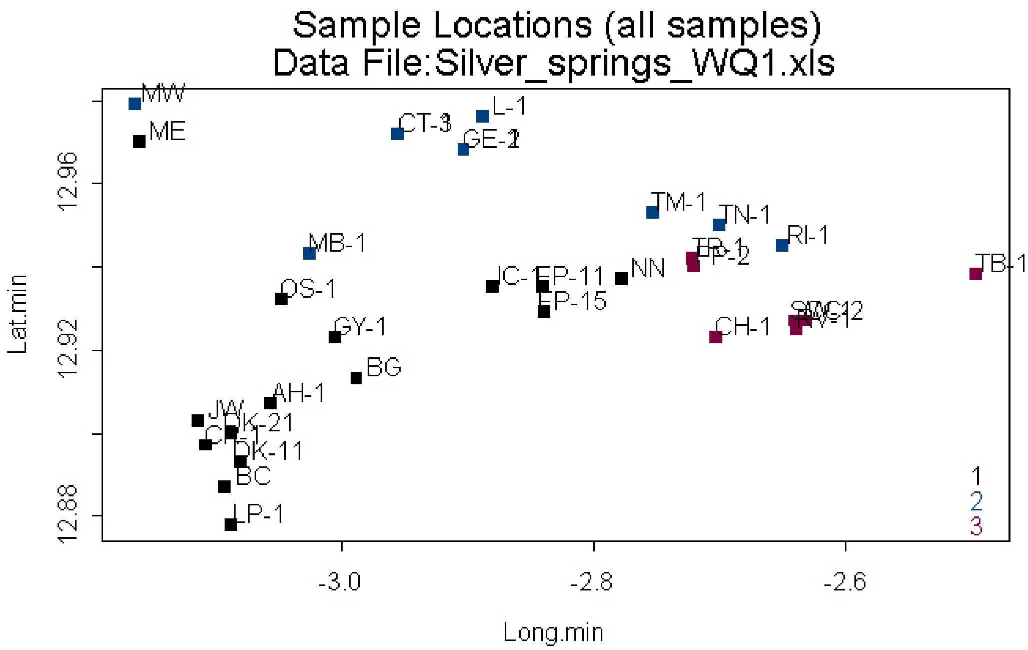


Figure B4. A zoom-in for part of the study are in Figure A3. The boundaries of this area are defined by map.x.min(max) and map.y.min(max).

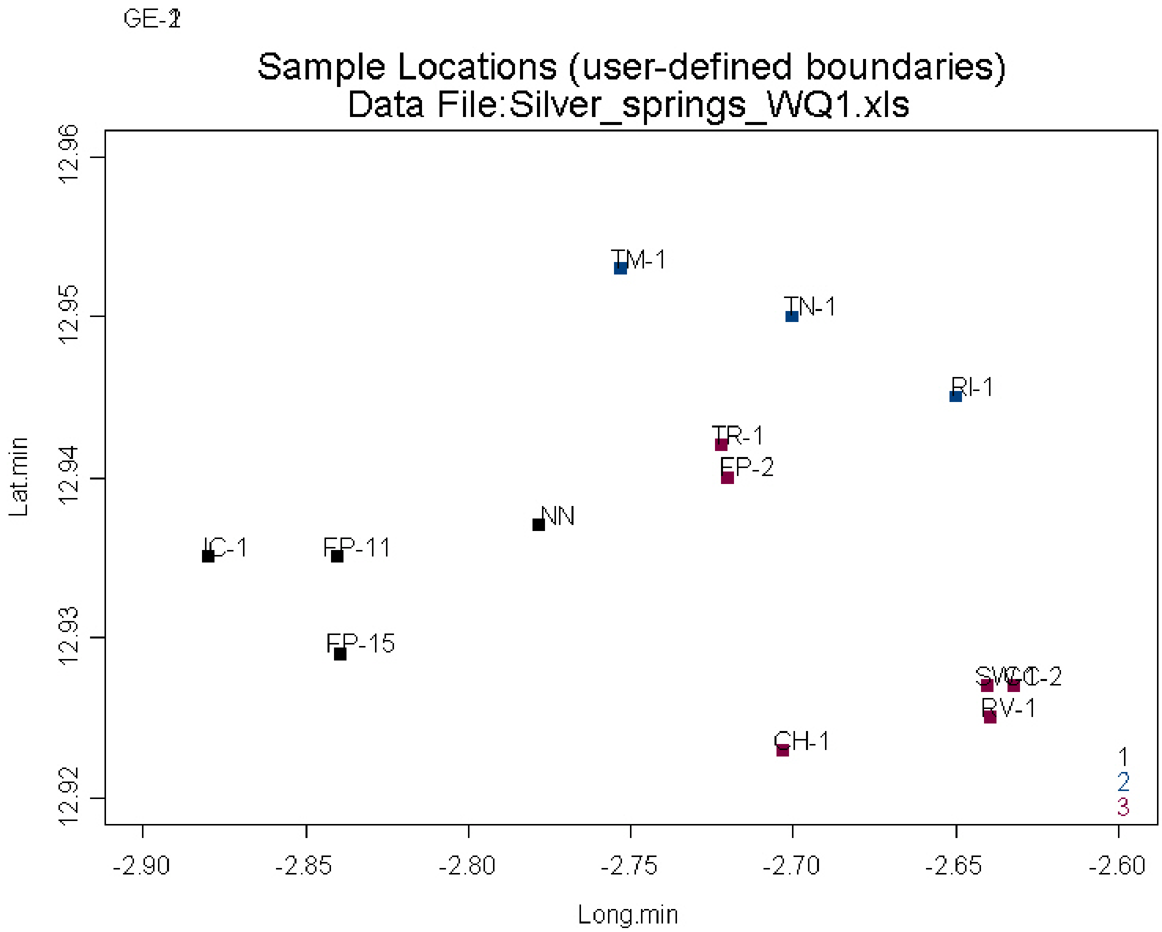
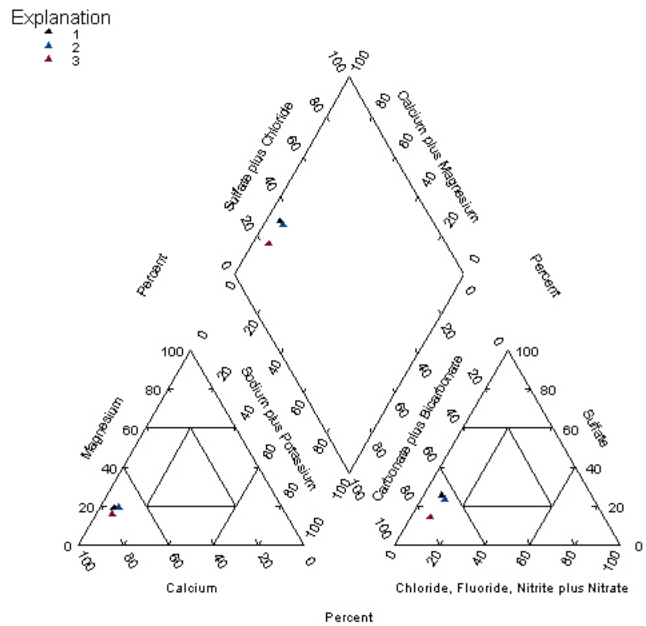
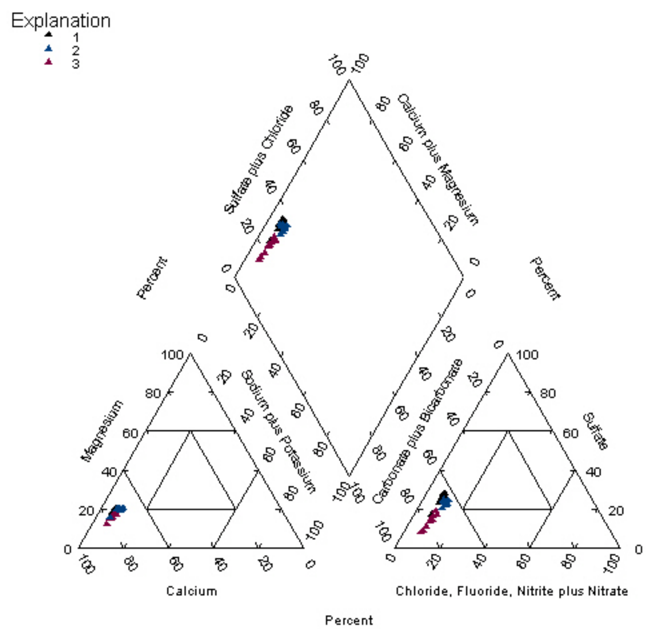


Figure B5. Piper Diagrams. First diagram is the means of each group. Second diagram is each individual point, colored by group.





Report

The report gives the mean chemical composition of each cluster:

```
> # Summary Stats
clust.means
  clusts.sort...2.       pH       DO     Cond      Alk      NOx       Ca         Mg
Na          K       Cl
1                1 7.345455 3.173636 462.7909 179.0000 1.445455 77.63636 11.818182
6.809091 0.7181818 11.49091
2                2 7.450000 3.175455 379.0091 136.3636 1.497273 58.36364  9.427273
6.972727 0.8000000 11.45455
3                3 7.357000 1.265000 377.9200 165.8000 1.154900 62.60000  7.800000
5.980000 0.7460000 10.30400

       SO4      TDS
1 65.58182 303.0000
2 45.98182 230.3636
3 28.72000 227.1000
```

and the group membership of each sample:

```
   Sample Number Abbreviation Cluster
 1             1           ME       1
 3             3           JW       1
 4             4         CR-1       1
 5             5           BC       1
 6             6         OS-1       1
 7             7        DK-21       1
 8             8         LP-1       1
 9             9        DK-11       1
10            10         AH-1       1
12            12         GY-1       1
13            13           BG       1
19            20         IC-1       1
20            21        FP-11       1
21            22        FP-15       1
22            23           NN       1
 2             2           MW       2
11            11         MB-1       2
14            14         CT-1       2
15            15         CT-3       2
16            16         GE-1       2
17            17         GE-2       2
18            19         GE-5       2
23            24         TM-1       2
26            27         TN-1       2
28            29         RI-1       2
24            25         FP-2       3
25            26         CH-1       3
27            28         TR-1       3
29            30         RV-1       3
30            31         SW-1       3
31            33         CC-2       3
32            34         TB-1       3
```

The report also gives the samples that failed the charge balance and their chemical composition:

```
if(charge.bal.flag == 1) {
      err.charge.exceed
}
 [1] pH   DO   Cond Alk  NOx  Ca   Mg   Na   K    Cl   SO4  TDS
< 0 rows>
```

For this example, all samples were within the charge balance tolerance of 0.1.

B.2 Principal_Components_Analysis.ssc

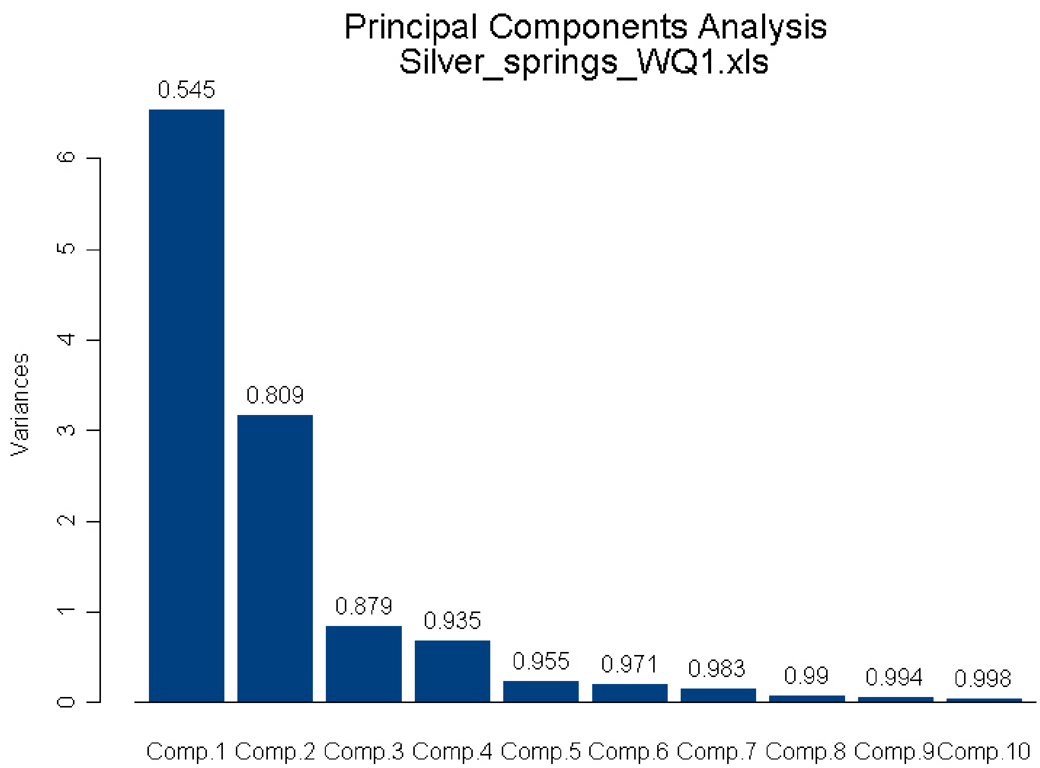
PCA reduces a multivariate dataset to a few factors that explain most of the variance. For example, Ca and HCO3 often correlate very closely in natural water samples, so a list of samples with Ca and HCO3 could be reduced to a single vector (eigenvector) that, when multiplied by a conversion factor (eigenvalue), gives the observed Ca and HCO3 concentration.

As in the previous script (B.1), the main input required by the user, other than the file and path name, is the constituent list. There is also an option to write the figures to jpeg files.

Output

The script produces two figures and a report:

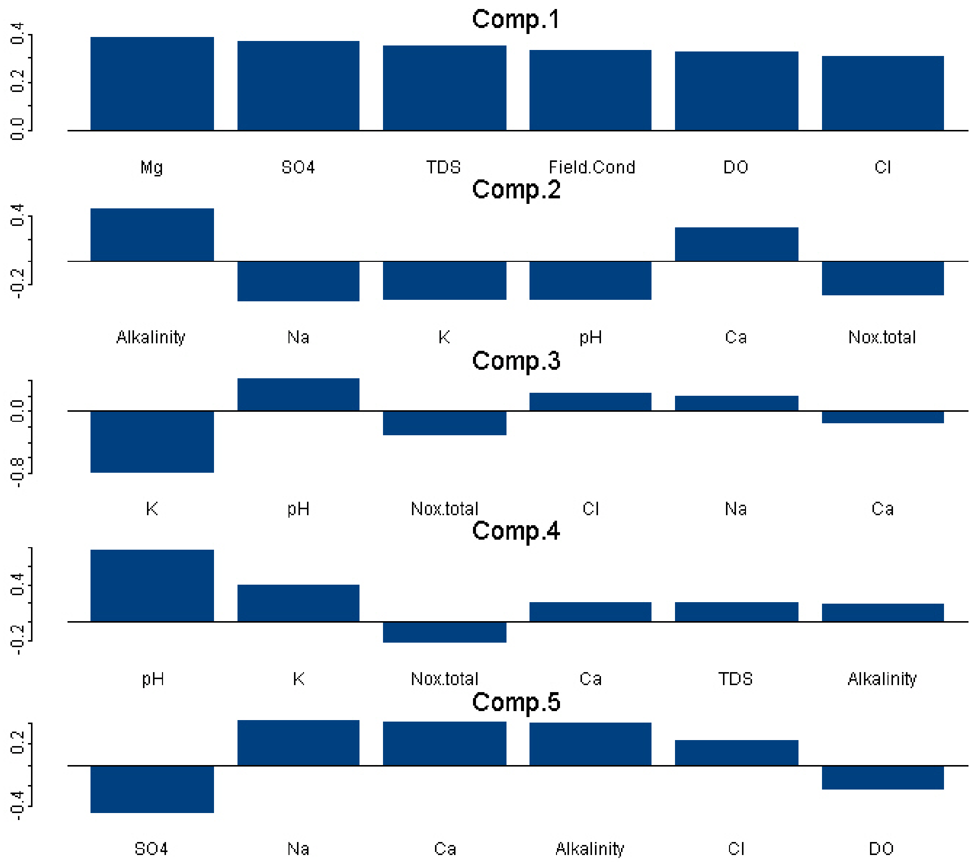
Figure B6 shows the variance explained by each principal component, starting with the factor that explains the most variance (PC 1):



The number above each bar is cumulative fraction of the total variance explained by adding each principal component. For example, Comp.1 explains 54.5% of the total variance in the data. Comp.2 explains less variance than Comp.1, but adding Comp.2 brings the total variance explained to 80.9%. Note that the variance explained by adding an additional component decreases with the number of components.

This plot helps determine the number of components to keep for the final report. The cutoff can be set to include any number of components, but typically the cutoff is set at 90-95% of the total variance explained. In this example, using a 90% cutoff would include components 1 through 3.

Figure B7 shows the loadings on each constituent for the first 5 components:



Only the six constituents with the highest loadings are displayed. In this example, Comp.1 has high loadings in Mg, SO4, TDS, FieldCond, DO, and Cl, and can be thought of as a "TDS and DO" component. Comp.2 has high loadings in Alk, Na, K, pH, Ca, and NO3. Since it is highest in Alk, Na, and Cl, it could be thought of as an Na-K component. Comp.3 has high loadings in K, pH, NOx, Cl, Na, and Ca. It could be thought of as an K-NOx component.

Report

The report contains the values used to produce Figure 1 and 2, and some additional output including the correlation matrix:

```
cor.out
numeric matrix: 12 rows, 12 columns.
                     pH           DO Field.Cond  Alkalinity   Nox.total         Ca
Mg         Na
        pH  1.000000000  0.006432464 -0.4397742 -0.51160059 -0.09722307 -0.4601506 -
0.2678734  0.1365002
        DO  0.006432464  1.000000000  0.4844212 -0.08942228  0.86823911  0.3021174
0.7959701  0.8677639
Field.Cond -0.439774231  0.484421166  1.0000000  0.72985609  0.39276359  0.8169963
0.8292386  0.2962535
Alkalinity -0.511600594 -0.089422281  0.7298561  1.00000000 -0.11482854  0.8047924
0.4527705 -0.1867397
 Nox.total -0.097223070  0.868239109  0.3927636 -0.11482854  1.00000000  0.2871793
0.6515588  0.7678793
        Ca -0.460150552  0.302117430  0.8169963  0.80479241  0.28717932  1.0000000
0.7380517  0.1638288
        Mg -0.267873418  0.795970098  0.8292386  0.45277054  0.65155878  0.7380517
1.0000000  0.6817397
        Na  0.136500170  0.867763853  0.2962535 -0.18673968  0.76787927  0.1638288
0.6817397  1.0000000
         K  0.297301490  0.126235376 -0.2627169 -0.49445787  0.30256805 -0.2882306 -
0.1984558  0.1206238
        Cl  0.089158648  0.892085181  0.4151913 -0.06111361  0.74458271  0.2694915
0.7550914  0.9173291
       SO4 -0.164284479  0.851660655  0.7433512  0.27541251  0.70983098  0.6217460
0.9463121  0.6805332
       TDS -0.383952601  0.542758736  0.9276195  0.70393257  0.40244902  0.8768768
0.9118578  0.3622148

                    K          Cl         SO4        TDS
        pH  0.29730149  0.08915865 -0.16428448 -0.3839526
        DO  0.12623538  0.89208518  0.85166066  0.5427587
Field.Cond -0.26271693  0.41519134  0.74335116  0.9276195
Alkalinity -0.49445787 -0.06111361  0.27541251  0.7039326
 Nox.total  0.30256805  0.74458271  0.70983098  0.4024490
        Ca -0.28823059  0.26949153  0.62174601  0.8768768
        Mg -0.19845581  0.75509135  0.94631212  0.9118578
        Na  0.12062379  0.91732912  0.68053320  0.3622148
         K  1.00000000  0.05595437 -0.02854355 -0.2726048
        Cl  0.05595437  1.00000000  0.77013222  0.5042483
       SO4 -0.02854355  0.77013222  1.00000000  0.8461429
       TDS -0.27260478  0.50424826  0.84614288  1.0000000
```

The data used to produce Figure 1 is in "summary(pca.out)":

```
> summary(pca.out)
Importance of components:
numeric matrix: 3 rows, 12 columns.
                          Comp.1    Comp.2     Comp.3     Comp.4     Comp.5     Comp.6
Comp.7      Comp.8
    Standard deviation 2.5570518 1.7792003 0.91625838 0.82452723 0.48131007 0.43794768
0.3928511 0.274752255
```

```
Proportion of Variance 0.5448762 0.2637962 0.06996078 0.05665376 0.01930495 0.01598318
0.0128610 0.006290733
 Cumulative Proportion 0.5448762 0.8086723 0.87863312 0.93528688 0.95459183 0.97057501
0.9834360 0.989726739

                            Comp.9   Comp.10     Comp.11      Comp.12
    Standard deviation 0.239328243 0.2019752 0.130453646 0.0904929684
Proportion of Variance 0.004773167 0.0033995 0.001418179 0.0006824148
 Cumulative Proportion 0.994499906 0.9978994 0.999317585 1.0000000000
```

The data used to produce Figure 2 are produced by typing "loadings(pca.out)":

```
> loadings(pca.out)
           Comp.1 Comp.2 Comp.3 Comp.4 Comp.5 Comp.6 Comp.7 Comp.8 Comp.9 Comp.10
Comp.11 Comp.12
        pH -0.116 -0.324  0.421  0.779        -0.277  0.129
        DO  0.324 -0.286        -0.112 -0.225 -0.157        -0.116  0.124 -0.825
Field.Cond  0.329  0.233         0.147 -0.219  0.116  0.651  0.250  0.444  0.161
0.164
Alkalinity  0.172  0.472         0.182  0.408         0.314 -0.256 -0.538 -0.252
0.157
 Nox.total  0.282 -0.289 -0.301 -0.219  0.211 -0.643  0.269 -0.130 -0.147  0.324  -
0.139
        Ca  0.290  0.306 -0.136  0.212  0.411 -0.296 -0.502         0.454
0.169
        Mg  0.386                                    -0.143  0.207 -0.228         -
0.464   0.708
        Na  0.273 -0.345  0.206 -0.139  0.429  0.284         0.612 -0.144
0.128  -0.262
         K        -0.332 -0.776  0.392         0.331
        Cl  0.306 -0.286  0.228         0.238  0.410        -0.642  0.272  0.213
0.108
       SO4  0.371                0.105 -0.463        -0.292        -0.344  0.231
0.609
       TDS  0.352  0.207         0.209 -0.223  0.127 -0.143                0.107  -
0.544  -0.625
```

Appendix 7
Photographs