Summary of Existing Data - Silver Glen Springs (Marion Co.)

Prepared by

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Contents

Cover photo: A large school of ladyfish (*Elops saurus*) and Crevalle jack (*Caranx hippos*) circling the main vent of Silver Glen Springs, tape grass (*Vallisneria americana*) and filamentous algae (*Lyngbya sp.*) growing on the bottom, and data sonde housing visible in the middle (S.K. Notestein, 02/18/09).

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Summary of Existing Springs Data

This report summarizes known existing physical, chemical, and biological data for Silver Glen Springs (Marion County). These data were collected from sources such as the St. Johns River Water Management District (SJRWMD), the U.S. Geological Survey (USGS), and the Florida Department of Environmental Protection (FDEP); as well as through literature searches of journal publications, technical reports, and student dissertations.

Silver Glen Springs Recreation Area

Physical address

Silver Glen Springs Recreation Area; Marion County, Florida, 32134; latitude/longitude: 29.247226°, -81.643009°). The spring is administered by the US Forest Service, Lake George Ranger District; 17147 East State Road 40; Silver Springs, Florida, 34488; phone: 352-625-2520; Spring website: http://www.fs.fed.us/r8/florida/ocala/attractions/silverGlenSpringsRecArea.php?p=1.1.3.4 .

Driving Directions

Silver Glen Springs is in the Ocala National Forest approximately 48.3 km (30 mi) northeast of Ocala. At the intersection of SR 40 and CR 326, travel east on SR 40 for approximately 40 km (25 mi), turn north on SR 19 and travel approximately 9.7 km (6 mi) to Silver Glen Springs Recreation Area located on the east side of SR 19. The spring is south of the parking area.

General

This first magnitude spring system is located in the Ocala National Forest adjacent to the border of Marion and Lake Counties (**Figure 1**). Two spring vents comprise the

spring pool and the resulting spring run travels east to Lake George. Operated by private concession, the park facilities are well developed and include rest rooms and picnic facilities. A popular regional swimming and camping destination, the spring run is also accessed by boat via Lake George and the St. Johns River. During summer holidays and weekends hundreds of boats routinely travel into and anchor in the spring run (Pandion Systems, Inc. 2003).

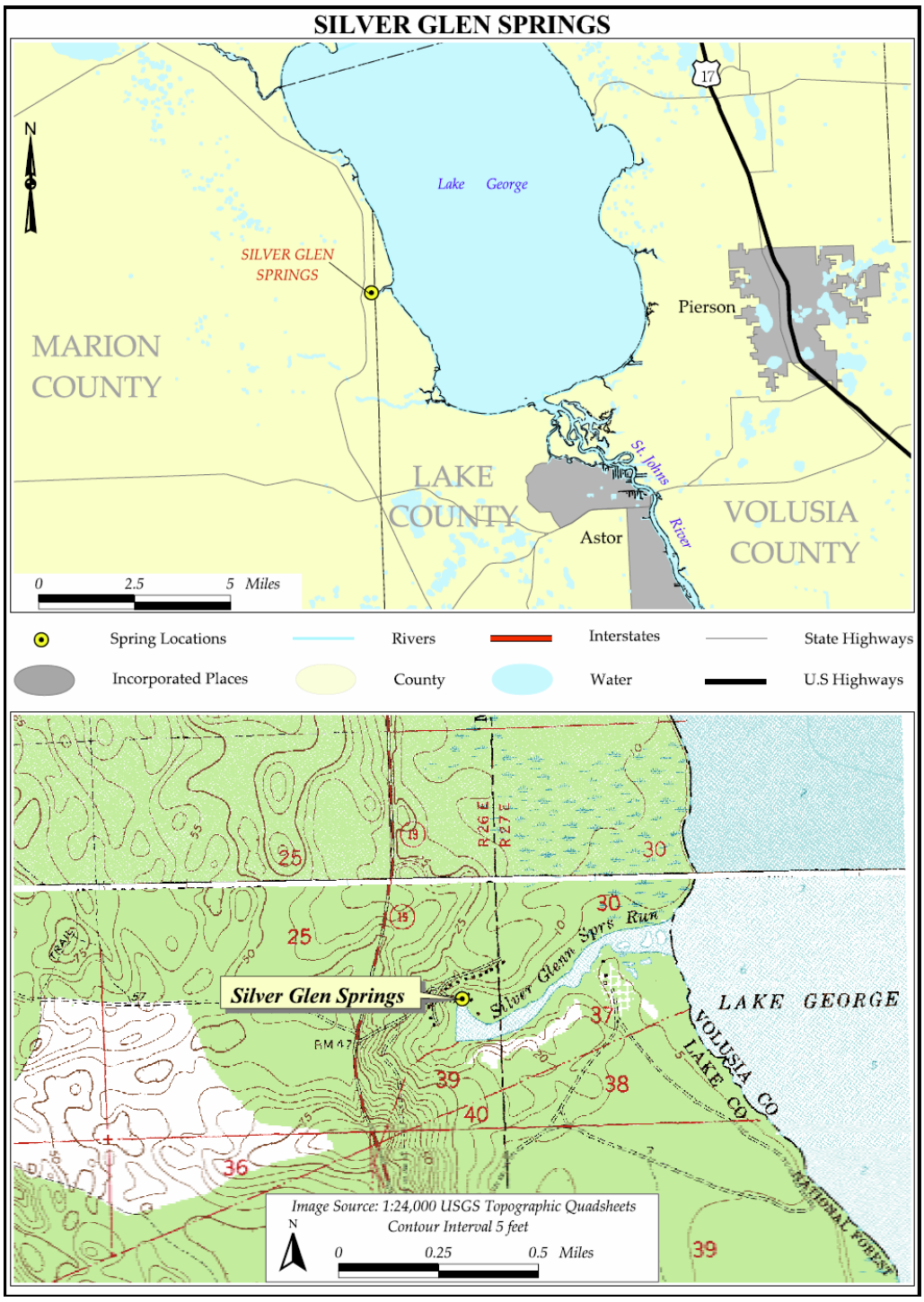


FIGURE 1
Silver Glen Springs location (from Scott *et al.* 2002).

Physical

Silver Glen Springs has two vents and a large combined spring pool with a mostly bare sand bottom. The spring pool is approximately 61 m (200 ft) north to south and 53 m (175 ft) east to west. The depth is 5.5 m (18 ft) at the east vent or "Main spring" which has a conical basin. The second vent, often referred to as "The Well" due to its vertical cylindrical opening into the limestone, is on the southwestern edge of the pool. It is 3.7 m (12 ft) in diameter and approximately 12.2 m (40 ft) deep.

Water is clear and light blue. Large boils occur over both vents. Some patches of submersed aquatic vegetation are in the pool. Two ropes separate the spring pool from boat traffic. Within the main pool, access to "The Well" is maintained as a natural area with recreational access restricted. The spring run ranges from 30 to 60 m (100 to 200 ft) wide, with maximum depths approaching 3.6 m (12 ft), and continues east approximately 1.2 km (0.75 mi) before joining Lake George. The spring pool and upper run are heavily utilized by swimmers and boaters respectively. Resultantly, submersed aquatic vegetation (except filamentous algae which has no need to be rooted to the sediments) has declined in these portions of Silver Glen Springs (**Figures 2** and **3**). The lands around the springs rise to approximately 3.7- 4.6 m (12 to 15 ft) of elevation, where oak, cedar, palm, and pine trees are common, and several large Native American earthen mounds are evident. The underwater cave system at Silver Glen Springs has been extensively mapped. Original cartographic maps of the cave system as well as a color photograph of the largest "room" are displayed in the Silver River State Park museum.

FIGURE 2
Silver Glen Springs circa 1930 photo (anonymous, from Scott *et al*. 2004).

FIGURE 3
Silver Glen Springs pool with "main" spring to the right and "The Well" in the back-center (from Scott *et al*. 2004).

Geology

The geology Silver Glen Springs is dominated by sand dunes and well sorted fine sand of the Pleistocene and Holocene deposits (Brooks 1981) with underlying Pliocene age material (Scott *et al.* 2001) (**Figure 4**). The area is contained in the Ocala Scrub division of the Central Lake District; and contains uplifted limestones of the Floridan aquifer below the surficial sands, has active sinkhole development, and is a significant recharge area of the Floridan aquifer (Brooks 1981).

Hydrogeologic Setting

Shoemaker *et al.* (2004) describe the region containing Silver Glen Springs as mostly underlain by unconsolidated sand and clay sediments that form the surficial aquifer system; followed by less permeable clay and carbonate rocks which form the intermediate confining unit; more permeable carbonate rocks that form the intermediate aquifer system; and a thick sequence of limestone and dolomitic limestone of variable permeability that form the Floridan aquifer system; and low permeability dolomite beds that form the sub-Floridan confining unit, which functions as the base of the fresh ground-water flow system.

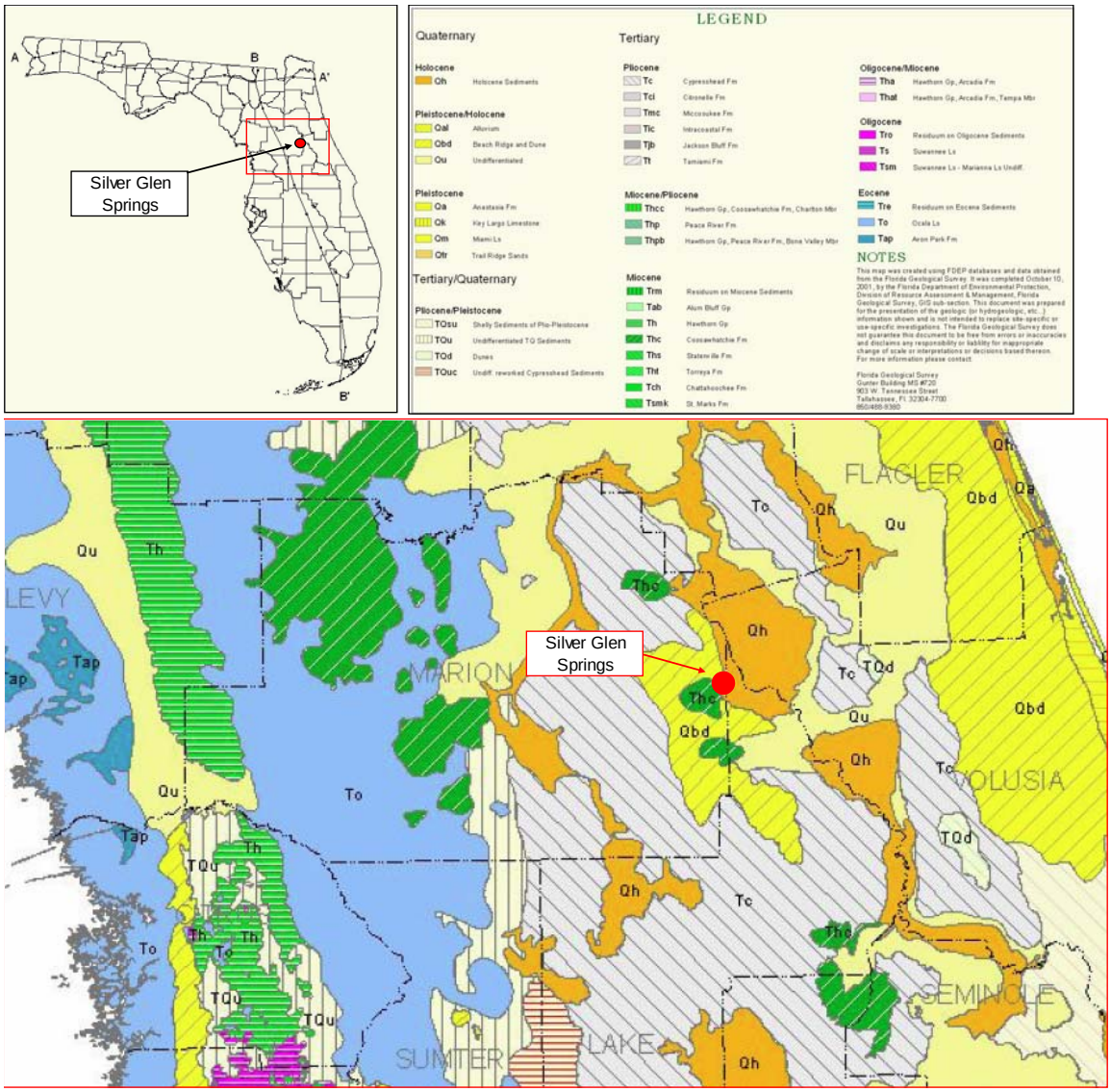


FIGURE 4
Geologic map of Silver Glen Springs (adapted from Scott *et al.* 2001).

Springshed

The springshed of Silver Glen Springs has been estimated using three different recharge models by Shoemaker *et al.* (2004). Depending on the model employed, the land area contributing recharge to Silver Glen Springs ranged in size from 104 to 233 km^2 (40 to 90 mi^2, **Figure 5**). By combining the areas of each model, a composite area was generated which encompasses about 311 km^2 (120 mi^2 or 76,800 ac). This composite area suggests that a portion of the ground water discharged from Silver Glen Springs originates from areas northwest and southeast of the spring, but that most of the area contributing recharge, lies southwest of the spring because the prevailing direction of ground-water flow in the Upper Floridan Aquifer of this area is from southwest to northeast (Shoemaker *et al.* 2004).

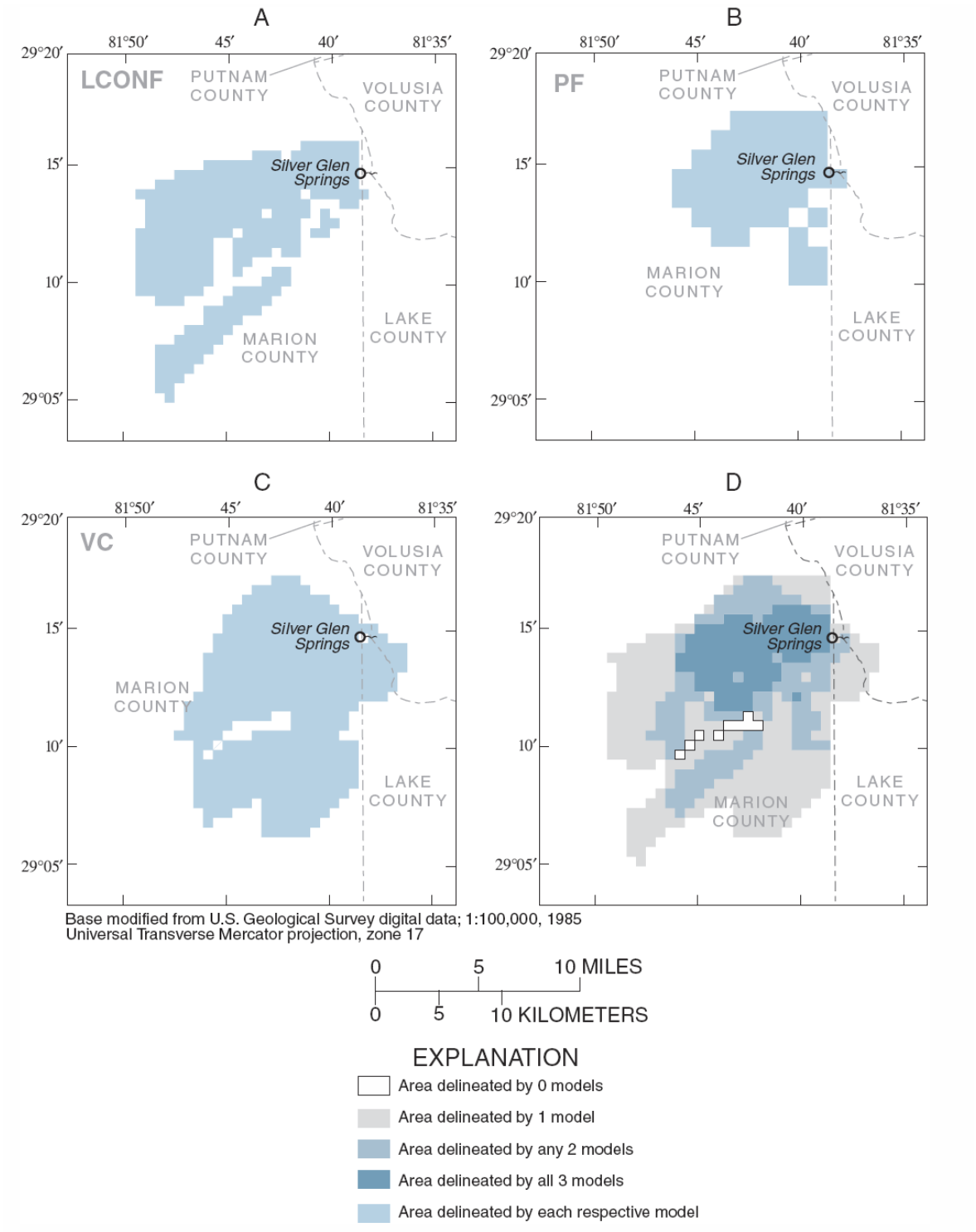


FIGURE 5
Modeled springsheds of Silver Glen Springs based on travel times up to 100 years as simulated by (A) Lake County/Ocala National Forest; (B) Peninsular Florida; (C) North-Central Florida models for the average hydrologic conditions of the calibration period; and (D) composite area of all three models (from Shoemaker *et al.* 2004).

Study Area

The project study area is defined as the spring pool and the upper-half of the spring run. **Figure 6** shows an approximation of the study area.

FIGURE 6
The study area for Silver Glen Springs.

Meta data (source, station, location, and STORET Origin ID) for the water quality data presented in the historical description of Silver Glen Springs are given in **Table 1** below.

TABLE 1
Source information for Silver Glen Springs historical water quality data described in this report.

Org ID	Org Name	Station ID	Station Name	Latitude	Longitude
USGS	USGS	2236160	Silver Glen Springs near Salt Springs	29.244444	-81.642778
21FLKWAT	Florida Lakewatch	MAR-SIVERGLEN-1	Marion-Silver Glen-1	29.244861	-81.643250
21FLKWAT	Florida Lakewatch	MAR-SIVERGLEN-2	Marion-Silver Glen-2	29.244861	-81.643250
21FLKWAT	Florida Lakewatch	MAR-SIVERGLEN-3	Marion-Silver Glen-3	29.244861	-81.643250
21FLCEN	Florida Department of Environmental Protection	20010358	Silver Glenn Springs at Main Boil	29.245783	-81.643450
21FLGW	Florida Department of Environmental Protection	9687	Silver Glen Springs	29.245844	-81.643473
21FLCEN	Florida Department of Environmental Protection	20010335	Silver Glenn Springs Run @ Lake George.	29.248361	-81.635061

Discharge and Stage

Historical discharge data for Silver Glen Springs are reported by Rosenau *et al.* (1977), with eleven sporadic measurements spanning the time period of 1931 to 1972, with discharge values ranging from a minimum of 90 cfs (February 7, 1933) to a maximum of 129 cfs (April 12, 1935). Other measures of discharge include a value of 109 cfs (September 13, 2001) by Scott *et al.* 2002. The US Geological Survey has a station which monitors discharge and stage (station # 02236160) with daily records mostly available between November 2002 and December 2008. **Table 2** illustrates the variability of discharge and stage at this spring system (USGS 2006). Discharge data are plotted in **Figure 7** for the available period-of-record.

TABLE 2
Summary statistics for the discharge and stage of Silver Glen Spring (from USGS 2006).

SUMMARY STATISTICS							
	Calendar Year 2005		Water Year 2006		Water Years 2003 - 2006		
Annual total	32,835		35,649				
Annual mean	93.3		97.7		107		
Highest annual mean					118		2003
Lowest annual mean					97.7		2006
Highest daily mean	111	Sep 10	116	Jun 19, 20	132	Dec 1-3, 2002	
Lowest daily mean	68	Apr 24	80	Dec 19, 21	68	Apr 24, 2005	
Annual seven-day minimum	72	Apr 19	83	Sep 24	72	Apr 19, 2005	
Maximum peak stage			3.14	Oct 7	4.68	Sep 26, 2004	
10 percent exceeds	105		107		121		
50 percent exceeds	93		98		110		
90 percent exceeds	83		89		90		

Note.--Monthly and annual summary statistics include periods of missing daily discharge record.

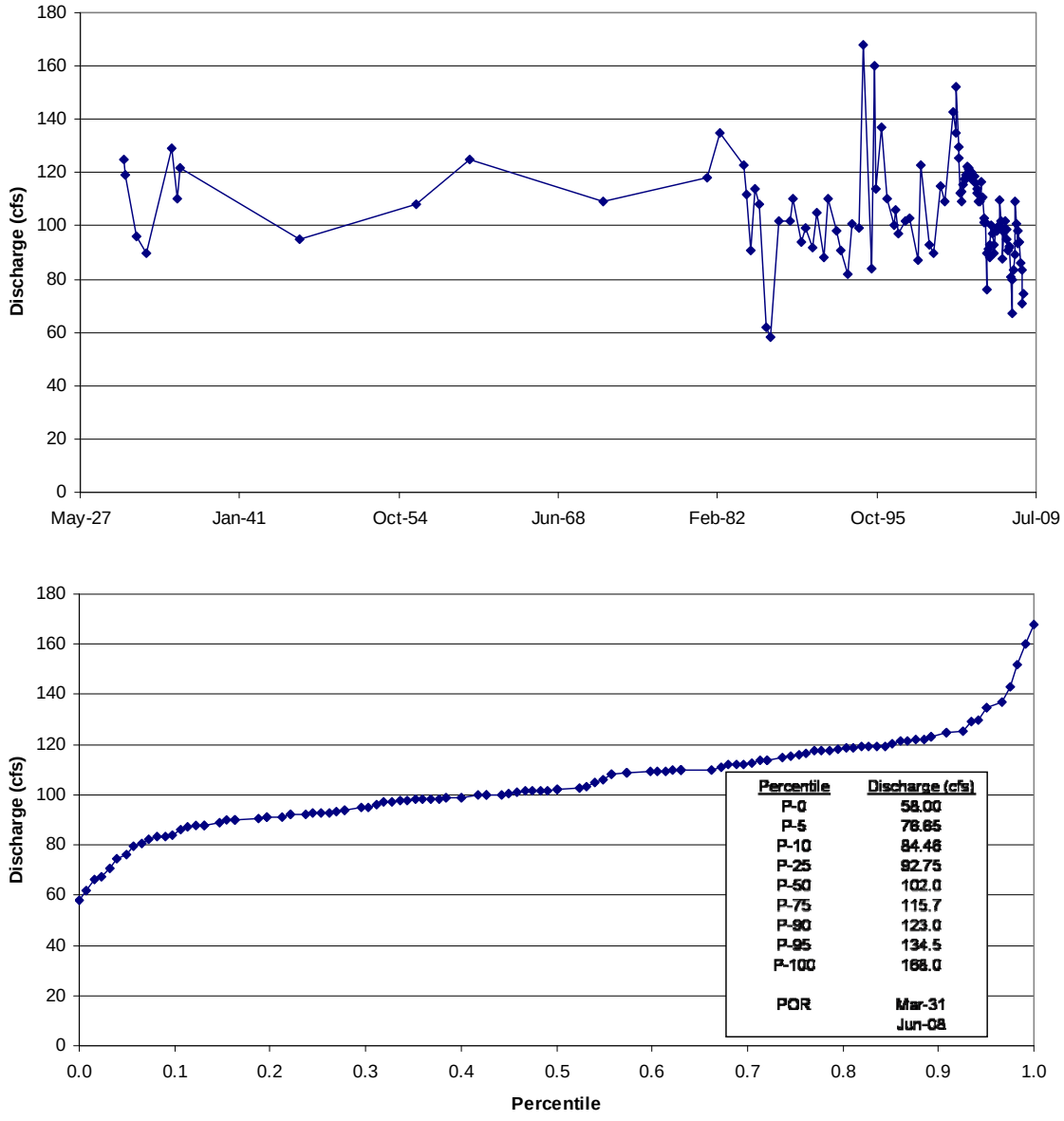


FIGURE 7
Monthly average discharge time series and frequency curve for Silver Glen Springs.

Water Quality

Sporadic water quality data for Silver Glen Springs are summarized from March 1931 through June 2008 from STORET (USGS and FDEP data). The numbers of samples collected were highly variable between parameters, ranging from 1 to 364 records. Samples appear to have been collected solely from the main boil. **Table 3** provides statistics for the available water quality parameters, as well as decadal averages (if available), and the period-of-record (POR) dates. The Silver Glen Springs POR averages for several key parameters and the numbers of samples in parenthesis are:

- Water temperature – 23.4 °C (n = 22)
- Dissolved oxygen – 2.91 mg/L (n = 22)
- pH – 7.72 SU (n = 22)
- Specific conductance – 1,862 umhos/cm (n = 43)
- Turbidity – 0.125 NTU (n = 16)
- Color – 0.7 CPU (n= 21)
- Total chloride – 449 mg/L (n = 40)
- Sulfate – 169 mg/L (n = 40)
- Nitrate+nitrite nitrogen – 0.05 mg/L (n = 40)
- Total phosphorus – 0.03 mg/L (n = 364)

TABLE 3
Silver Glen Springs water quality table for the period-of-record.

GROUP DESC	PARAMETER	UNITS	Station	Decade Average								Statistics					Period of Record	
				1930	1940	1950	1960	1970	1980	1990	2000	Average	Min	Max	StDev	N		
BACTERIOLOGICAL	EColi	#/100ml	Main Boil								1.00	1.00	1.00	1.00	0.00	2	10/25/01	1/29/02
			Lake George								20.0	20.0	4.00	44.0	21.2	3	5/22/01	5/28/01
	Enterococci	#/100ml	Main Boil								4.33	4.33	1.00	46.0	10.2	21	10/25/01	10/25/06
			Lake George								8.67	8.67	2.00	20.0	9.87	3	5/22/01	5/28/01
	FC	#/100ml	Main Boil								1.48	1.48	1.00	2.00	0.512	21	10/25/01	10/25/06
			Lake George								72.3	72.3	8.00	190	102	3	5/22/01	5/28/01
	TC	#/100ml	Main Boil								2.90	2.90	1.00	20.0	4.47	20	10/25/01	10/25/06
			Lake George								1,543	1,543	44.0	4,090	2,217	3	5/22/01	5/28/01
BIOLOGICAL	Pheo-a	µg/L	Spring Run								0.800	0.800	0.100	1.80	0.804	4	1/31/07	10/10/07
DISSOLVED OXYGEN	DO	%	Spring Run					43.0			42.2	42.3	33.0	65.0	10.4	14	4/13/72	10/10/07
	DO	mg/L	Main Boil								2.91	2.91	2.03	4.10	0.45	22	5/22/01	10/25/06
			Spring Run					3.70	4.73		3.55	4.08	2.80	6.20	1.02	32	4/13/72	10/10/07
			Lake George								5.20	5.20	3.56	6.50	1.50	3	5/22/01	5/28/01
FLOW	Flow	cfs	Main Boil								66.4	66.4	66.4	66.4		1	7/21/04	7/21/04
			Spring Run	113	95.0	108	125	109	102	107	102	102	56.0	168	15.1	2048	3/17/31	6/30/08
	Flow-Inst	cfs	Spring Run	113	95.0	108	125	109	102	107	117	110	58.0	168	19.8	68	3/17/31	1/13/05
GENERAL INORGANIC	Alk	mg/L as CaCO3	Spring Run					69.0	66.0			67.5	66.0	69.0	2.12	2	4/13/72	4/16/81
	Cl-T	mg/L	Main Boil								449	449	360	480	26.6	40	10/25/01	10/25/06
			Spring Run					520	460	470		478	420	520	43.5	4	4/13/72	2/4/97
	CO2	mg/L	Spring Run					2.10	5.50	3.40		4.13	2.10	8.40	2.90	4	4/13/72	2/4/97
	F-D	mg/L	Spring Run					0.200	0.350	0.100		0.250	0.100	0.500	0.173	4	4/13/72	2/4/97
	Hardness	mg/L as CaCO3	Spring Run					340	330	340		335	310	350	16.0	8	4/13/72	2/4/97
	Si-D	mg/L	Spring Run					8.80	8.95	8.40		8.78	8.40	9.20	0.330	4	4/13/72	2/4/97
	SO4	mg/L	Main Boil								169	169	150	180	7.36	40	10/25/01	10/25/06
			Spring Run					190	180	180		183	160	200	17.1	4	4/13/72	2/4/97
GENERAL ORGANIC	TOC	mg/L	Main Boil								1.30	1.30	1.30	1.30		1	10/25/01	10/25/06
			Spring Run					5.00				5.00	0.00	15.0	8.66	3	4/13/72	4/13/72
METAL	Ag-T	µg/L	Spring Run					0.00	0.670			0.503	0.00	1.00	0.574	4	4/13/72	1/23/85
	Ba-T	µg/L	Main Boil								6.78	6.78	5.50	7.90	0.698	12	10/29/02	4/13/05
			Spring Run						100			100	100	100	0.00	2	1/23/85	1/23/85
	Ca-D	mg/L	Spring Run					74.0	73.5	74.0		73.8	71.0	76.0	1.91	8	4/13/72	2/4/97
	Ca-T	mg/L	Main Boil								72.2	72.2	61.8	83.4	4.01	41	10/25/01	10/25/06
	Cd-T	µg/L	Spring Run						1.00			1.00	1.00	1.00	0.00	2	1/23/85	1/23/85
	Co-T	µg/L	Main Boil								5.00	5.00	5.00	5.00		1	10/25/01	4/13/05
	Cr-T	µg/L	Spring Run					0.00	1.00			0.667	0.00	1.00	0.577	3	4/13/72	1/23/85
	Fe-T	µg/L	Main Boil								7.60	7.60	7.60	7.60		1	10/25/01	4/13/05
	Hg-T	µg/L	Spring Run					0.00	0.300			0.150	0.00	0.300	0.173	4	4/13/72	1/23/85
	K-D	mg/L	Spring Run					11.0	9.15	8.20		9.38	8.20	11.0	1.29	4	4/13/72	2/4/97
	K-T	mg/L	Main Boil								8.54	8.54	6.70	9.50	0.622	41	10/25/01	10/25/06
	Mg-D	mg/L	Spring Run					38.0	35.5	37.0		36.5	33.0	38.0	2.38	4	4/13/72	2/4/97
	Mg-T	mg/L	Main Boil								35.5	35.5	30.0	38.8	1.90	41	10/25/01	10/25/06
	Mn-T	µg/L	Main Boil								2.90	2.90	0.510	7.50	3.98	3	10/25/01	4/13/05
	NA-D	mg/L	Spring Run					290	250	250		260	230	290	23.9	8	4/13/72	2/4/97
	NA-T	mg/L	Main Boil								248	248	192	285	18.3	41	10/25/01	10/25/06
	NA-T	%	Spring Run					64.0	61.5	61.0		62.0	61.0	64.0	1.41	4	4/13/72	2/4/97
	SAR	ratio	Spring Run					6.80	6.00	5.90		6.18	5.70	6.80	0.486	4	4/13/72	2/4/97
	SR-D	µg/L	Spring Run						1,550	1,400		1,500	1,400	1,600	100	3	4/16/81	2/4/97
	SR-T	µg/L	Main Boil								1,591	1,591	1,450	1,720	98.7	13	10/25/01	4/13/05
	Zn-T	µg/L	Main Boil								2.60	2.60	2.10	3.10	0.707	2	10/25/01	4/13/05

TABLE 3 (CONTINUED)
Silver Glen Springs water quality table for the period-of-record.

				Decade Average								Statistics						
GROUP DESC	PARAMETER	UNITS	Station	1930	1940	1950	1960	1970	1980	1990	2000	Average	Min	Max	StDev	N	Period of Record	
NITROGEN	NH4-N	mg/L	Main Boil								0.015	0.015	0.011	0.022	0.004	9	10/25/01	10/25/06
			Spring Run					0.030	0.010			0.020	0.010	0.030	0.012	4	4/13/72	1/23/85
			Lake George								0.010	0.010	0.010	0.010		1	5/22/01	5/28/01
	NO2-N	mg/L	Spring Run					0.002	0.010			0.006	0.002	0.010	0.005	4	4/13/72	1/23/85
	NO3-N	mg/L	Spring Run					0.030				0.030	0.030	0.030	0.00	2	4/13/72	4/13/72
	NOx-N	mg/L	Main Boil								0.050	0.050	0.046	0.056	0.002	40	10/25/01	10/25/06
			Spring Run						0.050			0.050	0.050	0.050	0.00	2	1/23/85	1/23/85
			Lake George								0.028	0.028	0.013	0.043	0.021	2	5/22/01	5/28/01
	NOx-N-D	mg/L	Spring Run								0.047	0.047	0.043	0.050	0.005	2	10/19/06	3/15/07
	OrgN	mg/L	Spring Run					0.180	0.040			0.110	0.040	0.180	0.081	4	4/13/72	1/23/85
	TKN	mg/L	Main Boil								0.105	0.105	0.030	0.210	0.054	41	10/25/01	10/25/06
			Spring Run						0.050			0.050	0.050	0.050	0.00	2	1/23/85	1/23/85
			Lake George								0.190	0.190	0.120	0.260	0.099	2	5/22/01	5/28/01
	TN	mg/L	Spring Run						0.200			0.200	0.100	0.400	0.173	3	1/23/85	1/23/85
OXYGEN DEMAND	BOD5	mg/L	Spring Run					0.100				0.100	0.100	0.100	0.00	2	4/13/72	4/13/72
PESTICIDE	Alachlor-D	µg/L	Spring Run								0.005	0.005	0.005	0.005	0.00	2	10/30/06	3/15/07
	Atrazine-D	µg/L	Spring Run								0.007	0.007	0.007	0.007	0.00	2	10/30/06	3/15/07
	Diazinon-D	µg/L	Spring Run								0.070	0.070	0.005	0.200	0.101	6	10/19/06	3/15/07
	Dieldrin-D	µg/L	Spring Run								0.009	0.009	0.009	0.009	0.00	4	10/30/06	3/15/07
PHOSPHORUS	OrthoP	mg/L	Main Boil								0.027	0.027	0.022	0.037	0.003	21	10/25/01	10/25/06
			Spring Run					0.020	0.020			0.020	0.020	0.020	0.00	4	4/13/72	1/23/85
	TP	mg/L	Main Boil							0.022	0.033	0.030	0.000	2.800	0.146	364	2/28/91	10/25/06
			Spring Run					0.030	0.040			0.035	0.019	0.061	0.017	6	4/13/72	1/23/85
PHYSICAL	Color	CPU	Main Boil								0.71	0.71	0.00	5.00	1.79	21	10/25/01	10/25/06
			Spring Run					0.00	2.50	5.00		2.50	0.00	5.00	2.67	8	4/13/72	2/4/97
			Lake George								5.00	5.00	5.00	5.00	0.00	3	5/22/01	5/28/01
	Depth	m	Main Boil								5.21	5.21	4.20	6.30	0.576	12	10/25/01	10/25/06
	pH	SU	Main Boil								7.72	7.72	7.43	7.92	0.124	22	5/22/01	10/25/06
			Spring Run					7.80	7.40	7.75	7.75	7.61	6.20	8.50	0.471	38	4/13/72	10/10/07
			Lake George								7.92	7.92	7.65	8.16	0.230	5	5/22/01	5/28/01
	Secchi	m	Main Boil								4.96	4.96	4.20	5.60	0.382	22	5/22/01	10/25/06
			Lake George								2.87	2.87	1.60	5.00	1.86	3	5/22/01	5/28/01
	SpCond	umhos/cm	Main Boil								1,862	1,862	176	2,050	281	43	5/22/01	10/25/06
			Spring Run					2,200	2,031	1,960	1,926	1,992	1,890	2,200	81.5	52	4/13/72	10/10/07
			Lake George								1,723	1,723	1,670	1,760	47.3	3	5/22/01	5/28/01
	Stage	ft	Spring Run						1.09	1.69	1.39	1.39	0.060	17.2	1.49	2086	3/17/31	6/30/08
	Stage	ft MSL	Spring Run					1.39	1.11	0.823	2.09	1.08	-2.41	5.76	1.20	62	9/27/78	9/19/00
	Turb	NTU	Main Boil								0.125	0.125	0.050	0.350	0.075	16	10/25/01	10/25/06
			Spring Run					0.00			0.014	0.011	0.00	0.100	0.033	9	4/13/72	10/10/07
			Lake George								0.343	0.343	0.070	0.600	0.265	3	5/22/01	5/28/01
SOLID	TDS	mg/L	Main Boil								1,012	1,012	854	1,060	50.7	21	10/25/01	10/25/06
			Spring Run					1,200	1,074	1,120		1,105	975	1,220	96.3	7	4/13/72	2/4/97
	TSS	mg/L	Main Boil								2.00	2.00	2.00	2.00	0.00	21	10/25/01	10/25/06
TEMPERATURE	Wtr Temp	C	Main Boil								23.4	23.4	22.4	24.3	0.455	22	5/22/01	10/25/06
			Spring Run					23.0	23.5	23.1	23.3	23.3	23.0	24.5	0.458	46	4/13/72	10/10/07
			Lake George								23.8	23.8	23.2	24.1	0.471	3	5/22/01	5/28/01

Select water chemistry parameters for Silver Glen Springs are also monitored by the St. Johns River Water Management District (SJRWMD 2008a). Nitrate-nitrogen concentrations in the water discharged by Silver Glen Springs indicate that nitrate concentrations are typically low and do not appear to be increasing (**Figure 8**).

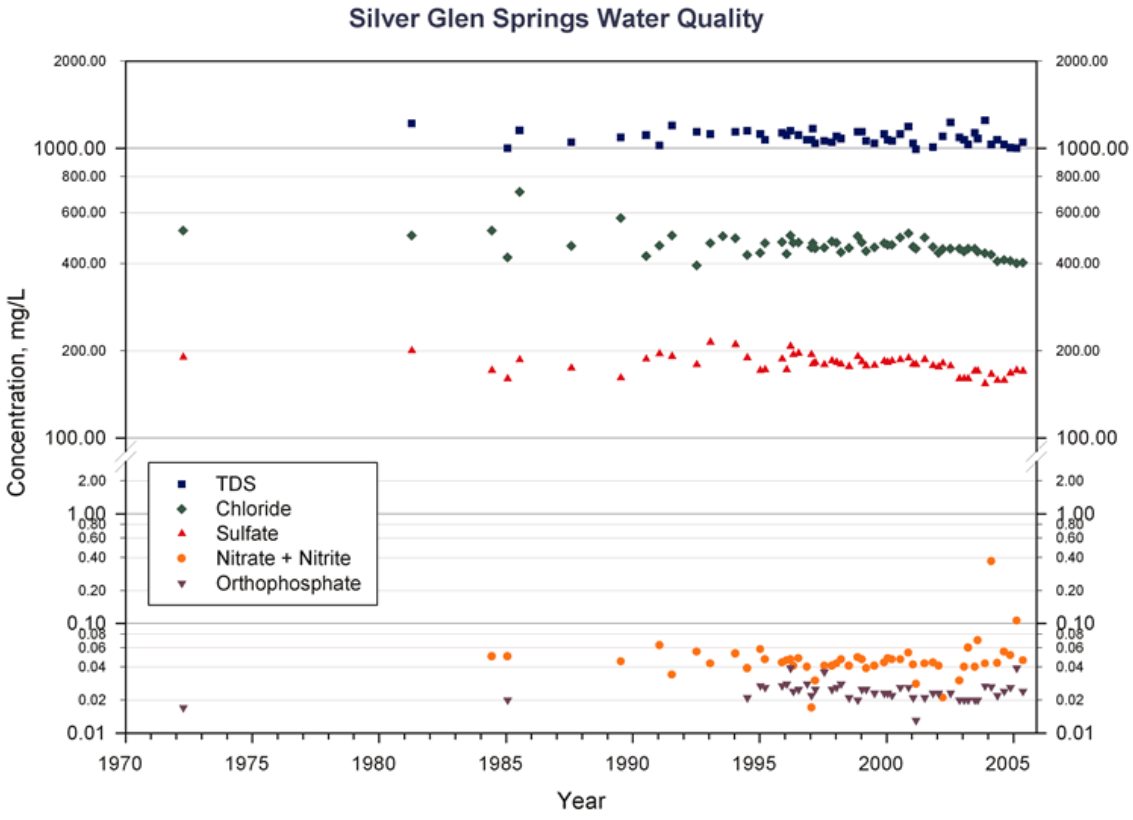


FIGURE 8
Silver Glen Springs water quality values by time and parameter (SJRWMD 2008a).

Field parameters were measured over both of the spring vents, as well as in the spring run to the confluence of Lake George via a boat on July 29, 2008 (**Figure 9**). Water discharging from the spring vents was slightly different (**Figures 10** and **11**), and overall had elevated conductivity (~ 1,900 µS/cm), lower dissolved oxygen values (~ 30 % or 2.70 mg/L), and slightly alkaline pH. The spring pool water had good clarity and a very appealing blue apparent color, likely enhanced by the predominance of white quartz sands. In the spring run, temperature increased slightly, conductivity declined slightly, and dissolved oxygen concentrations increased to over 70 % or 6.0 mg/L, with corresponding pH increases (**Figure 12**).

Downstream increases in dissolved oxygen (DO) were evident in the Silver Glen ecosystem and afford the opportunity to estimate ecosystem metabolism based on these changes (**Figure 12**). During our reconnaissance, average DO concentrations at the spring vent were roughly 3 mg/L and increased to approximately 6 mg/L within 2,000 feet downstream. These values were measured near midday in full sunlight summer conditions, still higher downstream DO concentrations are likely to be observed between 16:00 to 18:00 hours on days without cloud cover.

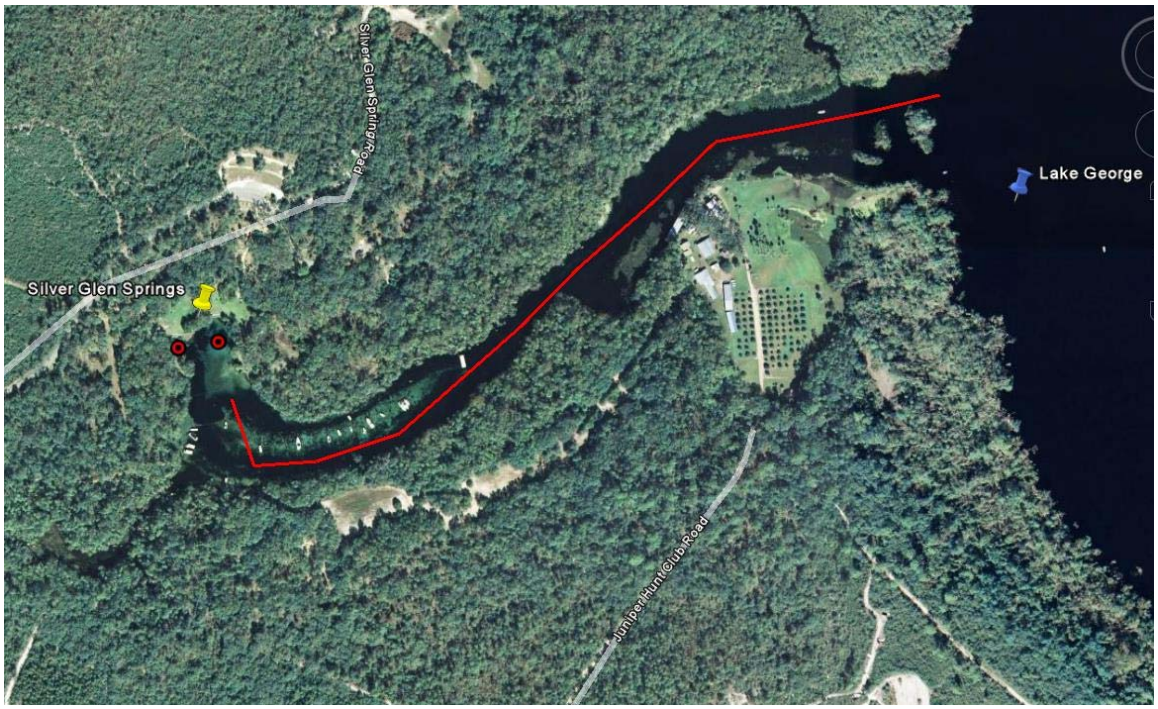


FIGURE 9
Image of Silver Glen Springs showing the location of sampled spring vents (red icons) and the sampling path (red line) taken on July 29, 2008.

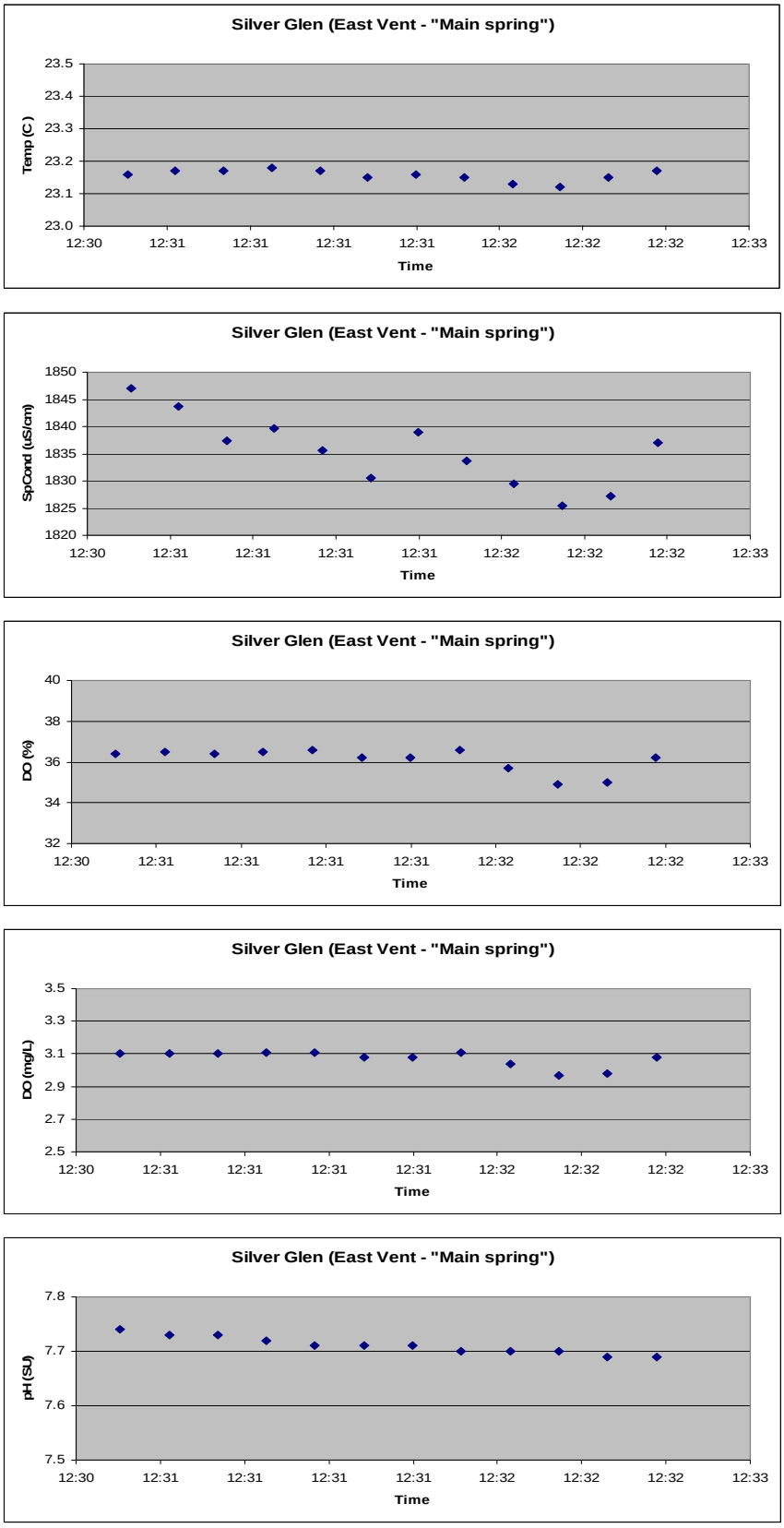


FIGURE 10
Measured field parameters from Silver Glen Springs east vent ("Main spring") on July 29, 2008.

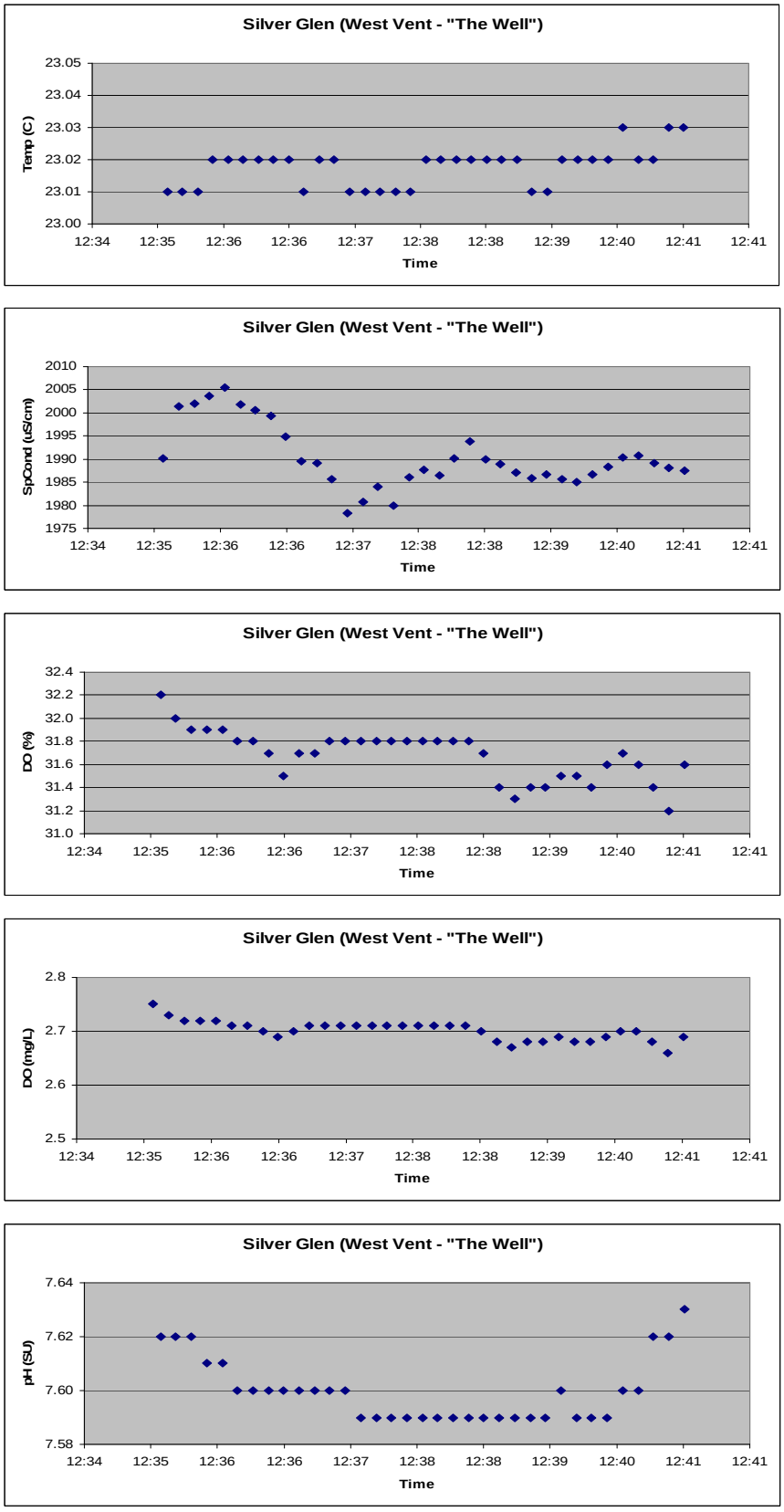
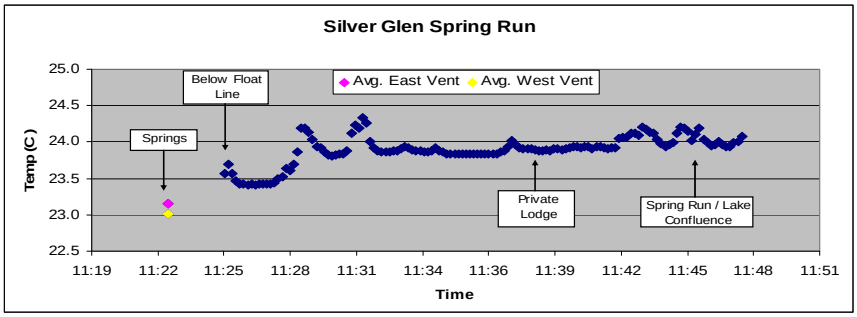
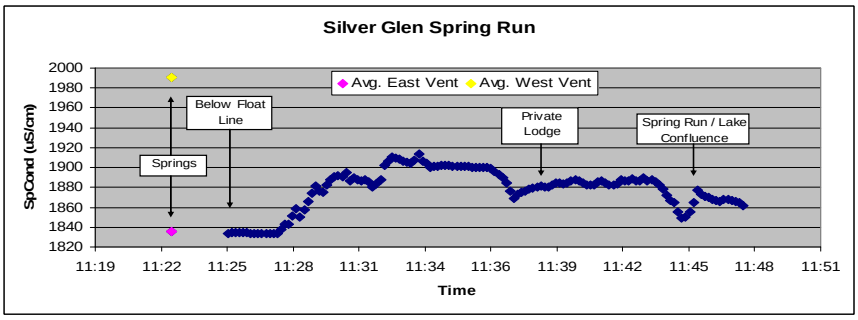
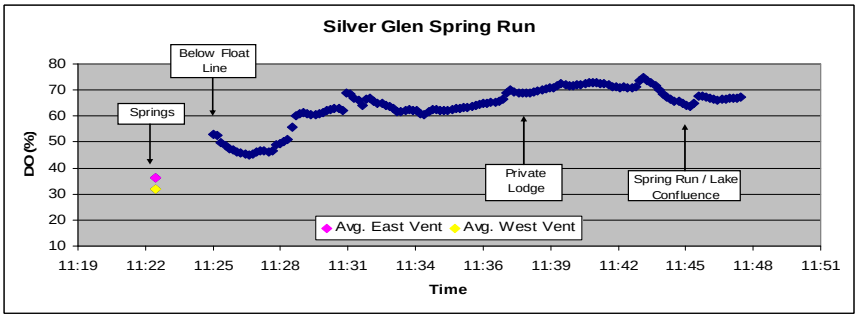
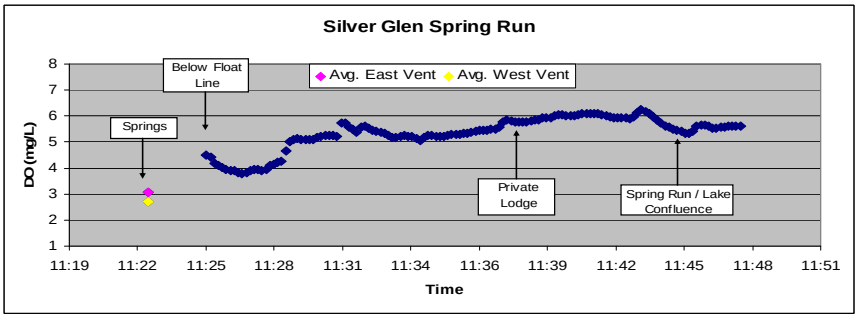


FIGURE 11
Measured field parameters from Silver Glen Springs west vent ("The Well") on July 29, 2008.









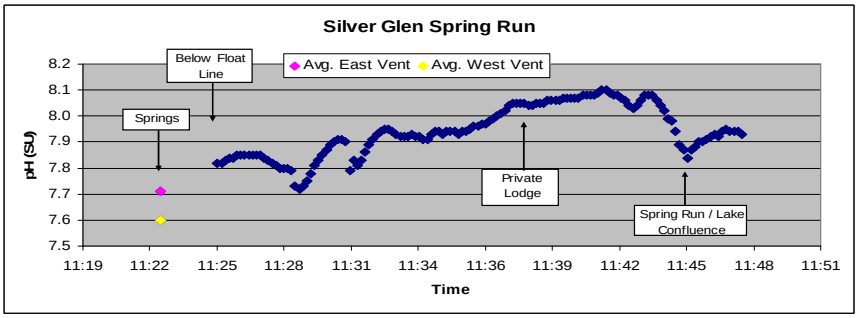


FIGURE 12
Measured field parameters from Silver Glen Springs pool and run on July 29, 2008.

Biological

Vegetation

During a site visit on July 29, 2008 the submersed aquatic vegetation within the Silver Glen spring ecosystem was a mix of filamentous algae and tape grass (*Vallisneria americana*). In areas surrounding the "The Well" vent, plants cover the substrate and grow to the surface. In the main pool and spring run, maximum submersed aquatic vegetation was located in deeper areas were swimmers and boats are presumably not concentrated.

The aquatic vegetation of Silver Glen Springs in 1992 was reported by Woodruff (1993), who noted that hydrilla (*Hydrilla verticillata*) was the dominant submersed plant, while tape grass and southern naiad (*Najas guadalupensis*) were also present.

The most complete investigation into the submersed aquatic vegetation (SAV) of Silver Glen Springs was conducted by Pandion Systems, Inc. (2003); which included a baseline vegetation survey, vegetation re-growth research, estimating the impacts of recreation on SAV, and developing management recommendations. Findings from the January to May 2003 sampling estimated that SAV covered 31%, or 2.7 ha (6.7 ac) of the 8.85 ha (21.88 ac) Silver Glen Spring and Run. SAV species observed included tape grass, water milfoils (*Myriophyllum sp*.), hydrilla, coontail (*Ceratophyllum demersum*), and strap-leaf sagittaria (*Sagittaria kurziana*) (**Figure 13**). Of particular interest in this spring was the presence of non-indigenous hydrilla due to its potential to colonize aquatic habitats. Hydrilla was present in 20.6% (1.8 ha or 4.5 ac) of the run and was noted as the dominant species in 5.2% (0.45 ha or 1.1 ac) of the run (**Figure 14**). Other undesirable aquatic vegetation included benthic filamentous algae which were dominant in 6.8%

(0.61 ha or 1.5 ac) of the run. In areas where algae were particularly abundant, algal mats were sometimes more than 0.61 m (2 ft) thick (Pandion Systems, Inc. 2003).

As part of a multi-spring survey of macroalgae, the pool of Silver Glen Springs was sampled in March 26 and October 30, 2003 for SAV (Stevenson *et al.* 2007). Vascular plants were estimated to cover 27.2% of the pool area during both events and were composed of 22% tape grass, 2.5% hydrilla, 2.5% strap-leaf sagittaria, 2% *Riccia sp*. (an aquatic liverwort), and 1% southern naiad. Macroalgae coverage was 82.7 % with an average thickness of 39.1 cm (15.4 in) during March and coverage was 74.1% with an average thickness of 30.4 cm (12 in) during October (Stevenson *et al.* 2007). Combining both sampling events, the Silver Glen Springs pool macroalgae community was made up of 78.4% *Lyngbya sp.*, 1.9% *Oscillatoria sp.*, and 0.6% *Spirogyra sp.* (Stevenson *et al.* 2007).

Detailed examination of the macroalgal and periphyton communities of Silver Glen Springs was conducted over four quarterly sampling events in 2007 (GreenWater Laboratories 2008). These researchers noted the dominant submersed vascular plant was tape grass, but other species included southern naiad, hydrilla, and horned pondweed (*Zannichellia palustris*), as well as the macroalgae muskgrass (*Chara sp.*). Thick mats (>20cm) of *Lyngbya wollei* were present at the majority of sampled transects as were two other filamentous cyanobacteria, *Oscillatoria sp*. and *Phormidium sp*. The most common green macroalgae were *Oedogonium sp*. and *Cladophora glomerata* and large chain-forming diatoms *Terpsinoe musica* and *Pleurosira laevis* were observed as well (GreenWater Laboratories 2008). Periphyton samples were dominated by cyanobacteria and diatoms in terms of cell numbers and biovolume in all sampling quarters.

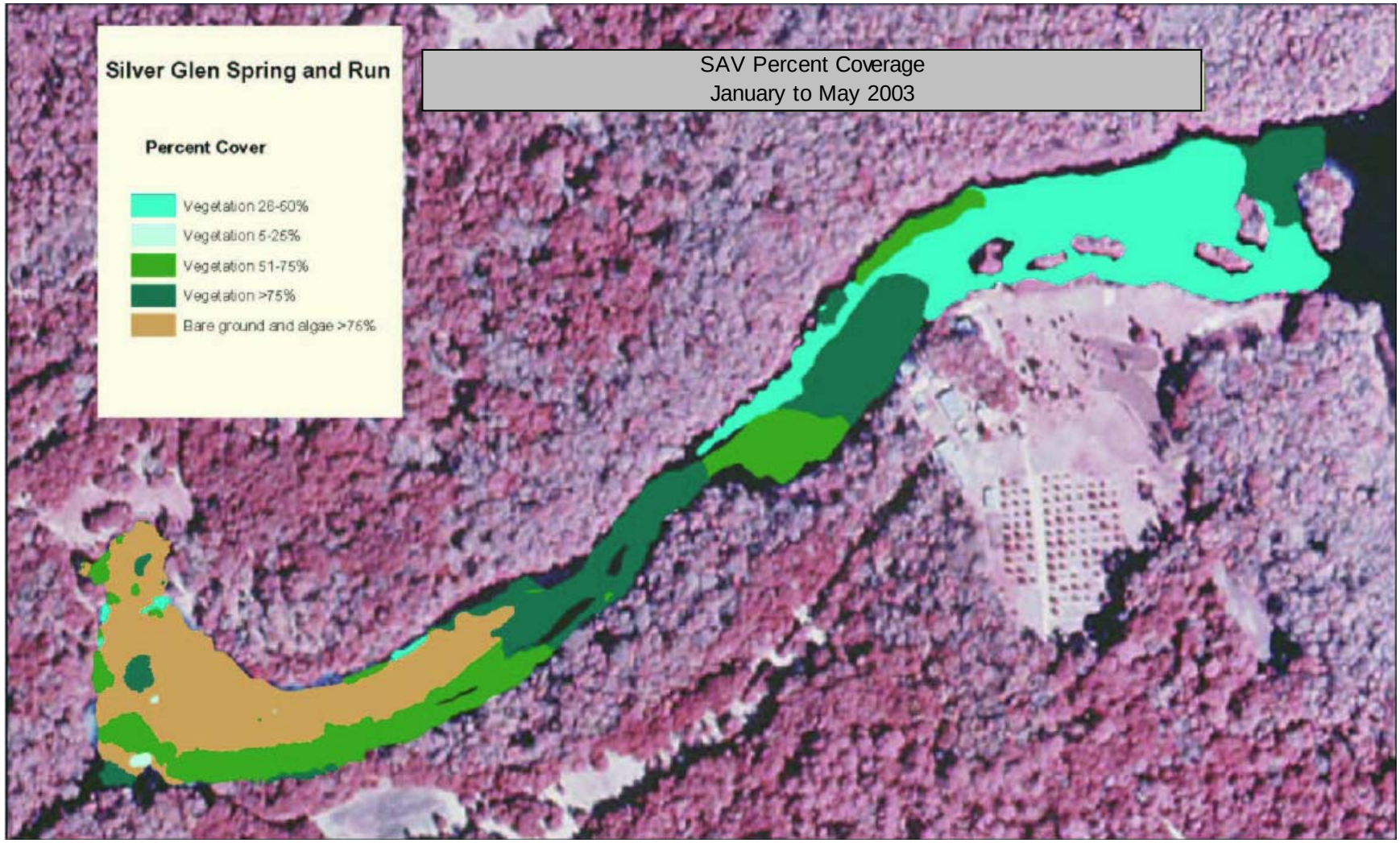


FIGURE 13
Submersed aquatic vegetation (SAV) coverage in Silver Glen Springs during January to May 2003 (from Pandion Systems, Inc. 2003).

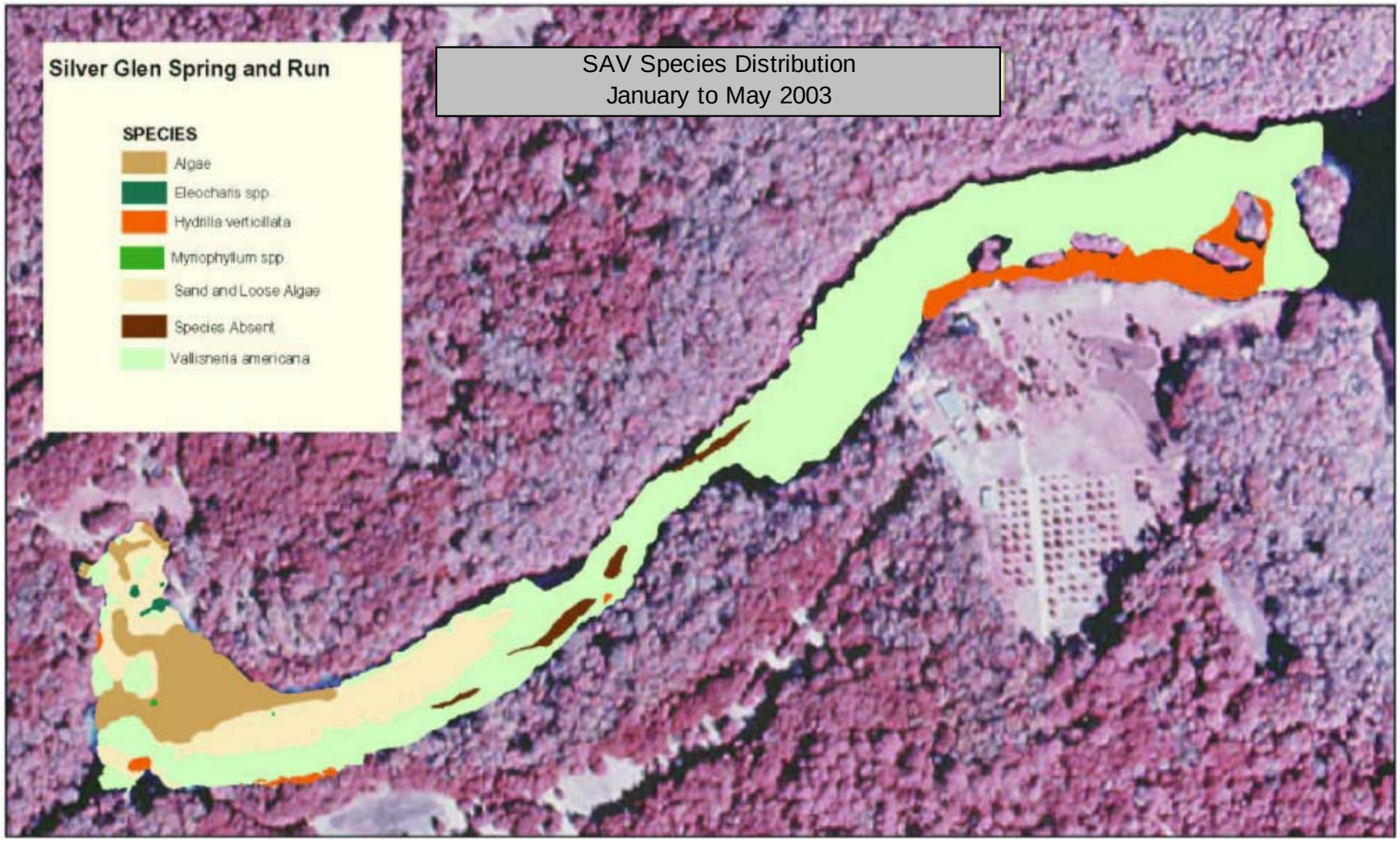


FIGURE 14
Submersed aquatic vegetation (SAV) species distribution in Silver Glen Springs during January to May 2003 (from Pandion Systems, Inc. 2003).

Macroinvertebrates

The benthic macroinvertebrate community of Silver Glen Springs is assessed as part of the FDEP EcoSummary sampling. The monitoring site is a 100 meter reach located in the spring run approximately 100 meters downstream of the headspring. A summary of these sampling events occurring from 2002 through 2007 reveals that the habitat assessment ranges from suboptimal to optimal, the total number of invertebrate taxa ranged from 13 to 32, and the number of sensitive invertebrate taxa never exceeded one (**Figure 15**, FDEP 2008). Stream condition index (SCI) values are also calculated as part of the EcoSummary sampling. Prior to June 2004, a SCI value greater than 21 indicated healthy conditions, following this date, the SCI was re-calibrated and values greater than 34 indicated healthy invertebrate communities. Of eight sampling events only one (or 13%) SCI score was in the healthy range for Silver Glen Springs (**Figure 15**, FDEP 2008).

Based on a literature review of museum records by Shelton (2005), two rare snails have been collected from Silver Glen Springs; *Aphaostracon pycnum* a species endemic to Silver Glen Springs and Alexander Springs, and *Floridobia floridana* a species endemic to the St. Johns River basin.

The crustaceans, mollusks, and benthic invertebrates of Silver Glen Springs were extensively surveyed by Woodruff (1993). Crustacean species collected included the amphipods (scuds) *Crangonyx sp.*, *Gammarus sp.*, and *Hyalella sp.*; isopods (sowbugs) included *Cyathura polita* and *Cassidinidea ocalis*; decapods (crayfish and shrimp) included *Procambarus sp*. and *Palaemonetes paludosus*; and a single mysid (opossum shrimps) *Taphromysis bowmani*. The large freshwater shrimp, *Macrobrachium carcinus*, has anecdotally been reported from Silver Glen Springs as well.

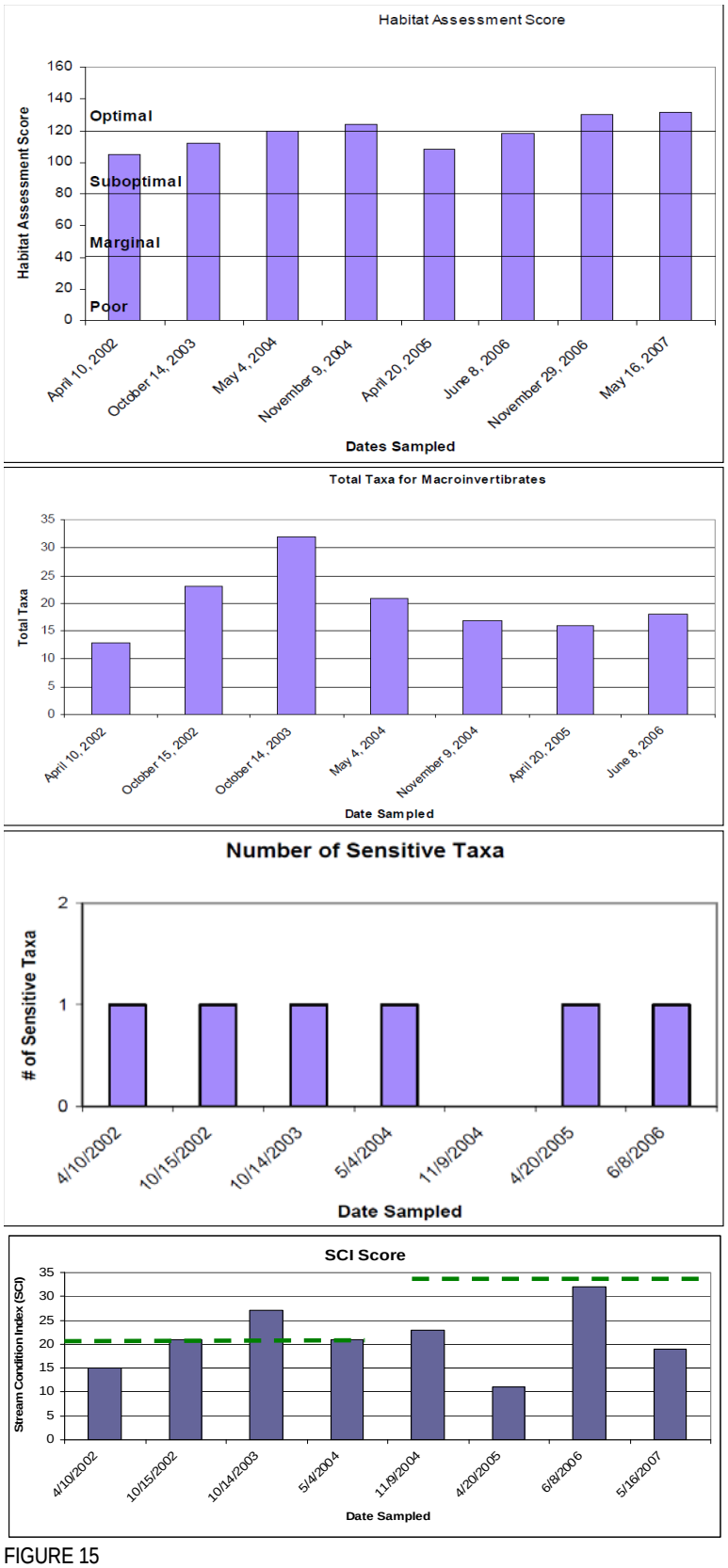


FIGURE 15
Time series of habitat assessment, total number of aquatic macroinvertebrate taxa, number of sensitive aquatic macroinvertebrate taxa, and SCI values for Silver Glen Springs (from FDEP 2008).

Five types of gastropods were documented at Silver Glen Springs by Woodruff (1993). These include members of the Hydrobiidae family, apple snail (*Pomacea paludosa*), goblin elimia (*Elimia vanhyningiana)*, *Gyraulus parvus*, and *Planorbella sp*. Woodruff (1993) also made ten benthic core collections, five from non-vegetated substrate and five from vegetated substrate in Silver Glen Springs. In the non-vegetated substrate oligochaetes (segmented worms) made up 36% of the invertebrates, followed by diptera (fly) larvae (34%), amphipods (14%), isopods (12%), and Hirudinea (leeches) at 4%. In the vegetated substrate, the composition of invertebrates was dominated by amphipods (74%), followed by oligochaetes (17%), diptera (5%), Odonata (dragonfly) and Hirudinea both at 4%. The difference between substrate type was significantly different as well (Woodruff 1993).

Macro fauna

Fish

A variety of fish were observed in the spring pool and run during July 29, 2008, including largemouth bass, several sunfish species, striped mullet, and white catfish. Of particular note were the dozens of fish congregating amongst both spring vents; composed primarily of striped bass (*Morone saxatilis*), many approaching 3 feet in length. Although these anadromous fish spawn in freshwater, they are believed to be attracted to these springs due their cooler water temperatures (compared to Lake George/St. Johns River) and perhaps their elevated conductivity.

The fish community of Silver Glen Springs was assessed through seining and examination of Florida Museum of Natural History (FLMNH) records, with a resulting 19 total species recorded. Five species present in FLMNH records but not collected by Woodruff (1993) included warmouth (*Lepomis gulosus*), golden shiner (*Notemigonus*

crysoleucas), coastal shiner (*Notropis petersoni*), golden topminnow (*Fundulus chrysotus*), and marsh killifish (*Fundulus confluentus*). The fourteen species that were collected by Woodruff (1993) include blue tilapia (*Oreochromis aureus*), Okefenokee pygmy sunfish (*Elassoma okefenokee*), bluegill (*Lepomis macrochirus*), redear (*L. microlophus*), largemouth bass (*Micropterus salmoides*), redeye chub (*Notropis harperi*), bluefin killifish (*Lucania goodei*), rainwater killifish (*Lucania parva*), striped bass (Morone saxatilis), hybrid Sunshine bass (*Morone chrysops x saxatilis*), striped mullet (*Mugil cephalus*), mosquitofish (*Gambusia holbrooki*), least killifish (*Heterandria formosa*), and sailfin molly (*Poecilia latipinna*). Freshwater eels (*Anguilla anguilla*) are anecdotally reported for this system.

A listing of the fish observed in 2003 (Pandion Systems, Inc.) includes schools of striped mullet (*Mugil cephalus*), Crevalle jack (*Caranx hippos*), and ladyfish (*Elops saurus*). The non-indigenous sailfin catfish (*Pterygoplichthys multiradiatus*) was observed; as were blue tilapia, the latter in schools of hundreds of individuals. Florida gar (*Lepisosteus platyrhincus*), largemouth bass, striped bass (*Morone saxatilis*), three species of sunfish (*Lepomis spp.*), killifish (*Fundulus spp.*), mosquitofish, and shiners (*Notropis sp*p.) were seen in the spring pool and run as well (Pandion systems, Inc.). Silver Glen Springs connects to Lake George and the St. Johns River, a diversity of marine species may be expected to utilize this spring system, including Atlantic stingray (*Dasyatis sabina*).

Reptiles

Aquatic turtles utilizing Silver Glen Springs include redbelly turtle (*Pseudemys nelsoni*), peninsula cooter (*Pseudemys floridana peninsularis*), common musk turtle (*Sternotherus odoratus*), and Florida softshell (*Apalone ferox*). American alligators

(*Alligator mississippiensis*) ranging in size from juveniles to six foot individuals utilize the spring run as well (Pandion Systems, Inc. 2003).

Birds

Notable bird observations include great blue heron (*Ardea herodias*), great egret (*Ardea alba*), little blue heron (*Egretta caerulea*), green heron (*Butorides striatus*), double-crested cormorant (*Phalacrocorax auritus*), American anhinga (*Anhinga anhinga*), mallard duck (*Anas platyrhynchos*), purple gallinule (*Porphyrula martinica*), osprey (*Pandion haliaetus*), bald eagle (*Haliaeetus leucocephalus*), Coopers hawk (*Accipiter cooperii*), red shouldered hawk (*Buteo lineatus*), black vulture (*Coragyps atratus*) and turkey vulture (*Cathartes aura*) (Pandion Systems, Inc. 2003).

Mammals

Mammal observations included river otter (*Lutra Canadensis*), wild boar (*Sus scrofa*), grey fox (*Urocyon cinereoargenteus*), and eleven manatees (*Trichechus manatus*) were seen using the run during January to March 2003 (Pandion Systems, Inc. 2003).

Manatees

While manatees are known to utilize Silver Glen Springs, particularly during winter months as a thermal refuge, the springs appear to be used by low numbers of manatees. The maximum one day count of seven manatees was documented from January through March 2003 (Pandion Systems, Inc. 2003). Other researchers which have documented manatee usage in Silver Glen Springs include Hartman (1974) who suggested that the spring was used by two to three animals during winter months; and Beeler and O'Shea (1988) who noted one to five manatees in early and late winter. The suitability of this spring system for manatees has been investigated by Taylor (2006) who identified

accessibility issues including a spring run with shallow portions and large numbers of boats. Fortunately, peak recreational usage of Silver Glen Springs occurs during summer months and peak manatee usage occurs during winter months, factors which reduce the potential for conflict.

Ecosystem Functions

Based on field parameters (temperature, conductance, dissolved oxygen, and pH) measured in the spring pool and spring run during the reconnaissance trip of July 29, 2008, Silver Glen Springs are suitable for measuring ecosystem metabolism based on changes in dissolved oxygen. Complicating factors may include surface water inputs to the spring run from wetlands to the west and potential backwater effects from Lake George.

Human-Use Attendance and Activities

Research into recreational usage and the opinions of recreationalists was conducted by Denny and Stein (2001) for the purpose of assessing Silver Glen Springs as a possible candidate for Public Private Ventures (PPVs) by the USDA Forest Service. The goal of PPVs is to combine public land with private sector capital and initiative to improve public recreational experiences. Concessions are currently operated by private parties at Silver Glen Springs and USFS records suggest that approximately 30 thousand people visit this spring annually (**Figure 16).**

Silver Glen is a popular destination, particularly during summer months (**Figure 16)**. Detailed human recreation observations have been made by Pandion Systems, Inc. (2003) with the main types of recreation observed being swimming, fishing and boating. Swimmers utilize both the spring pool and run. Fishing takes place in the spring run

from boats with rod and reel, bow hunting, and cast net gear. A large range of powerboat types and sizes utilize the spring run; including houseboats approaching 60 feet in length which may stay moored in the run for several days to months. Boaters utilized the run every day, but usage levels were dependent on the time of year, time of week, and weather; with peak boating occurring on summer holiday weekends (*e.g.* Memorial Day, Fourth of July, and Labor Day) when approximately 200 boats could be found in the run (**Figure 17**, Pandion Systems, Inc. 2003).

The research by Pandion Systems, Inc. (2003) found that much of Silver Glen Springs Run shows undesirable impacts from recreation (**Figure 18**). In most of the run area the eelgrass exhibited some type of mechanical damage due to contact from boat propellers. Boat anchors caused disturbance to the sediment and damage to the submersed vegetation in the form of drag marks or pits. These observations likely explain the open sand area in the western part of the run where boaters preferred to anchor. Although swimming generally causes little impact on vegetation, wading can result in the trampling of native grasses, and most of the area near the spring pool was devoid of vegetation (Pandion Systems, Inc. 2003).

Minimum Flow and Levels

Silver Glen Spring has been placed on the St. Johns River Water Management District MFL priority list for 2011 (SJRWMD 2008b). As of this report, an MFL has not been adopted for this spring.

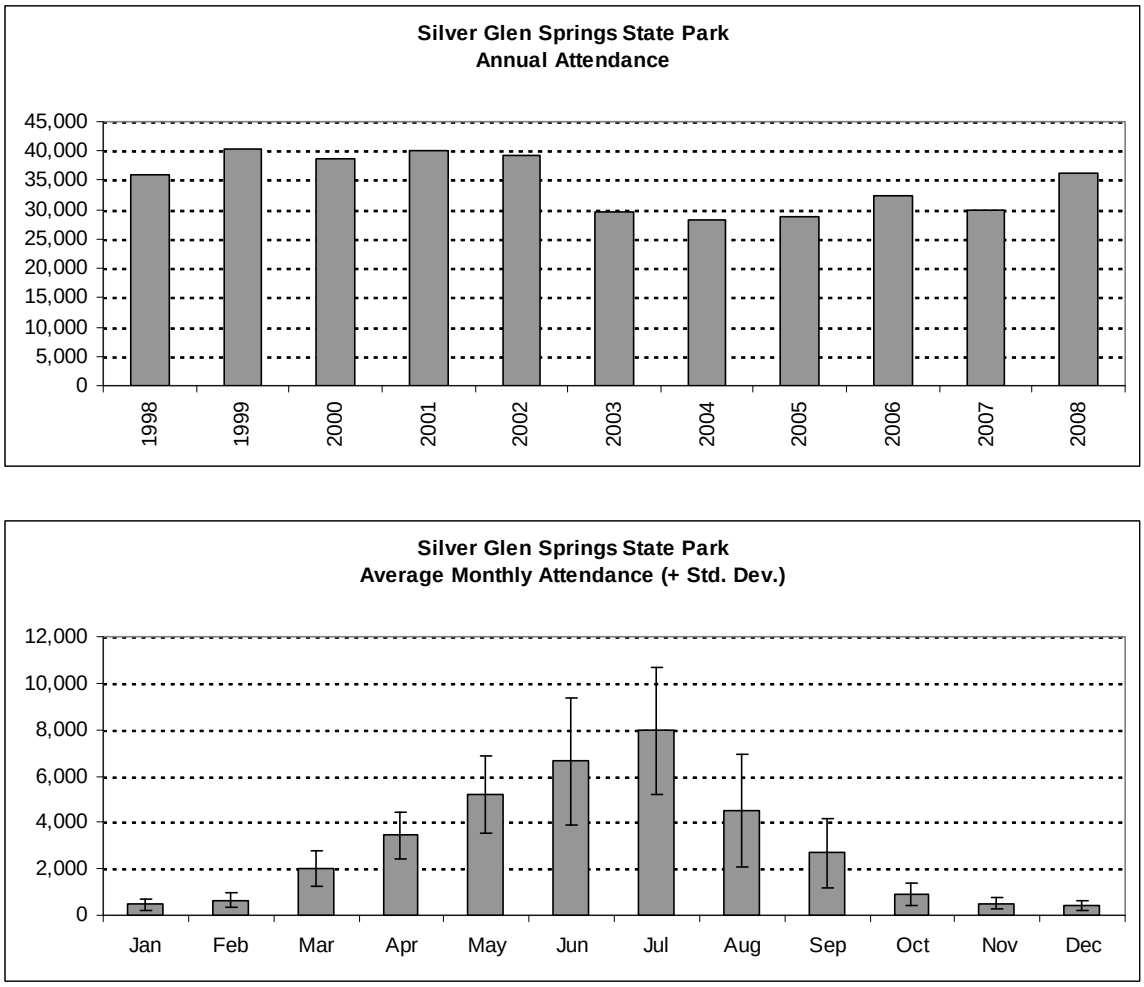


FIGURE 16
Human use statistics for Silver Glen Springs (data from US Forest Service).

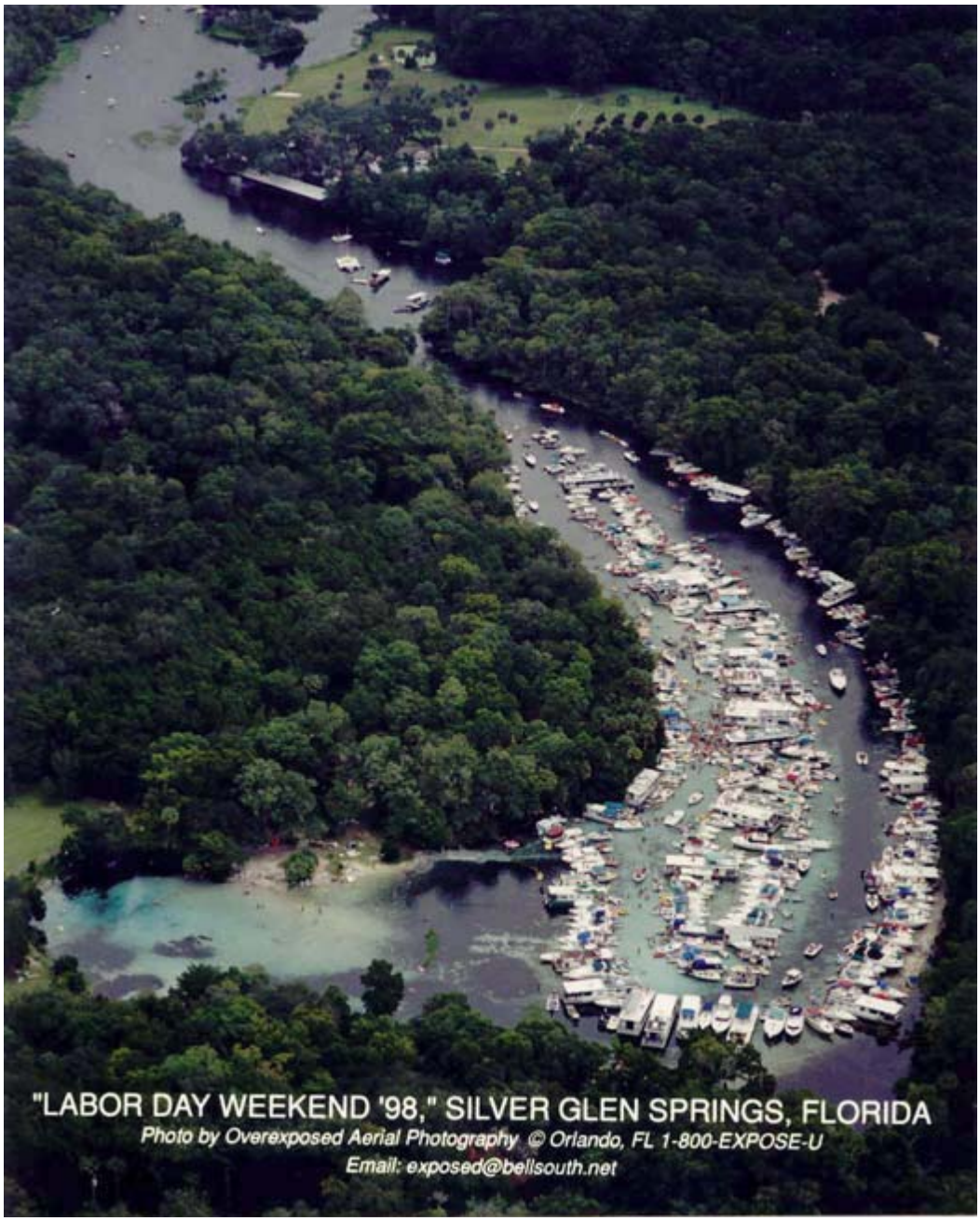


FIGURE 16
Aerial photo of Silver Glen Springs during Labor Day 1998 (from Pandion Systems, Inc. 2003).

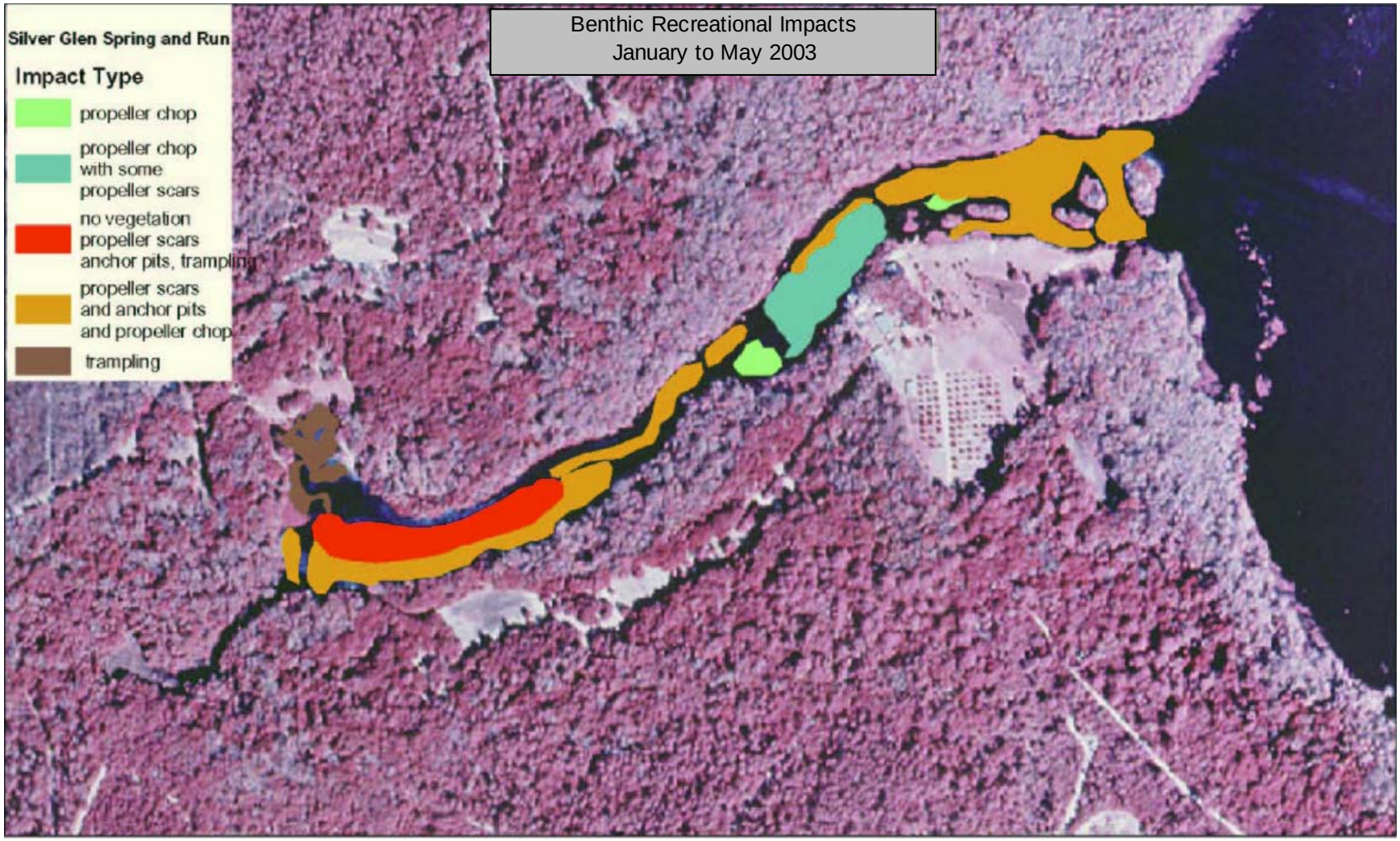


FIGURE 17
The types and location of recreational disturbance to the benthos of Silver Glen Springs (from Pandion Systems, Inc. 2003).

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