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Horse Creek Stewardship Program
2005 Annual Report

Prepared for:

Mosaic

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EXECUTIVE SUMMARY

INTRODUCTION

This is the third annual report summarizing the status of the Horse Creek Stewardship Program (HCSP). After a series of legal challenges to the required permits, the Mosaic Company (Mosaic) and the Peace River Manasota Regional Water Supply Authority (PRMRWSA) executed a settlement agreement to ensure that mining would not have negative impacts on Horse Creek, a major tributary of the Peace River, as a result of proposed mining activities by Mosaic in eastern Manatee and western Hardee Counties, Florida. A principal component of the agreement was the creation of the HCSP. The overall goals of the HCSP are to ensure that Mosaic's mining activities do not interfere with the ability of the PRMRWSA to withdraw water from the Peace River for potable use nor adversely affect Horse Creek, the Peace River, or Charlotte Harbor. The program, which is funded and managed by Mosaic, has two purposes: 1) in order to detect any adverse conditions or significant trends that may occur as a result of mining, the HCSP provides a protocol for the collection of information on the physical, chemical, and biological characteristics of Horse Creek during Mosaic's mining activities in the watershed, and 2) if detrimental changes or trends caused by Mosaic's activities are found, the HCSP provides mechanisms for corrective action. The program is limited to the investigation of the potential impact of Mosaic mining activities on Horse Creek Basin and is not intended to investigate the potential impacts of other land uses or mining activities by other entities.

This program has three basic components: 1) monitoring and reporting on stream quality, 2) investigating adverse conditions or significant trends that are identified through monitoring, and 3) implementing corrective action for adverse changes to Horse Creek caused by Mosaic's mining activities. The HCSP is unique in that it does not rely solely upon the exceedance of a standard or threshold to bring about further investigation and corrective action, where appropriate. The presence of a significant temporal trend alone will be sufficient to initiate such steps. This program offers additional protection to Horse Creek; this protection is not usually present in the vast majority of regulatory scenarios.

Monitoring for the HCSP began in April 2003, and this report, which is the third of a series of Annual Reports, presents the results of the first three years of monitoring, including historical data from the last decade. Approximately 12,000 acres of land in the Upper Horse Creek Basin had been mined at the time the HCSP was initiated; about 10,000 acres are located upstream of all HCSP monitoring stations on land controlled by Mosaic, with the remaining mined area on other parties' lands lying upstream of all but the northernmost monitoring location. From 2003 to 2005, a total of 1571 acres of land located upstream of the northernmost Horse Creek monitoring location was mined by Mosaic.

RECENT MINING AND RECLAMATION

About 590 acres were mined in the Horse Creek Basin at the Mosaic Fort Green Mine in 2005. An average of 50 acres was mined each month. Some additional phosphate mining may or may not have been conducted by other companies in the Horse Creek drainage basin in 2005, but Mosaic is not aware of the extent or timing of that mining.

There are two clay settling areas in the Horse Creek Basin at the Fort Green Mine. The FGH-3 clay settling area, completed in 1999, is located predominantly in Sections 5, 8, and 9, T33S, R23E. The FGH-4 clay settling area, completed in 2001, is located predominantly in Section 31, T33S, R23E. Both settling areas have real-time monitoring of the liquid level in the ponds, with monitoring level data relayed to the PRMRWSA.

About 206 acres were reclaimed through revegetation in 2005 at the Fort Green Mine within the Horse Creek Basin. Earthwork, which included spreading of overburden onto land backfilled with tailings and final contouring of the ground surface, was completed on those 206 acres.

MONITORING PROGRAM COMPONENTS

Four locations on Horse Creek were monitored for physical, chemical, and biological parameters; two of these sites are also long-term US Geological Survey (USGS) gauging stations. Water quantity data were collected continuously from the USGS gauging stations. Rainfall data were collected daily from one USGS gauging station and three Mosaic rain gauges located in the Horse Creek Basin. Water quality data were collected during monthly sampling events, continuously from one Horse Creek location, and during biological sampling events. Biological (fish and benthic macroinvertebrates) sampling events were generally conducted three times each year, but a series of hurricanes affecting southwest Florida in Summer 2004 made biological sampling impossible during summer and early fall of 2004.

WATER QUANTITY

For 2005, temporal patterns of average daily stream flow and stage were similar across all stations, with the majority of high flows and stages occurring during the rainy season (June through September), but with some additional heavy spring rains. A similar pattern during the rainy season was observed for Mosaic's National Pollutant Discharge Elimination System (NPDES)-permitted discharges upstream of northernmost monitoring location. As indicated by the 2003 to 2005 rainfall data, an unusually high rainfall event occurred in late June 2003 and three hurricanes dropped large amounts of rain in August, September, and October 2004. The effects of these events were apparent in all the water quantity data, and negatively affected the November 2004 biological sampling effort.

WATER QUALITY

Reported water quality constituents were compared with HCSP trigger levels. Water quality parameters were almost always well within the desirable ranges relative to trigger levels, with trigger levels exceeded for five parameters, and four of these parameters more than once in 2005. Dissolved oxygen concentrations consistently exceeded the trigger level (was below 5 mg/l) at HCSW-2, the station located on Horse Creek at County Road 663A/Goose Pond Road. HCSW-2 is located downstream of a segment of the creek known as Horse Creek Prairie, an area of very slow-moving water with chronic low dissolved oxygen levels (Durbin and Raymond 2006). Dissolved oxygen exceedances at other stations are limited to periods of high temperatures or rainfall, as were other exceedances (chlorophyll *a* and pH). Fatty acids were higher than the trigger level at HCSW-2 in March and April and at HCSW-3 in February. Several parameters (e.g., dissolved ions, oxidized nitrogen and phosphate) were consistently higher at the lower end of the study area than in the upper segment; this is generally attributed to contributions of groundwater entering the stream as runoff or seepage from irrigated agricultural areas, although direct documentation or characterization of agricultural effects is beyond the scope of the HCSP. Dissolved iron was consistently higher than the trigger level set at HCSW-4, but this trigger level has been recognized by all parties as being too low for the historical levels observed at that station.

BENTHIC MACROINVERTEBRATES

Benthic invertebrate habitat scores were "Optimal" to "Sub-optimal" and SCI scores were "Fair" or "Poor" at all stations from 2003 to 2005; these scores are typical of southwestern Florida streams, including those used to develop the Habitat Assessment and SCI indices. Species diversity in Horse Creek exhibits both seasonal and year-to-year variation. Seasonally, diversity is often lower in the summer wet season that during the dry season. Over the three years of the HCSP study, species diversity at HCSW-1 has remained relatively constant when similar seasons are compared. At HCSW-2 and HCSW-3, diversity was slightly higher in 2005 than in 2003 or 2004, but HCSW-4 showed the opposite pattern. The effects of Hurricane Charley, which primarily hit stations HCSW-2 to HCSW-4 in 2004, do not appear to have affected the long-term species diversity or SCI scores in Horse Creek.

FISH

Thirty-seven species of fish have been collected from 2003 to 2005. We expect to add very few more species during future monitoring events, because the species accumulation curves have begun to level off. Additional native species almost certainly occur in Horse Creek but were not collected from 2003 to 2005. Over 30 species of introduced fish have established reproducing populations in Florida, so we expect to continue to collect additional introduced species in Horse Creek during future monitoring events as new introductions occur and as introduced species continue to expand their ranges in Florida. Fish species richness and diversity were higher in the more downstream locations in 2003, likely because of their proximity to the more species-rich Peace River. After the hurricanes in late 2004, however, richness and diversity were consistently higher at HCSW-1, which was relatively unaffected by the hurricanes. Fish communities were fairly similar between stations and between dates at each station. Patterns in fish species richness, diversity, and abundance seem more tied to the effects of Hurricane Charley in 2004 than to any possible mining effects, considering that in 2005 the station closest to the mining area had the highest species diversity.

CONCLUSIONS

Although this report covers only the third year of an ongoing monitoring program, some general conclusions can be drawn. Expected relationships between rainfall, runoff and stream flow were observed in the 2003 to 2005 water quantity data. Water quality parameters were almost always well within the desirable range relative to trigger levels. Program trigger levels were exceeded for five parameters in 2005, but only four parameters more than once. The benthic macroinvertebrate and fish communities found in Horse Creek in 2003 to 2005 were typical of those found in a Southwest Florida stream, and no impacts from mining were apparent, but very clear and pronounced effects were apparent from the 2004 hurricanes.

RECOMMENDATIONS

Mosaic and the PRMRWSA should investigate the availability and cost of LIDAR or Doppler radar rainfall electronic data for the Horse Creek Basin because of its potential to more accurately represent widespread rainfall patterns.

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1.0 INTRODUCTION

As a result of proposed mining operations by The Mosaic Company (Mosaic) in eastern Manatee and western Hardee Counties, Florida, and a series of legal challenges to the permits required for such mining, Mosaic and the Peace River Manasota Regional Water Supply Authority (PRMRWSA) executed a settlement agreement structured to ensure that mining would not have negative impacts on Horse Creek, a major tributary of the Peace River. A principal component of that agreement was the creation of the Horse Creek Stewardship Program (HCSP), which is funded and managed by Mosaic. The program document, as referenced in the settlement agreement, is provided as Appendix A.

There are two purposes for the HCSP. First, it provides a protocol for the collection of information on the physical, chemical, and biological characteristics of Horse Creek during Mosaic's mining activities in the watershed in order to detect any adverse conditions or significant trends that may occur as a result of mining. Second, it provides mechanisms for corrective action with regard to detrimental changes or trends caused by Mosaic's activities, if any are found. The program is limited to the investigation of the potential impact of Mosaic mining activities on Horse Creek Basin and is not intended to investigate the potential impacts of other land uses or mining activities by other entities.

The overall goals of the program are to ensure that Mosaic's mining activities do not interfere with the ability of the PRMRWSA to withdraw water from the Peace River for potable use nor adversely affect Horse Creek, the Peace River, or Charlotte Harbor. There are three basic components to the HCSP: 1) monitoring and reporting on stream quality, 2) investigating adverse conditions or significant trends identified through monitoring, and 3) implementing corrective action for adverse stream quality changes attributable to Mosaic's activities. An important aspect of this program is that it does not rely solely upon the exceedence of a standard or threshold to bring about further investigation and, where appropriate, corrective action. The presence of a significant temporal trend alone is sufficient to initiate such steps. This protection mechanism is not present in the vast majority of regulatory scenarios.

In brief, the HCSP provides for the following data collection:

- Continuous recording (via USGS facilities) of stage and discharge at two locations on the main stem of Horse Creek
- Daily recording of rainfall via Mosaic and USGS rain gauges in the upper Horse Creek basin
- Continuous recording of temperature, dissolved oxygen, conductivity, turbidity and pH at the Horse Creek station nearest to Mosaic's active mining operations
- Monthly water quality monitoring of 21 parameters at four stations on the main stem of Horse Creek
- Sampling of fish, benthic macroinvertebrates and field water quality parameters (temperature, dissolved oxygen, conductivity, turbidity and pH) three times annually at four stations on the main stem of Horse Creek

HCSP monitoring began in April 2003. At the time the HCSP was initiated, some 12,000 acres of land in the Upper Horse Creek Basin had been mined, about 10,000 acres of which lies upstream of all HCSP monitoring stations on land controlled by Mosaic, with the remaining mined area on other parties' lands lying upstream of all but the northernmost monitoring location. In 2005, a total of 590 acres was mined in the Horse Creek Basin upstream of the northernmost monitoring location (Figure 1). Water quantity data are collected essentially continuously, water quality data are collected monthly, and biological data (fish and benthic macroinvertebrates) are collected three times annually (March - April, July - September and October - December). Specific months when biological sampling occurs may change from year to year to avoid very low or very high flows which would impede representative sampling.

This report, which is the third of a series of Annual Reports, presents the results of monitoring conducted in 2005. Additionally, water quality monitoring results from 2003 to 2004, the previous years of the HCSP, are also included to allow comparisons between years. Additional sources of data for the last decade have also been included to provide a short historical perspective. A separate report contains a review and summary of all available historical water quality and biological information for Horse Creek (Durbin and Raymond 2006).

2.0 DESCRIPTION OF HORSE CREEK BASIN

The Horse Creek basin is located in five counties of South-Central Florida: Hillsborough, Polk, Manatee, Hardee, and Desoto, with the majority of the watershed spanning portions of western Hardee and DeSoto Counties (Figures 1 and 2). Horse Creek is a major tributary of the Peace River that drains the south-western portion of the Peace River Basin and supplies approximately 15 percent of the surface water runoff to the Peace River (Lewelling 1997).

The basin occupies some 241 square miles, and the length of the channel is approximately 43 miles. Horse Creek has an elongated basin with a north-to-south drainage that is influenced by the general topography of the area. Six sub-basins and five tributaries make up the Horse Creek Basin. West Fork Horse Creek and Brushy Creek, two northern tributaries in the Polk Uplands, are generally straight, at least partially channelized, and have relatively rapid flows (Lewelling 1997). The remaining tributaries, occupying the central to southern Horse Creek Basin, include Buzzard Roost Branch and Brandy Branch. These lower reaches are located in the DeSoto Plains/Gulf Coast Lowlands area and are generally meandering, slower streams. Horse Creek ultimately discharges into the Peace River near Fort Ogden (SWFWMD 2000).

The topography of the Horse Creek basin generally follows the north-to-south drainage flows of the creek. Elevation in the basin ranges from 135 feet in the north to 30 feet in the south near the confluence of Horse Creek and the Peace River. The basin is located in the mid-peninsular physiographic zone of Florida, in three subdivisions: Polk Uplands, DeSoto Plains, and Gulf Coast Lowlands. The Polk Uplands underlie the northern portion of the Horse Creek Basin, where the elevation generally exceeds 100 feet NGVD. In this location, the channel of Horse Creek is generally steep and slightly incised, with swiftly moving water. The central Horse Creek basin is located in the DeSoto Plain. Average elevations in this area range from 30 to 100 feet NGVD. Where Horse Creek enters the Peace River, the Gulf Coast Lowlands range in elevation from about 30 to 40 feet NGVD. The Horse Creek channel in the Desoto Plain and Gulf Coast Lowlands is slower and more sinuous than the northern channel (SWFWMD 2000, Lewelling 1997).

The northern Horse Creek Basin is located in the Polk Uplands, with Pomona-Floridana-Popash soils characterized by nearly level, poorly drained, and very poorly drained sandy soils. Some soils in this association have dark colored subsoil at a depth of less than 30 inches over loamy material, and some are sandy to a depth of 20 - 40 inches and are loamy below. The extreme northern basin of Horse Creek contains isolated areas of the Arents-Hydraquents-Neilhurst soils group, parts of which have been strip-mined for phosphate (Robbins et al. 1984).

The central and southern Horse Creek Basin is located in the DeSoto Plain, which is a very flat, submarine plain probably formed under Pleistocene Wicomico seas, 70 to 100 feet above present sea level (Cowherd et al. 1989). The Smyrna-Myakka-Ona and Smyrna-Myakka-Immokalee soil associations characterize this portion of the Horse Creek Basin with flat, poorly drained soils that are sandy throughout (Lewelling 1997). The soil group Bradenton-Felda-Chobee is also located immediately adjacent to the main channel of Horse Creek, from below State Road 64 to just above the mouth of the creek. These soils are characterized by nearly level, poorly drained and very poorly drained soils that are sandy to a depth of 20 to 40 inches and underlain by loamy material or that are loamy throughout and subject to frequent flooding. The dominant soil groups in the Horse Creek basin are generally poorly drained, reducing the infiltration of rainwater to the water table in the surficial aquifer, thereby limiting the amount of water available to support baseflow (SWFWMD 2000).

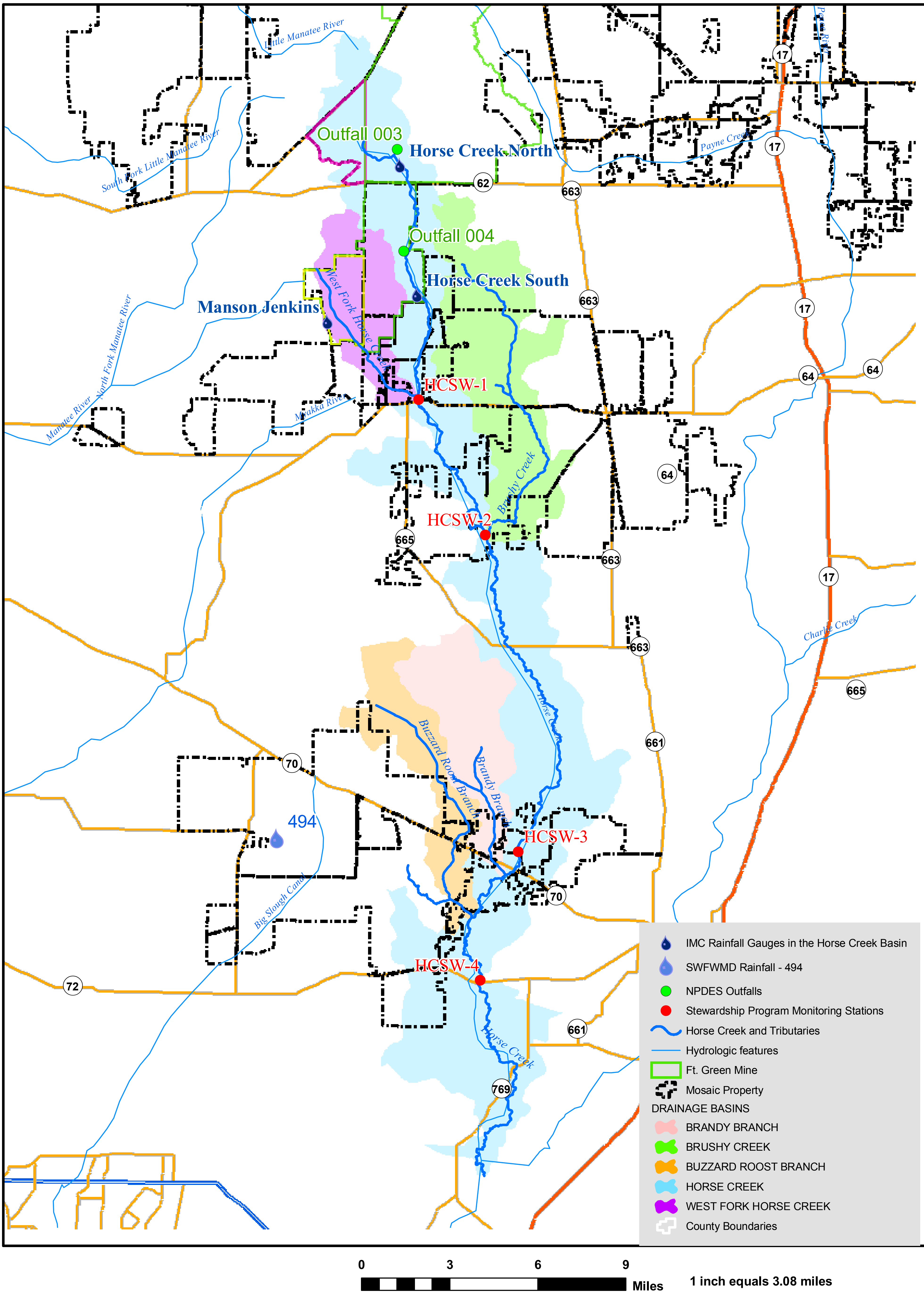
The climate of Horse Creek Basin is subtropical and humid with an average temperature of about 72 º F. Summer temperatures average 80 ºF, and winter temperatures average 60 º F (Hammett, 1990). The average daily temperatures in Hardee County, in the northern Horse Creek Basin, range from is 52 º F to 91 º F (Robbins et al. 1984). The average daily temperatures in DeSoto County, in the southern Horse Creek Basin, range from 49 º F to 92 º F. Average relative humidity in Horse Creek Basin ranges from 57 percent in the mid-afternoon to 87 percent at dawn. The prevailing wind is from the east-northeast, with the highest average wind speed, 7.8 mph, occurring in March (Cowherd et al. 1989).

The average annual rainfall in the Peace River Basin, which includes Horse Creek, is 52 inches, with more than half of that falling during localized thundershowers in the wet season (June - September) (Hammett, 1990). Rain during fall, winter, and spring is usually the result of large, broad frontal systems instead of local storms (Hammett, 1990). November is typically the driest month of the year, averaging 1.77 inches over the historic period from 1915 to 2004. The months of April and May are also characteristically dry, averaging 2.56 and 3.95 inches respectively. Dry conditions coincide with high evaporation rates and generally result in the lowest stream flows, lake stages, and ground-water levels of the year (Hammett, 1990). The wettest month of the year is typically June, averaging 8.27 inches.

Horse Creek flows through a generally rural area. Major land use activities in the basin are primarily agricultural, with extractive mining activities occurring in the northern part of the basin. Agricultural activities include cattle grazing, row crop farming, citrus grove production, sod farming, and conversion of native lands to pasture for both cattle grazing and hay production.

Small rural agricultural communities are located in and near the Horse Creek drainage basin including Fort Green, Ona, and Myakka Head in the northern portion of the basin, Limestone, Lily, and Edgeville in the approximate center of the basin, and Arcadia, Fort Ogden and Nocatee near the southern end of the basin (Post et al. 1999). Generally the northern Horse Creek basin is covered more by natural vegetation, while the southern basin is covered mostly by pasture and row crops (SWFWMD 2000).

Total acreages in each land cover type and proportions of the various land uses differ between regions of the basin. Mining is the primary land use above State Road 64, but the percentage of land devoted to mining decreases rapidly downstream. Agricultural land use, on the other hand, more than doubles in acreage from above County Road 663 (HCSW-2) to above SR 72 (HCSW-4). Rangeland covers a greater percentage of land in the northern part of the basin than in the southern portion. Upland forest and wetland area increase substantially from above SR 64 (HCSW-1) to above CR 663 (HCSW-2), but the percent forest and wetland cover remains relatively constant between CR 663 and further downstream (Durbin and Raymond 2006).



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Revision Date: 11 January 2007
Project Number: 2476-065-b23
Project Manager: DJD
GIS Operator: KMNR
GIS QA/ QC:
ArcMap Name: horsecreek_aerial_ver2.mxd
Plot File: horsecreek_aerial_ver2.pdf

Figure 1. Overview of drainage basins, HCSP sampling locations, and Mosaic property in the Horse Creek Basin.

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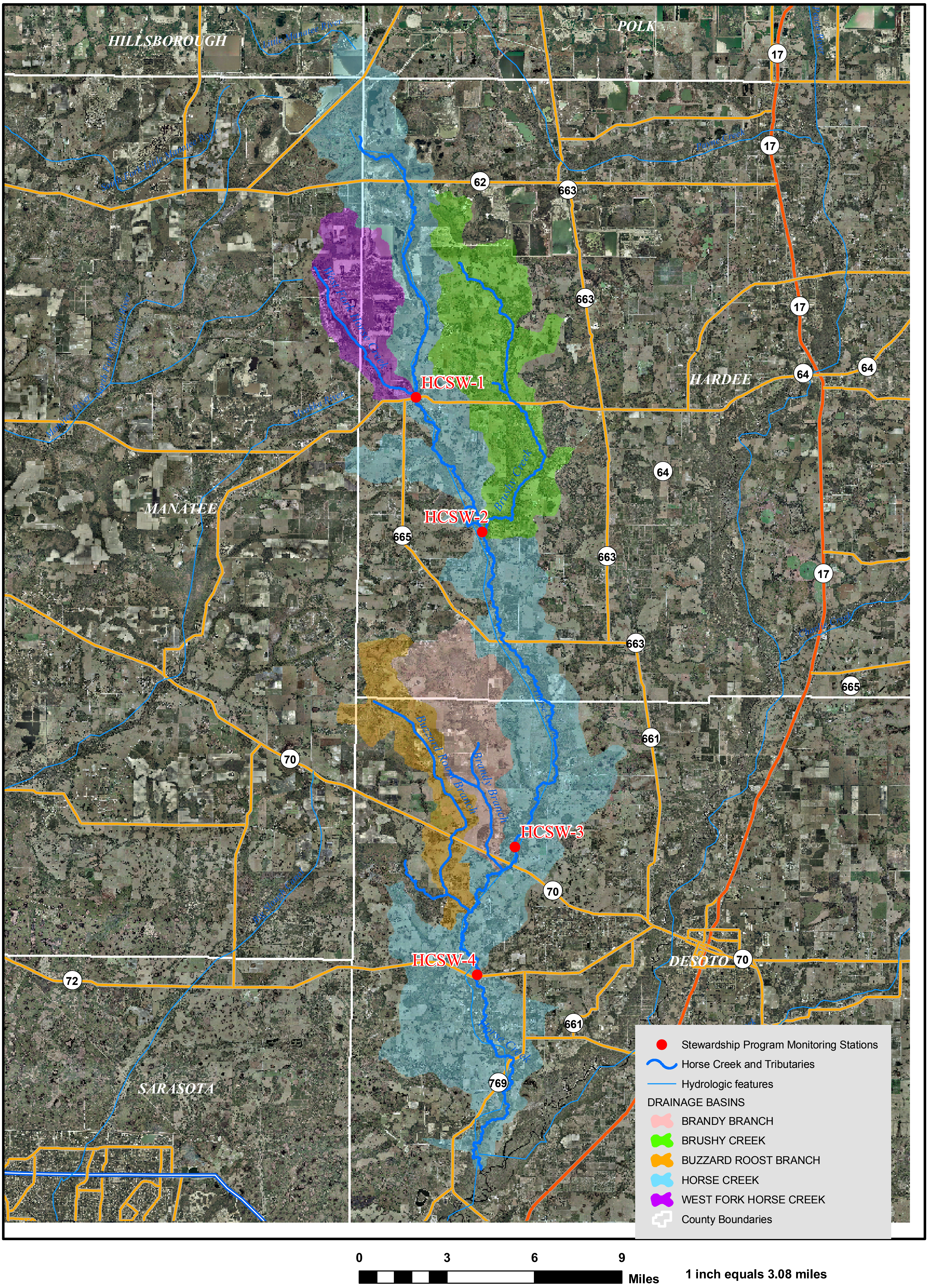

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Figure 2. Aerial Photograph of Horse Creek Basin and HCSP sampling locations.

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3.0 SUMMARY OF MINING AND RECLAMATION ACTIVITIES

3.1 MINING

About 590 acres were mined in the Horse Creek Basin at the Mosaic Fort Green Mine in 2005 (Figure 3). Mining occurred in the basin during all months in 2005, with an average of about 50 acres mined per month. Mining rates varied by month from a low of 39 acres in December to a maximum of 66 acres in August. There have been, and will be in the future, mining activities in the Horse Creek Basin outside of those performed by the Mosaic Corporation. Some additional phosphate mining may or may not have been conducted by other companies in the Horse Creek drainage basin, but Mosaic is not aware of the extent or timing of that mining. Information on pre-mining conditions in the Horse Creek Basin may be found in an Environmental Impact Statement prepared by Environmental Science and Engineering, Inc (1982) and a Development of Regional Impact statement prepared by Ardaman and Associates and colleagues (1979).

There are two clay settling areas in the Horse Creek Basin at the Fort Green Mine. The FGH-3 clay settling area is located predominantly in Sections 5, 8, and 9, T33S, R23E. Construction of clay settling area FGH-3 was completed in 1999, and it was immediately put into service. The settling area was designed by Ardaman & Associates with a crest elevation of 151 ft. NGVD, and a final pool elevation of 146 ft. NGVD. The effective area of the dam is approximately 933 acres. Three decant spillways, two on the west wall and one on the north wall, were designed to return water to the Ft. Green plant. Flow can also be directed to the south, using the 003 outfall, through spillways located in the return water ditch near the southwest corner of FGH-3. Clays are introduced into the settling area approximately midway on the east wall. Pond elevations in 2005 ranged from a low of approximately 143.0 ft. NGVD in May to a high of approximately 145.4 ft. NGVD in October.

The FGH-4 clay settling area is located predominantly in Section 31, T33S, R23E. Construction of the clay settling area was completed in 2001, and it was put into service shortly thereafter. The settling area was designed by Ardaman & Associates with a crest elevation of 164.0 ft. NGVD, and a final pool elevation of 159.0 ft. NGVD. The effective area of the dam is approximately 415 acres. Two decant spillways, one on the north wall, and one on the south wall were designed to return water to the Ft. Green central screening station. Decant spillways located in the south return water ditch also have the capability of discharging water to the 004 outfall. Clay slurry is introduced into the settling area at the southwest corner, and at a point approximately midway on the west wall of the dam. The settling area is also used to store mine pit water, which is pumped in at the northwest corner and at approximately the center of the south wall. Pond elevations in 2005 ranged from a low of approximately 137.6 ft. NGVD in February, to a high of approximately 143.4 ft. NGVD in March.

Aside from routine maintenance, repairs to wave erosion damage to the upstream slope of FGH-4 were completed in 2005. Both settling areas have real-time monitoring of the pond level, which is relayed to the PRMRWSA. Any sudden drop in pond level elevations, suggesting a substantial release of wastewater from the settling areas, would be detected promptly, allowing for an expedited response to the situation.

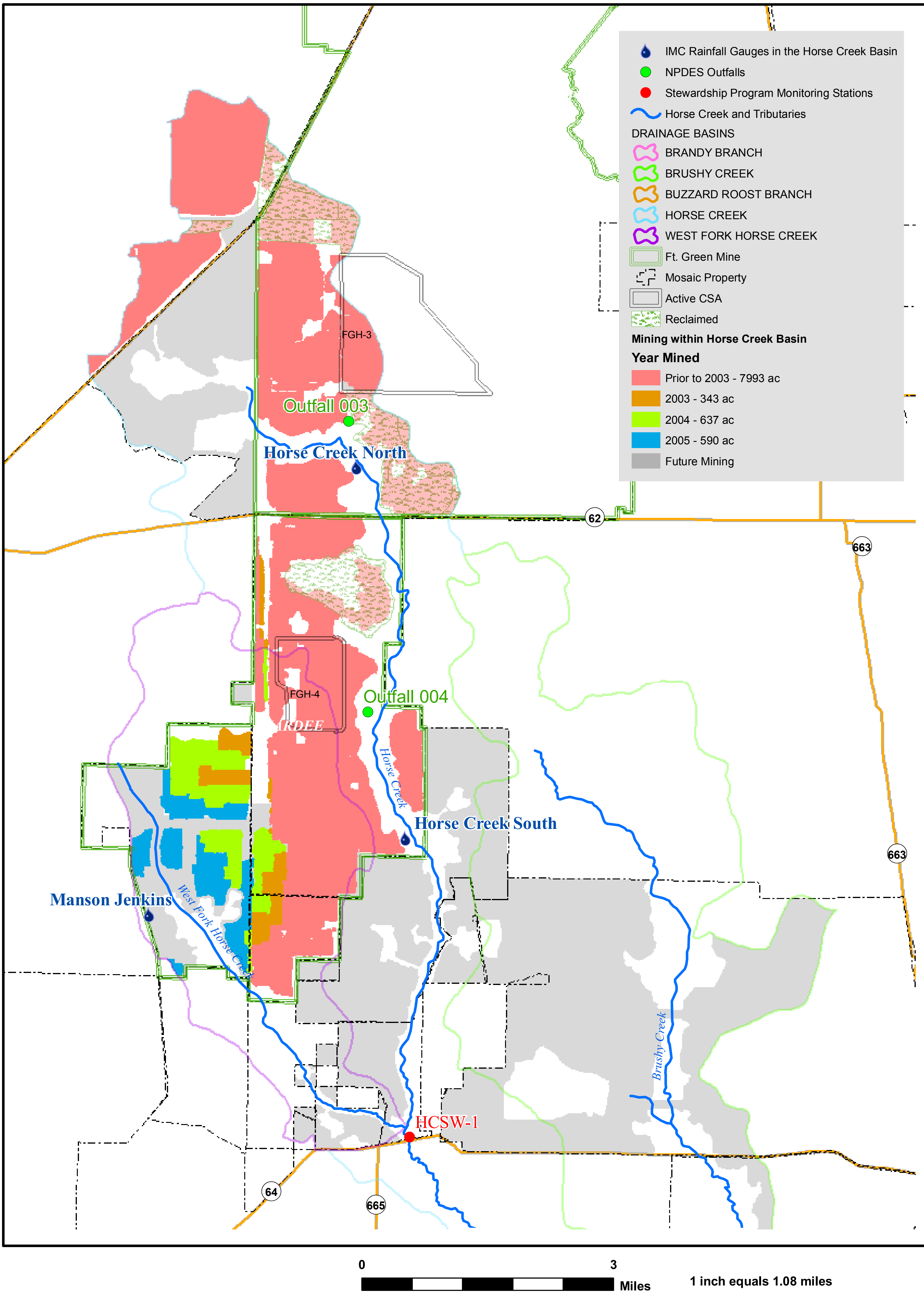

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Figure 3. Mining and reclamation areas in the Horse Creek Basin.

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3.2 RECLAMATION

Reclamation of lands that have been mined is an ongoing process at Mosaic's Fort Green Mine including lands in the Horse Creek Basin. The reclamation process consists of backfilling of the mined excavations with sand "tailings" produced as a by-product of the phosphate production process or shaping existing deposits of overburden material to bring the ground surface up to rough grade. Overburden material is spread over the backfilled areas and the areas are brought to the required final contours. Planting of both upland and wetland communities is done with appropriate species. Reclaimed areas are monitored, and supplemental plantings are done as necessary until the revegetation of the land is successful.

About 206 acres were reclaimed through revegetation in 2005 at the Fort Green Mine. Earthwork, which included spreading of overburden onto land backfilled with tailings and final contouring of the ground surface, was completed on those 206 acres. In 2005, 12 of the 206 acres were planted in wetland plants and 194 of the 206 acres were planted in upland plants in reclamation projects within the Horse Creek Basin at the Fort Green Mine.

4.0 METHODS

4.1 STATION LOCATIONS AND SAMPLING SCHEDULE

Four Horse Creek locations are monitored for physical, chemical, and biological parameters (Figure 1):

HCSW-1 - Horse Creek at State Road 64 (USGS Station 02297155)
HCSW-2 - Horse Creek at County Road 663A (Goose Pond Road)
HCSW-3 - Horse Creek at State Road 70
HCSW-4 - Horse Creek at State Road 72 (USGS Station 02297310)

As indicated above, HCSW-1 and HCSW-4 are also long-term US Geological Survey (USGS) gauging stations, with essentially continuous stage and discharge records since 1977 and 1950, respectively. Water quality sampling has been conducted monthly beginning in April 2003, while biological sampling events have been conducted an average of three times per year (Table 1).

Table 1. 2005 Schedule of Water Quality and Biological Sampling Events of the HCSP.

Date	Water Quality Sampling Events	Biology Sampling Events
26 January 2005	X	
15 February 2005		X
24 February 2005	X	
30 March 2005	X	
21 April 2005		X
27 April 2005	X	
25 May 2005	X	
22 June 2005	X	
27 July 2005	X	
23 August 2005	X	
15 September 2005		X
29 September 2005	X	
27 October 2005	X	
17 November 2005	X	
15 December 2005		X
20 December 2005	X	

4.2 WATER QUANTITY

Provisional discharge data were obtained from the USGS (http://waterdata.usgs.gov/fl/nwis/nwis) for HCSW-1 and HCSW-4. Staff gauges were installed and stream cross sections were surveyed by Mosaic at HCSW-2 and HCSW-3; stage data were obtained at those stations during monthly water quality sampling. Discharge data were obtained for Mosaic's National Pollutant Discharge Elimination System (NPDES)-permitted discharges into Horse Creek (Outfalls 003 and 004) for 2003 - 2005 (Figure 1). Daily rainfall data were obtained from the USGS for HCSW-1 (gauge discontinued in 2005), from

SWFWMD's Horse Creek IMC gauge 494, and from Mosaic's rain gauges in the Horse Creek Basin (Figure 1). The general relationship between rainfall and streamflow was graphically evaluated. All rainfall gauges are located in the upper portion of the Horse Creek basin, so longitudinal comparisons along the basin are not possible. A separate report (Durbin and Raymond 2006) addresses long-term rainfall patterns in the area.

4.3 WATER QUALITY

A continuous monitoring unit was installed at HCSW-1 to record pH, specific conductivity, dissolved oxygen, and turbidity. Beginning in April 2003, data were recorded hourly, and daily mean, maximum, and minimum were downloaded at least monthly. These data provide for the characterization of natural background fluctuations and allow for the detection of instantaneous conditions or general water quality changes not observed during the collection of monthly grab samples.

Water quality samples were obtained monthly, when flow was present, by Mosaic at each of the four monitoring stations beginning in April 2003. The four locations were sampled the same day, working from upstream to downstream. All activities affecting sample collection, sample handling, and field-testing activities were thoroughly documented. Field sample collection logs were completed at each station that include the following information: stream level elevations at the time of sampling (from on-site gauges or from the USGS real-time web site); stream size; a qualitative description of the water color, odor, and clarity; weather conditions; field measurements; sample preservation; and any anomalous or unusual conditions. Individual sample containers were labeled with identification codes, date and time of sampling, sample preservation, and the desired analysis. Sample transmittal chain-of-custody records were filled out during sampling listing locations, times, and required analysis.

Field measurements were taken for pH, dissolved oxygen, specific conductivity, and turbidity using meters that were operated and maintained according to manufacturer's instructions. Instruments were calibrated in the field prior to making measurements using the appropriate standards and acceptance limits (Table 2). All calibration activities were documented and records checked for completeness and accuracy. Field measurements by BRA in association with the three biological sampling events employed a HydroLab Quanta multiparameter unit with the same measuring methods and acceptance limits listed in Table 2. BRA also employed a Hach 2100P unit for turbidity measurement.

Table 2. HCSP Water Quality Sampling Field Methods and Acceptance Limits Associated with Monthly Sampling by Mosaic Staff.

Analyte	Meter Used	Method	Minimum Detection Limit	Acceptance Limit
pH	Hach Sension 2	150.1	1 su	+/- 0.2 standards units of the calibration standard
Temperature	Hach Sension 2	170.1		1 degree Centigrade
Specific Conductivity	Hach CO150	120.1	10 uS/cm	+/- 5% of the calibration standard
Dissolved Oxygen	YS1 Model 52	360.1	0.5 mg/l	+/- 0.2 mg/l of the correct Dissolved Oxygen - Temperature value
Turbidity	Hach 2100P	180.1	0.1 NTU	+/- 8% of the calibration standard

Surface water samples were collected in a manner that represented the physical and chemical characteristics of Horse Creek without contamination or bias in the sampling process. Water samples for chemical analysis were generally collected from mid-stream and from mid-depth to the upper portion of the water column unless flows were at either extreme (flood stage or nearly dry at the upper stations). Samples were usually obtained by wading into the stream (taking care not to disturb or stir up bottom sediments) and collecting samples upstream from the sampler. When flooded conditions precluded wading to collect samples (principally at HCSW-3), samples were taken from the top of the water column in the main flow path from the bridge. Samples were collected directly into unpreserved sample containers which were used to fill the other sample containers. Pre-preserved sample containers (with either sulfuric or nitric acid) were filled and their pH levels checked. Hydrochloric acid was added in the field to unpreserved samples for petroleum range organics analysis. The sample containers were stored on ice prior to transport to laboratories for analysis. Sample containers were either taken directly to the laboratory or laboratory personnel picked them up in the field, using appropriate chain-of-custody procedures. The monthly surface water samples were analyzed for the parameters listed in Table 3. Table 3 also includes the laboratory analysis methods.

In addition to the continuous recorders and monthly water quality sampling, field measurements of temperature, pH, specific conductivity, turbidity and dissolved oxygen were collected during each biological sampling event (Table 1) using a Hydrolab Quanta. All sampling was conducted according to the Florida Department of Environmental Protection's (DEP's) Standard Operating Procedures (SOPs) for field sampling. Laboratory analyses were performed by experienced personnel according to National Environmental Laboratory Accreditation Council (NELAC) protocols, including quality assurance/quality control (QA/QC) considerations contained in the QA/QC plan developed for this program (currently in review). There were no substantial problems during water quality sampling events or laboratory analysis of samples during the 2005 monitoring.

Results were tabulated to allow for comparisons among stations and sampling events, through time, and to the "trigger values" established for the HCSP (Table 4). In addition, results were compared with applicable Florida surface water quality standards (which in many cases are the same as the trigger values).

Table 3. Parameters Analyzed and Laboratory Methods for HCSP 2003 - 2005 Monthly Water Quality Samples.

Parameter	Method	Hold Time	Preservation	Minimum Detection Limit	Container
Color	110.2	48 hours	Unpreserved	2.5 PCU	Clear HDPE bottle
Total Kjeldahl Nitrogen	351.2	28 days	Sulfuric Acid, pH < 2	0.1 mg/l	Clear HDPE bottle
Nitrate-Nitrite Nitrogen	353.2	28 days	Sulfuric Acid, pH < 2	0.02 mg/l	Clear HDPE bottle
Nitrate Nitrogen	SM 4500E	48 hours	Unpreserved	0.02 mg/l	Clear HDPE bottle
Total Ammonia Nitrogen	350.1	28 days	Sulfuric Acid, pH < 2	0.03 mg/l	Clear HDPE bottle
Orthophosphate	365.1	48 hours	Unpreserved	0.05 mg/l	Clear HDPE bottle
Chlorophyll *a*	SM 10200H	48 hours	Unpreserved	1 mg/l	Opaque plastic bottle
Specific Conductivity	120.1	28 days	Unpreserved	10 uS/cm	Clear HDPE bottle
Total Alkalinity	310.1	14 days	Unpreserved	mg/l CaCO3	Clear HDPE bottle
Dissolved Calcium*	200.7	28 days	Unpreserved	0.1 mg/l	Clear HDPE bottle
Dissolved Iron*	200.7	28 days	Unpreserved	0.1 mg/l	Clear HDPE bottle
Chloride	300.0	28 days	Unpreserved	1 mg/l	Clear HDPE bottle
Fluoride	300.0	28 days	Unpreserved	0.1 mg/l	Clear HDPE bottle
Total Radium (Radium 226+228)	903.0	6 months	Nitric Acid, pH < 2	1 pCi/l	Clear HDPE bottle
Sulfate	300.0	28 days	Unpreserved	1 mg/l	Clear HDPE bottle
Total Dissolved Solids	160.1	7 days	Unpreserved	5 mg/l	Clear HDPE bottle
Petroleum Range Organics	FL-PRO	7 days	Hydrochloric Acid, pH < 2	0.1 mg/l	Amber Glass Bottle
Fatty Amido-amines	8270	7 days	Unpreserved	0.2 mg/l	Amber Glass Bottle
Total Fatty Acids	8270C	7 days	Unpreserved	0.5 mg/l	Amber Glass Bottle

- If a field conductivity measurement exceeded 1,400 umhos/cm, the laboratory performed an analysis of specific conductivity.
- All water samples were preserved at 4C while awaiting analysis.
- Orthophosphate samples were filtered in the laboratory rather than the field. While Mosaic is cognizant of the FDEP SOP for field sampling, the decision was made to have samples lab filtered (less risk of contamination and the guarantee of lab filtering within hours of lab delivery). Starting in January 2005, samples were field-filtered.
- * - The analytical method for iron and calcium was changed during the 2003 – 2005 monitoring period; see results section for details.
- Total radium is the arithmetic sum of Radium 226 and Radium 228. As requested by the PRMRWMA, if either Radium 226 or Radium 228 is undetected, the MDL of the undetected constituent will be used as part of the "Radium 226 + 228." This use of MDL for undetected constituents is contrary to both laboratory and DEP SOPs.
- Total nitrogen is reported as the arithmetic sum of nitrate+nitrite nitrogen and total Kjeldahl nitrogen. As requested by the PRMRWMA, if either constituent is undetected, the MDL of the undetected constituent will be used as part of the total. This use of MDL for undetected constituents is contrary to both laboratory and DEP SOPs.

Table 4. Parameters, General Monitoring Protocols, and Corrective Action Trigger Values for the HCSP.

Pollutant Category	Analytical Parameters	Analytical Method	Reporting Units	Monitoring Frequency	Trigger Level	Basis for Initiating Corrective Action Process
General Physio-chemical Indicators	pH	Calibrated Meter	Std. Units	Monthly	<6.0->8.5	Excursions beyond range or statistically significant trend line predicting excursions from trigger level minimum or maximum.
	Dissolved Oxygen	Calibrated Meter	mg/L(1)	Monthly	<5.0	Excursions below trigger level or statistically significant trend line predicting concentrations below trigger level.
	Turbidity	Calibrated Meter	NTU(2)	Monthly	>29	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Color	EPA 110-2	PCU	Monthly	<25	Excursions below trigger level or statistically significant trend line predicting concentrations below trigger level.
Nutrients	Total Nitrogen	EPA 351 + 353	mg/l	Monthly	>3.0	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Ammonia	EPA 350.1	mg/l	Monthly	>0.3	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Ortho Phosphate	EPA 365	mg/l	Monthly	>2.5	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Chlorophyll *a*	EPA 445	mg/l	Monthly	>15	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
Dissolved Minerals	Specific Conductance	Calibrated Meter	µs/cm(3)	Monthly	>1,275	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Alkalinity	EPA 310.1	mg/l	Monthly	>100	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Calcium	EPA 200.7	mg/l	Monthly	>100	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Iron	EPA 200.7	mg/l	Monthly	>0.3 (6); >1.0(7)	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Chloride	EPA 325	mg/l	Monthly	>250	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Fluoride	EPA 300	mg/l	Monthly	>1.5(6); >4(7)	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Radium 226+228	EPA 903	pCi/l(4)	Quarterly	>5	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Sulfate	EPA 375	mg/l	Monthly	>250	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Dissolved Solids	EPA 160	mg/l	Monthly	>500	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
Mining Reagents	Petroleum Range Organics	EPA 8015 (FL-PRO)	mg/l	Monthly(5)	>5.0	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Fatty Acids, Incl.Oleic, Linoleic, and Linolenic Acid	EPA/600/4-91/002	mg/l	Monthly(5)	>NOEL	Statistically significant trend predicting concentrations in excess of the No Observed Effects Level (NOEL to be determined through standard toxicity testing with Mosaic reagents early in monitoring program, NOEL to be expressed as a concentration – e.g., mg/L)
	Fatty Amido-Amines	EPA/600/4-91-002	mg/l	Monthly(5)	>NOEL	Statistically significant upward trend predicting concentrations in excess of No Observed Effects Level (NOEL to be determined through standard toxicity testing with Mosaic reagents early in monitoring program, NOEL expressed as a concentration – e.g., mg/L)
Biological Indices: Macroinvertebrates	Total Taxa	Stream Condition Index (SCI) sampling protocol, taxonomic analysis, calculation of indices according to SOP-002/01 LT 7200 SCI Determination	Units vary based upon metric or index	3 times per year	N/A	Statistically significant declining trend with respect to SCI values, as well as presence, abundance or distribution of native species
	Ephemeropteran Taxa					
	Tricopteran Taxa					
	Percent Collector-Filterer Taxa					
	Long-lived Taxa					
	Clinger Taxa					
	Percent Dominant Taxon					
	Percent Tanytarsini					
	Sensitive Taxa					
	Percent Very Tolerant Taxa					
	Shannon-Wiener Diversity(a)					
Biological Indices: Fish	Total Number of Taxa	Various appropriate standard sampling methods, taxonomic analysis, calculation of indices using published formulas	Units vary based upon metric or index	3 times per year	N/A	Statistically significant declining trend with respect to presence, abundance or distribution of native species
	Abundance					
	Shannon-Wiener Diversity(a)					
	Species Turnover (Morisita Similarity Index(a)					
	Species Accumulation Curves(b)					

Notes:
(1) Milligrams per liter.
(2) Nephelometric turbidity units.
(3) Microsiemens per centimeter.
(4) PicoCuries per liter.
(5) If reagents are not detected after two years, sampling frequency will be reduced to quarterly - if subsequent data indicate the presence of reagents, monthly sampling will be resumed.
(6) At Station HCSW-4 only, recognizing that existing levels during low-flow conditions exceed the trigger level.
(7) At Stations HCSW-1, HCSW-2, and HCSW-3.
(8) Some metrics have been revised from original HCSP plan document due to revision of DEP SCI Protocol.

References:
(a) Brower, J. E., Zar, J. H., von Ende, C. N. Field and Laboratory Methods for General Ecology. 3rd Edition. Wm. C. Brown Co.,
(b) Gotelli, N.J., and G.R. Graves. 1996. Null Models in Ecology. Smithsonian Institution Press, Washington, DC.

4.4 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate sampling was conducted at each of the four sampling stations on 15 February 2005, 21 April 2005, 15 September 2005, and 15 December 2005. At each station, a Stream Habitat Assessment (DEP-SOP-001/01 FT 3100) was performed, and a Physical/Chemical Characterization Field Sheet (DEP Form FD 9000-6) was completed. The habitat assessment is comprised of a variety of physical criteria that are independently evaluated on a numerical scale, and the component values are summed to provide a quantitative rating for a stream segment that is presumed to be proportional to the quality of the stream for native macroinvertebrates. The Physical/Chemical form records a variety of other information and also provides for the delineation of various microhabitats in the stream into categories to allow for sampling of such microhabitats in general proportion to their abundance.

Macroinvertebrate sampling was performed according to the Stream Condition Index (SCI) protocol developed by the DEP (DEP-SOP-002/01 LT 7200) by personnel with training and experience in the SCI protocol and who have successfully passed DEP audits for the protocol. The SCI is a standardized macroinvertebrate sampling methodology that accounts for the various microhabitats available (e.g. leaf packs, snags, aquatic vegetation, roots/undercut banks) within a 100-m segment of stream. Utilizing this methodology, 20 0.5-m D-frame dip net sweeps are performed within a 100-m segment of the stream. The number and quality of benthic macroinvertebrate microhabitats present during the sampling event determines the number of sweeps performed within each microhabitat type. Consistent with DEP protocols, each benthic macroinvertebrate sample was processed and taxonomically analyzed.

Data from each invertebrate sample were used to calculate the various SCI metrics and resulting overall SCI values as per the methodology for the Florida Peninsula (Table 5). The general interpretation for SCI score ranges are provided in Table 6. The calculation methodology for the SCI was revised by DEP in June 2004, and this report uses the new methodology. This change requires a departure from the specific metrics listed for benthic macroinvertebrates in the HCSP plan; however, the plan contemplated such changes in methodology and the use of the revised protocol is acceptable with the plan. Between the 2004 and 2005 biological sampling, individuals conducting biological sampling were trained and audited by the DEP in SCI and Stream Habitat Assessment techniques. Because of this improvement, some SCI results from previous years may not be directly comparable with results from 2005 and beyond.

Table 5. Equations for Calculating SCI Metrics for Peninsular Florida (Range from Zero to Ten).

SCI Metric	Peninsula Score (*)
Total Taxa	10(X-16)/25
Ephemeropteran Taxa	10X/5
Trichopteran Taxa	10X/7
Percent Collector-Filterer Taxa	10(X-1)/39
Long-lived Taxa	10X/4
Clinger Taxa	10X/8
Percent Dominant Taxon	10-(10[(X-10)/44])
Percent Tanytarsini	10[ln(X+1)/3.3]
Sensitive Taxa	10X/9
Percent Very Tolerant Taxa	10-(10[ln(X+1)/4.1])

* In each equation, “X” equals the number representing the count or percentage listed in the corresponding row of the left column. For calculated values greater than ten, the score is set to ten; for values calculated less than zero, the score is set to zero.

Fortunately, the revisions to the SCI protocol were implemented before the previous methodology was used to calculate SCI values for the HCSP, so there was no need to retroactively adjust SCI values from previous years' sampling results. Changes made to the calculation protocol were fairly esoteric, essentially based upon a broad array of statistical analyses with invertebrate samples collected across Florida to determine the best correlates with human disturbance to stream habitats (Fore 2004). Table 5 provides the new list of metrics used in calculating SCI scores, while the parameter table from the HCSP methodology document (copied as Table 4 above) includes the metrics used in the original SCI protocol. Table 6 gives the ecological interpretation of SCI scores as given by the FDEP.

The Shannon-Wiener Diversity Index was calculated using Ecological Methodology Software, Version 6.1 (www.exetersoftware.com). In the future, when more than a few years of data will be available, the focus of the analyses will be to screen for statistically significant declining trends with respect to presence, abundance, and distribution of native species, as well as SCI values.

Table 6. Ecological Interpretation of SCI Scores Calculated for Benthic Macroinvertebrate Samples Collected for the HCSP

SCI Category	Range	Typical Description for Range
Good	73-100	Similar to natural conditions, up to 10% loss of taxa expected
Fair	46-73	Significantly different from natural conditions; 20-30% loss of Ephemeroptera, Trichoptera and long-lived taxa; 40% loss of clinger and sensitive taxa; percentage of very tolerant individuals doubles
Poor	19-46	Very different from natural conditions; 30% loss of total taxa; Ephemeroptera, Trichoptera, long-lived, clinger and sensitive taxa uncommon or rare; Collector-Filterer and Tanytarsini individuals decline by half; 25% of individuals are very tolerant
Very Poor	0-19	Extremely degraded; 50% loss of expected taxa; Ephemeroptera, Trichoptera, long-lived, clinger, and sensitive taxa missing or rare; 60% of individuals are very tolerant

4.5 FISH

Fish sampling was conducted concurrently with the benthic macroinvertebrate sampling at each station on 15 February, 21 April, 15 September, and 15 December 2005. Fish were collected with a 4-foot x 8-foot seine (3 mm mesh size) and by electrofishing with a Smith-Root, Inc. backpack unit (Model 15-B Electrofisher). Electrofishing was timed (typically 4 to 6 minutes), and the number of seine hauls (typically 3 or 4) was recorded to standardize the sampling efforts among stations and between events.

Some fish (generally those larger than about 10 cm) were identified, weighed, measured, and released in the field, while some large and most small fish (<10 cm) were preserved in the field for analysis in the laboratory. All fish collected were identified in the field or laboratory according to *American Fisheries Society*-accepted taxonomic nomenclature (American Fisheries Society 2004). Total length (mm) and weight (g) were recorded for each individual, with the following exceptions: for samples with very large numbers of fish of the same species [a common occurrence with species like eastern mosquitofish (*Gambusia holbrooki*), least killifish (*Heterandria formosa*), and sailfin molly (*Poecilia latipinna*)], a randomly selected subset of individuals (approximately 8 to 10) were measured for length and weight, while the remaining individuals were counted and then weighed *en masse*. All fish retained as voucher specimens were submitted to the Ichthyology Collection at the Florida Museum of Natural History in Gainesville.

Taxa richness (number of species) and abundance were determined by station and for each event, and data were compared among stations and across sampling events. The Shannon-Wiener Diversity Index and Morisita's Community Similarity Index were calculated using the Ecological Methodology Software. Species accumulation curves were plotted to estimate the efficacy of the sampling at producing a complete list of the species present in the sampled portions of the stream. The focus of these analyses will be to screen for statistically significant declining trends with respect to presence, abundance, and distribution of fish in future annual reports, when more than a few years of data are available.

4.6 INITIAL GENERAL HABITAT CONFIGURATION AT MONITORING STATIONS

The following descriptions and panoramic photos of the four HCSP sampling sites represent the general habitat conditions at the time of initial sampling, April 2003. Several hurricanes in summer 2004, however, substantially altered the landscape and channel of Horse Creek (see explanation below).

The sampling segment at HCSW-1 is a deeply incised, narrow valley with very steep banks of rock-like outcroppings (Figure 4). The substrate is also rocky with little sand accumulation except in deeper holes. There is little woody/herbaceous structure at the water level. There are few undercut banks, but some eroded holes are available for fish and macroinvertebrates in the rocky substrate. Canopy cover in the sampling zone is heavy (>75 percent); thus the area receives a minimal amount of direct sunlight.

At HCSW-2, the sampling segment is essentially an oxbow of the main Horse Creek channel (Figure 4). The substrate is generally sandy. There are numerous holes, snags, and undercut banks and roots present. Canopy cover along the sampling zone is moderate (approximately 25 to 50 percent).

The sampling segment at HCSW-3 is more sinuous than the other three stations, with some shallow, sandy areas and several deep holes (Figure 4). There are numerous snags, undercut banks/roots, and occasional organic debris. Sand is the primary substrate component. During periods of low flow, portions of the sandy bottom are exposed, creating large sand bars. The canopy cover is low (approximately 25 percent); so, the area receives considerable direct sunlight.

At HCSW-4, the sampling segment is less sinuous (Figure 4). Submerged habitats include holes, undercut banks/roots, snags, and small amounts of emergent aquatic vegetation. The substrate is primarily sand, with occasional areas of small gravel. Several sand bars are located in the sampling zone and are exposed during periods of low flow. Canopy cover is moderate (about 50 percent).

4.7 POST-HURRICANE HABITAT CONFIGURATION AT MONITORING STATIONS

Because Hurricane Charley traveled more-or-less directly up the Horse Creek basin in mid-2004, the stream and its floodplain were left visibly different in a number of ways (Figure 5). Loss of tree canopy was the primary change through much of the floodplain, mainly through the loss of a large portion of tree limbs and foliage, as well as the downing of many mature trees. The channel itself was altered through the combined effects of the large discharge brought about by Charley (and subsequent storms in 2004), as well as the sudden introduction of massive amounts of vegetation debris and sediment into the stream. The vegetation debris ranged from fresh leaves blown from trees (and many still attached to branches), to woody material varying in size from small twigs to entire trees. Introduction of this material obviously had a powerful effect on in-stream hydraulics, leading to changes in channel configuration, local velocity patterns, and erosion/deposition patterns. As the floodplain continues to 'recover' from hurricane effects (i.e., through re-growth of damaged vegetation), and as organic material (primarily wood) breaks down and is transported into the stream and longitudinally downstream, it can be assumed that Horse Creek will see further changes in its morphometry, and probably its ecology, over and above typical year-to-year changes that might otherwise be expected.

At Stations HCSW-2, 3 and 4, there was severe damage to the riparian and floodplain forest directly after the hurricanes, with trees of all sizes and species damaged or destroyed. For example, the live oak hammock in the floodplain at HCSW-3, which previously provided nearly 90 percent canopy cover suffered so much tree and branch loss that the forest floor was in virtually full sun. The very high flows resulting from the hurricanes' rainfall combined with the altered hydraulics brought about by the new debris in the stream caused major shifts in the locations of sandbars, pools, runs, etc at HCSW-3 and HCSW-4. Farther upstream, Station HCSW-2 had marked floodplain forest damage, but the stream channel segment that is sampled was not dramatically changed. Station HCSW-1 was only minimally affected in terms of either its floodplain or the channel. This is because the path of Charley was several miles to the east of that station, and because the stream is very deeply incised at HCSW-1, so the channel and its riparian canopy lie somewhat below the surrounding landscape, presumably resulting in lower localized wind speeds as the hurricanes went through.

Beyond the immediate response of the stream to the 2004 hurricanes, the overall morphometry of Horse Creek continued to undergo noticeable changes through 2005. Between the April 2005 and September 2005 biological sampling events, a number of changes were evident.

At HCSW-1, the channel configuration in the sampling area is essentially fixed by the deeply incised, rock-like banks. However, where at least portions of the stream bed were clean, rock-like material during prior sampling events, the September 2005 biological event found the bottom covered by at least several inches of sand throughout the sampling area. It is possible that this sand was transported into the stream during heavy rain events in the early part of the 2005 wet season, but it seems likely that it was sediment that continued to be transported downstream after initially being moved into the stream by rainfall associated with Hurricane Charley and other tropical systems during 2004.

At HCSW-2, the size and position of a sand bar on the west side of the stream in the sampling area had changed noticeably from the April to the September biological event. Although the stream stage was somewhat higher in September, the exposed portion of the sandbar was larger, indicating accrual of sediment there.

At HCSW-3, shoreline changes were apparent, with significant erosion in some places and deposition in others. Some spots that had been steep shorelines were much more gradual, and vice-versa. The canopy of the floodplain forest is clearly regenerating, although in September 2005 it was still just a fraction of its pre-Hurricane Charley degree of cover.

At HCSW-4, conditions are still far different than before Charley. The stream channel is steep-sided and generally deeper throughout the sampling area, which continues to complicate sampling efforts. Large woody debris is gradually decomposing, but large logs and tree trunks still litter the banks and extend into the channel. Much of the channel bed at mid-stream has a substantial layer of soft sand which has obviously been recently deposited, and which continues to move slowly downstream. Where a USGS staff gauge reading of 5.0 feet indicated favorable biological sampling conditions prior to Hurricane Charley, the stage should be at least one foot lower now to provide the same degree of access (particularly for fish sampling); due to the deeper channel created by Hurricane Charley.

HCSW-1 Horse Creek above SR 64

HCSW-2 Horse Creek above CR 663

HCSW-3 Horse Creek above SR 70

HCSW-4 Horse Creek above SR 72

Figure 4. Panoramic Photographs of the HCSP Sampling Locations, Photos taken on 25 April 2003.

Figure 5. Photographs of HCSP Sampling Locations in Late 2005. Photos taken 15 December 2005.

5.0 RESULTS AND DISCUSSION

Below we present a summary of water quantity and quality data collected as part of the HCSP in 2005. In addition, results of the 2005 benthic macroinvertebrate and fish sampling are presented.

5.1 WATER QUANTITY

5.1.1 Rainfall

Continuous rainfall data are collected by the SWFWMD at HCSW-3 (SWFWMD Station 494). (Previous HCSP Annual reports used the USGS gauge at HCSW-1, which has been discontinued.) Figure 6 includes 2005 total monthly rainfall data from SWFWMD gauge 494, as well as data from the three Mosaic rain gauges located in the Horse Creek watershed (see Figure 1 for locations). Total and median monthly rainfall in 2005 was slightly different at each station, but the heaviest rainfall was observed during June and July 2005 at all four locations (Figures 6 and 7). August and September rainfall for 2005 (< 5 in per month) was less than that for 2003 (6 – 12 in) or 2004 (6 – 15 in). Dry season rainfall was limited to isolated storm events. Total annual rainfall was about 50 - 70 inches from 2003 to 2005, well within the historic range for that station (Durbin and Raymond 2006). Overall, rainfall in 2005 may have been greater than in 2003 and 2004, but it was mostly limited to two wet season months (Table 7).

Table 7. Annual Total Rainfall in Inches at Gauges in the Horse Creek Watershed in 2003 to 2005.

Gauge	2003	2004	2005
Horse Creek North	53.40	53.82	54.52*
Horse Creek South	59.75	60.74	64.53
Manson Jenkins	30.10*	62.15	31.34*
SWFWMD 494	60.10	53.28	69.80
USGS at Hwy 64	65.01	56.96	49.49
Average of All Gauges	53.67	57.39	62.55

* - Gauge was non-functional during portion of year.

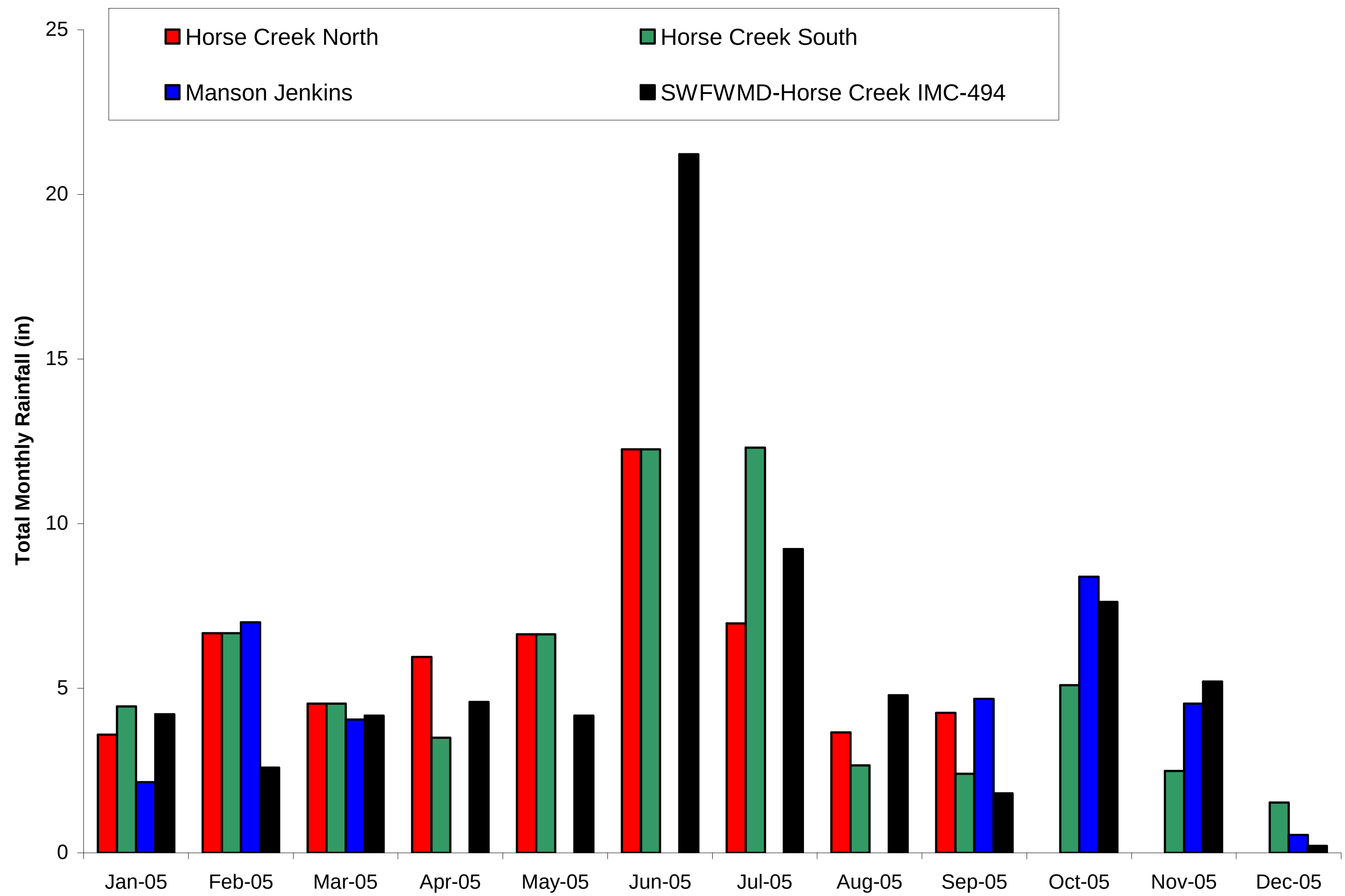

Figure 6. Total Monthly Rainfall From Gauges in the Horse Creek Watershed in 2005.

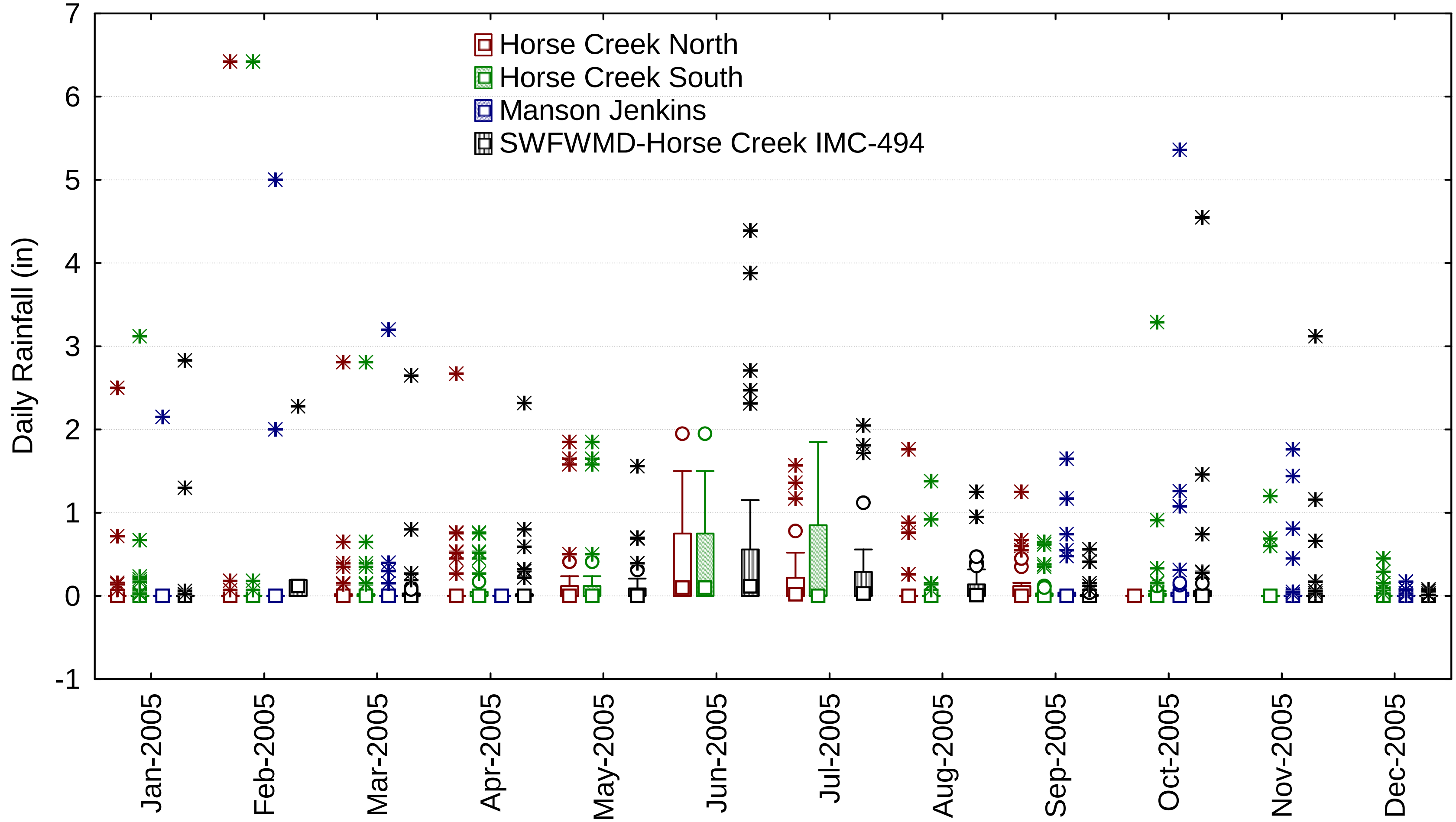

Figure 7. Median box-and-whisker plots[1] Showing Monthly Summaries of Daily Rainfall From Gauges in the Horse Creek Watershed in 2005.

[1] In median box-and-whisker plots, the small center square is the median of the distribution, and the large box is bounded by the 25% (mean – standard error) and 75% (mean + standard error) quartiles of the distribution. The length of the large box is designated H, and the "whiskers" represent the range of values between the box limits and 1.5H above and below the box limits. Outside the whiskers lie outliers and extreme values. Outliers are values that lie between 1.5H and 3H from the box limits, and extreme values lie beyond 3H from the box limits (StatSoft, Inc 2005).

5.1.2 Stream Stage

Figure 8 illustrates the relationship between the staff gauge readings made during each monthly water-quality sampling event. It also provides the average daily stage as recorded at the USGS gauging stations at HCSW-1 and HCSW-4 (after adjustment to NGVD datum). The correlation of stage values among the stations is close, as indicated in Table 8.

Patterns of daily stage levels, based upon monthly readings by Mosaic and data collected continuously by the USGS, were clearly temporally correlated among the four stations (Figure 8). Stage height (feet NGVD) collected monthly by Mosaic at four sites and continuously by the USGS at two sites was examined using Spearman's rank correlations (Zar 1999). Spearman's rank correlation procedure, a nonparametric procedure, was used because three of the six stations had gauge heights that were not distributed normally (Shapiro-Wilk test for normality, $p < 0.05$). Gauge heights showed a strong and significant correlation between all Mosaic stations and USGS stations (Table 8). Such close correspondence is expected for a fairly small watershed in a low gradient setting like peninsular Florida.

Mean daily stage levels in 2005 were highest in March, June, and July, corresponding with high streamflow. Stage duration curves for 2005 were developed for HCSW-1 and HCSW-4 (Figure 9) to indicate the percentage of time stream stage was above particular elevations. Stage at HCSW-1 varied only three to four feet between the curve's P10 and P90 in 2005, indicating that stream height is relatively constant over time (P10 and P90 are commonly used to bracket the 'typical' fluctuation of a water body, thus omitting the highest and lowest 10 percent of the flows). Stages reached above the P10 show that a few rain events caused the stream at HCSW-1 to rise up to eight feet higher for short periods of time in 2005. Stream stage at HCSW-4 is more variable than at HCSW-1 between the P10 and P90 (about seven feet), but showed a smaller rise in stage beyond the P10 level (3 feet). Stage duration P10 and P90 were similar between years, but stream elevation did remain at its highest levels for more days in 2004 than in 2003 or 2005, probably because of three hurricanes.

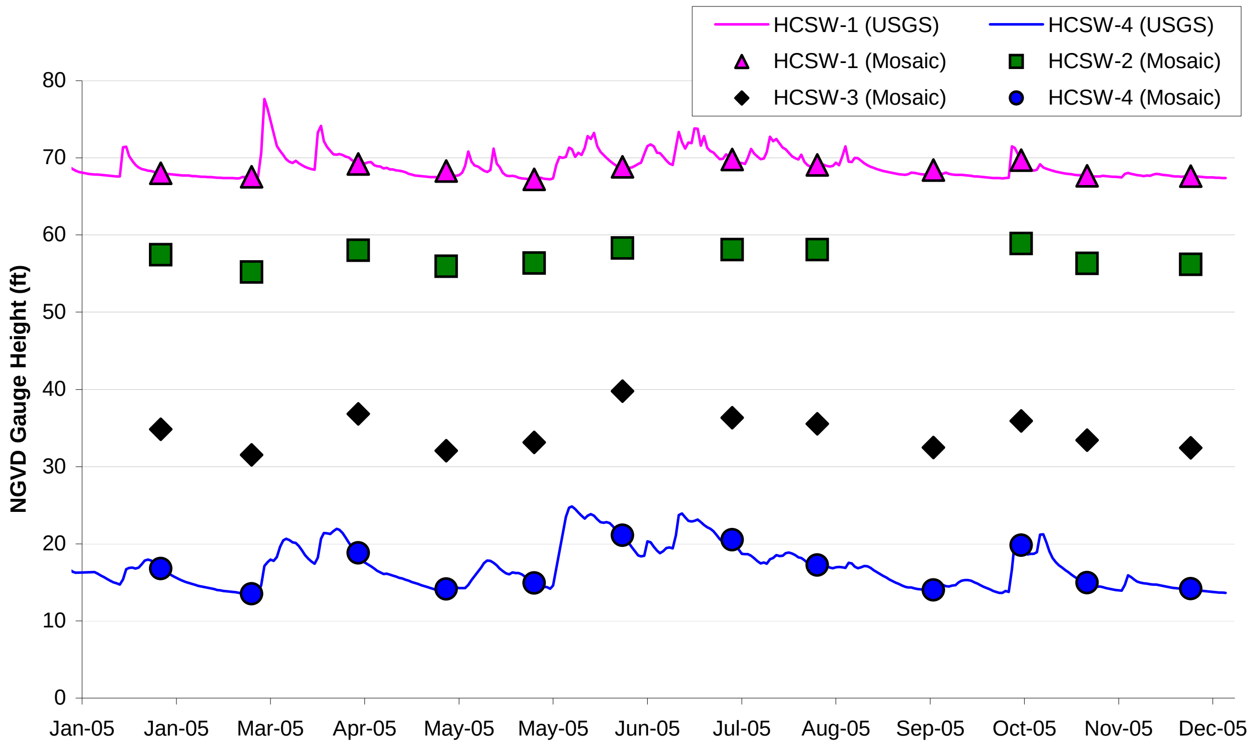

Figure 8. Stream Stage at HCSP Monitoring Stations in 2005. Individual data points are from Mosaic's monthly monitoring; continuous lines are average daily stage from USGS (Stations 02297155 and 02297310). HCSW-3 is missing three gauge heights; water was above the gauge or below the gauge. HCSW-2 is missing one gauge height because of incorrect data (Figure uses provisional data from USGS website).

Table 8. Coefficients of Rank Correlation (r_s) for Spearman's Rank Correlations of Monthly Gauge Height (NGVD) for 2003-2005 ($p < 0.05$).

	HCSW-2 (Mosaic)	HCSW-3 (Mosaic)	HCSW-4 (Mosaic)	HCSW-1 (USGS)	HCSW-4 (USGS)
HCSW-1 (Mosaic)	0.74	0.84	0.76	0.97	0.81
HCSW-2 (Mosaic)		0.95	0.95	0.77	0.97
HCSW-3 (Mosaic)			0.95	0.85	0.99
HCSW-4 (Mosaic)				0.79	0.97
HCSW-1 (USGS)					0.89

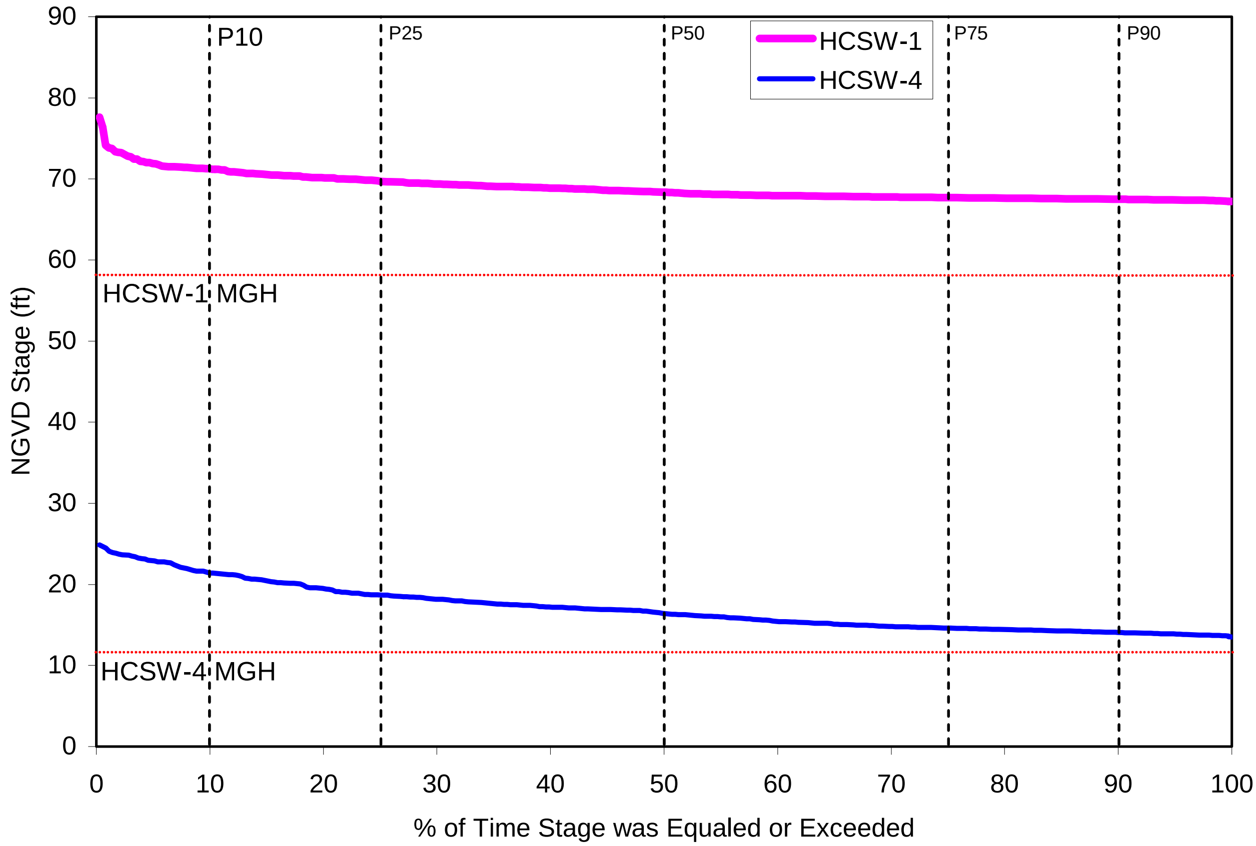

Figure 9. Stage Duration Curves for HCSW-1 and HCSW-4 in 2005, showing percent of year water levels were at or above a given stage. Typical reference points of 10% (P10), 25% (P25), 50% (P50), 75% (P75), and 90% (P90) are indicated on the graph, as well as the minimum gauge heights of HCSW-4 (10.96 ft, NGVD) and HCSW-1 (58.12 ft NGVD). (Figure uses provisional data from USGS website, USGS Stations 02297155 and 02297310).

5.1.3 Discharge

The HCSP required that staff gauges be installed at HCSW-2 and HCSW-3, but does not mandate that discharge be measured at those stations. Thus, all discharge results and discussion are based upon USGS data from HCSW-1 and HCSW-4. The average daily stream flow for 2005, obtained from the USGS continuous recorder data for HCSW-1 and HCSW-4, is presented in Figure 10 and Table 9. The seasonal pattern of streamflow seen in 2005 is slightly different than historical monthly patterns (Durbin and Raymond 2006). The highest flows occurred during the early wet-season months of June through July, but the late wet season, August through September, flows were lower than historic conditions. Average daily stream flows exhibited a similar pattern at both HCSW-1 and HCSW-4 (Figure 10); stream discharge, however, was much higher at HCSW-4 than at HCSW-1 as a logical consequence of

HCSW-4's lower position in the basin. HCSW-1 had a faster discharge in response to heavy rainfall in early 2005 than did HCSW-4, but HCSW-4 had a slower drop-off in discharge after the initial rise. This pattern was reversed in June and July 2005, when HCSW-4 had the quick response and drop-off. Average daily streamflow was significantly less in 2005 than it was in 2003 or 2004 at HCSW-4 (One-way ANOVA $F = 4.95$, $p = 0.007$), but was not significantly different between years at HCSW-1 (One-way ANOVA $F = 0.67$, $p = 0.51$).

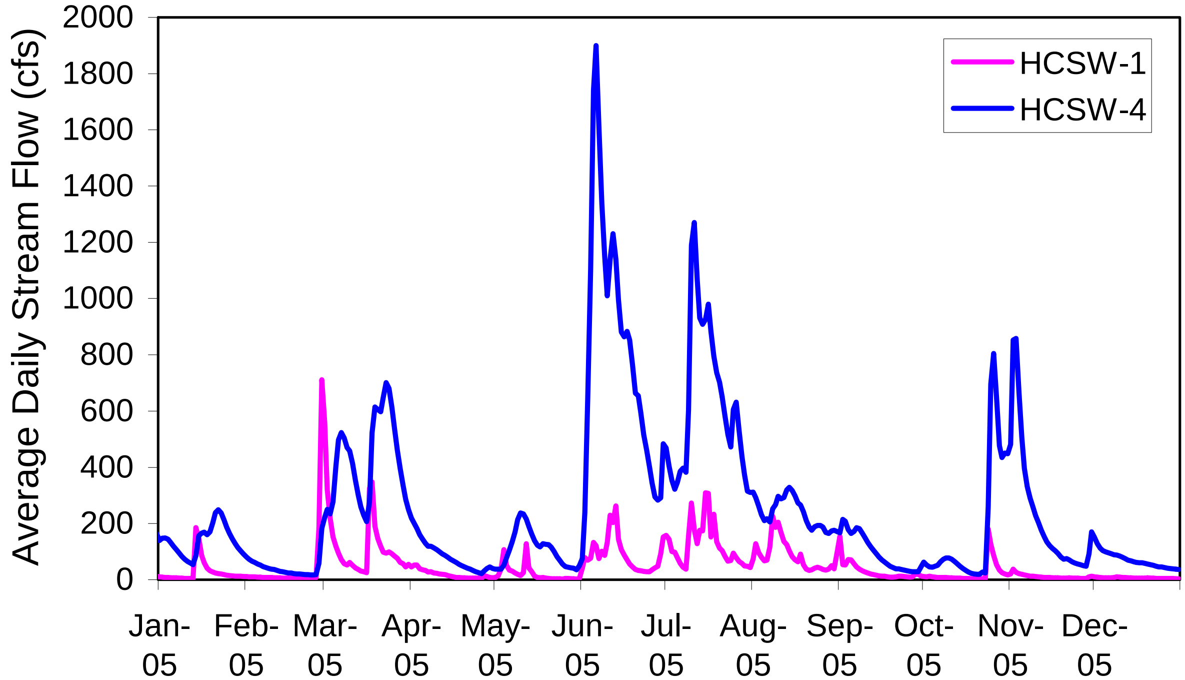

Figure 10. Average Daily Stream Flow for HCSW-1 and HCSW-4 in 2005 (Figure uses provisional data from USGS website).

Table 9. Median, 10th Percentile, and 90th Percentile Stream Discharge at HCSW-1 and HCSW-4 in 2003-2005, Based upon Provisional Data from USGS Website.

Station	Year	10th	Median	90th
HCSW-1	2003	4 cfs	20 cfs	128 cfs
	2004	< 1 cfs	7 cfs	166 cfs
	2005	5 cfs	19 cfs	133 cfs
HCSW-4	2003	20 cfs	75 cfs	1220 cfs
	2004	14 cfs	56 cfs	1170 cfs
	2005	36 cfs	144 cfs	651 cfs

5.1.4 Rainfall-Runoff Relationship

Stream discharge at HCSW-1 and the average daily rainfall for 2005 (average of daily rainfall at HCSW-3 (494 – SWFWMD gauges) and three Mosaic rain gauges upstream of Highway 64) are compared in Figure 11. Higher stream discharge was usually associated with high rainfall, especially during the wet season; the pattern, however, was not consistent, because rainfall events of one inch or more often resulted in little or no change in stream discharge at HCSW-1.

To further examine the strength of covariation between daily stream discharge and rainfall, Spearman's rank correlation procedure was used (Zar 1999). Average monthly stream discharge at HCSW-1 was compared to total monthly rainfall at HCSW-3 (494 – SWFWMD gauges) and three Mosaic rain gauges, as well the average total monthly rainfall of the gauges for the years 2003-2005. Spearman's rank correlation procedure, a nonparametric procedure, was used because stream discharge and rainfall at Horse Creek were not distributed normally (Shapiro-Wilk test for normality, $p < 0.0001$ for all data). The correlation between stream discharge at HCSW-1 and rainfall was statistically significant for each rainfall gauge (Table 10). Although these results suggest that stream discharge and rainfall in Horse Creek covary more than would be expected by chance alone, the correlation coefficients are not very strong ($0.46 > r < 0.70$). The lag between rainfall and runoff, as well as other antecedent condition factors, are strongly affecting this relationship. Historical rainfall and discharge are also significantly correlated, but the relationship is much stronger because the lag influences the relationship less when considered over time (Durbin and Raymond 2006).

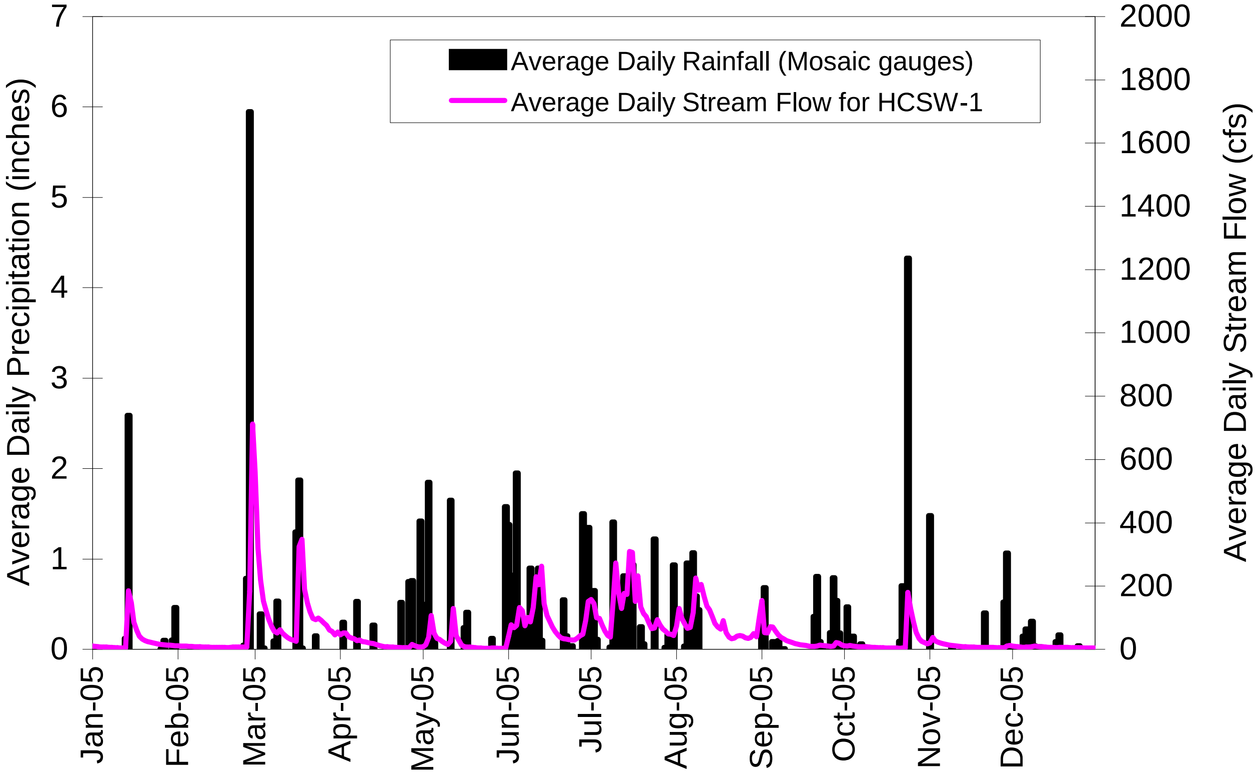

Figure 11. Average Daily Stream Flow and Average Daily Rainfall (from 3 Mosaic gauges and 1 SWFWMD gauge) in the Horse Creek Watershed in 2005 (Figure uses provisional data from USGS website).

Table 10. Coefficients of Rank Correlation (r_s) for Spearman's Rank Correlations of HCSW-1 Monthly Average Stream Discharge and Total Monthly Rainfall at SWFWMD Gauge and Three Mosaic Gauges in 2003 - 2005.

Rainfall Gauge	r_s (with HCSW-1 Streamflow)	p value	N (Sample Size)
Horse Creek North	0.61	0.0002	31
Horse Creek South	0.67	< 0.0001	33
Manson Jenkins	0.46	0.01	29
494 (SWFWMD)	0.58	0.0005	33
Average Rainfall	0.70	< 0.0001	33

In an attempt to make stream discharge and rainfall more comparable, HCSW-1 discharge was converted from cubic feet per second (cfs) to equivalent inches of runoff for the 42-square mile area of the watershed lying upstream of the gauging station (USGS website). Figure 12 illustrates the relationship between cumulative daily discharge at HGSW-1 and rainfall from the average of all gauges in the Horse Creek Basin upstream of Highway 64 (3 gauges). Comparison of the curves shows that 2004 saw less discharge for the first half of the year than other years, but the cumulative discharge and rainfall over the years were similar. The largest increase in discharge relative to rainfall for each year occurred in late June 2003, early August 2004, and February-March and June 2005. Cumulative discharge was the greatest in 2003 and cumulative rainfall was greatest in 2005.

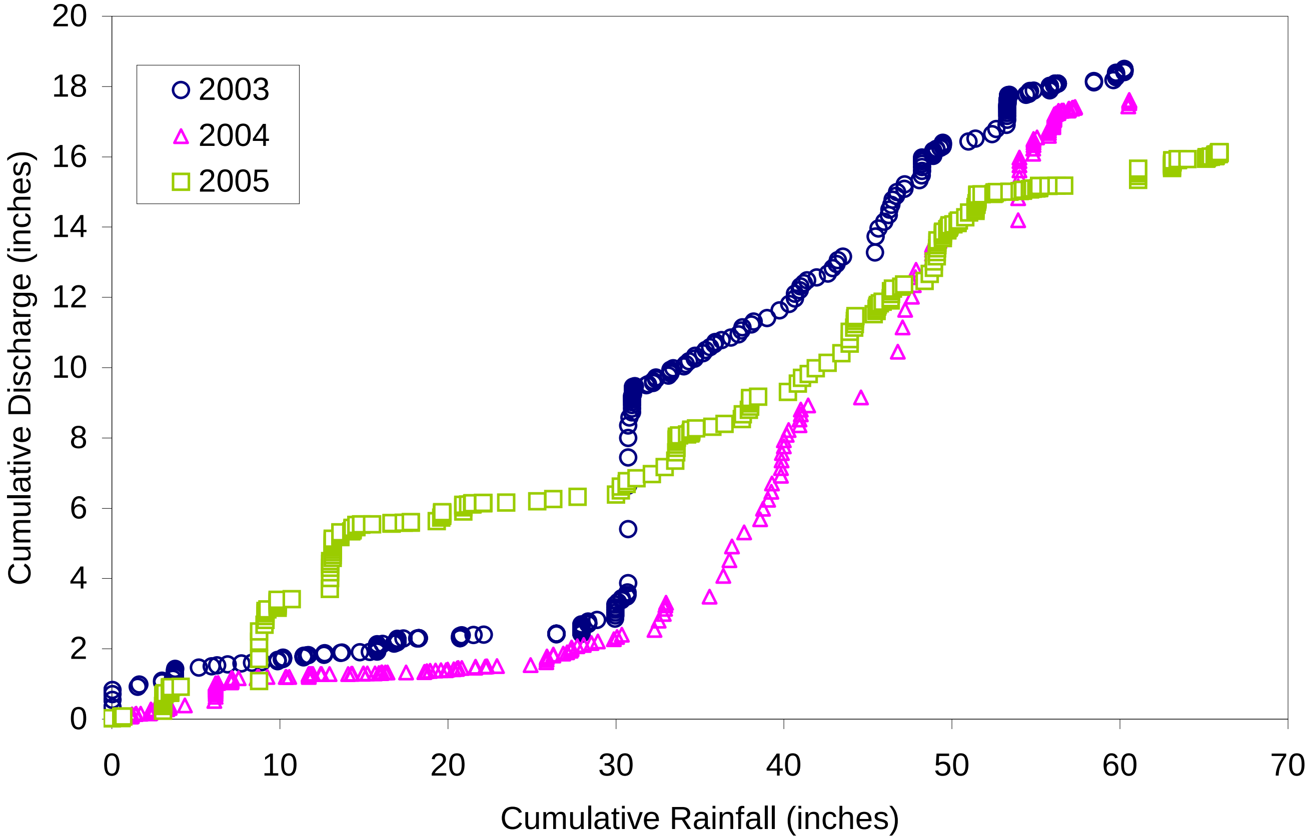

Figure 12. Double Mass Curve of Cumulative Daily Runoff and Rainfall (3 Mosaic gauges) in the Horse Creek Watershed in 2003, 2004, and 2005 (Figure uses provisional data from USGS website).

5.1.5 NPDES Discharges

Industrial wastewater is discharged to Horse Creek through two outfalls located at the Fort Green Mine (Outfalls 003 and 004 on NPDES Permits FL0027600, see Figure 1). Both outfalls are 20-foot wide concrete flumes with continuous flow measurement. A mine wastewater system consists of clay settling areas, mined but not yet reclaimed land, and unmined but disturbed lands. The runoff from all these lands is contained within the industrial wastewater system boundaries. The "loop" of wastewater from the plant to the clay settling areas with the subsequent return of clarified water to the plant for reuse is the backbone of the system. The system has a finite storage capacity and excess wastewater (as a result of rainfall into the system) is discharged from permitted outfalls. This general relationship is illustrated in the rainfall and NPDES discharge data for 2005 (Figure 13). The Horse Creek outfalls, however, are not the only discharge points of the mine, so this data represents only a portion of the mine's rainfall-discharge relationship (Table 11). The Horse Creek portion of the Fort Green Mine is not a distinct entity on the ground; the mine property is continuous and covers portions of several basins. Mosaic has no other discharges to Horse Creek, and no other known industrial wastewater discharges to Horse Creek or any tributary by any other firm are known.

Because they potentially affect stream discharge, the combined 2005 daily discharge of two Mosaic NPDES outfalls (Outfalls 003 and 004) located upstream of HCSW-1 was plotted against the 2005 daily flow for HCSW-1 (Figure 14). Peak NPDES discharge corresponds with the highest flows in Horse Creek, but the total flow at HCSW-1 commonly included water discharged from the NPDES outfalls. Comparing HCSW-1 stream discharge and NPDES discharge in 2003 - 2005 using a Spearman's rank correlation procedure (Zar 1999) indicates they covary strongly ($r_s = 0.56$, $p < 0.0001$, $N = 1077$). Thus, an increase in one parameter will correspond to an increase in the other. This does not necessarily suggest a causal relationship between NPDES discharge and stream discharge. Just as stream discharge at HCSW-1 was weakly correlated with rainfall (Table 10), so too is NPDES discharge (Table 12, Figure 13), with lagtimes and antecedent conditions affecting this relationship.

Discharge volume at Mosaic's NPDES outfalls is manually checked for accuracy every week and represents a constant cross-section flowing over a smooth surface. The USGS discharge gauge at HCSW-1 is not checked manually and represents open channel flow, which is much harder to accurately measure. If the cross section of the stream at or near the gauge changed during the period in question (e.g., debris became lodged or dislodged near the gauge) the cross-sectional area could have changed sufficiently to give erroneous readings. Data from the USGS data recorder at HCSW-1 may be unreliable during some periods; the sensor has been observed to be well above the water line during the dry season, and packed with sand during the wet season (R. Franklin, *pers. comm.*).

Table 11. 2005 Average monthly Mosaic Industrial Wastewater Discharge (NPDES) to Horse Creek (Outfalls 003 and 004) and Payne Creek (Outfall 001, 002, 005, 006) from the Fort Green Mine.

Month	Discharge to Payne Creek (MGD)	Discharge to Horse Creek (MGD)
January	34.6	0.0
February	37.2	0.0
March	225.8	10.1
April	17.3	11.9
May	22.0	12.1
June	141.1	16.2
July	62.3	37.9
August	47.1	23.1
September	29.2	0.0
October	40.0	0.0
November	28.3	0.0
December	25.8	0.0
Annual Total	**710.7**	**111.3**

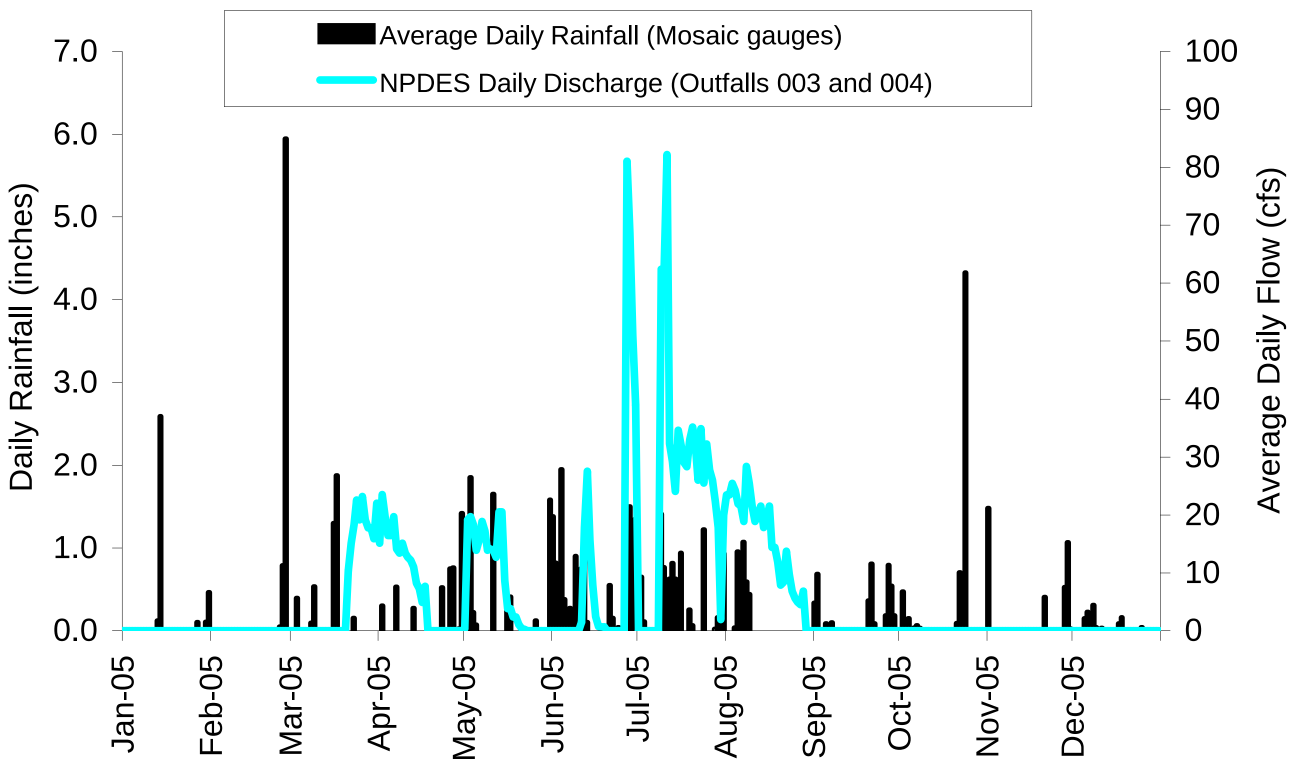

Figure 13. Combined Mosaic NPDES Discharge and Average Daily Rainfall in the Horse Creek Watershed in 2005.

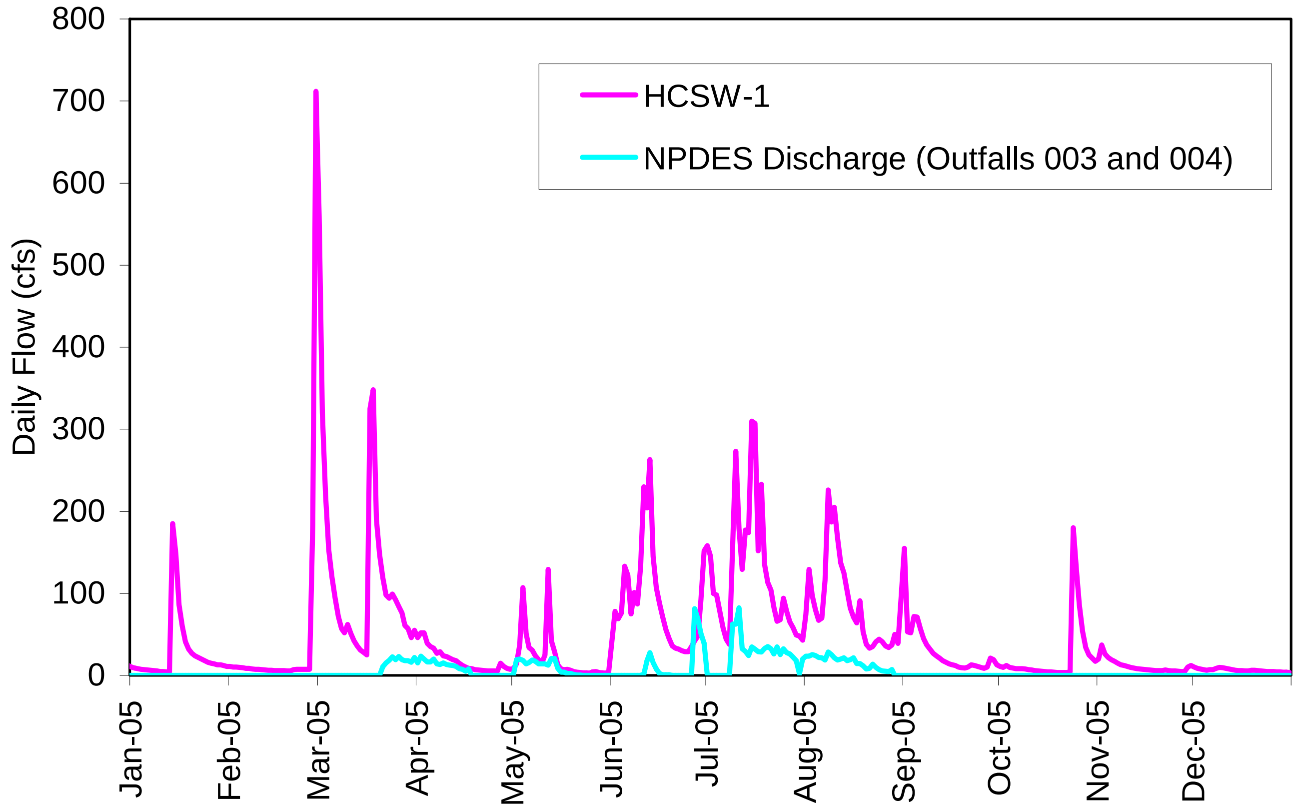

Figure 14. Daily Flow at HCSW-1 and Combined Mosaic NPDES Discharge for 2005 (Figure uses provisional data from USGS website).

Table 12. Coefficients of Rank Correlation (r_s) for Spearman's Rank Correlations of NPDES Daily Discharge and USGS Daily Discharge and Daily Rainfall at SWFWMD Gauge and Three Mosaic Gauges in 2003 - 2005

Gauge	r_s (with NPDES Outfall)	p value	N (Sample Size)
HCSW-1 (USGS Discharge)	0.56	< 0.0001	1077
Horse Creek North (Rain)	0.13	< 0.0001	1007
Horse Creek South (Rain)	0.13	< 0.0001	1096
Manson Jenkins (Rain)	0.09	0.004	939
494 (SWFWMD Rain)	0.10	0.0007	1040
Average Rainfall	0.19	< 0.0001	1096

5.1.6 Summary of Water Quantity Results

For 2005, temporal patterns of average daily stream flow and stage were similar across all stations, with the majority of high flows and stages occurring during the rainy season (June through September), but with some additional heavy spring rains. Mosaic's NPDES-permitted discharges upstream of HCSW-1 exhibited a similar pattern, contributing more water to Horse Creek during wet periods than dry. Rainfall and discharge in 2005 were within historical ranges for the region, (Durbin and Raymond 2006).

5.2 WATER QUALITY

The results of field measurements and laboratory analyses of water samples obtained monthly from April 2003 through December 2005 at each HCSP monitoring station are presented below. Continuous recorder data for pH, dissolved oxygen, turbidity, and specific conductivity are also presented, along with the field measurements obtained during benthic macroinvertebrate and fish sampling on 15 February, 21 April, 15 September, and 15 December 2005. Water quality raw data are included in a database on the attached CD-ROM.

Line graphs are used to display water quality measurements for each parameter, but the lines connecting each station's measurements are included merely to enhance visual interpretation and not to imply that the values between actual measurements are known. For continuous recorder data measured at HCSW-1 in 2005, the daily mean is plotted with high-low lines representing the daily minimum and maximum. Monthly water quality data for 2003–2005 were compared to other data sources (SWFWMD, FDEP, USGS) for the last decade using median box-and-whisker plots. Graphical representations of HCSP data include undetected values, represented by the respective MDLs for each parameter, except for total nitrogen, total radium, FL-PRO, fatty acids, and amines. Because so many of the results for FL-PRO, fatty acids, and amines were undetected, we chose to display only the detected values for clarity. Total nitrogen and total radium are composite parameters without MDLs. Values of these parameters for which one or both components were undetected are circled in red. Undetected results for all parameters were removed from any statistical analyses.

Trend analysis for HCSP water quality data is not specifically addressed in this report because only three years of HCSP monitoring data have been collected. We have, however, compared the HCSP data with historical sources of data in the region over the last decade. We have used the non-parametric Kendall Tau correlation procedure to examine water quality annual medians over time for monotonic trends. Differences in methodology or sampling frequency between the HSCP and other agencies make comparisons over time exploratory, and any trends we find are tentative pending more HCSP data collection.

Differences in water quality between stations for each water quality parameter were evaluated using ANOVA and Duncan's post hoc test. This analysis will help to identify potential differences among stations that can be examined in more detail as the HCSP continues. Water quality parameters were also correlated with daily streamflow and/or total monthly rainfall using Pearson's or Spearman's correlation coefficient. All statistics calculated for this report represent exploratory analyses.

Water quality of NPDES discharge was obtained periodically when water was discharged from Outfalls 003 and 004. A summary of water quality for these outfalls during 2005 is presented in Table 13. Water quality at the outfalls in 2005 reached or exceeded the HCSP trigger values for only two parameters: dissolved oxygen at Outfall 004 and chlorophyll a at Outfall 003 (1 value).

Table 13. Water quality summary of NPDES discharge into Horse Creek during 2005 at Outfalls 003 and 004.

	2005							
	Outfall 003 (June-July)				**Outfall 004 (Mar - August)**			
Constituent	Avg	Count	Min	Max	Avg	Count	Min	Max
pH (su)	7.57	5	7.14	8.22	6.73	17	6.40	7.78
Conductivity (umhos/cm)	404	5	365	429	402	17	370	444
Temperature (degrees C)	31.1	5	29	33.6	26.6	17	18.7	33.7
Turbidity (NTU)	5.6	5	3.0	7.1	4.3	16	1.5	7.4
Dissolved Oxygen (mg/L)	6.43	4	5.2	7.4	5.4	12	**4.1**	7.6
TSS	4.8	5	3.0	6.8	1.9	16	0.8	5
Fixed Suspended Solids	2.3	4	1.0	5.2	2.3	16	1	5
Total Phosphorus (mg/L)	0.36	5	0.02	0.51	0.13	16	0.05	0.29
TKN (mg/L)	0.75	5	0.56	0.9	0.67	16	0.35	1.1
Nitrate-Nitrite (mg/L)	0.08	5	0.01	0.15	0.08	16	0.01	0.13
Total Nitrogen (mg/L)	0.83	5	0.71	0.98	0.74	16	0.47	1.11
Fluoride (mg/L)	0.86	2	0.78	0.93	0.94	3	0.6	1.3
Sulfate (mg/L)	51	2	41	61	0.6	3	110	130
Chlorophyll *a* (mg/m^3)	**57**	1	**57**	**57**	1.3	3	1	18

5.2.1 Physio-Chemical Parameters

Levels of pH, dissolved oxygen, and turbidity were obtained in the field during each monthly water-quality sampling event. Values of pH were within the range of established trigger levels during most 2005 sampling events at all stations (Figure 15). The lower trigger level for pH was exceeded once at HCSW-3 in July 2005, and was also low in June 2005, near the beginning of the wet season. The pH levels increased by August 2005, to again be within the trigger levels. Values obtained during biological sampling events were consistent with pH levels determined during the monthly water quality sampling events, except at HCSW-2, where biological sampling occurs at a point upstream of monthly sampling with lower flow (Figure 15). The pH levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (FDEP, SWFWMD, USGS) and exhibited no monotonic trend over the last decade (Kendall Tau of annual median pH, $p > 0.05$) (Figures 16 and 17).

Continuous pH data obtained daily at HCSW-1 from April to December was within a range similar to that obtained during monthly water quality sampling (Figure 18), but continuous recorder values obtained in January through March 2005, during very low flows, were lower than monthly samples. Mean daily continuous pH values at HCSW-1 were within the range of the trigger levels, except during exceptionally low values recorded during January – March 2005. (Figure 19). The lowest values from the continuous pH recorder were measured from January – February 2005, when rainfall and flow were minimal. The continuous recorder was removed for repair in March – April 2005.

Levels of pH were significantly different among stations over 2003 – 2005 (ANOVA $F = 7.3$, $p = 0.0002$). Station HCSW-2, which had significantly lower pH than other stations (Duncan's multiple range-test, $p < 0.05$), lies just downstream of a large swamp complex that has the potential to add substantial organic acids from plant decomposition and will tend to decrease the pH (Reid and Wood 1976). Levels of pH were not significantly correlated with streamflow at HCSW-1 (Spearman's rank correlation, $r = -0.17$), but were negatively correlated with streamflow at HCSW-4 (Spearman's rank correlation, $r = -0.37$, $p < 0.05$).

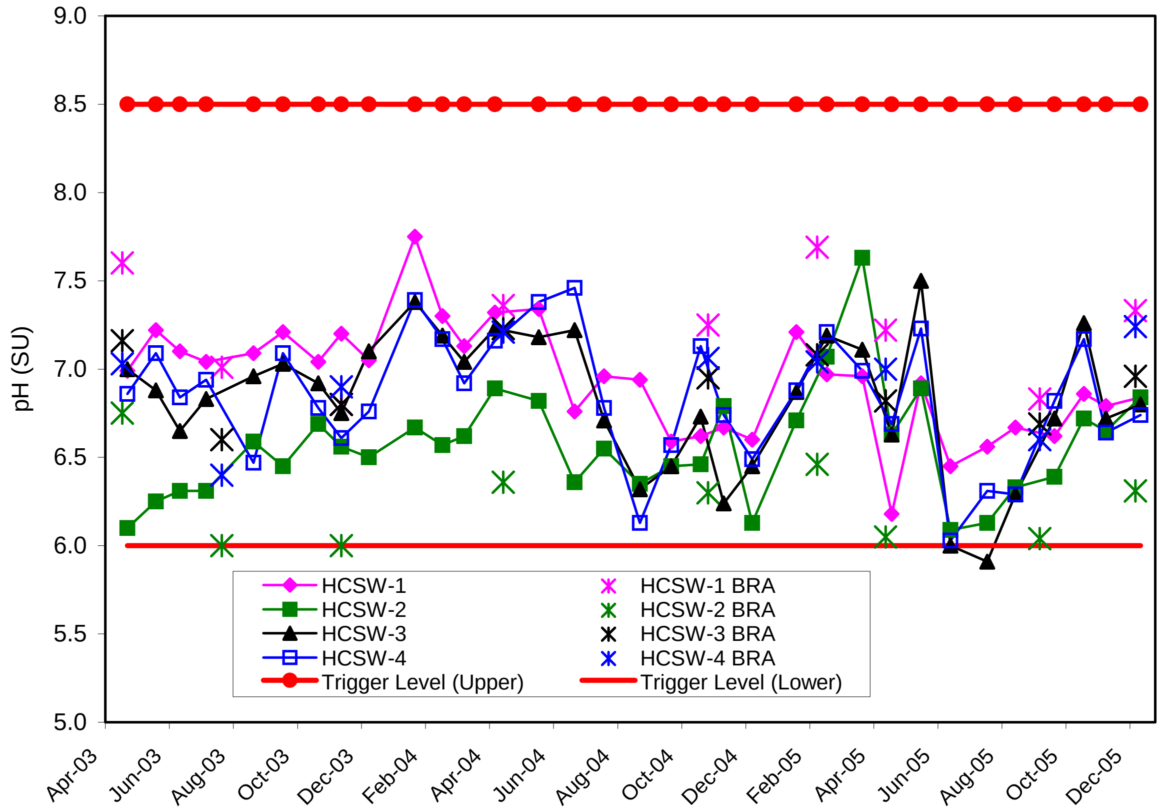

Figure 15. Values of pH Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2003 - 2005. Minimum Detection Limit = 1 su.

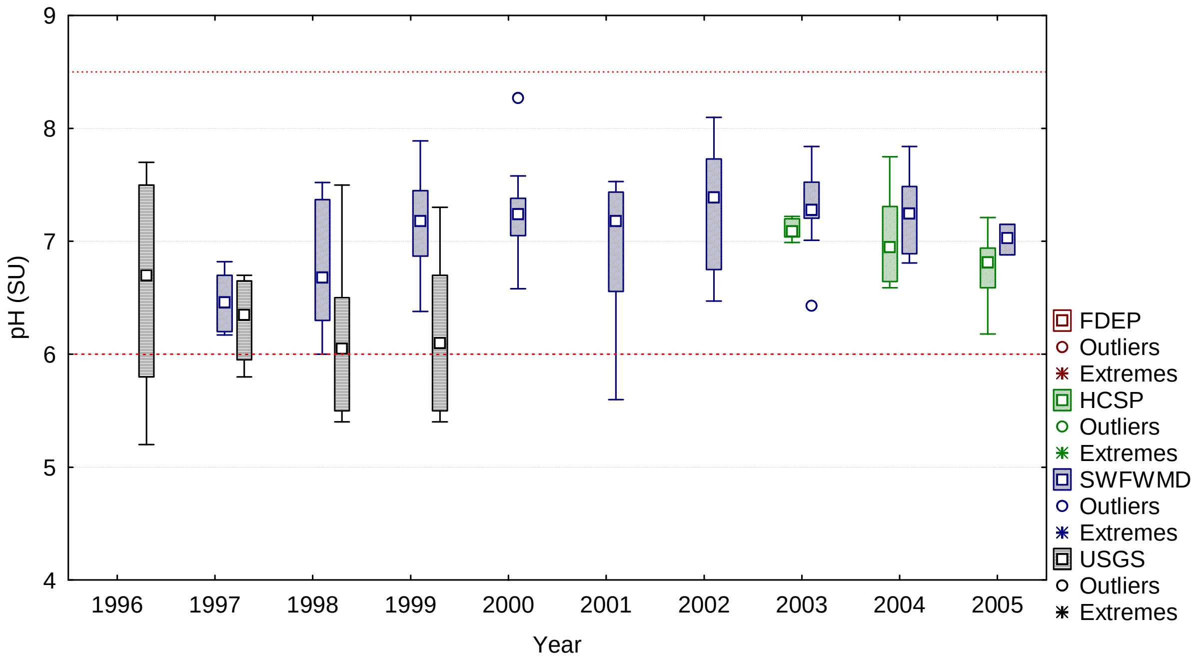

Figure 16. HCSW-1 Values of pH Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

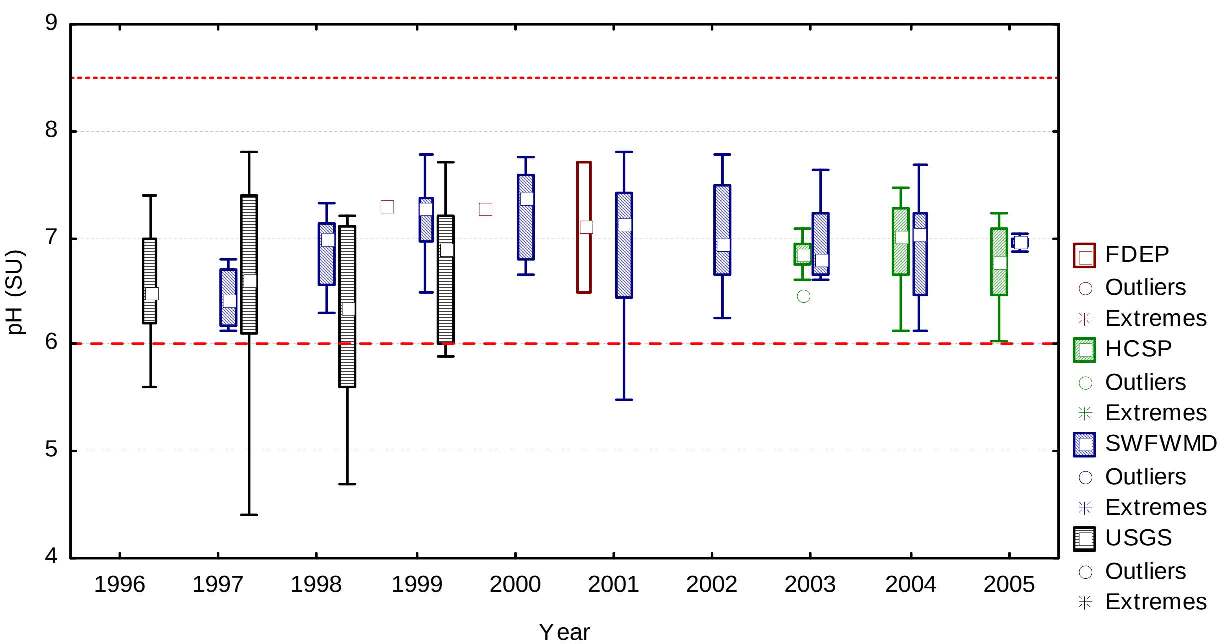

Figure 17. HCSW-4 Values of pH Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

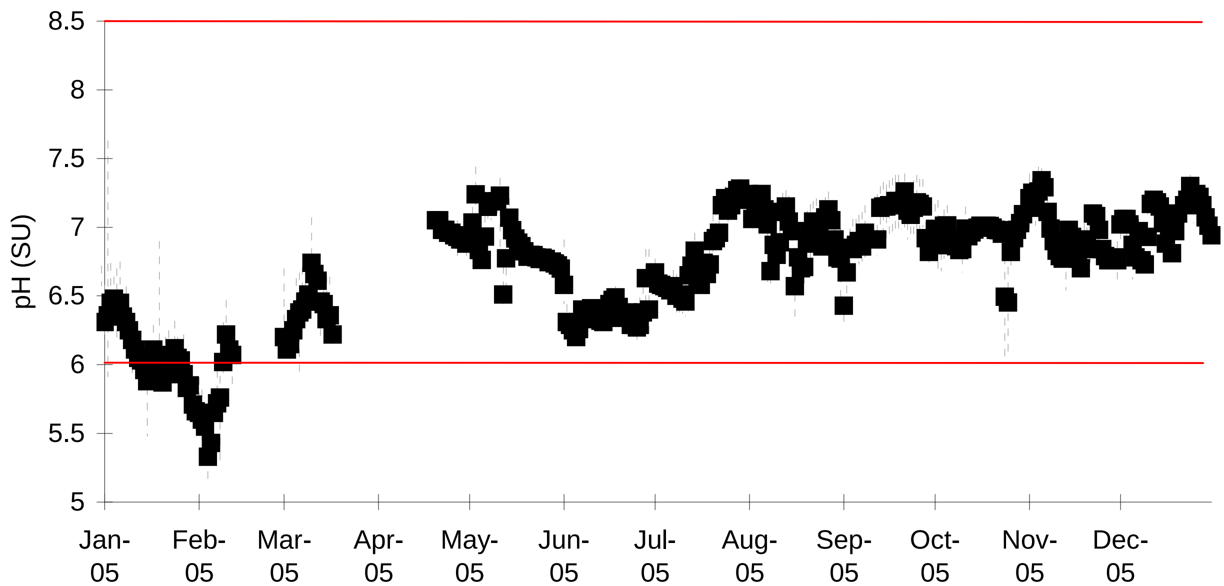

Figure 18. Daily Mean pH (With Daily Min. and Max. pH as Grey-Dashed High-Low Lines) Obtained from the Continuous Recorder at HCSW-1 for 2005. Minimum Detection Limit = 1 su. Red Lines are HCSP Trigger Values.

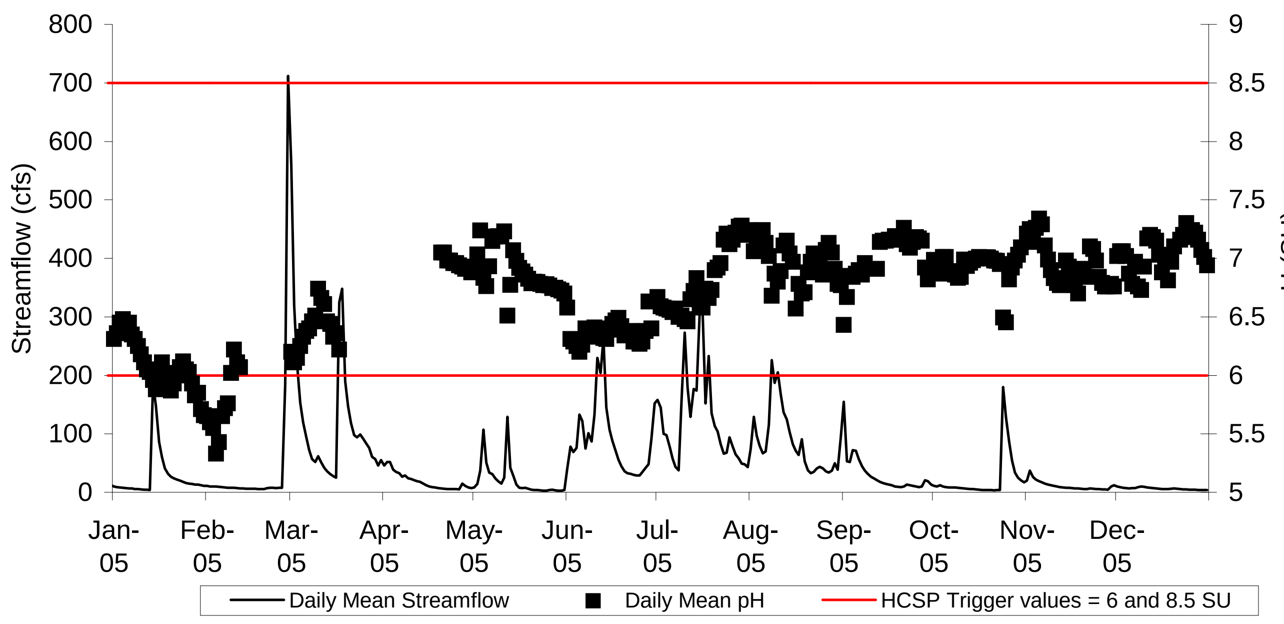

Figure 19. Relationship Between Daily Mean pH (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2005. Minimum pH Detection Limit = 1 su.

Dissolved oxygen (DO) concentrations were above the trigger level and Class III Standard of 5.0 mg/l (indicating desirable conditions) during sampling events in most of 2005 at HCSW-1, HCSW-3, and HCSW-4 (Figure 20). However, levels of DO were consistently below 5.0 mg/l at HCSW-2; this station is just downstream of the Horse Creek Prairie, a blackwater swamp that typically has low DO concentrations. In addition, DO was below the trigger value at three of the four stations in June and July 2005, and at two of the four stations in August 2005, corresponding to times of high streamflow and high temperatures**.** DO was also below the trigger level during the August and September 2004, corresponding to the time that Hurricane Charley brought high rainfall, runoff, and organic debris to Horse Creek.

Dissolved oxygen was negatively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation $r = -0.57$, and $r = -0.67$, respectively, $p < 0.05$). Dissolved oxygen was also negatively correlated with total monthly rainfall at HCSW-1 and HCSW-4 (Spearman's rank correlation $r = -0.55$, and $r = -0.63$, respectively, $p < 0.05$). During times of high streamflow in the wet season, higher temperatures in the stream drive down the oxygen saturation. The DO levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median DO, $p > 0.05$) (Figures 21 and 22). Levels of dissolved oxygen were significantly different among stations in 2003 - 2005 (ANOVA, $F = 47.7$, $p < 0.0001$), with HCSW-2 significantly lower than other stations (Duncan's multiple range test, $p < 0.05$).

DO concentrations at HCSW-1, HCSW-3, and HCSW-4 obtained during biological sampling events were consistent with those found during the monthly water quality sampling (Figure 20). The continuous DO concentrations obtained at HCSW-1 occasionally fell below the trigger level during the summer months when the water's potential for holding DO is low, which is not unexpected for a stream of this type in peninsular Florida (Figure 23). Usually, only minimum daily DO was below the trigger level, but the mean daily DO concentration was also below the trigger value during parts of the wet season, especially during June and July 2005 (Figure 24). The continuous recorder DO probe was non-functional during February and was removed for repair in March – April 2005.

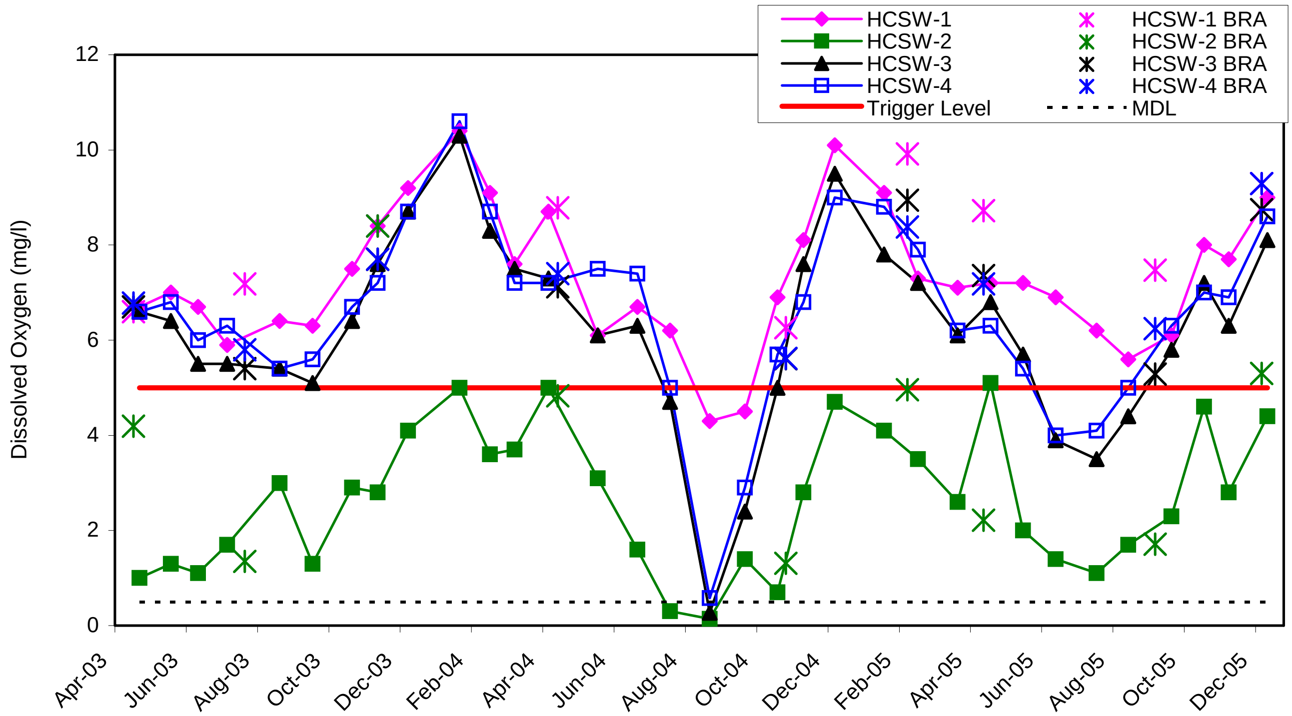

Figure 20. Dissolved Oxygen Levels Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2003 - 2005.

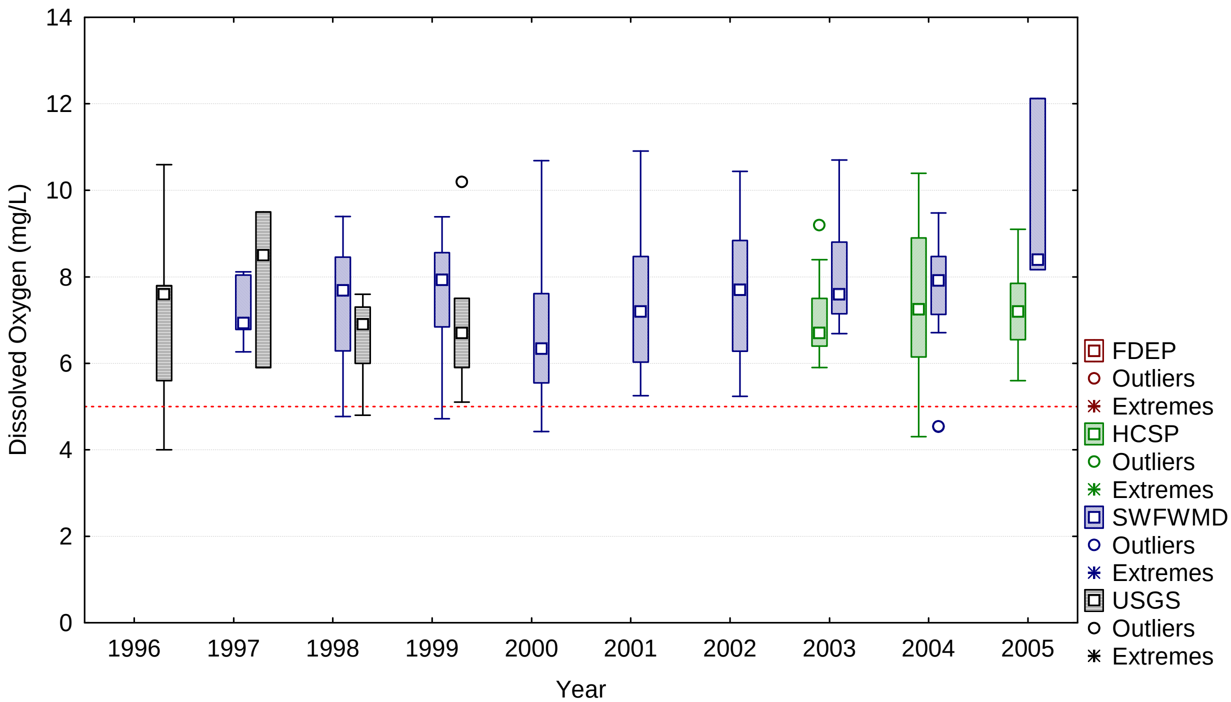

Figure 21. HCSW-1 Values of Dissolved Oxygen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

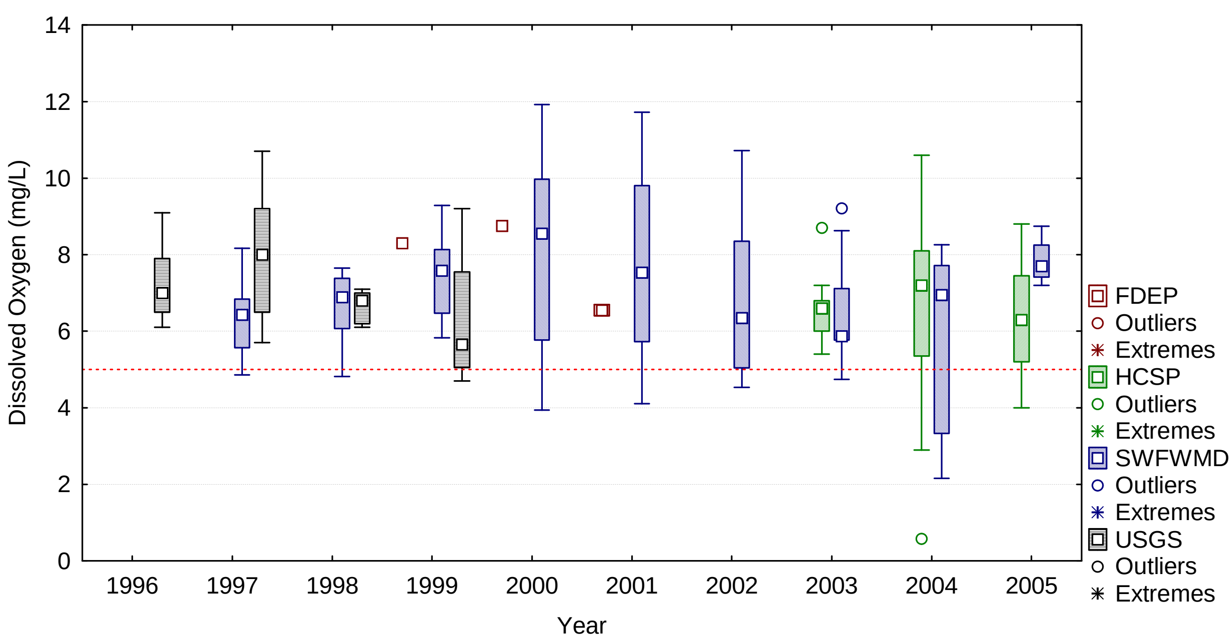

Figure 22. HCSW-4 Values of Dissolved Oxygen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

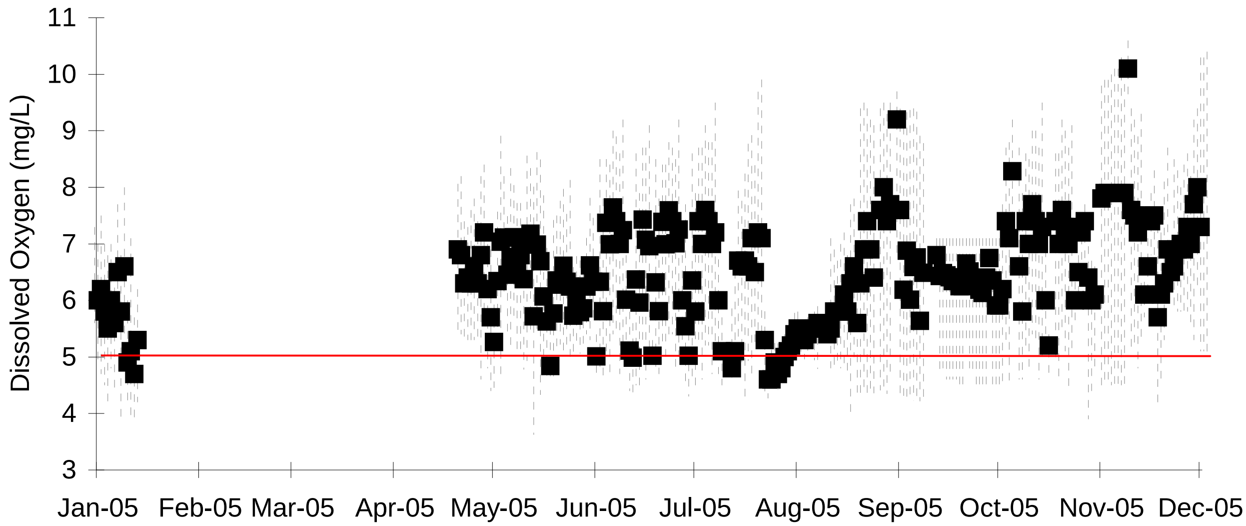

Figure 23. Daily Mean Dissolved Oxygen (With Daily Minimum and Maximum as Grey-Dashed High-Low Lines) Obtained From the Continuous Recorder at HCSW-1 for 2005. Minimum Detection Limit = 0.5 mg/L). The Red Line is the HCSP Trigger Value.

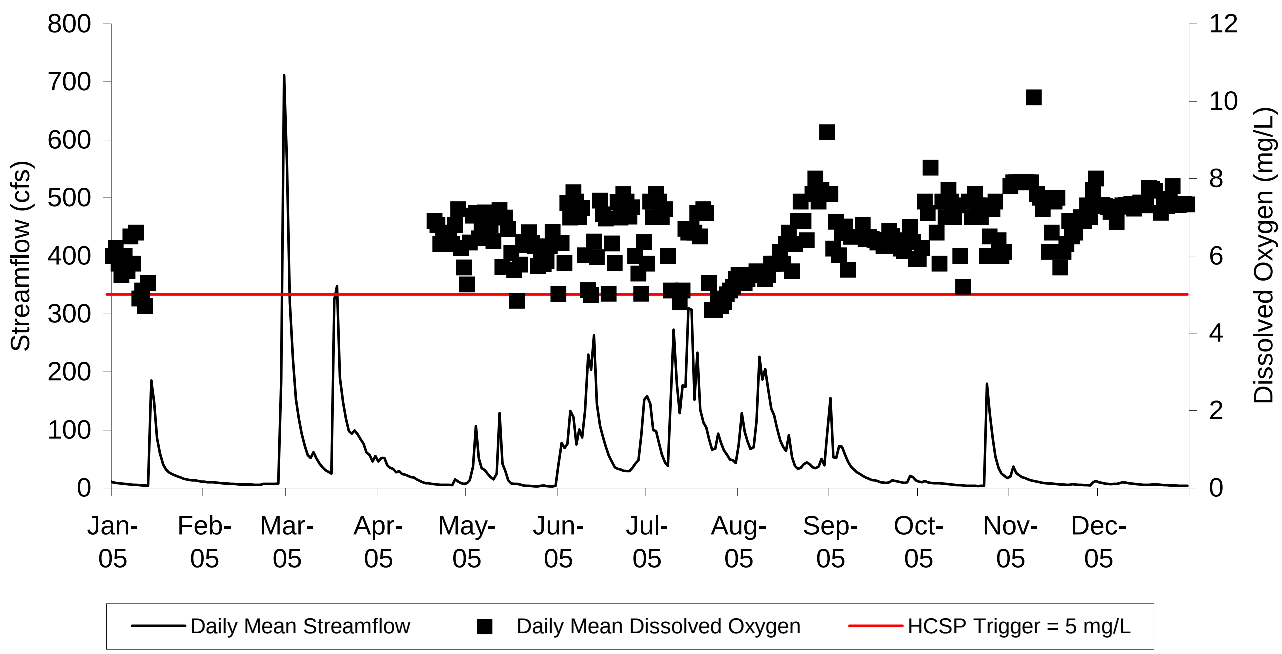

Figure 24. Relationship Between Daily Mean DO (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2005. Minimum DO Detection Limit = 5.0 mg/L.

Turbidity levels as measured monthly were not significantly different among stations in 2003 - 2005 (ANOVA, $F = 0.5$, $p = 0.68$) (Figure 25). Turbidity levels obtained during biological sampling events were similar to those found during monthly water quality sampling events. Turbidity levels at all stations in 2005 were below the trigger level and Class III Surface Water Quality Standard of 29 nephelometric turbidity units (NTUs). The turbidity levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median turbidity, $p > 0.05$) (Figures 26 and 27). Turbidity was weakly correlated with streamflow at HCSW-1 (Spearman's rank correlation r = 0.42, $p < 0.05$), but not at HCSW-4.

The continuous recorder data for HCSW-1 indicated that turbidity levels occasionally were higher than those obtained during the monthly water quality sampling events, but the trigger level was only exceeded once in 2005, in November (Figure 28). High values for continuous turbidity were measured when rainfall was extremely high (Hurricane Charley in 2004) or when rainfall was low. Dry conditions may increase the turbidity of the stream (Figure 29). Perhaps during dry spells, cattle may be more prone to wade in the stream, thereby making it more turbid in the vicinity of the recording unit. The continuous recorder was removed for repair in March – April 2005.

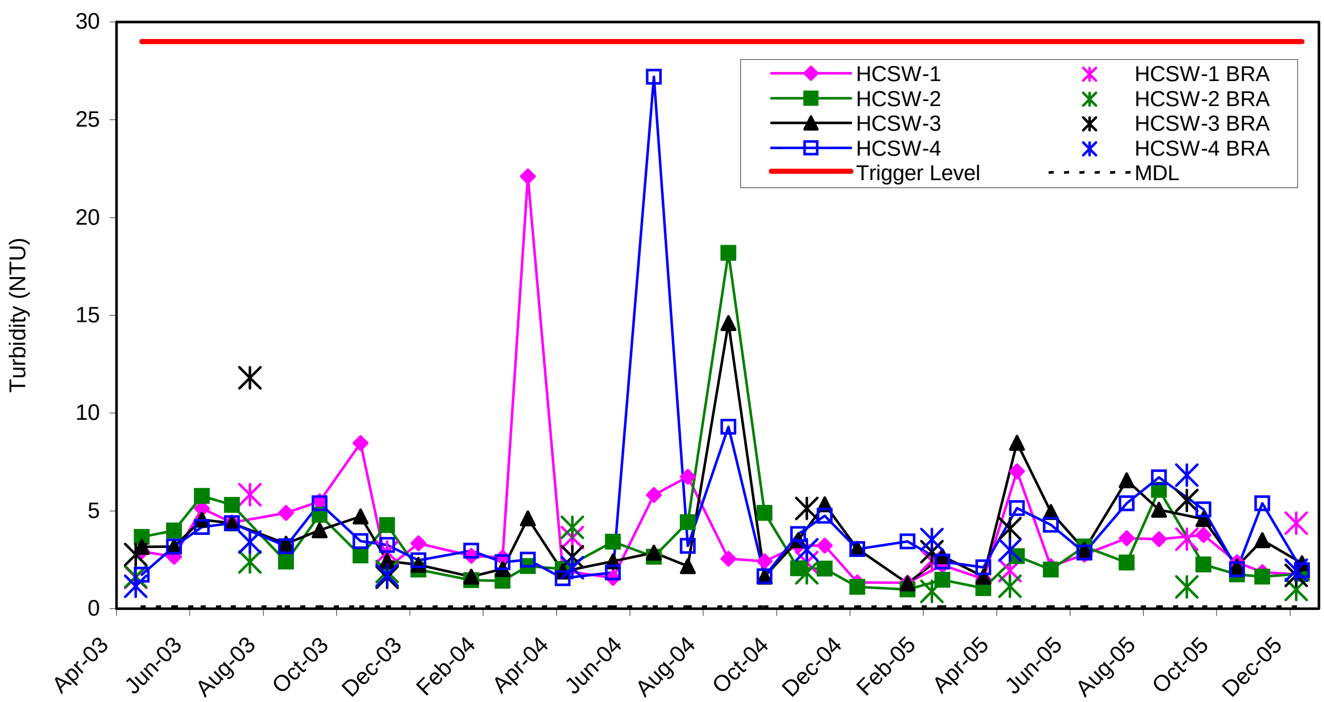

Figure 25. Turbidity Levels Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2003 – 2005.

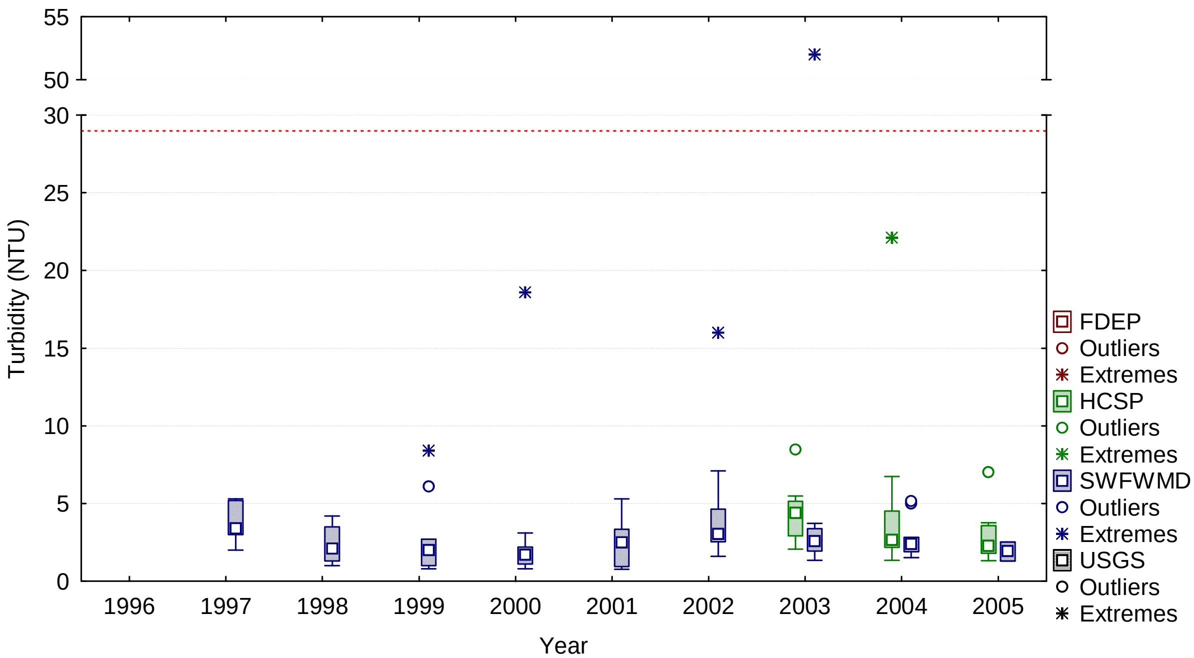

Figure 26. HCSW-1 Values of Turbidity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

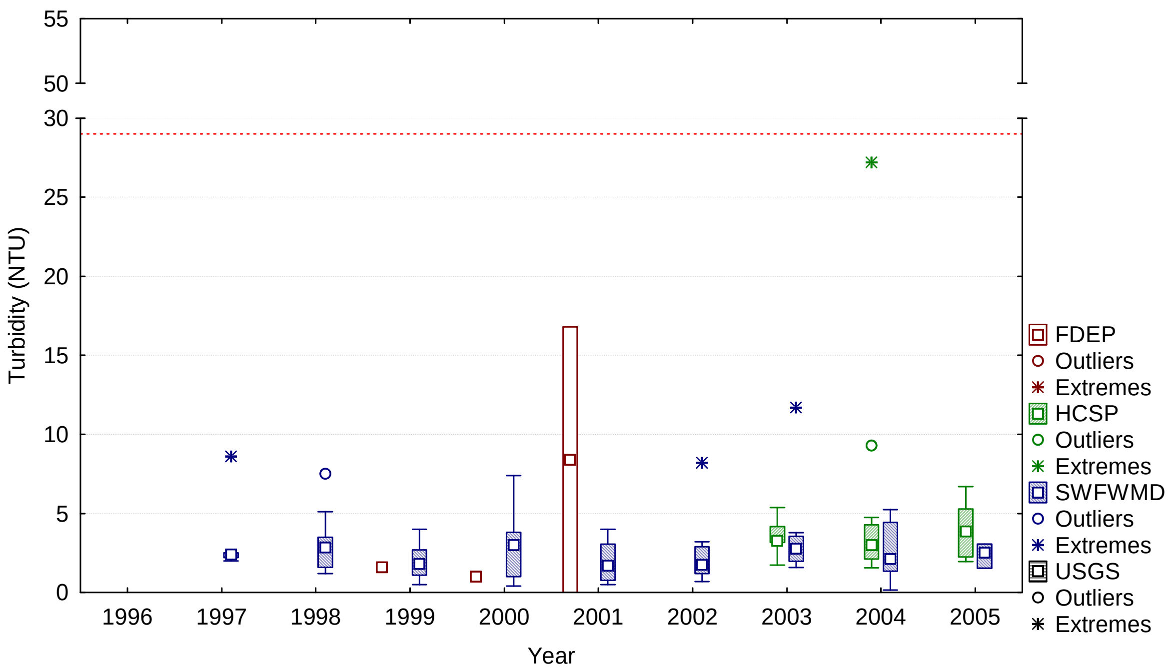

Figure 27. HCSW-4 Values of Turbidity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

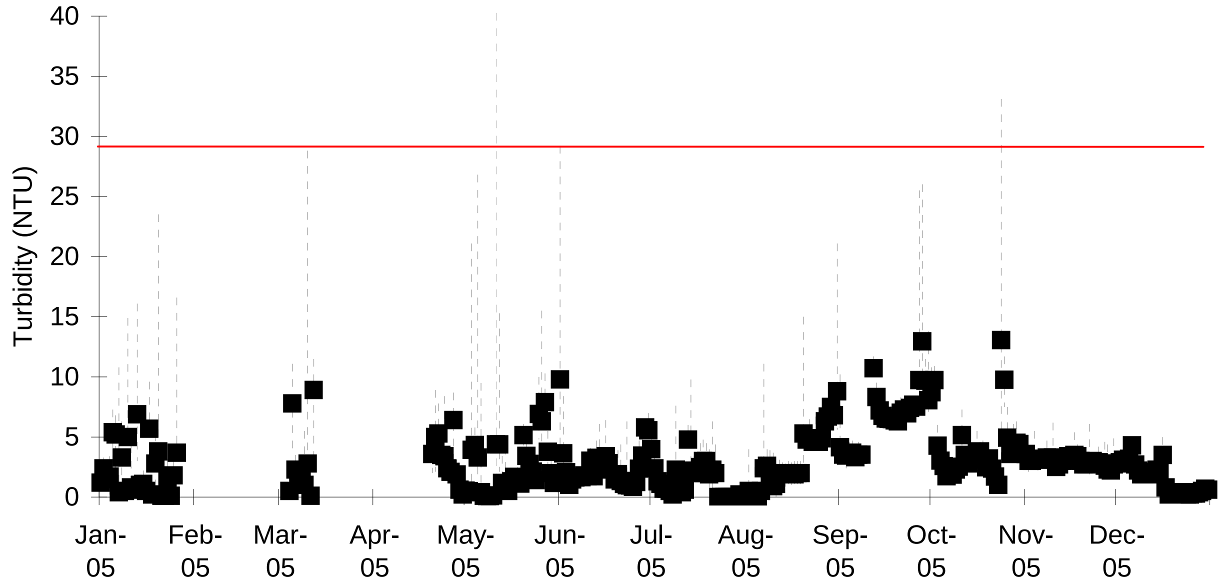

Figure 28. Daily Mean Turbidity (With Daily Minimum and Maximum as Grey-Dashed High-Low Lines) Obtained From the Continuous Recorder at HCSW-1 for 2005. Minimum Detection Limit = 0.1 NTU). The Red Line is the HCSP Trigger Value.

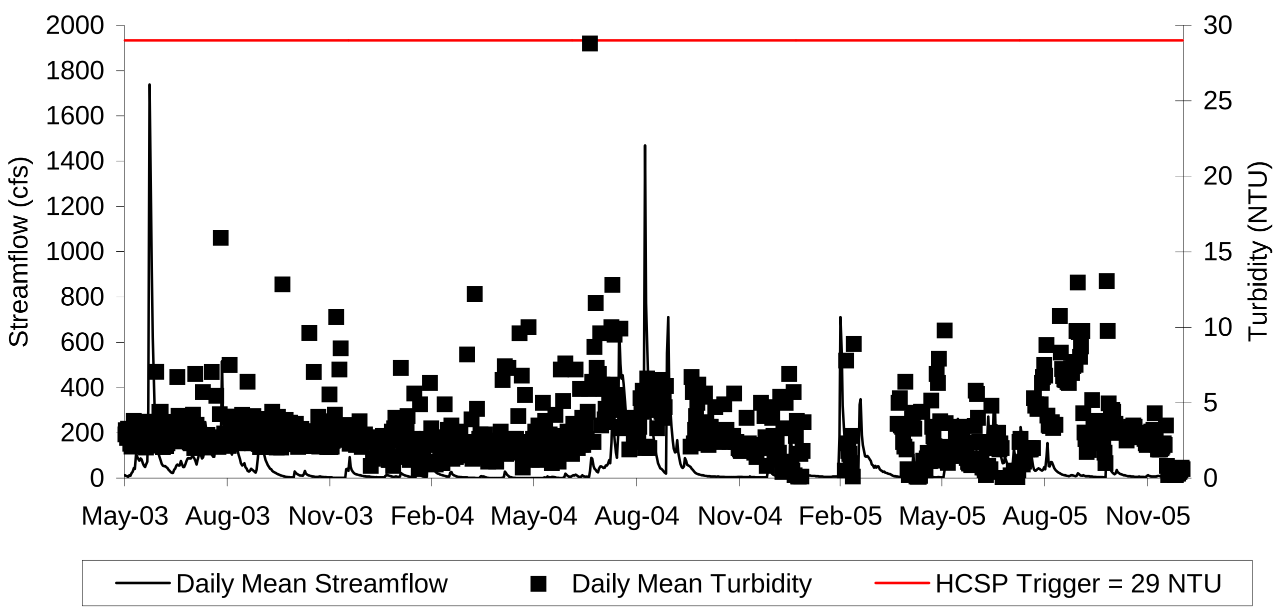

Figure 29. Relationship Between Daily Mean Turbidity (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2003 - 2005. Minimum pH Detection Limit = 0.1 NTU.

All color values in 2005 were above the trigger level of 25 Platinum-Cobalt units (PCU) (indicating desirable conditions) during all events at all stations (Figure 30). Color was significantly correlated with streamflow at both HCSW-1 (Spearman's $r = 0.43$, $p < 0.05$) and HCSW-4 (Spearman's $r = 0.73$, $p < 0.05$). Color was also significantly correlated with rainfall at HCSW-4 (Spearman's $r = 0.48$, $p < 0.05$), but not HCSW-1. Color levels were not significantly different among stations in 2003 - 2005 (ANOVA, $F = 1.6$, $p = 0.17$). The similar pattern among the stations, with higher color in the summer months and lower levels in the winter months, suggest that color is affected by the differential inputs of surface water and groundwater seepage. During the wet season when surface flows from wetland areas are highest, the transport of tannins to Horse Creek adds more color to the water (Reid and Wood 1976). This is very evident during and after Hurricane Charley in 2004 (Figure 30). As the dry season begins, groundwater seepage provides a proportionally higher contribution of clearer water to Horse Creek, thereby decreasing the color of the water. It is likely that agricultural irrigation return flows also have some impact on color in the stream by introducing clearer water during the drier parts of the year. This agricultural factor is also noted below with respect to several other parameters. Low rainfall in most months in 2005 may help explain why color levels are lower than in 2003 and 2004. The color levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median color, $p > 0.05$) (Figures 31 and 32).

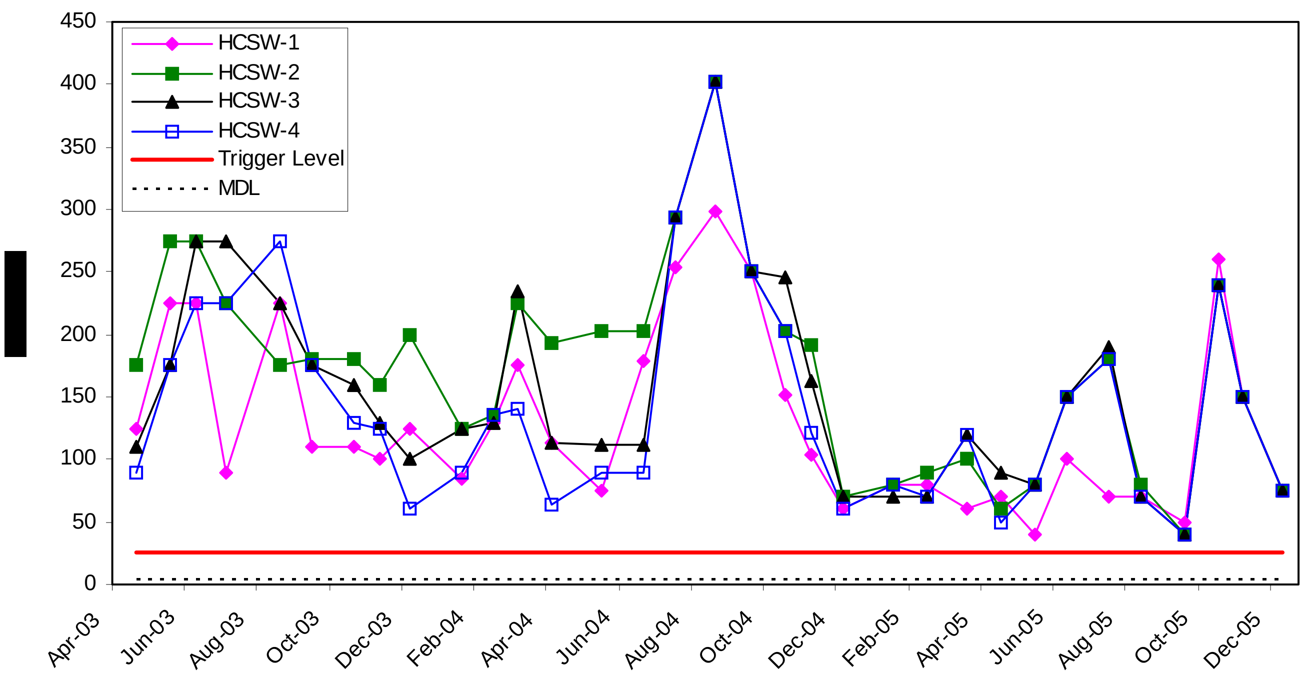

Figure 30. Color Levels Obtained During Monthly HCSP Water Quality Sampling in 2003 – 2005.

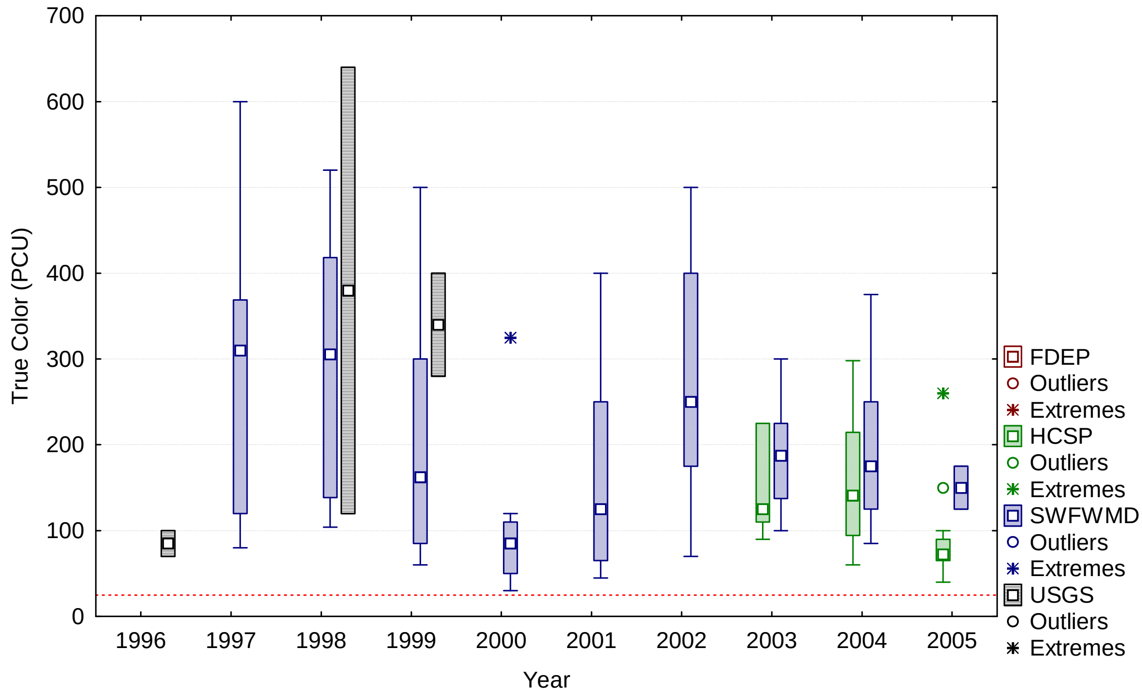

Figure 31. HCSW-1 Values of Color Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

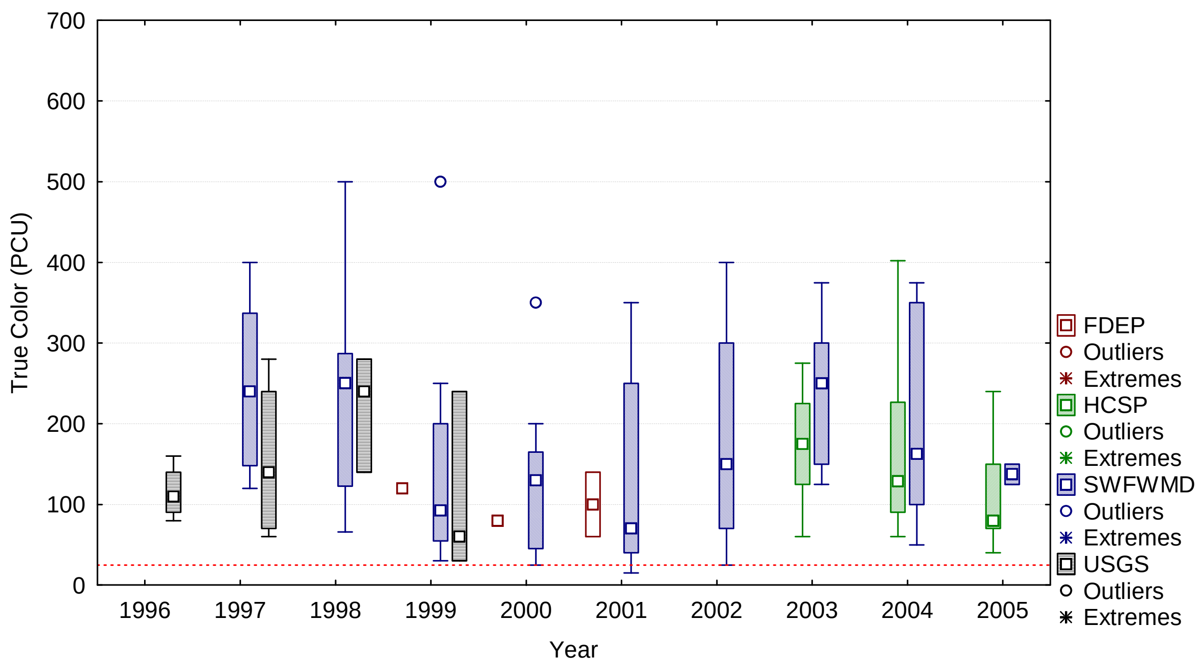

Figure 32. HCSW-4 Values of Color Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

5.2.2 Nutrients

Total nitrogen[2] concentrations were between 0.5 and 1.5 mg/l during most sampling events at all stations in 2005 (Figure 33). During 2005, total nitrogen was consistently below the trigger value of 3.0 mg/l. The major component of total nitrogen in nearly all samples was organic nitrogen. Nitrogen concentrations in surface waters may increase during times of extremely high rainfall when plant debris, animal waste, and other nitrogen sources are washed into streams with force (Reid and Wood 1976). During and after Hurricane Charley in 2004, total nitrogen, and TKN concentrations rose in the basin as debris was washed into the stream.

Overall, nitrogen was not correlated with stream discharge at HCSW-1 or HCSW-4. Total nitrogen concentrations were significantly different among stations for 2003 – 2005 (ANOVA, F = 3.72, p = 0.01), with concentrations increasing from upstream to downstream (Duncan's multiple range test, HCSW-1 and HCSW-2 lower than HCSW-4, with HCSW-3 indistinct from both groups). The total nitrogen concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median TN, p > 0.05) (Figures 34 and 35).

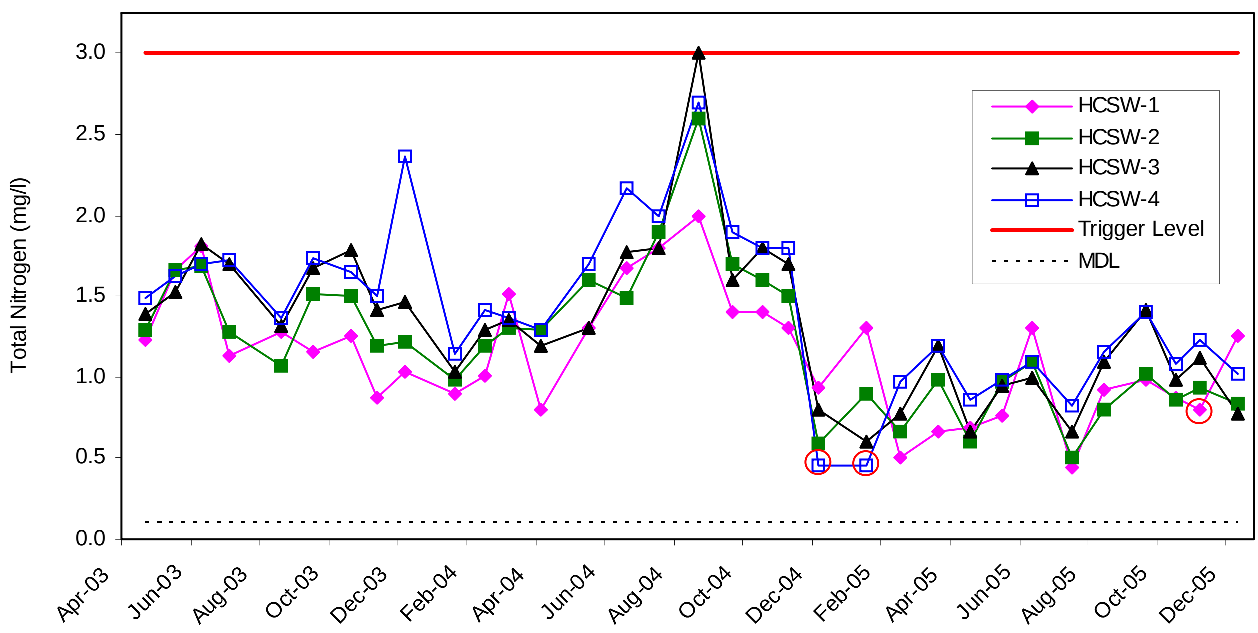

Figure 33. Total Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 – 2005. (Samples with undetected TKN or Nitrate+nitrite are circled in red.)

[2] Total nitrogen is calculated as the arithmetic sum of TKN and nitrate+nitrtite. As requested by the PRMRWSA, if either TKN or nitrate+nitrite is undetected, the MDL of the undetected constituent will be used as part of the total nitrogen calculation. Note that this use of MDL for undetected constituents is inconsistent with typical laboratory and DEP SOPs and may result in artificially high estimates of total nitrogen.

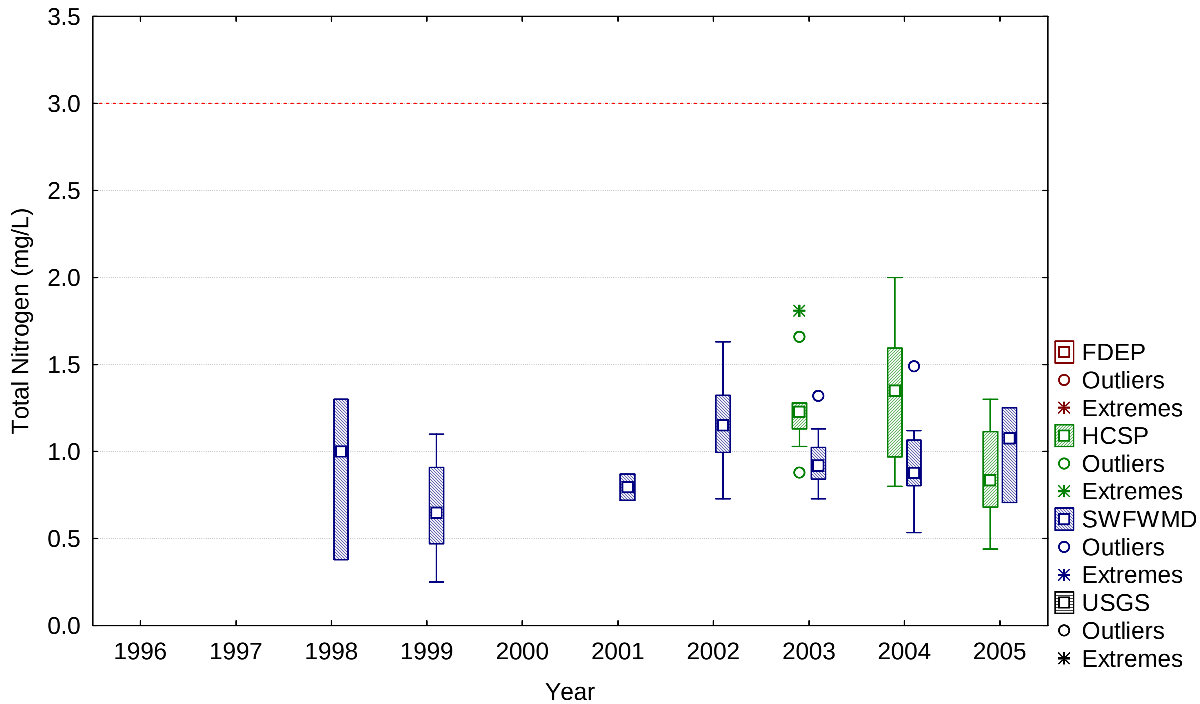

Figure 34. HCSW-1 Values of Total Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

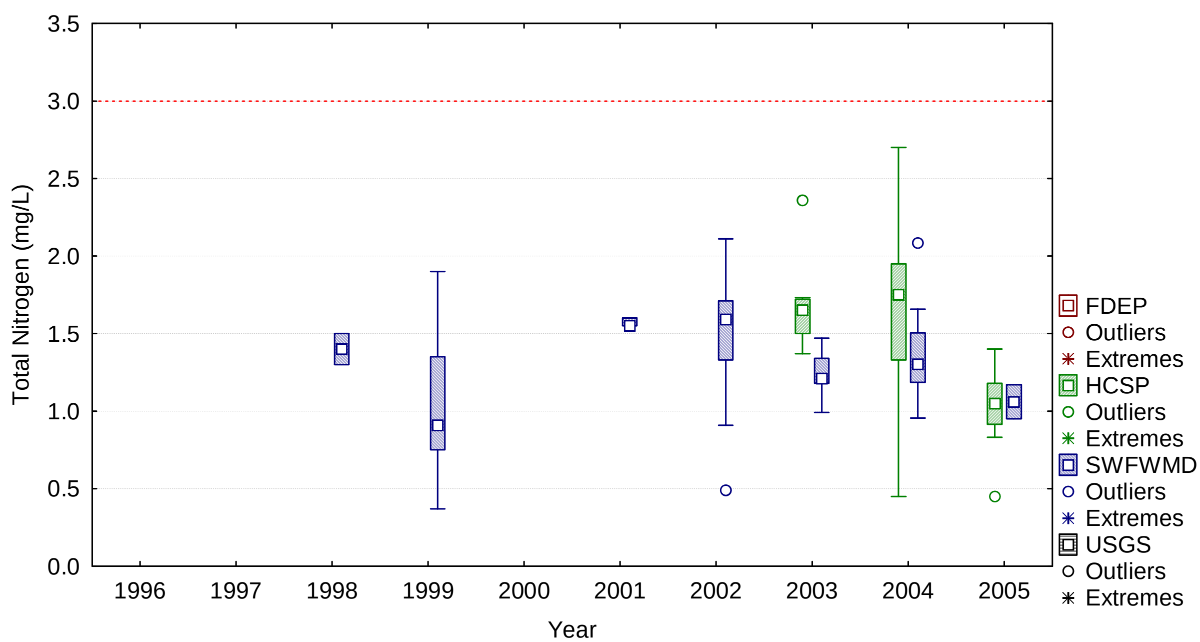

Figure 35. HCSW-4 Values of Total Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

As noted above, total Kjeldahl nitrogen (TKN) comprised the majority of total nitrogen in most samples (Figure 36, compare with Figure 33). The HCSP does not have an independent trigger value for TKN. Concentrations of TKN were not significantly different among stations (ANOVA, F = 0.57, p = 0.63). Streamflow and TKN concentration were not significantly correlated at HCSW-1, but were weakly correlated at HCSW-4 (Spearman's r = 0.54, p < 0.05). Rainfall was also positively correlated with TKN at HCSW-4 (Spearman's r = 0.41, p < 0.05). The total Kjeldahl nitrogen concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median TKN, p > 0.05) (Figures 37 and 38).

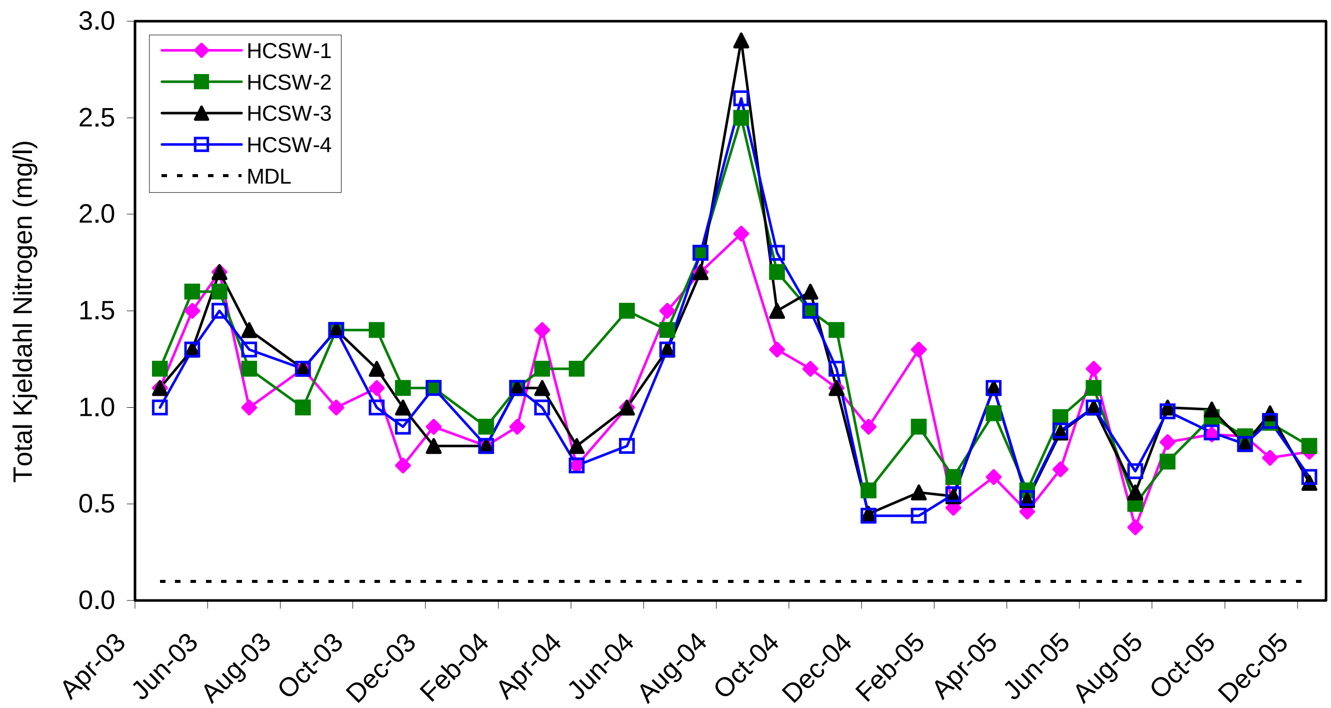

Figure 36. Total Kjeldahl Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005.

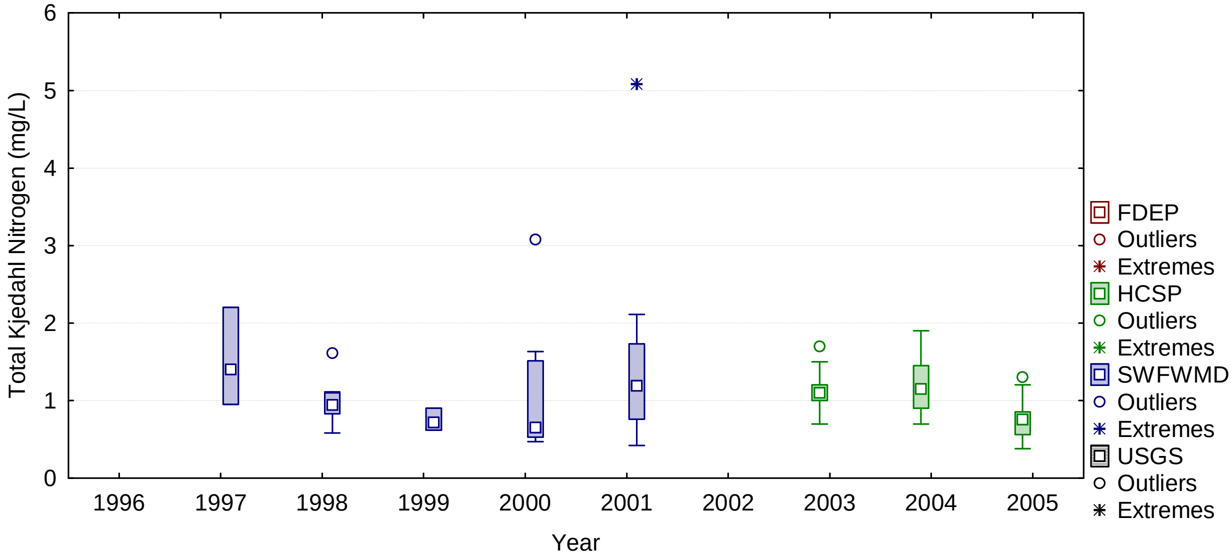

Figure 37. HCSW-1 Values of Total Kjeldahl Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

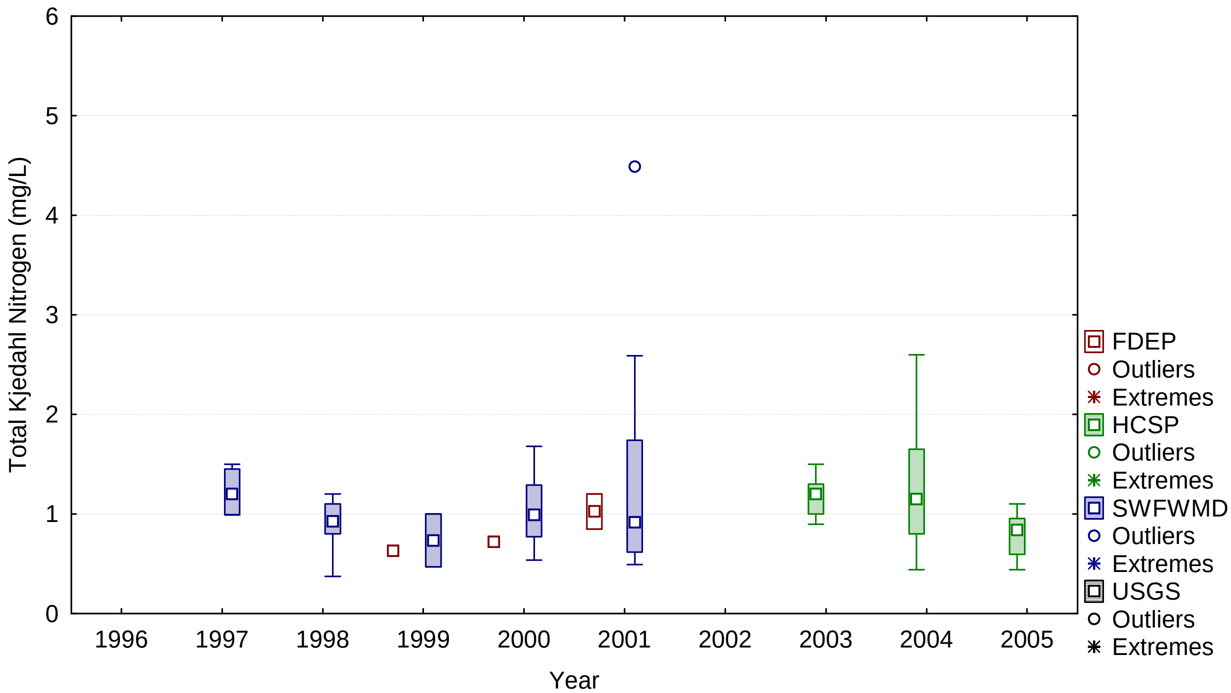

Figure 38. HCSW-4 Values of Total Kjeldahl Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

Nitrate+nitrite nitrogen levels were significantly different among stations for 2003 – 2005 (ANOVA, F = 23.6, $p < 0.0001$), with concentrations lower at HCSW-1 and HCSW-2 and higher at HCSW-3 and HCSW-4 (Duncan's multiple range test, $p < 0.05$) (Figure 39). Nitrate+nitrite levels were highest during times of low stream flow at HCSW-4 (Spearman's rank correlation r = -0.75, $p<0.05$), but not at upstream sites where groundwater seepage is less likely. Nitrate+nitrite levels were highest during times of low rainfall at both HCSW-1 (Spearman's rank correlation r = -0.47, $p<0.05$) and HCSW-4 (Spearman's rank correlation r = -0.61, $p<0.05$). The HCSP does not have an independent trigger value for nitrate-nitrite nitrogen. The nitrate+nitrite concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median nitrate+nitrite, $p > 0.05$) (Figures 40 and 41).

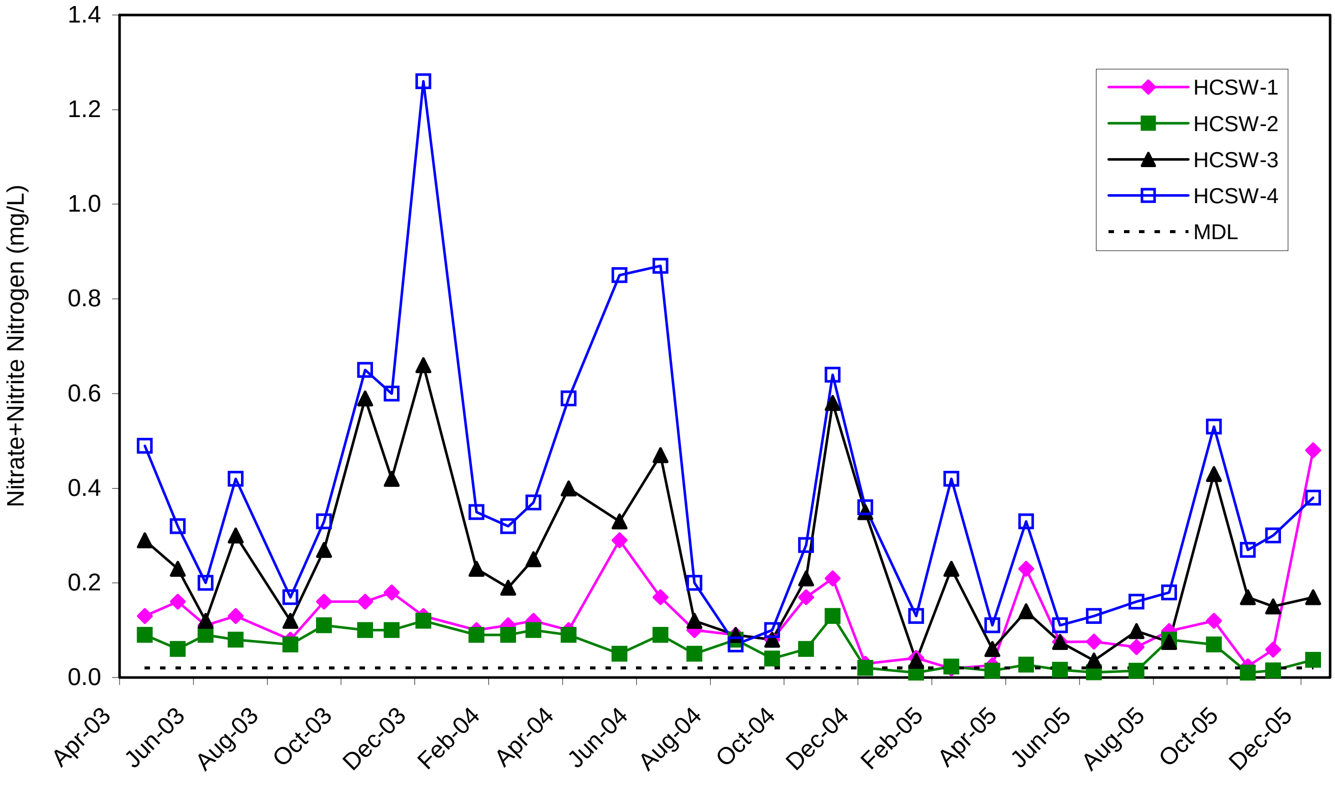

Figure 39. Nitrate-Nitrite Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005.

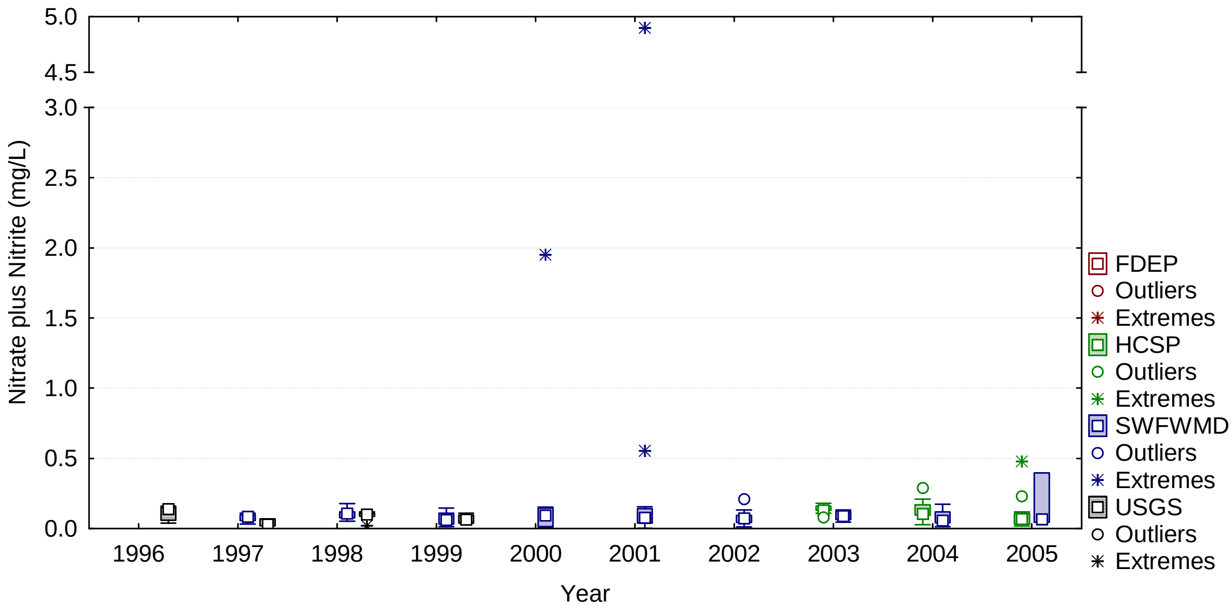

Figure 40. HCSW-1 Values of Nitrate plus Nitrite Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

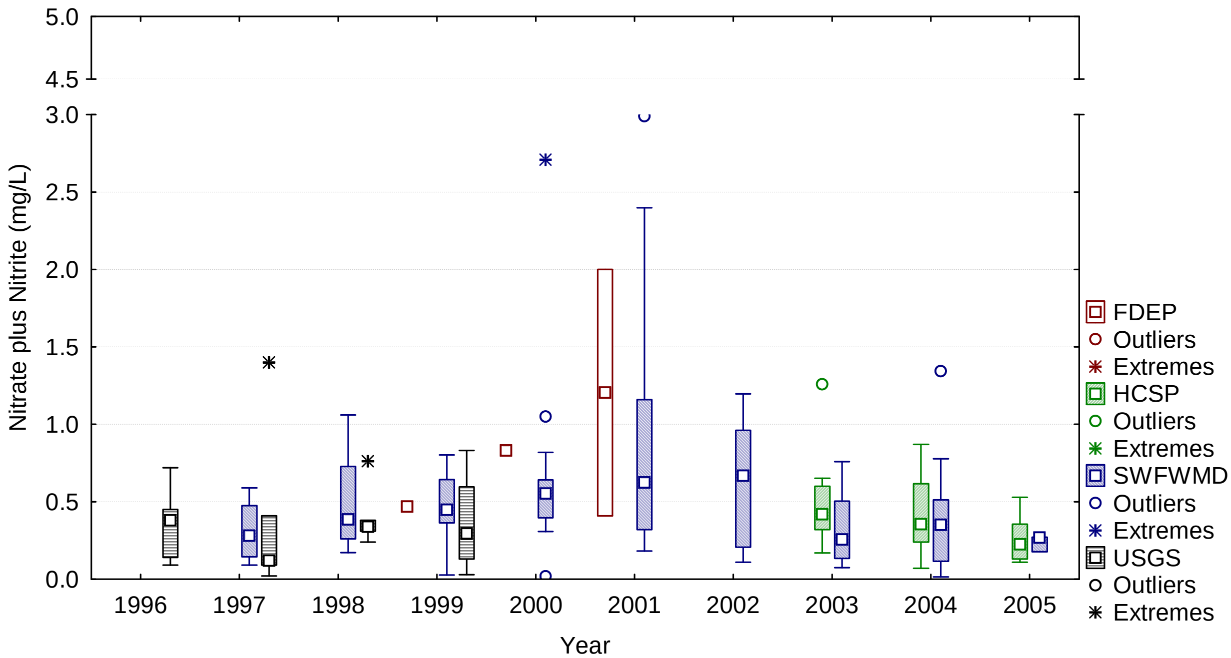

Figure 41. HCSW-4 Values of Nitrate plus Nitrite Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

Total ammonia nitrogen levels were within a similar range during all sampling events at all stations (ANOVA, F = 1.26, p = 0.29) (Figure 42). Ammonia levels were below 0.15 mg/L in 2005, which is well below the HCSP trigger value of 0.3 mg/L. The ammonia concentrations at HCSW-1 and HCSW-4 measured by the HCSP are notably higher than other water quality data sources for the same time period, but are at levels within the range for the last decade of data (Figures 43 and 44). Ammonia at HCSW-4 exhibited no monotonic trend over the last decade (Kendall Tau of annual median ammonia, p > 0.05), but may be increasing over time at HCSW-1 (Kendall Tau = 0.47, p = 0.36). Ammonia was not correlated with streamflow at HCSW-1 or HCSW-4, where streamflow data was available.

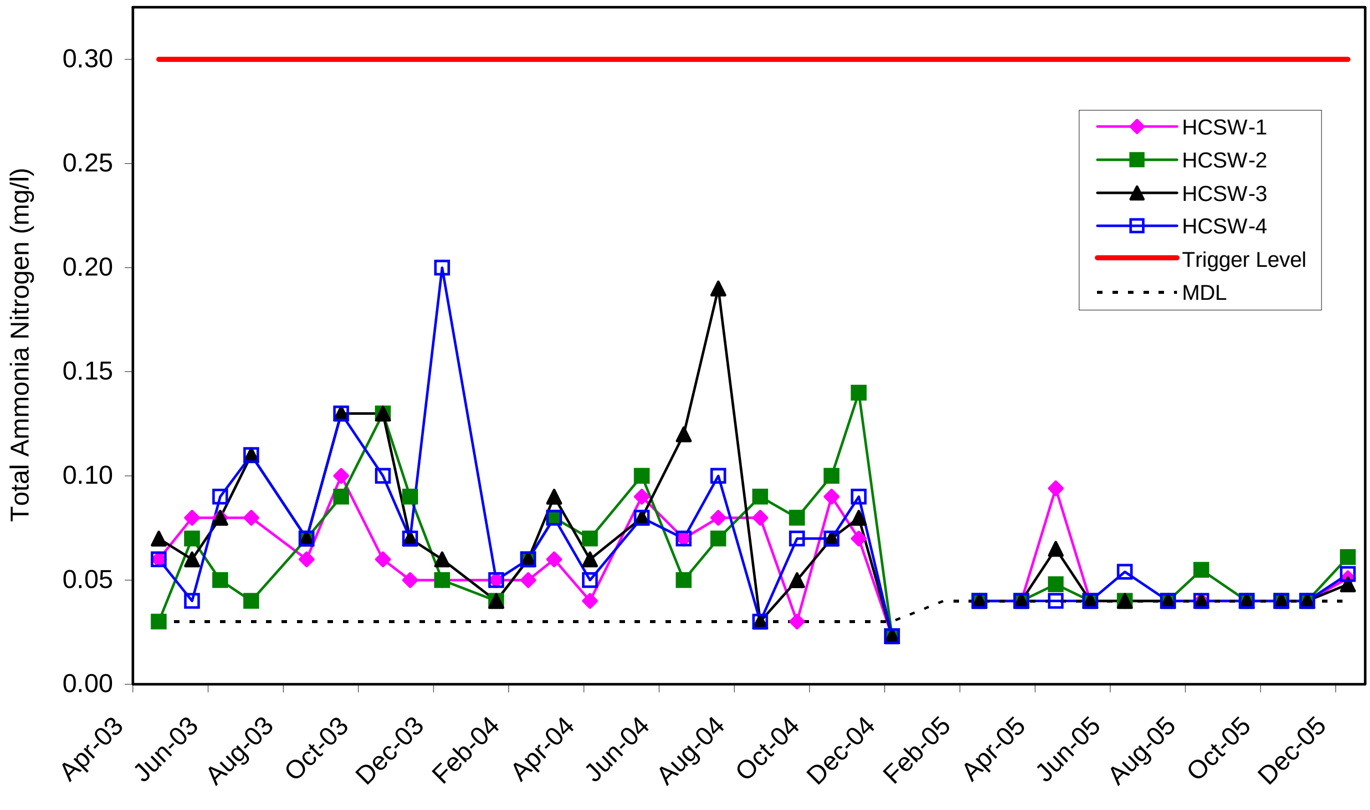

Figure 42. Total Ammonia Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005. (January 2005 values missing because of lab oversight.)

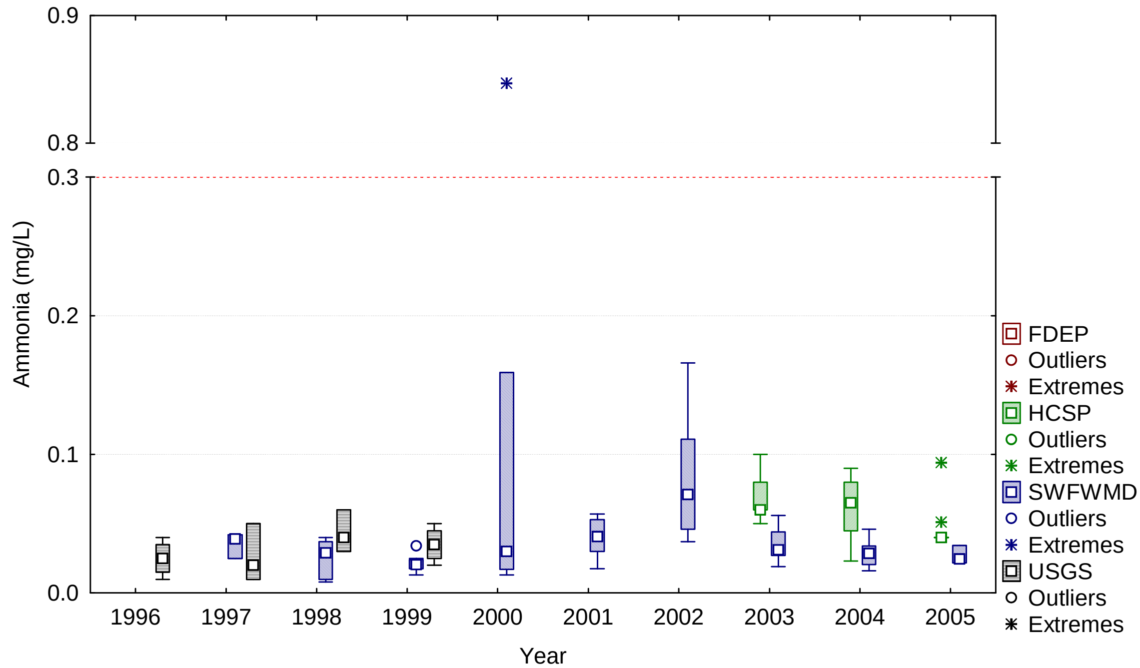

Figure 43. HCSW-1 Values of Ammonia Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

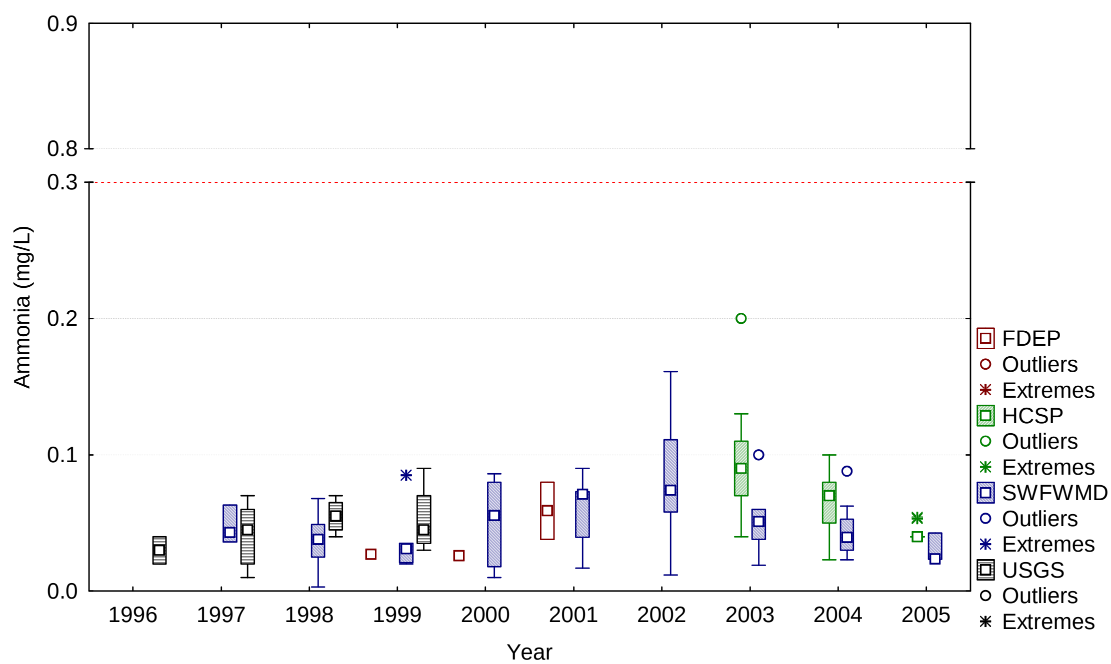

Figure 44. HCSW-4 Values of Ammonia Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

Levels of orthophosphate were well below the trigger level of 2.5 mg/l (Figure 45). Orthophosphate concentrations were significantly different among stations (ANOVA, $F = 14.8$, $p < 0.001$), with concentrations at HCSW-2 lower and HCSW-4 higher than other stations (Duncan's multiple range test, $p < 0.05$). While the observed phosphorus levels would be considered quite high in some portions of the state, they are well within the expected range for streams in the Bone Valley Phosphate Region. The orthophosphate concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median OP, $p > 0.05$) (Figures 46 and 47). Orthophosphate was negatively correlated with streamflow at HCSW-1 (Spearman's rank correlation $r = -0.51$, $p < 0.05$).

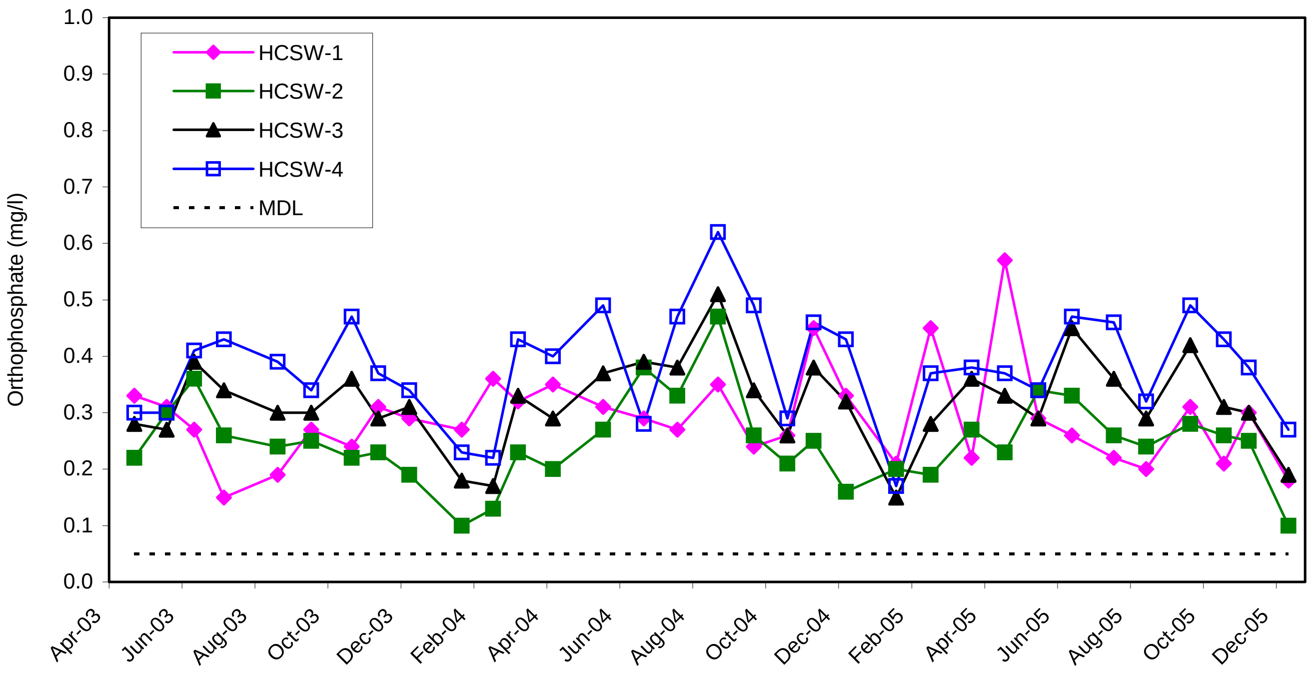

Figure 45. Orthophosphate Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005. (The HCSP trigger level for orthophosphate is 2.5 mg/l.)

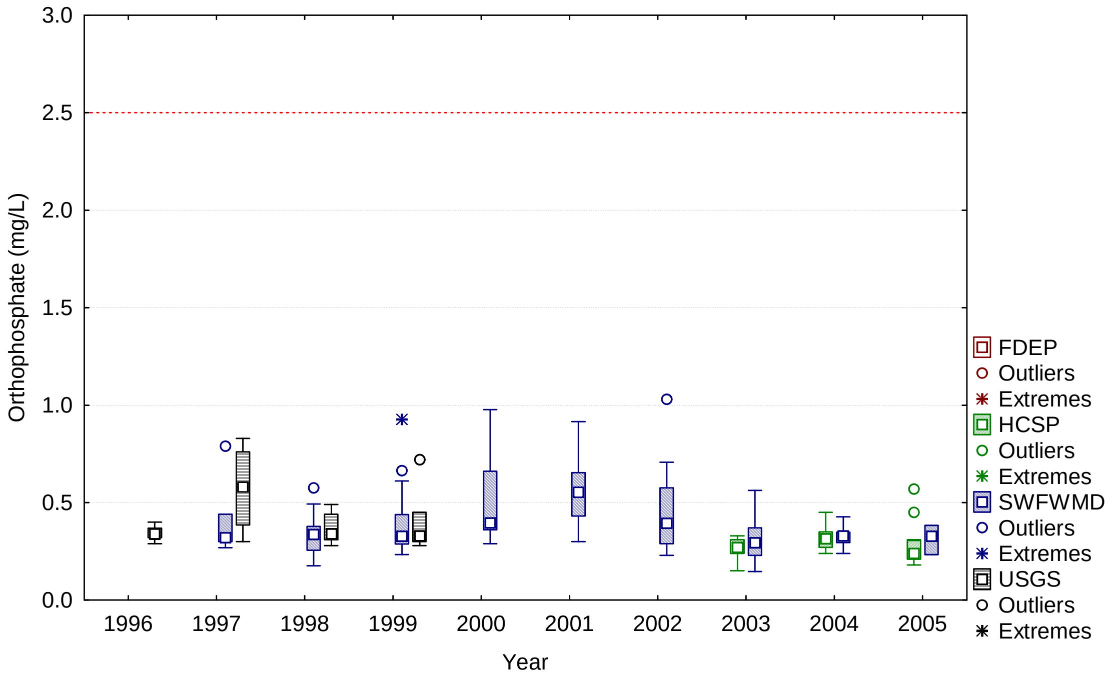

Figure 46. HCSW-1 Values of Orthophosphate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

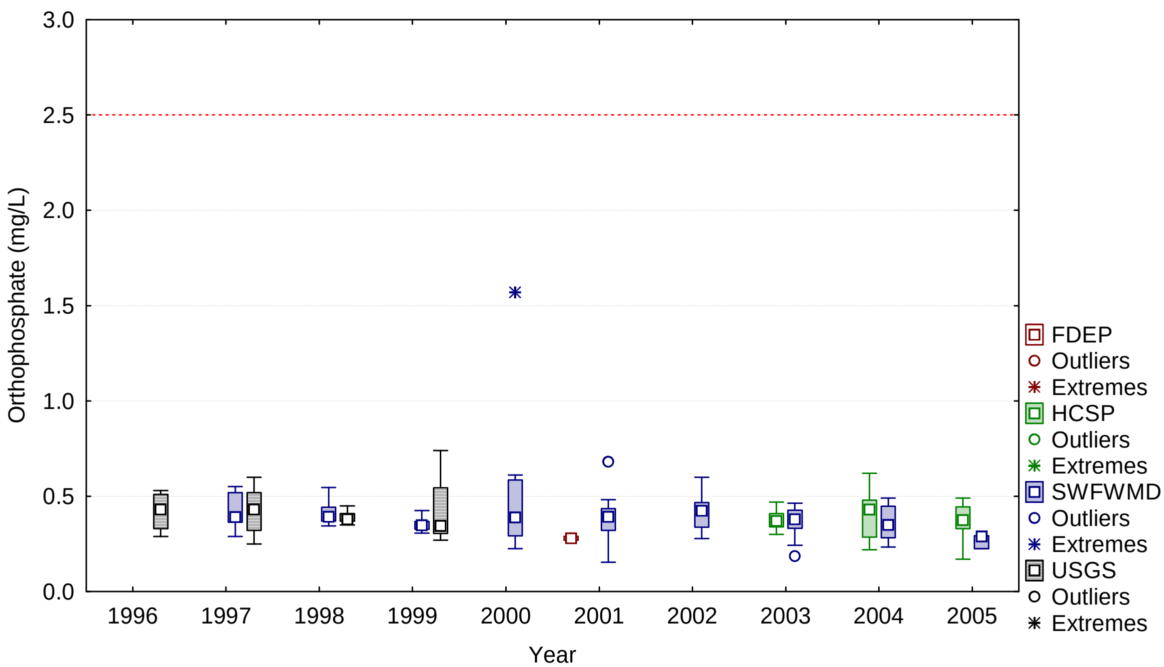

Figure 47. HCSW-4 Values of Orthophosphate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

Chlorophyll *a* values were well below the trigger level of 15 mg/m^3 during most sampling events at all stations in 2005, but HCSW-2 exceeded the trigger value for chlorophyll *a* in May and October (Figure 48). In 2004, during and after Hurricane Charley, chlorophyll *a* levels were elevated because of increased organic debris in Horse Creek. The chlorophyll a concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median chlorophyll-*a*, $p > 0.05$) (Figures 49 and 50). Chlorophyll *a* concentrations were not significantly different between stations (ANOVA, $F = 1.97$, $p = 0.12$). Chlorophyll *a* concentrations were not significantly correlated with streamflow but were negatively correlated with total monthly rainfall at HCSW-1 (Spearman's $r = -0.69$, $p < 0.05$).

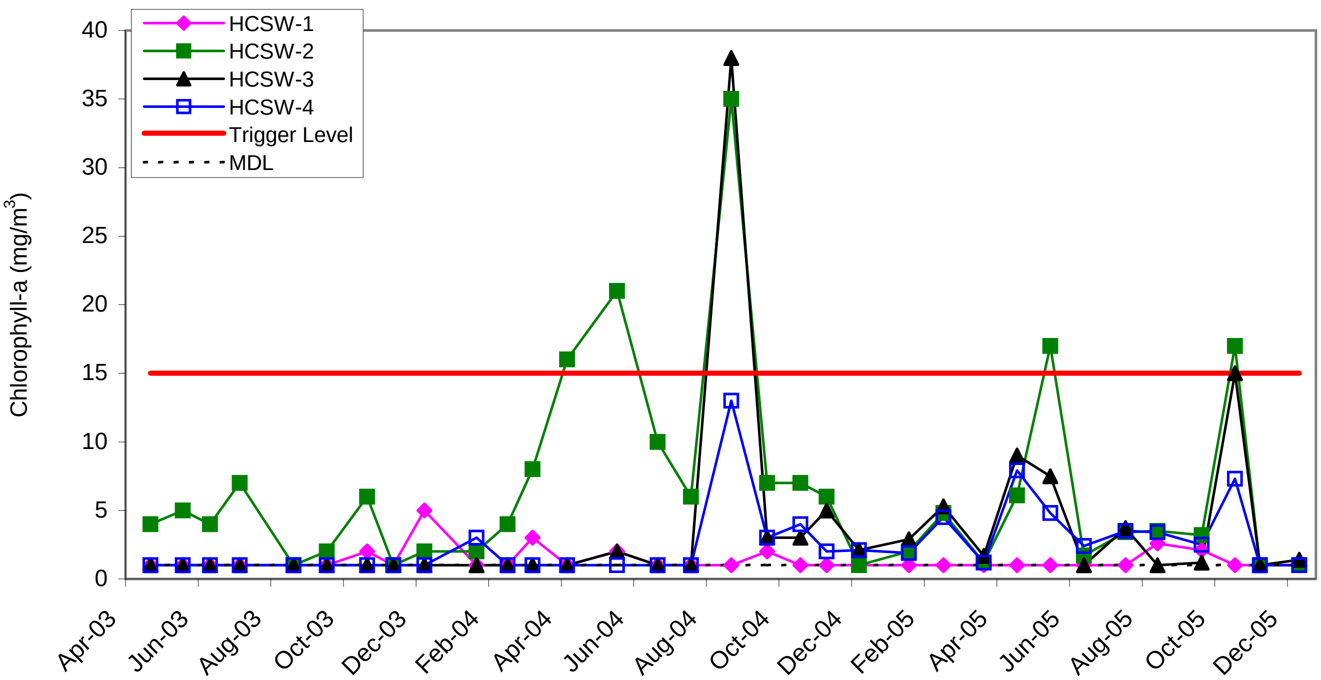

Figure 48. Chlorophyll-a Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005. Minimum Detection Limit = 1 mg/m^3.

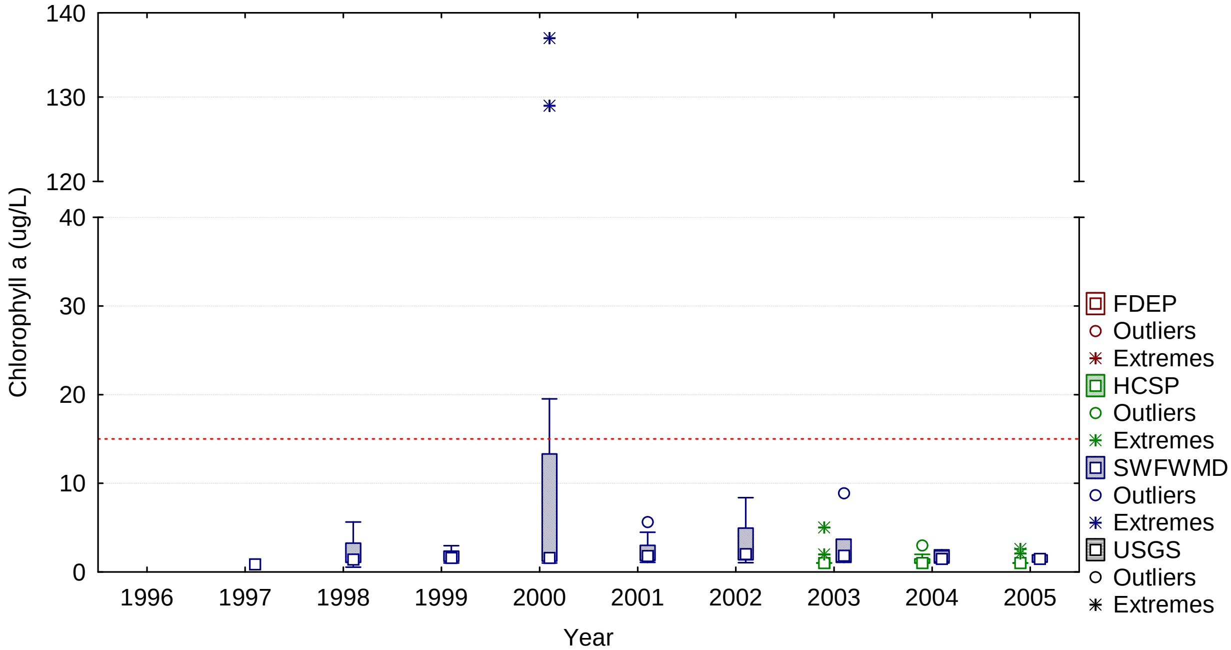

Figure 49. HCSW-1 Values of Chlorophyll a Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

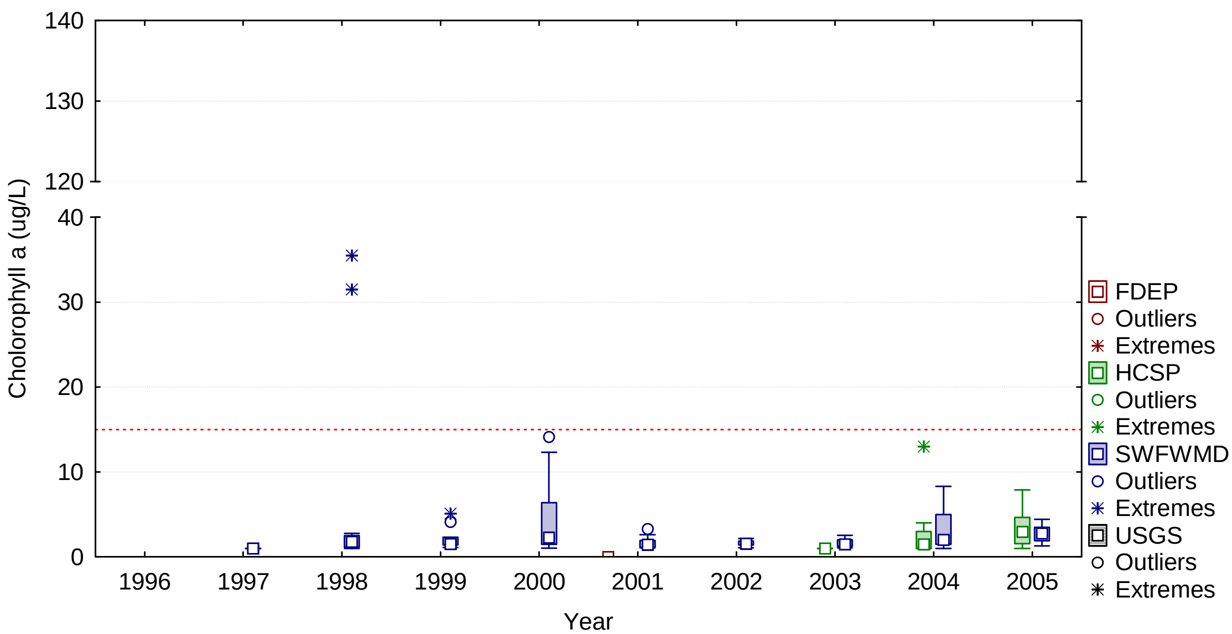

Figure 50. HCSW-4 Values of Chlorophyll a Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

5.2.3 Dissolved Minerals, Mining Reagents, and Radionuclides

During all sampling events and at all stations, specific conductivity levels were well below the trigger level of >1275 µmhos/cm^2 (Figure 51). Specific conductivity was significantly different among stations (ANOVA, $F = 18.2$, $p < 0.0001$), with the lowest concentrations at HCSW-2 and the highest at HCSW-4 (Duncan's multiple range test, $p < 0.05$). Levels of specific conductivity determined during each biological sampling event were consistent with those obtained during monthly water quality sampling events (Figure 51). Mean daily specific conductivity values obtained from the recorder at HCSW-1 were within the range obtained during the monthly water quality sampling events (Figure 54). Mean daily specific conductivity reached its lowest levels in 2005 during the wet season (Figure 55). The continuous recorder was removed for repair in March – April 2005.

Specific conductivity was negatively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation $r = -0.44$ and $r = -0.82$, respectively, $p < 0.05$) and was also negatively correlated with monthly rainfall at HCSW-4 (Spearman's rank correlation $r = -0.57$, $p < 0.05$). The specific conductivity at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median specific conductivity, $p > 0.05$) (Figures 52 and 53).

Higher conductivity at downstream stations was probably the cumulative result of contributions of groundwater that either seeped into Horse Creek directly or ran off of agricultural irrigation water pumped from the aquifer. This pattern has been present for many years and is more apparent in the review of the long-term data in a separate report (Durbin and Raymond 2006). It is also possible that some of the conductivity differential may simply be the result of changes in geology of the watershed from high elevations the upper part of the basin to low elevations in the lower part of the basin near the Peace River. Groundwater, which generally contains more concentrated dissolved ions than surface water, is closer to the surface in the lower Horse Creek Basin, making seepage into the stream more likely.

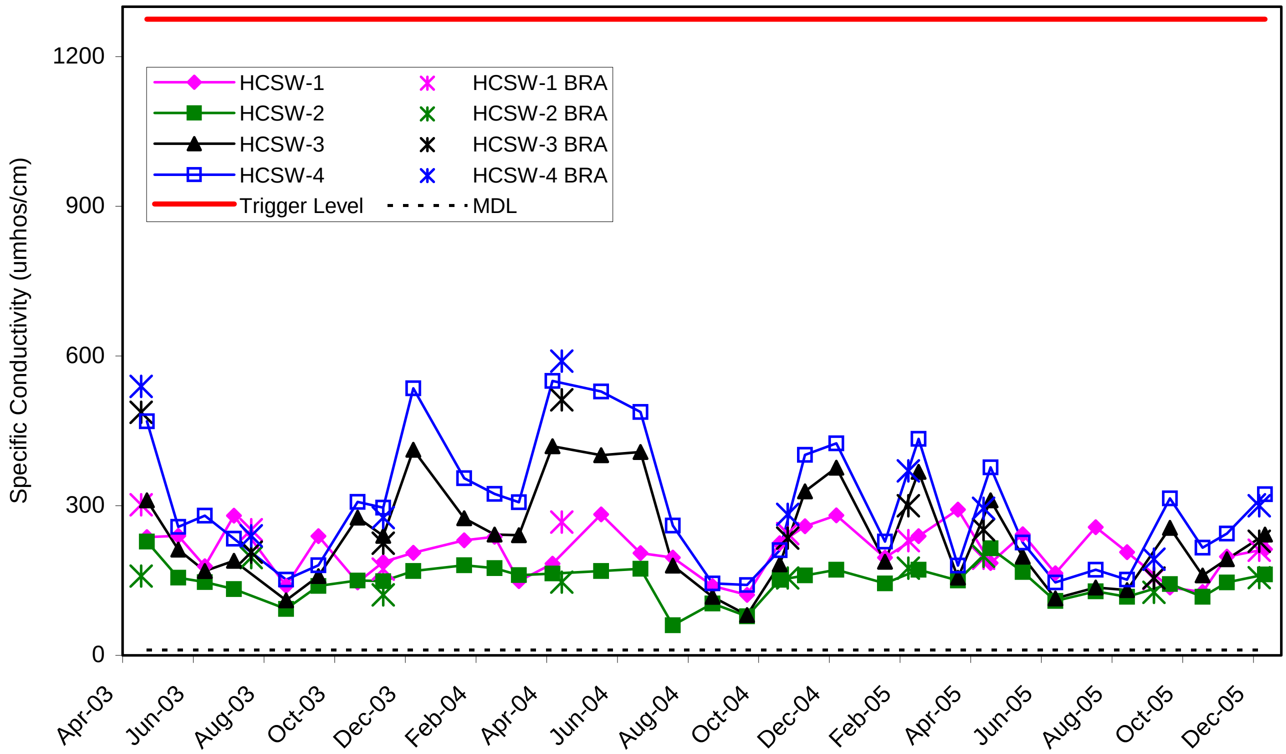

Figure 51. Levels of Specific Conductivity Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2003 - 2005.

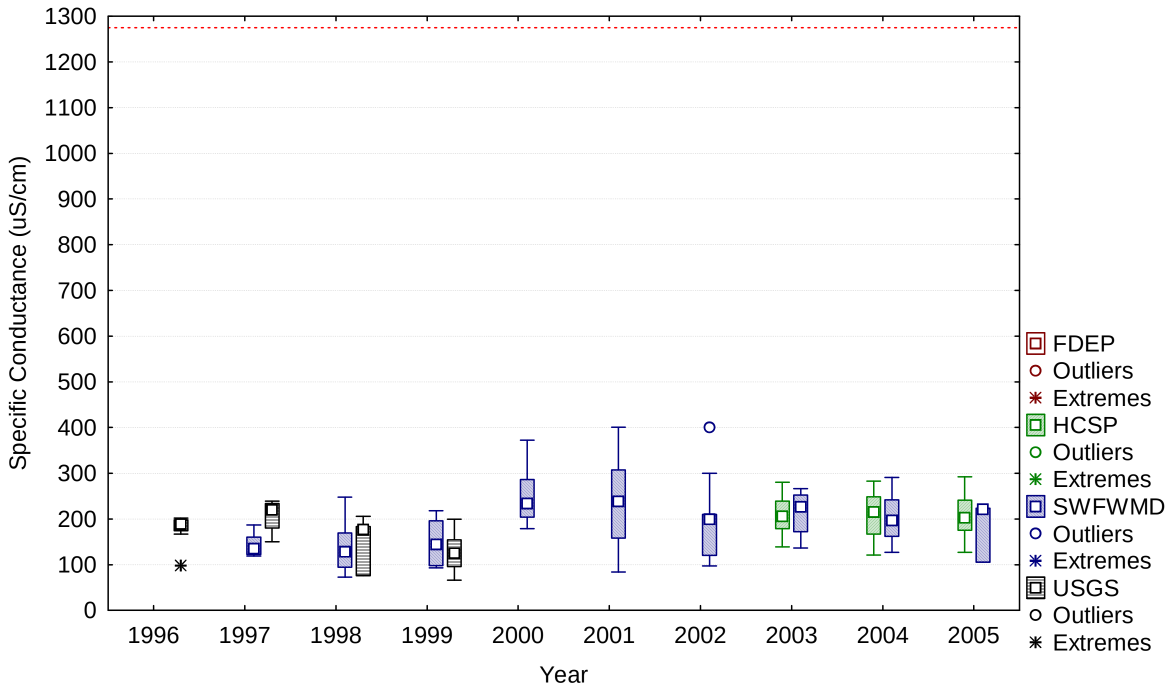

Figure 52. HCSW-1 Values of Specific Conductance Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

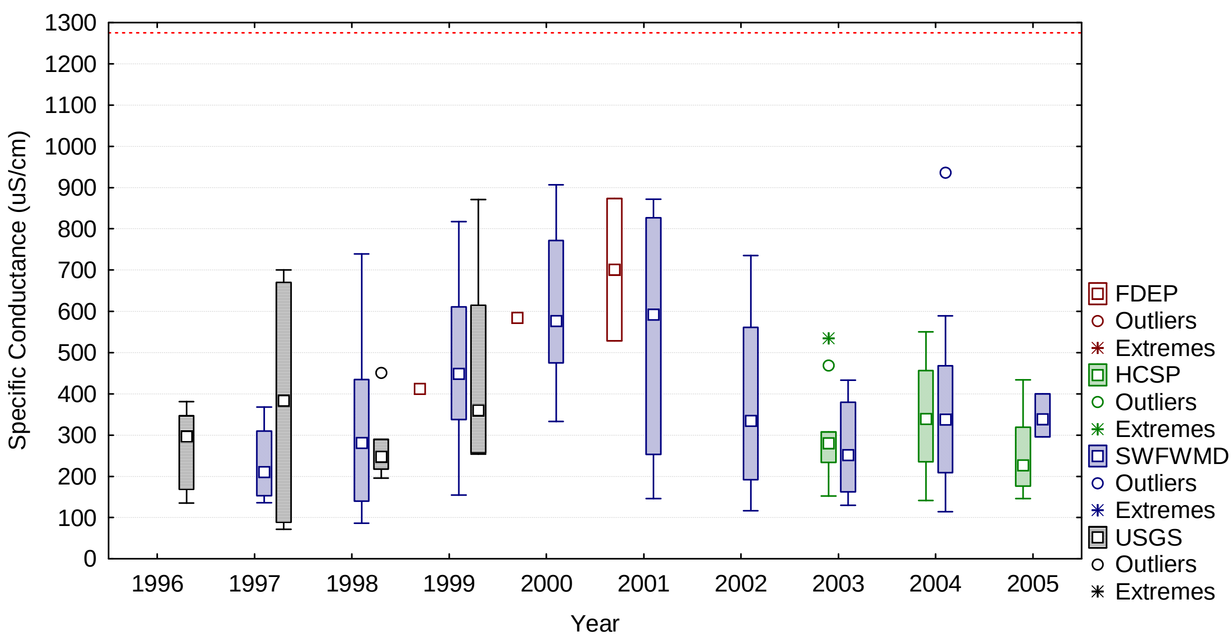

Figure 53. HCSW-4 Values of Specific Conductance Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

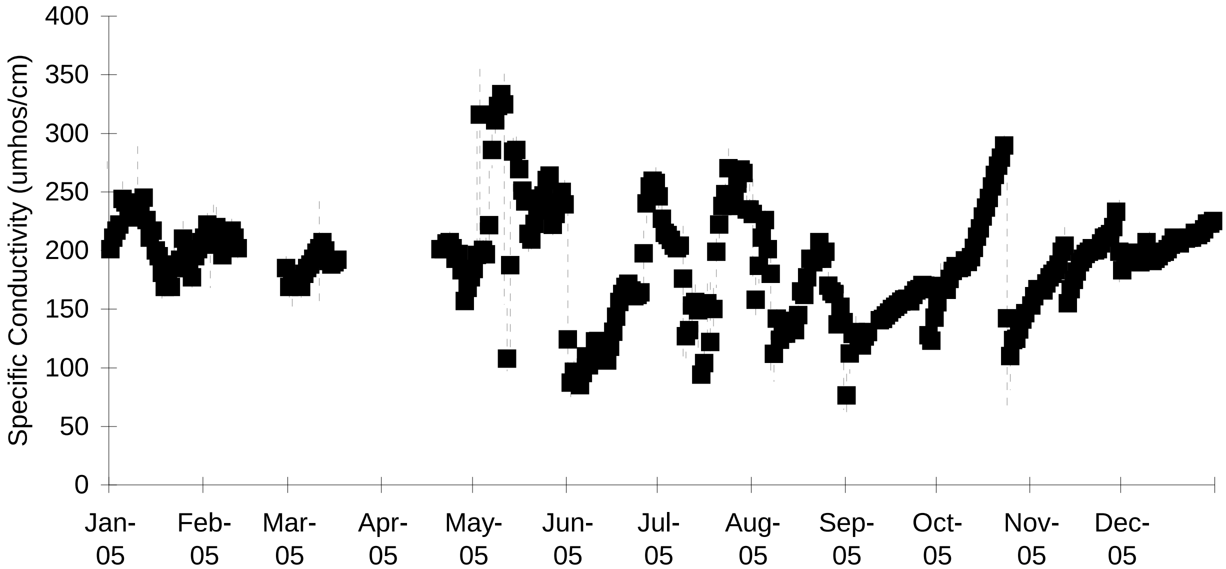

Figure 54. Daily Mean Specific Conductivity (With Daily Min. and Max. as Grey-Dashed High-Low Lines) Obtained From the Continuous Recorder at HCSW-1 for 2005. Minimum Detection Limit = 100 umhos/cm).

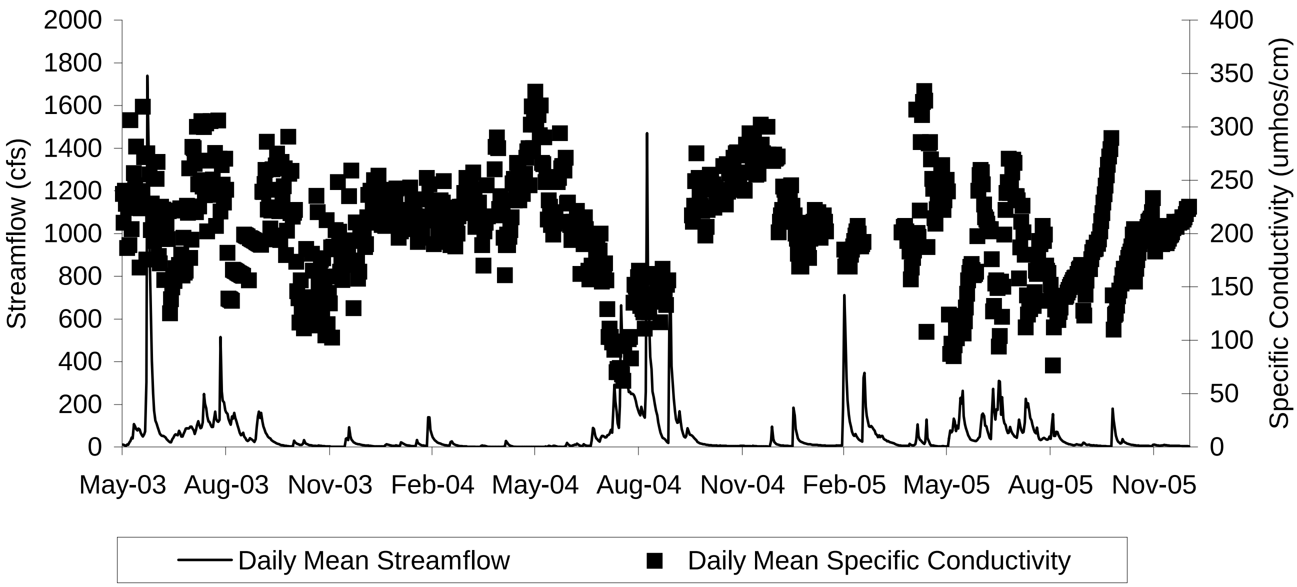

Figure 55. Relationship Between Daily Mean Specific Conductivity (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2003 - 2005. Min. Detection Limit = 100 umhos/cm.

Concentrations of calcium were significantly different between stations (ANOVA, $F = 17.8$, $p < 0.0001$), with significantly lower levels at HCSW-2 and higher levels at HCSW-4 (Duncan's post hoc test, $p < 0.05$) (Figure 56). As with specific conductivity, calcium levels were higher downstream where the groundwater contribution to baseflow is higher. Dissolved calcium was negatively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation $r = -0.52$ and $r = -0.83$, respectively, $p < 0.05$) and also negatively correlated with rainfall at HCSW-4 (Spearman's rank correlation $r = -0.58$, $p < 0.05$). Calcium levels were lower than the trigger value of 100 mg/l at all stations during all events. The calcium concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median calcium, $p > 0.05$) (Figures 57 and 58). The analytical procedure for calcium and iron changed during the 2003-2004 monitoring period, although the change did not affect the general magnitude or interpretation of results.[3]

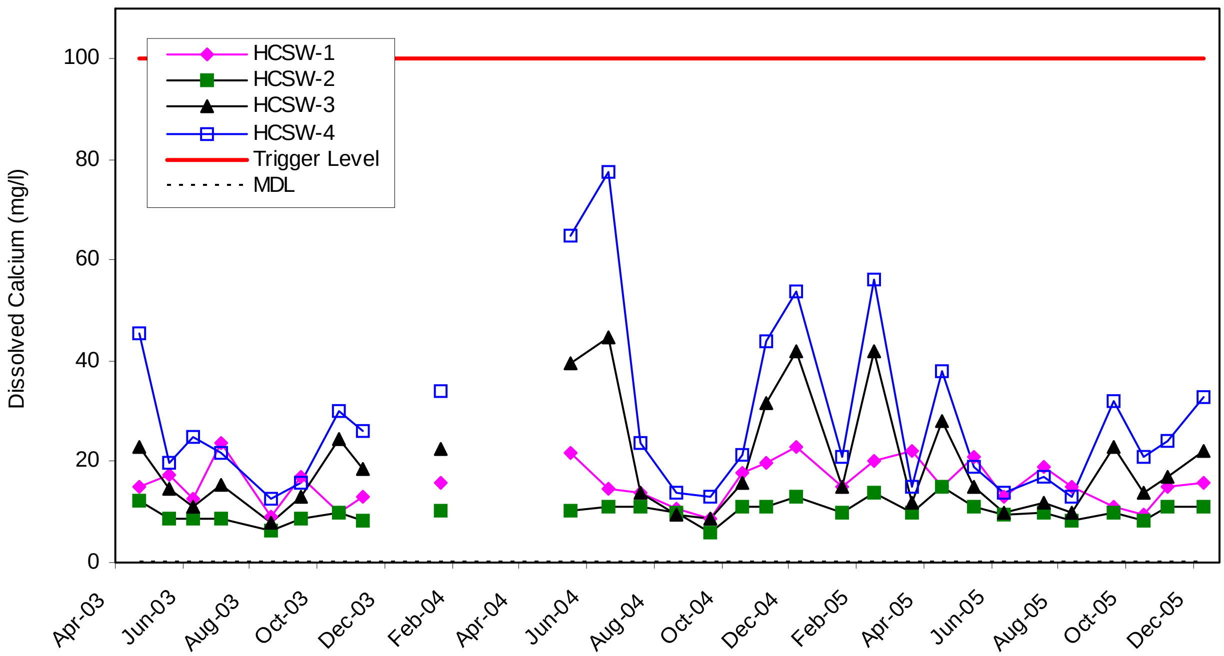

Figure 56. Dissolved Calcium Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005. Minimum Detection Limit = 0.1 mg/l.

[3] HCSP began with sampling of dissolved iron and calcium (April – November 2003). At a meeting with the PRMRWSA and EarthBalance, it was requested that Mosaic begin sampling for total metals since the text in the body of the HCSP methodology specifies only "Calcium" and "Iron," so sub-samples for iron and calcium were not filtered before analysis in November and December 2003 and February to April 2004. Later the PRMRWSA noted that Table 1 of the Agreement has "Iron" and "Calcium" listed with a row heading of "Dissolved Minerals" and requested that the analysis be switched back to dissolved iron and calcium. Samples from January 2004 and May 2004 to the present have been analyzed for dissolved iron and calcium. All iron and calcium data (both total and dissolved) is included on the attached CD-ROM. As total iron and total calcium should by definition be equal or greater than the dissolved fractions alone, the months with total iron and calcium represent a conservative determination of the iron and calcium concentrations and in no way are any less protective than measuring dissolved concentrations. For the 20 November 2003 sampling event, during which measurements of both Total and Dissolved Calcium and Iron were made, the measurements for each mineral were very similar.

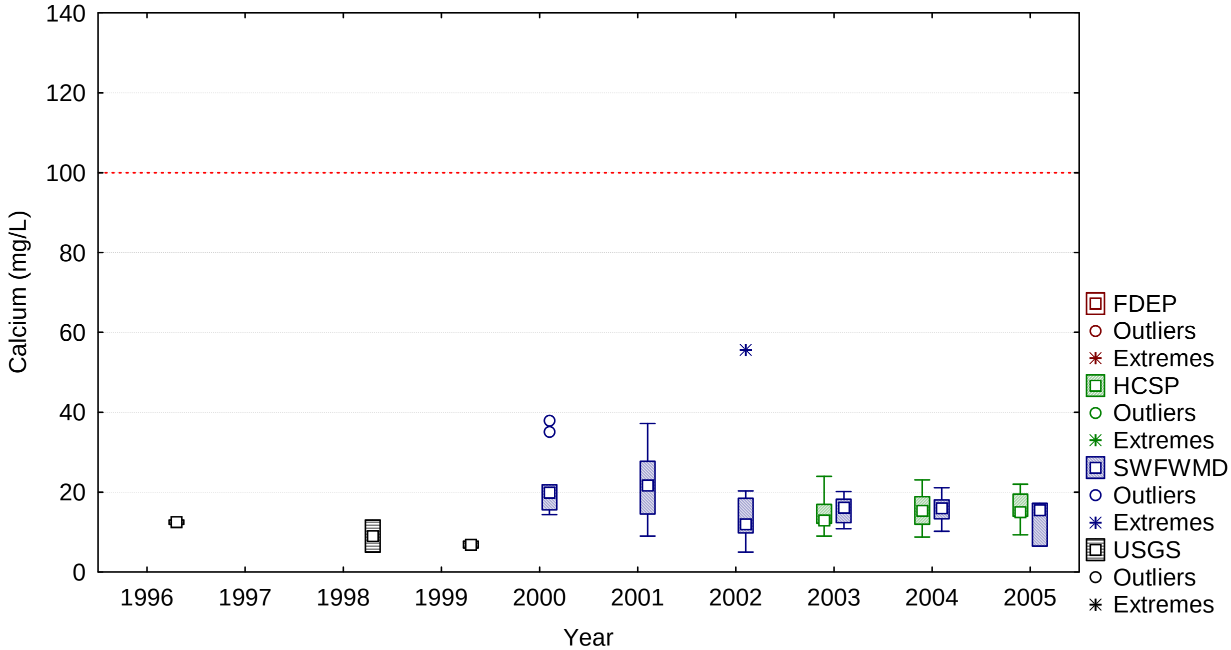

Figure 57. HCSW-1 Values of Calcium Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

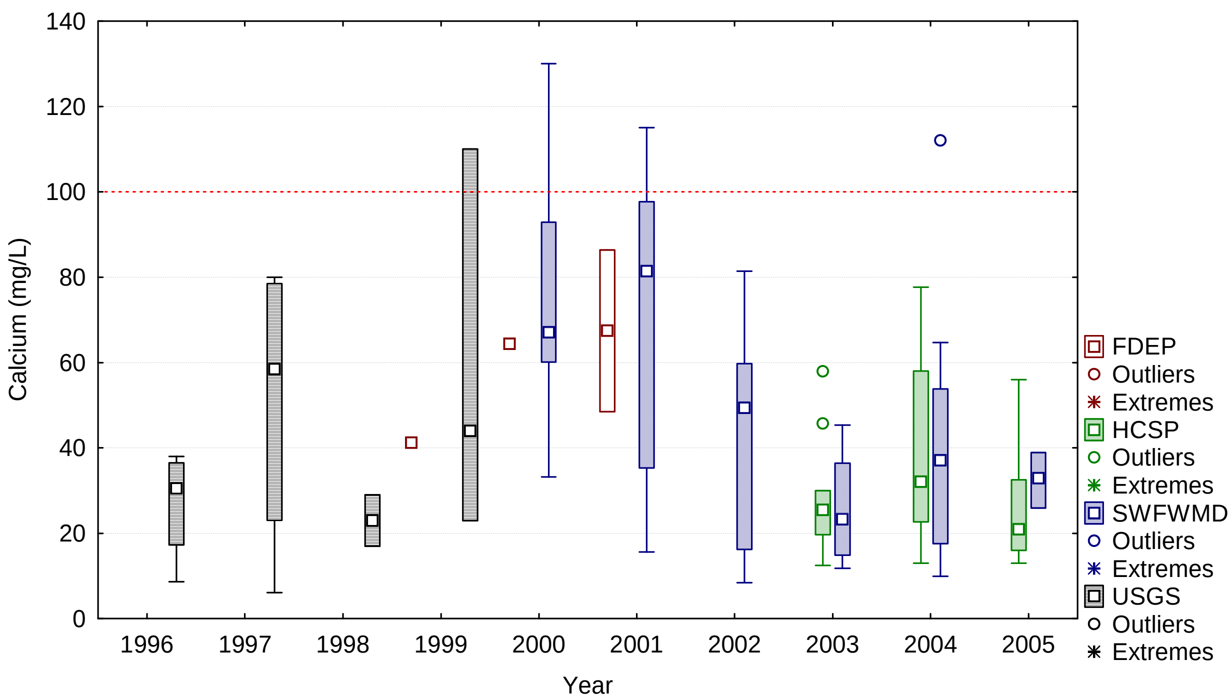

Figure 58. HCSW-4 Values of Calcium Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

Levels of dissolved iron at all stations were below the trigger level of 1 mg/l during all sampling events (Figure 59). With few exceptions, dissolved iron concentrations at HCSW-4 exceeded the trigger value of 0.3 mg/l established for that sampling station. HCSW-4 has a different trigger level for iron because of its location upstream of a segment of Horse Creek that is designated as Class I waters, which carries a lower standard value for iron (0.3 mg/l) than Class III waters (1.0 mg/l). The iron concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and are at levels within the range for the last decade of data, although data on iron is very limited (Figures 60 and 61). Dissolved iron was positively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation $r = 0.56$ and $r = 0.62$, respectively $p < 0.05$). Dissolved iron was also positively correlated with monthly rainfall at both HCSW-1 and HCSW-4 (Spearman's rank correlation $r = 0.60$ and $r = 0.64$, respectively $p < 0.05$). Dissolved iron concentrations were not significantly different among stations (ANOVA, $F = 0.61$, $p = 0.61$).

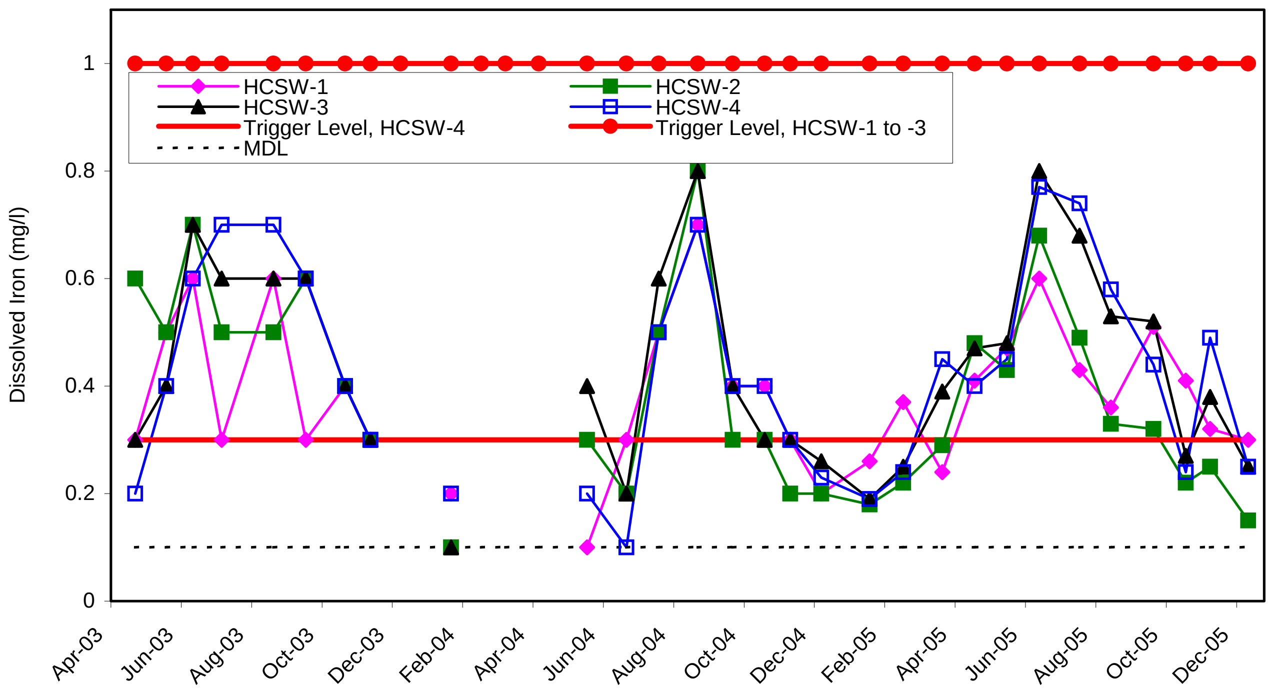

Figure 59. Dissolved Iron Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005.

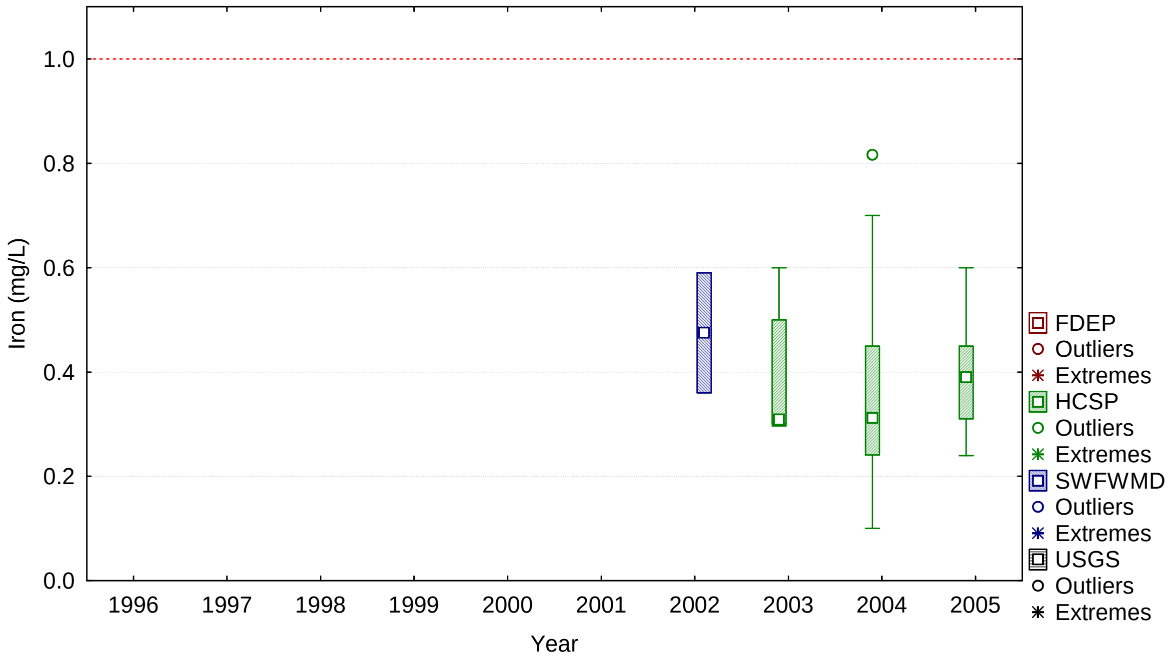

Figure 60. HCSW-1 Values of Iron Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

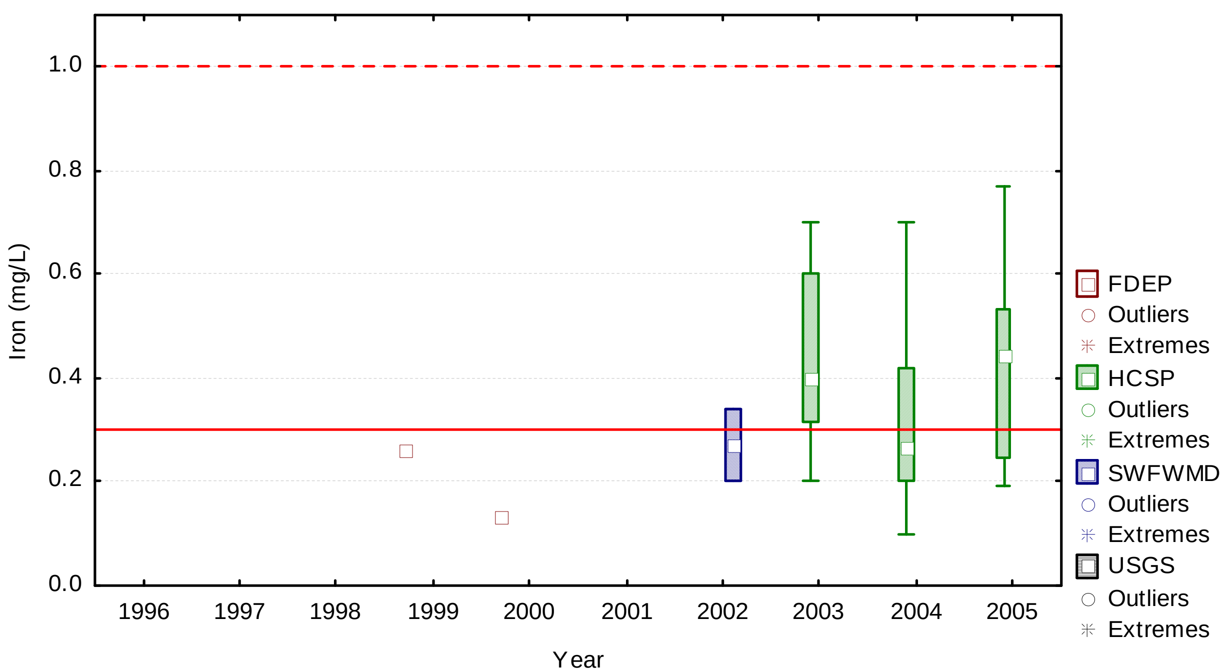

Figure 61. HCSW-4 Values of Iron Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

Total alkalinity was significantly different among stations (ANOVA, F = 17.4, $p < 0.00001$), with highest levels at HCSW-1 (Duncan's multiple range test) (Figure 62). Levels of total alkalinity were well below the trigger value of 100 mg/l during 2003 – 2005. The alkalinity levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median alkalinity, $p > 0.05$), although historic alkalinity data is limited (Figures 63 and 64). Alkalinity was negatively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation r = -0.56 and r = -0.83, respectively, $p < 0.001$). Alkalinity was also negatively correlated with rainfall at HCSW-4, which is consistent with the concept that higher flows from rainfall would reflect the lower alkalinity of rainwater, compared with dry season inputs of groundwater. High levels of alkalinity at HCSW-1 may be partly attributed to the exposed rock in the stream banks that is unique to that station.

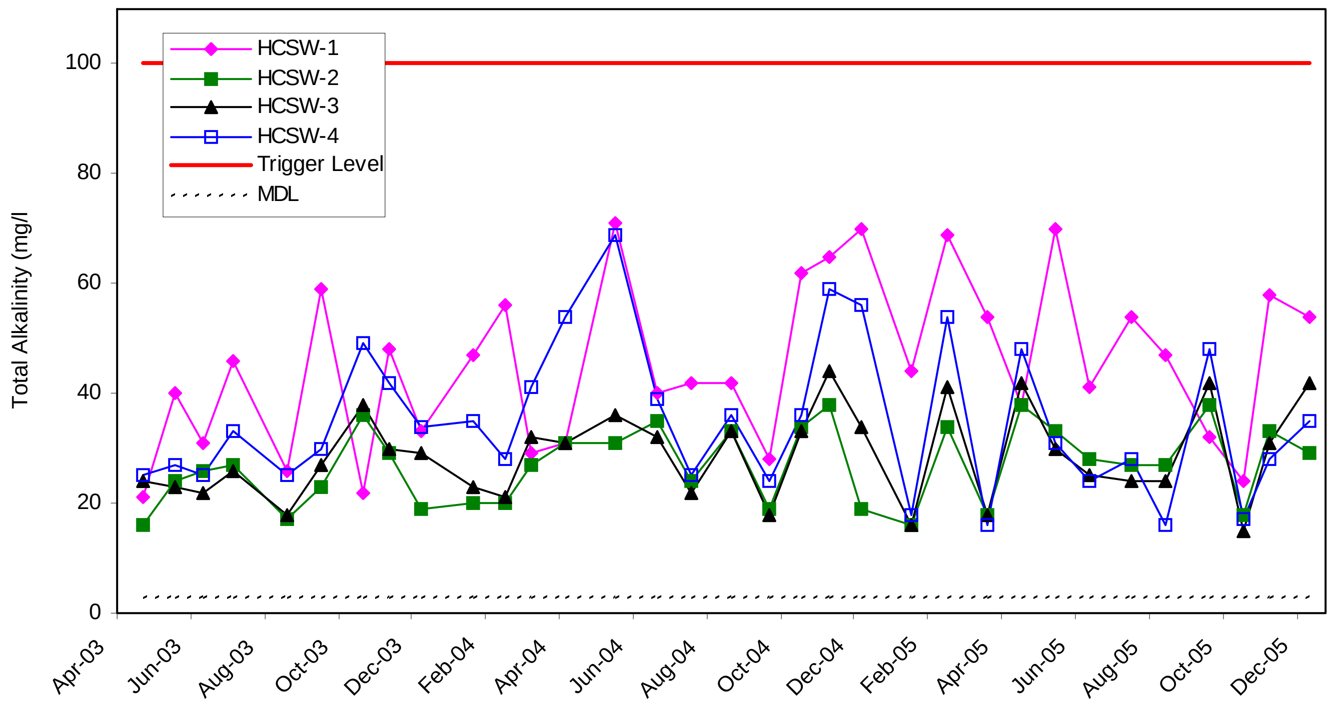

Figure 62. Levels of Total Alkalinity Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005.

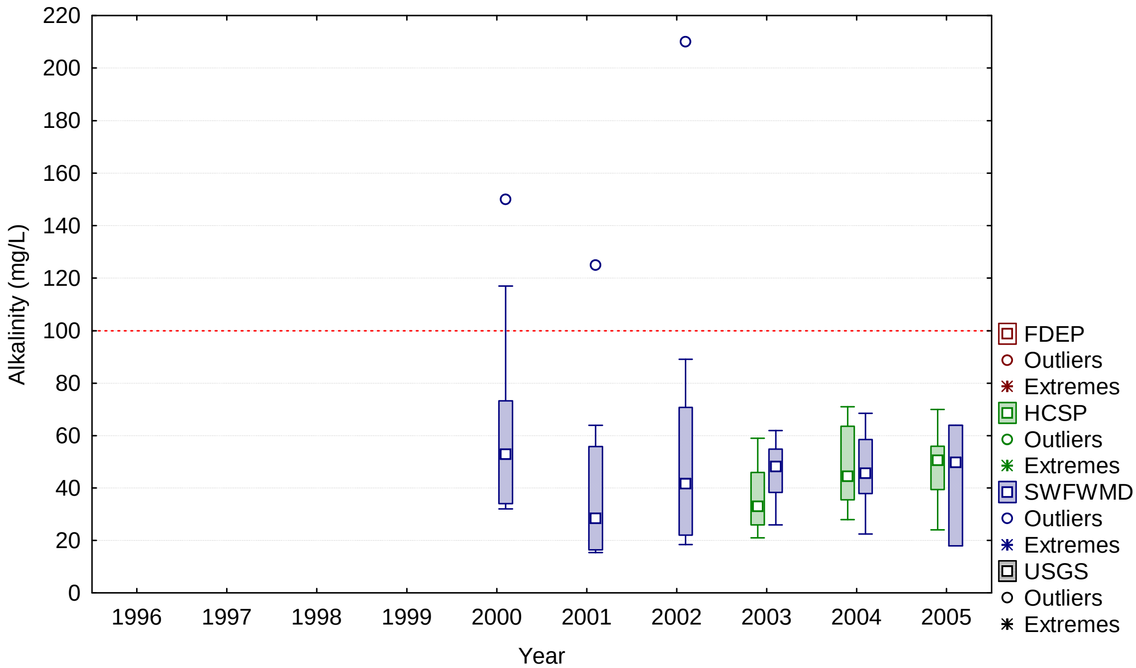

Figure 63. HCSW-1 Values of Alkalinity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

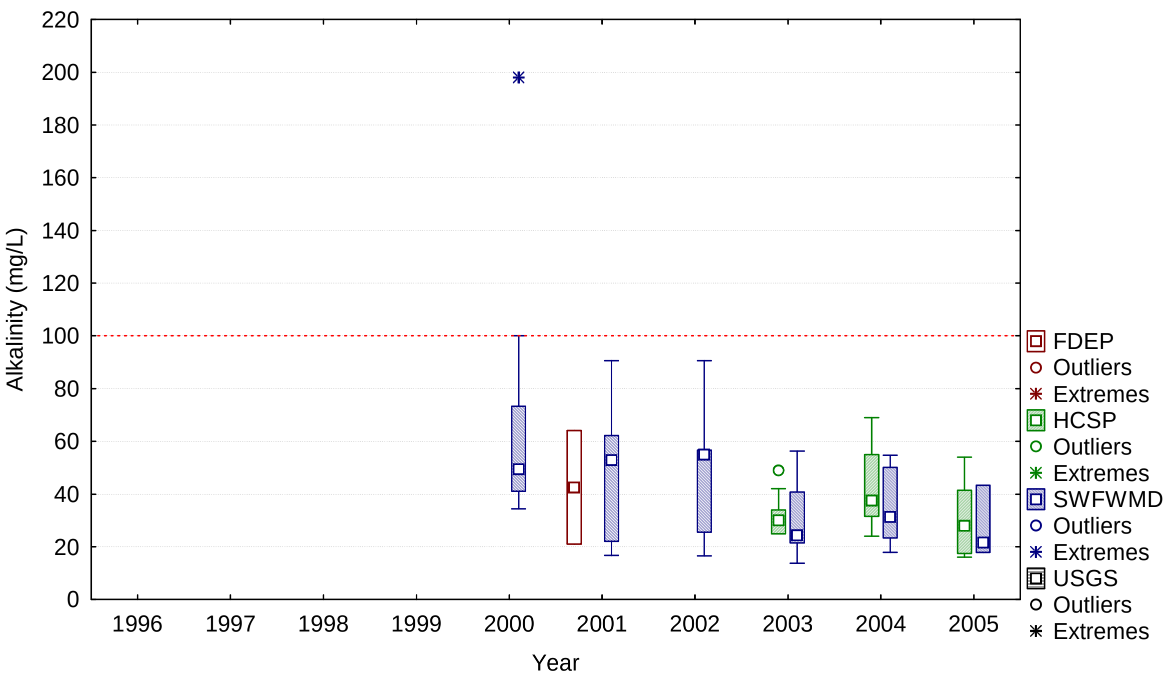

Figure 64. HCSW-4 Values of Alkalinity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

Chloride concentrations were significantly different among stations during all sampling events (ANOVA, $F = 36.1$, $p = 0.0006$), with a pattern of increasing concentration downstream (Figure 65). Levels of chloride were below 30 mg/l during 2003 - 2005, considerably lower than the trigger level of 250 mg/l. The chloride concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median chloride, $p > 0.05$) (Figures 66 and 67). Chloride was negatively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation $r = -0.77$ and $r = -0.85$, respectively $p < 0.05$). Chloride was also negatively correlated with monthly rainfall at both HCSW-1 and HCSW-4 (Spearman's rank correlation $r = -0.43$ and $r = -0.54$, respectively $p < 0.05$).

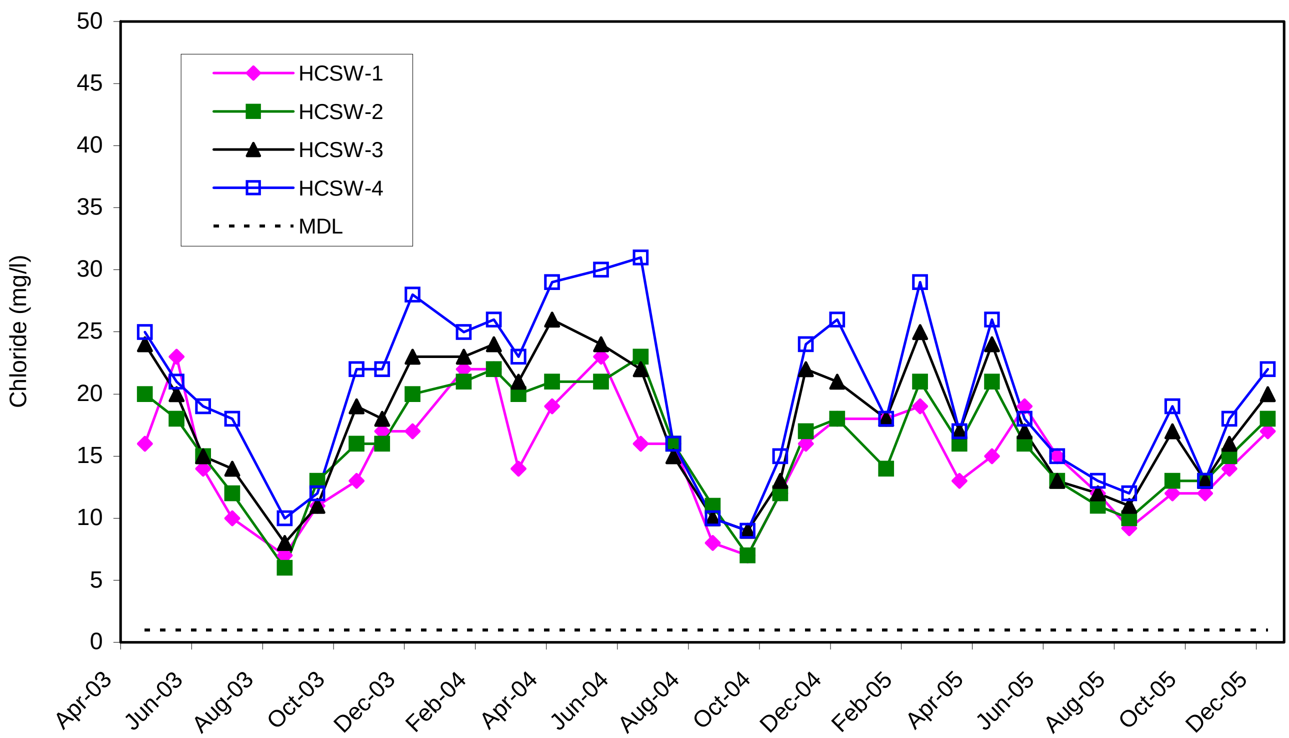

Figure 65. Chloride Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005. (HCSP trigger value for Chloride is 250 mg/L.)

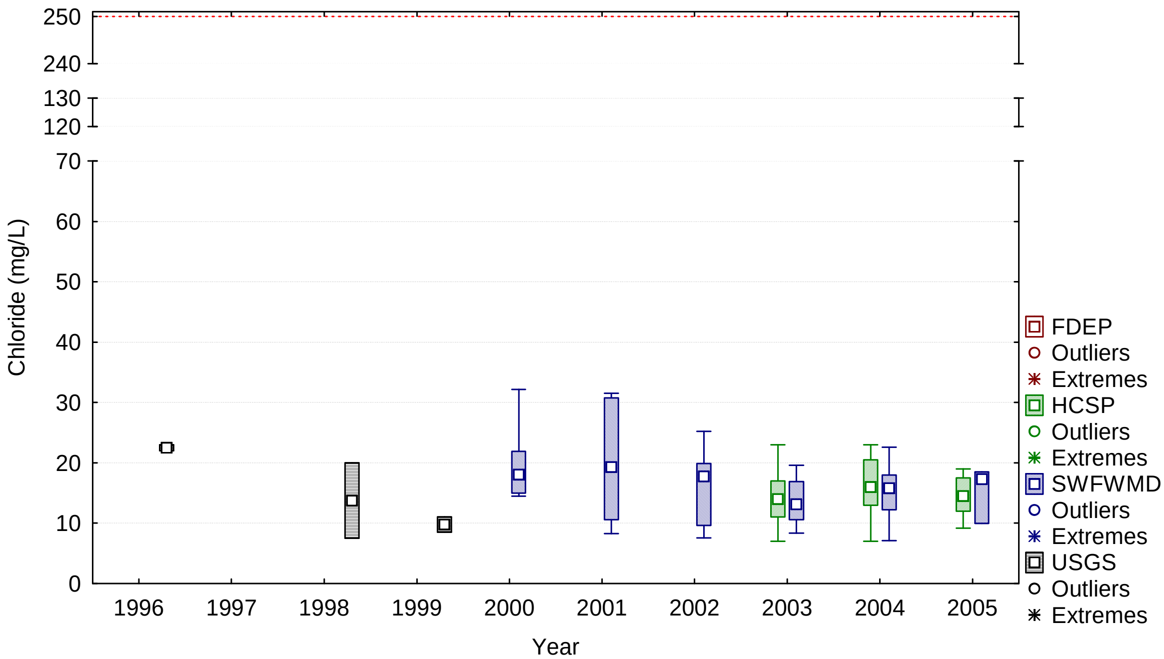

Figure 66. HCSW-1 Values of Chloride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

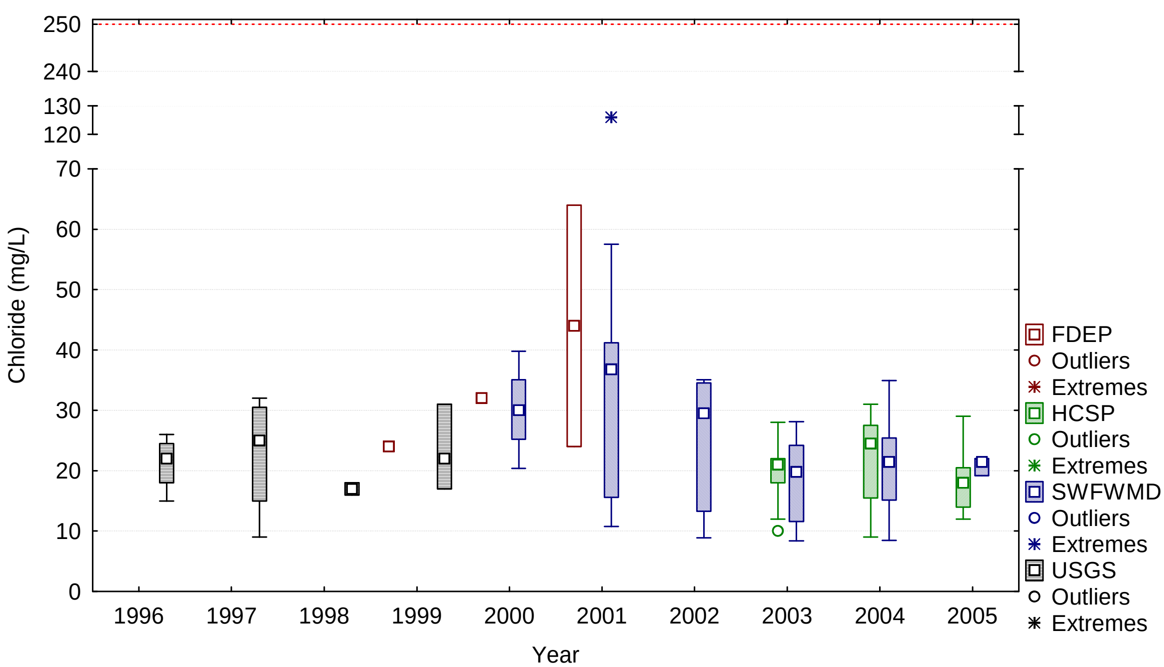

Figure 67. HCSW-4 Values of Chloride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

Fluoride levels were below 1.0 mg/l at all stations and were significantly different among sites (ANOVA, $F = 12.1$, $p < 0.0001$), with HCSW-1 having the highest values (Duncan's multiple range test, $p < 0.05$) (Figure 68). Concentrations of fluoride were well below the trigger levels of 4.0 and 1.5 mg/l, established for HCSW-1, HCSW-2, and HCSW-3 and HCSW-4, respectively. HCSW-4 has a different trigger level for fluoride than the other stations because of its proximity to Class I waters. Fluoride was negatively correlated with streamflow and rainfall at HCSW-4 (Spearman's rank correlation $r = -0.91$ and $r = -0.59$, respectively, $p < 0.05$).

The fluoride concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and may have increased at HCSW-1 (Kendall Tau = 1.0, $p < 0.001$) and decreased at HCSW-4 (Kendall Tau = -0.87, $p = 0.008$) over the last decade (Figures 69 and 70). The trend of increasing fluoride at HCSW-1 may be an artifact of using the last decade of data in the trend analysis. When fluoride is considered over the period of record (non-HCSP sources), it appears that annual median fluoride at HCSW-1 was unusually low between 1993 and 1999 (0.15 – 0.2 mg/L). Fluoride levels between 1976 and 1992 (0.21 - 0.45 mg/L) are very similar to those between 2000 and 2006 (0.3 – 0.45 mg/L). Therefore, fluoride appears to be fluctuating over time at HCSW-1, rather than exhibiting a monotonic increasing trend.

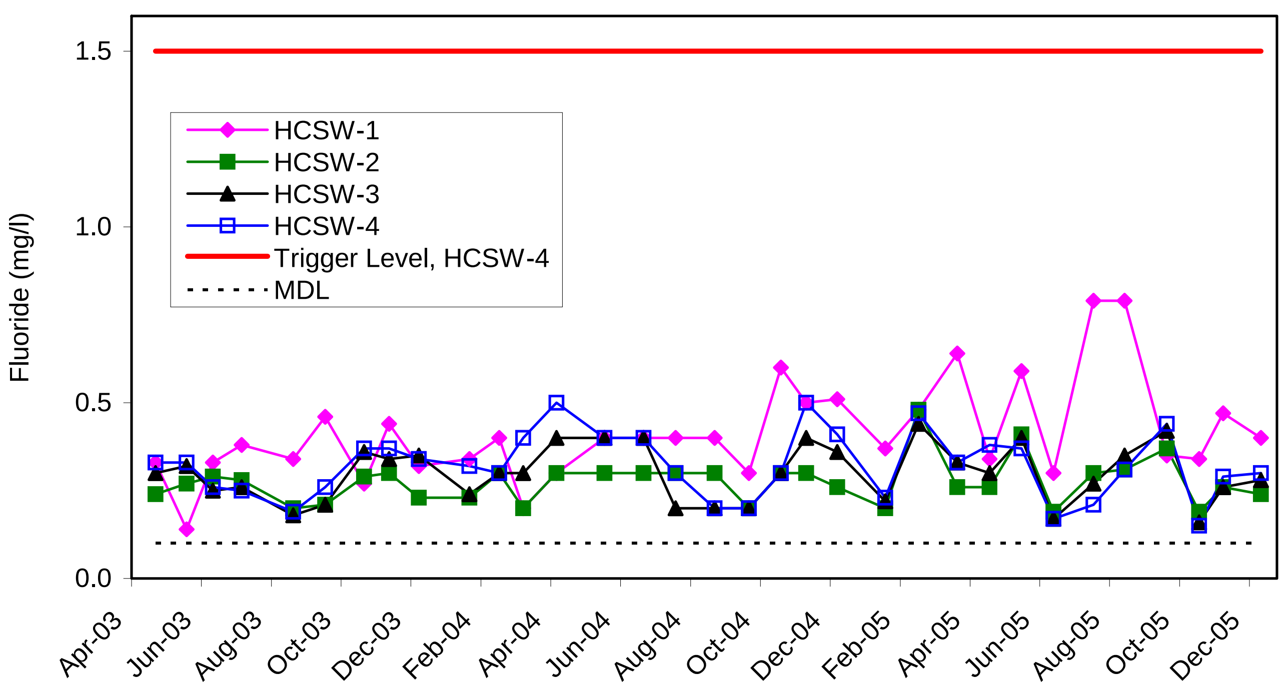

Figure 68. Fluoride Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005. (HCSP trigger level for HCSW-1 to HCSW-3 is 4.0 mg/L, and for HCSW-4 is 1.5 mg/L.)

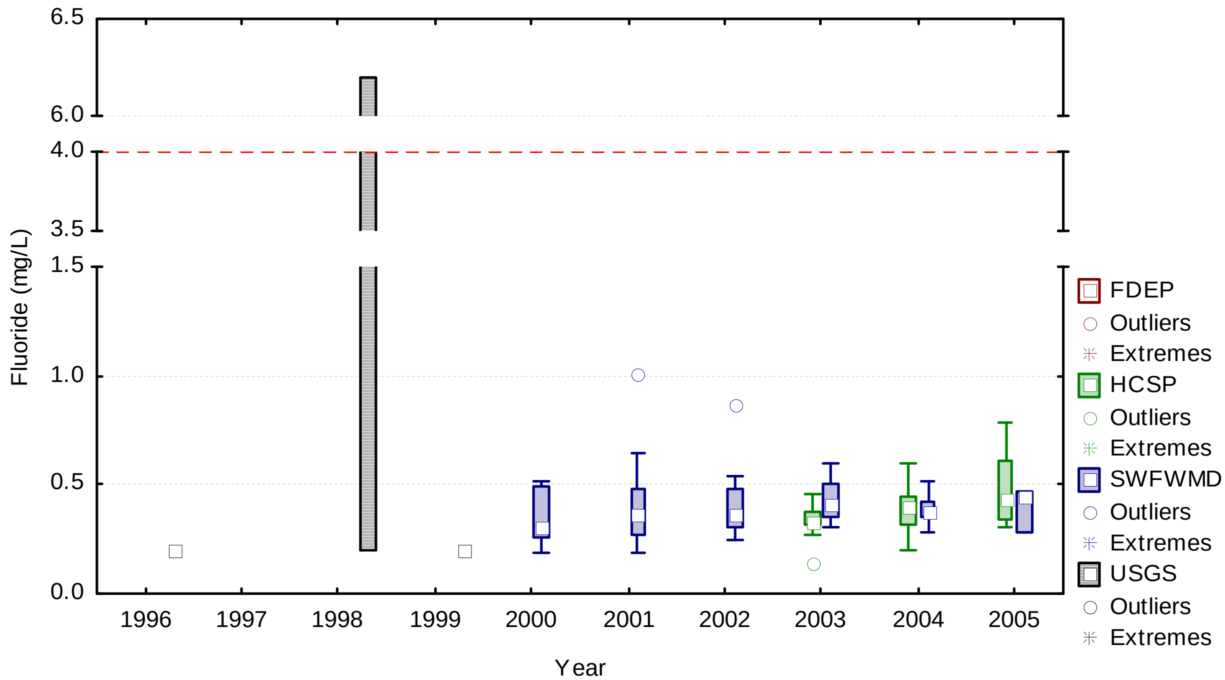

Figure 69. HCSW-1 Values of Fluoride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

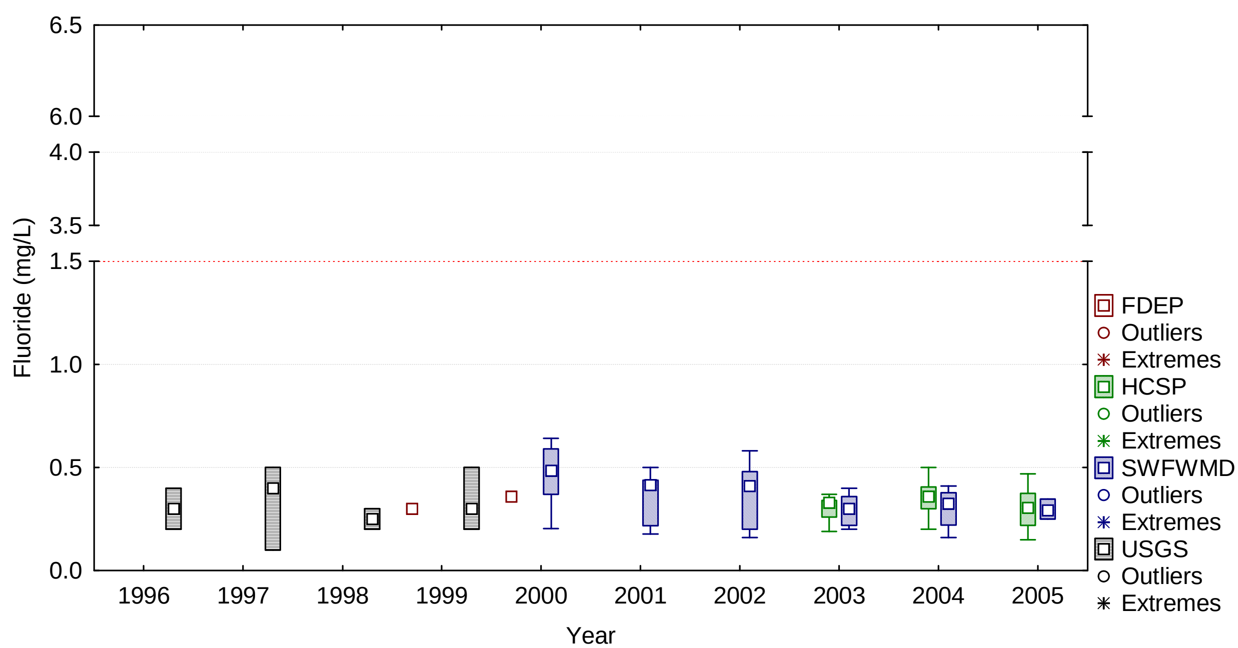

Figure 70. HCSW-4 Values of Fluoride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

Sulfate concentrations were below the trigger level of 250 mg/l at all sampling stations during all sampling events in 2005 (Figure 71). Sulfate concentrations were negatively correlated with streamflow and rainfall at the downstream station, HCSW-4 (Spearman's r = -0.72 and r = -0.52, respectively, $p < 0.05$). In 2003 - 2005, levels of sulfate were significantly different among stations (ANOVA, F = 17.05, $p < 0.0001$), with lowest levels at HCSW-1 and HCSW-2 and highest at HCSW-4 (Duncan's multiple range test, $p < 0.05$). As with specific conductivity and calcium, sulfate concentrations may be higher downstream because of increased groundwater seepage or irrigation runoff. The sulfate concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median sulfate, $p > 0.05$) (Figures 72 and 73).

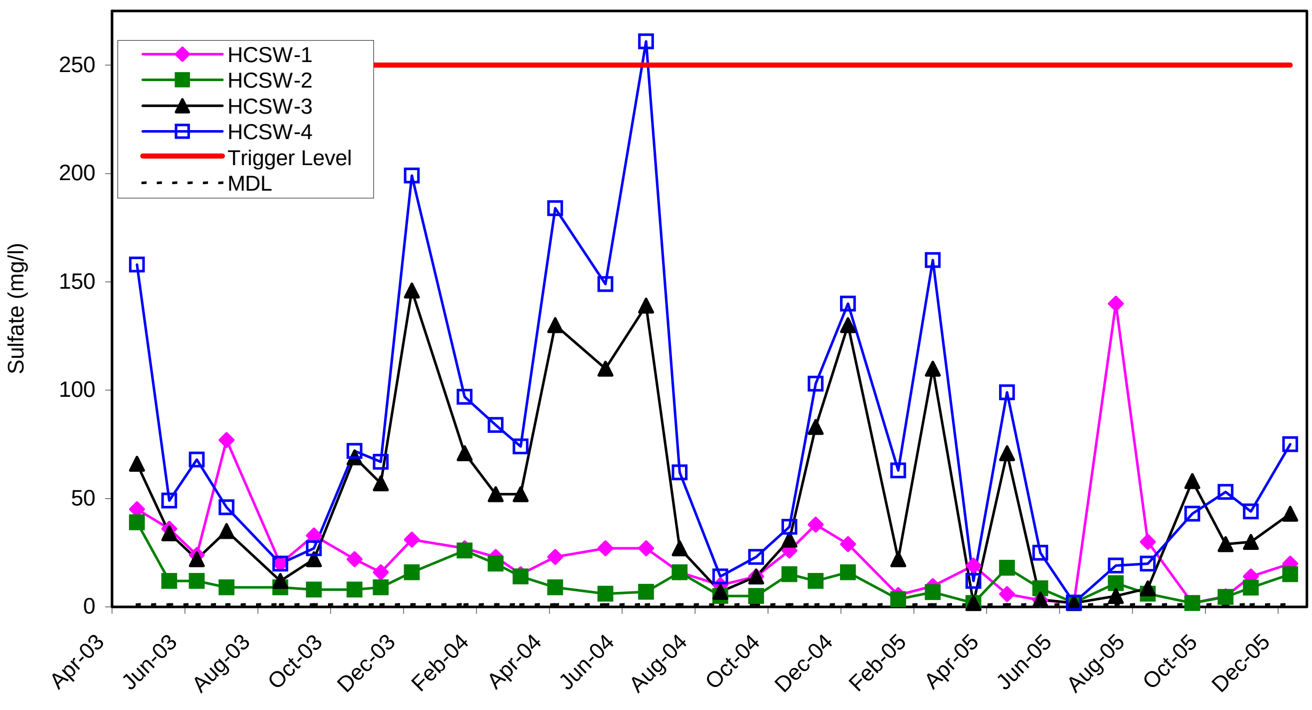

Figure 71. Sulfate Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005.

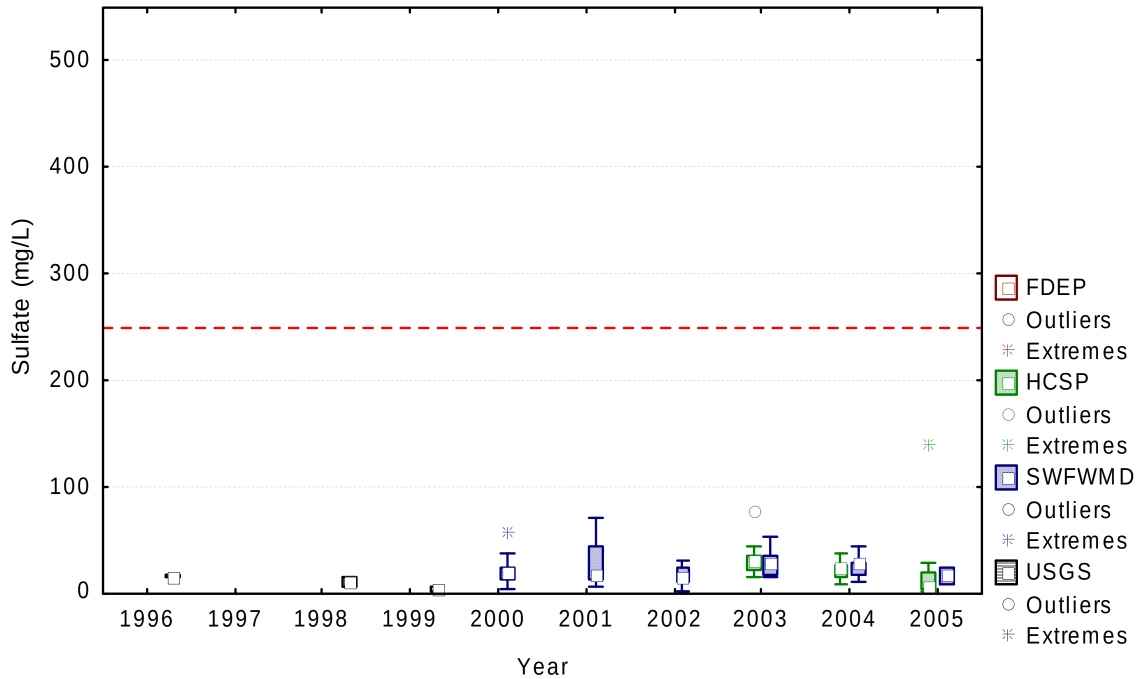

Figure 72. HCSW-1 Values of Sulfate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

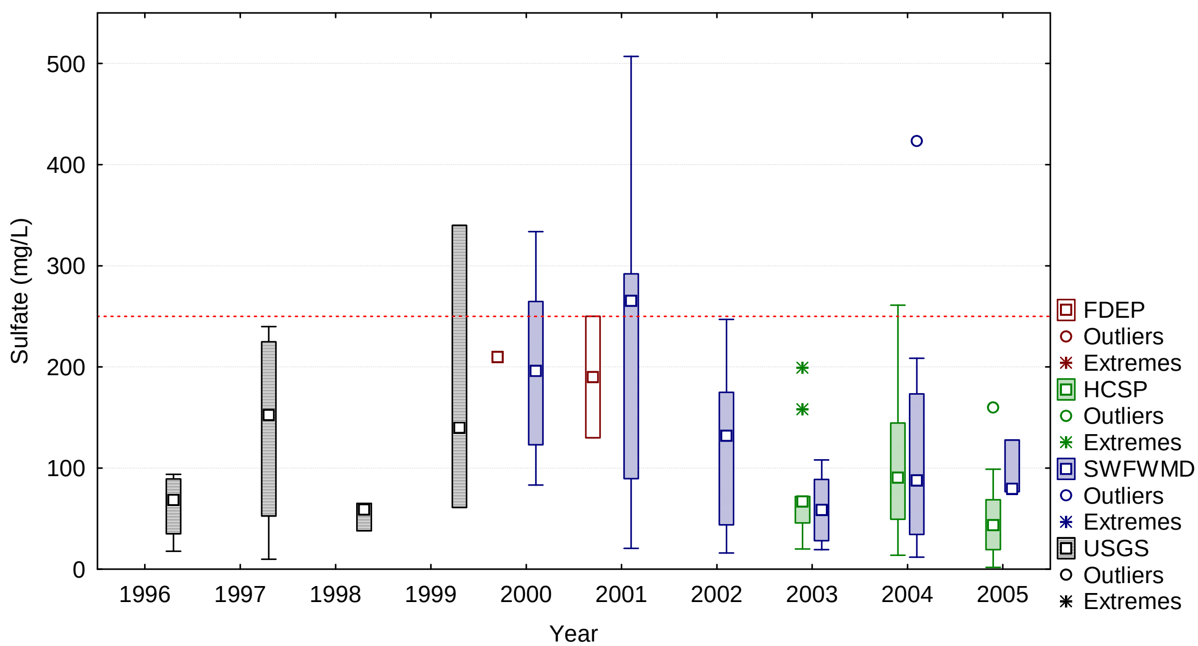

Figure 73. HCSW-4 Values of Sulfate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

As with sulfate concentrations, total dissolved solids levels were lowest at HCSW-1 and HCSW-2 and highest at HCSW-4 (ANOVA, $F = 15.04$, $p < 0.00001$; Duncan's multiple range test, $p < 0.05$) (Figure 74). Total dissolved solids levels were below the trigger level of 500 mg/l during all sampling events in 2003 - 2005. As expected, concentrations of TDS were highest during times of low stream discharge and rainfall at HCSW-4 (Spearman's rank correlation, $r = -0.63$ and $r = -0.36$, respectively, $p < 0.001$). Both sulfate and total dissolved solids are probably affected by agricultural irrigation return flows and groundwater seepage in the same manner as discussed above for conductivity and calcium. The TDS concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend over the last decade (Kendall Tau of annual median TDS, $p > 0.05$) (Figures 75 and 76).

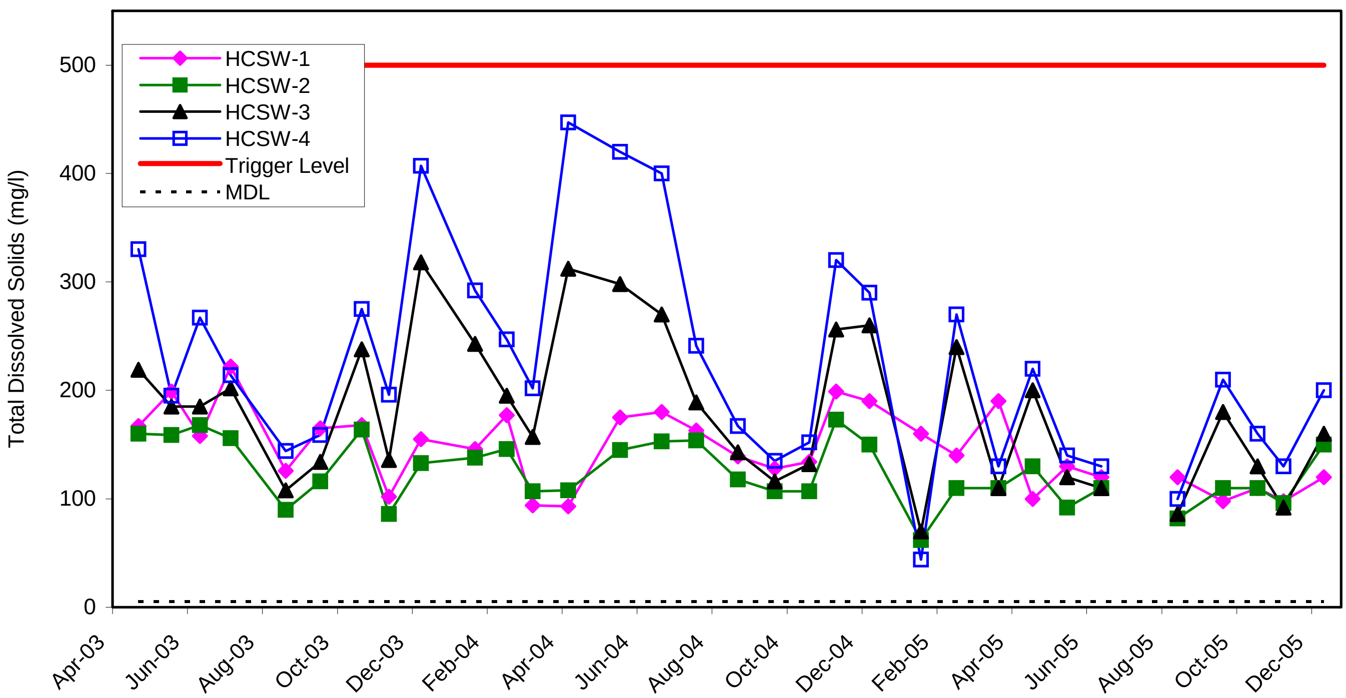

Figure 74. Levels of Total Dissolved Solids Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005.

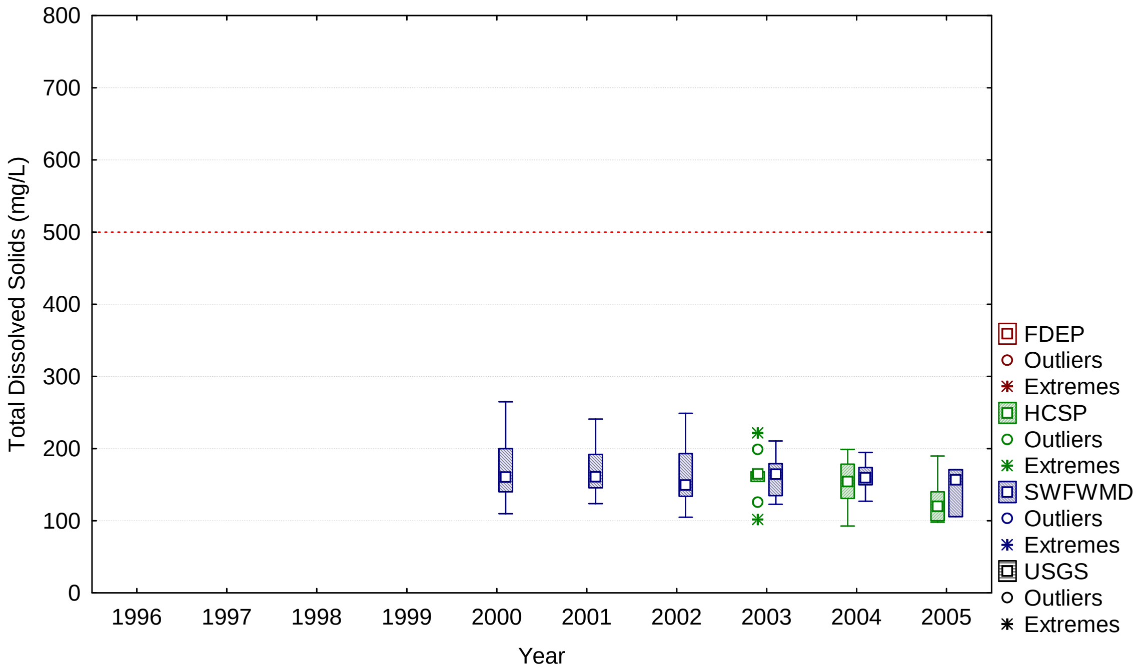

Figure 75. HCSW-1 Values of Total Dissolved Solids Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

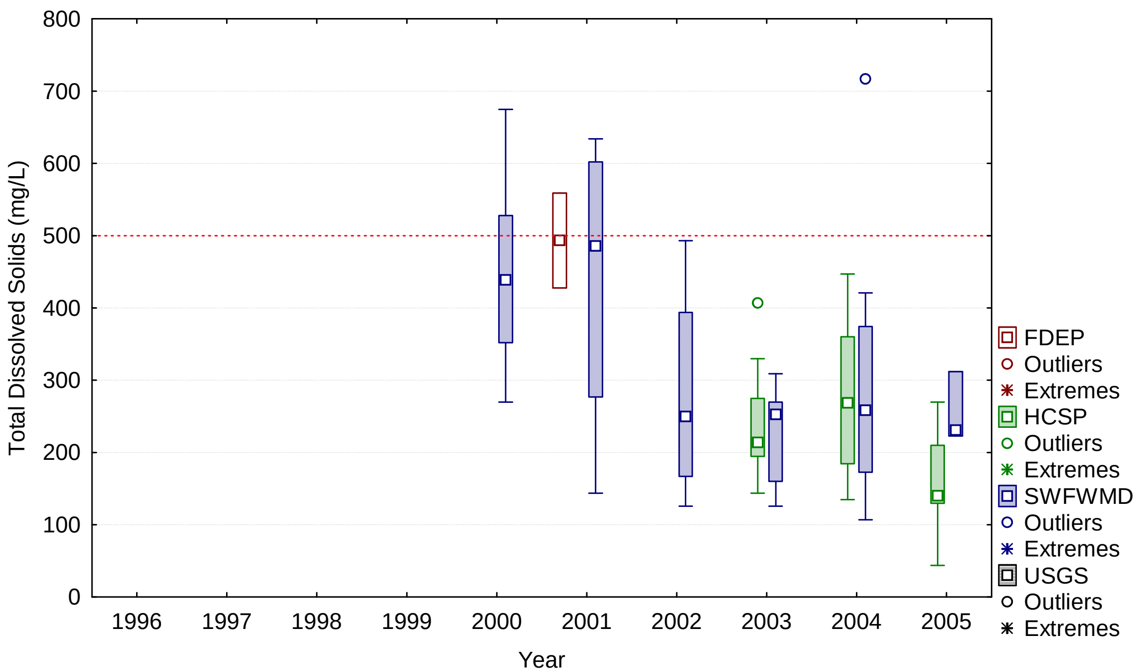

Figure 76. HCSW-4 Values of Total Dissolved Solids Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPS STORET) for Years 1996 – 2005.

The phosphate beneficiation process that refines the mined phosphate ore uses several chemicals as reagents in the physio-chemical separation process. Three of these chemicals (fuel oil, fatty acids, and fatty amines) were selected for testing in the water-quality sampling program as potential indicator parameters of specific mining wastewater impacts. The FDEP Petroleum Range Organics (FL-PRO) test was selected as a test for fuel oil. Specific test methods were developed for fatty acids (obtained by Mosaic as a by-product of the paper industry and largely composed of oleic and linoleic acids) and fatty amines (fatty acids reacted with ammonia). PRO, fatty acid and amines all degrade biologically and/or photochemically within mine recirculation waters and clay settling areas. These organic parameters were added to the HCSP monitoring list as an extra safeguard, although it was Mosaic's position that they would never be present at detectable limits in any waters discharged from mining areas.

Petroleum range organics were detected only six times from 2003 – 2005, in March and August 2005 (Figure 77). Each of those readings was only slightly above the minimum detection limit (MDL) and well below the trigger level for that parameter. Petroleum range organics were detected above the MDL (but below the trigger level) at least once for each HCSP station. Total amines were not detected at any sampling station in 2003 - 2005. Total fatty acids were detected only four times above the trigger level at two stations: November 2004, March 2005 and April 2005 at HCSW-2, and February 2005 at HCSW-3 (Figure 78). Not enough data was available for these three parameters to evaluate differences between stations or relationships with streamflow and rainfall.

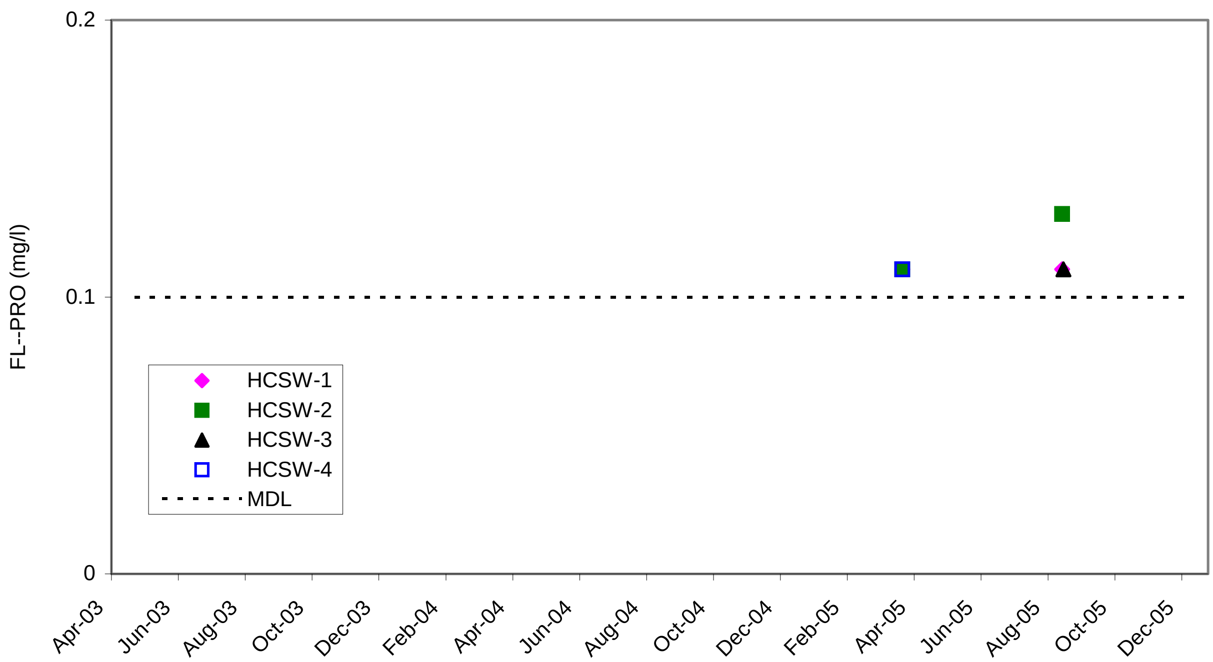

Figure 77. Levels of Petroleum Range Organics (Above MDL only) Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005. (HCSP trigger level is 5.0 mg/l.)

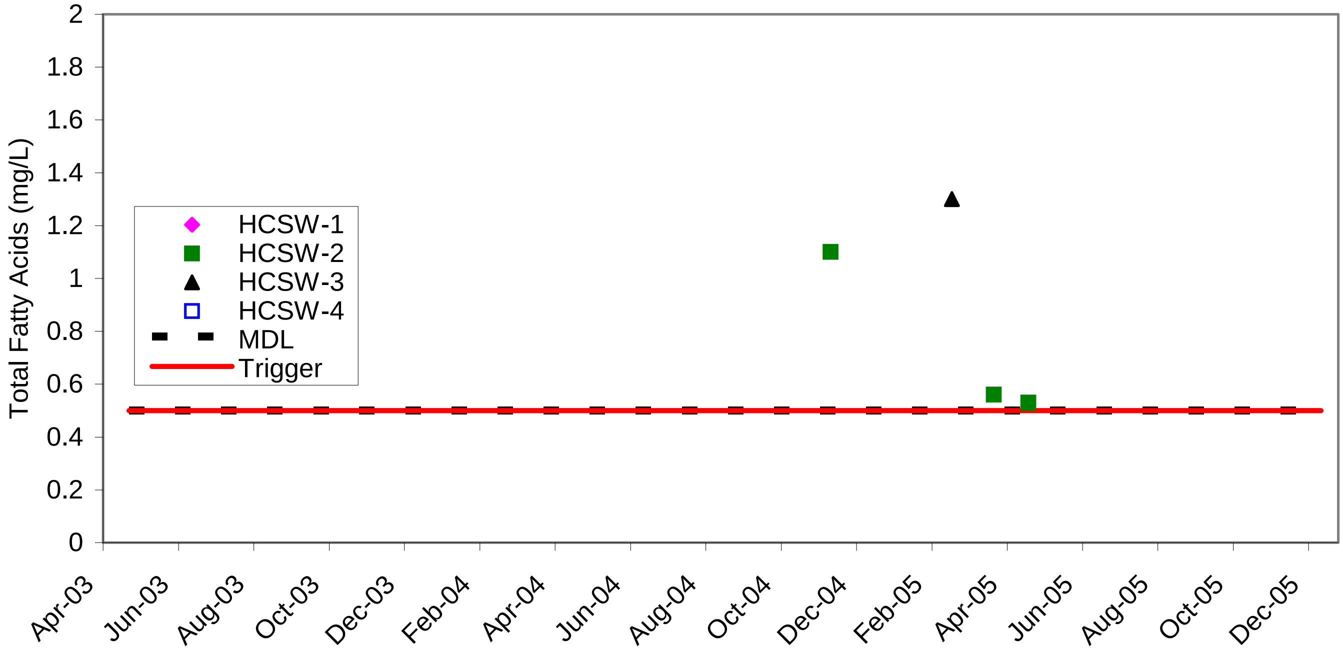

Figure 78. Levels of Total Fatty Acids (Above MDL only) Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005.

Phosphate ore is a source of radioactivity as naturally occurring uranium-238 disintegrates into isotopes of radium and radon, which emit alpha particles in water. A water quality study of unmined and reclaimed basins in phosphate-mining areas found that radium concentrations of surface waters were slightly higher in unmined areas than in reclaimed basins, probably because of undisturbed phosphate deposits near the surface of unmined lands (Lewelling and Wylie 1993). The study also found that general radiochemical concentrations in groundwater from the surficial aquifer were greater below unmined lands than reclaimed lands. Clay-settling areas may trap radioactive chemicals associated with clay slurry, but release only small amounts of radioactive chemicals into surface waters (Lewelling and Wylie 1993). In Horse Creek during 2005, total radium[4] levels were below the trigger level of 5 pCi/l

[4] The HCSP methodology specifies that "Radium 226 + 228" be analyzed as part of the monthly sampling. This data has been reported as both individual constituents and as a total. The data in Appendix E reflects these changes. Starting in December 2003 and continuing through the present, the data has been analyzed and reported as Radium 226 and Radium 228 separately and an arithmetic sum of the two numbers ("Radium 226 + 228"). As requested by the PRMRWSA, if either Radium 226 or Radium 228 is undetected, the MDL of the undetected constituent will be used as part of the "Radium 226 + 228." This use of MDL for undetected constituents is contrary to both laboratory and DEP SOPs.

(Figure 79). Total radium levels during 2003-2005 were not significantly different among stations (ANOVA, F = 0.26, p = 0.85) or correlated with streamflow (Figure 79).

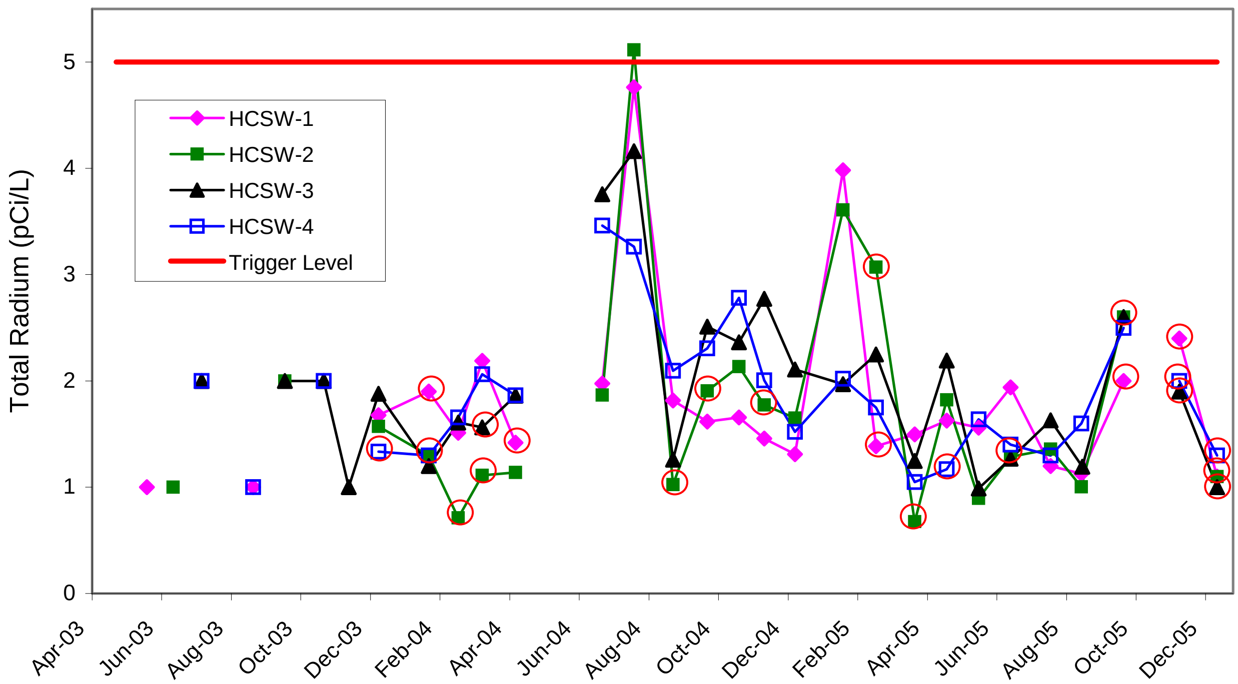

Figure 79. Levels of Total Radium Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2005. (Data from samples where both Radium 226 and Radium 228 were undetected are not included and where one was undetected are circled in red.)

5.2.4 Summary of Water Quality Results

Water quality parameters in 2005 were almost always within the desirable range relative to trigger levels and water quality standards. Trigger levels were exceeded at least once for five parameters in 2005: dissolved oxygen, chlorophyll *a*, fatty acids, pH, and dissolved iron (Table 14). Dissolved oxygen was exceeded the trigger level (was below 5 mg/L) during almost all sampling events at HCSW-2. Based upon historical conditions in Horse Creek (Durbin and Raymond 2006), the reported values for dissolved oxygen at HCSW-2 are the result of natural conditions (proximity to hypoxic segment of stream – Horse Creek Prairie) and are not related to mining activities. Dissolved oxygen triggers were also exceeded at two other stations during summer wet months of 2005, when high temperatures reduce the oxygen carrying capacity of the stream. Chlorophyll *a* trigger values in 2005 were exceeded twice at HCSW-2, just before and after the wet season. HCSW-2 is a slow-moving section of Horse Creek located immediately downstream of Horse Creek Prairie, thereby creating conditions that would naturally foster algal growth. Fatty acids exceeded the trigger level three times in 2005, but not at the station closest to mining. The other exceedance (pH at HCSW-3) was an isolated event, occurring during the wet season when rainfall and discharge were high. Dissolved iron concentrations exceeded the trigger value set at HCSW-4 in eight of twelve months, but all parties agree that the trigger value at that station has been set too low given historical and upstream concentrations of dissolved iron.

From the 21 months of HCSP data available (Figure 80), there was no evidence of temporal trends that could be attributed to anything other than long-term climatic oscillations or general wet season/dry season fluctuations. When historic data from other sources are considered, fluoride exhibits an increasing trend at HCSW-1 and a decreasing trend at HCSW-4, while ammonia exhibits a possible increasing trend at HCSW-1. The increasing trend in fluoride at HCSW-1 disappears, however, if more than ten years of historical data are included in the analysis.

Several water quality parameters were highest during periods of high rainfall and streamflow at station HCSW-1 (positive correlation with discharge), including color, organic nitrogen, turbidity, dissolved iron, and to a lesser extent, chlorophyll *a*. These parameters are most likely to exceed the HCSP trigger values during the wet season months (June – September) because of intrinsic relationships with hydrology, not mining activities. Other parameters were lowest during the wet season (negative correlation with discharge), including dissolved oxygen, pH, nitrogen oxides, orthophosphate, and most dissolved ions. DO and pH are most likely to exceed trigger values in the wet season when acidic runoff and organic decomposition is high and oxygen carrying capacity is low. Orthophosphate, nitrogen oxides, and dissolved ions are highest during the dry season or during drought years, when groundwater seepage and irrigation runoff are highest.

Significant differences between stations were evident for several parameters. Overall, HCSW-2 was the most dissimilar from the other three stations, especially in pH, dissolved oxygen, and some dissolved ions. Some nutrients (nitrate + nitrite and orthophosphate) and dissolved ions (specific conductivity, calcium, sulfate) had higher concentrations downstream in Horse Creek, probably because of increased groundwater seepage and agricultural runoff in the lower Horse Creek basin. Differences in topography, geology, and land use that could account for these trends in Horse Creek are examined in the Horse Creek Stewardship Program Historical Report (Durbin and Raymond 2006).

Table 14. Instances of Trigger Level Exceedance Observed in 2005 HCSP Monthly Monitoring (Excluding HCSW-1 Continuous Recorder Data). (Dissolved iron exceedances of HCSW-4 trigger level are not included.)

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger
Horse Creek at Goose Pond Road	HCSW-2	01/26/05	Dissolved Oxygen (mg/l)	4.1	5.0
Horse Creek at Goose Pond Road	HCSW-2	02/24/05	Dissolved Oxygen (mg/l)	3.5	5.0
Horse Creek at Goose Pond Road	HCSW-2	03/30/05	Dissolved Oxygen (mg/l)	2.6	5.0
Horse Creek at Goose Pond Road	HCSW-2	05/27/05	Dissolved Oxygen (mg/l)	2	5.0
Horse Creek at Goose Pond Road	HCSW-2	06/22/05	Dissolved Oxygen (mg/l)	1.4	5.0
Horse Creek at Goose Pond Road	HCSW-2	07/27/05	Dissolved Oxygen (mg/l)	1.1	5.0
Horse Creek at Goose Pond Road	HCSW-2	08/23/05	Dissolved Oxygen (mg/l)	1.7	5.0
Horse Creek at Goose Pond Road	HCSW-2	09/29/05	Dissolved Oxygen (mg/l)	2.3	5.0

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger
Horse Creek at Goose Pond Road	HCSW-2	10/27/05	Dissolved Oxygen (mg/l)	4.6	5.0
Horse Creek at Goose Pond Road	HCSW-2	11/17/05	Dissolved Oxygen (mg/l)	2.8	5.0
Horse Creek at Goose Pond Road	HCSW-2	12/20/05	Dissolved Oxygen (mg/l)	4.4	5.0
Horse Creek at State Road 70	HCSW-3	06/22/05	Dissolved Oxygen (mg/l)	3.9	5.0
Horse Creek at State Road 70	HCSW-3	07/27/05	Dissolved Oxygen (mg/l)	3.5	5.0
Horse Creek at State Road 70	HCSW-3	08/23/05	Dissolved Oxygen (mg/l)	4.4	5.0
Horse Creek at State Road 72	HCSW-4	06/22/05	Dissolved Oxygen (mg/l)	4.0	5.0
Horse Creek at State Road 72	HCSW-4	07/27/05	Dissolved Oxygen (mg/l)	4.1	5.0
Horse Creek at State Road 70	HCSW-3	07/27/05	pH (SU)	5.9	6.0
Horse Creek at Goose Pond Road	HCSW-2	05/27/05	Chlorophyll a (mg/m^3)	17	15
Horse Creek at Goose Pond Road	HCSW-2	11/17/05	Chlorophyll a (mg/m^3)	17	15
Horse Creek at Goose Pond Road	HCSW-2	03/30/2005	Total Fatty Acids (mg/L)	0.56	0.5
Horse Creek at Goose Pond Road	HCSW-2	04/27/2005	Total Fatty Acids (mg/L)	0.53	0.5
Horse Creek at State Road 70	HCSW-3	02/24/2005	Total Fatty Acids (mg/L)	1.3	0.5
Horse Creek at State Road 72	HCSW-4	3/30/2005	Dissolved Iron (mg/L)	0.45	0.3
Horse Creek at State Road 72	HCSW-4	4/27/2005	Dissolved Iron (mg/L)	0.40	0.3
Horse Creek at State Road 72	HCSW-4	5/25/2005	Dissolved Iron (mg/L)	0.45	0.3
Horse Creek at State Road 72	HCSW-4	6/22/2005	Dissolved Iron (mg/L)	0.77	0.3
Horse Creek at State Road 72	HCSW-4	7/27/2005	Dissolved Iron (mg/L)	0.74	0.3
Horse Creek at State Road 72	HCSW-4	8/23/2005	Dissolved Iron (mg/L)	0.58	0.3
Horse Creek at State Road 72	HCSW-4	9/29/2005	Dissolved Iron (mg/L)	0.44	0.3
Horse Creek at State Road 72	HCSW-4	11/17/2005	Dissolved Iron (mg/L)	0.49	0.3

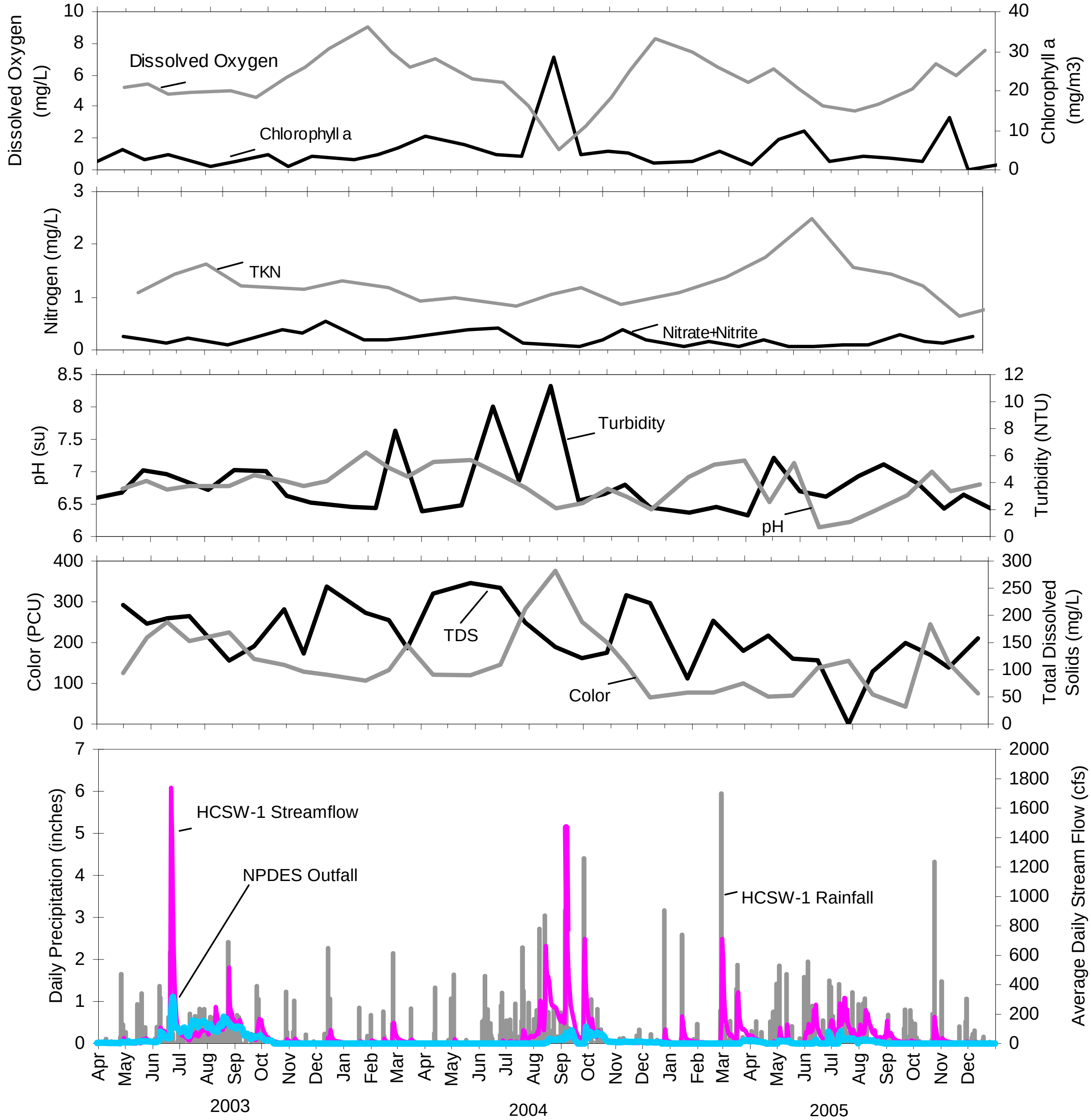

Figure 80. HCSP Water Quality Correlations With NPDES Discharge, Streamflow, and Rainfall at HCSW-1 in 2003 - 2005.

5.3 BENTHIC MACROINVERTEBRATES

Biological sampling and aquatic habitat assessment were conducted four times in 2005 because of a missed sampling event in 2004 in the wake of Hurricane Charley.

Figure 81. Seining for fish during biological sampling in Horse Creek.

Figure 82. Electrofishing and SCI Stream Habitat Assessment during biological sampling in Horse Creek.

5.3.1 Stream Habitat Assessment

The majority of the habitat assessment parameters evaluated through the DEP procedure are not directly related to mining, but are generally related to the nature of the system being examined and its surroundings (e.g., substrate diversity and availability, artificial channelization, bank stability, buffer width, and vegetation quality). Parameters that might be hypothesized to have some linkage to mining are water velocity and habitat smothering, primarily as a result of NPDES discharges to a stream. Water velocity was slightly higher when NPDES discharge was elevated in 2005 (wet season), coincident with heavy rainfall and overall high discharge in Horse Creek (Figure 13). Habitat smothering in 2005 was highest during the early months, as the system was still recovering from Hurricane Charley.

The habitat quality of Horse Creek was within the optimal or sub-optimal range during all sampling events in 2005 (Table 15), as it was for 2003 and 2004 (Figure 83). Prior to Hurricane Charley in 2004, habitat quality at HCSW-1 was not better than at other stations. In 2005, however, HCSW-1 always has optimal habitat quality, while the other three stations, which were more affected by Hurricane Charley, often have sub-optimal habitat quality. Some of the minor variation among the sampling events for a given station after Hurricane Charley primarily reflects differences in habitat quality caused by changes in stream stage, which affects the availability and ratios of in-stream habitats, and also the inherent variability in the habitat scoring protocol itself.

Because Hurricane Charley effectively traveled up the Horse Creek basin in mid-2004, the stream and its floodplain were still visibly different in 2005 in a number of ways. The most downstream stations still showed evidence of significant tree canopy loss, although regeneration was occurring. In many areas, the Horse Creek channel itself was altered through the combined effects of the large discharge brought about by Charley (and subsequent storms in 2004), as well as the sudden introduction of massive amounts of sediment into the stream. Introduction of this material obviously had a powerful effect on in-stream hydraulics, leading to changes in channel configuration, local velocity patterns, and erosion/deposition patterns. As the floodplain continues to 'recover' from hurricane effects (i.e., through re-growth of damaged or destroyed vegetation), it can be assumed that Horse Creek will see further changes in its morphometry, and probably its ecology, over and above typical year-to-year changes that might otherwise be expected.

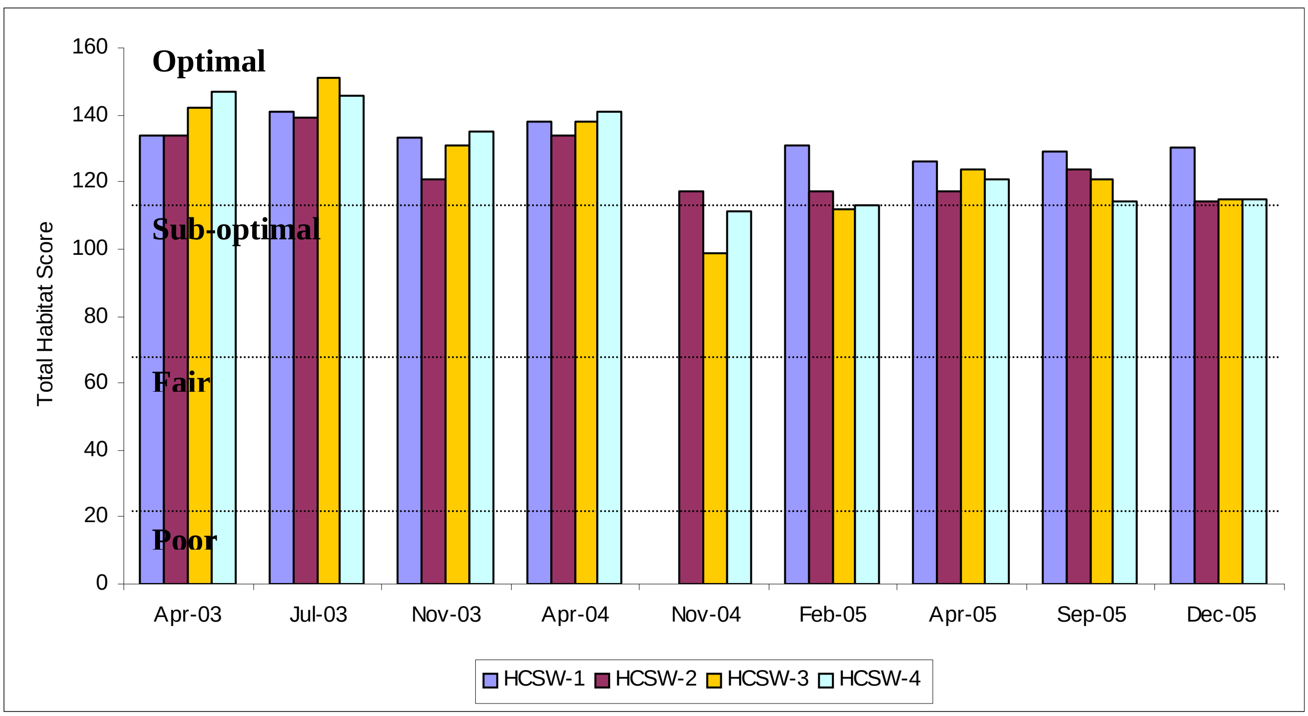

Figure 83. Total Habitat Scores Obtained During HCSP Biological Sampling Events in 2003-2005. (HCSW-1 November 2004 score omitted because of sampler oversight.)

5.3.2 Stream Condition Index

A database containing a list of the benthic macroinvertebrate taxa collected during 2003 - 2005 is on the attached CD-ROM. Table 16 provides the SCI metrics, resulting SCI values, and total SCI scores calculated for the benthic macroinvertebrates collected at the four stations during each sampling event in 2005. The numbers of individuals included in Table 16 represent the number extrapolated for the entire sample (i.e., all 20 dipnet sweeps). This estimate is also given in the database, as well as the actual number of individuals in the subsample analyzed by the taxonomist (only a portion of each sample is sorted and processed, per the SOP). The various components of the SCI calculations are briefly described in the subsections below.

5.3.2.1 Total Taxa

In general, a healthy stream system will support colonization by a diverse number of taxa. Therefore, the more taxa a station is shown to have, the healthier that system is regarded. Figure 84 illustrates the number of taxa collected at each of the HCSP stations during the quarterly events. For all stations, the highest number of benthic macroinvertebrates species was collected during February 2005 (or December 2005 for HCSW-2). The fewest number of species were collected in July 2003 or November 2004 at all stations as a result of very high water levels from the large amount of rainfall received in previous months. Low taxa richness for July 2003 is largely a sampling artifact and does not reflect lessened habitat quality in the stream. Differences in taxa numbers among samples are expected, both spatially and temporally, as a result of natural variability, as well as differences in sampling conditions and sample processing, even when the invertebrate communities are very similar. The number of invertebrate taxa collected in each sample was similar to historic sampling in the basin (Durbin and Raymond 2006).

Table 15. Habitat Scores Obtained During HCSP Biological Sampling Events in 2005.

	HCSW-1				HCSW-2				HCSW-3				HCSW-4			
	15 Feb 2005	21 Apr 2005	15 Sep 2005	15 Dec 2005	15 Feb 2005	21 Apr 2005	15 Sep 2005	15 Dec 2005	15 Feb 2005	21 Apr 2005	15 Sep 2005	15 Dec 2005	15 Feb 2005	21 Apr 2005	15 Sep 2005	15 Dec 2005
Substrate Diversity	14	15	14	15	13	14	14	10	10	12	12	6	16	12	4	4
Substrate Availability	12	12	10	11	12	9	12	4	10	8	9	5	10	9	9	5
Water Velocity	12	13	14	13	12	4	13	13	16	15	17	15	13	18	14	15
Habitat Smothering	18	11	16	16	17	18	15	16	15	18	13	15	15	18	16	16
Artificial Channelization	20	20	20	20	15	15	15	15	20	20	20	20	19	19	19	19
Bank Stability																
Right Bank	8	8	8	8	8	8	9	10	5	8	7	8	6	8	8	9
Left Bank	9	9	9	9	9	9	8	8	6	8	7	8	6	6	8	9
Riparian Buffer Zone Width																
Right Bank	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Left Bank	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Riparian Zone Vegetation Quality																
Right Bank	9	9	9	9	9	9	9	9	5	8	8	9	4	8	8	9
Left Bank	9	9	9	9	9	9	9	9	5	7	8	9	4	7	8	9
Total Score*	**131**	**126**	**129**	**130**	**117**	**117**	**124**	**114**	**112**	**124**	**121**	**115**	**113**	**121**	**114**	**115**
Habitat Descriptor	Optimal	Optimal	Optimal	Optimal	Sub-optimal	Sub-optimal	Optimal	Sub-optimal	Sub-optimal	Optimal	Optimal	Sub-optimal	Sub-optimal	Optimal	Sub-optimal	Sub-optimal

- * - The maximum possible score under this protocol is 160 (120-160 Optimal, 80-119 Suboptimal, 40-79 Marginal, <40 Poor).

Table 16. SCI Metrics Calculated for Benthic Macroinvertebrates Collected at Four Locations on Horse Creek for the HCSP During 2005.

SCI Metric	HCSW-1								HCSW-2							
	15 Feb 2005		21 Apr 2005		15 Sep 2005		15 Dec 2005		15 Feb 2005		21 Apr 2005		15 Sep 2005		15 Dec 2005	
	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value
Total Taxa	43.0	**10.0**	16.0	**0.0**	29.0	**5.2**	26.0	**4.0**	33.0	**6.8**	28.0	**4.8**	18.0	**0.8**	36.0	**8.0**
Ephemeropteran Taxa	3.0	**6.0**	1.0	**2.0**	4.0	**8.0**	3.0	**6.0**	3.0	**6.0**	3.0	**6.0**	4.0	**8.0**	1.0	**2.0**
Trichopteran Taxa	0.0	**0.0**	2.0	**2.9**	7.0	**10.0**	2.0	**2.9**	4.0	**5.7**	1.0	**1.4**	0.0	**0.0**	1.0	**1.4**
Percent Filterer Taxa	24.2	**6.0**	6.9	**1.5**	5.1	**1.0**	15.4	**3.7**	15.5	**3.7**	6.9	**1.5**	9.7	**2.2**	25.2	**6.2**
Long-lived Taxa	0.0	**0.0**	3.0	**7.5**	0.0	**0.0**	0.0	**0.0**	2.0	**5.0**	2.0	**5.0**	0.0	**0.0**	1.0	**2.5**
Clinger Taxa	2.0	**2.5**	4.0	**5.0**	10.0	**10.0**	8.0	**10.0**	7.0	**8.8**	2.0	**2.5**	0.0	**0.0**	2.0	**2.5**
Percent Dominant Taxon	18.2	**8.1**	64.5	**0.0**	58.1	**0.0**	36.1	**4.1**	13.4	**9.2**	30.1	**5.4**	25.0	**6.6**	19.6	**7.8**
Percent Tanytarsini	30.3	**10.0**	0.6	**1.4**	2.8	**4.0**	8.4	**6.8**	4.4	**5.1**	7.3	**6.4**	1.4	**2.6**	47.6	**10.0**
Sensitive Taxa	2.0	**2.2**	2.0	**2.2**	6.0	**6.7**	2.0	**2.2**	5.0	**5.6**	1.0	**1.1**	0.0	**0.0**	0.0	**0.0**
Percent Very Tolerant Taxa	31.5	**1.5**	1.8	**7.5**	0.0	**10.0**	0.6	**8.9**	3.1	**6.6**	28.5	**1.8**	22.2	**2.3**	15.4	**3.2**
Total SCI Score	**51.5**		**33.4**		**61.0**		**53.9**		**69.3**		**40.0**		**25.1**		**48.5**	
Interpretation	**Fair**		**Poor**		**Fair**		**Fair**		**Fair**		**Poor**		**Poor**		**Fair**	
Total Number of Individuals	2640		1992		5859		5644		1288		984		1152		2717	

SCI Metric	HCSW-3								HCSW-4							
	15 Feb 2005		21 Apr 2005		15 Sep 2005		15 Dec 2005		15 Feb 2005		21 Apr 2005		15 Sep 2005		15 Dec 2005	
	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value
Total Taxa	44.0	**10.0**	26.0	**4.0**	31.0	**6.0**	27.0	**4.4**	35.0	**7.6**	26.0	**4.0**	27.0	**4.4**	19.0	**1.2**
Ephemeropteran Taxa	7.0	**10.0**	8.0	**10.0**	5.0	**10.0**	2.0	**4.0**	3.0	**6.0**	6.0	**10.0**	5.0	**10.0**	2.0	**4.0**
Trichopteran Taxa	1.0	**1.4**	1.0	**1.4**	4.0	**5.7**	2.0	**2.9**	2.0	**2.9**	1.0	**1.4**	3.0	**4.3**	1.0	**1.43**
Percent Filterer Taxa	19.0	**4.6**	24.7	**6.1**	14.5	**3.5**	14.1	**3.4**	27.7	**6.8**	34.2	**8.5**	8.7	**2.0**	11.0	**2.6**
Long-lived Taxa	1.0	**2.5**	0.0	**0.0**	1.0	**2.5**	0.0	**0.0**	1.0	**2.5**	1.0	**2.5**	1.0	**2.5**	1.0	**2.5**
Clinger Taxa	7.0	**8.8**	4.0	**5.0**	5.0	**6.3**	6.0	**7.5**	5.0	**6.3**	6.0	**7.5**	7.0	**8.8**	6.0	**7.5**
Percent Dominant Taxon	29.8	**5.5**	13.7	**9.2**	27.0	**6.1**	47.4	**1.5**	18.3	**8.1**	19.4	**7.9**	26.2	**6.3**	59.9	**0.0**
Percent Tanytarsini	8.6	**6.9**	14.7	**8.4**	6.9	**6.3**	5.2	**5.5**	12.9	**8.0**	18.0	**8.9**	4.0	**4.9**	3.8	**4.8**
Sensitive Taxa	4.0	**4.4**	3.0	**3.3**	2.0	**2.2**	3.0	**3.3**	4.0	**4.4**	3.0	**3.3**	3.0	**3.3**	2.0	**2.2**
Percent Very Tolerant Taxa	6.7	**5.0**	1.0	**8.3**	6.3	**5.2**	4.4	**5.9**	10.8	**4.0**	2.9	**6.7**	0.7	**8.8**	0.8	**8.7**
Total SCI Score	**65.7**		**61.8**		**59.7**		**42.6**		**62.9**		**67.5**		**61.4**		**38.7**	
Interpretation	**Fair**		**Fair**		**Fair**		**Poor**		**Fair**		**Fair**		**Fair**		**Poor**	
Total Number of Individuals	2040		3420		3021		5220		1488		3336		1043		2112	

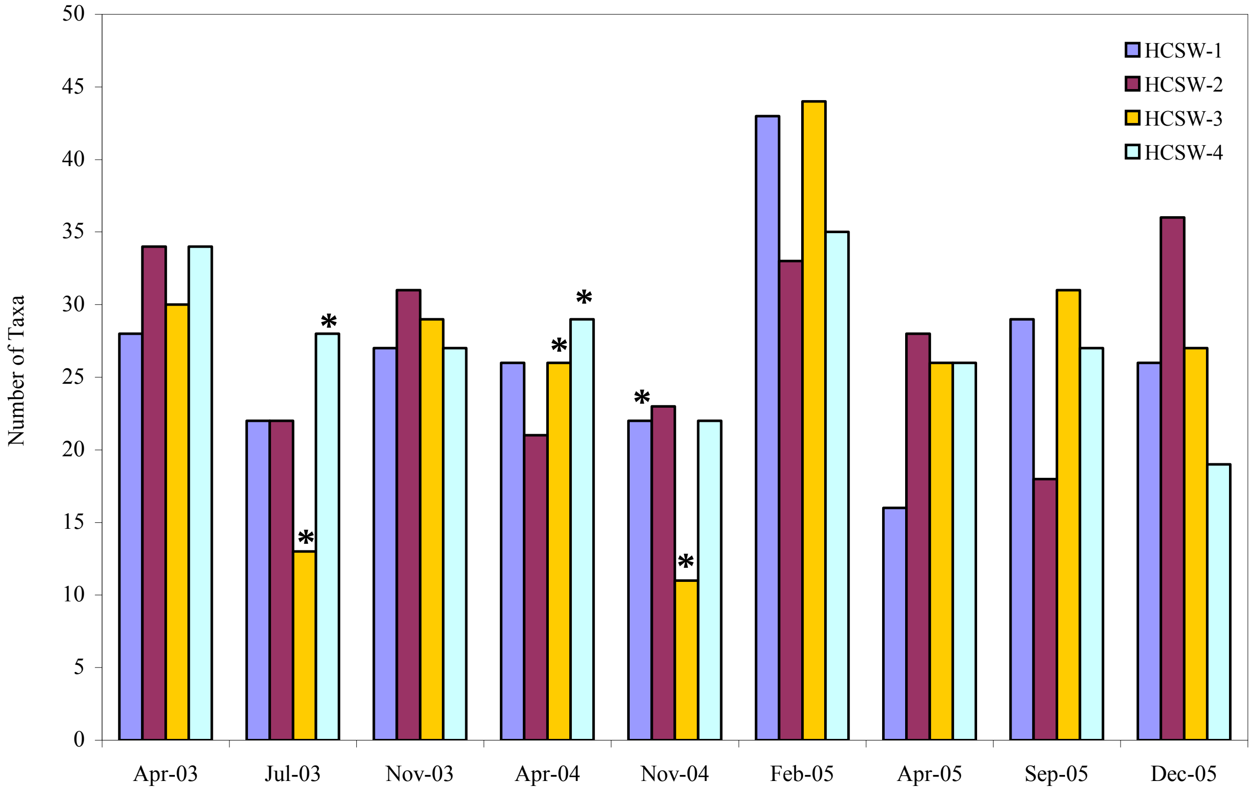

Figure 84. Number of Invertebrate Taxa Collected from the Horse Creek Stewardship Project in 2003 - 2005. (* represent samples with less than the recommended 100 individuals in the sorted portion; the SCI score for these samples is suspect.)

5.3.2.2 Ephemeroptera Taxa

Ephemeropterans (mayflies) are typically associated with more pristine waters and better habitat conditions. A higher taxa count for this group is associated with better habitat value. At least one mayfly taxon must be present to score a SCI metric above zero. None were collected during the July 2003 event at HCSW-2 and HCSW-3, the April and November 2004 events at HCSW-3, or the April 2004 event at HCSW-4; therefore, those stations received a zero for the metric on those dates. All stations in 2005 had at least one ephemeropteran species. The greatest number of mayfly taxa collected at any station during any event was eight, in April 2005 at HCSW-3. Although the number of Ephemeroptera taxa was as high as six at some sites used in developing the SCI calculation protocols, typical samples produce only 0-2 taxa (Fore 2004). This is consistent with the findings from the Horse Creek stations (Table 16).

5.3.2.3 Trichoptera Taxa

Trichopterans (caddisflies) are also associated with more pristine waters and better habitats, so higher counts of caddisflies are associated with better ecological conditions. At least one taxon must be collected in order for the SCI metric to be above zero. This metric was zero several times in 2003-2004, as well as twice in 2005 (once at each of two stations). The greatest number of caddisfly taxa in any sample was seven (in HCSW-1 in September 2005). According to Fore (2004), caddisfly taxa ranged from zero to eight in samples used for calibrating the SCI protocol, with most samples having four or fewer taxa. This is quite comparable to the observed pattern from Horse Creek in 2005 (Table 16).

5.3.2.4 Percent Collector-Filterer Taxa

Taxa whose functional feeding group is "collector-filterer" are often more prolific in pristine natural waters. A reduction in the collector-filterer community can indicate a water quality problem. The SCI metric increases as the percentage of a sample comprised by these taxa increases. To score above zero for this metric, more than one percent of the sample must be composed of collector-filterers. Samples at each station during each 2003 event were composed of at least 15 percent collector-filterers, with a maximum of 78 percent (Table 16). In 2004, however, scores were lower at most stations, reaching as low as 0. The scores in 2005 were more comparable to 2003 scores than 2004 scores. This is within the range reported by Fore (2004) in developing the SCI calculation protocol. For all stations except HCSW-4, the highest percentage of filter-collectors was found in the July 2003 samples; the basis for this difference is unclear.

5.3.2.5 Long-lived Taxa

Long-lived taxa are those that require more than one year to complete their life cycles (Fore, 2004), so they would not be expected in great numbers in intermittent streams or tributaries that go dry before their life cycle can be completed. Some long-lived taxa might also be less frequently encountered in less pristine waters, where these taxa could be exposed to potential contaminants for longer than their short-lived counterparts. To score above zero for this SCI metric, at least one long-lived taxon must be present in a sample. Each station met this threshold during each event in 2003-2004, except during November 2004, suggesting that such species may have been displaced by high flows following Hurricane Charley, Frances and Jeanne and had not yet recovered. In 2005, however, the number of long-lived taxa was very low (0-3), with many samples having no long-lived taxa. These long-lived taxa may not have had sufficient time to recover from the 2004 hurricanes. The observed range of long-lived taxa (0 - 5 taxa) in samples collected from Horse Creek in 2003-2005 (Table 16) corresponds with the range used to develop the SCI methodology (Fore 2004).

5.3.2.6 Clinger Taxa

Taxa whose mode of existence is identified as clinging by Merritt and Cummins (1996) are defined as "having behavioral (e.g., fixed retreat construction) and morphological adaptations for attachment to surfaces in stream riffles." The SCI metric increases as the number of clinger taxa increases within a sample. To score above zero for this SCI metric, at least one clinger taxon must be present in a sample. No clinger taxa were found at HCSW-2 during the July 2003, September 2005 or November 2003 or 2004 events (Table 16). This is presumed to be the result of more sluggish flow at that station, which yields conditions not generally suited for clingers that prefer riffles. Clinger taxa were found at the other three stations at all sampling events, with the most in any sample being ten (Table 16). While Fore (2004) reported more than ten clinger taxa in some cases, most samples used to develop the SCI protocol had less than five taxa.

5.3.2.7 Percent Dominant Taxon

As the contribution of the dominant taxon increases, the diversity of taxa within a system generally decreases. Therefore, higher percent contribution by one taxon is interpreted as less ecologically desirable, and lowers the numerical value associated with this metric. The SCI score is zero if the percentage contribution of the dominant taxon is at or above 54 percent, which was the case at three of the four stations in July 2003 and in April and September 2005 at HCSW-1. Overall, ten of the 16 samples in 2005 had a single taxon representing more than one fourth of the invertebrate community (Table 16). For six of the 16 samples in 2005, a dipteran (fly) dominated, with five of those six dominated by a *Polypedilum*. Mayflies (Ephemeroptera) dominated five samples, with four of those five samples dominated by a *Caenis*. The coleopteran (beetle) *Microcylloepus pusillus* dominated four of the remaining 2005 samples, and one sample was dominated by an amphipoda. HCSW-1 was mostly dominated by coleopterans, and HCSW-4 by dipterans, but the other two stations showed no trend. The dominant taxa vary from year to year, with the 2003 samples dominated by molluscs, 2004 samples dominated by amphipodans, coleopterans, and dipterans, and 2005 samples dominated by ephemeropterans, coleopterans, and dipterans.

5.3.2.8 Percent Tanytarsini

Species in the chironomid tribe Tanytarsini (comprising several genera found in Florida) are commonly associated with less disturbed sites. Therefore, as the percentage of Tanytarsini increases for a sampling site, the SCI metric score also increases. If no Tanytarsini individuals are collected in a sample, this SCI metric score is zero; this occurred at three of the four stations in July 2003 and November 2004, at half the stations in April 2004, but at no stations in 2005. The contribution by Tanytarsini was less than ten percent in all 2003 – 2004 samples, but not all 2005 samples (Table 16).

5.3.2.9 Sensitive Taxa

Sensitive taxa are those that have been identified as sensitive to human disturbance (Fore, 2004). Using this definition, one would expect to find more sensitive taxa in undeveloped "natural" areas as opposed to developed watersheds. At least one sensitive taxon must be collected to raise this SCI metric score above zero. The number of sensitive taxa collected at Horse Creek stations in 2003 - 2005 ranged from zero to six (Table 16). Very few sensitive taxa were collected from HCSW-2, which corroborates well with the lower dissolved oxygen regime at that station and the sluggish nature of the stream segment there, as caused by its proximity to the Horse Creek Prairie.

5.3.2.10 Percent Very Tolerant Taxa

Fore (2004), classified a number of taxa as "very tolerant", meaning they are commonly present in areas with marked human disturbance (although they may also be found in undisturbed sites). More disturbed and/or developed areas, therefore, would be expected to have a higher percentage of tolerant taxa in comparison to areas that have not experienced human disturbance. This SCI metric is similar to the percent contribution of dominant taxa in that, as the fraction of a sample comprised by tolerant taxa increases, the calculated metric decreases. If the percentage of very tolerant taxa reaches or surpasses fifty-nine percent, the SCI metric is zero. This did not occur during the 2003 or 2005 sampling periods at any station, with the highest value being 32 percent; in November 2004 at HCSW-2, however, 73 percent of the taxa were classified as very tolerant (Table 16).

5.3.2.11 SCI Overall Score

Final SCI scores for the samples (with the recommended > 100 individuals in the sorted portion) ranged from about 22 to 73 in 2003, from six to 62 in 2004, and from 25 to 69 in 2005 (Table 16 and Figure 85). In 2003, eight of the samples are interpreted as indicating "Fair" conditions, three as "Poor," and one as "Good" (see Table 6 for interpretation of scores). In 2004, SCI scores were lower than in the same months of 2003, with one sample resulting in "Very Poor" conditions, five samples with "Poor" conditions, and two samples with "Fair conditions" (Figure 85). In 2005, SCI scores were higher than 2004, with 11 samples resulting in "Fair" conditions and 5 samples with "Poor" conditions. In 2003 and 2004, HCSW-1 and HCSW-4 had consistently higher SCI scores than the other two stations, implying that those two stations may harbor more desirable communities. In 2005, however, HCSW-3 and HCSW-4 had higher scores. Comparisons between years may be suspect at this point, because 2004 samples may not have contained enough individual invertebrates for an accurate SCI evaluation. Future sampling will improve the relevance of comparisons across the stations to allow for more robust conclusions.

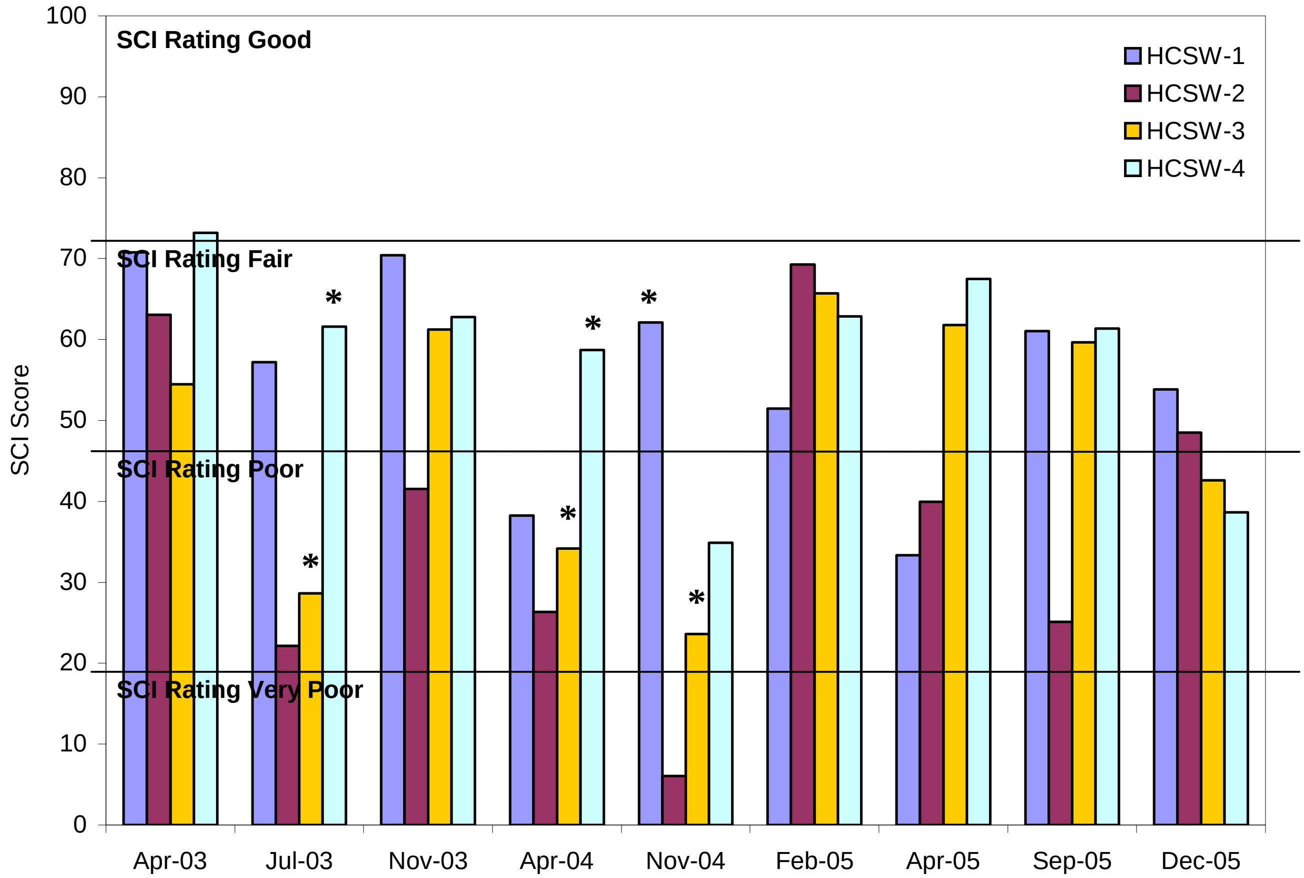

Figure 85. SCI Scores for Samples Collected from Horse Creek, 2003 - 2005. (* represent samples with less than the recommended 100 individuals in the sorted portion; the SCI score for these samples is suspect.)

5.3.3 Shannon-Wiener Diversity Index

Although not a component of the SCI protocol, the Shannon-Wiener Diversity Index is calculated for each benthic macroinvertebrate sampling event at each location. This index, one of the most popular measures of species diversity, is based on information theory and is a measure of the degree of uncertainty in predicting what species would be drawn at random from a collection of species and individuals (Ludwig and Reynolds 1988). The Shannon-Wiener Index assumes that all species are represented in a sample and that the sample was obtained randomly:

$$H' = \sum_{i=1}^{S} (p_i)(\log_2 p_i)$$

where, H' = Information content of sample (bits/individual), index of species diversity,
S = Number of species, and
p_i = Proportion of total sample belonging to ith species.

The Shannon-Wiener Index, H', increases with the number of species in the community and theoretically can reach very large values (Krebs 1998). In practice, however, H' does not generally exceed 5.0 for biological communities. The index is affected both by the number of species and their relative abundance; a greater number of species and a more even distribution of individuals across species both increase diversity as measured by H'. For example, consider two communities, each with 100 individuals of 10 species captured. Community A is dominated by one species (91 of 100 individuals), while only one individual was captured for each of the other nine species. Community B, however, is even, with 10 individuals captured for each of the ten species. While taxa richness is the same for both communities, the Shannon-Wiener Diversity Index shows that Community B is much more diverse than Community A (H' = 3.3 and 0.7, respectively), because Community A is dominated by only one species.

In Horse Creek in 2005, the Shannon-Wiener Diversity Index ranged from 2.0 to 4.5, with highest diversity for each station in February (Figure 86). The February values for 2005, however, may not be comparable to index values collected during the normal sampling regime. There was not a clear 2005 pattern when all stations were considered. The diversity at HCSW-1 increased steadily from April to November 2005, while HCSW-4 showed the opposite pattern. At HCSW-2, diversity was highest in November, but at HCSW-3, diversity was lowest during that month.

The range of diversity values were similar among all years (2003-2005), ranging from 1.4 to 4.0. In 2003 and 2004 higher diversity values occurred for the April and November events than for July (because of high water inhibiting the July sample collection) (Figure 86). Hurricanes affecting the region in August – October 2004 probably negatively affected the invertebrate community of Horse Creek. In 2005, diversity was not consistently higher or lower than 2003-2004 across stations.

Diversity was not statistically different among years (ANOVA $F = 0.47$, $p = 0.62$), but diversity was significantly lower in July 2003 and higher in February 2005 than during other events (ANOVA $F = 2.16$, $p = 0.06$). Temporal trends at individual stations were not identified because the sample size for those analyses would be too small with only nine sampling events.

When results from all events in 2003 - 2005 were combined by station (Figure 87), HCSW-4 showed the highest benthic macroinvertebrate diversity in 2003 – 2004, but HCSW-2 had the highest diversity in 2005. HCSW-3 had the lowest diversity in 2003-2004, but HCSW-1 had the lowest in 2005. The diversity among stations was not statistically different (ANOVA $F = 0.80$, $p = 0.50$).

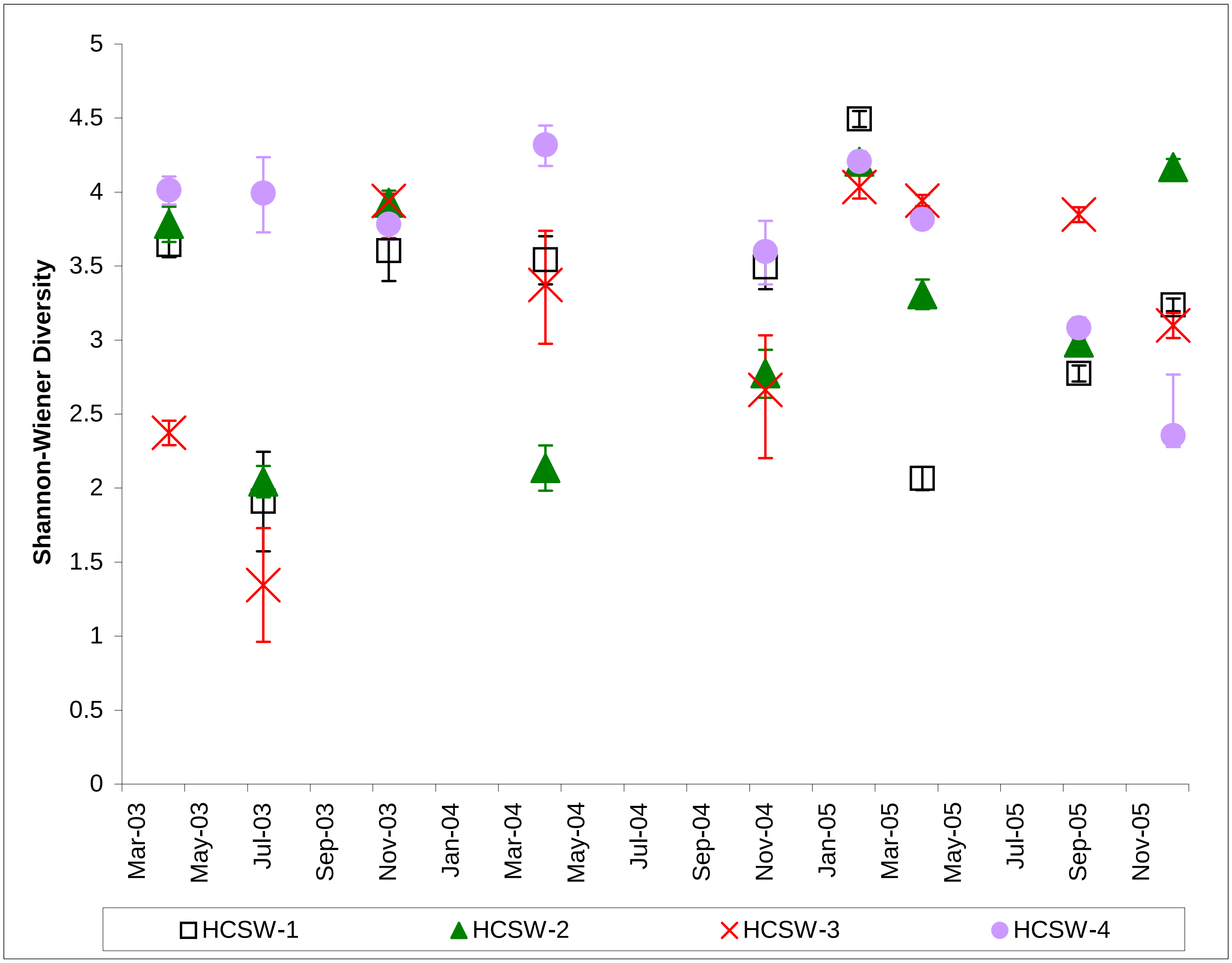

Figure 86. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrates from Four Stations on Horse Creek from 2003 - 2005. (90% confidence limits are automatically provided by the software used to calculate the index values (Ecological Methods v 6.1.1, Exeter Software 2003).

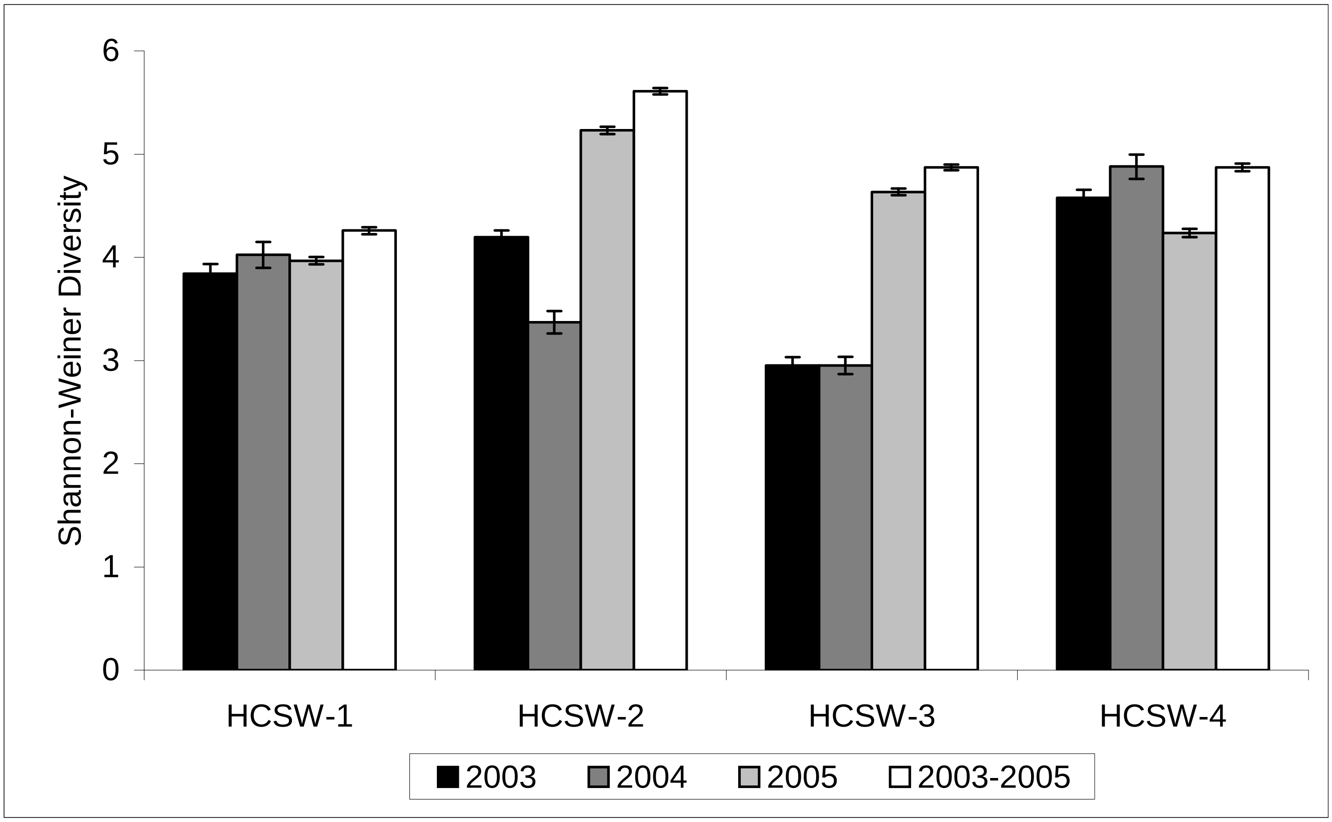

Figure 87. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrates from Four Stations on Horse Creek for combined sample dates. (90% confidence limits are automatically provided by the software used to calculate the index values (Ecological Methods v 6.1.1, Exeter Software 2003).)

5.3.4 Taxa Abundance

Although it is not a component of the SCI protocol, the total number of specimens from each station is also evaluated as a supplemental ecological measure (Figure 88 and Table 16). (Sample size should not be compared between samples from 2003-2004 and those from 2005-present because the SCI sampling and sorting methodology changed during this period.) From Figure 88, the wide variation in sample size is evident, and reviewing this figure along with data in the attached CD-ROM indicates the manner in which one or two taxa can dramatically increase the overall sample size (e.g., 181 of the 296 specimens picked from the April 2003 HCSW-3 sample were *Corbicula fluminea*).

It is important to keep in mind that the SCI metric calculations were developed for samples that contain at least 100 to 125 individuals, and samples with fewer individuals are not expected to yield valid SCI results. If the target range of 100 to 125 individuals was not reached in a given sample, as occurred at HCSW-1 in November 2004, HCSW-3 in July 2003 and April and November 2004, and at HCSW-4 in July 2003 and April 2004, the SCI results cannot be considered to be comparable to those for larger samples. This may explain why HCSW-3 was evaluated as "Poor" by the SCI index in July 2003, April 2004, and November 2004.

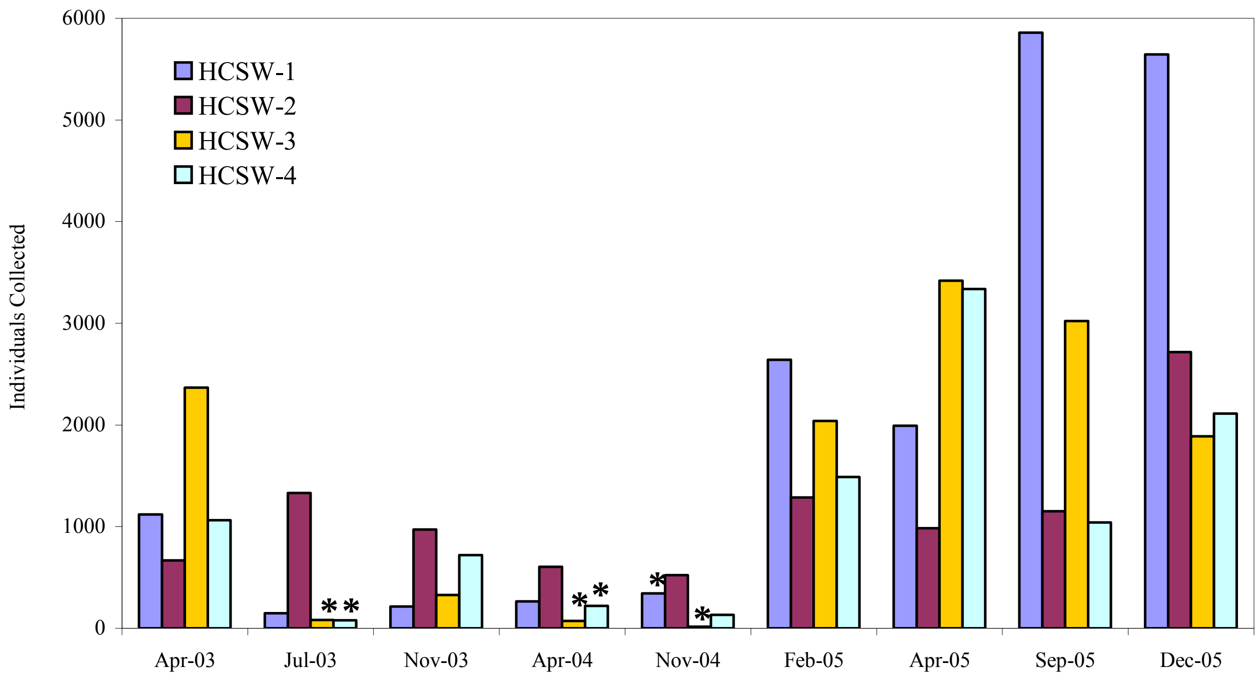

Figure 88. Invertebrate Abundances in Samples Collected from Horse Creek in 2003 - 2005[5] (values are extrapolated based upon numbers of individuals sorted from known proportions of samples). (* represent samples with less than the recommended 100 individuals in the sorted portion; the SCI score for these samples is suspect.)

5.3.5 Summary of Benthic Macroinvertebrate Results

The SCI value calculated for each individual metric, as well as the total SCI scores, were lowest during the November 2004 sample at stations affected by hurricanes (HCSW-2 – HCSW-4). High water levels and stream alteration (see Section 5.4.5) as a result of the several hurricanes passing through the area in August-October 2004 probably lowered SCI scores and benthic macroinvertebrate species diversity. Macroinvertebrates may be washed from the stream during high streamflow, resulting in lower invertebrate diversity during and after high rainfall events. In addition, many productive invertebrate habitats were smothered by sediment or washed downstream during the storms.

The brief discussion of each of the SCI parameters above conveys two important aspects of this particular ecological metric. First, there can be a large degree of variability among stations and among

[5] Between the 2004 and 2005 biological sampling, individuals conducting biological sampling were trained and audited by the FDEP in SCI and Stream Habitat Assessment techniques. Because of this improvement, some SCI results from previous years may not be directly comparable with results from 2005 and beyond.

samples from the same station for a given calculated metric. Second, the actual range over which many of the measured parameters fluctuates can be very small, particularly for the parameters relying on integer counts of taxa (e.g., Ephemeroptera taxa generally range between 0 and about 4 across the various stream types evaluated in developing the SCI). These considerations suggest that care should be exercised in using any individual metric of the SCI as a separate indicator of stream habitat quality. This is the justification for combining all the parameters into a composite index that presumably has a stronger correlation to stream conditions than the separate metrics themselves.

The general quality of the macroinvertebrate community at the Horse Creek stations was within the range commonly observed by BRA in similarly-sized natural streams in this region of Florida, although the generally lower diversity, abundance and SCI scores attributed to the effects of Hurricane Charley are at the lower end of the expected ranges for healthy streams in this region. It may appear inconsistent that when the Habitat Assessment scores indicated optimal or sub-optimal conditions, the total SCI scores indicated that the benthic communities were Fair or Poor. However, this is essentially a matter of semantics resulting from the assignment of qualitative categories under the two different assessment protocols (which were developed independently and not necessarily designed to provide matching qualitative assignments for a given location). Following the adoption of the revised SCI calculation procedure, DEP found that the majority of the reference/background stations it had sampled fell into the Fair category when calculated under the new SCI (R. Frydenbourg, pers. comm.). This indicates that the sampled segments of Horse Creek are comparable in quality (as determined via the SCI) to other reference streams in Florida.

Benthic invertebrate species diversity in Horse Creek exhibits both seasonal and year-to-year variation. Seasonally, diversity is often lower in the summer wet season that during the dry season. Over the three years of the HCSP study, species diversity at HCSW-1 has remained relatively constant when similar seasons are compared. At HCSW-2 and HCSW-3, diversity was slightly higher in 2005 than in 2003 or 2004, but HCSW-4 showed the opposite pattern. The effects of Hurricane Charley, which strongly affected the appearance and morphology of the stream at stations HCSW-2 to HCSW-4 in 2004, do not appear to have affected the long-term species diversity or SCI scores in Horse Creek.

5.4 FISH

During 2003 - 2005, 37 species of fish were collected from the four Horse Creek sampling stations; they are listed in Table 17 (the attached CD-ROM provides the scientific nomenclature for the species in the database). In 2005, four species were collected than had not been collected in previous samples (2003-2004): bowfin, pirate perch, redface topminnow, and white catfish. However, five species of fish that had been collected in 2003-2004 were not collected in 2005: brown bullhead, hogchoker, longnose gar, redear sunfish, and taillight shiner. Of the species not collected in 2005, only one, the hogchoker, had been collected more than a few times during past sampling.

Of the native species collected, most are quite common regionally and none were unexpected for this portion of Florida. Catfishes, killifishes, shiners and sunfishes were the most commonly collected groups. Six of the 37 species are not native to Florida: the walking catfish (*Clarias batrachus*), African jewelfish (*Hemichromis letourneuxi*), brown hoplo (*Hoplosternum littorale*), vermiculated sailfin catfish[6] (*Pterygoplichthys disjunctivus*), oriental weatherfish (*Misgurnus anguillicaudatus*), and sailfin catfish (*Pterygoplichthys pardalis*[7]).

5.4.1 Taxa Richness and Abundance

The greatest numbers of individual fish were collected in November 2004, February 2005, and April 2005 (Table 18, Figure 90), and more species of fish were collected prior to November 2004 than during sampling events after that date (Figure 89). Compared to the other sampling events, fewer individuals were collected in December 2005 and fewer species were collected after April 2004 (Table 18, Figures 89 and 90). A decrease in species richness at HCSW-2, HCSW-3, and HCSW-4 was clearly evident after the hurricanes of 2004, strongly suggesting that the fish communities of these stations were affected by the hurricanes. HCSW-1, which was not as affected by the hurricane, shows similar species richness before and after summer 2004.

Usually, most of the individuals collected at a sampling station consisted of eastern mosquitofish, sailfin molly, or least killifish. This can generally be attributed to conditions that are conducive to seining for small species. Eastern mosquitofish were collected at all sampling stations during all but one of the 2003-2005 sampling events. Warmouth (*Lepomis gulosus*), spotted sunfish (*Lepomis punctatus*), least killifish (*Heterandria formosa*), and coastal shiners (*Notropis petersoni*) were collected at all four sampling stations the majority of the time. Small numbers (as few as one) of individual fish were collected for most of the species found in 2003 -2005 (Table 17). The fewest fish species were collected at HCSW-1 prior to November 2004, but after that date, all sampling stations had about the same number of species (Table 18, Figure 89). Before November 2004, more species were found at HCSW-4 as compared to the other stations, but since that time Hurricane Charley has dramatically changed the lower reaches of Horse Creek.

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[6] Previously identified in 2004 Annual Report as *Hypostomus plecostomus* (suckermouth catfish). Confirmation identification as *P. disjunctivus* by Florida Museum of Natural History (FLMNH).
[7] Previously identified in 2003 and 2004 Annual Reports as *P. multirandians* (Orinoco saillfin catfish). Confirmation identification as *P. pardalis* (sailfin catfish) by Florida Museum of Natural History (FLMNH).

Table 17. Fish Collected from Horse Creek during HCSP Sampling in 2005. (Introduced species represented by "*".)

		HCSW-1				HCSW-2				HCSW-3				HCSW-4			
	Common Name	2 Feb 2005	21 Apr 2005	15 Sep 2005	15 Dec 2005	2 Feb 2005	21 Apr 2005	15 Sep 2005	15 Dec 2005	2 Feb 2005	21 Apr 2005	15 Sep 2005	15 Dec 2005	2 Feb 2005	21 Apr 2005	15 Sep 2005	15 Dec 2005
Hemichromis letourneuxi	African jewelfish			1	1			1			1	1	1	1	4	1	13
Lucania goodei	Bluefin killifish					2	4	2			1	1					
Lepomis macrochirus	Bluegill			1			1										1
Enneacanthus gloriosus	Bluespotted sunfish							5									
Amia calva	Bowfin						1										
Labidesthes sicculus	Brook silverside	2	7	1								2	1			1	
Hoplosternum littorale	Brown hoplo			1											1		
Ictalurus punctatus	Channel catfish																1
Notropis petersoni	Coastal shiner	13	10		8			1					2		1		
Lepomis marginatus	Dollar sunfish	1										14					
Gambusia holbrooki	Eastern mosquitofish	39	24		7	631	507	374	38	1610	1598	317	6	141	393	12	25
Elassoma evergladei	Everglades pygmy sunfish	1	2	1	1		17								3		
Jordanella floridae	Flagfish						1	2		2	3			1	1		
Lepisosteus platyrhincus	Florida gar		2														1
Fundulus chrysotus	Golden topminnow	3					1					2					
Erimyzon sucetta	Lake chubsucker														2		
Micropterus salmoides	Largemouth bass										9				2		
Heterandria formosa	Least killifish	1	4			138	1230	19	1	20	199	9		13	65	2	
Misgurnus anguilllicaudatus	Oriental weatherfish				2	5	2	13	1	6	27	1		3	4		
Aphredoderus sayanus	Pirate perch								1								
Fundulus rubrifrons	Redface topminnow		1			1	2										
Pterygoplichthys pardalis	Sailfin catfish													1		1	
Poecilia latipinna	Sailfin molly					6	13	130	6	102	82	176	6	10	37	6	1
Fundulus seminolis	Seminole killifish				2							1	6				
Lepomis punctatus	Spotted sunfish	1	4	2	5				1	1		5	4				2
Etheostoma fusiforme	Swamp darter	1			2		6	1	1		1		1		2		
Noturus gyrinus	Tadpole madtom		1														
Pterygoplichthys disjunctivus	Vermiculated sailfin catfish													1			
Clarias batrachus	Walking catfish																1
Lepomis gulosus	Warmouth	5	4		8	1			1				2				
Ameiurus catus	White catfish													1			
Ameiurus natalis	Yellow bullhead		2														
	Total Taxa	**10**	**11**	**6**	**9**	**7**	**12**	**10**	**8**	**6**	**9**	**11**	**9**	**9**	**12**	**6**	**8**
	Total Individuals	**67**	**61**	**7**	**36**	**784**	**1785**	**548**	**50**	**1741**	**1921**	**529**	**29**	**172**	**515**	**23**	**45**

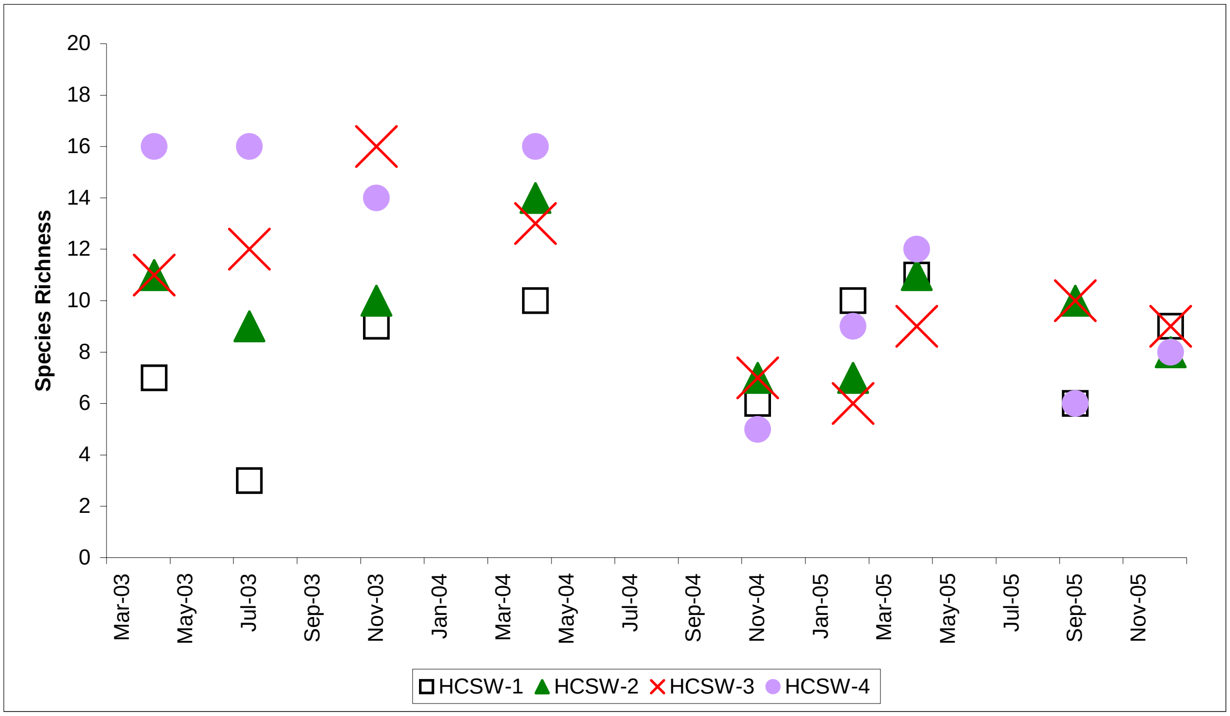

Figure 89. Species Richness for Fish from Four Stations on Horse Creek from 2003 - 2005.

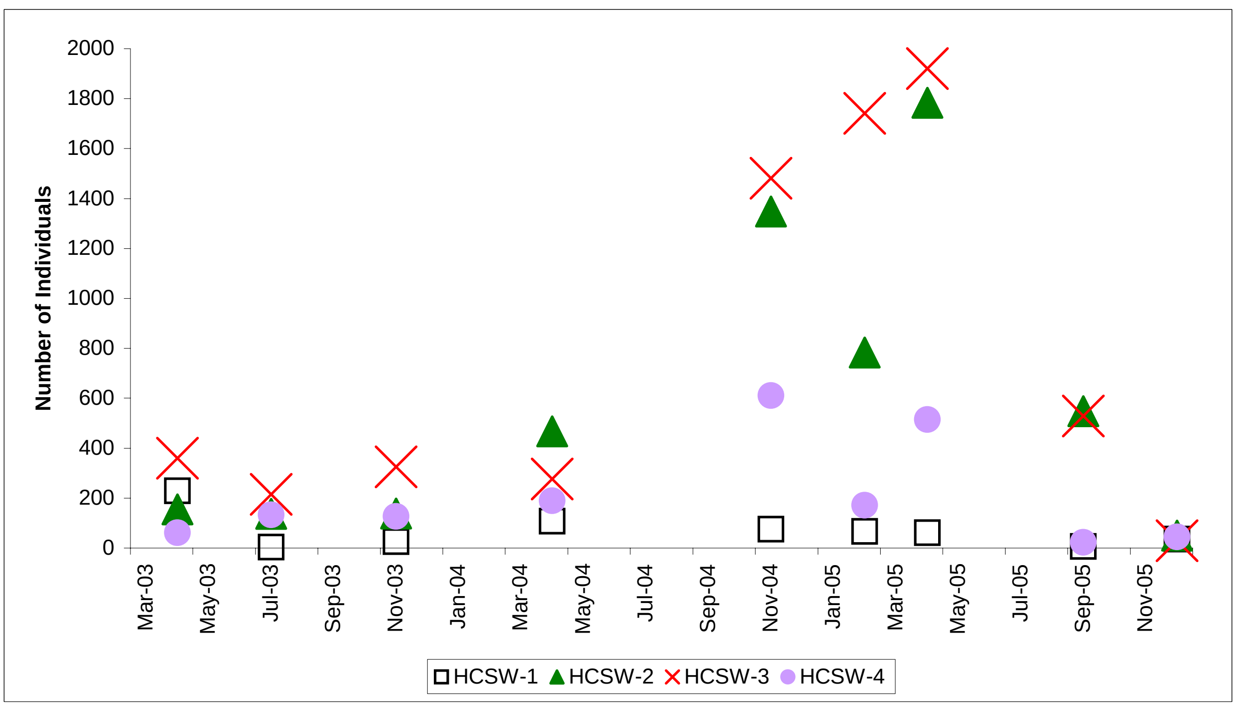

Figure 90. Number of Individual Fish Captured from Four Stations on Horse Creek from 2003 - 2005.

5.4.2 Shannon-Wiener Diversity Index

Diversity of individual fish samples in 2005 ranged from 0.5 (HCSW-3, February) to 2.6 (HCSW-1, April and December) (Figure 91), similar to 2003 and 2004 ranges. When fish samples were combined across all sampling events, HCSW-1 had the highest species diversity in 2004 and 2005, but it had the lowest diversity in 2003 (Figure 92).

Over all sampling dates combined, fish diversity was slightly higher at HCSW-1 and HCSW-4 than at the midstream stations, but the differences were not significant (ANOVA F = 1.09, p = 0.36). At all stations except HCSW-1, Shannon-Wiener Diversity Index values are lower for all sampling events after November 2004 (Kendall-Tau non-parametric correlation), after the hurricanes affected the three downstream stations (Figure 91); the diversity value was primarily affected by the lowered species richness after the hurricanes, as opposed to the number of individuals. In 2003 and early 2004, before the hurricanes, diversity generally increased from upstream to downstream. After the hurricanes, however, diversity was consistently higher at HCSW-1, which was relatively unaffected by the hurricanes.

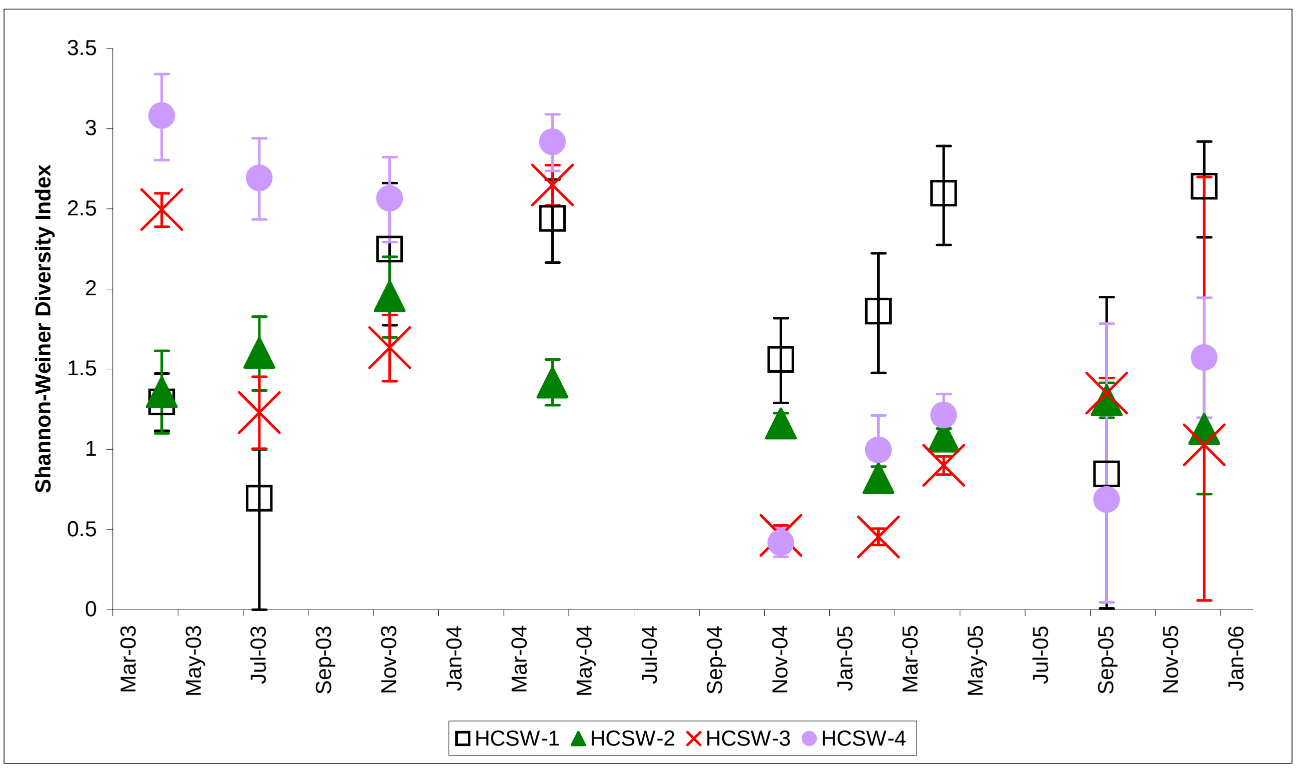

Figure 91. Shannon-Wiener Diversity Indices and 90% Confidence Limits for Fish Samples from Four Stations on Horse Creek in 2003 - 2005. (90% confidence limits are automatically provided by the software used to calculate the index values (Ecological Methods v 6.1.1, Exeter Software 2003).

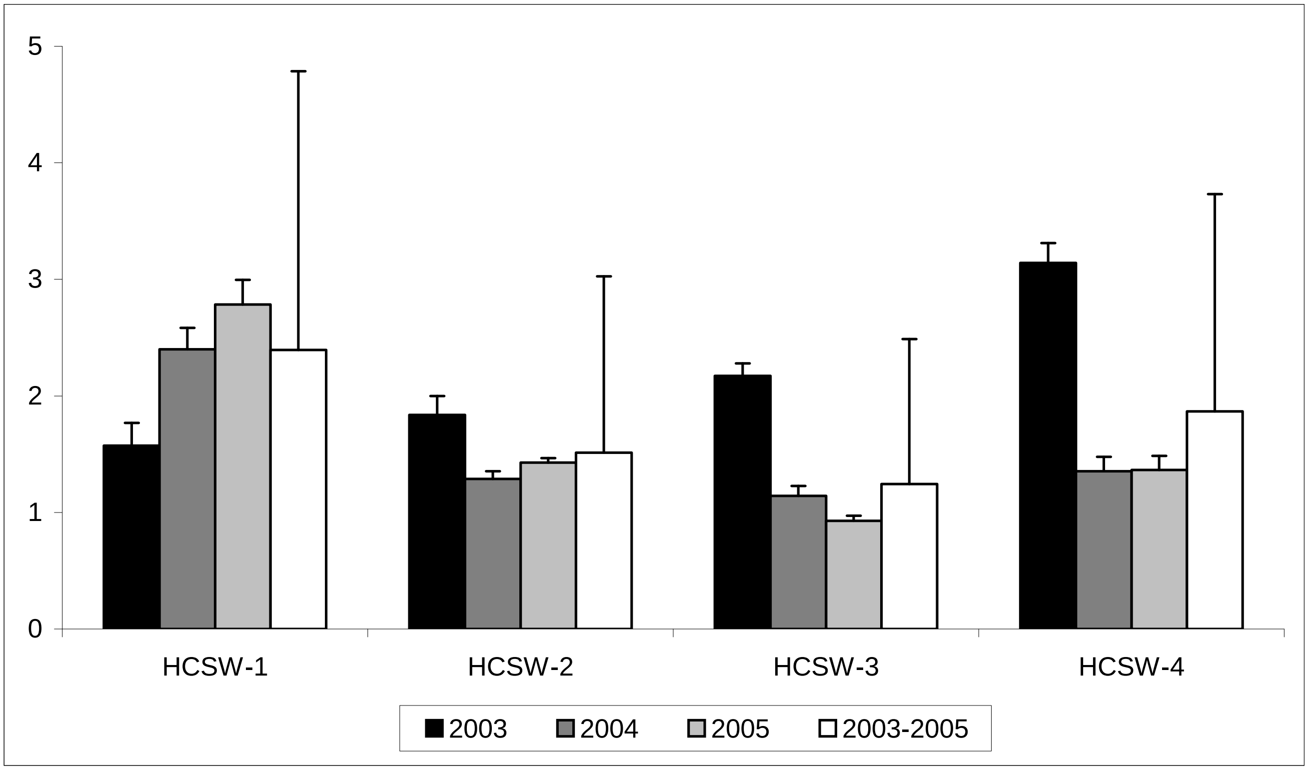

Figure 92. Shannon-Wiener Diversity Indices and 90% Confidence Limits for Fish Samples from Four Stations on Horse Creek summarized over sampling events. (90% confidence limits are automatically provided by the software used to calculate the index values (Ecological Methods v 6.1.1, Exeter Software 2003).

5.4.3 Morisita's Index of Similarity

Morisita's Index of Similarity measures the similarity of two communities by comparing the relative abundance of each species within and between communities. Of the similarity measures available, this index is preferred because it is nearly independent of sample size (Krebs 1998). Morisita's Index of Similarity is calculated as:

$$C_\lambda = \frac{2\sum X_{ij} X_{ik}}{(\lambda_1 + \lambda_2) N_j N_k}$$

Where C_λ = Morisita's index of similarity between sample *j* and *k*

X_{ij}, X_{ik} = Number of individuals of species *i* in sample *j* and sample *k*

N_j = Σ X_{ij} = Total number of individuals in sample *j*

N_k = Σ X_{ik} = Total number of individuals in sample *k*

Morisita's Index varies from 0 (no similarity – no species in common) to about 1 (complete similarity – all species in common) (Krebs 1998).

Table 18 includes Morisita's Index values calculated for each station, as well as all stations combined, by sampling event. Values ranged from 0.00 (HCSW-1, comparing July 2003 and September 2005) to around 1.00 (many comparisons). Fish communities were at least 50% similar during most events at most stations, but the following events were less similar than other events at that station: September 2005 at HCSW-1, April 2005 at HCSW-2, April 2004 and December 2005 at HCSW-3, and April 2003 at HCSW-4. When combining all sampling locations for a given sampling event, fish communities were similar for all sampling events. Although Morisita's Index is robust to differences in sample size, only four individuals were captured at HCSW-1 in July 2003, thereby inflating similarity measures of this sample with other dates or stations.

Values of Morisita's Index were also calculated for each sampling event, as well as all events combined, for each station (Table 19). Fish communities were at least 50% similar at most stations during most events. The lowest values of 0.00 to 0.07 were calculated when comparing HCSW-1 to the other three stations during September 2005. HCSW-1 was also less than 50% similar to the other stations in November 2004, reflecting the effects of the hurricane on the downstream stations. Fish communities were very similar at all stations when sampling events were combined

Table 18. Morisita's Similarity Index Values Comparing Sampling Dates within Stations for 2003 to 2005 Samples. (Values less than 50% similarity are highlighted.)

Event	HCSW-1								HCSW-2								All Stations Combined			
	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004	15 Feb 2005	20 Apr 2005	15 Sep 2005	15 Dec 2005	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004	15 Feb 2005	20 Apr 2005	15 Sep 2005	15 Dec 2005	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004
25 Apr 2003	1.00	0.78	0.90	0.49	0.95	0.82	0.12	0.51	0.98	0.97	1.00	0.99	0.99	0.52	0.95	0.99	0.95	0.95	0.99	0.86
29 Jul 2003		1.00	1.00	0.93	1.00	1.00	0.00	0.99		0.97	0.99	0.98	0.97	0.64	0.90	0.94		0.99	0.96	0.96
20 Nov 2003			0.82	0.51	0.81	0.95	0.76	0.85			0.96	0.97	0.94	0.49	0.97	0.98			0.95	0.95
22 Apr 2004				0.54	0.97	0.97	0.18	0.71				1.00	0.99	0.59	0.93	0.97				0.87
3 Nov 2004					0.67	0.66	0.09	0.7					0.99	0.59	0.95	0.98				
15 Feb 2005						0.94	0.06	0.68						0.57	0.93	0.97				
20 Apr 2005							0.32	0.81							0.41	0.4				
15 Sep 2005								0.5								0.99				

Event	HCSW-3								HCSW-4								All Stations Combined			
	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004	15 Feb 2005	20 Apr 2005	15 Sep 2005	15 Dec 2005	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004	15 Feb 2005	20 Apr 2005	15 Sep 2005	15 Dec 2005	15 Feb 2005	20 Apr 2005	15 Sep 2005	15 Dec 2005
25 Apr 2003	1.00	0.64	0.79	0.55	0.55	0.63	0.67	0.69	0.75	0.65	0.73	0.31	0.36	0.38	0.59	0.42	0.85	0.89	0.88	0.95
29 Jul 2003		1.00	0.51	0.99	0.98	1.00	0.87	0.45		0.94	0.83	0.74	0.80	0.83	0.98	0.81	0.95	0.92	0.93	0.93
20 Nov 2003			0.59	0.97	0.97	0.98	0.89	0.52			0.82	0.77	0.83	0.85	0.92	0.94	0.94	0.87	0.94	0.95
22 Apr 2004				0.46	0.48	0.50	0.72	0.82				0.56	0.63	0.68	0.76	0.65	0.85	0.90	0.89	0.95
3 Nov 2004					1.00	0.99	0.85	0.39					0.99	0.97	0.83	0.83	1.00	0.89	0.91	0.83
15 Feb 2005						0.99	0.86	0.41						1.0	0.90	0.86		0.87	0.91	0.82
20 Apr 2005							0.88	0.43							0.92	0.87			0.82	0.79
15 Sep 2005								0.66								0.87				0.89

Table 19. Morisita's Similarity Index Values Comparing Stations within Sampling Dates for 2003 to 2005 Samples. (Values less than 50% similarity are highlighted.)

Station	**25 April 2003**			**29 July 2003**			**20 November 2003**			**22 April 2004**			**3 November 2004**		
	HCSW-2	***HCSW-3***	***HCSW-4***	***HCSW-2***	***HCSW-3***	***HCSW-4***	***HCSW-2***	***HCSW-3***	***HCSW-4***	***HCSW-2***	***HCSW-3***	***HCSW-4***	***HCSW-2***	***HCSW-3***	***HCSW-4***
HCSW-1	0.98	0.68	0.60	1.00	1.00	1.00	0.92	0.93	1.00	0.93	0.88	0.86	0.37	0.37	0.37
HCSW-2		0.71	0.55		0.97	0.94		0.98	0.94		0.75	0.80		0.96	0.96
HCSW-3			0.86			0.95			0.95			0.83			1.00

Station	**15 February 2005**			**20 April 2005**			**15 September 2005**			**15 December 2005**			**All Dates Combined**		
	HCSW-2	***HCSW-3***	***HCSW-4***	***HCSW-2***	***HCSW-3***	***HCSW-4***	***HCSW-2***	***HCSW-3***	***HCSW-4***	***HCSW-2***	***HCSW-3***	***HCSW-4***	***HCSW-2***	***HCSW-3***	***HCSW-4***
HCSW-1	0.89	0.87	0.91	0.42	0.74	0.77	0.00	0.04	0.07	0.43	0.76	0.47	0.81	0.88	0.92
HCSW-2		0.97	0.99		0.49	0.53		0.98	0.99		0.52	0.88		0.89	0.92
HCSW-3			0.99			1.00			1.00			0.53			0.99

5.4.4 Species Accumulation Curves

One way to determine when enough individuals in a community have been sampled to accurately estimate species diversity with some level of confidence is to plot the cumulative number of species collected through the sampling period. The result should be a curve that increases steeply at first when new species are continually being found, then gradually levels off when new species become very rare. The asymptote of the curve suggests the point at which additional sampling will provide no additional species. The total number of species in a community, as well as the number of rare species, strongly influences the sampling effort needed to offer some certainty that most species have been reported. As indicated by the curves plotted for each of the sampling locations, as well as that for all stations combined, we continue to collect species with subsequent sampling events, but the curves have generally leveled off for each station (Figure 93). This suggests that few additional species will be collected in the future.

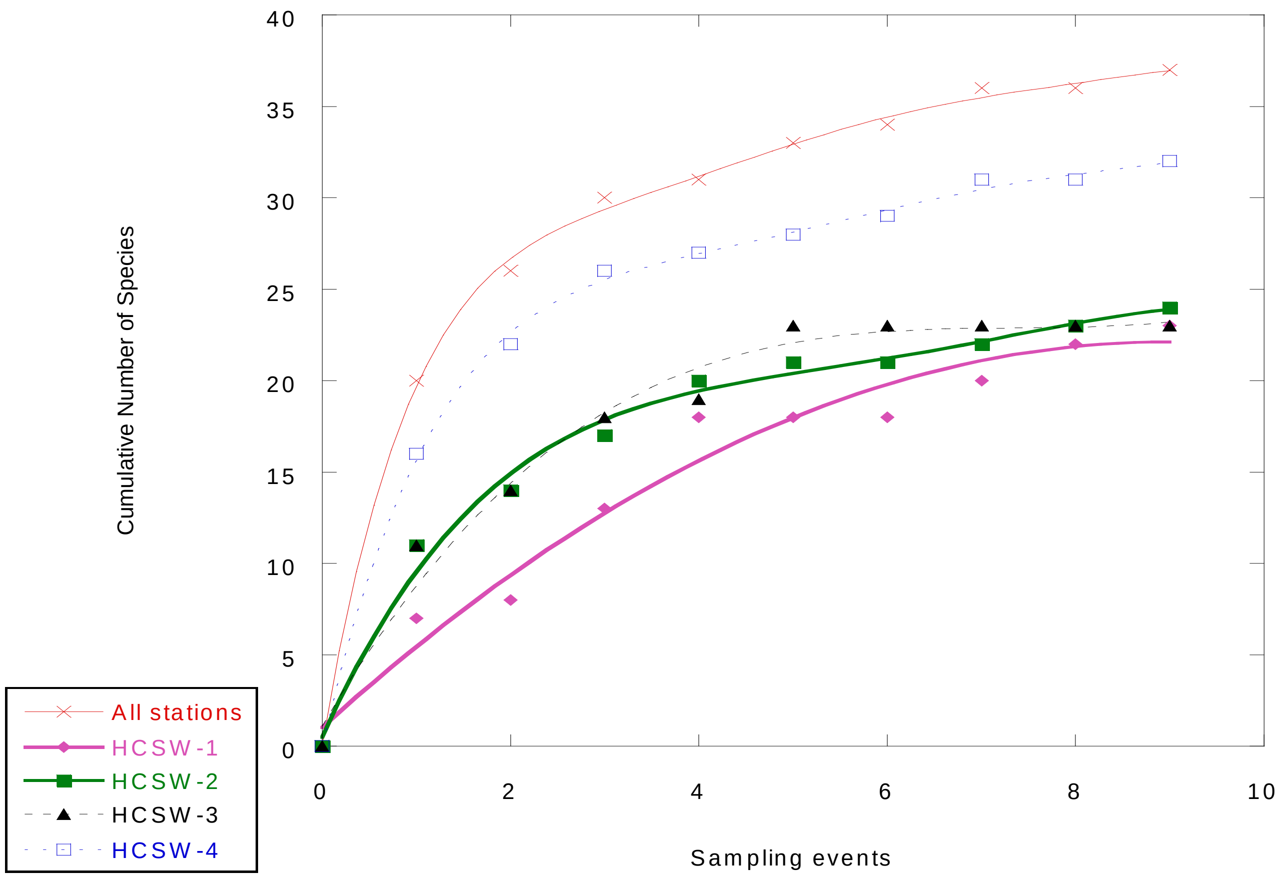

Figure 93. Cumulative Numbers of Fish Species Collected at Horse Creek Stations During 2003 - 2005. (Species accumulation curves were fit for visual purposes only using KaleidaGraph 4.0.)

5.4.5 Summary of Fish Results

Thirty-seven species of fish were collected in 2003 to 2005, with most captured individuals belonging to one of four families (Table 20). We expect to add very few additional species during future monitoring events, because the species accumulation curves based on the samples collected in 2003 to 2005 have begun to level off. Several native species are almost certainly present in Horse Creek but were not collected in 2003 to 2005. These include the American eel (*Anguilla rostrata*) and black crappie (*Pomoxis nigromaculatus*). Samples collected included six introduced species: walking catfish, African jewelfish, brown hoplo, suckermouth catfish, oriental weatherfish, and sailfin catfish. Introduced species rank second only to habitat destruction in their effects on native species, communities, and ecosystems (Wilson 1992, Parker et al. 1999). Over 30 species of introduced fish have established reproducing populations in Florida (http://floridafisheries.com), and more will likely continue to be introduced in spite of laws restricting such introductions, thus, we expect to continue to collect additional introduced species in Horse Creek during future monitoring events as new introductions occur and as such species expand their ranges in Florida.

Table 20. Percentage of individual fish captured for most abundant fish families in Horse Creek during 2003 – 2005 as part of the Horse Creek Stewardship Program.

Fish Family	HCSW-1	HCSW-2	HCSW-3	HCSW-4	Total
Poeciliidae	54 %	96 %	93 %	85 %	91 %
Centrarchidae	17 %	1 %	2 %	4 %	2 %
Cyprinidae	18 %	< 0.1 %	3 %	3 %	2 %
Cyprinodontidae	2 %	1 %	1 %	2 %	1 %
Other families	Athernininidae (2%), Ictaluridae (3%)	Cobititae (0.4%), Ictaluridae (0.1%)	Cobititae (1%), Soleidae (1%)	Cichlidae (2%), Antherinidae (1%), Soleidae (1%)	

For 2005 sampling, the effects of Hurricane Charley continued to affect species abundance and diversity at stations HCSW-2, HCSW-3, and HCSW-4. Before Hurricane Charley, species richness and diversity were lowest at HCSW-1 and highest at HCSW-4. This pattern of longitudinal zonation of increasing species diversity with increasing stream order is typical of stream systems (Harrel et al. 1967, Whiteside and McNatt 1972, Sheldon 1988). In 2005, fish diversity was similar at all stations, probably because of modified habitat conditions at downstream stations after Hurricanes Charley, Jeanne, and Frances. Fish communities were similar for all events when locations were combined and for all locations when events were combined.

Results of the sampling, as well as observations by the ecologists conducting the sampling, indicated a dramatic reduction in overall fish biomass and species diversity at the end of 2004 and through 2005. The samples were dominated by *Gambusia holbrooki*, with smaller numbers of *Poecilia latipinna*. The two upstream stations produced a few more species, including *Heterandria formosa* and several exotic fishes. Obviously missing from the samples collected from the first few events after Hurricane Charley (and not observed in the stream as they had been in previous sampling) were adult sunfishes. One small *Lepomis* sp. was taken at HCSW-2, and several more were taken at HCSW-1, but no sunfish larger than about 10 cm was seen. Similarly, no native catfish species, gar or darters were collected. The virtual absence of these species must be somehow related to physical and/or water quality changes in the stream resulting from the hurricanes. Sampling in 2005 showed that Horse Creek is recovering from the hurricane-related changes. Several large sunfish, native catfish, largemouth bass, and gar were collected at HCSW-1, which was less affected by the hurricanes, than at the downstream stations.

6.0 CONCLUSIONS

6.1 WATER QUANTITY

From 2003 to 2005, rainfall, streamflow, stream stage, and NPDES discharge showed expected relationships within the Horse Creek Basin. Rainfall varied between gauges, but showed similar seasonality at all sites. Stream stage was also similar among sites, with the highest stages maintained for only 10 to 20 percent of 2003 - 2005. Logically, stream discharge was higher at the downstream USGS gauging station than the upstream station, but streamflow patterns were similar at both sites. Streamflow, NPDES discharge, and rainfall were significantly correlated, preventing the relative magnitude of the effects of each on water quality and biological parameters from being clearly determined. Abnormally high streamflow, gauge heights, and rainfall resulted from three hurricanes that affected the area from August to October 2004.

6.2 WATER QUALITY

Trigger levels were exceeded at least once for five parameters in 2005: dissolved oxygen, chlorophyll *a*, fatty acids, pH, and dissolved iron. Based upon historical conditions in Horse Creek (Durbin and Raymond 2006), most of these exceedances were probably the result of natural conditions (proximity to historically hypoxic stream segment, high temperatures, and high streamflow) and are not related to mining activities. Some seasonal patterns in water quality parameters were evident. Other spatial factors, such as the predominance of some types of agriculture, may also have an effect on such water quality parameters as pH, nutrients (nitrogen oxides and orthophosphate), and dissolved ions (calcium and sulfate). Land use analysis in a separate historical report (Durbin and Raymond 2006) may provide a means of gauging the effect of these landscape factors on water quality in Horse Creek, but an extensive investigation to precisely pinpoint and/or quantify the effects of non-mining land use is beyond the scope of the Horse Creek Stewardship Program.

6.3 BENTHIC INVERTEBRATES

Benthic invertebrate habitat scores were “Optimal” to “Sub-optimal” and SCI scores were “Fair” or “Poor” at all stations from 2003 to 2005; these scores are typical of southwestern Florida streams, including those used by DEP to develop the Habitat Assessment and SCI indices. Species diversity in Horse Creek exhibits both seasonal and year-to-year variation. Seasonally, diversity is often lower in the summer wet season than during the dry season. Over the three years of the HCSP study, species diversity at HCSW-1 has remained relatively constant when similar seasons are compared. At HCSW-2 and HCSW-3, diversity was slightly higher in 2005 than in 2003 or 2004, but HCSW-4 showed the opposite pattern. The effects of Hurricane Charley, which primarily hit stations HCSW-2 to HCSW-4 in 2004, do not appear to have affected the long-term species diversity or SCI scores in Horse Creek.

6.4 FISH

Fish species richness and diversity were higher in the more downstream locations in 2003, likely because of their proximity to the species-rich Peace River. After the hurricanes in late 2004, however, richness and diversity were consistently higher at HCSW-1, which was relatively unaffected by the hurricanes. Fish communities were fairly similar between stations and between dates at each station. Patterns in fish species richness, diversity, and abundance appear to have been affected by Hurricane Charley in 2004, rather than any possible mining effects, considering that in 2005 the station closest to the mining area had the highest species diversity.

7.0 RECOMMENDATIONS

Mosaic, BRA, and the PRMRWSA should investigate the availability and cost of LIDAR or Doppler rainfall electronic data for the Horse Creek Basin because of its potential to more accurately represent widespread rainfall patterns. However, this option should not be pursued if the cost of obtaining, formatting, or analyzing the data is cost prohibitive.

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APPENDICES

Appendix A

Horse Creek Stewardship Program

Horse Creek
Stewardship Program

Intent

The purpose of this program is two-fold. First, it provides a protocol for the collection of information on physical, chemical and biological characteristics of Horse Creek during IMC Phosphates' (IMC) mining activities in the watershed in order to detect any adverse conditions or significant trends that may occur as a result of mining. Second, it provides mechanisms for corrective action with regard to detrimental changes or trends caused by IMC's' activities, if any are found.

The overall goals of the program are to ensure that IMC Phosphates' mining activities do not interfere with the ability of the Peace River/Manasota Regional Water Supply Authority (Authority) to withdraw water from the Peace River for potable use nor adversely affect Horse Creek, the Peace River or Charlotte Harbor.

There are three basic components to this stewardship program:

- Monitoring and Reporting on Stream Quality,
- Investigating Adverse Conditions or Significant Trends Identified Through Monitoring, and
- Implementing Corrective Action for Adverse Stream Quality Changes Attributable to IMC Activities

An important aspect of this program is that it will not rely solely upon the exceedence of a standard or threshold to bring about further investigation and, where appropriate, corrective action. The presence of a significant temporal trend alone will be sufficient to initiate such steps. This protection mechanism is not present in the vast majority of regulatory scenarios.

The mission of the Authority is to provide a reliable and safe drinking water supply to the citizens of the four counties comprising the Authority, Charlotte, DeSoto, Manatee and Sarasota Counties. The Peace River Facility is a critical component of the Authority's water supply system. The Peace River Facility located in DeSoto County utilizes the Peace River as its supply source.

It is critical for the Authority to protect the Peace River from impacts that would be detrimental to the operation of the Peace River Facility. As a tributary to the Peace River, the Authority's goal for the Horse Creek Stewardship Program is to provide assurance that the quantity and quality of Horse Creek flow as it contributes to the Peace River does not adversely impact the operation of the Peace River Facility.

Program Implementation and Oversight

IMC will implement and fund the Horse Creek Stewardship Program with oversight by the Authority. The Authority will create and coordinate a Technical Advisory Group (TAG) to consist of a representative from each of its members to review and provide input on the program throughout the duration of the monitoring. IMC will create a project-specific quality assurance and quality control (QA/QC) plan for the program detailing all sampling, laboratory procedures, benthic and fish monitoring protocols and data analysis. The QA/QC plan will be consistent with the analogous protocols established in the HydroBiological Monitoring Program (HBMP) for the Lower Peace River/Upper Charlotte Harbor.

Historical, Background and Contemporaneous Data

IMC will compile available data collected by others on water quality, quantity and aquatic biology of Horse Creek. This is expected to include, but is not limited to, information collected by the U.S. Geological Survey (USGS), the Florida Department of Environmental Protection (DEP), the Southwest Florida Water Management District (SWFWMD), the Charlotte Harbor Environmental Center (CHEC). Horse Creek data contained in the U.S. Environmental Protection Agency's (EPA) STORET database will also be obtained. Historic data will be reviewed to provide background information on Horse Creek, and data from ongoing collection efforts will be obtained to supplement that collected by IMC.

Monitoring Period

Water quantity, water quality, macroinvertebrates and fish will be monitored as outlined below during the time that IMC Phosphates is conducting mining and reclamation in the Horse Creek watershed. Monitoring will begin no later than April 2003. In the event of temporary interruptions in mining activities (up to one year), this monitoring will continue during the period of inactivity. Monitoring will cease when mining and reclamation operations are completed in the Horse Creek watershed.

1.0 Surface Water Monitoring Stations

Four locations on Horse Creek will be monitored for physical, chemical and biological parameters:

HCSW-1 - Horse Creek at State Road 64 (USGS Station 02297155)
HCSW-2 - Horse Creek at County Road 663A (Goose Pond Road)
HCSW-3 - Horse Creek at State Road 70
HCSW-4 - Horse Creek at State Road 72 (USGS Station 02297310)

As indicated above by their station ID numbers, HCSW-1 and HCSW-4 are also long-term US Geological Survey (USGS) gaging stations, with essentially continuous stage and discharge records since 1977 and 1950, respectively.

2.0 Water Quantity Monitoring and Analysis

Discharge data will be obtained from the USGS for stations HCSW-1 and HCSW-4 for compilation with other data collected through this monitoring program. If not already present, staff gauges will be installed in the stream at HCSW-2 and HCSW-3 and surveyed to NGVD datum. If not already available, stream cross sections will be surveyed at those locations, extending to the approximate limits of the 25-year floodplain. Staff gauge readings will be recorded at the time of any sampling efforts at those stations. Data on rainfall will be obtained using IMC's rain gauge array (including any additional gauges installed in the Horse Creek basin in the future).

Data analysis will focus upon, but not necessarily be limited to, the ongoing relationship between rainfall and streamflow in the Horse Creek watershed. This relationship can be established from data collected early in the monitoring program and used to track the potential effects of mining on streamflow. Analytical approaches are outlined under Water Quality below and such methods will be more fully described in the QA/QC plan to be developed as part of this stewardship program.

3.0 Surface Water Quality Monitoring and Analysis

Water quality data will be obtained monthly at each station where flow is present. Field measurements will be made of temperature, pH, specific conductance, turbidity and dissolved oxygen. Grab samples will be collected and analyzed for:

Nitrate + Nitrite
Total Kjeldahl Nitrogen
Total Nitrogen
Total Ammonia Nitrogen
Ortho Phosphate
Chlorophyll *a*
Calcium
Iron
Color
Total Alkalinity
Chloride
Fluoride
Radium 226 + 228
Sulfate
Mining Reagents (petroleum-based organics, fatty acids, fatty amido amines).

At Station HCSW-1, a continuous monitoring unit will be installed to record temperature, pH, conductivity, dissolved oxygen and turbidity. Because this station is located at a bridge crossing for a highway, the unit will be located some distance (within 100 m) upstream or downstream from the bridge to minimize the likelihood of vandalism. The unit will be permanently installed and its location surveyed. Data will be recorded frequently (at least hourly) and will be downloaded at least monthly. This data will provide for the characterization of natural background fluctuations and may allow for the detection of general water quality changes not observed during the collection of monthly grab samples.

Table 1 presents the analytical schedules and procedures. All sampling will be conducted according to DEP's Standard Operating Procedures (SOP) for field sampling. Laboratory analyses will be performed by experienced personnel according to National Environmental Laboratory Accreditation Council (NELAC) protocols, including quality assurance/quality control considerations. Invertebrate sampling will be conducted by personnel with training and experience in the DEP's SOP for such sampling.

Results will be tabulated to allow for comparisons among stations and sampling events and through time. Results will be compared with available historic data for Horse Creek and its tributaries, and with applicable Florida surface water quality standards. Typical parametric and non-parametric statistics will be used to describe the results. In particular, regression analysis is expected to be employed to examine the relationship between each parameter and time. Both linear and non-linear regression will be considered, depending upon the patterns observed in the data. Since at least some of the parameters can be expected to vary seasonally, use of methods such as the Seasonal Kendall's Tau Test is anticipated. Other potential methods include Locally Weighted Scatterplot Smooth (LOWESS). In addition to trend analyses, annual reports will contain general statistics such as mean, median, standard deviation and coefficient of variance for each numerical parameter. Such general statistics will be calculated on both an annual and seasonal basis. Because the data will be maintained in a standard software format (i.e., MS Excel or MS Access), there will be virtually no logistical limitations on the types of analyses that can be conducted. The only limitations will result from the nature of the data itself (i.e., data quantity, distributions, etc.).

For each parameter, data analysis will focus upon, but not necessarily be limited to, (1) the relationship between measured values and the "trigger values" as presented in Table 1 and (2) temporal patterns in the data which may indicate a statistically significantly trend toward the trigger value. Statistical significance will be based upon $\alpha=0.05$, unless data patterns/trends or other related information indicate that use of another significance level is more appropriate. Since the purpose of this monitoring is to detect trends toward the trigger values, should they be present, trend analyses and other statistical tests will generally focus only upon changes toward the trigger values. This will increase the statistical power for detecting such changes.

At least initially, the term over which trends are analyzed will be dependent upon the data collected to date. As the period of record increases, data analysis can move from a comparison of months, to seasons, to years. As noted above, seasonal patterns will always be considered during data analysis and attention will be given to differentiation between natural seasonal/climatic variation and anthropogenic effects (including mining), where possible. Where historic data exist for a given parameter or station, such data can be evaluated relative to that collected through this effort, although sampling frequency and consistency may not be sufficient to conduct standard trend analysis methods. Analytical methods will be more fully described in the QA/QC plan to be developed as part of this stewardship program.

4.0 Aquatic Macroinvertebrate Sampling and Analysis

Macroinvertebrate sampling will be performed three times annually and, in general, will be conducted concurrently with a monthly water quality sampling event. The first event would occur in March or April, the second event in July or August, and the third event in October or November. Specific months when sampling occurs may change from year to year to avoid very low or very high flows which would impede representative sampling.

In accordance with the DEP Standard Operating Procedures (DEP-SOP-001/01 FS 7000 General Biological Community Sampling), invertebrate sampling will not be conducted ". . . during flood stage or recently dry conditions." This is interpreted here to mean that a given sampling station will not be sampled for macroinvertebrates if (a) water is above the top of the stream bank, or is too deep or fast-moving to sample safely, or (b) if the stream has been dry during the preceding 30 days. In the event either of these situations occurs, the station will be revisited approximately one month later to determine whether sampling is appropriate at that time. If the stream is still in flood, or has again been dry during the preceding 30 days, invertebrate sampling will be postponed until the next season's sampling event. Note that the above situations are expected to be quite rare at the Horse Creek stations, and sampling efforts will generally be planned to avoid such conditions.

Sampling will be conducted at the same four stations on Horse Creek used for flow and water quality monitoring. The aquatic habitats at each station will be characterized, streamside vegetation surveyed, and photostations established. Qualitative macroinvertebrate sampling will be performed according to the Stream Condition Index (SCI) protocol developed by DEP (DEP-SOP-002/01 LT 7200) or subsequently DEP-approved sampling methodology. Consistent with DEP protocols, each invertebrate sample will be processed and taxonomically analyzed. Data from the samples will be used to determine the ecological index values presented in Table 1. Additional indices may also be calculated to further evaluate the invertebrate community. As noted in Table 1, the focus of the analysis will be to screen for statistically significant declining trends with respect to presence, abundance and distribution of native species, as well as SCI values. Results may also be compared with available historic macroinvertebrate data for Horse Creek and its tributaries, or with data from other concurrent collecting efforts in the region, if appropriate. Analysis of invertebrate community characteristics will include consideration of flow conditions, habitat conditions and selected water quality constituents.

Analytical approaches are outlined under Water Quality Monitoring and Analysis section above and such methods will be more fully described in the QA/QC plan to be developed as part of this Horse Creek Stewardship Program.

5.0 Fish Sampling and Analysis

Fish sampling will be conducted three times annually, concurrent with aquatic macroinvertebrate sampling at the same four stations on Horse Creek. Based upon stream morphology, flow conditions and in-stream structure (logs, sand bars, riffles, pools, etc.), several methods of sampling may be used, including seining, dipnetting, and electrofishing. Sample collection will be timed to standardize the sampling efforts among stations and between events.

All fish collected will be identified in the field according to the taxonomic nomenclature in *Common and Scientific Names of Fishes from the United States and Canada* (American Fisheries Society 1991, or subsequent editions). Voucher specimens will be taken of uncommonly encountered species and of individuals that cannot be readily identified in the field; with such specimens being preserved and logged in a reference collection maintained for this monitoring program. All fish will be enumerated and recorded. Total length and weight will be determined and recorded for individuals, however, for seine hauls with very large numbers of fish of the same species (a common occurrence with species like *Gambusia holbrooki, Heterandria formosa* and *Poecilia latipinna*), individuals of the same species may be counted and weighed *en masse*, with only a randomly selected subset (approximately 10 to 20 individuals of each such species) being individually measured for length and weight. Any external anomalies observed on specimens will be recorded.

Taxa richness and abundance and mean catch per unit effort will be determined for each station and each event, and data can be compared among stations and across sampling events. The ecological indices presented in Table 1 will be calculated and additional indices may also be calculated to evaluate the fish community, including similarity indices, species accumulation/rarefaction curves, diversity indices and evenness indices. As noted in Table 1, the focus of the analysis will be to screen for statistically significant declining trends with respect to presence, abundance and distribution of native species. Results may also be compared with available historic fisheries data for Horse Creek and its tributaries, and with data from other concurrent regional collecting efforts, if applicable. Analysis of fish community characteristics will include consideration of flow conditions, habitat conditions and selected water quality constituents.

Analytical approaches are outlined under Water Quality above and such methods will be more fully described in the QA/QC plan to be developed as part of this stewardship program.

6.0 Reporting

All data collected through this monitoring program will be compiled annually (January - December records) and a report will be generated summarizing the results. This report will include narrative, tabular and graphical presentation of the discharge records, surface water quality data, macroinvertebrate and fish sampling results. Results of statistical analyses will also be provided. Discussion will be included comparing across the sampling stations, as well as among seasons and sampling years. Emphasis will be placed upon identifying spatial and/or temporal trends in water quality and/or biological conditions. Where available, data collected from the same stations prior to the initiation of this program will be reviewed and incorporated to allow for longer-term evaluation of Horse Creek. In addition, data available from sampling/monitoring efforts by agencies or other public entities will be reviewed and incorporated, where pertinent. Each report will also provide general information on the location and extent of IMC mining activities in the Horse Creek watershed, as they relate to this monitoring effort. Reports will be submitted to the Authority, as well as to the DEP Bureau of Mine Reclamation (BMR) and Southwest Florida Water Management District (SWFWMD).

In addition to the reporting outlined above, raw data compiled through sampling will be provided to the Authority monthly. This data will be submitted within six (6) weeks of each sampling event (pending the completion of laboratory/taxonomic analyses).

Monitoring Program Evaluation

To ensure this program is providing useful information throughout its tenure, it will be evaluated regularly. Each annual report will include a section devoted to a summary of the immediate and long-term utility of each information type being collected. Recommendations will also be provided in the report regarding possible revisions, additions or deletions to the monitoring program to ensure that it is appropriately focused. Based upon such recommendations, IMC Phosphates will coordinate with the Authority and TAG on a regular basis regarding amendments to the monitoring program. Coordination on this issue may be initiated at any time by either party and will occur at least once every five years, whether or not either party individually requests it.

Protocol for Addressing Potential Problems Identified Through Monitoring

An important element of the monitoring program will be the ongoing analyses of data to detect exceedences of specific trigger values (see Table 1) as well as statistically significant temporal trends toward, but not necessarily in excess of, those values. The analyses will evaluate the data collected through this Horse Creek Stewardship Program, as well as that reported by other entities where appropriate.

Impact Assessment/Characterization

In the event the annual data evaluation identifies trigger value exceedences or statistically significant trends in Horse Creek, IMC will conduct an impact assessment to identify the cause of the adverse trend. The impact assessment may include more intensive monitoring of water quality in terms of frequency of sampling, laboratory analyses conducted, or locations monitored. In all cases, however, the impact assessment will include supplemental quantitative and qualitative data evaluations and consultation with Authority scientists, as well as perhaps other investigations within the basin (e.g., examination of land use changes, discharge monitoring records reviews of others, water use permit reports of others, etc.).

If the "impact assessment" demonstrates to the satisfaction of IMC and Authority scientists that IMC's activities in the Horse Creek watershed did not cause the exceedence or trend, IMC would support the Authority's efforts to implement actions to reverse or abate the conditions. IMC's support will focus upon scientific solutions where IMC can assist in the abatement of others' problems.

If the impact assessment indicates or suggests that IMC is the cause of the exceedences or trend, then IMC shall take immediate corrective actions. The intensity of such actions would be based upon the potential for ecological harm to the ecology of Horse Creek or the integrity of the potable water supply to the Authority.

Corrective Action Alternatives Evaluation and Implementation

The first step in the corrective action process shall be to prepare quantitative projections of the short-term and long-term impacts of the trigger value exceedence or adverse trends. Quantitative models and other analytical tools will provide IMC and Authority scientists with the analyses necessary to determine: (1) whether the impacts will persist or subside over the long term; (2) the cause(s) of the adverse trend(s) in terms of specific IMC activities that are contributing to the trend(s); and (3) alternative steps that IMC could effectuate to reverse the adverse trend, if needed.

If impact modeling confirms that adverse trends in water quality or a trigger value exceedance is caused by IMC activities in the Horse Creek watershed, IMC shall meet with Authority within 30 days of detection of the adverse trend or trigger exccedence to evaluate alternative solutions developed by IMC. IMC shall begin implementation of its proposed alternative solution selected by the Authority within 30 days and report to Authority as implementation milestones are reached. Throughout the modeling, alternatives assessment, and preferred alternative implementation steps of the corrective action process, more intensive impact assessment monitoring will continue to track the continuation, or the abatement, of the trigger value exceedance or adverse trend. Only when the impact assessment monitoring demonstrated conclusively that the condition has been reversed, with respect to the particular parameter(s) of concern, would IMC reduce its efforts back to the general monitoring and reporting program.

Alternative solutions may include conventional strategies such as the implementation of additional best management practices, raw material substitutions, hydraulic augmentation of wetlands, etc. IMC shall consider "out of the box" solutions (such as discharges of water to result in lower downstream concentrations of a parameter of concern, where the pollutant does not originate from IMC's activities) and emerging principles and technologies for water quantity management, water quality treatment and watershed protection, as well as other innovative solutions recommended by Authority.

Table 1. Parameters, General Monitoring Protocols and Corrective Action Trigger Values for the Horse Creek Stewardship Plan

Pollutant Category	Analytical Parameters	Analytical Method	Reporting Units	Monitoring Frequency	Trigger Level	Basis for Initiating Corrective Action Process
General Physio-chemical Indicators	pH	Calibrated Meter	Std. Units	Monthly	<6.0->8.5	Excursions beyond range or statistically significant trend line predicting excursions from trigger level minimum or maximum.
	Dissolved Oxygen	Calibrated Meter	mg/L[1]	Monthly	<5.0	Excursions below trigger level or statistically significant trend line predicting concentrations below trigger level.
	Turbidity	Calibrated Meter	NTU[2]	Monthly	>29	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Color	EPA 110-2	PCU	Monthly	<25	Excursions below trigger level or statistically significant trend line predicting concentrations below trigger level.
Nutrients	Total Nitrogen	EPA 351 + 353	mg/L	Monthly	>3.0	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Ammonia	EPA 350.1	mg/L	Monthly	>0.3	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Ortho Phosphate	EPA 365	mg/L	Monthly	>2.5	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Chlorophyll *a*	EPA 445	mg/L	Monthly	>15	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
Dissolved Minerals	Specific Conductance	Calibrated Meter	µs/cm[3]	Monthly	>1,275	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Alkalinity	EPA 310.1	mg/L	Monthly	>100	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Calcium	EPA 200.7	mg/L	Monthly	>100	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Iron	EPA 200.7	mg/L	Monthly	>0.3 [6]; >1.0[7]	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Chloride	EPA 325	mg/L	Monthly	>250	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Fluoride	EPA 300	mg/L	Monthly	>1.5[6]; >4[7]	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Radium 226+228	EPA 903	pCi/L[4]	Quarterly	>5	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Sulfate	EPA 375	Mg/L	Monthly	>250	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Dissolved Solids	EPA 160	Mg/L	Monthly	>500	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
Mining Reagents	Petroleum Range Organics	EPA 8015 (FL-PRO)	mg/L	Monthly[5]	>5.0	Exceedance of, or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total fatty acids, including Oleic, Linoleic, and Linolenic acid.	EPA/600/4-91/002	mg/L	Monthly[5]	>NOEL	Statistically significant trend line predicting concentrations in excess of the No Observed Effects Level (NOEL to be determined through standard toxicity testing with IMC reagents early in monitoring program, NOEL to be expressed as a concentration – e.g., mg/L)
	Fatty amido-amines	EPA/600/4-91-002	mg/L	Monthly[5]	>NOEL	Statistically significant upward trend line predicting concentrations in excess of No Observed Effects Level (NOEL to be determined through standard toxicity testing with IMC reagents early in monitoring program, NOEL to be expressed as a concentration – e.g., mg/L)
Biological Indices: Macroinvertebrates	Total Number of Taxa	Stream Condition Index (SCI) sampling protocol, taxonomic analysis, calculation of indices according to SOP-002/01 LT 7200 Stream Condition Index (SCI) Determination	Units vary based upon metric or index	3 times per year	N/A	Statistically significant declining trend with respect to SCI values, as well as presence, abundance or distribution of native species
	Abundance					
	Percent Diptera					
	Number of Chironomid Taxa					
	Shannon Weaver Diversity[a]					
	Florida Index					
	EPT Index					
	Percent Contribution of Dominant Taxon					
	Percent Suspension Feeders/Filterers					
Biological Indices: Fish	Total Number of Taxa	Various appropriate standard sampling methods, taxonomic analysis, calculation of indices using published formulas	Units vary based upon metric or index	3 times per year	N/A	Statistically significant declining trend with respect to presence, abundance or distribution of native species
	Abundance					
	Shannon-Weaver Diversity[a]					
	Species Turnover (Morisita Similarity Index[a]					
	Rarefaction/Species Accumulation Curves[b]					

Notes:

(1) Milligrams per liter.
(2) Nephelometric turbidity units.
(3) Microsiemens per centimeter.
(4) PicoCuries per liter.
(5) If reagents are not detected after two years, sampling frequency will be reduced to quarterly - if subsequent data indicate the presence of reagents, monthly sampling will be resumed.
(6) At Station HC SW-4 only, recognizing that existing levels during low-flow conditions exceed the trigger level.
(7) At Stations HC SW-1, HC SW-2, and HC SW-3.

References:

(a) Brower, J. E., Zar, J. H., von Ende, C. N. Field and Laboratory Methods for General Ecology. 3rd Edition. Wm. C. Brown Co., Dubuque, IA. pp. 237; 1990
(b) Gotelli, N.J., and G.R. Graves. 1996. Null Models in Ecology. Smithsonian Institution Press, Washington, DC.

Appendix B

Cumulative Chronological List of Procedural Changes to the HCSP

Cumulative Chronological List of Procedural Changes to the HCSP

Change 1: Summer Biological sampling from July – Aug to July – Sep.
Year Implemented: 2004
Comments: Allows flexibility with sampling during high flows.
Provisional Acceptance: 2004
Final Acceptance: April 4, 2007

Change 2: Fall Biological sampling from Oct – Nov to Oct – Dec.
Year Implemented: 2004
Comments: Allows flexibility with sampling during high flows.
Provisional Acceptance: 2004
Final Acceptance: April 4, 2007

Change 3: Biological sampling should be separated by at least 6 weeks in time.
Year Implemented: 2004
Comments: Ensures that sample results capture seasonal variation.
Provisional Acceptance: 2004
Final Acceptance: April 4, 2007

Change 4: Accept that historical background levels of dissolved iron at HCSW-4 exceeds the trigger level of 0.3 mg/l.
Year Implemented: 2004
Comments: Station HCSW-4 trigger levels reflect the more stringent Class I levels. Historically Station HCSW-4 background levels for dissolved iron are similar to the rest of the basin but also higher than 0.3.
Provisional Acceptance: 2004
Final Acceptance: April 4, 2007

Change 5: Accept that historical background levels of dissolved oxygen and chlorophyll at HCSW-2 exceeds the trigger level.
Year Implemented: 2004
Comments: Station HCSW-2 is directly downstream of Horse Creek Prairie which routinely delivers slow moving water low in dissolved oxygen and high in chlorophyll to station HCSW-2
Provisional Acceptance: 2004
Final Acceptance: April 4, 2007

Change 6: Continue to compile, compare, present and discuss on going Horse Creek Data from WMD, DEP and USGS with HCSP data.
Year implemented: 2005
Comments: Enhances program
Provisional Acceptance: July 2006
Final Acceptance: April 4, 2007

Change 7: Biological Sampling stage level criteria from > 10 ft at HCSW-1 & > 5 ft at HCSW-4 to > 10 ft at HCSW-1 & > 4 ft at HCSW-4
Year implemented: 2007
Comments: Biological samples will be collected when stage levels are below these stated levels to ensure safety and quality samples.
Provisional Acceptance: July 2006
Final Acceptance: April 4, 2007