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Shaping the Future



Horse Creek Stewardship Program

2010 Annual Report

March 2014

Prepared For

Mosaic Phosphates Company

Horse Creek Stewardship Program

2010 Annual Report

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Prepared for
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Introduction

This is the eighth 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 impacts 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 eighth of a series of Annual Reports, presents the results of the first eight years of monitoring, including historical data since 1990. 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 of the total 12,000 acres mined 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.

Recent Mining and Reclamation

A total of 283 acres was mined in the Horse Creek Basin at the Mosaic Fort Green Mine in 2010. Some additional phosphate mining may or may not have been conducted by other companies in the Horse Creek drainage basin in 2010, but Mosaic is not aware of the extent or timing of that mining. In 2010, there was a total of 390 acres planted in the Horse Creek Basin (189 in the West Fork Horse Creek Basin and 201 in the Horse Creek Basin). Tailing/grading activities also occurred throughout the year in the West Fork Horse Creek Basin totaling 53 acres. There were also a total of 270 acres reclaimed to the final contour.

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 SWFWMD 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 are scheduled to occur three times each year.

Water Quantity Results

For 2010, 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 October). The winter dry season (November to December) was extremely dry, resulting in periods of little to no flow. Mosaic's NPDES-permitted discharges upstream of HCSW-1 discharged for portions of ten months of the year. Although low and median stream discharge in 2010 was average for the region, rainfall in 2010 was below the long-term average annual rainfall of 52.72 inches (1908-2010)[1].

With no rainfall in October 2010 and very little rainfall in November and December 2010, streamflow at HCSW-1 and NPDES discharge was essentially zero. During other months, NPDES discharge accounted for the majority of the streamflow at HCSW-1, except for some peak streamflow events during the wet season.

Water Quality Results

Water quality parameters in 2010 were almost always within the desirable range relative to trigger levels and water quality standards at the station closest to mining. Trigger levels were exceeded only twice at HCSW-1 in 2010: alkalinity in January and chlorophyll *a* in February. At HCSW-2, trigger levels were exceeded for dissolved oxygen during most of the year as the result of natural conditions (proximity to hypoxic segment of stream – Horse Creek Prairie) and are not related to mining activities. HCSW-3 exceeded trigger levels for dissolved oxygen in April and July through September. HCSW-4 exceeded trigger levels for dissolved oxygen (July), sulfate (November), TDS (November), and iron (4 months). Dissolved oxygen triggers were exceeded during summer wet months of 2010, when high temperatures reduce the oxygen carrying capacity of the stream. Sulfate and TDS were exceeded in the dry season, when low rainfall and streamflow likely led to increased groundwater inputs from baseflow and agricultural runoff. Dissolved iron concentrations consistently exceeded the trigger value set at HCSW-4, but Mosaic and the PRMRWSA agree that the trigger value at that station has been set too low given historical and upstream concentrations of dissolved iron. Based on impact assessments already completed, there is no evidence that any of the observed exceedances can be attributed to mining.

Several of the trends detected during the statistical analysis either have an estimated slope that 1) was not in the direction of an adverse trend (color, ammonia) or 2) was very small compared to limits in laboratory prediction or the observed differences between primary and duplicate field samples (pH, fluoride). For the trends with higher estimated rates of change (orthophosphate and various dissolved

[1] Historical rainfall information came from the following stations and years: 1908-1943 NOAA station 148, 1944-2010 average of NOAA station 148 and 336

ions), the potential trends are discussed in Appendix I. Appendix I shows that the apparent trend in orthophosphate from 2003-2010 is caused by a data bias, and that extending the period of record eliminates this trend. The trend for specific conductivity and other ions may have been influenced by changes in mining practices, but the current concentrations are stable and not biologically harmful.

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 dissolved ions (specific conductivity, calcium, chloride, sulfate) had higher concentrations downstream in Horse Creek, probably because of increased groundwater seepage and agricultural runoff in the lower Horse Creek basin.

Water quality parameters were compared with water quantity variables recorded during the same month: average daily streamflow for the month, average daily NPDES discharge for the month, and total monthly rainfall (Figure 74). In general, pH, dissolved oxygen, and most dissolved ions are higher when the overall quantity of water in the Horse Creek system is low. (In 2010, specific conductivity, sulfate, and TDS showed the opposite pattern with NPDES discharge at HCSW-1; this is discussed as part of the trend analysis in Appendix I.) Conversely, turbidity, color, iron, and some nutrients are high when the water quantity is also high.

Benthic Macroinvertebrate Results

Benthic invertebrate habitat scores were “Optimal” to “Sub-optimal” and SCI scores were “Healthy” or “Impaired” at all stations in 2010; 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. When considered over time from 2003 to 2010, the SCI scores were variable over time at each station, but showed no monotonic trend. SCI scores and invertebrate diversity was significantly lower overall at HCSW-2.

Fish Results

Twenty-five species of fish were collected in 2010. In 2010, fish richness and diversity was lowest at HCSW-2, with no annual trends at any station. Fish communities were similar for all years when stations were combined and for all stations when years were combined. Catch per effort is variable over time and dependent on sampling technique, a station’s physical characteristics, water levels, and available recruitment sources. No trends were evident in the abundance of fish from exotic and native fish groups.

Conclusions

Although this report covers only the eighth year of an ongoing monitoring program, some general conclusions can be drawn. Expected relationships between rainfall, runoff and streamflow were observed in the 2003 to 2010 water quantity data. Program trigger levels were exceeded for several parameters in 2010 and several parameters had statistically significant trends from 2003 to 2010, but the exceedances and trends were related to low rainfall and streamflow for 2006 to 2007 or the influence of surrounding land use in the southern basin. The benthic macroinvertebrate and fish communities found in Horse Creek in 2003 to 2010 were typical of those found in a Southwest Florida stream.

Recommendations

There are no additional recommendations at this time besides those listed in Appendix E (TAG Meeting Summary).

Section 1.

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. This information would then allow the ability 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 exceedance 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[2]
- 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 lie 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 2010, 283 acres were mined in the Horse Creek Basin (58 in the West Fork Horse Creek Basin and 226 in 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 eighth of a series of Annual Reports, presents the results of monitoring conducted from April 2003 through 2010. Additional sources of data since 1990 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] In 2009, the list of parameters was reduced by three (total amines, total fatty acids, and FL-PRO were removed), and an additional station on Brushy Creek (tributary of Horse Creek) was added.

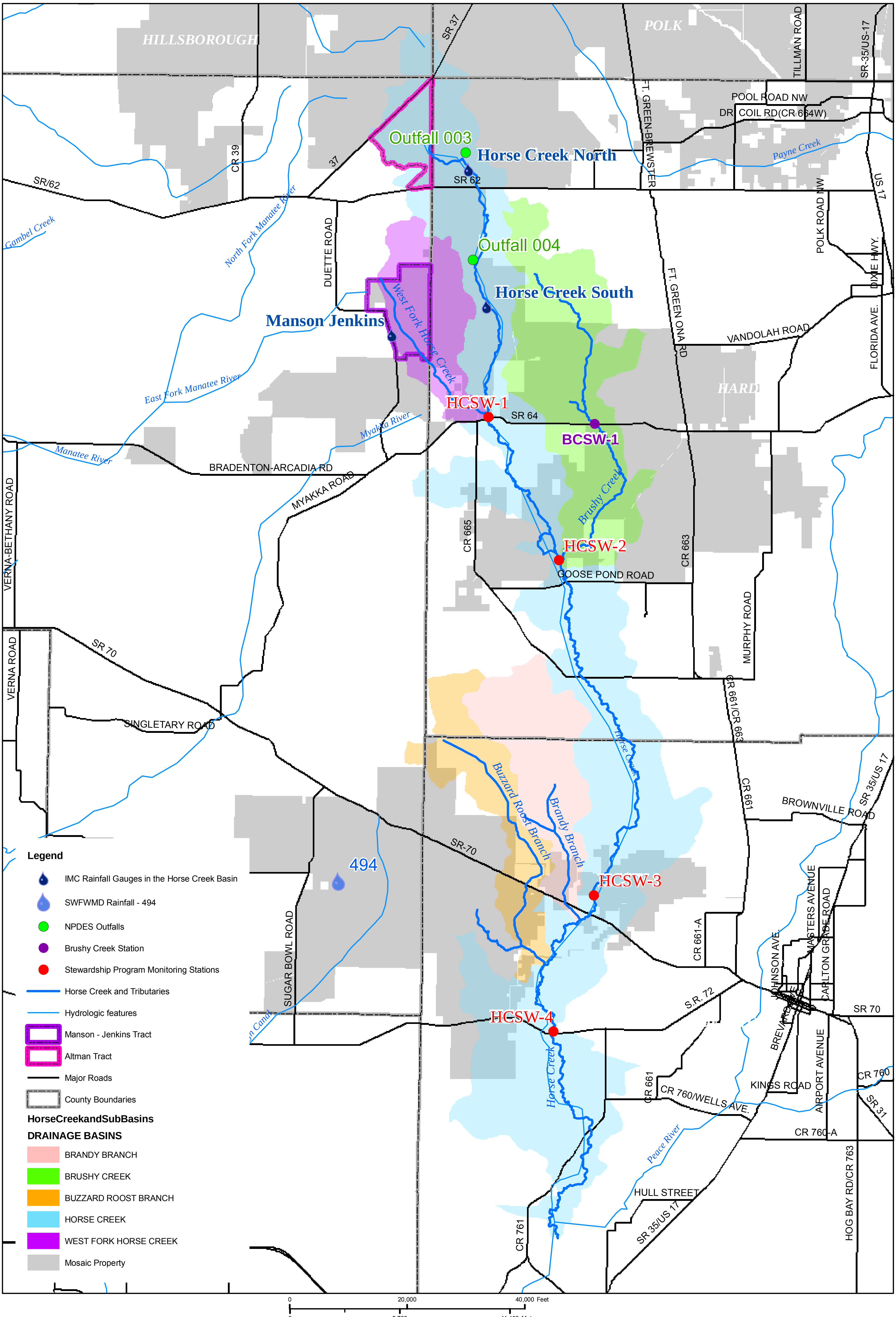

Figure 1. Overview of drainage basins, HCSP sampling locations, and Mosaic property in the Horse Creek Basin.

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Date: 06/04/10 Rev. Date: 02/02/2011 PM: KMNR GIS Analyst: KMNR Map Document: horsecreek_overview_2009.mxd Project Number: 2476-065 PDF Document: horsecreek_overview_v2009.pdf Plot Size: 11 x 17

Section 2.

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 into the southwestern 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 52.72 inches, with more than half of that falling during localized thundershowers in the wet season (June – September)[3]. Rain during fall, winter, and spring is usually the result of large, broad frontal systems instead of local storms. November is typically the driest month of the year, averaging 1.77 inches over the historic period from 1908 to 2010. The months of April and May are also characteristically dry, averaging 2.41 and 3.78 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 8.39 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. The percent mining cover has increased between 1988 and 2009, according to SWFWMD landuse maps for those years. The majority of land newly identified as mined in 2009 was agricultural or rangeland in 1988. Mining is the primary land use above State Road 64, but the percentage of land devoted to mining decreases rapidly downstream. Agricultural land use more than doubles in acreage from above County Road 663 (HCSW-2) to above SR 72 (HCSW-4). Rangeland covers about the same percentage of land in the northern part of the basin and in the southern portion. The percent upland forest and wetland cover also remains relatively constant in upstream and downstream sections of the creek.

[3] Historical rainfall information came from the following stations and years: 1908-1943 NOAA station 148, 1944-2010 average of NOAA station 148 and 336

Water quality sampling on Brushy Creek was newly added to the HCSP in 2009. Landuse in 2009 in the Brushy Creek basin is primarily agricultural (38%), with a relatively small percentage of mining (6%) compared to Horse Creek above State Road 64 or County Road 663. Overall, the Brushy Creek basin has a similar percentage of rangeland (15%), upland forest (13%), and wetland (29%) landuse as does the Horse Creek Basin.

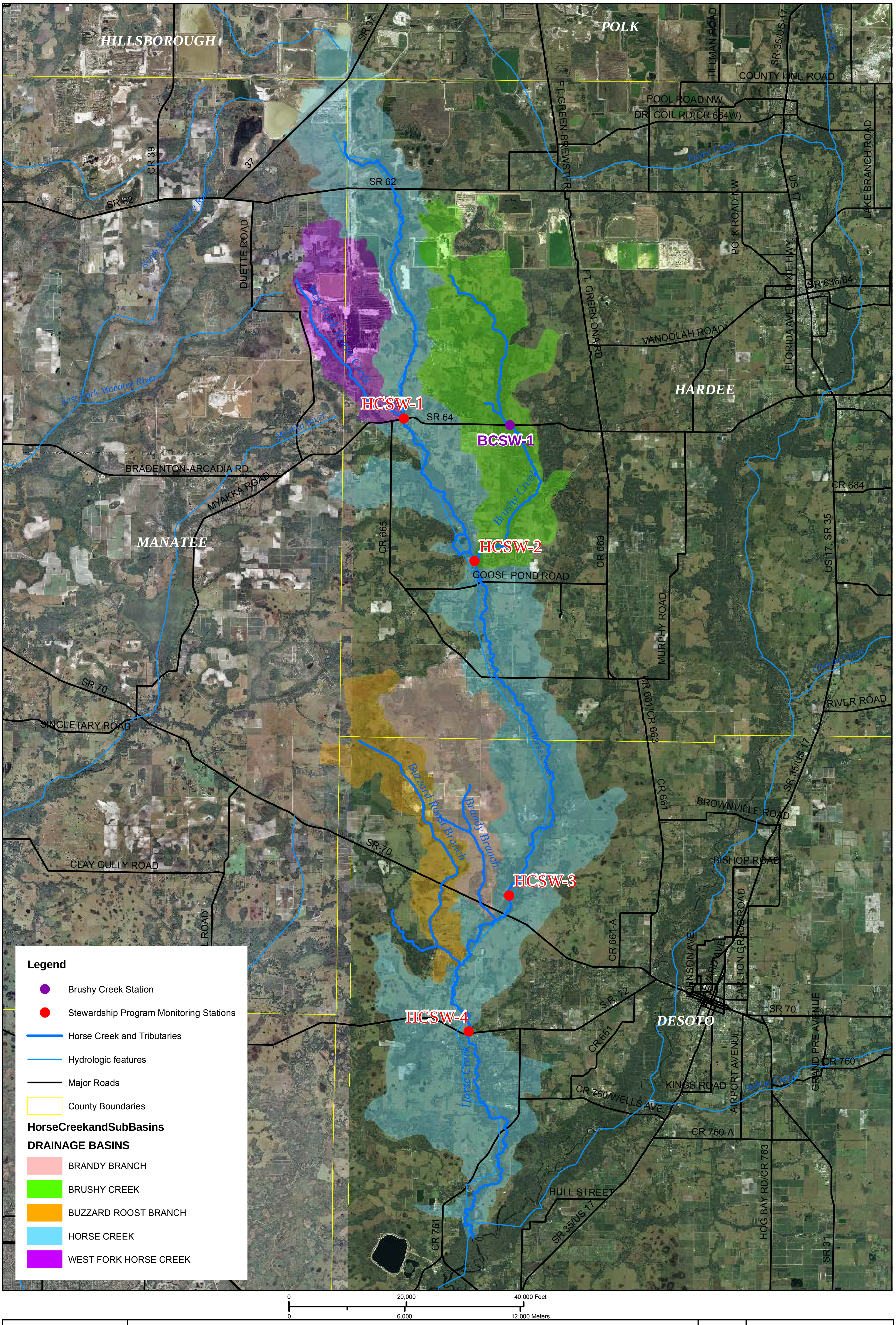

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Figure 2. Aerial photograph of the Horse Creek Basin and HCSP sampling locations

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Section 3.

Summary of Mining and Reclamation Activities

3.1 Mining

A total of 283 acres was mined in the Horse Creek Basin at the Mosaic Fort Green Mine in 2010 (Figure 3). A summary of all mining and reclamation activities from 2004 to 2010 is provided below in Table 1. There have been, and will be in the future, mining activities in the Horse Creek Basin outside of those performed by Mosaic. 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).

Table 1 lists mining and reclamation data for the Horse Creek Basin over the course of the HCSP (omitting the partial year of 2003). The table lists the acres mined, the acres reclaimed to the final contour (but not necessarily vegetated), and the acres released and reconnected to Horse Creek. The table does not include the acres revegetated because the same areas could potentially be revegetated more than once if less than ideal climate conditions result in plant loss.

Table 1. Total Acres mined, reclaimed to final contour, and reconnected to Horse Creek by Mosaic in the Horse Creek Basin from 2004 through 2010.

Year	Acres Mined	Acres Reclaimed to Final Contour	Acres Reconnected to Horse Creek
2004	638	30	0
2005	590	205	38
2006	187	0	205
2007	0	106	0
2008	150	245	66
2009	137	711	315
2010	283	270	0

There are three 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.

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.

The third settling area, FM-1 is located predominately in Section 1, T34S, R22E. FM-1 was constructed in 2006-2007 and put into service in March 2009. The settling area was designed by Ardaman and Associates with a crest elevation of 164 NGVD and a final pool elevation of 159 NGVD. The effective area of the dam is approximately 350 acres. Two decant spillways, both located on the west wall of the dam, are designed to return water to a holding area at the base of the dam, which is then pumped via pipeline back to the Wingate Creek Mine. Water from this dam can also be routed via a series of pumps and surface water conveyance ditches to the 004 outfall; thus discharges from the clay settling area can be routed to either the Myakka or Horse Creek basins. The FGH-3, FGH-4, and FM-1 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.

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. In 2010, there was a total of 390 acres planted in the Horse Creek Basin (189 in the West Fork Horse Creek Basin and 201 in the Horse Creek Basin). Tailing/grading activities also occurred throughout the year in the West Fork Horse Creek Basin totaling 53 acres. The number of acres reclaimed to the final contour and the acres reconnected to Horse Creek are summarized in Table 1 above.

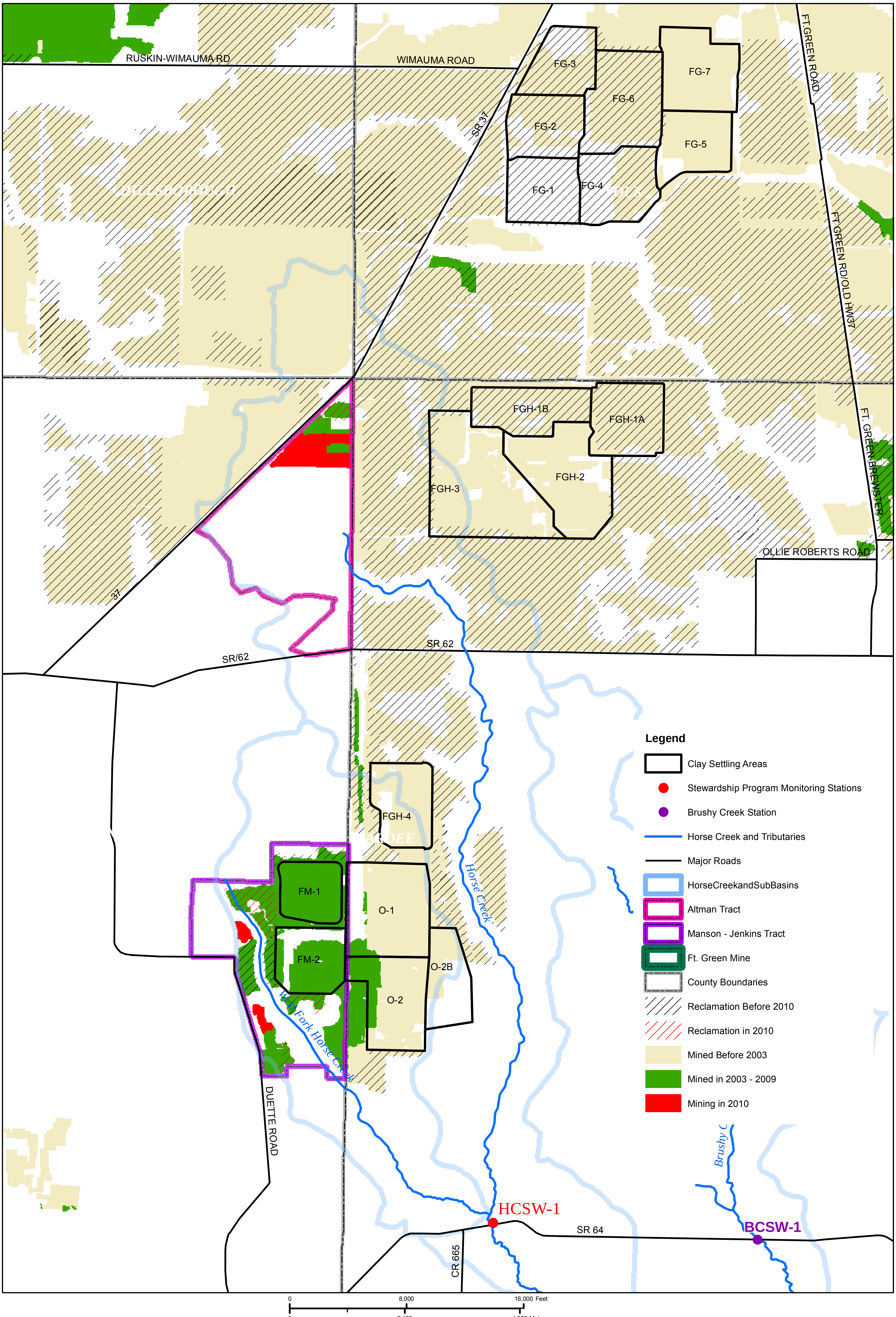

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Figure 3. Mining and reclamation areas in the Horse Creek Basin

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Section 4.

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 typically three times per year (Table 2).

In September 2009, based on recommendations of the PRMRWSA and the TAG, Mosaic began sampling water quality at an additional station on Brushy Creek (BCSW-1 at State Road 64). Brushy Creek is a tributary to Horse Creek and flows into Horse Creek between the HCSW-1 and HCSW-2 sampling stations.

This additional station was added for comparison purposes, and will not be evaluated against the HCSP trigger levels and exceedances. Mosaic does not have a NPDES discharge on Brushy Creek. In September 2009, Mosaic also discontinued water quality analysis for FL-PRO, total fatty acids, and total amines based on recommendations made in previous HCSP annual reports. Mosaic, PRMRWSA, and the TAG agree that the results for these parameters from 2003-2009 show that these substances are present only occasionally at low concentrations, and are not a cause for concern at this time.

Table 2. 2010 Schedule of Water Quality and Biological Sampling Events of the HCSP

Date	Water Quality Sampling Events	Biology Sampling Events
5 January 2010	X	
2 February 2010	X	
3 March 2010	X	
6 April 2010	X	
20 April 2010		X
5 May 2010	X (BCSW-1 dry)	
2 June 2010	X	
12 July 2010	X	
3 August 2010	X	
8 September 2010	X	
28 September 2010		X
6 October 2010	X	
3 November 2010	X (BCSW-1 dry)	
4 & 11 November 2010		X
7 December 2010	X (BCSW-1 dry)	

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 - 2010 (Figure 1). Daily rainfall data were obtained from the USGS 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. This data provides 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. Low flow or low water conditions resulted in no continuous data from October through December 2010.

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 3). All calibration activities were documented and records checked for completeness and accuracy. Field measurements by Cardno ENTRIX (formerly Biological Research Associates) in association with the three biological sampling events employed an YSI 6920 multiparameter data sonde with the same measuring methods and acceptance limits listed in Table 3. Cardno ENTRIX also employed a Hach 2100P unit for turbidity measurement.

Table 3. 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. 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 4. Table 4 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 2) using a YSI 6920 data sonde. All sampling was conducted according to the Florida Department of Environmental Protection's (FDEP's) Standard Operating Procedures (SOPs) for field sampling. Laboratory analyses were performed by experienced personnel according to National Environmental Laboratory Accreditation Conference (NELAC) protocols.

Results were tabulated to allow for comparisons among stations and sampling events, through time, and to the "trigger values" established for the HCSP (Table 5). In addition, results were compared with applicable Florida surface water quality standards (which in many cases are the same as the trigger values).

Table 4. Parameters Analyzed and Laboratory Methods for HCSP 2003 - 2010 Monthly Water Quality Samples.

Parameter	Method	Hold Time	Preservation	Minimum Detection Limit Range	Container
Color	110.2	48 hours	Unpreserved	2-5 PCU	Clear HDPE bottle
Total Kjeldahl Nitrogen	351.2	28 days	Sulfuric Acid, pH < 2	0.02-0.24 mg/l	Clear HDPE bottle
Nitrate-Nitrite Nitrogen	353.2	28 days	Sulfuric Acid, pH < 2	0.0001-1.0 mg/l	Clear HDPE bottle
Total Ammonia Nitrogen	350.1	28 days	Sulfuric Acid, pH < 2	0.0008-0.04 mg/l	Clear HDPE bottle
Orthophosphate	365.1	48 hours	Unpreserved	0.002-0.75 mg/l	Clear HDPE bottle
Chlorophyll *a*	SM 10200H	48 hours	Unpreserved	0.25-2.0 mg/l	Opaque plastic bottle
Specific Conductivity	120.1	28 days	Unpreserved	10 µS/cm	Clear HDPE bottle
Total Alkalinity	310.1	14 days	Unpreserved	0.02-3.0 mg/l CaCO3	Clear HDPE bottle
Dissolved Calcium*	200.7	28 days	Unpreserved	0.03-0.72 mg/l	Clear HDPE bottle
Dissolved Iron*	200.7	28 days	Unpreserved	0.009-0.10 mg/l	Clear HDPE bottle
Chloride	300.0	28 days	Unpreserved	0.022-30 mg/l	Clear HDPE bottle
Fluoride	300.0	28 days	Unpreserved	0.01-5.0 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	0.054-100 mg/l	Clear HDPE bottle
Total Dissolved Solids	160.1	7 days	Unpreserved	5-25 mg/l	Clear HDPE bottle

- 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.
- Total radium is the arithmetic sum of Radium 226 and Radium 228. Total nitrogen is reported as the arithmetic sum of nitrate+nitrite nitrogen and total Kjeldahl nitrogen. As requested by the PRMRWMA, if either of each pair 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.
- Petroleum Range Organics, Fatty Amido-amines, and Total Fatty Acid analysis were discontinued in September 2009.

Table 5 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 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)	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
Biological Indices: Fish	Total Number of Taxa Abundance Shannon-Wiener Diversity(a) Species Turnover (Morisita Similarity Index(a) Species Accumulation Curves(b)	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

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., .Dubuque, IA. pp. 237; 1990
(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 stations on 20 April 2010, 28 September 2010, HCSW-1 on 4 November 2010 and the remaining three downstream stations on 11 November 2010. In November 2010, there was a significant rainfall event that occurred the day prior to the scheduled sampling event, causing water levels to rise significantly at the three downstream stations. Since water levels did not appear to have been affected at HCSW-1, sampling occurred on 4 November 2010. Cardno ENTRIX waited a week for water levels to decrease to pre-rainfall levels before sampling the other stations on 11 November 2010.

At each station, a Stream Habitat Assessment (DEP-SOP-001/01, Form FD 9000-5) was performed, and a Physical/Chemical Characterization Field Sheet (DEP Form FD 9000-3) 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 6). The general interpretation for SCI score ranges are provided in Table 7. The calculation methodology for the SCI was revised by DEP in June 2004, and sampling conducted in 2003 - 2007 uses that 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 6. 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 Taxa	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 in 2004 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 2003 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).

In 2007, the FDEP SCI protocol was again revised, this time to include provisions for the taxonomic analysis of two aliquots for every SCI sample collected to account for variation in sample sorting (DEP-SOP-002/01 LT 7200). Under the new protocol, the SCI score for each sample is the arithmetic average of the SCI scores of the two aliquots. Table 6 provides the list of metrics used in calculating SCI scores, while the parameter table from the HCSP methodology document (copied as Table 5 above) includes the metrics used in the original SCI protocol. In addition to the change in aliquots in 2007, the new protocol also gives a slightly different ecological interpretation of SCI scores (Table 7). Scores from the 2004 SCI and the 2007 SCI may not be directly comparable, given the differences in how they were collected.

The Shannon-Wiener Diversity Index was calculated using Ecological Methodology Software, Version 6.1 (www.exetersoftware.com).

Table 7. Ecological Interpretation of SCI Scores Calculated for Benthic Macroinvertebrate Samples Collected for the HCSP

SCI Category	Range	Typical Description for Range
Category 3 (Exceptional)	68-100	Higher diversity of taxa than for Category 2, particularly for Ephemeroptera and Trichoptera; several more clinger and sensitive taxa than found in Category 2; high proportion for Tanytarsini; few individuals in the dominant taxon; very tolerant individuals make up a very small percentage of the assemblage.
Category 2 (Healthy)	35-67	Diverse assemblage with 30 different species found on average; several different taxa each of Ephemeroptera, Trichoptera, and long-lived and, on average, 5 unique clinger and 6 sensitive taxa routinely found; small increase in dominance by a single taxon relative to Category 1; very tolerant taxa represent a small percentage of individuals, but noticeably increased from Category 1.
Category 1 (Impaired)	0-34	Notable loss of taxonomic diversity; Ephemeroptera, Trichoptera, long-lived, clinger, and sensitive taxa uncommon or rare; half the number of filterers than expected; assemblage dominated by a tolerant taxon, very tolerant individuals represent a large portion or the individuals collected.

4.5 Fish

Fish sampling was conducted at each of the four stations on 20 April 2010, all but HCSW-2 on 28 September 2010, HCSW-1 on 4 November 2010, and the remaining three downstream stations on 11 November 2010. No fish sampling occurred at HCSW-2 in September 2010 due to high water levels and inability to access much of the stream and suitable habitats. In November 2010, there was significant rainfall event that occurred the day prior to the scheduled sampling event, causing water levels to rise significantly at the three downstream stations. Since water levels did not appear to have been affected at HCSW-1, sampling occurred on 4 November 2010. Cardno ENTRIX waited a week for water levels to decrease to pre-rainfall levels before sampling the other stations on 11 November 2010.

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 500 seconds), and the number of seine hauls (typically 5) 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.

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 Current Habitat Configuration at Monitoring Stations

Beyond the immediate response of the stream to the 2004 hurricanes, the overall morphometry of Horse Creek continued to undergo noticeable changes through 2010. Between the April 2005 and November 2010 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. Sand and silt deposition was relatively low during the April and September sampling events, but sand smothering was once again a bit higher in November. The substrate diversity and availability was consistent in 2010, but water levels and velocities varied, with September having the highest water levels and velocity (Figures 5-7).

At HCSW-2, the size and position of a sand bar on the west side of the stream in the sampling area has changed noticeably, indicating accrual of sediment there. Smothering and water velocities were similar to 2009, with the exception of the September event where sand smothering was moderate. During the September event, many habitats were not accessible due to high water levels, and there was a thick muck layer accumulating on the stream bottom. The substrate diversity was still not very high in 2010, and there was not much productive habitat or substrate located upstream of the 50 meter mark (Figures 5-7). Horse Creek at this station became choked with water hyacinth during the beginning of 2008, limiting flow. Hyacinth was not present in 2010, and much of the torpedo grass previously present was inundated. During the 2010 wet season, the water levels appeared to overflow both banks.

At HCSW-3, very few productive habitats were present, and the large area of water hyacinth previously sampled was flushed out by high flows throughout 2010 (Figures 5-7). Sand and silt smothering were both moderate for most of the year, while water velocity was higher than in previous years. During the wet season, water appeared to overflow the banks, and some bank erosion was present.

At HCSW-4, the stream channel is steep-sided and generally deeper throughout the sampling area, which continues to complicate sampling efforts. The sand and silt smothering at this station was once again higher for most of the year compared to 2009. There was more sand deposition in April and September, and water levels and velocities were also higher than previous years due to a fairly wet rainy season. The water hyacinth was greatly reduced in April and not present for the rest of 2010 (Figures 5-7). The stream remained fairly tannic, and water depth was a limiting factor for accessing many habitats during 2010.

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 on 20 April 2010.

Figure 6. Photographs of HCSP Sampling Locations on 29 September 2010.

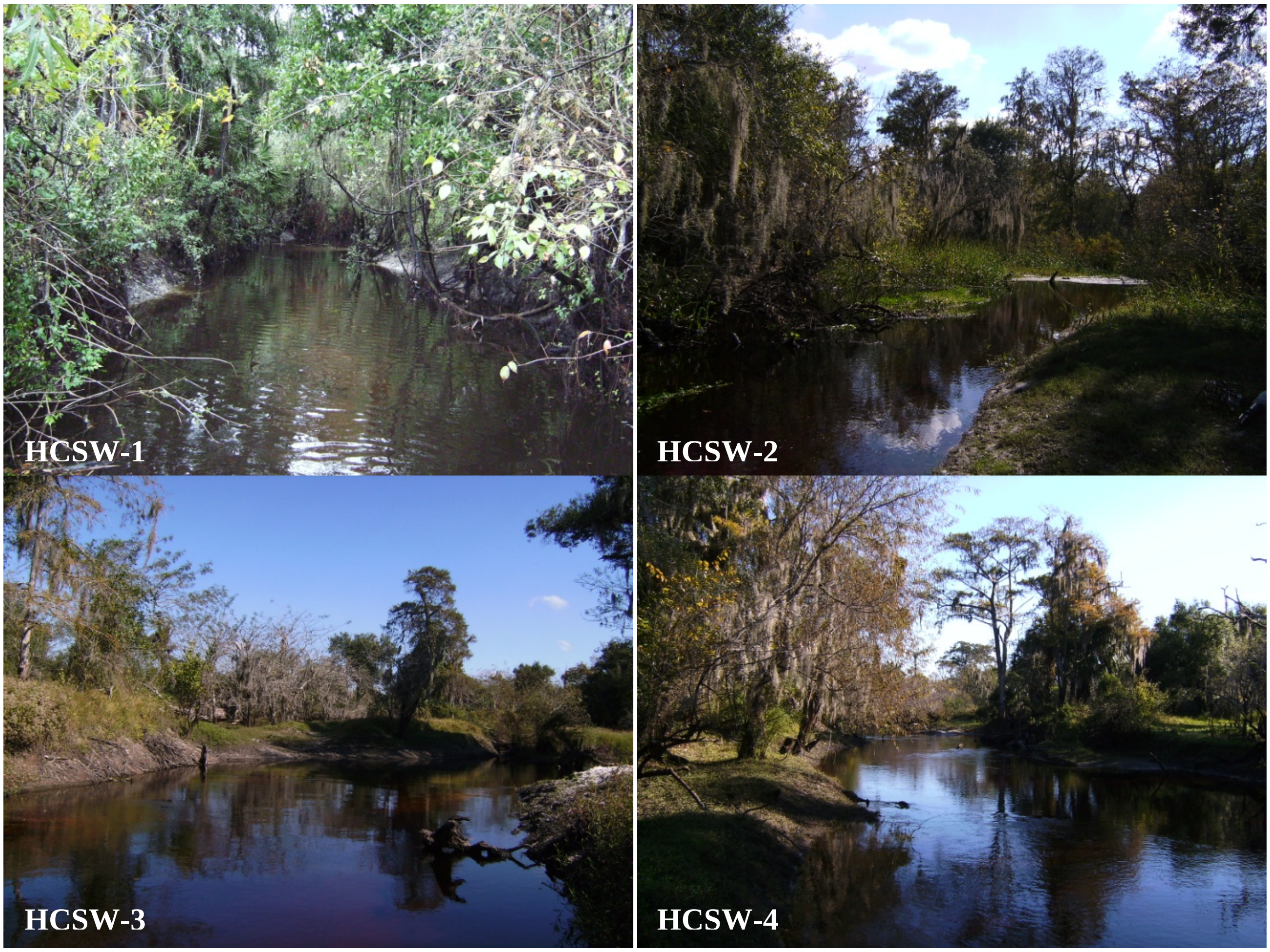

Figure 7. Photographs of HCSP Sampling Locations on 4 and 11 November 2010.

Section 5.

Results and Discussion

Below we present a summary of water quantity and quality data collected as part of the HCSP in 2010 in Sections 5.1 and 5.2. Results of the 2010 benthic macroinvertebrate and fish sampling are presented in Sections 5.3 and 5.4.

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 8 includes 2010 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 2010 was slightly different at each gauge, but the heaviest rainfall was observed during June to August at all four locations (Figure 8). Overall rainfall for 2008 – 2010 was less than that for 2003 – 2005, greater than totals observed in 2006 – 2007 (Table 8, Figure 9), and below the historic range (52.72 in) for that station[4]. When one of rainfall gauges was non-functional, average daily rainfall was calculated from the other functional gauges, and total monthly or annual rainfall was calculated from these adjusted daily averages.

Table 8. Annual Total Rainfall in Inches at Gauges in the Horse Creek Watershed in 2003 to 2010.

Gauge	2003	2004	2005	2006	2007	2008	2009	2010
Horse Creek North	53.40	53.82	54.52*	31.82*	33.90	40.49	36.36	32.53
Horse Creek South	59.75	60.74	64.53	34.17	31.97	36.80	43.70	37.47
Manson Jenkins	30.10*	62.15	31.34*	41.26	32.48	37.48	46.87	41.84
SWFWMD 494	60.10	53.28	69.80	37.75	38.21	53.48	39.30	51.82
Average of Gauges	53.67	57.39	62.55	37.53	34.14	42.06	41.62	40.92

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

[4] Historical rainfall information came from the following stations and years: 1908-1943 NOAA station 148, 1944-2010 average of NOAA station 148 and 336

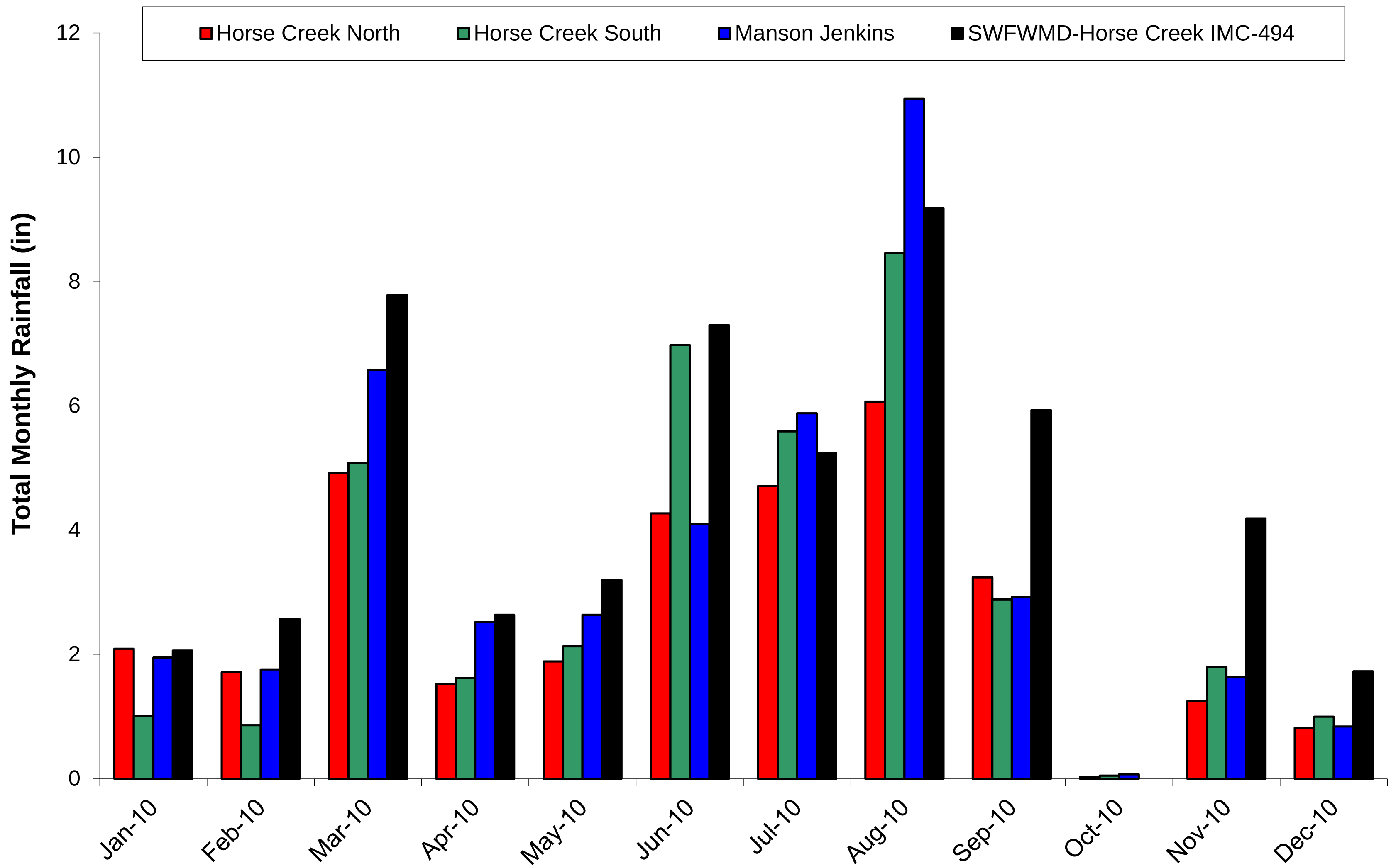

Figure 8. Total Monthly Rainfall From Gauges in the Horse Creek Watershed in 2010.

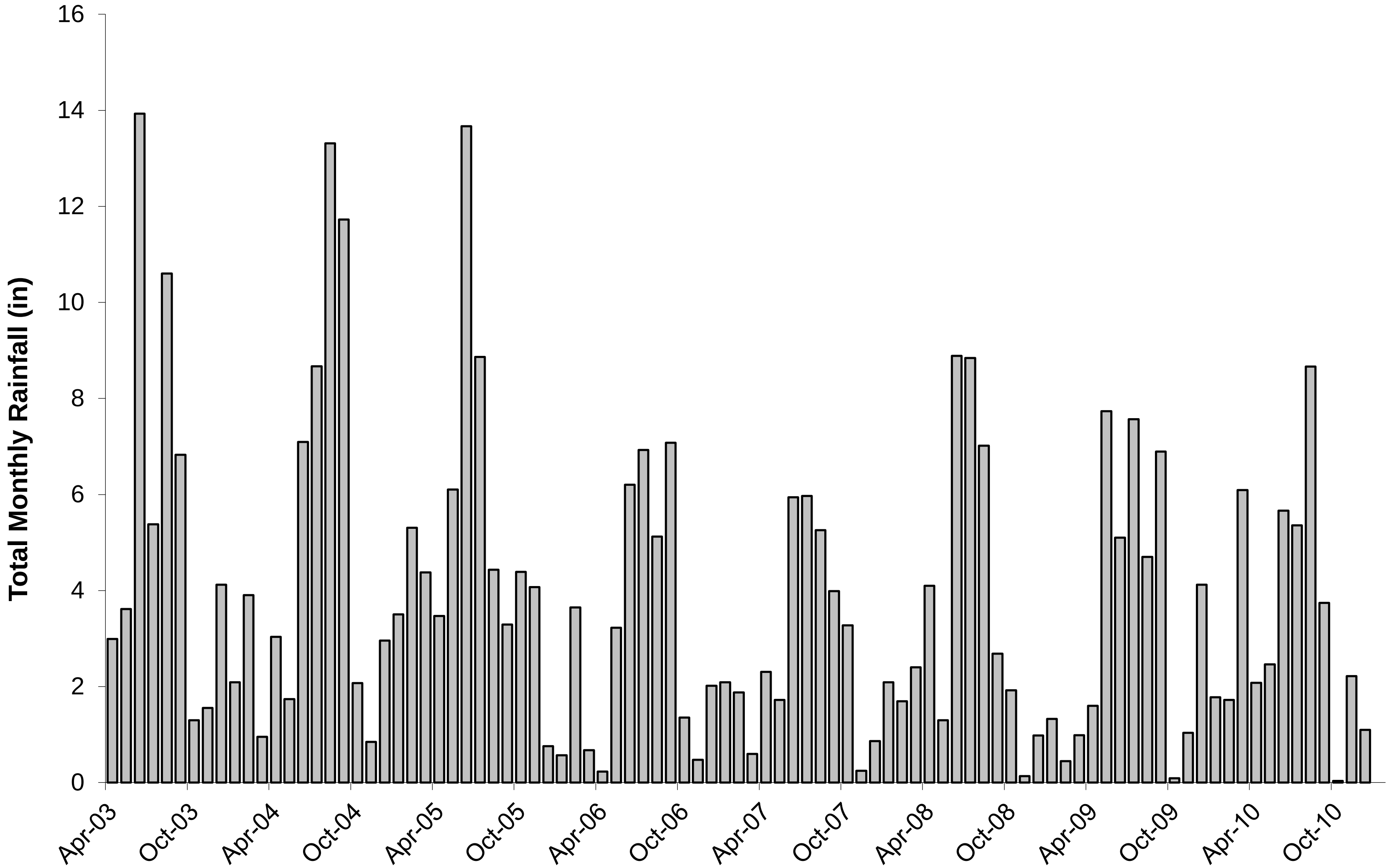

Figure 9. Total Monthly Rainfall from the Average of Four Gauges in the Horse Creek Watershed in 2003 - 2010.

5.1.2 Stream Stage

Figure 10 illustrates the relationship between the staff gauge readings made during each Mosaic 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). Patterns of daily stage levels were clearly temporally correlated among the four stations (Figure 10). 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) because the gauge heights are 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 9). Such close correspondence is expected for a fairly small watershed in a low gradient setting like peninsular Florida.

Mean daily stage levels in 2010 were fairly low during the dry season at HCSW-1 and HCSW-4. Stage duration curves for 2010 were developed for HCSW-1 and HCSW-4 (Figure 11) to indicate the percentage of time stream stage was above particular elevations. Stage at HCSW-1 varied less than three feet between the curve's P10 (69.32 ft) and P90 (66.96 ft) in 2010, indicating that stream height was 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). The small difference in height between the maximum and the P10 show that 2010 rainfall was not enough to raise the stream significantly at HCSW-1. Stream stage at HCSW-4 is more variable than at HCSW-1 between the P10 (18.7 ft) and P90 (13.07 ft) (over five and a half feet), but it also showed a rise in stage beyond the P10 level (~3.1 feet). Stage levels in 2010 were slightly higher than the low levels in 2006 through 2008, but were lower than those recorded in 2003, 2004, and 2005.

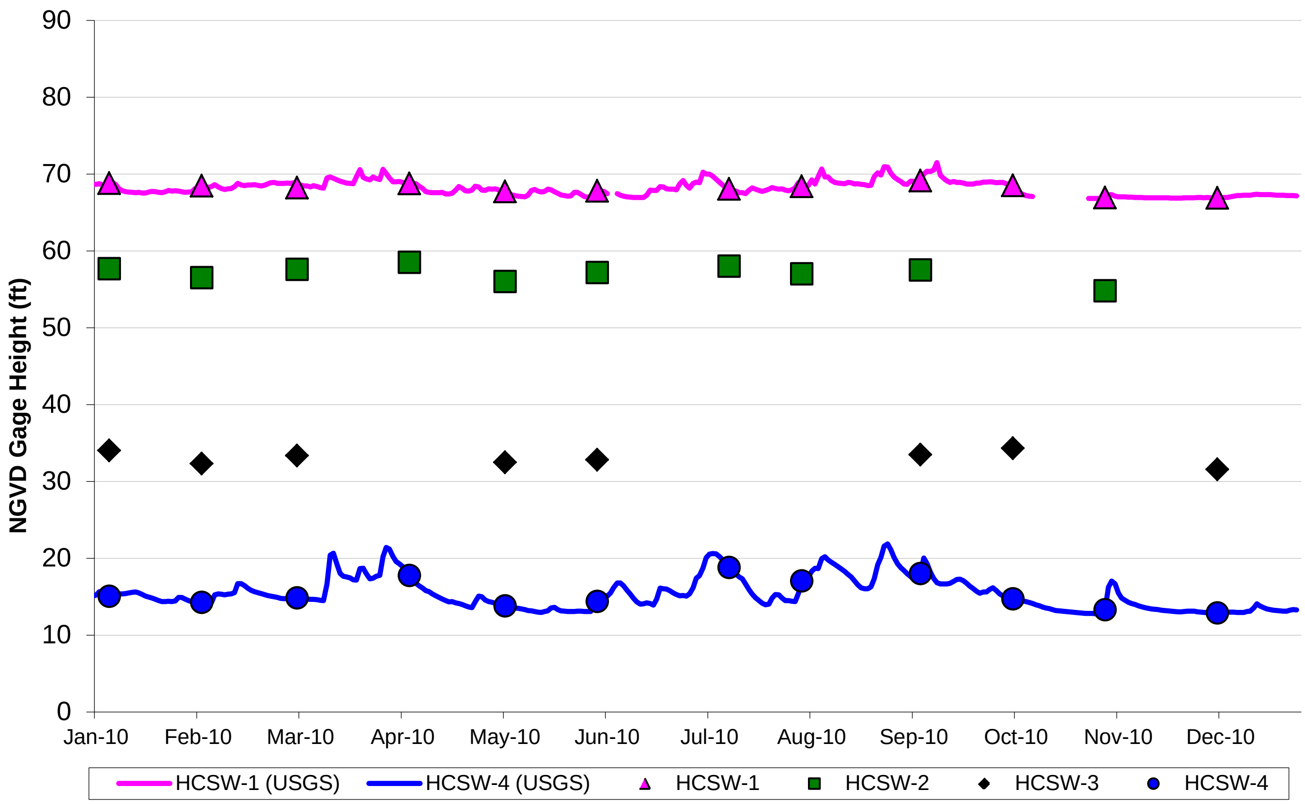

Figure 10. Stream Stage at HCSP Monitoring Stations in 2010. Individual data points are from Mosaic's monthly monitoring; continuous lines are average daily stage from USGS (Stations 02297155 and 02297310).

Table 9. Coefficients of Rank Correlation (rs) for Spearman's Rank Correlations of Monthly Gauge Height (NGVD) for 2003-2010 (p < 0.0001).

	HCSW-1 (USGS)	HCSW-4 (USGS)	HCSW-1 (Mosaic)	HCSW-2 (Mosaic)	HCSW-3 (Mosaic)	HCSW-4 (Mosaic)
HCSW-1 (USGS)		0.90	0.99	0.73	0.83	0.90
HCSW-4 (USGS)			0.89	0.82	0.92	0.99
HCSW-1 (Mosaic)				0.72	0.82	0.89
HCSW-2 (Mosaic)					0.86	0.81
HCSW-3 (Mosaic)						0.91
HCSW-4 (Mosaic)						

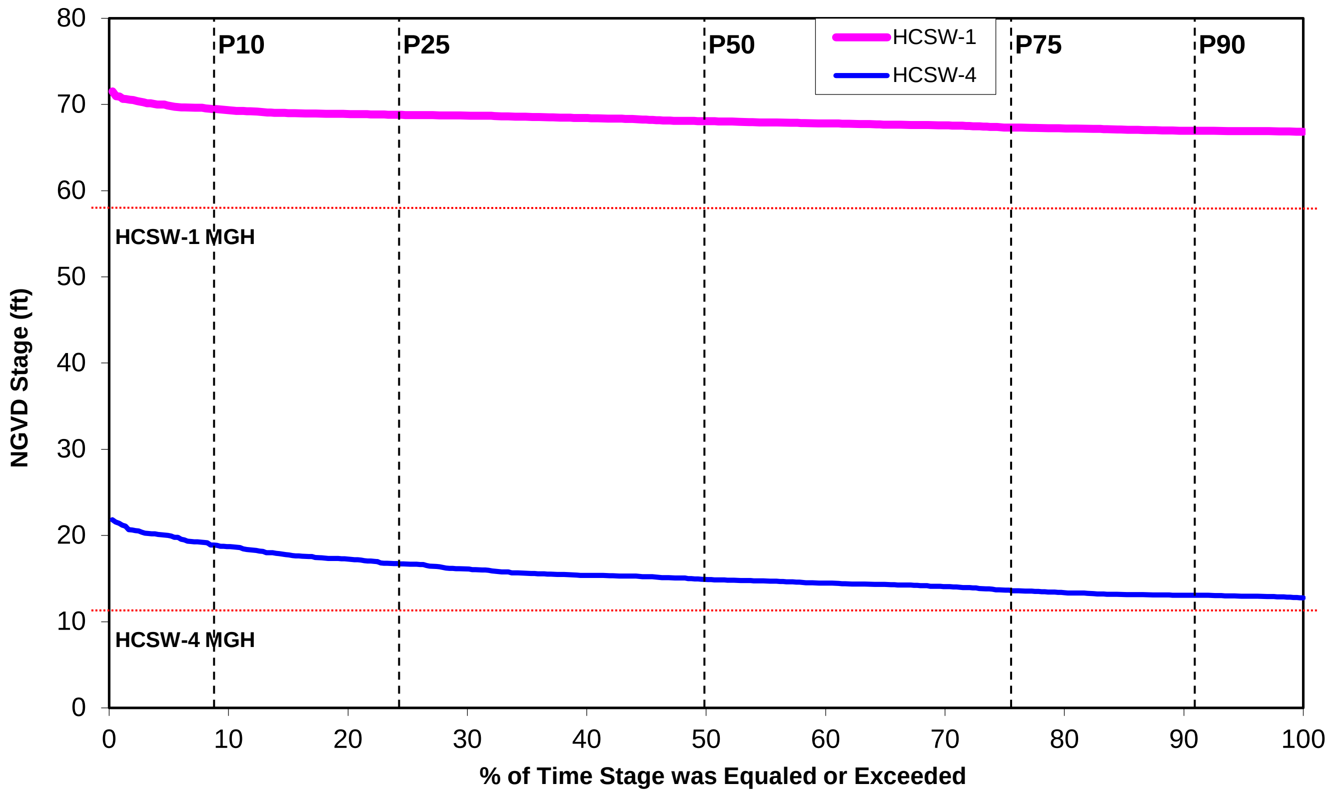

Figure 11. Stage Duration Curves for HCSW-1 and HCSW-4 in 2010, showing percent of year water levels were at or above a given stage. Typical reference points of 10% (P10), 25% (P25), 50% (P50), 75% (P75), and 90% (P90) are indicated on the graph, as well as the minimum gauge heights of HCSW-4 (10.96 ft, NGVD) and HCSW-1 (58.12 ft NGVD).

5.1.3 Stream Discharge

The average daily streamflow for 2010, obtained from the USGS continuous recorder data for HCSW-1 and HCSW-4, is presented in Figure 12 and Table 10. The seasonal pattern of streamflow seen in 2010 is similar to historical monthly patterns (Durbin and Raymond 2006), with the highest flows occurring during the wet-season months of June through October. Average daily stream flows exhibited a similar pattern at both HCSW-1 and HCSW-4 (Figure 11); 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. Average daily streamflow was significantly less in 2006 – 2008 than it was in 2003 – 2005 at HCSW-1, but streamflow in 2010 was similar to that of 2009 and more like 2004 – 2005 than 2006-2008 (One-way ANOVA $F = 10.95$, $p < 0.0001$, Duncan's post hoc test). At HCSW-4, streamflow in 2010 was significantly less than 2003 – 2004, but very similar to 2006 – 2008 (One-way ANOVA $F = 11.93$, $p < 0.0001$, Duncan's post hoc test). The 10th and Median percentile of discharge at HCSW-1 and HCSW-4 in 2010 were similar to historic averages (Table 10), but the 90th percentile streamflow at HCSW-4 was below average historic flow.

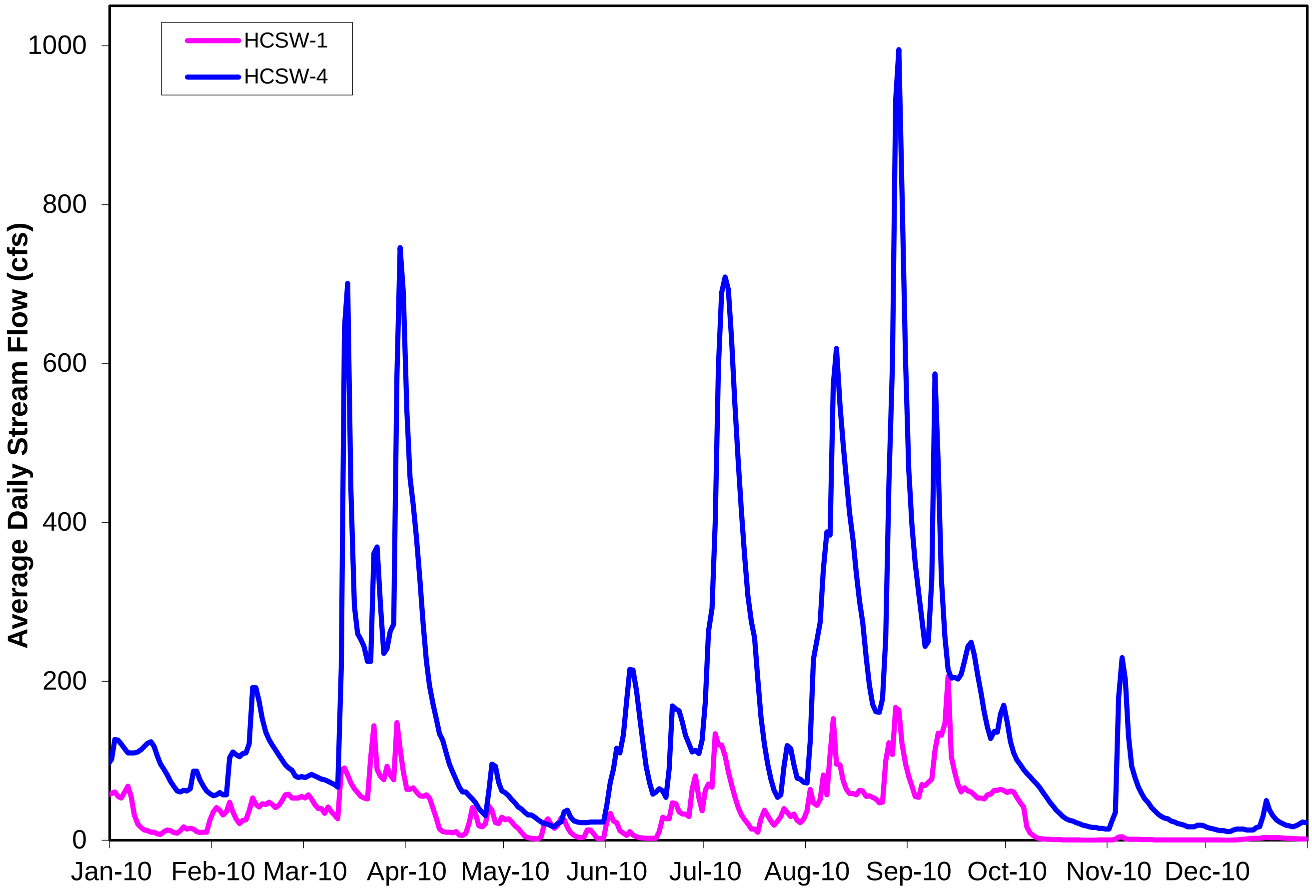

Figure 12. Average Daily Stream Flow for HCSW-1 and HCSW-4 in 2010.

Table 10. Median, 10th Percentile, and 90th Percentile Stream Discharge at HCSW-1 and HCSW-4 in 2003-2010

Station	Year	10th	Median	90th
HCSW-1	2003	2 cfs	20 cfs	127 cfs
	2004	< 1 cfs	7 cfs	166 cfs
	2005	6 cfs	21 cfs	134 cfs
	2006	< 1 cfs	5 cfs	29 cfs
	2007	< 1 cfs	3 cfs	8 cfs
	2008	0 cfs	2 cfs	39 cfs
	2009	< 1 cfs	5 cfs	102 cfs
	2010	< 1 cfs	27 cfs	80 cfs
HCSW-4	2003	21 cfs	84 cfs	1222 cfs
	2004	15 cfs	56 cfs	1184 cfs
	2005	36 cfs	145 cfs	653 cfs
	2006	4 cfs	24 cfs	379 cfs
	2007	4 cfs	14 cfs	43 cfs
	2008	2 cfs	13 cfs	285 cfs
	2009	2 cfs	26 cfs	368 cfs
	2010	19 cfs	93 cfs	379 cfs

5.1.4 Rainfall-Runoff Relationship

Stream discharge at HCSW-1 and the average daily rainfall for 2010 (average of daily rainfall at SWFWMD 494 gauge and three Mosaic rain gauges upstream of Highway 64) are compared in Figure 13. To 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 494 (SWFWMD gauge) and three Mosaic rain gauges, as well the average total monthly rainfall of the gauges for the years 2003 - 2010. The correlation between stream discharge at HCSW-1 and rainfall was statistically significant for each rainfall gauge (Table 11). Although these results suggest that stream discharge and rainfall in Horse Creek covary more than would be expected by chance alone, not all of the variation in streamflow is explained by rainfall ($0.52 < r < 0.62$). The lag between rainfall and runoff, as well as other antecedent condition factors, are strongly affecting this relationship. In addition, discharge from the NPDES outfalls may also affect the timing of the rainfall-discharge relationship, although outfall discharge is much more likely to occur in conjunction with periods of increased rainfall.

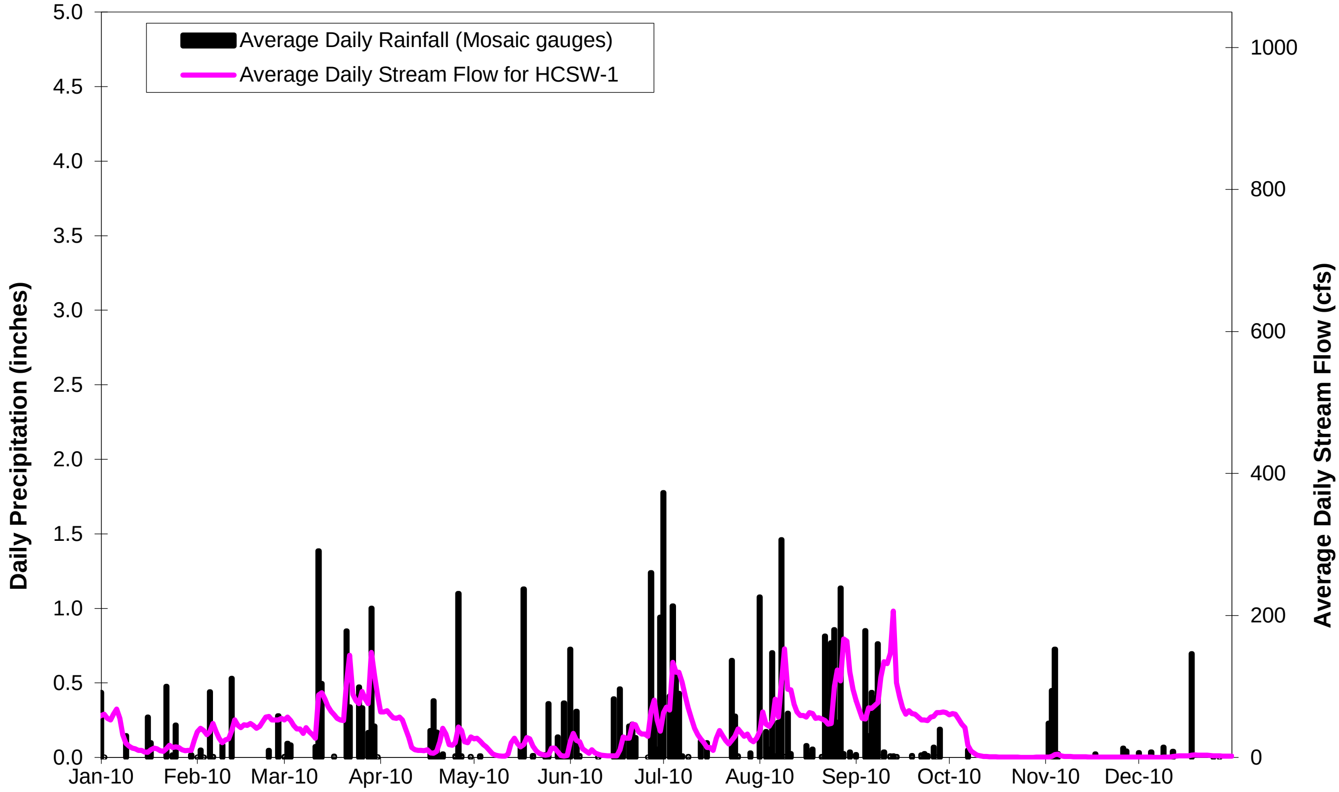

Figure 13. Average Daily Stream Flow at HCSW-1 and Average Daily Rainfall (from 3 Mosaic gauges and 1 SWFWMD gauge) in the Horse Creek Watershed in 2010.

Table 11. 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 - 2010.

Rainfall Gauge	rs (with HCSW-1 Streamflow)	p value	N (Sample Size)
Horse Creek North	0.58	<0.0001	87
Horse Creek South	0.58	<0.0001	93
Manson Jenkins	0.52	<0.0001	89
494 (SWFWMD)	0.57	<0.0001	93
Average Rainfall	0.62	<0.0001	93

To look at the relationship between stream discharge and rainfall over the stream gauge period of record, HCSW-1 discharge was converted from cubic feet per second (cfs) to cumulative discharge in thousands of cfs days. Cumulative historical rainfall was calculated from NOAA gauges 148 and 336, which have a longer period of record than the SWFWMD or Mosaic gauges. Figure 13 illustrates the relationship between cumulative discharge at HCSW-1 and NOAA rainfall from 1978 to 2010. Changes in the relationship between rainfall and stream discharge can be seen as inflection points in the overall slope. Of the HCSW-1 period of record, we identified three potential inflection points. In 2000, cumulative discharge began to increase slightly relative to rainfall for a few years, when compared to the slope of the overall period of record. Between 2005 and 2008, which included several very dry years, cumulative discharge had almost no increase, despite changed in cumulative rainfall. After 2008, when rainfall began to return to average conditions, cumulative discharge began to resume previous patterns relative to cumulative rainfall.

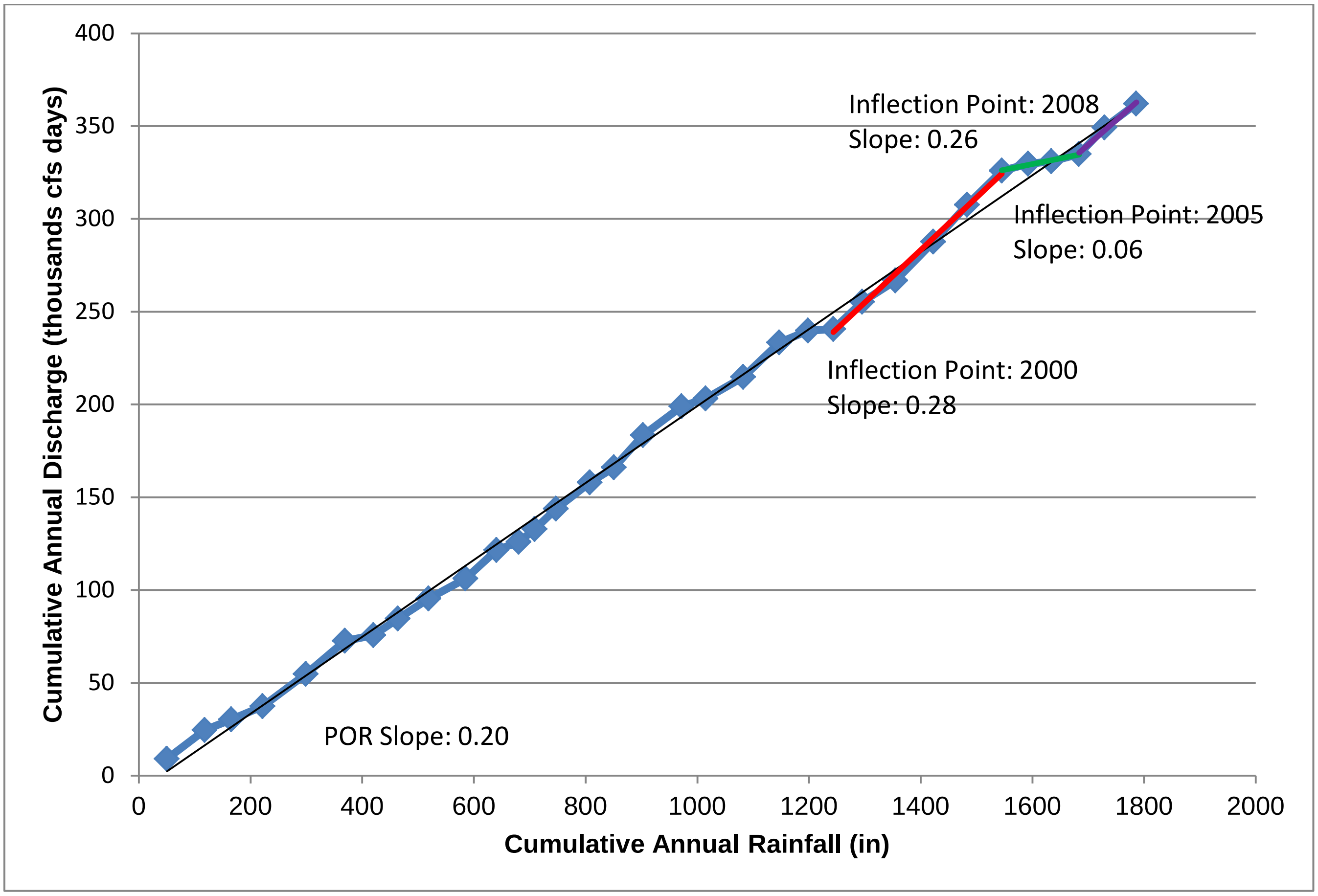

Figure 14. Double Mass Curve of Cumulative Daily Discharge (USGS gauge) and Rainfall (NOAA gauges 148 and 336) at HCSW-1 in 1978 – 2010.

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 Permit 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 2010 (Figure 15). 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 12). 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 and as such conclusions drawn from this data may be misleading. 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 2010 daily discharge of two Mosaic NPDES outfalls (Outfalls 003 and 004) located upstream of HCSW-1 was plotted against the 2010 daily flow for HCSW-1 (Figure 16)[5]. In 2010, the Ft. Green NPDES outfalls discharged during portions of ten months into Horse Creek. Comparing HCSW-1 stream discharge and NPDES discharge in 2003 - 2010 using a Spearman's rank correlation procedure (Zar 1999) indicates they covary strongly ($r_s = 0.74$, $p < 0.001$). Thus, an increase in one parameter will correspond to an increase in the other. Just as stream discharge at HCSW-1 was correlated with rainfall (Table 11), so too is NPDES discharge (Table 13, Figure 15), with lagtimes and antecedent conditions affecting this relationship.

Table 12. 2010 Total 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 (MG)	Discharge to Horse Creek (MG)
January	513.59	529.69
February	770.79	972.75
March	1,282.65	1,108.32
April	213.31	551.51
May	24.71	369.36
June	132.02	325.00
July	1,020.29	454.92
August	1,493.98	992.91
September	1,485.23	1,190.65
October	34.88	216.90
November	4.80	0.00
December	5.95	0.00
Annual Total	6,982.19	6,712.01

[5] Mosaic gauge may be based on instantaneous rather than continuous flow.

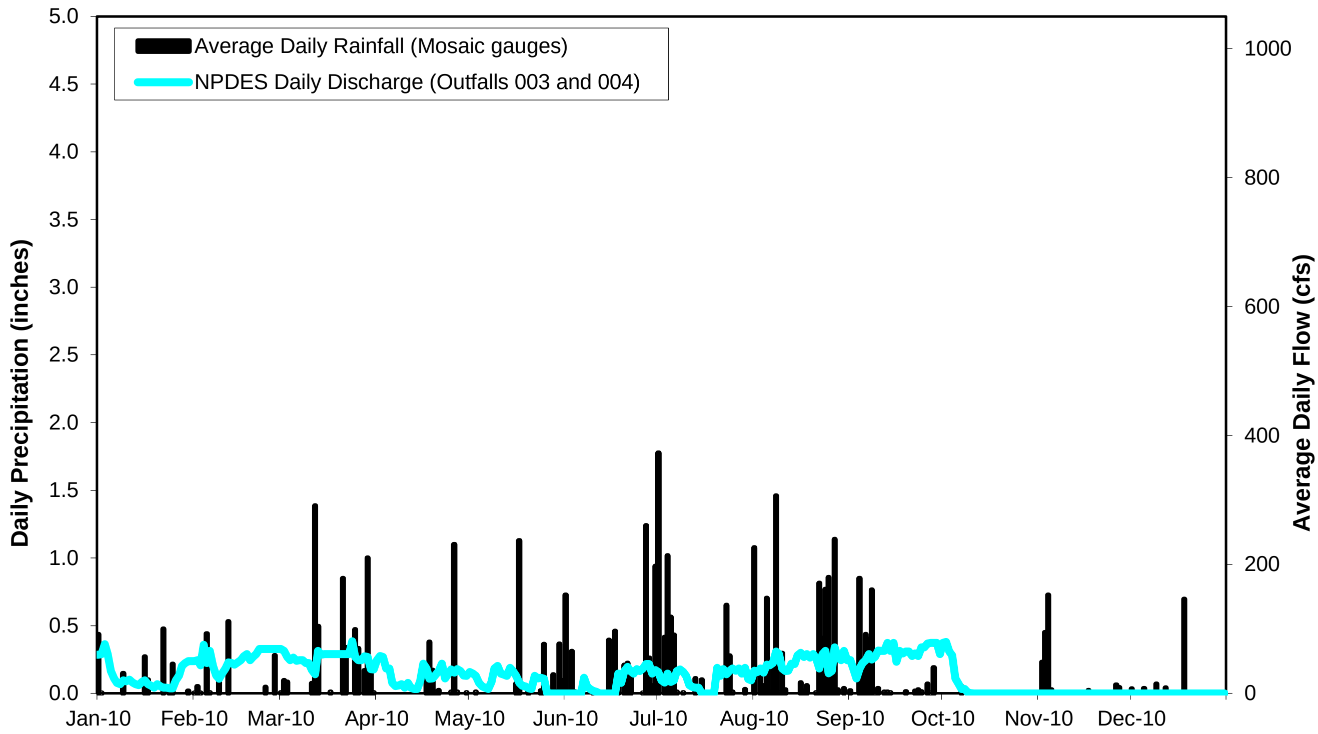

Figure 15. Combined Mosaic NPDES Discharge and Average Daily Rainfall in the Horse Creek Watershed in 2010.

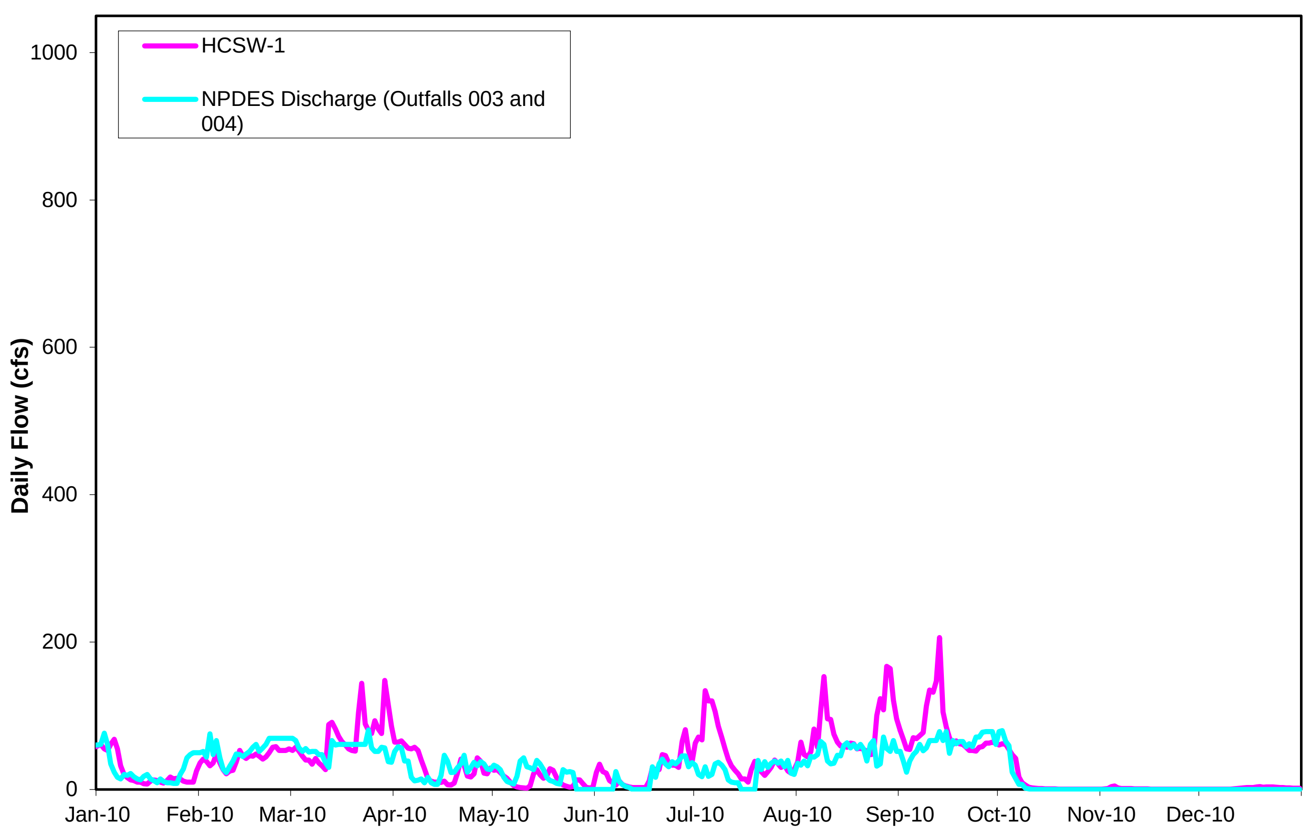

Figure 16. Daily Flow at HCSW-1 and Combined Mosaic NPDES Discharge for 2010.

Table 13. Coefficients of Rank Correlation (r_S) for Spearman's Rank Correlations of NPDES Monthly Average Discharge and USGS Daily Discharge, Gage Height, and Monthly Total Rainfall at SWFWMD Gauge and Three Mosaic Gauges in 2003 – 2010.

Gauge	r_S (with NPDES Outfall)	p value	N (Sample Size)
HCSW-1 (USGS Discharge)	0.74	< 0.0001	93
HCSW-1 (USGS Gauge Ht)	0.72	< 0.0001	92
Horse Creek North (Rain)	0.41	< 0.001	87
Horse Creek South (Rain)	0.36	< 0.001	93
Manson Jenkins (Rain)	0.28	< 0.05	89
494 (SWFWMD Rain)	0.40	< 0.001	93
Average Rainfall	0.41	< 0.001	93

5.1.6 Summary of Water Quantity Results

For 2010, 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 October). The winter dry season (November to December) was extremely dry, resulting in periods of little to no flow. Mosaic's NPDES-permitted discharges upstream of HCSW-1 discharged for portions of ten months of the year. Although low and median discharge in 2010 was average for the region, rainfall in 2010 was below the long-term average annual rainfall of 52.72 inches (1908-2010)[6].

With no rainfall in October 2010 and very little rainfall in November and December 2010, streamflow at HCSW-1 and NPDES discharge was essentially zero. During other months, NPDES discharge accounted for the majority of the streamflow at HCSW-1, expect for some peak streamflow events during the wet season.

In a previous study (Robbins and Durbin 2011) that compared streamflow during dry years in reference and potentially impacted streams before and during phosphate mining, there was no evidence that phosphate mining practices caused lower flows in the potentially impacted streams (including Horse Creek) than what would be expected given the conditions in a reference stream (Charlie Creek).

[6] Historical rainfall information came from the following stations and years: 1908-1943 NOAA station 148, 1944-2010 average of NOAA station 148 and 336

5.2 Water Quality

The results of field measurements and laboratory analyses of water samples obtained monthly during 2010 at each HCSP monitoring station are presented in this section (see Appendix C for water quality figures from 2003 through present). 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 20 April, 28 September, 4 and 11 November 2010. Water quality raw data are included in a database on the attached CD-ROM.

In September 2009, based on recommendations of the PRMRWSA and the TAG, Mosaic began sampling water quality at an additional station on Brushy Creek (BCSW-1 at State Road 64). Brushy Creek is a tributary to Horse Creek and flows into Horse Creek between the HCSW-1 and HCSW-2 sampling stations. This additional station was added for comparison purposes, and will not be evaluated against the HCSP trigger levels and exceedances. Mosaic does not have a NPDES discharge on Brushy Creek. While the Brushy Creek data has been included in the graphs of the 2010 water quality data, it was not included in any other plots or analyses.

In September 2009, Mosaic also discontinued water quality analysis for FL-PRO, total fatty acids, and total amines based on recommendations made in previous HCSP annual reports. Mosaic, PRMRWSA, and the TAG agree that the results for these parameters from 2003-2009 show that these substances are present only occasionally at low concentrations, and are not a cause for concern at this time.

Water quality of NPDES discharge is normally obtained periodically when water is discharged from Outfalls 003 and 004. Water was discharged for two hundred sixty days in 2010 from Outfall 004, with multiple water quality samples taken. No water was discharged from Outfall 003 in 2010. For NPDES discharge, no water quality parameters were above the Horse Creek trigger levels (Table 14).

Table 14. Water quality summary of NPDES discharge into Horse Creek during 2010 at Outfall 004.

2010

Constituent	Outfall 004 (January - October)			
	Avg	**Count**	**Min**	**Max**
pH (su)	7.53	39	6.82	8.44
Conductivity (umhos/cm)	601	39	548	657
Temperature (degrees C)	24.5	39	8.60	35.1
Turbidity (NTU)	6.14	39	2.03	13.4
Dissolved Oxygen (mg/L)	6.94	39	5.01	11.2
TSS (mg/L)	5.29	38	1.80	10.4
Total Phosphorus (mg/L)	0.69	38	0.26	1.24
TKN (mg/L)	0.99	10	0.72	1.16
Nitrate-Nitrite (mg/L)	0.04	10	0.007	0.185
Total Nitrogen (mg/L)	1.04	10	0.73	1.35
Fluoride (mg/L)	0.87	5	0.67	1.28
Sulfate (mg/L)	144	4	44.9	191
Chlorophyll *a* (mg/m^3)	8.07	4	4.19	12.1

5.2.1 Data Analysis

Line graphs are used to display water quality measurements for each parameter during 2010, 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 (Appendix C contains line graphs for each parameter from 2003 to 2010). For continuous recorder data measured at HCSW-1 in 2010, the daily mean of the water quality parameter is plotted with streamflow from the USGS gauge at HCSW-1. Monthly water quality data for 2003–2010 were compared to other data sources (SWFWMD, FDEP, USGS) since 1990 using median box-and-whisker plots[7]. Graphical representations of HCSP data include undetected values, represented by the respective MDLs for each parameter, except for total nitrogen and total radium. 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 changed to one-half of the MDL for any statistical analyses.

Based on a literature review (Appendix D) on tests for water quality data trend detection, the best monotonic trend detection method for use in the Horse Creek Stewardship Program (HCSP) is the Seasonal Kendall. Because the USGS recommends a minimum of five years of data collection before applying the Seasonal Kendall test (Schertz et al. 1991), the 2008 Annual Report was the first report to include this analysis. The Seasonal Kendall method is a frequently recommended method for detecting trends in water quality data (Lettenmaier 1988, Hirsch et al. 1982, Harcum et al. 1992, Helsel et al. 2005). The Seasonal Kendall was developed by and is now the method of choice for the United States Geological Survey (USGS) (Hirsch et al. 1982, Helsel et al. 2005).

The Seasonal Kendall test determines water quality trends after correcting for seasonality by only comparing values between similar seasons over time (Schertz et al. 1991). The Seasonal Kendall test selects one value for each season (average, median, or subsample) and makes all pair-wise comparisons between time-ordered seasonal values (Harcum et al. 1992). A test statistic (Tau) is computed by comparing the number of times a later value is larger than an earlier value in the data set, and vice-versa (Schertz et al. 1991). Results for the Seasonal Kendall include the magnitude of the statistic Tau, its significance (p), its slope (Sen slope estimator), and the direction of significant trends. The trend (Sen) slope is the median slope of all pairwise comparisons. The direction of this slope (positive or negative) is more resistant to the effects of observations below minimum detection limits and missing data than the magnitude of the slope. The slope is a measure of the monotonic trend; the actual temporal variation may include step trends or trend reversals. If alternate seasons exhibit trends in opposite directions, the Seasonal Kendall test will not detect an overall trend (Lettenmaier 1988).

Trend detection in this report is limited by several factors. With only eight years of data, the power of the test to detect trends of small magnitude will be limited (Harcum et al. 1992, Hirsch et al. 1982). Data for parameters whose method detection limits have changed several times over the HCSP (fluoride, nitrate+nitrite, ammonia) would have to be truncated to the highest detection limit, thereby reducing the available data for the test. As a result, trends were evaluated using alternative data collected by SWFWMD for these parameters. Because HCSW-1 and HCSW-4 were the only stations with USGS flow data that is necessary for interpreting trends in flow-dependent parameters, they were the only stations used in this trend

[7] 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).

analysis. Any changes over time detected using the Seasonal Kendall test should be further examined to determine if the perceived change is caused by a data bias, if its magnitude is ecologically significant, and if the cause of the trend is related to Mosaic mining activities. If warranted, an impact analysis can be performed on statistically significant trends to determine if trends are caused by Mosaic mining activities and if a corrective action by Mosaic is necessary.

A summary of the Seasonal Kendall Tau results for all parameters is presented in Table 15. The year was split into three seasons, corresponding to wet/dry periods. Season one encompassed the first part of peninsular Florida's dry season, January through April. Season two spanned May to September (the wet season along with May, which in this region tends to be fairly rainy) and season three represented the second dry season during the calendar year, October through December.

Parameters that were significantly correlated with USGS streamflow were corrected for the effect of annual variation in streamflow using a LOWESS smooth (F=0.5) before the Seasonal Kendall Tau was performed. LOWESS (locally weighted scatterplot smoothing) in the seasonal Kendall Tau describes the relationship between the concentrations of a water quality parameter and streamflow using a weighted linear least squares regression. The residuals of the smooth have the effect of streamflow subtracted, and are called flow-adjusted concentrations (Hirsch et al. 1991). Flow adjusted concentrations are necessary when the variable in question has an inherent relationship with streamflow, which can confound any comparisons made of water quality between stations or times with different instantaneous flow. If the variability of a water quality parameter could be completely explained by streamflow, then during smoothing, all of the data points would fall along a single best-fit line, and all of the residuals (distance between the points and the line) would be zero. For real data, the differences between the data points and the best-fit line show the part of the variability in water quality that is not caused by changes in streamflow, i.e. the flow-adjusted concentrations.

The Sen slope estimate for a parameter was only reported if the trend was statistically significant. For those parameters where SWFWMD data was used for trend analysis (fluoride, nitrate+nitrite, and ammonia), the magnitude of the slope estimate may not be accurate because some data in 2007 was missing from the SWFWMD dataset. For those parameters with statistically significant trends, Appendix I contains additional graphics from a more detailed impact analysis of the data than what is discussed under the relevant parameter headings in the report text below.

Table 15. Summary of Seasonal Kendall-tau with LOWESS (F=0.5) (unless noted) for HCSW-1 and HCSW-4 from 2003-2010.

Parameter	HCSW-1				HCSW-4			
	tau	p-value	slope	2010 median	tau	p-value	slope	2010 median
pH	0.41	0.02	0.06	7.25	0.01	0.96	N/A	7.02
Dissolved Oxygen	-0.19	0.28	N/A	7.00	-0.26	0.134	N/A	6.61
Turbidity	0.10	0.62	N/A	4.00	0.07	0.72	N/A	3.68
Color, total	0.21	0.22	N/A	155	0.43	0.01	12.07	150
Nitrogen, total	0.00	1.00	N/A	1.11	-0.14	0.43	N/A	1.45
Nitrogen, total Kjeldahl	0.02	0.94	N/A	0.97	0.17	0.35	N/A	1.09
Nitrogen, ammonia*	-0.36	0.04	-0.002	0.01	-0.29	0.10	N/A	0.03
Nitrogen, nitrate-nitrite*	-0.07	0.72	N/A	0.05	0.12	0.52	N/A	0.26
Orthophosphate	0.50	0.003	0.27	0.45	0.38	0.03	0.02	0.41
Chlorophyll a[1]	0.00	1.00	N/A	0.74	-0.08	0.66	N/A	1.00
Specific Conductance	0.57	0.001	16.68	432	0.07	0.72	N/A	414
Calcium, dissolved	0.51	0.004	1.60	33.1	0.21	0.22	N/A	35.3
Iron, dissolved	-0.29	0.10	N/A	0.21	-0.19	0.28	N/A	0.20
Alkalinity	0.57	0.001	4.19	70.8	0.52	0.002	1.62	43.0
Chloride	0.21	0.22	N/A	14.4	0.07	0.72	N/A	21.8
Fluoride*	0.43	0.01	0.01	0.61	0.14	0.43	N/A	0.36
Sulfate	0.29	0.10	N/A	116	0.00	1.00	N/A	112
Total Dissolved Solids	0.38	0.03	10.66	343	0.19	0.28	N/A	317
Radium, total[1]	0.10	0.62	N/A	1.45	-0.17	0.35	N/A	1.15

*SWFWMD data was used from April 2003-December 2010 (some parameters missing 2007 data).

[1]Data was not correlated with streamflow for either station; LOWESS was not used.

Differences in water quality between stations from 2003 to 2010 for each water quality parameter were evaluated using ANOVA and Duncan's post hoc test (Table 16). This analysis will help to identify potential differences among stations that can be examined in more detail as the HCSP continues. A summary of the ANOVA results for all parameters is presented in Table 16. Parameters whose MDLs have changed over the course of the program were omitted because of limited comparable data between sampling events and stations (i.e., fluoride, nitrate+nitrite, ammonia).

Table 16. Summary of results from ANOVA for differences between stations from 2003-2010.

Parameter	F	p-value
pH	31.18	< 0.001
Dissolved Oxygen	114.22	< 0.001
Turbidity	1.12	0.34
Color, total	5.40	0.001
Total Nitrogen	5.59	0.001
Total Kjeldahl Nitrogen	11.77	< 0.001
Orthophosphate	23.50	< 0.001
Chlorophyll A	13.25	< 0.001
Specific Conductance	29.34	< 0.001
Calcium, dissolved	47.22	< 0.001
Iron, dissolved	1.04	0.38
Alkalinity	42.85	< 0.001
Chloride	17.37	< 0.001
Sulfate	37.80	< 0.001
Total Dissolved Solids	32.20	< 0.001
Radium, Total	2.25	0.08

Water quality parameters were compared with water quantity variables recorded during the same month from 2003 to 2010: average daily streamflow for the month, average daily NPDES discharge for the month, and total monthly rainfall. Because these three water quantity variables are correlated to each other (Table 13), a statistically significant correlation between NPDES discharge and water quality does not prove a causal relationship between water quality and mining discharge. The results of this correlation analysis are presented in Table 17. Each of these correlations is discussed further in each water quality section. Parameters whose MDLs have changed over the course of the program were omitted because of limited comparable data between sampling events and stations (fluoride, nitrate+nitrite, ammonia).

Table 17. Spearman's rank correlation between water quality and water quantity at HCSW-1 and HCSW-4, as represented by average daily streamflow, average daily NPDES discharge, and total rainfall for the same month from 2003 - 2010.

	HCSW-1			HCSW-4		
	NPDES	Rainfall	Streamflow	NPDES	Rainfall	Streamflow
pH	-0.001	-0.29*	-0.31*	-0.29*	-0.31*	-0.52*
Dissolved Oxygen	-0.41*	-0.54*	-0.39*	-0.56*	-0.58*	-0.68*
Turbidity	0.52*	0.32*	0.48*	0.44*	0.35*	0.58*
True Color	0.46*	0.39*	0.42*	0.58*	0.31*	0.68*
Total Nitrogen	0.31*	0.46*	0.39*	0.18	0.17	0.35*
TKN	0.37*	0.49*	0.43*	0.38*	0.34*	0.50*
Orthophosphate	-0.001	-0.18	-0.32*	0.12	0.03	0.02
Chlorophyll a	-0.08	-0.14	-0.07	0.11	0.12	0.13
Specific Conductance	0.23*	-0.20	-0.14	-0.49*	-0.38*	-0.82*
Calcium	0.21	-0.26*	-0.18	-0.53*	-0.38*	-0.83*
Iron	0.33*	0.62*	0.59*	0.47*	0.47*	0.77*
Alkalinity	0.14	-0.18	-0.10	-0.42*	-0.59*	-0.76*
Chloride	-0.54*	-0.39*	-0.66*	-0.53*	-0.37*	-0.81*
Sulfate	0.35	-0.09	-0.06	-0.50*	-0.33*	-0.78*
TDS	0.37*	-0.06	-0.02	-0.38*	-0.26*	-0.73*
Total Radium	-0.36*	0.09	-0.15	-0.38*	0.12	-0.15

* - Statistically significant at $p < 0.05$

5.2.2 Physio-Chemical Parameters

pH

Levels of pH, dissolved oxygen, turbidity, and specific conductivity were obtained in the field during each monthly water-quality sampling event. Values of pH were within the range of established trigger levels during all of 2010 sampling events at all stations (Figure 17). Values obtained during biological sampling events were fairly consistent with pH levels determined during the monthly water quality sampling events (Figure 17). The pH levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (FDEP, SWFWMD, USGS) (Figures 18 and 19). Continuous pH data obtained daily at HCSW-1 in 2010 was within a range similar to that obtained during monthly water quality sampling (Figure 20).

HCSW-4 exhibited no monotonic trends over the last eight years for pH (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 15). There was a slightly increasing monotonic trend for pH at HCSW-1 (Seasonal Kendall Tau with LOWESS, Tau = 0.41, $p = 0.02$, Sen slope = 0.06 SU per year, Figures 18 and 19). The slope for this potential trend is very small compared to limits in laboratory prediction or the observed differences between primary and duplicate field samples, does not represent an adverse trend that would need additional analysis or corrective action (Appendix I).

Levels of pH were significantly different among stations in 2003 – 2010 (ANOVA $F = 31.18$, $p < 0.0001$, Table 16). 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 decrease the pH (Reid and Wood 1976). Brushy Creek also contributes to HCSW-2, and also has a relatively low pH compared to the Horse Creek stations. Levels of pH were significantly correlated with streamflow (r_s= -0.31) and rainfall (r_s= -0.29) at HCSW-1 and with streamflow (r_s= -0.52), rainfall (r_s= -0.31), and NPDES discharge (r_s= -0.29) at HCSW-4 (Spearman's rank correlation, $p < 0.05$, Table 17).

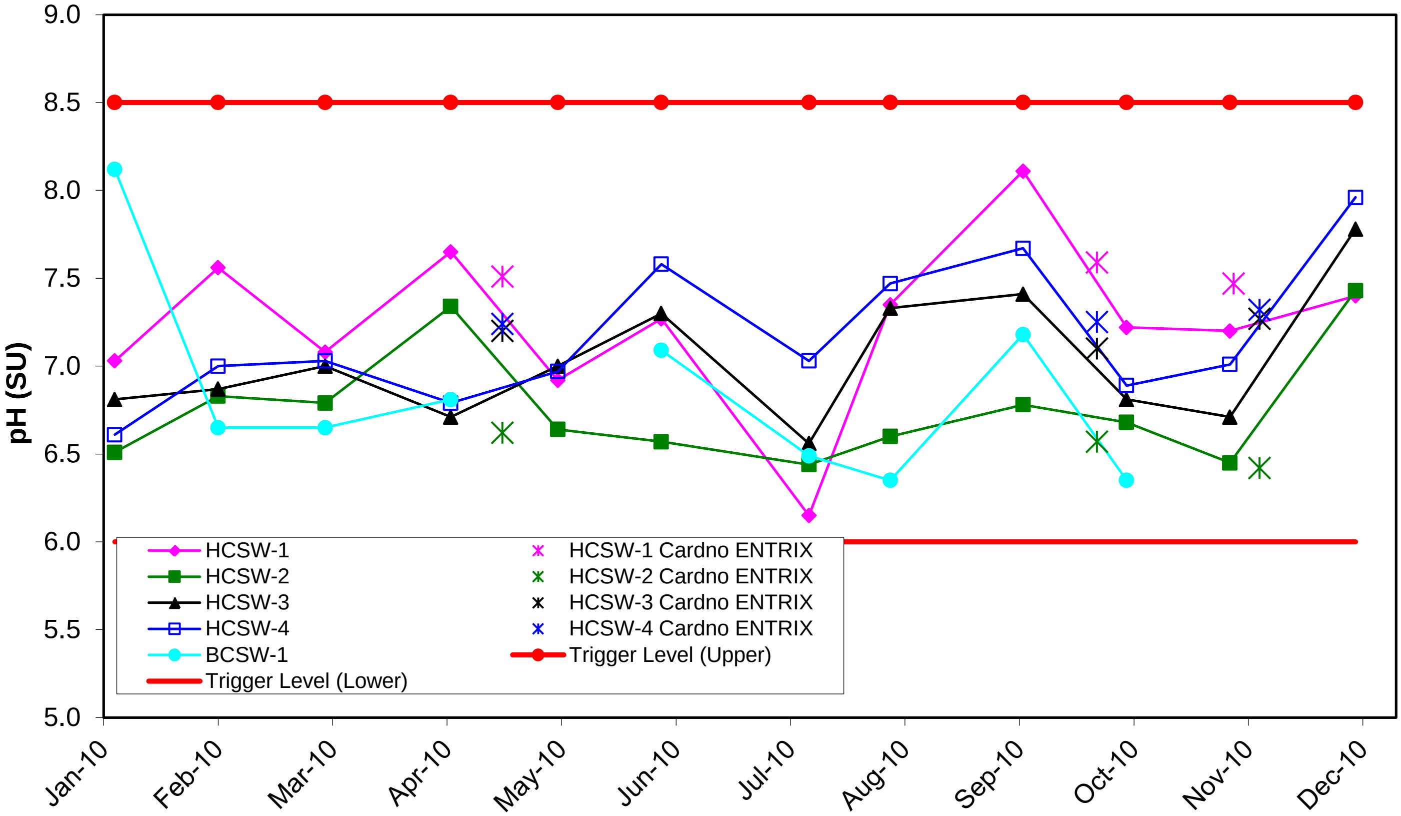

Figure 17. Values of pH Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2010.

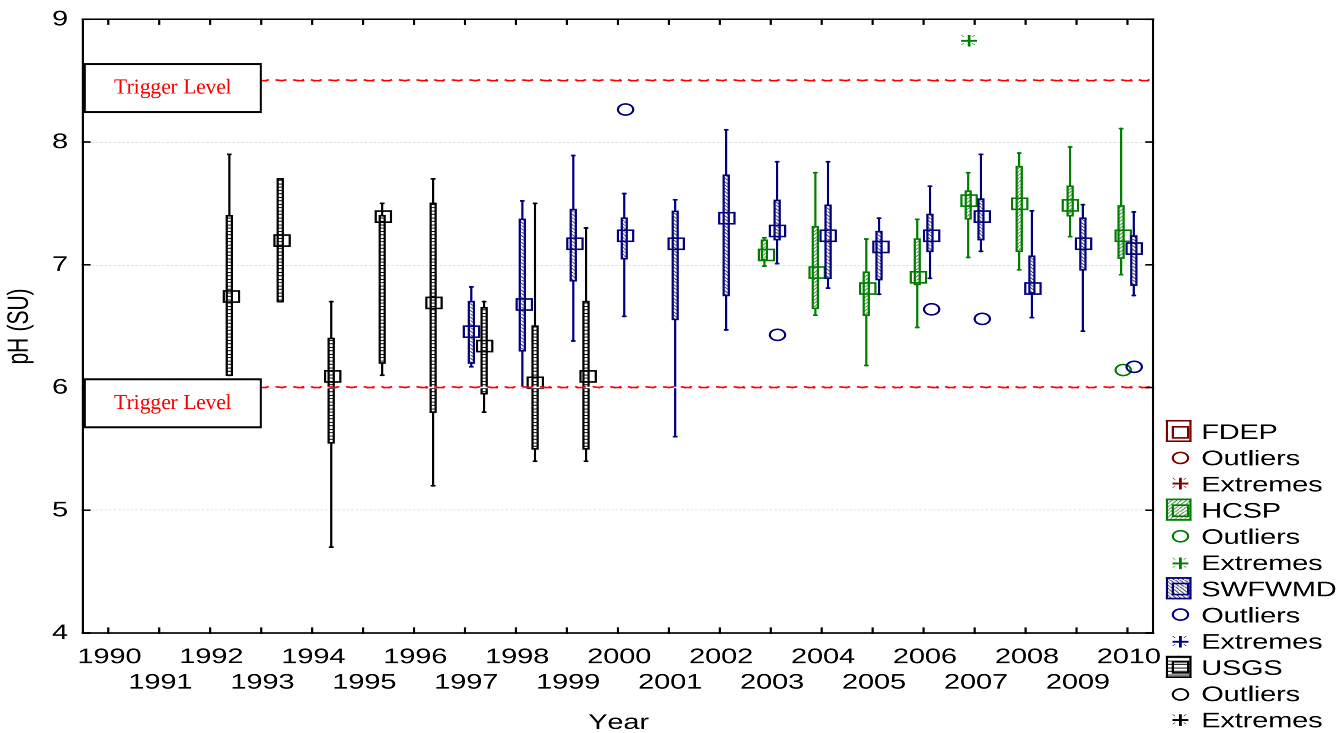

Figure 18. HCSW-1 Values of pH Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

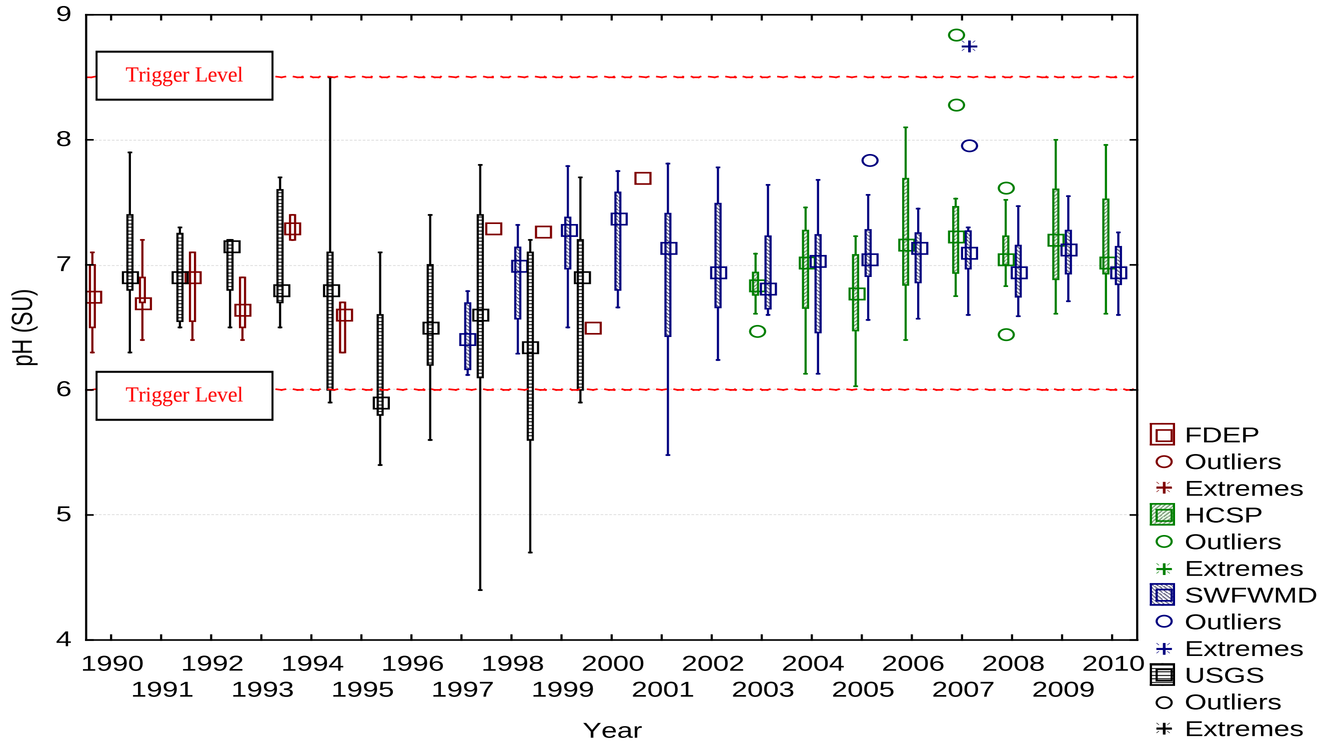

Figure 19. HCSW-4 Values of pH Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

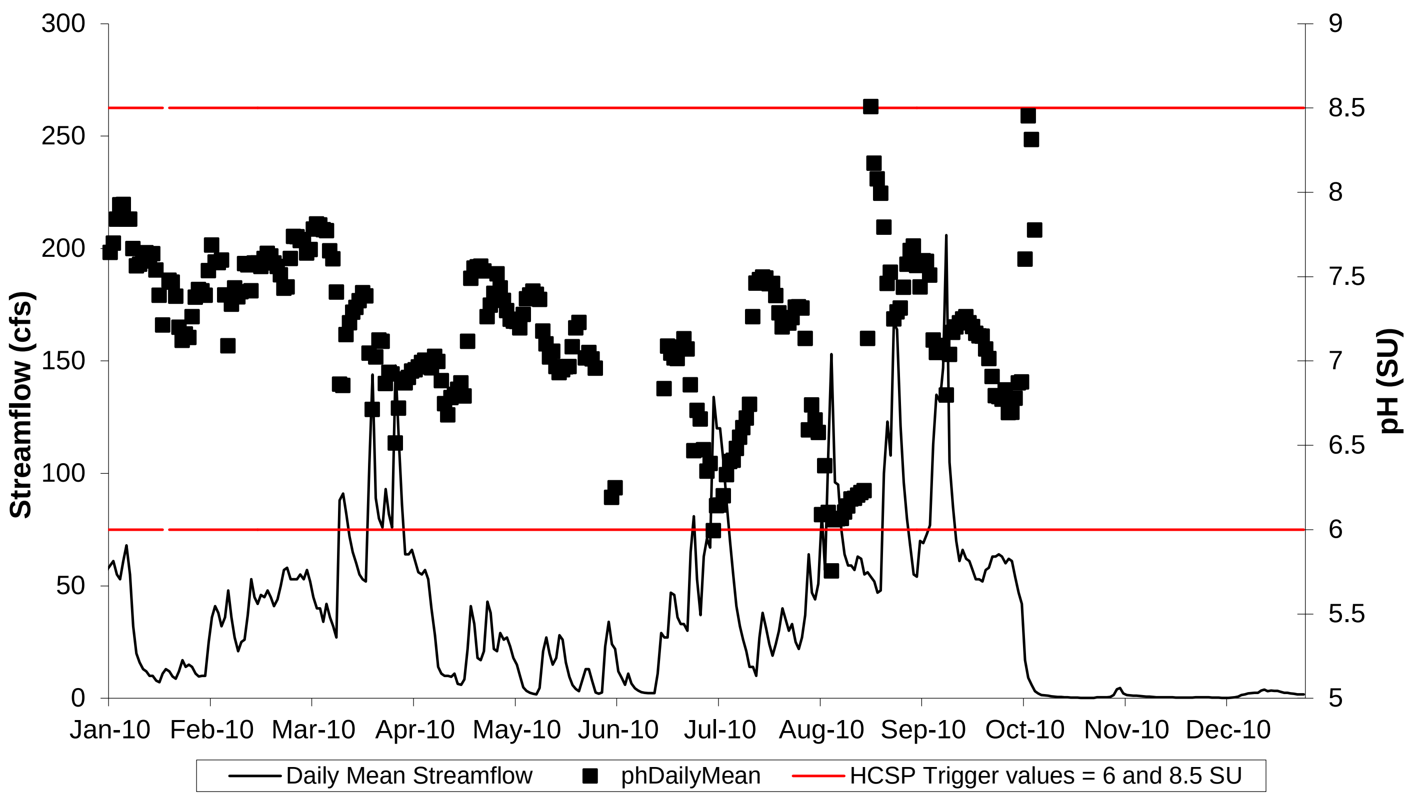

Figure 20. Relationship Between Daily Mean pH (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow for 2010. Minimum pH Detection Limit = 1 SU.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations were above the trigger level and Class III Standard of 5.0 mg/l (indicating desirable conditions) during all sampling events in 2010 at HCSW-1 (Figure 21). However, levels of DO were almost always below 5.0 mg/l at HCSW-2 (except during January and December 2010); this station is just downstream of the Horse Creek Prairie, a blackwater swamp that typically has low DO concentrations. The newly monitored Brushy Creek location had DO values below the trigger value during six of the nine sampling events that occurred, which may have also contributed to the low DO concentrations at HCSW-2. DO was below the trigger value at HCSW-3 in April 2010 and July through September 2010 and at HCSW-4 during July, corresponding to times of high temperatures and relatively normal streamflow that followed dry and stagnant conditions. DO concentrations at HCSW-1, HCSW-2, HCSW-3, and HCSW-4 obtained during biological sampling events and from the continuous recorder at HCSW-1 were fairly consistent with those found during the monthly water quality sampling (Figures 21 and 24).

The DO levels at HCSW-1 measured by the HCSP are consistent with other water quality data sources (Figures 22 and 23) and exhibited no monotonic trend between 2003 and 2010 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 15, Figures 22 and 23). Levels of dissolved oxygen were significantly different among stations in 2003 - 2010 (ANOVA , $F = 114.22$, $p < 0.0001$, Table 16), with HCSW-2 significantly lower than other stations followed by HCSW-3 (Duncan's multiple range test, $p < 0.05$). Dissolved oxygen was negatively correlated with streamflow, rainfall, and NPDES discharge at both HCSW-1 and HCSW-4 (Spearman's rank correlations $-0.39 > r > -0.68$, $p < 0.05$, Table 17). During the wet season, higher temperatures in the stream drive down the oxygen saturation and the decomposition of woody debris washed into the stream during high rains can increase oxygen demand.

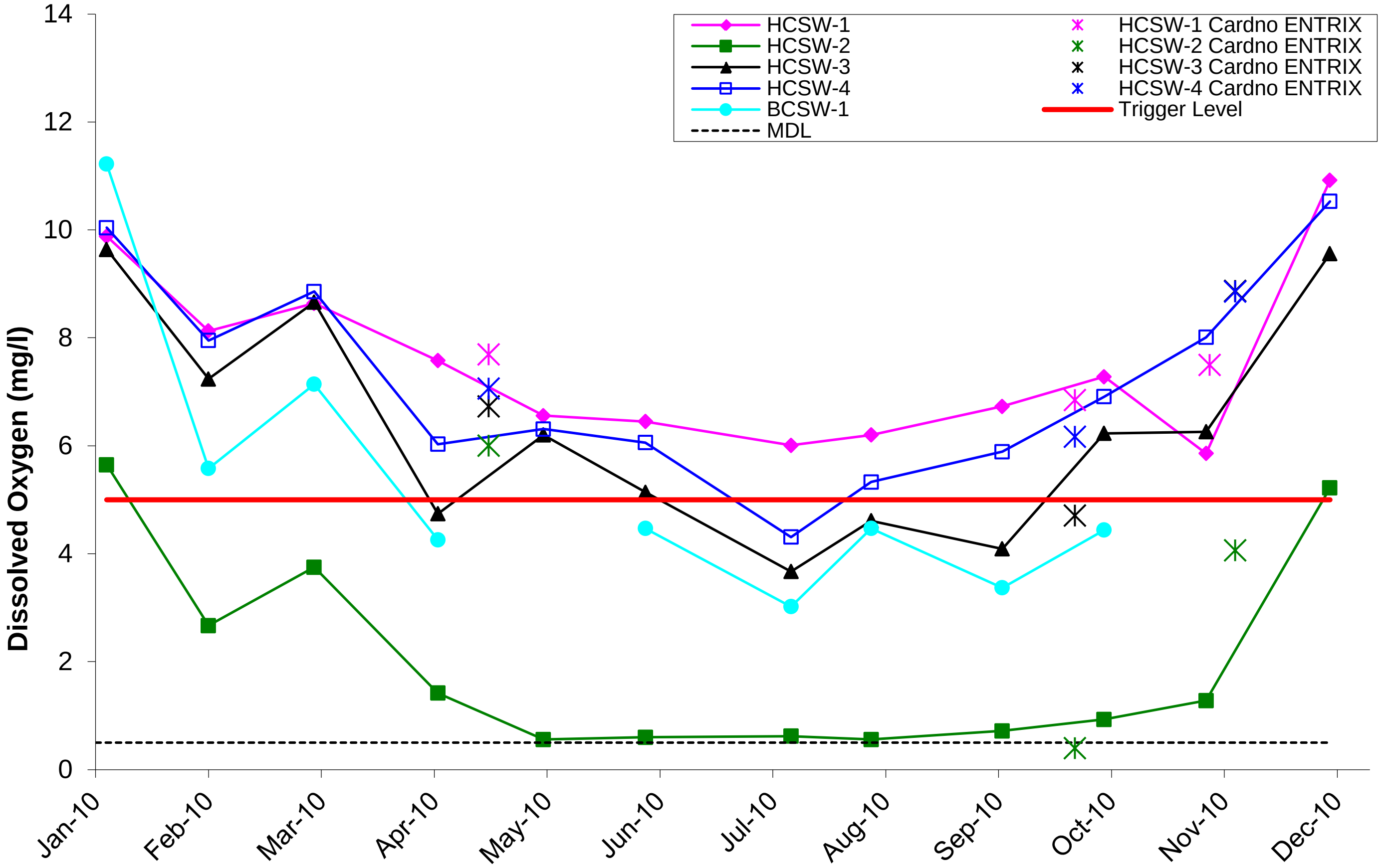

Figure 21. Dissolved Oxygen Levels Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2010.

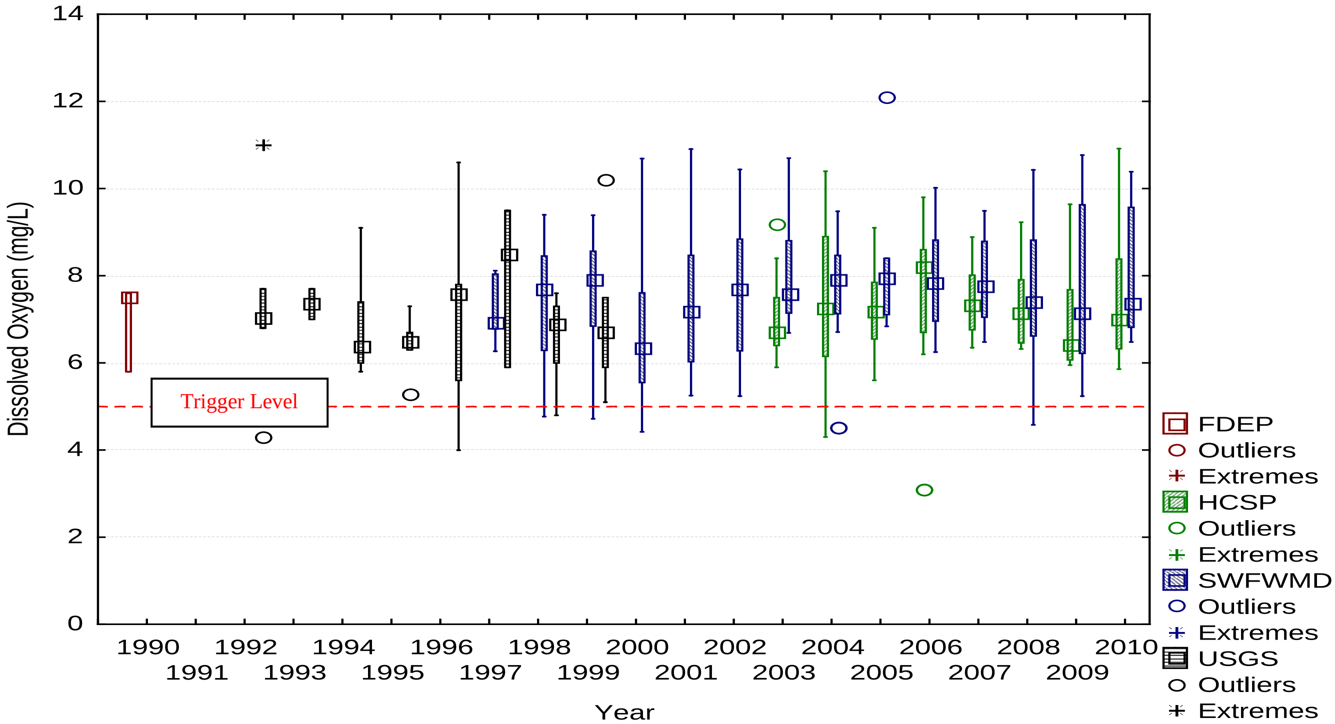

Figure 22. HCSW-1 Values of Dissolved Oxygen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

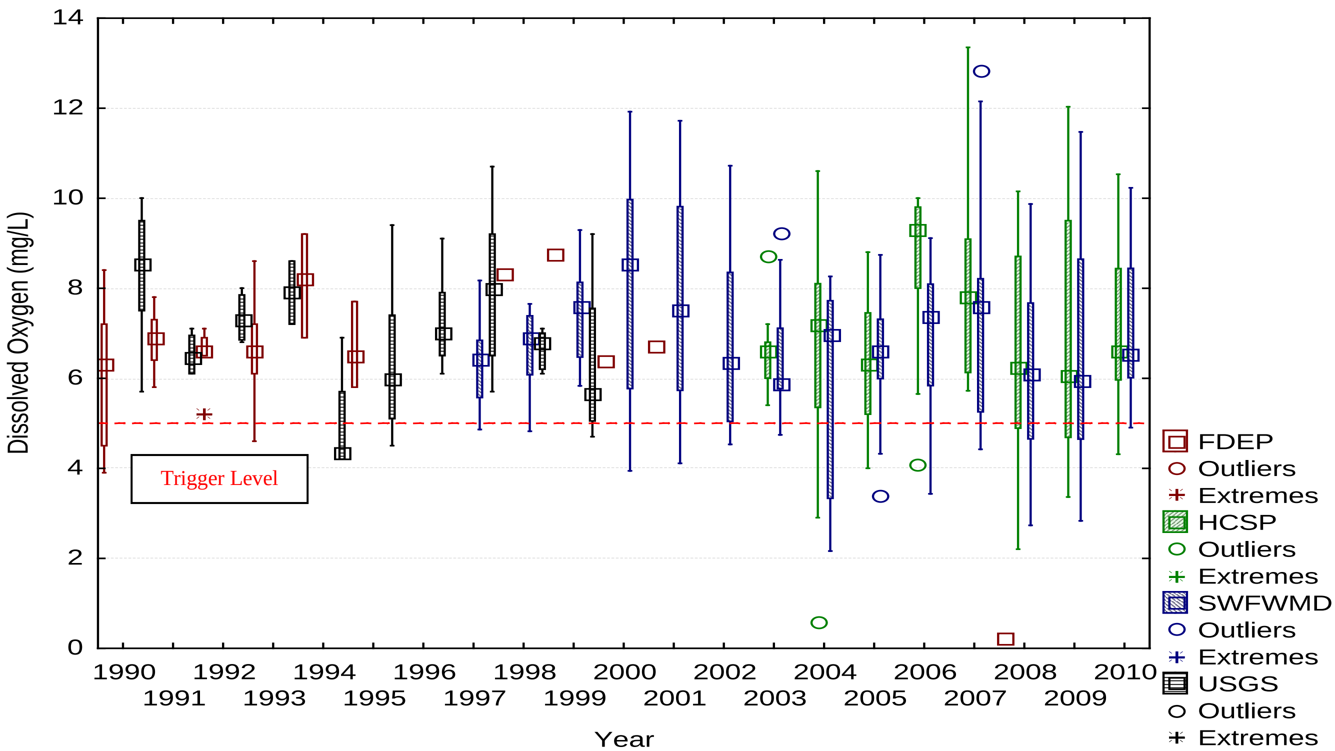

Figure 23. HCSW-4 Values of Dissolved Oxygen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

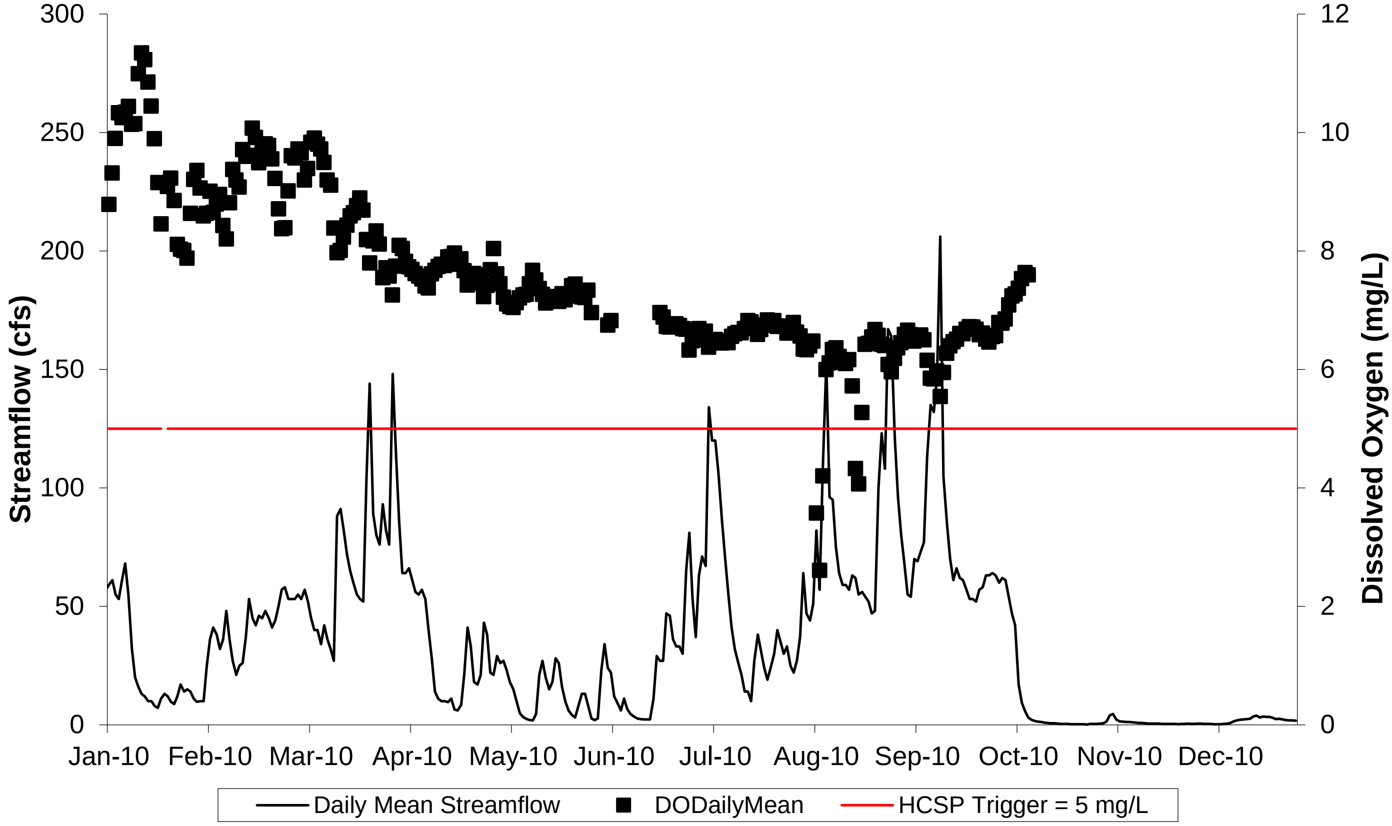

Figure 24. Relationship Between Daily Mean DO (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow for 2010. Minimum DO Detection Limit = 0.50 mg/L.

Turbidity

Turbidity levels obtained during biological sampling events or with the continuous recorder at HCSW-1 were similar to those found during monthly water quality sampling events (Figures 25 and 28). Turbidity levels at all stations in 2010 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 since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$) (Figures 26 and 27, Table 15). Turbidity levels as measured monthly were not significantly different among stations in 2003 - 2010 (ANOVA, $F = 1.12$, $p = 0.34$, Table 16). Turbidity was positively correlated with streamflow, rainfall, and NPDES discharge at HCSW-1 and HCSW-4 (Spearman's rank correlations $0.32 < r < 0.58$, Table 17). Turbidity measurements at Brushy Creek were similar to the Horse Creek stations.

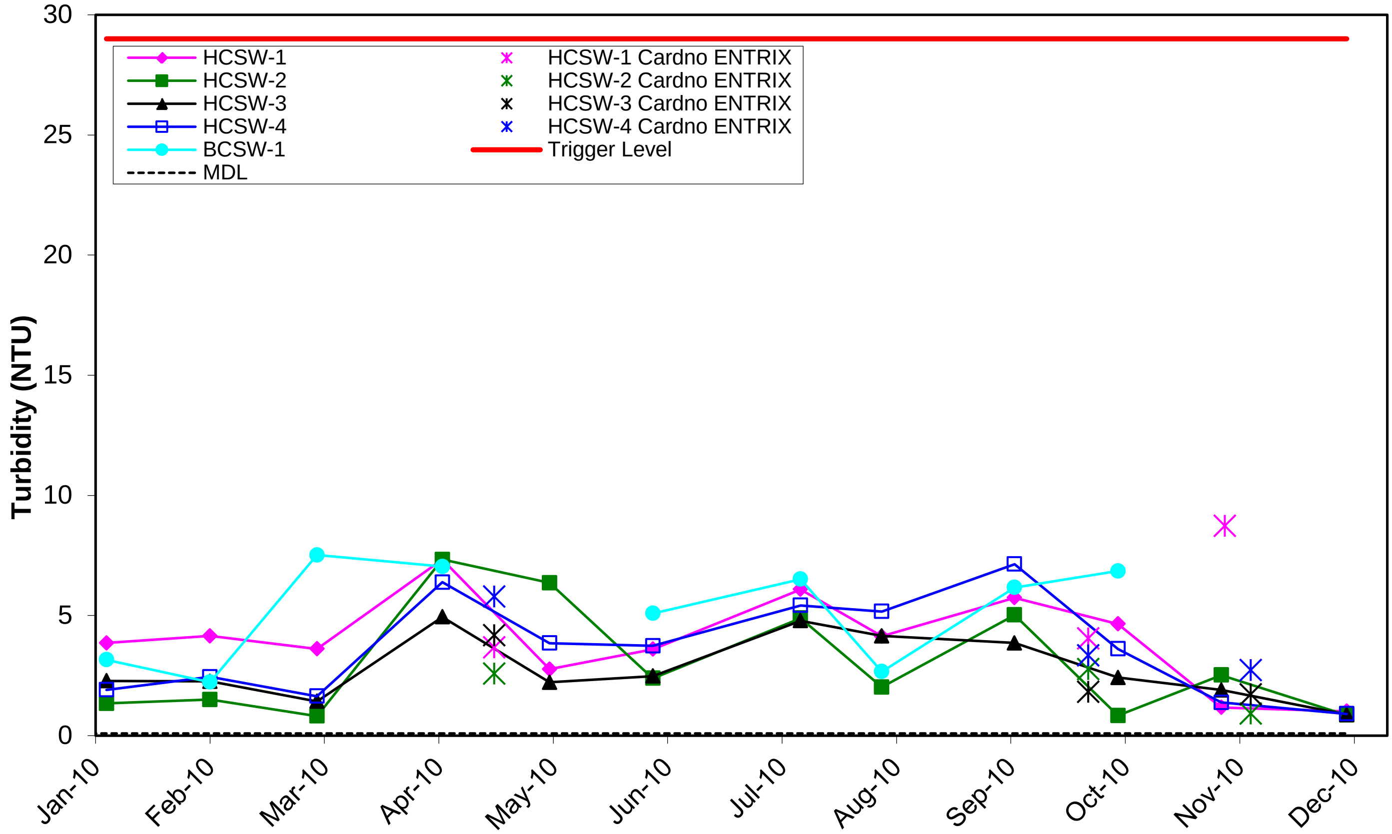

Figure 25. Turbidity Levels Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2010.

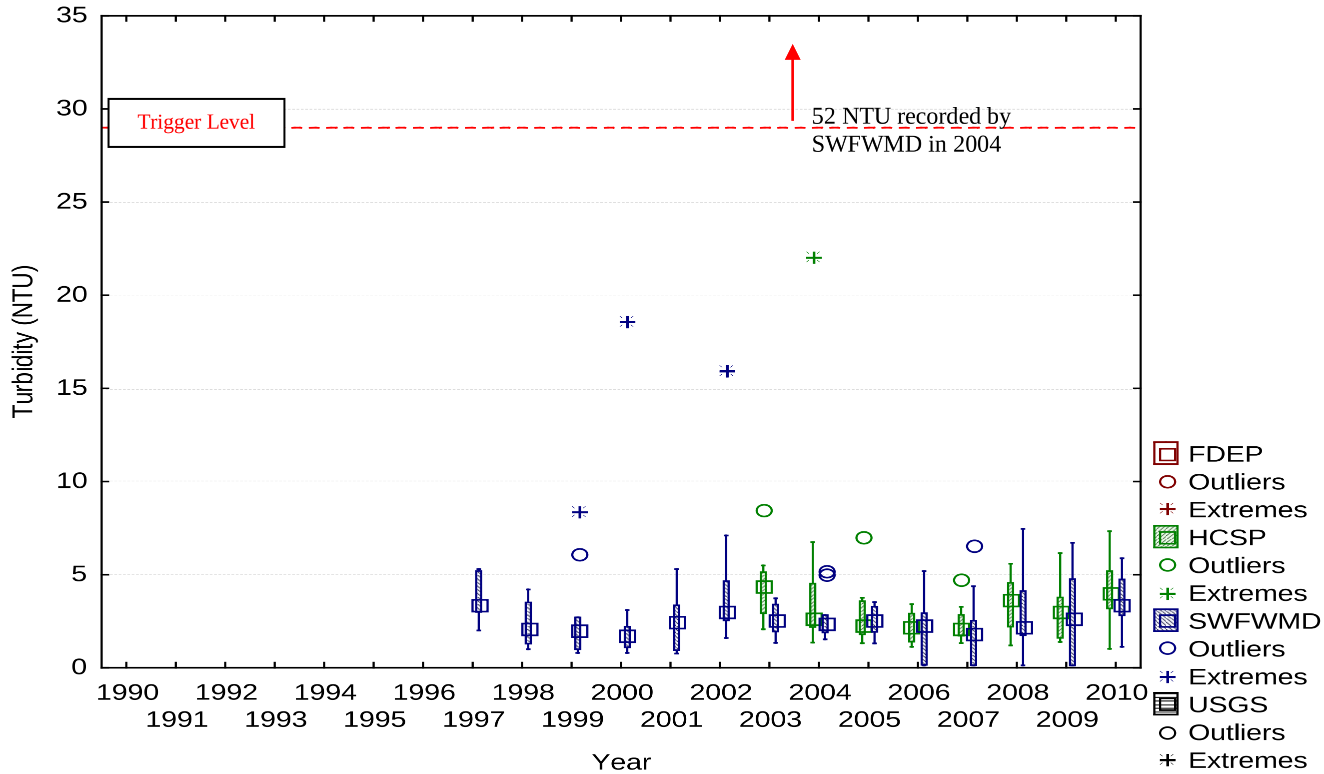

Figure 26. HCSW-1 Values of Turbidity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

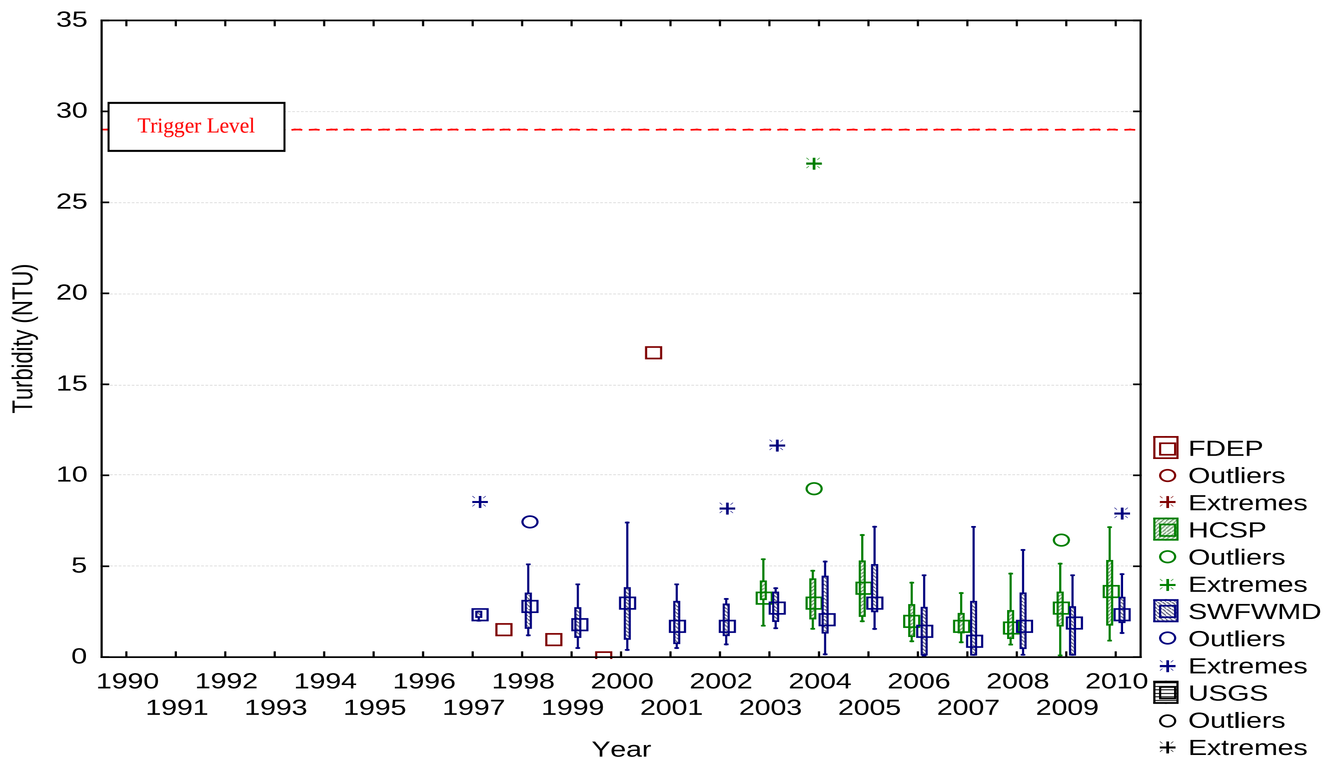

Figure 27. HCSW-4 Values of Turbidity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

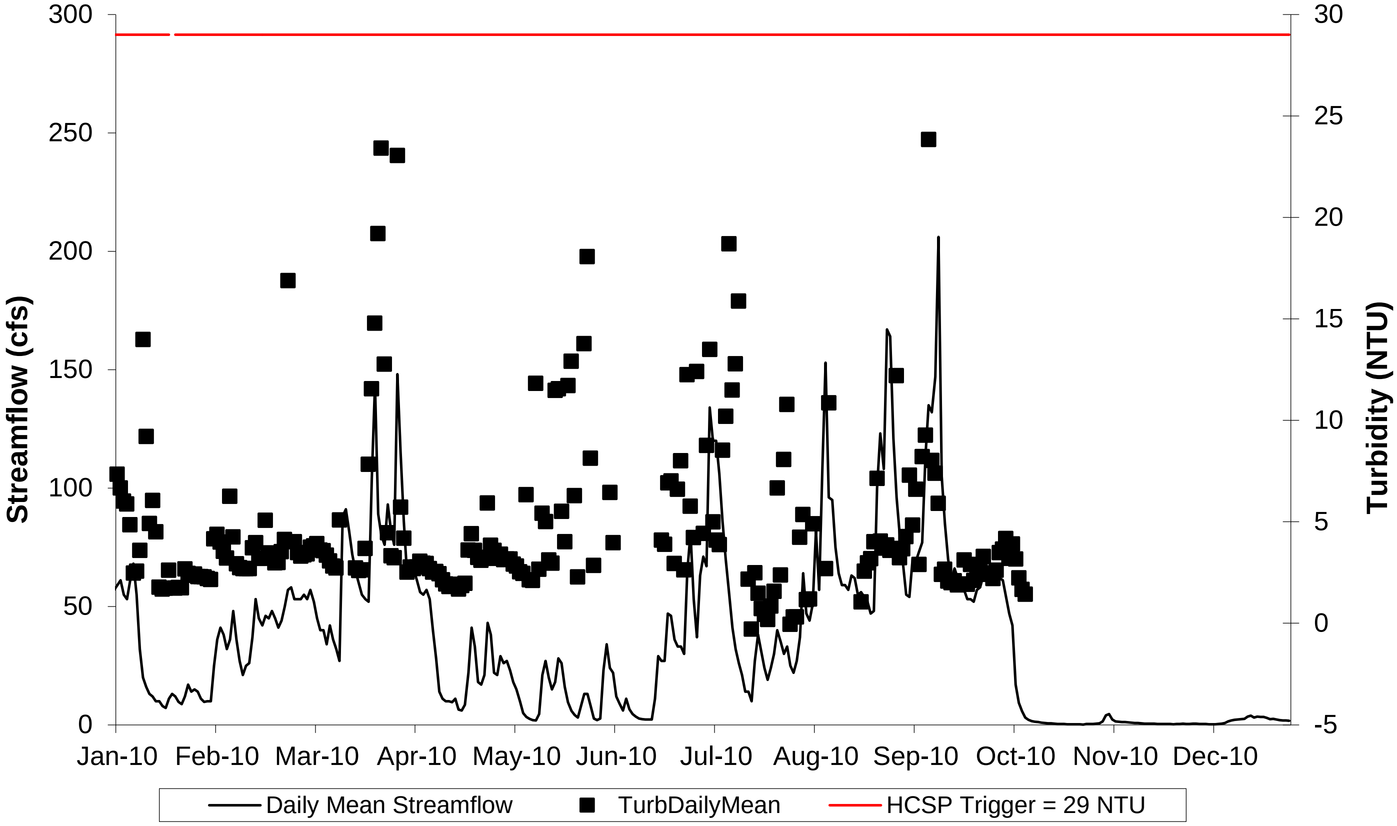

Figure 28. Relationship Between Daily Mean Turbidity (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow for 2010. Minimum Detection Limit = 0.1 NTU.

Color

All color values in 2010 were above the trigger level of 25 Platinum-Cobalt units (PCU) (indicating desirable conditions) during all events at all stations (Figure 29). The color levels at HCSW-1 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 15). HCSW-4 exhibited an increasing monotonic trend over the 2003-2010 time period (Seasonal Kendall Tau with LOWESS, Tau = 0.43, $p = 0.01$, Sen slope = 12.07 PCU per year, Figures 30 and 31). The trigger level for color in the HCSP is expressed as a minimum, so the observed upward trend at HCSW-4 is not of concern (Appendix I) as it relates to a defined trigger level (the program will continue to monitor this trend.

Color levels were significantly different among stations in 2003 - 2010 (ANOVA, $F = 5.40$, $p = 0.001$, Table 16), with HCSW-2 having higher color than other stations (Duncan's multiple range test, $p < 0.05$). HCSW-2 receives input from Horse Creek Prairie and Brushy Creek, which had higher color than the Horse Creek stations. Color was positively correlated with streamflow, rainfall, and NPDES discharge at HCSW-1 and HCSW-4 (Spearman's rank correlations $0.31 < r < 0.68$, Table 17).

The similar pattern among the stations, with higher color in the wet, summer months and lower levels in the dry, 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 was very evident during and after Hurricane Charley in 2004. 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 or during dry years like 2006 and 2007. This agricultural influence is also noted below with respect to several other parameters.

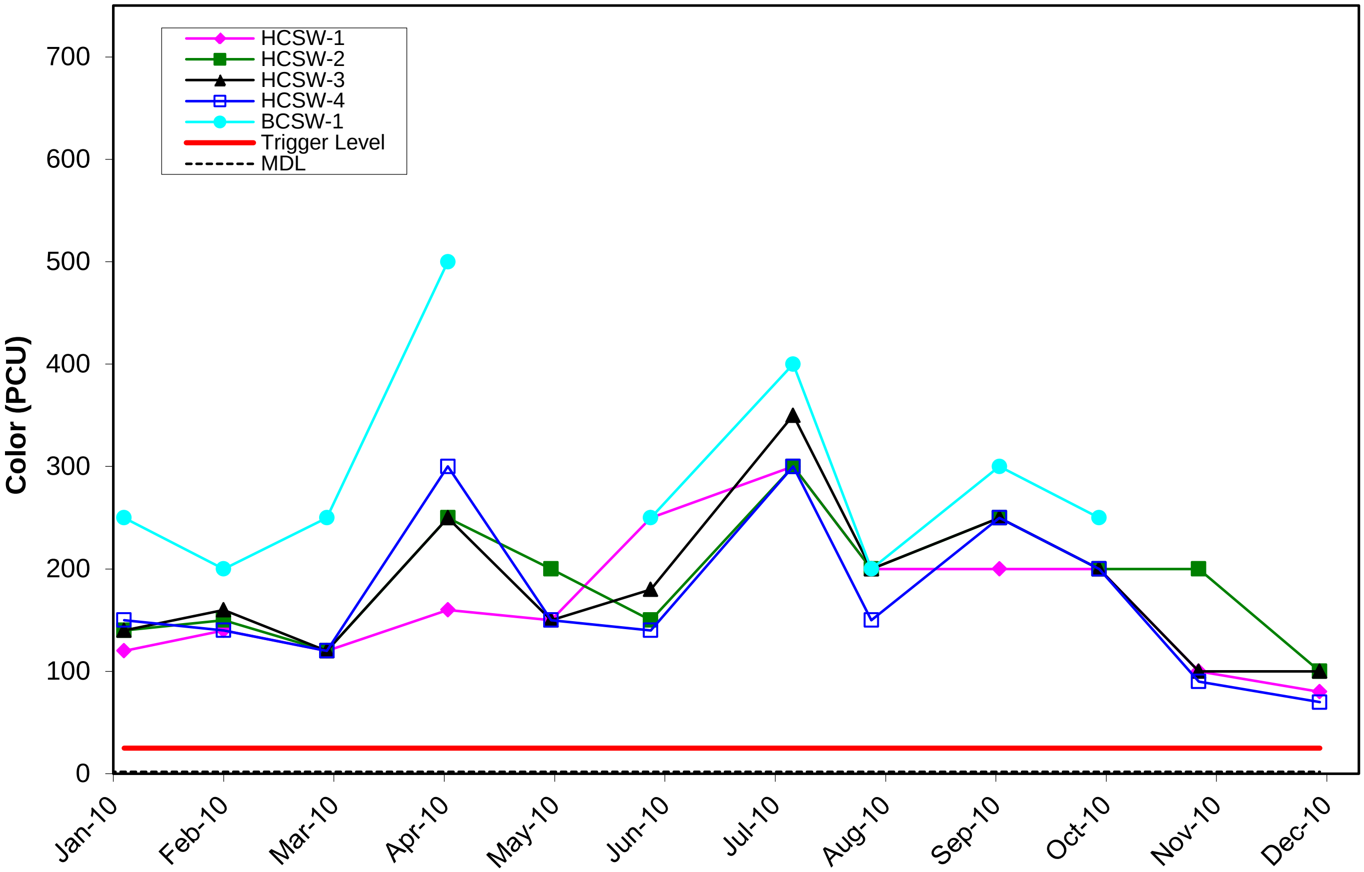

Figure 29. Color Levels Obtained During Monthly HCSP Water Quality Sampling in 2010.

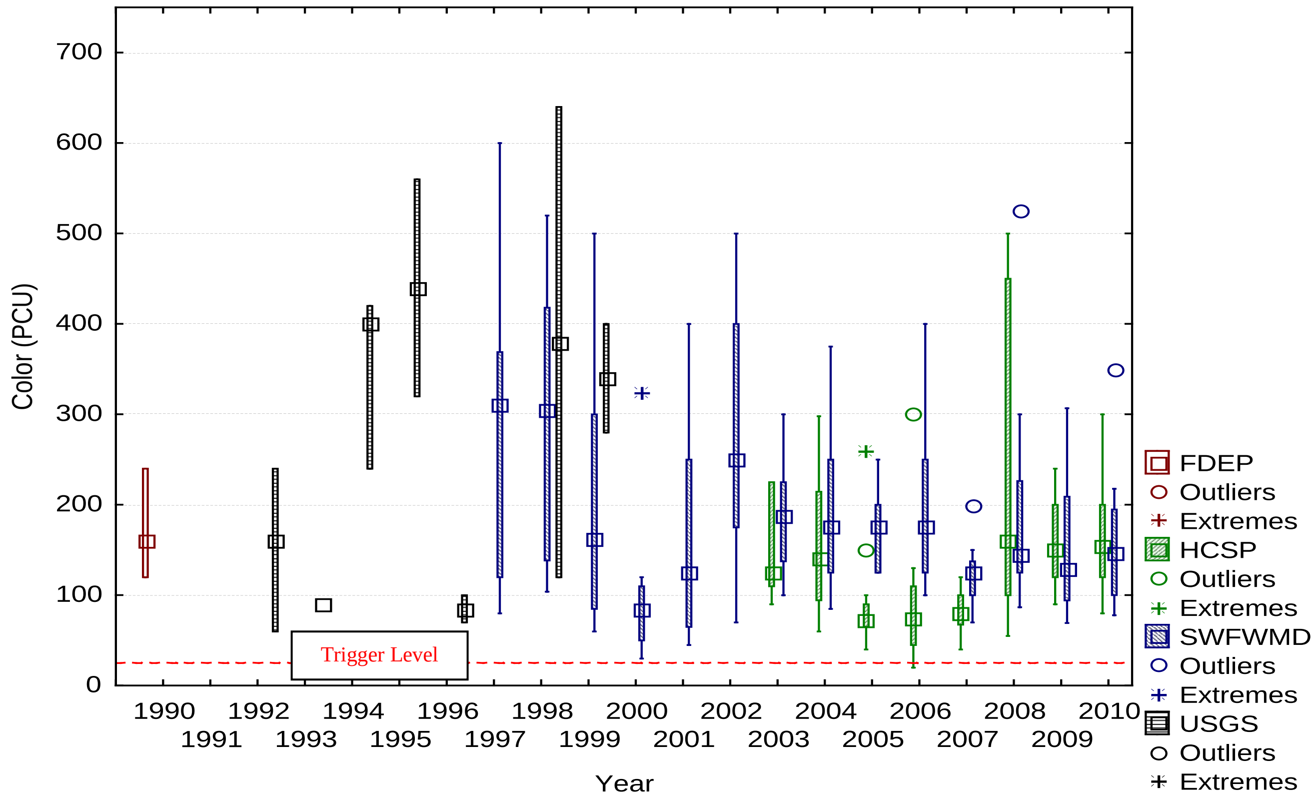

Figure 30. HCSW-1 Values of Color Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

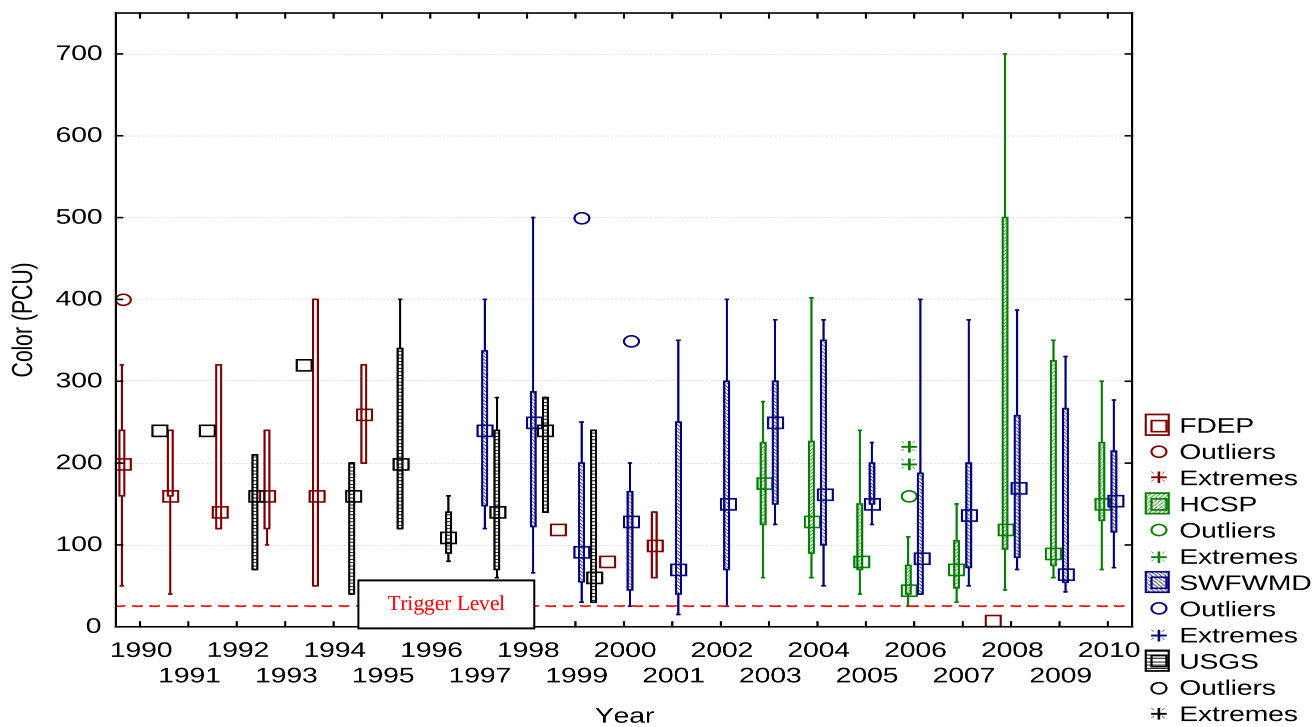

Figure 31. HCSW-4 Values of Color Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

5.2.3 Nutrients

Total Nitrogen

Total nitrogen[8] concentrations were between 0.5 and 2.5 mg/l during all sampling events at all stations in 2010 (Figure 32). During 2010, 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. 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 since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$) (Figures 33 and 34, Table 15). Total nitrogen concentrations were significantly different among stations for 2003 – 2010 (ANOVA, $F = 5.59$, $p = 0.001$, Table 16), with lower concentrations at HCSW-1 than other stations (Duncan's multiple range test, $p < 0.05$). Total nitrogen was positively correlated with streamflow (r_s= 0.39), rainfall (r_s= 0.46), and NPDES discharge (r_s= 0.31) at HCSW-1 while it was only positively correlated with streamflow (r_s= 0.35) at HCSW-4 (Spearman's rank correlations, $p < 0.05$, Table 17). Total nitrogen concentrations at Brushy Creek were similar to concentrations at the Horse Creek stations.

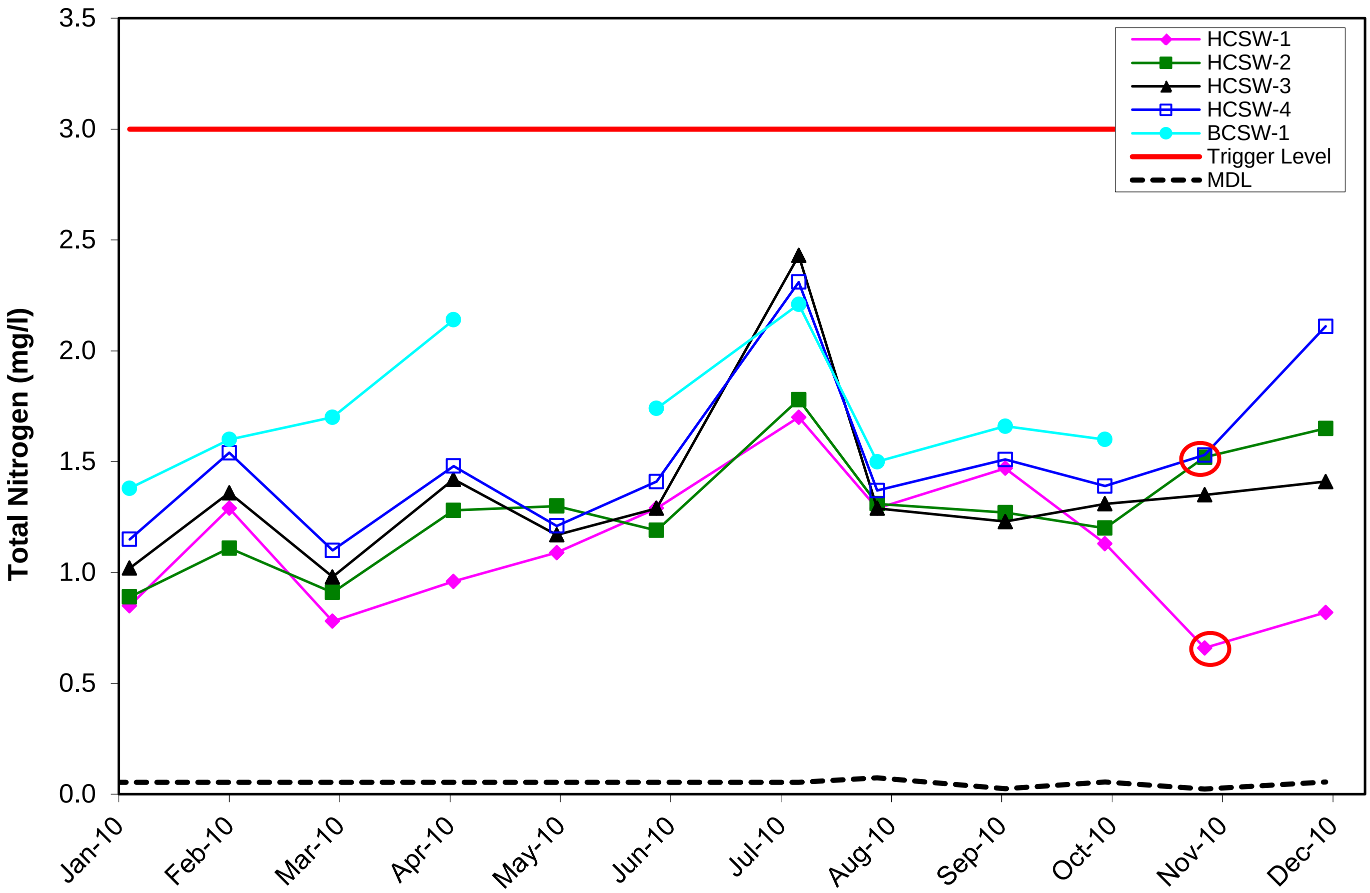

Figure 32. Total Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2010. (Data from samples where Nitrate-Nitrite Nitrogen was undetected are circled in red.)

8 Total nitrogen is calculated as the arithmetic sum of TKN and nitrate+nitrite. 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.

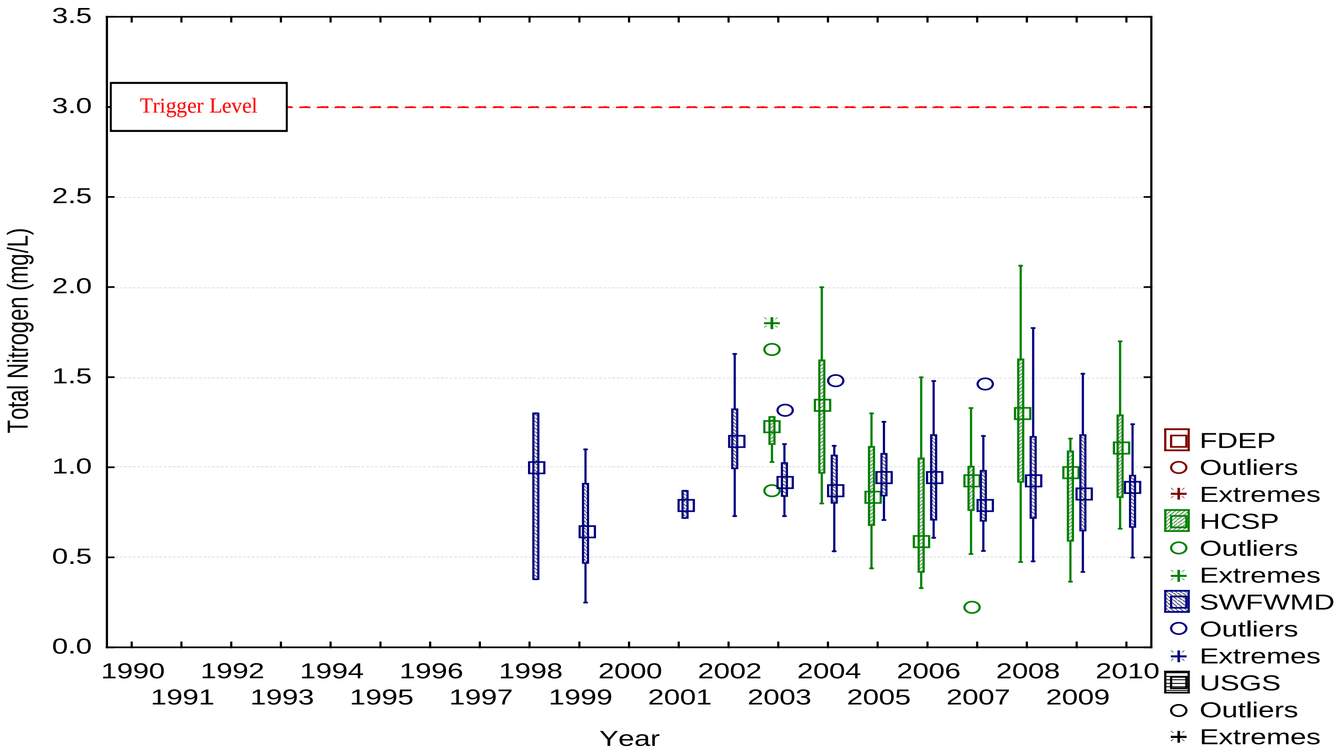

Figure 33. HCSW-1 Values of Total Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

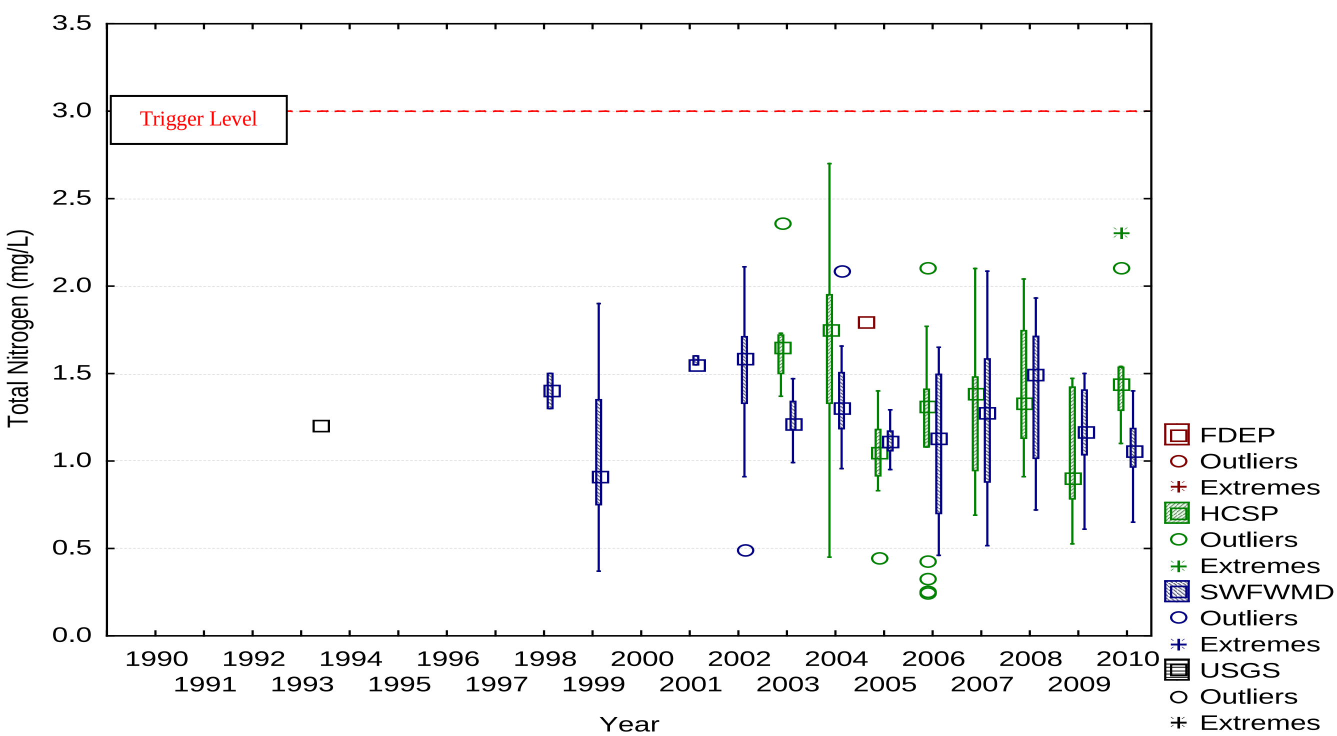

Figure 34. HCSW-4 Values of Total Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen (TKN) comprised the majority of total nitrogen in most samples (Figure 35, compare with Figure 32). The HCSP does not have an independent trigger value for TKN. 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 since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$) (Figures 36 and 37, Table 15). Concentrations of TKN were significantly different among stations (ANOVA, $F = 11.77$, $p < 0.0001$, Table 16), with HCSW-2 having a higher concentration than the other three stations (Duncan's multiple range test, $p < 0.05$). Brushy Creek, which contributes to HCSW-2, has higher TKN concentrations than the Horse Creek stations. Total Kjeldahl nitrogen was positively correlated with streamflow, rainfall, and NPDES discharge at HCSW-1 and HCSW-4 (Spearman's rank correlations $0.34 < r < 0.50$, Table 17).

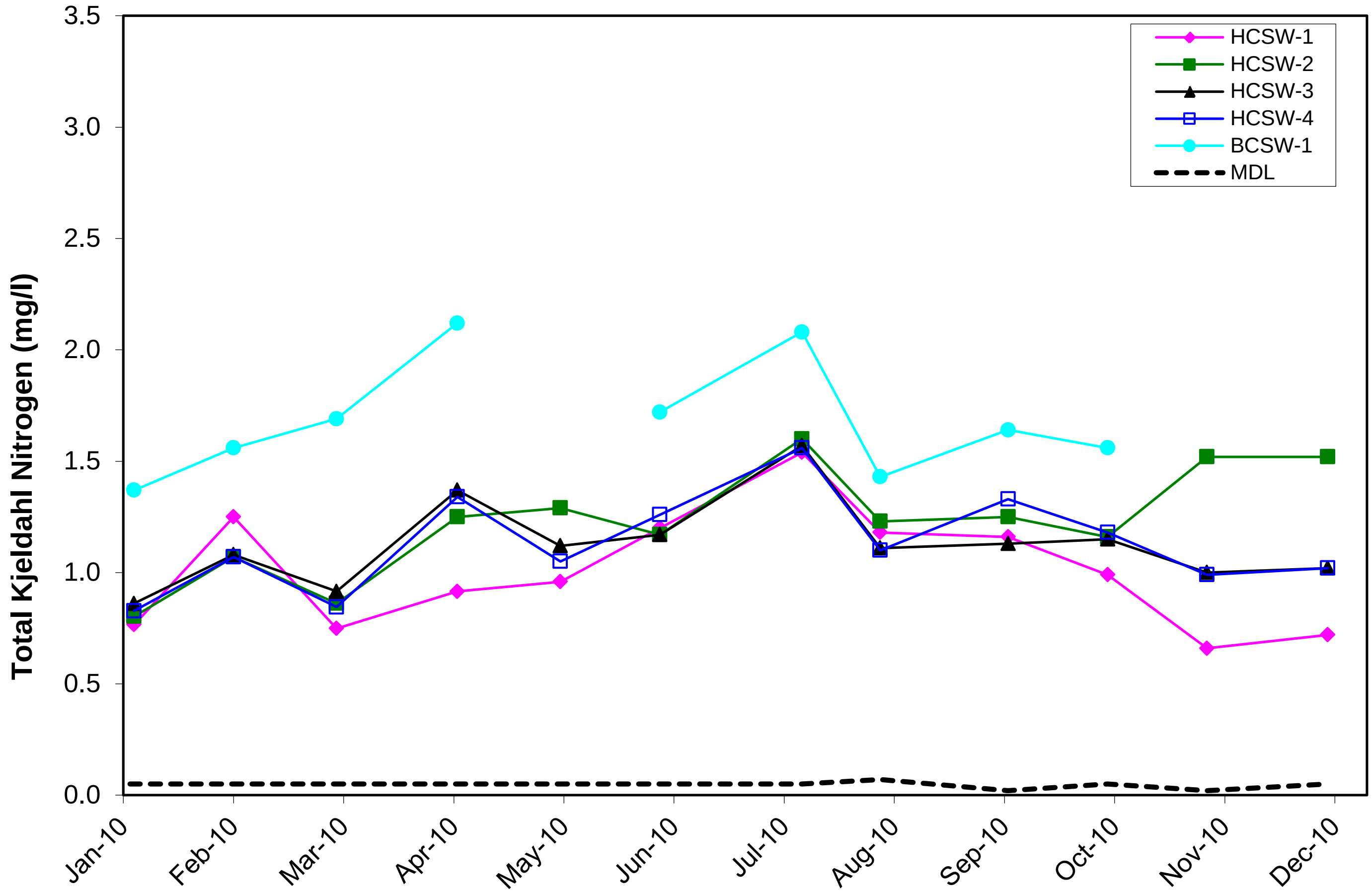

Figure 35. Total Kjeldahl Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2010.

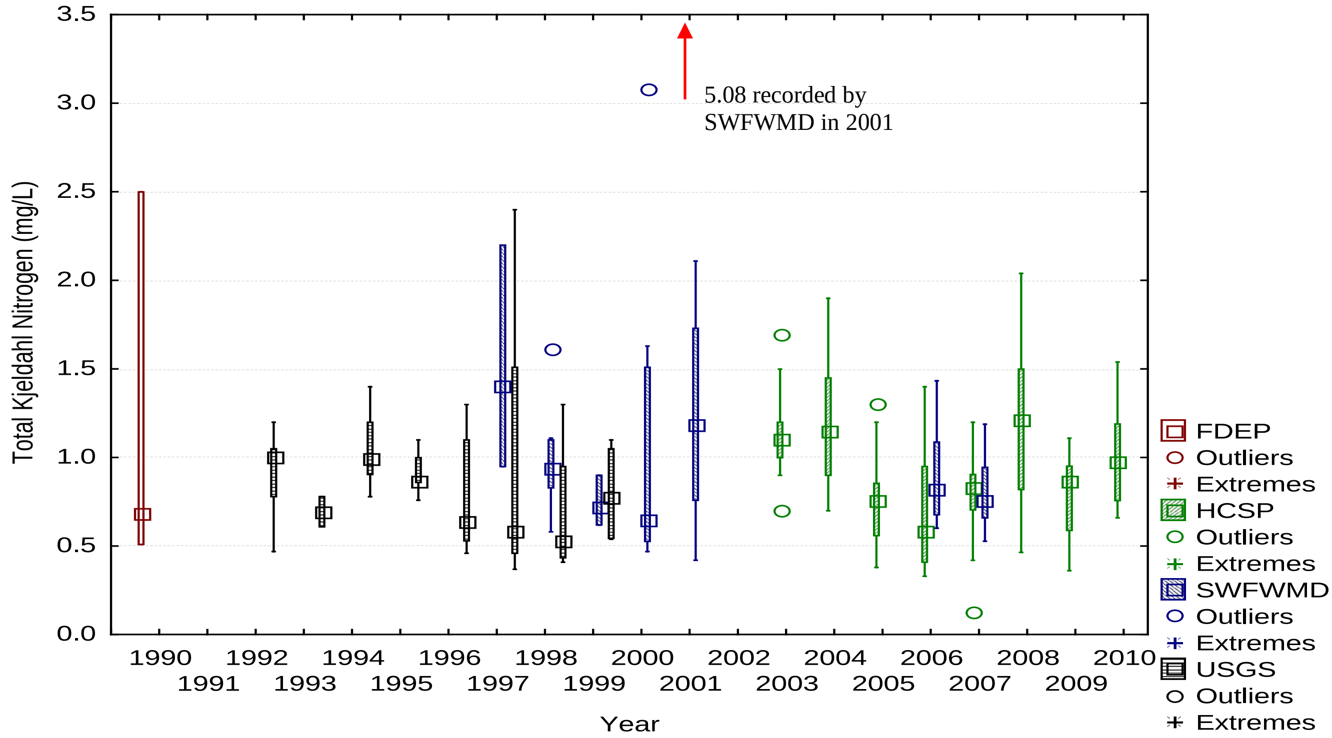

Figure 36. HCSW-1 Values of Total Kjeldahl Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

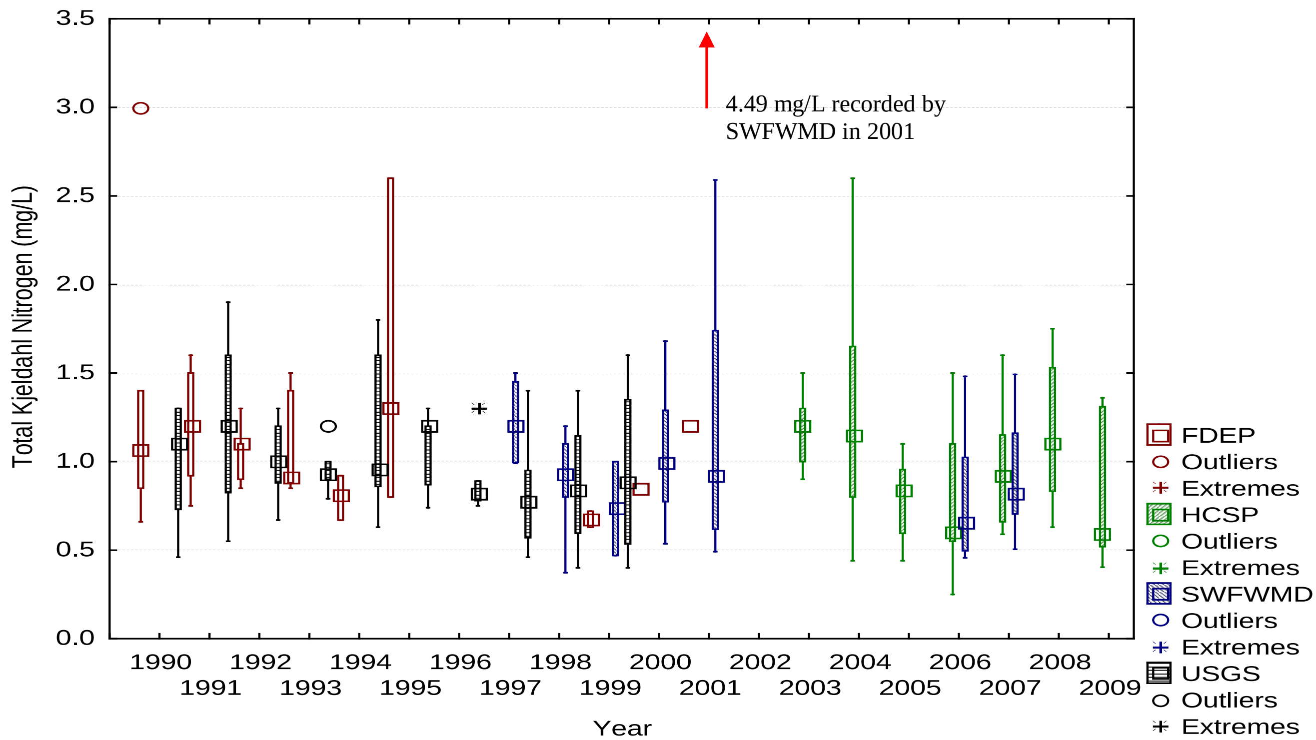

Figure 37. HCSW-4 Values of Total Kjeldahl Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

Nitrate-Nitrite Nitrogen

Nitrate+nitrite concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Figures 39 and 40), but could not be analyzed for monotonic trends or correlations with water quantity because of changes in MDL's over the course of the HCSP (Appendix C). In general, nitrate+nitrite concentrations are greater at the downstream Horse Creek stations (Figure 38). Based on an alternate trend analysis performed on data collected by SWFWMD from 2003-2010, there are no monotonic trends in nitrate+nitrite for HCSW-1 or HCSW-4 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 15).

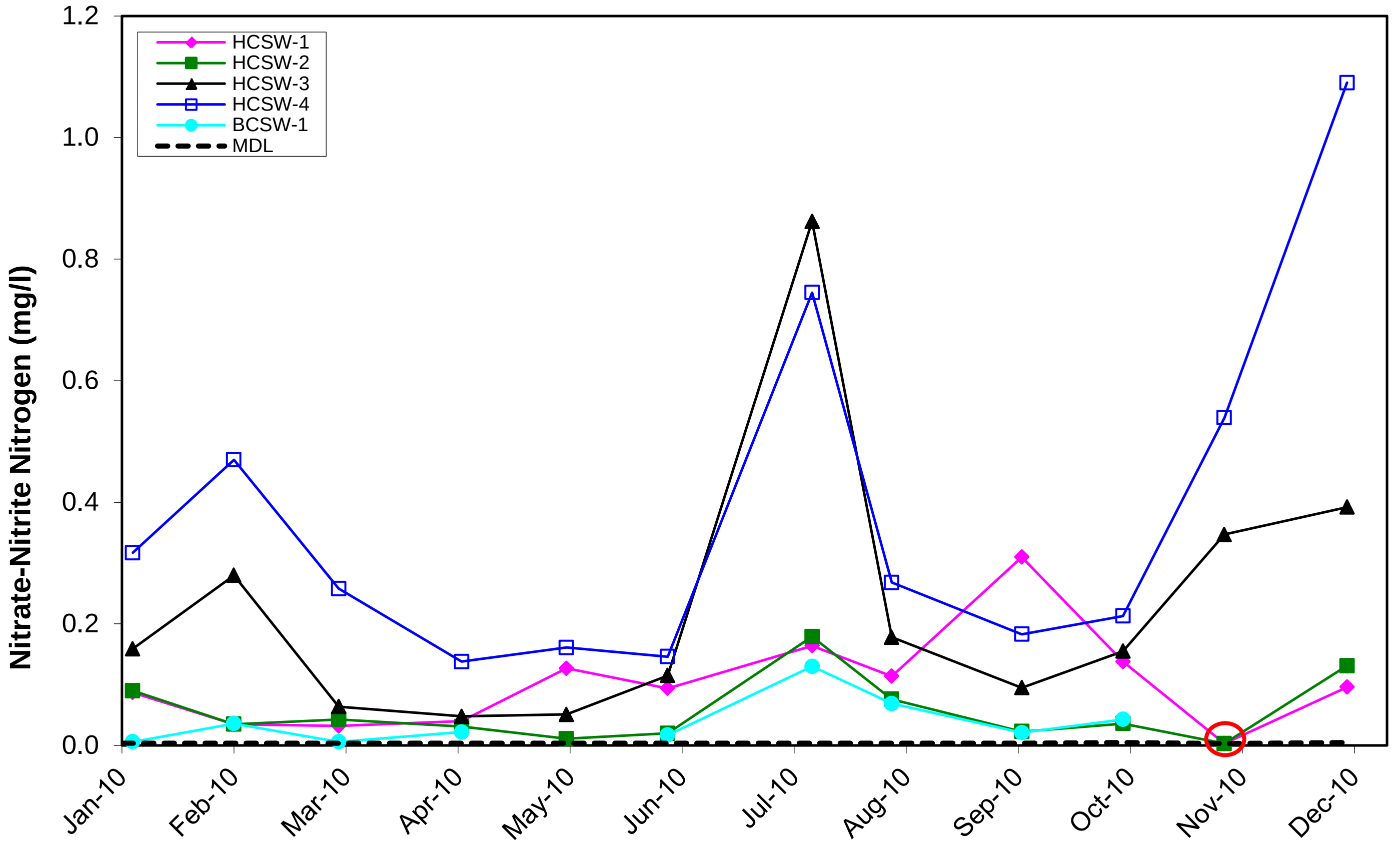

Figure 38. Nitrate-Nitrite Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2010. (Data from samples where Nitrate-Nitrite Nitrogen was undetected are circled in red.)

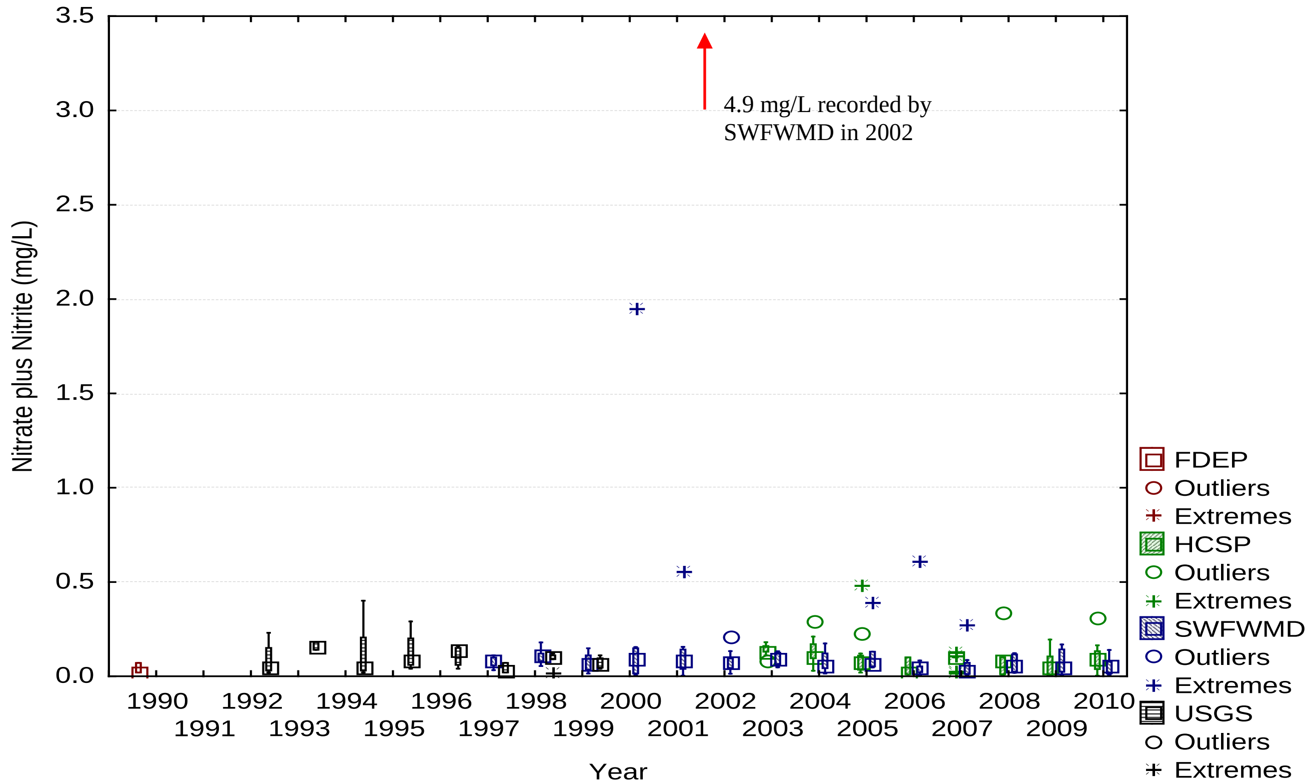

Figure 39. HCSW-1 Values of Nitrate plus Nitrite Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

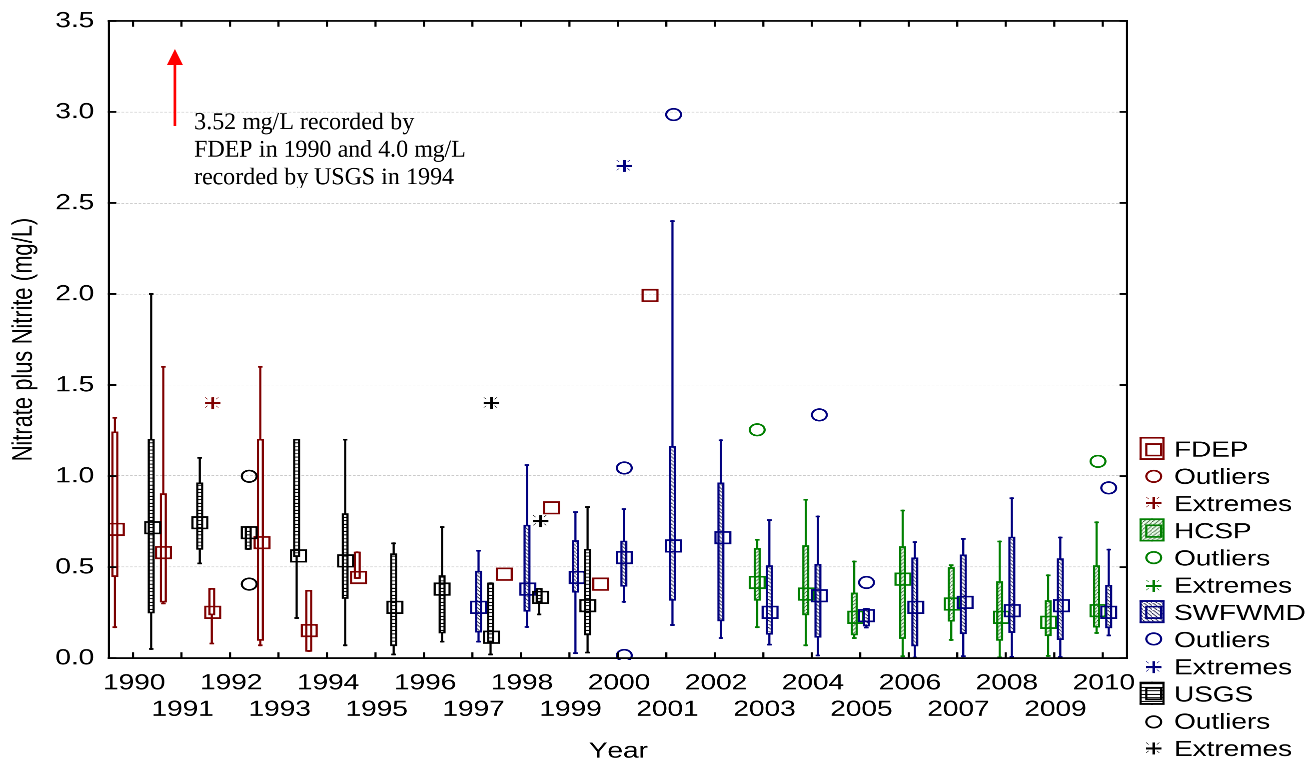

Figure 40. HCSW-4 Values of Nitrate plus Nitrite Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

Total Ammonia Nitrogen

Total ammonia nitrogen levels were within a similar range during all sampling events at all stations (Figure 41). The ammonia concentrations at HCSW-1 and HCSW-4 measured by the HCSP are at levels within the range for the last decade of data (Figures 42 and 43), but could not be analyzed for monotonic trends or correlations with water quantity because of changes in MDL's over the course of the HCSP. Based on an alternative trend analysis performed on data collected by SWFWMD since 2003, there are no monotonic trends in total ammonia nitrogen for HCSW-4 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 15). However, at HCSW-1 there is a slightly decreasing monotonic trend for total ammonia nitrogen from 2003-2010 (Seasonal Kendall Tau with LOWESS, Tau = -0.36, $p = 0.04$, Sen slope estimator = -0.002 mg/L per year, Figures 42 and 43). Because the direction of this potential trend is opposite that of the HCSP trigger level, it is not of concern (Appendix I). The program will however continue to monitor this condition over time.

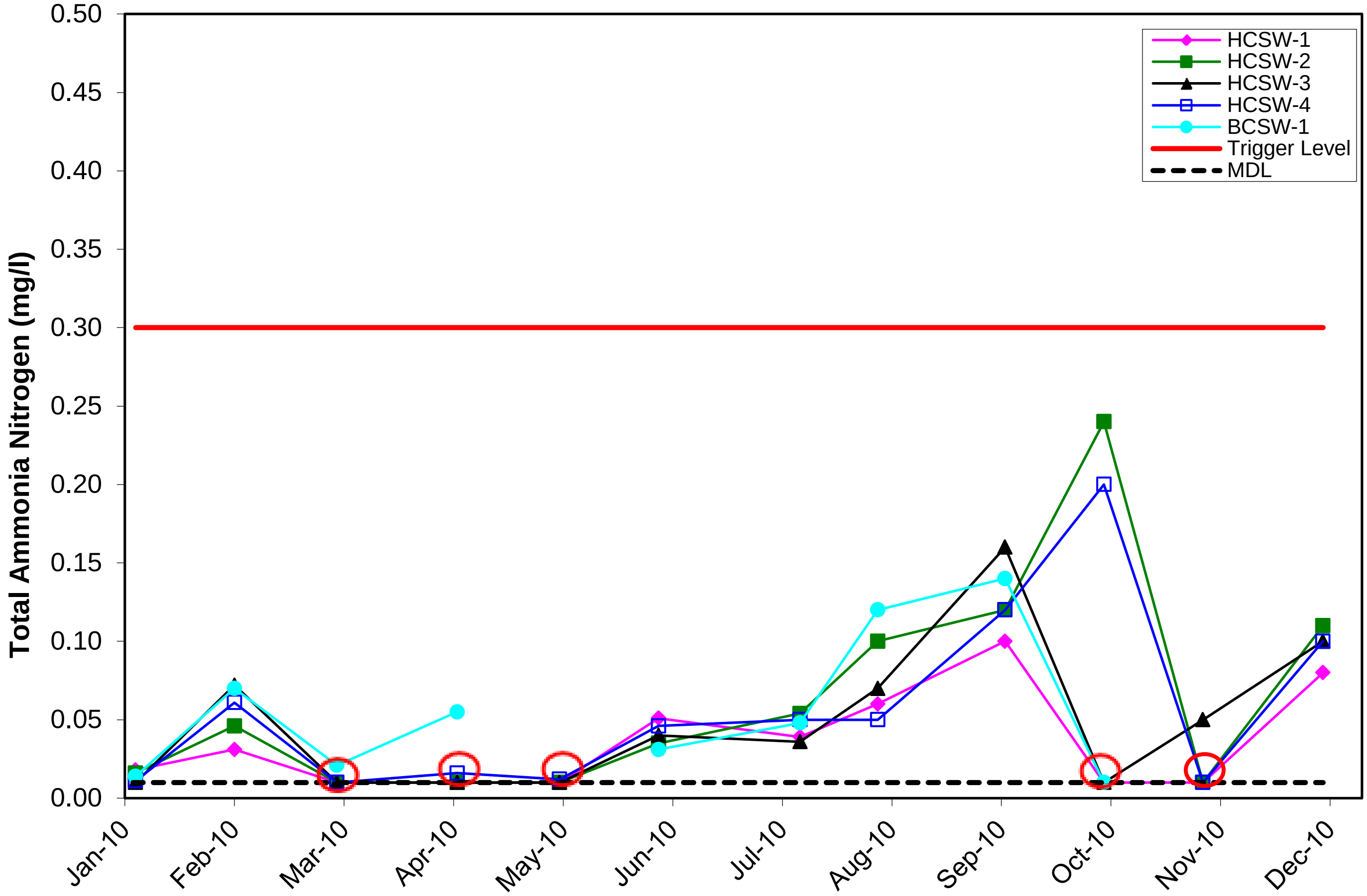

Figure 41. Total Ammonia Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2010. (Data from samples where Ammonia was undetected are circled in red.)

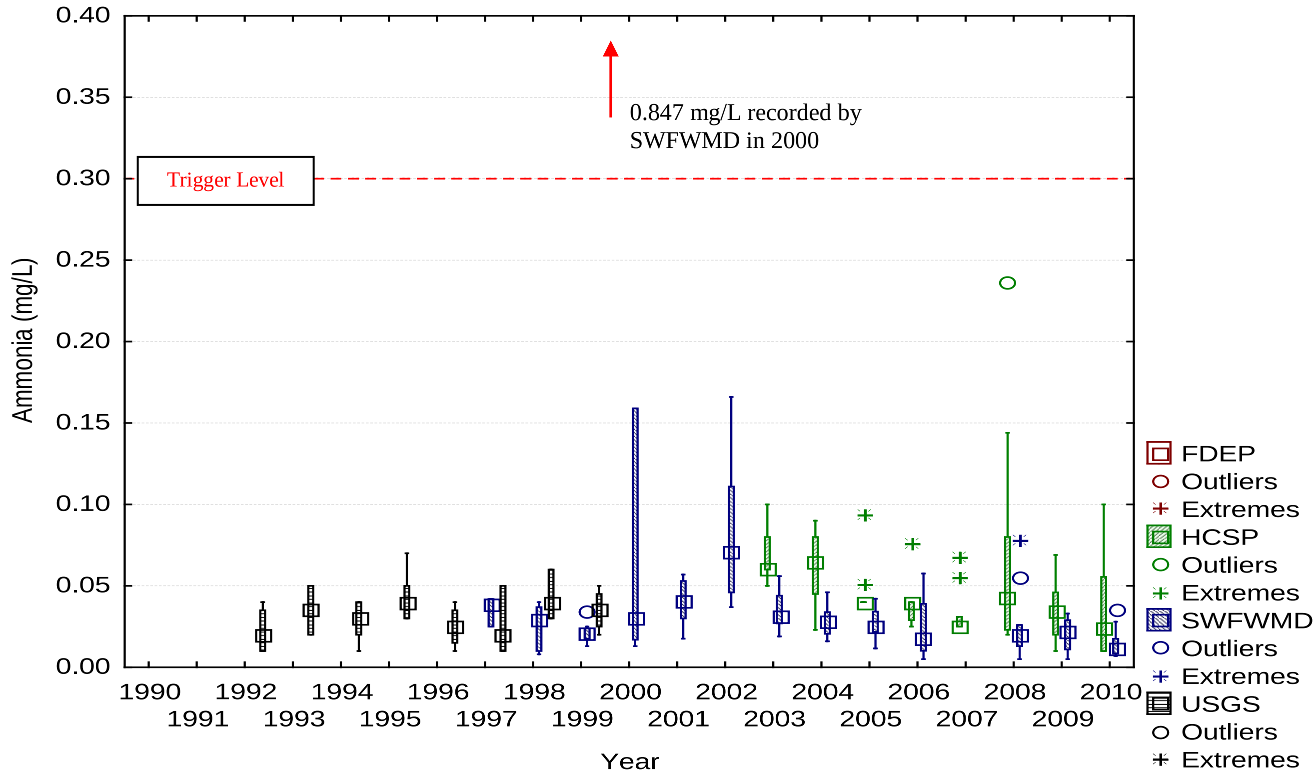

Figure 42. HCSW-1 Values of Ammonia Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

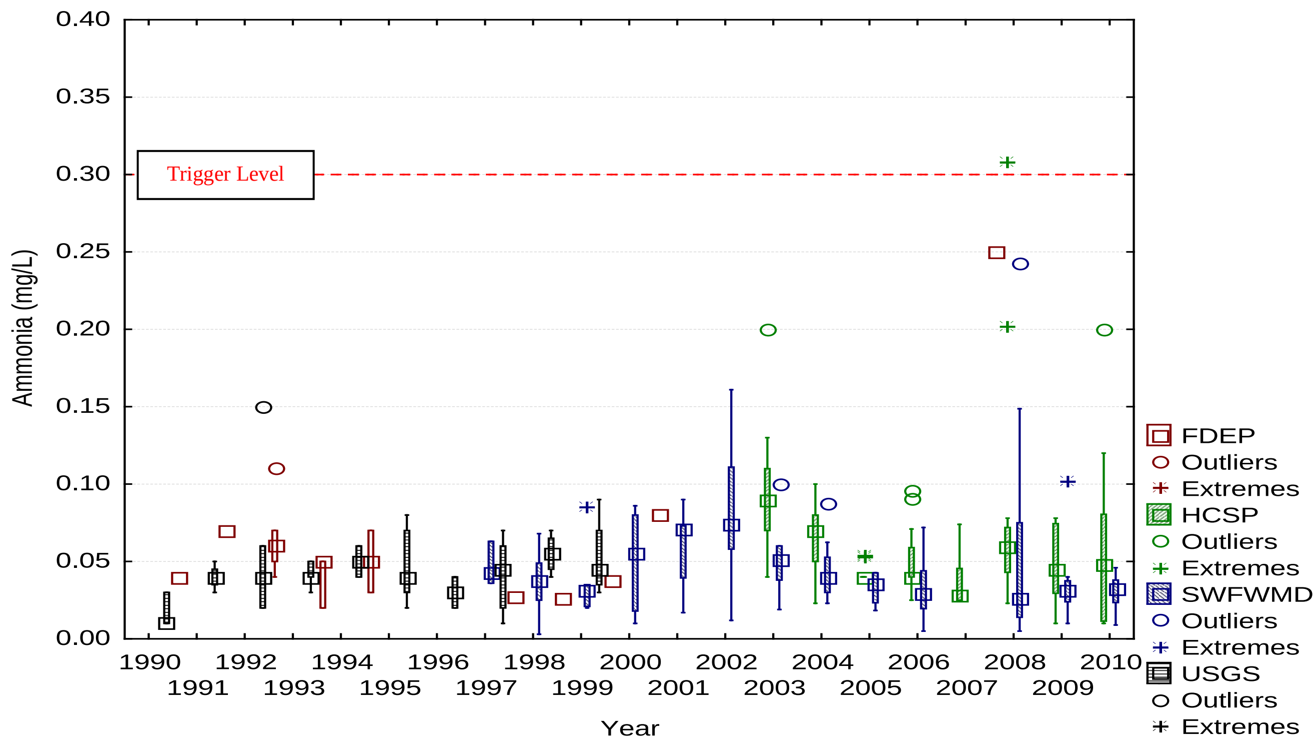

Figure 43. HCSW-4 Values of Ammonia Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

Orthophosphate

Levels of orthophosphate were well below the trigger level of 2.5 mg/l in 2010 (Figure 44). The orthophosphate concentrations at HCSW-1 measured by the HCSP are consistent with other water quality data sources and exhibited a slightly increasing monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, Tau=0.50, p=0.003, Sen slope estimator=0.27 mg/L per year). There was also an increasing monotonic trend at HCSW-4 (Seasonal Kendall Tau with LOWESS, Tau = 0.38, p = 0.03, Sen slope estimator = 0.02 mg/L per year) (Figures 45 and 46, Table 15). The impact assessment in Appendix I shows that the apparent trend in orthophosphate from 2003-2010 is caused by a data bias, and that extending the period of record eliminates this trend.

Orthophosphate concentrations were significantly different among stations (ANOVA, F = 23.50, $p < 0.0001$, Table 16), with concentrations at HCSW-2 lowest, then HCSW-3, and then the other two stations (Duncan's multiple range test, $p < 0.05$). Orthophosphate was only negatively correlated with streamflow (r_s= -0.32) at HCSW-1, while it was not correlated with streamflow, rainfall, or NPDES discharge at HCSW-4 (Spearman's rank correlation, $p > 0.05$, Table 17). Orthophosphate concentrations at Brushy Creek were similar to concentrations at all stations in Horse Creek.

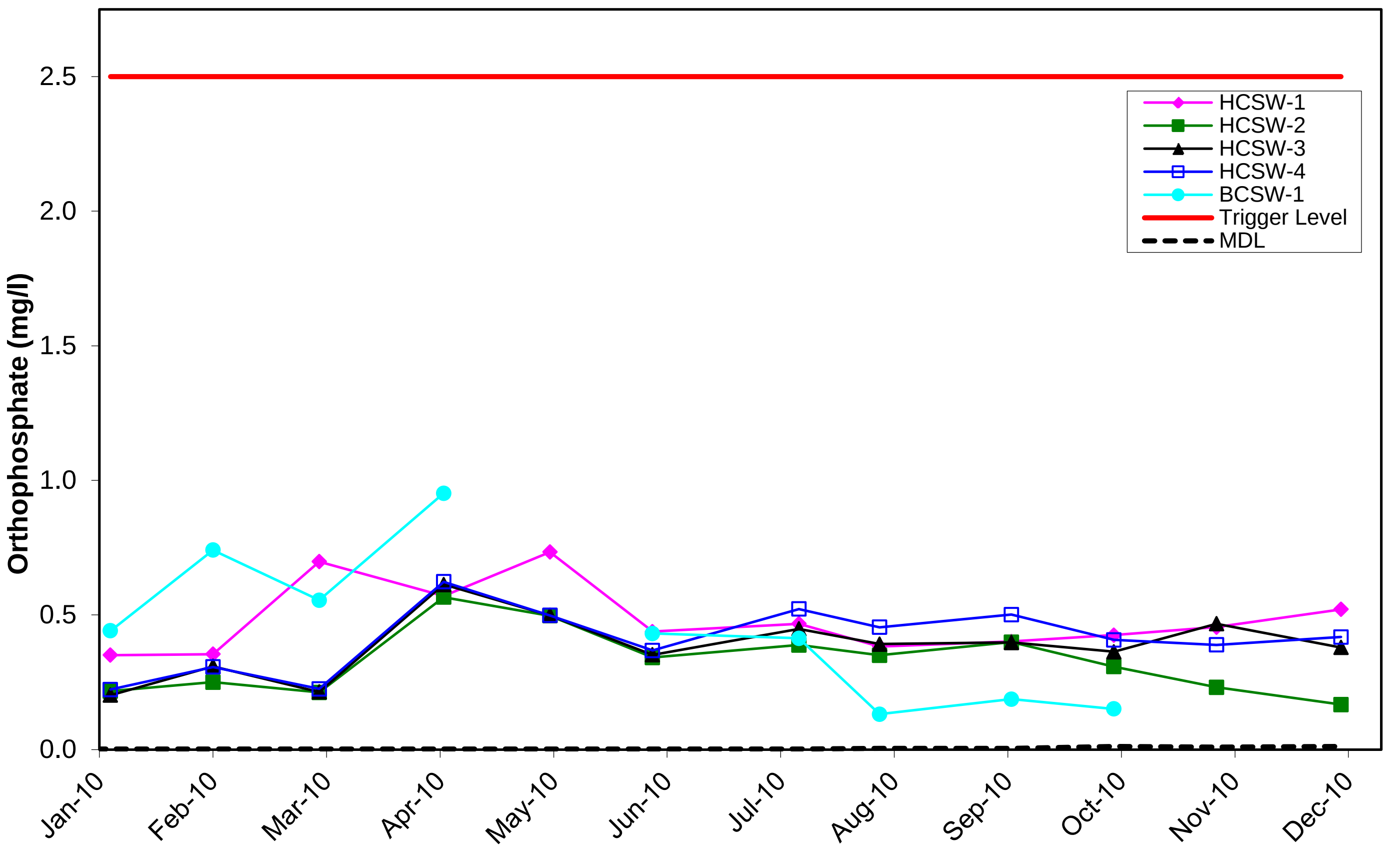

Figure 44. Orthophosphate Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2010.

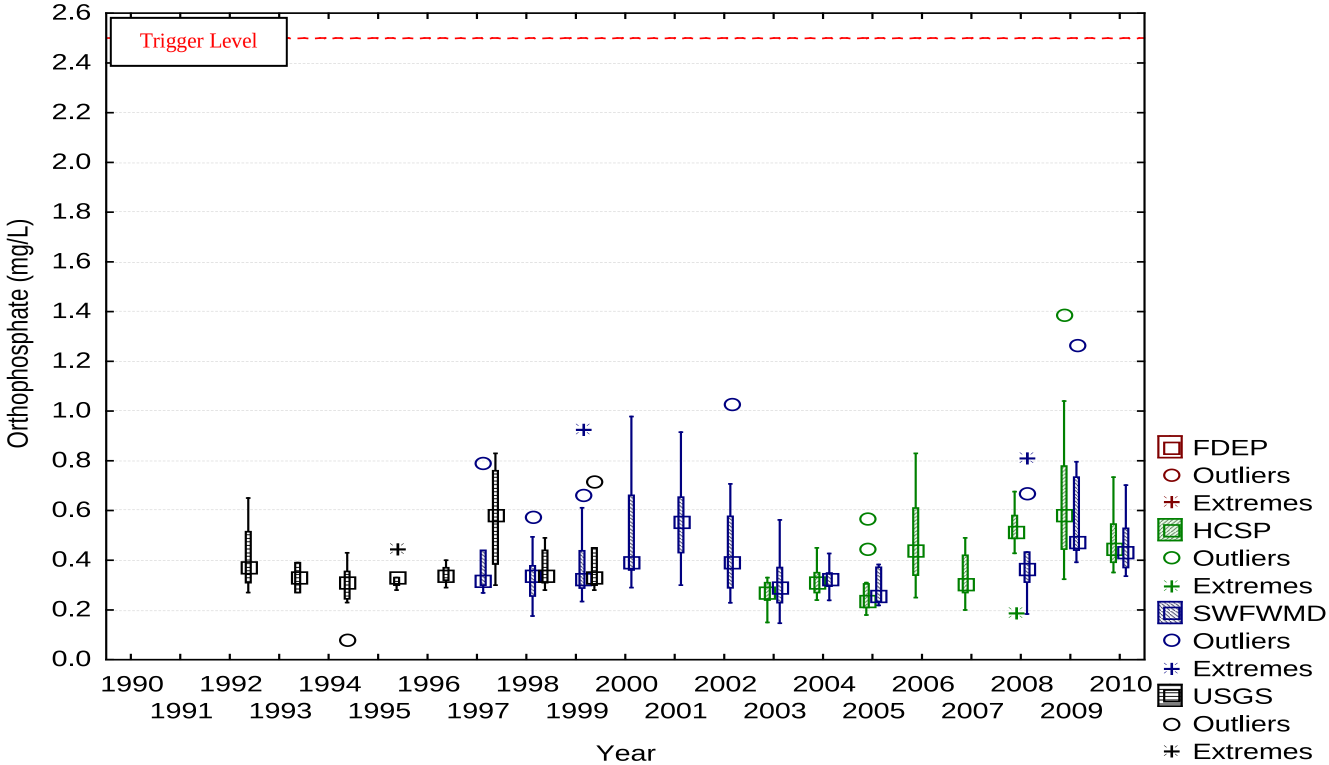

Figure 45. HCSW-1 Values of Orthophosphate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

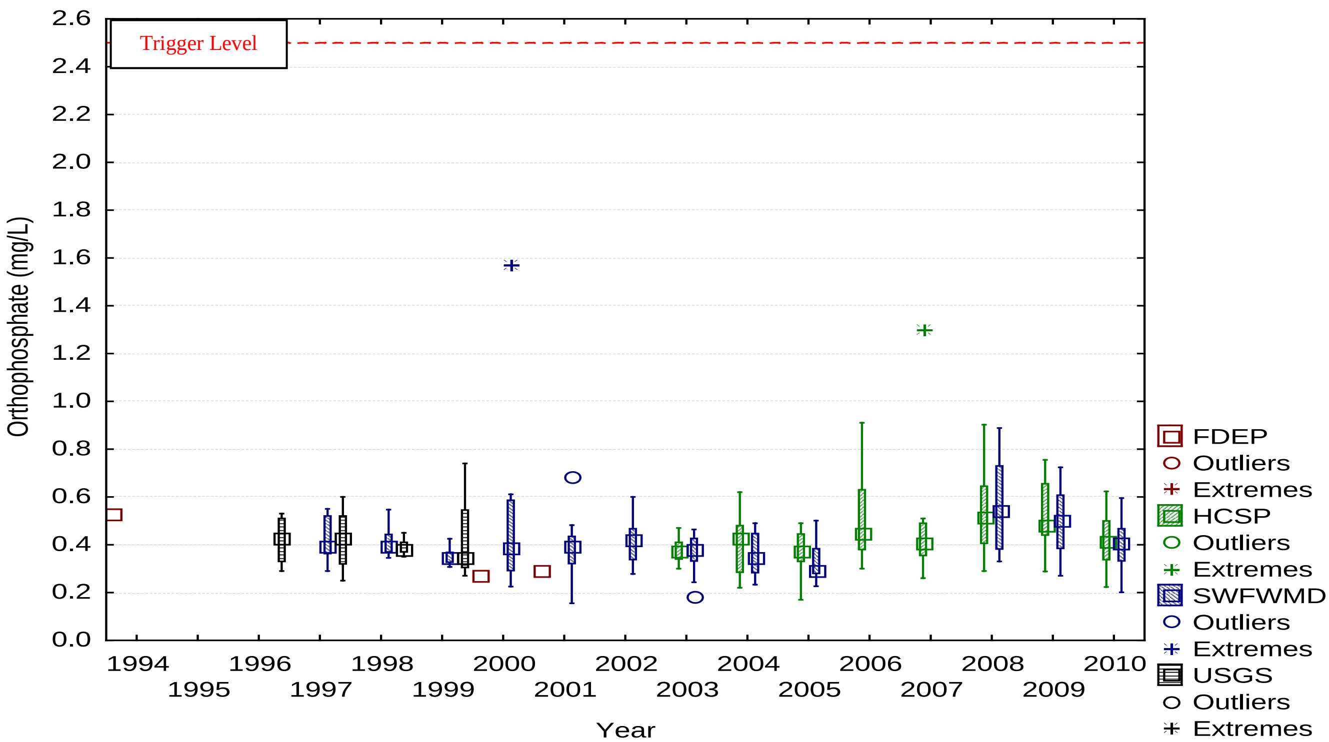

Figure 46. HCSW-4 Values of Orthophosphate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

Chlorophyll-a

Chlorophyll *a* values were well below the trigger level of 15 mg/m^3 during most sampling events at three stations in 2010, but HCSW-2 exceeded the trigger value for chlorophyll *a* in February of 2010 (Figure 47). 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 since 2003 (Seasonal Kendall Tau, $p > 0.05$) (Figures 48 and 49, Table 15). Chlorophyll *a* concentrations were significantly different between stations (ANOVA, $F = 13.25$, $p < 0.0001$, Table 16), with HCSW-2 significantly higher than other stations (Duncan's multiple range test, $p < 0.05$). Chlorophyll *a* was not correlated with streamflow, rainfall, and NPDES discharge at HCSW-1 or HCSW-4 (Spearman's rank correlation, $p > 0.05$, Table 17). Chlorophyll concentrations at Brushy Creek were consistent with concentrations at Horse Creek stations.

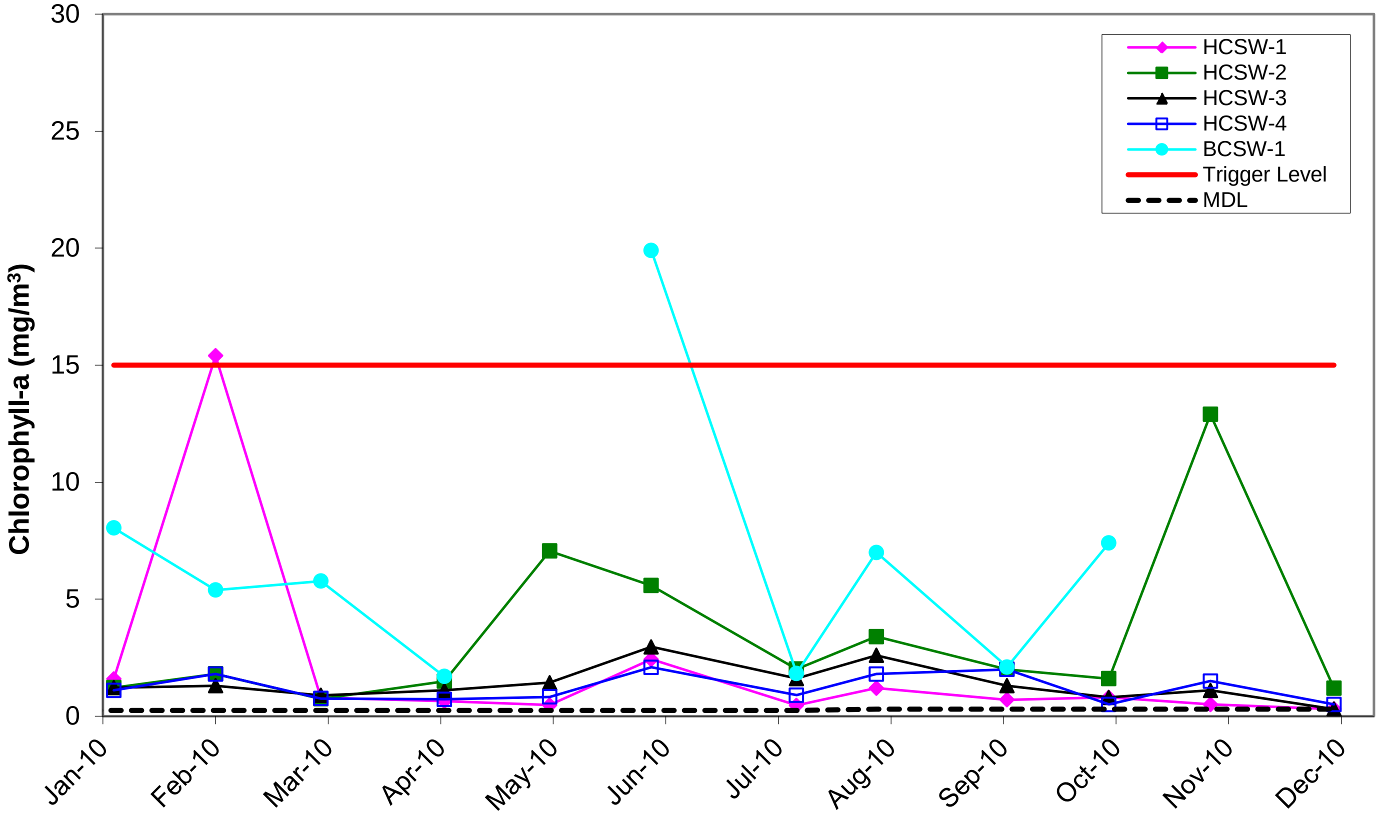

Figure 47. Chlorophyll-a Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2010.

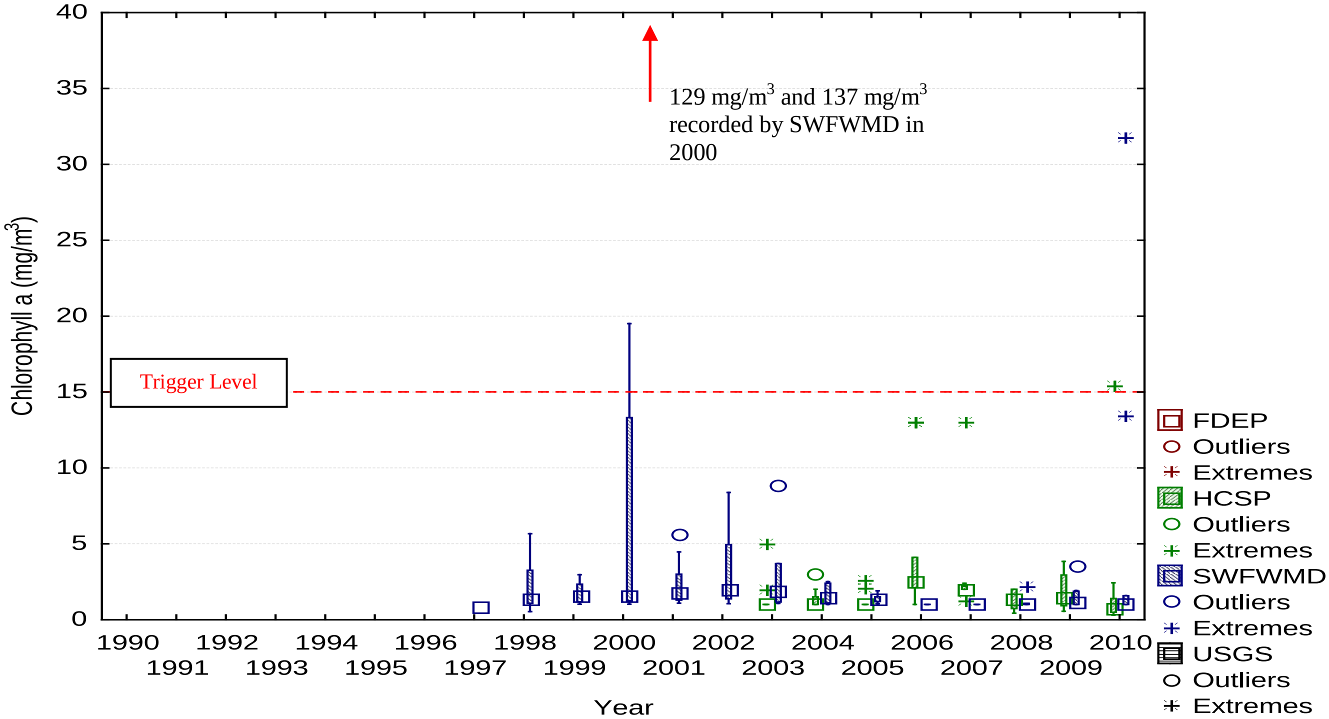

Figure 48. HCSW-1 Values of Chlorophyll a Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

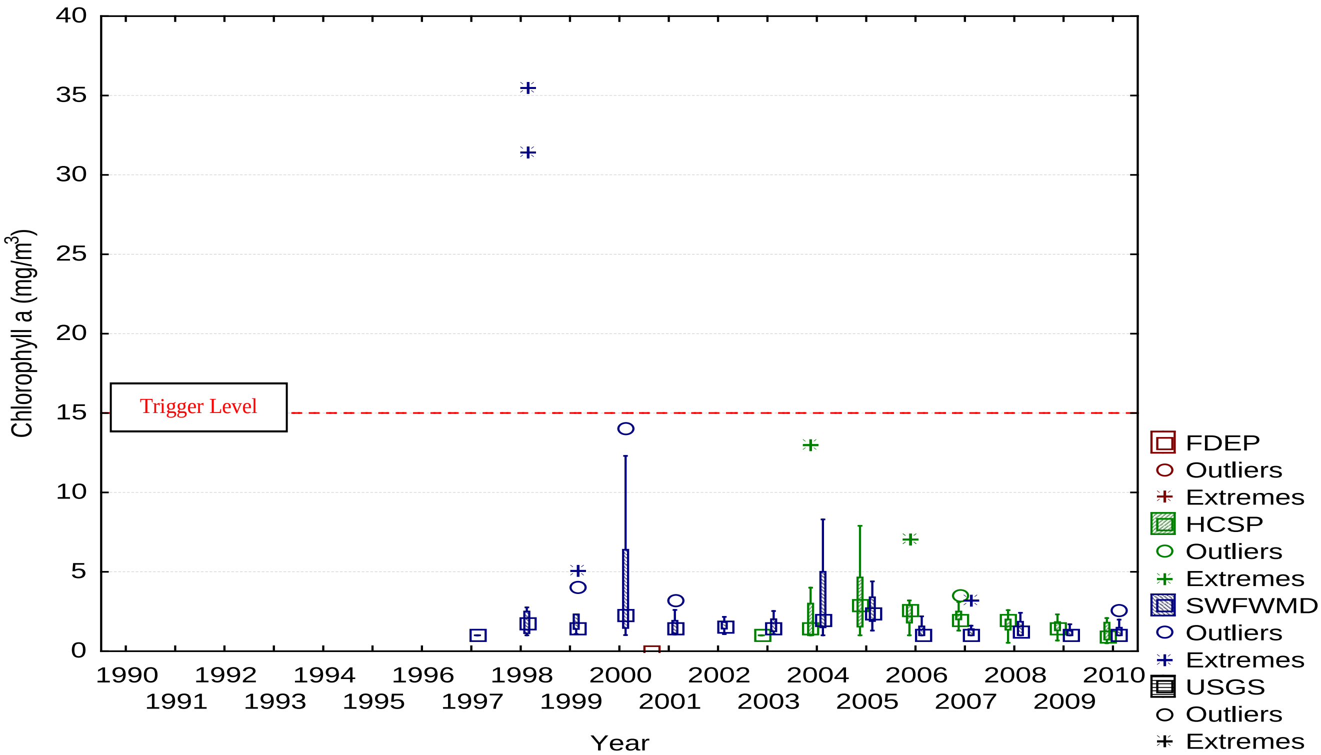

Figure 49. HCSW-4 Values of Chlorophyll a Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

5.2.4 Dissolved Minerals, Mining Reagents and Radionuclides

Specific Conductivity

During all sampling events and stations, specific conductivity levels were well below the trigger level of $\leq$1275 µmhos/cm^2 (Figure 50). Levels of specific conductivity determined during each biological sampling event were consistent with those obtained during monthly water quality sampling events (Figure 50). 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 53). The specific conductivity at HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 15, Figure 52), but there was an increasing monotonic trend at HCSW-1 (Seasonal Kendall Tau with LOWESS, Tau = 0.57, $p = 0.001$, Sen slope = 16.68 µmhos/cm per year, Figure 50). This potential trend is discussed in the impact analysis in Appendix I.

Specific conductivity was significantly different among stations over the period of record (2003 – 2010) (ANOVA, $F = 29.34$, $p < 0.0001$, Table 16), with the lowest overall readings at HCSW-2 followed by HCSW-1 (Duncan's multiple range test, $p < 0.05$). Specific conductivity was negatively correlated with streamflow, rainfall, and NPDES discharge at HCSW-4 (Spearman's rank correlations $-0.38 > r > -0.82$, $p < 0.05$, Table 17), but only positively correlated with NPDES discharge ($r_s = 0.23$) at HCSW-1. Concentrations at Brushy Creek were lower than Horse Creek stations throughout 2010.

Higher conductivity at downstream stations over the course of the HCSP 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 possible that some of the conductivity differential may simply be the result of changes in geology of the watershed from high elevations in 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. In recent years, changes in mining practices have raised the conductivity at the HCSW-1 station; although the new levels appear to be stable and not biologically harmful (see Appendix I).

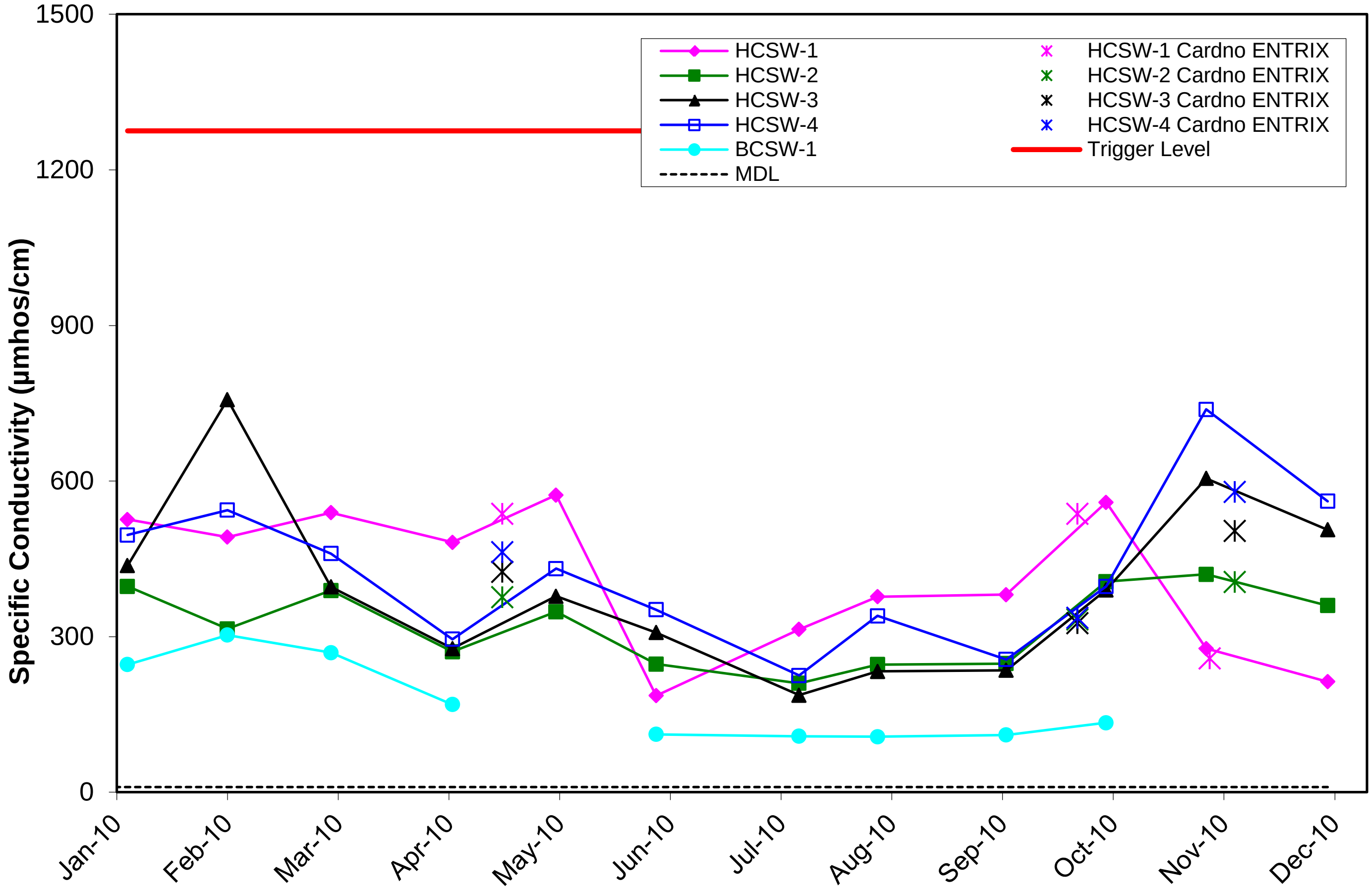

Figure 50. Levels of Specific Conductivity Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2010.

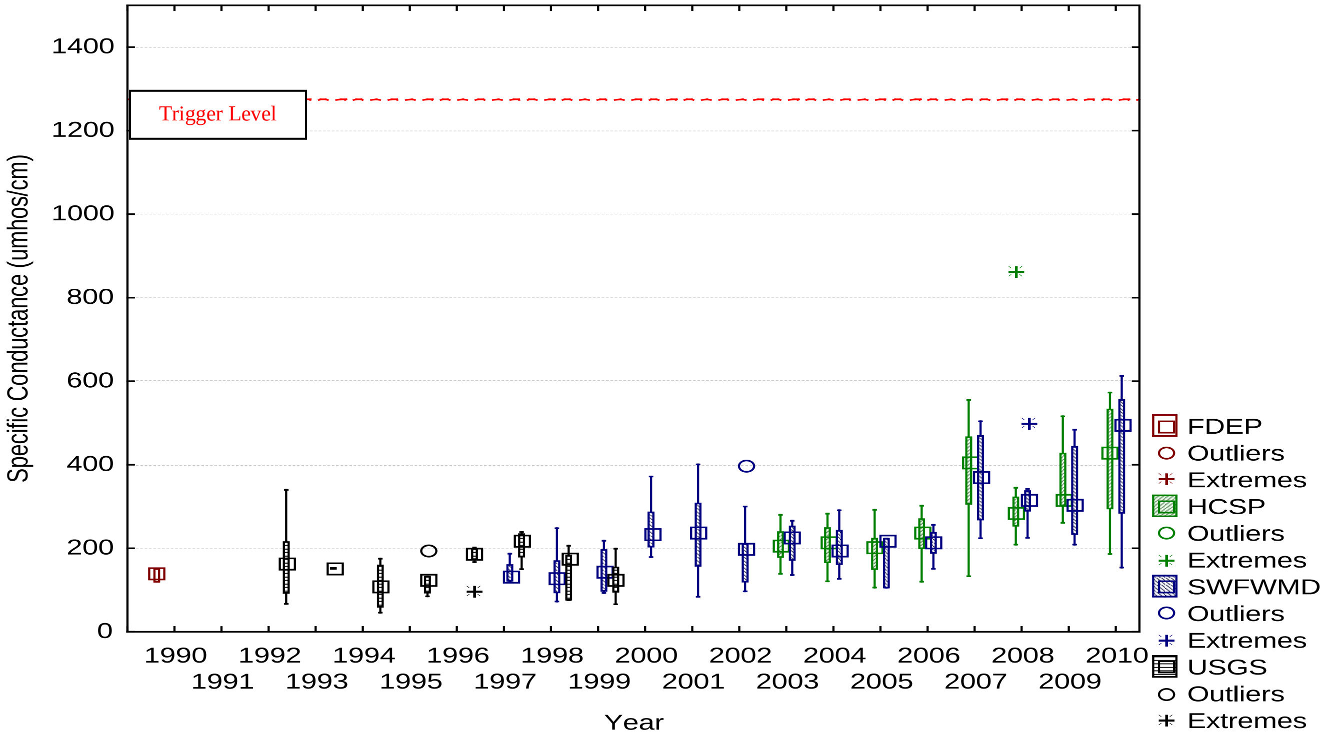

Figure 51. HCSW-1 Values of Specific Conductance Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

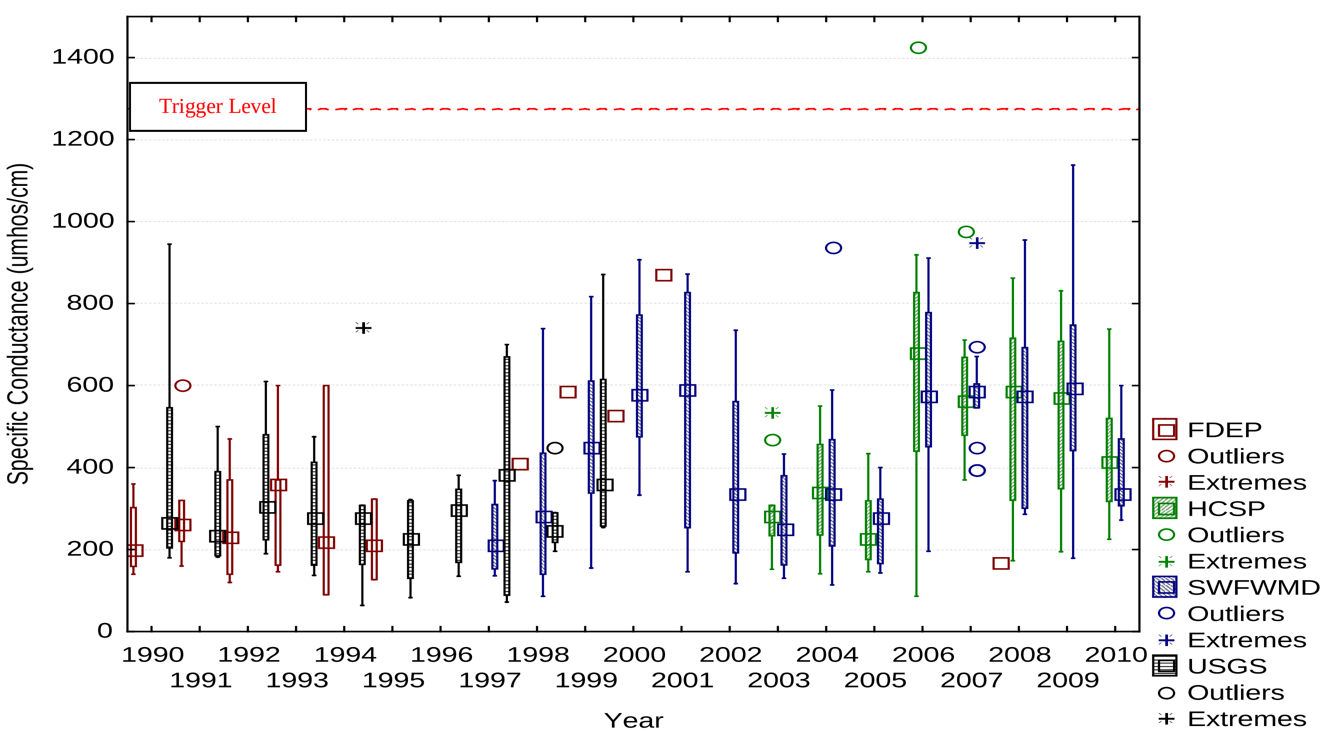

Figure 52. HCSW-4 Values of Specific Conductance Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

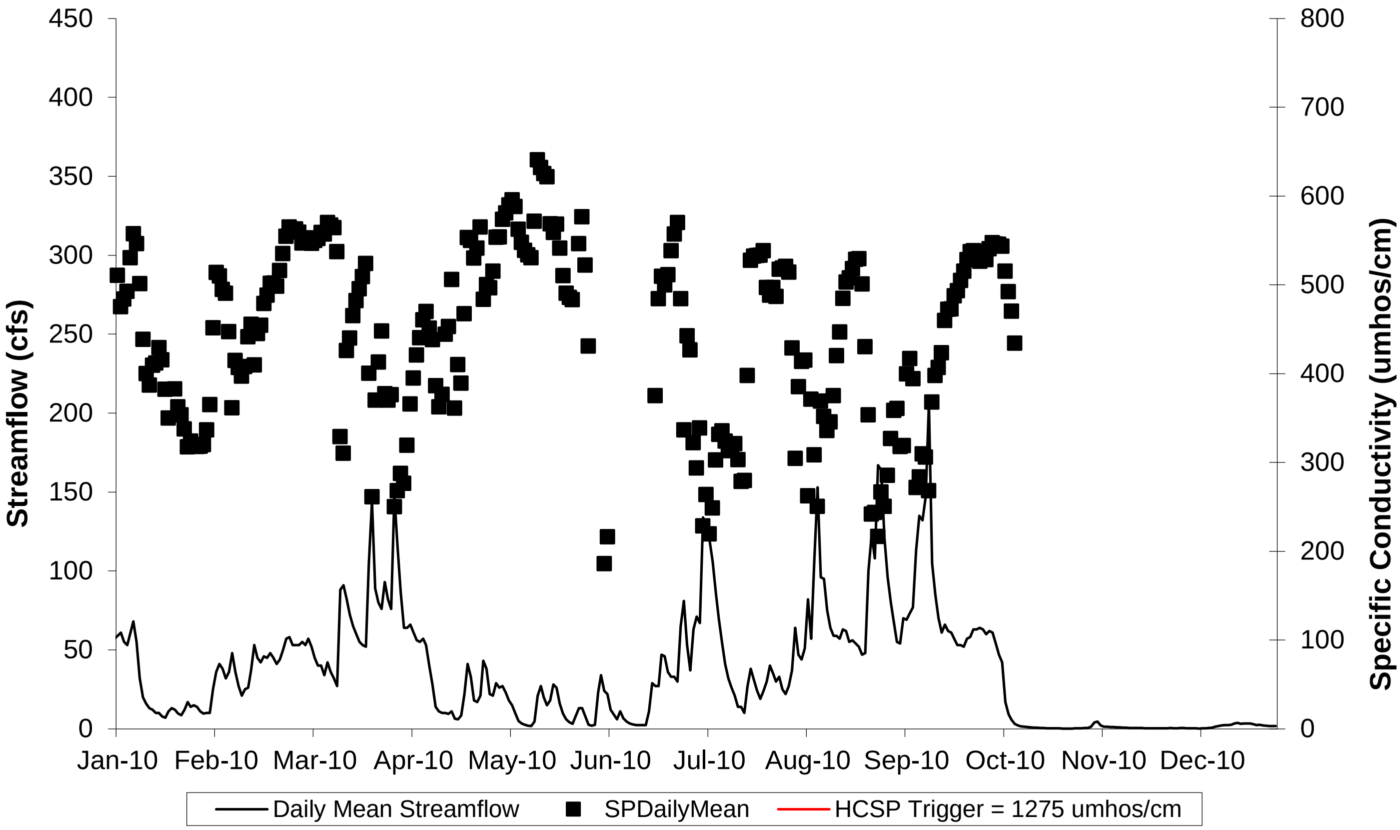

Figure 53. Relationship Between Daily Mean Specific Conductivity (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow for 2010. Min. Detection Limit = 100 µmhos/cm.

Dissolved Calcium

Calcium levels were lower than the trigger value of 100 mg/l at all stations during all events at all stations in 2010 (Figure 54). The calcium concentrations at HCSW-4 measured by the HCSP show no monotonic trend from 2003 to 2010 (Seasonal Kendall Tau with LOWESS, $p > 0.05$), however HCSW-1 exhibited an increasing trend since 2003 (Seasonal Kendall Tau with LOWESS, Tau = 0.51, $p = 0.004$, Sen slope = 1.60 mg/L per year, Figures 55 and 56, Table 15). The trend for HCSW-1 is small compared to historic HCSP differences between primary and field duplicate samples (≤8.0 mg/L). The trend for calcium and other ions may have been influenced by changes in mining practices, but the current concentrations are stable and not biologically harmful (Appendix I).

Concentrations of calcium were significantly different between stations (ANOVA, $F = 47.22$, $p < 0.0001$), with significantly higher levels at HCSW-4 and significantly lower levels at HCSW-2 (Duncan's post hoc test, $p < 0.05$, Figure 54, Table 16). As with specific conductivity, calcium levels were higher downstream where groundwater contributes more to baseflow. Calcium was negatively correlated with streamflow, rainfall, and NPDES discharge at HCSW-4 (Spearman's rank correlations $-0.38 > r > -0.83$, $p < 0.05$, Table 17), but only negatively correlated with streamflow ($r_s = -0.18$) and rainfall ($r_s = -0.26$) at HCSW-1. Brushy Creek had lower calcium concentrations than the Horse Creek stations.

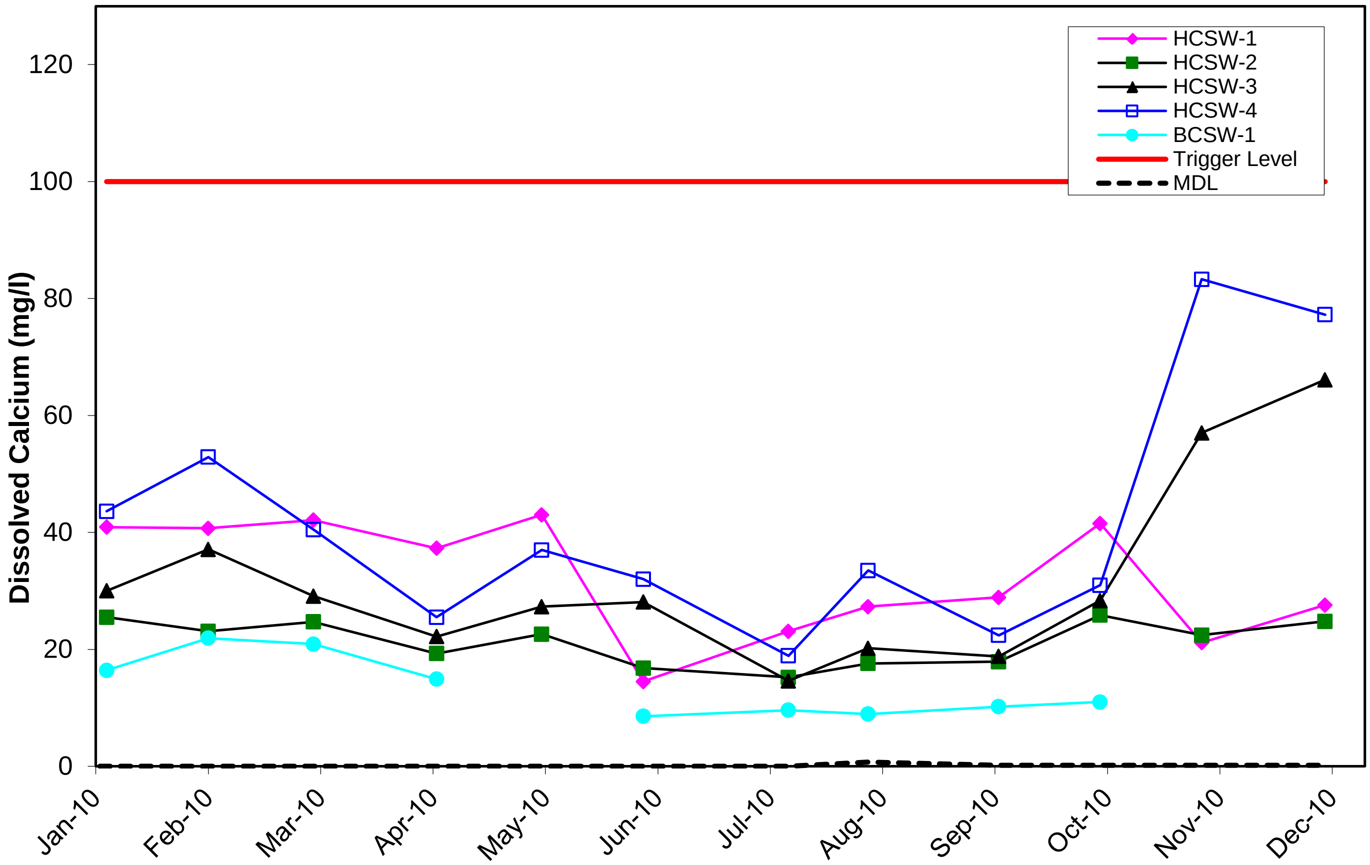

Figure 54. Dissolved Calcium Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2010. Minimum Detection Limit = 0.1 mg/l.

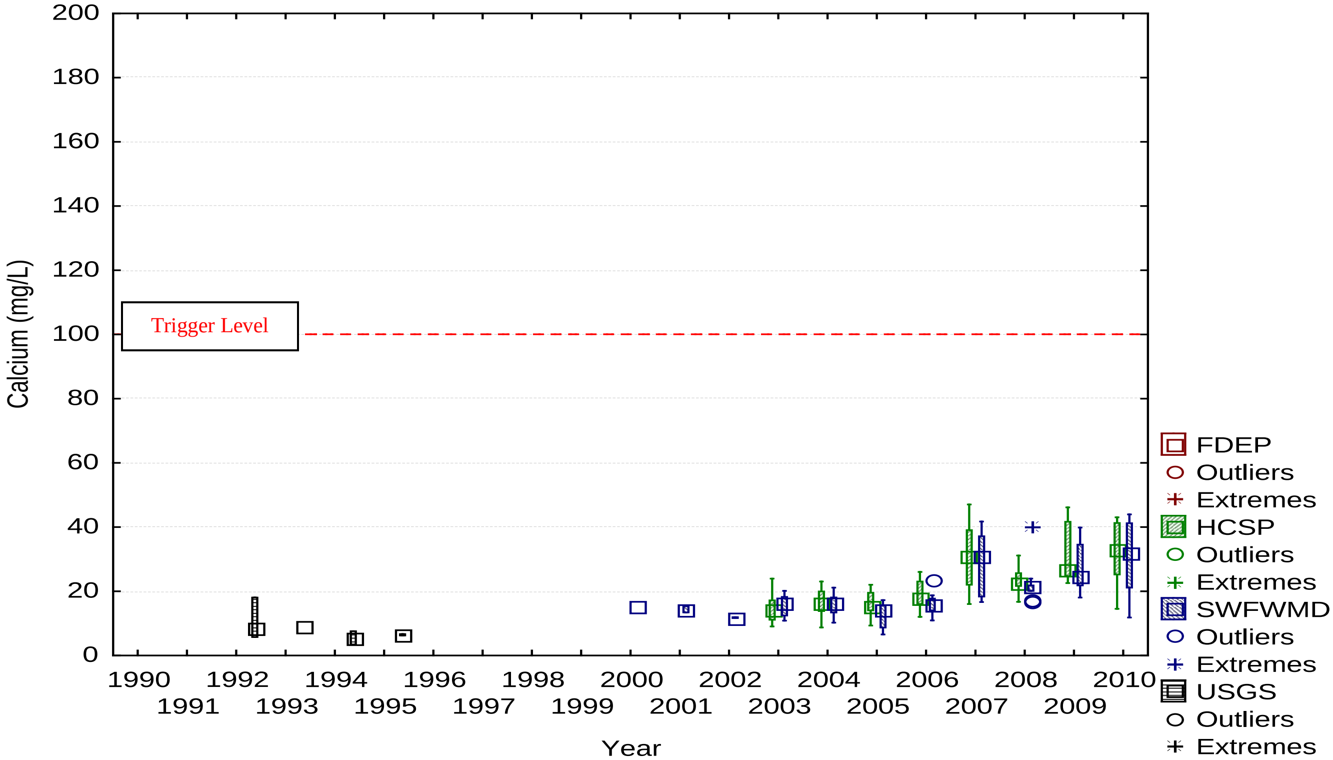

Figure 55. HCSW-1 Values of Calcium Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

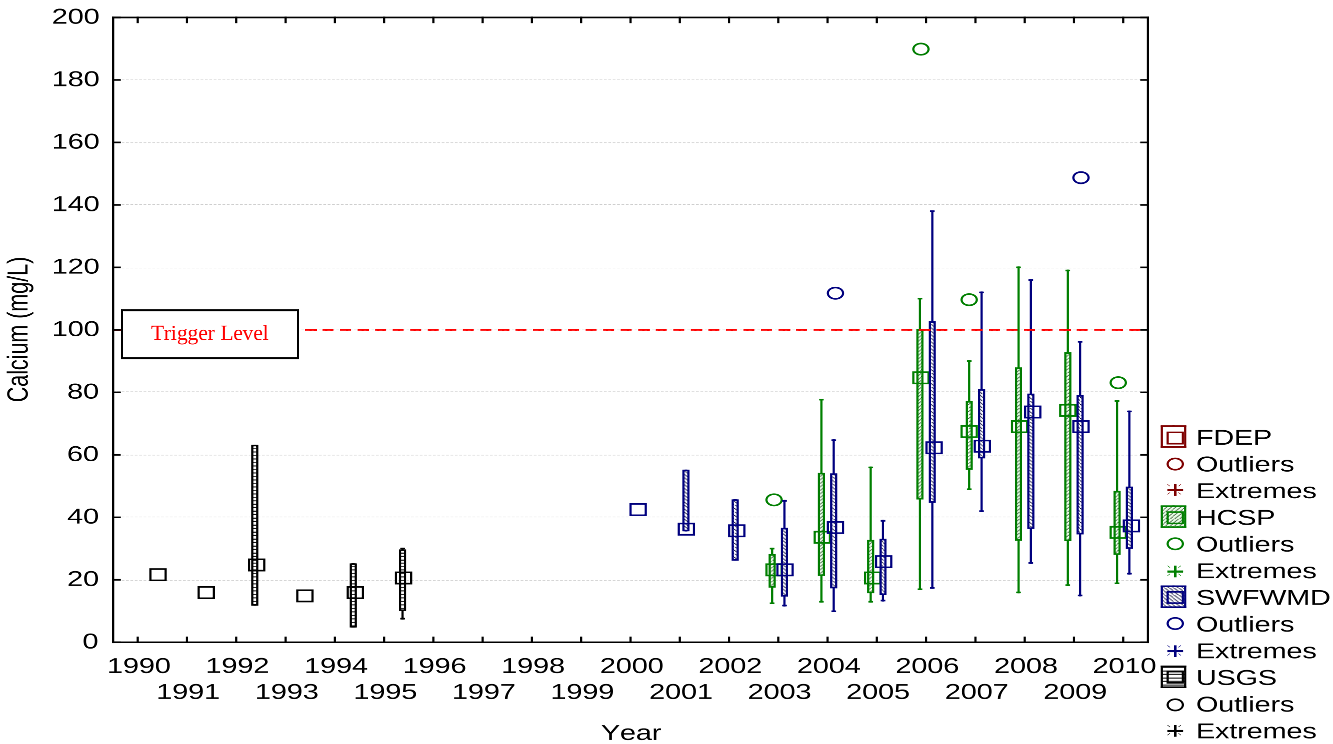

Figure 56. HCSW-4 Values of Calcium Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

Dissolved Iron

Levels of dissolved iron at all stations were below the trigger level of 1 mg/l during all sampling events in 2010 (Figure 57). Dissolved iron concentrations at HCSW-4 exceeded the trigger value of 0.3 mg/l established for that sampling station in April and from July through September. HCSW-4 has a different trigger level for iron because of its location upstream of a segment of the Peace River 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 were not compared to data collected by other sources because the historical data is limited for this water quality parameter.

There were no observed monotonic trends for dissolved iron since 2003 for HCSW-1 or HCSW-4 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 15). Dissolved iron concentrations were not significantly different among stations (ANOVA, $F = 1.04$, $p = 0.38$, Table 16). Iron was positively correlated with streamflow, rainfall, and NPDES discharge at HCSW-1 and HCSW-4 (Spearman's rank correlations $0.33 < r < 0.77$, $p < 0.05$, Table 17). Brushy Creek had slightly higher iron concentrations than the Horse Creek stations.

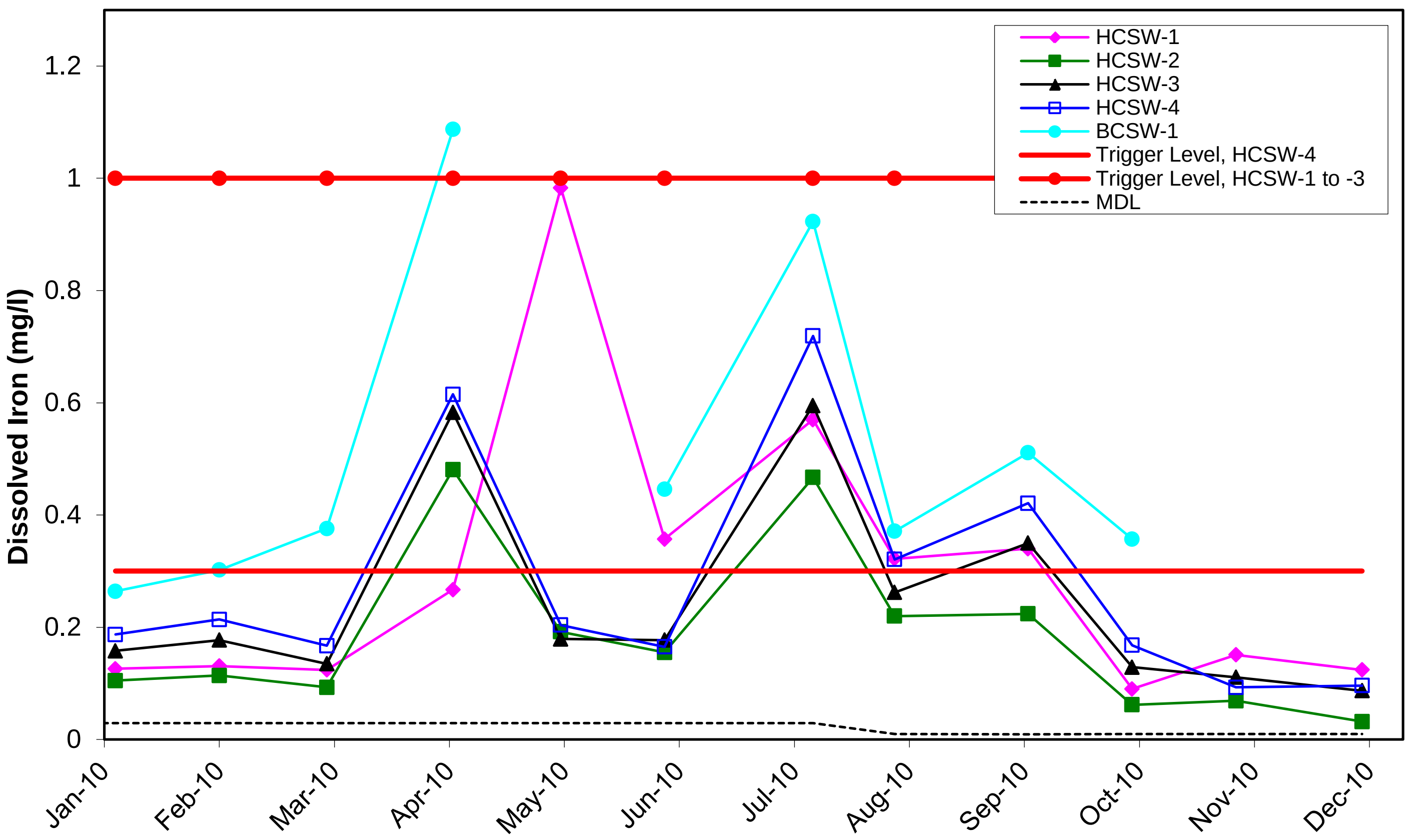

Figure 57. Dissolved Iron Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2010.

Total Alkalinity

Levels of total alkalinity were well below the trigger value of 100 mg/l during 2010 except for the January sample at HCSW-1 (Figure 58). The alkalinity levels at HCSW-4 measured by the HCSP are consistent with other water quality data sources and did not exhibit a monotonic trend since 2004 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 15). There was an increasing monotonic trend present at HCSW-1 from 2003-2010 (Seasonal Kendall Tau with LOWESS, Tau = 0.57, $p = 0.001$, Sen slope = 4.79 mg/L per year, Table 15, Figures 59 and 60). The estimated slope for HCSW-1 is small compared to the differences between primary and field duplicate samples (≤17 mg/L). The trend for alkalinity and other ions may have been influenced by changes in mining practices, but the current concentrations are stable and not biologically harmful (Appendix I).

Total alkalinity was significantly different among stations (ANOVA, $F = 42.85$, $p < 0.0001$, Table 16), with highest levels at HCSW-1 followed by HCSW-4 (Duncan's multiple range test, Figure 58). Alkalinity was negatively correlated with streamflow, rainfall, and NPDES discharge at HCSW-4 (Spearman's rank correlation $-0.42 > r > -0.76$, $p < 0.05$, Table 17), 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. However, streamflow, rainfall, and NPDES discharge were not correlated at HCSW-1(Spearman's rank correlation, $p > 0.05$, Table 17). 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. Brushy Creek had lower alkalinity concentrations than the Horse Creek stations.

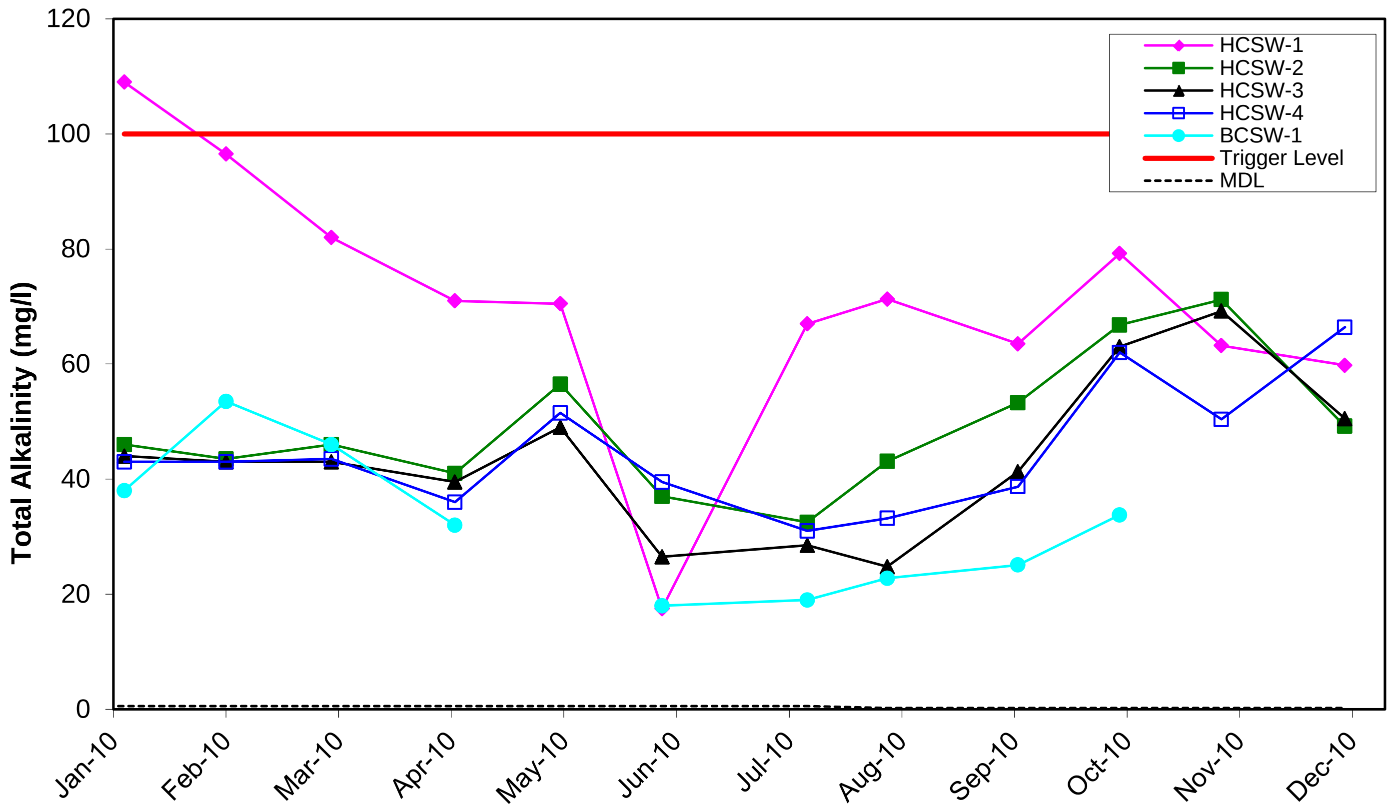

Figure 58. Levels of Total Alkalinity Obtained During Monthly HCSP Water Quality Sampling in 2010.

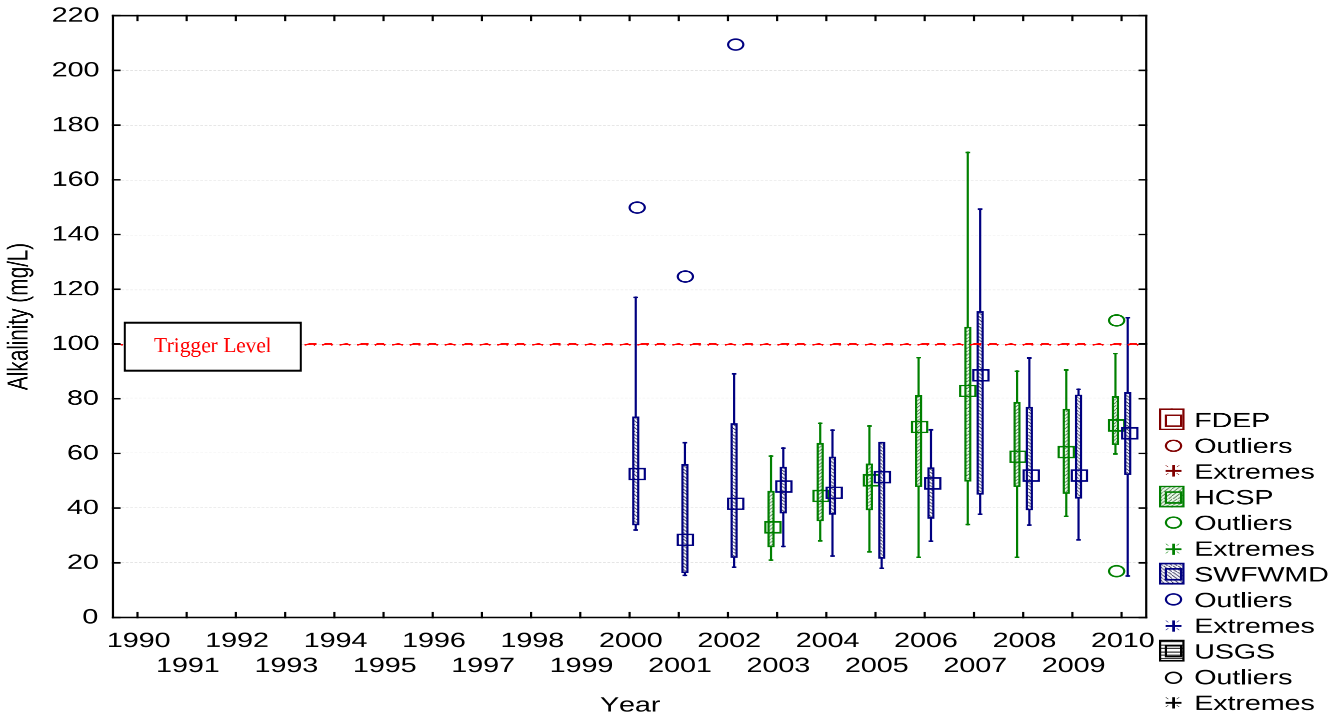

Figure 59. HCSW-1 Values of Alkalinity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

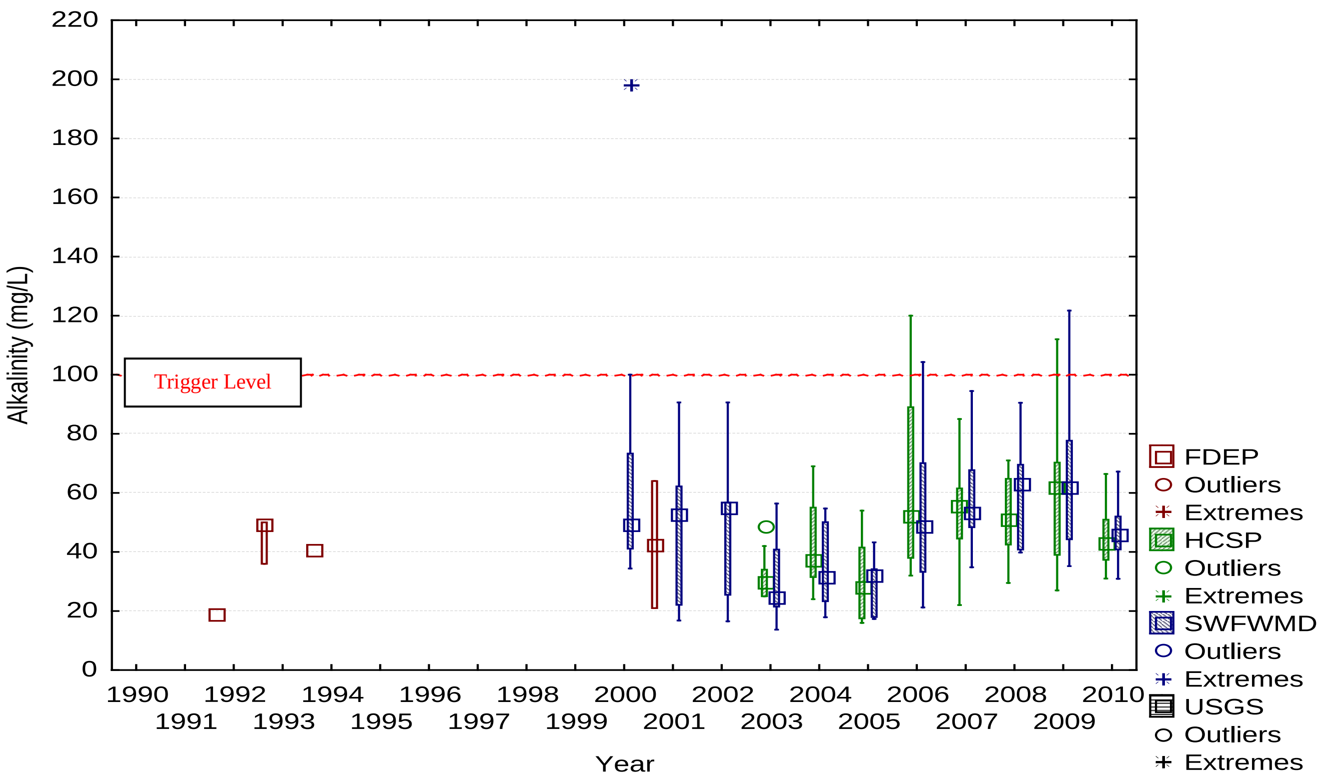

Figure 60. HCSW-4 Values of Alkalinity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

Chloride

Levels of chloride were below 45 mg/l during 2003 - 2010, 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 since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Figures 62 and 63, Table 15). Chloride concentrations were significantly different among stations during all sampling events (ANOVA, $F = 17.37$, $p < 0.0001$, Table 16), with a pattern of increasing concentration downstream (Figure 61). Chloride was negatively correlated with streamflow, rainfall, and NPDES discharge at HCSW-1 and HCSW-4 (Spearman's rank correlations $-0.37 > r > -0.81$, $p < 0.05$, Table 17). Brushy Creek had similar concentrations to the Horse Creek stations.

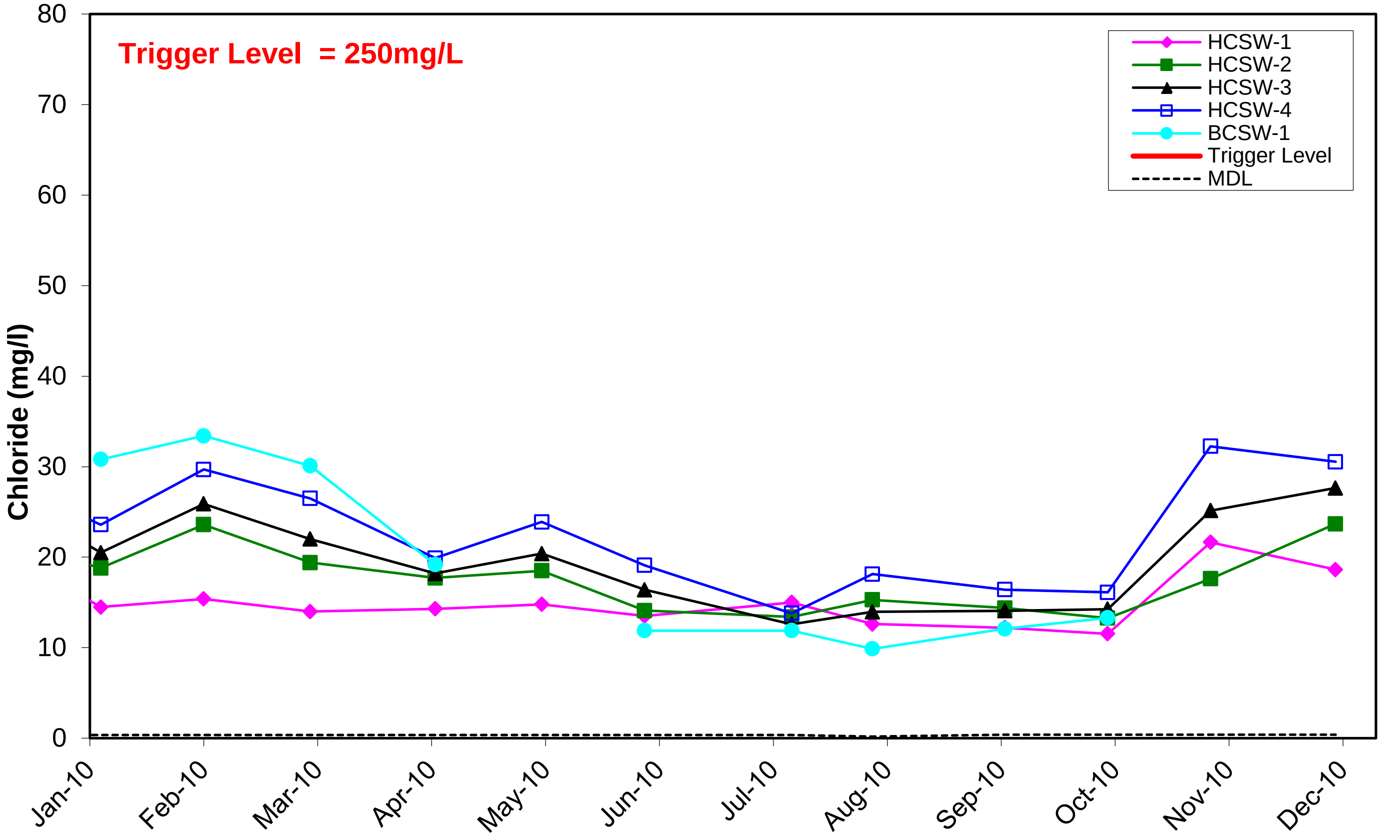

Figure 61. Chloride Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2010. (HCSP trigger value for Chloride is 250 mg/L.)

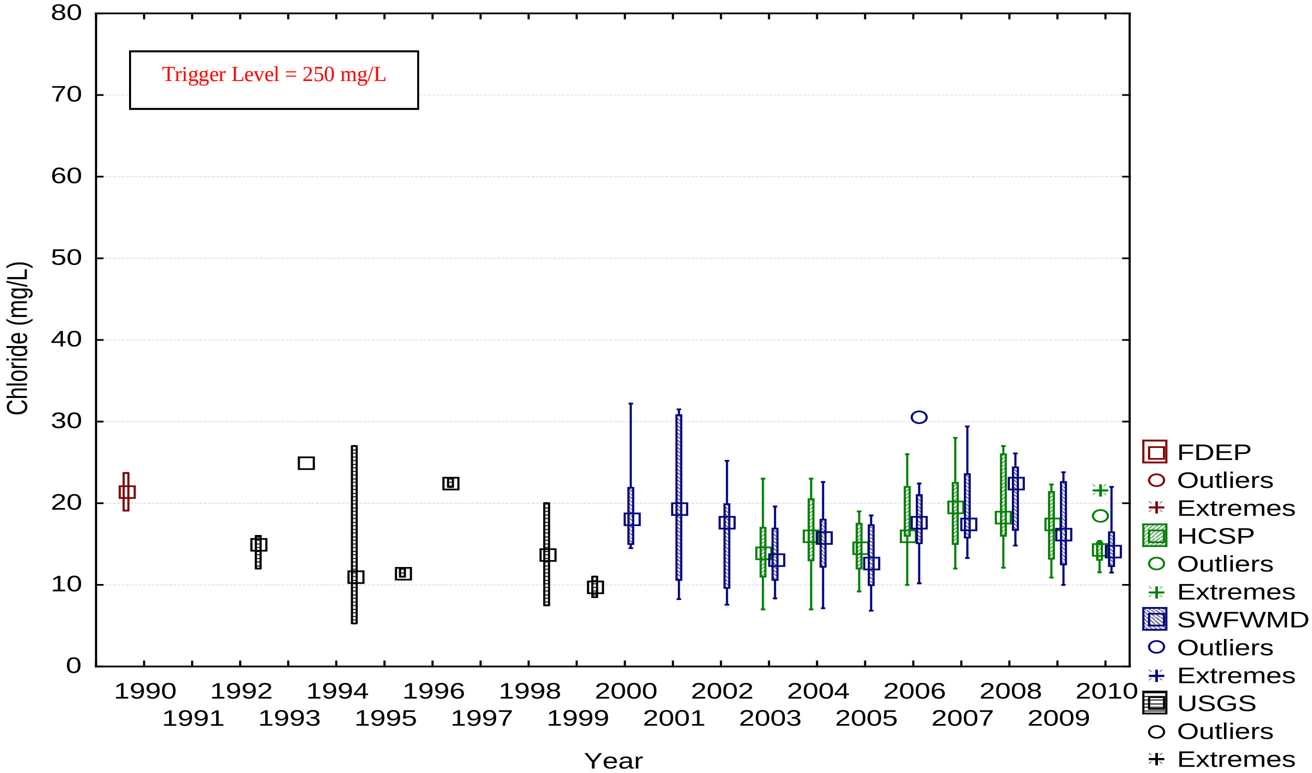

Figure 62. HCSW-1 Values of Chloride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

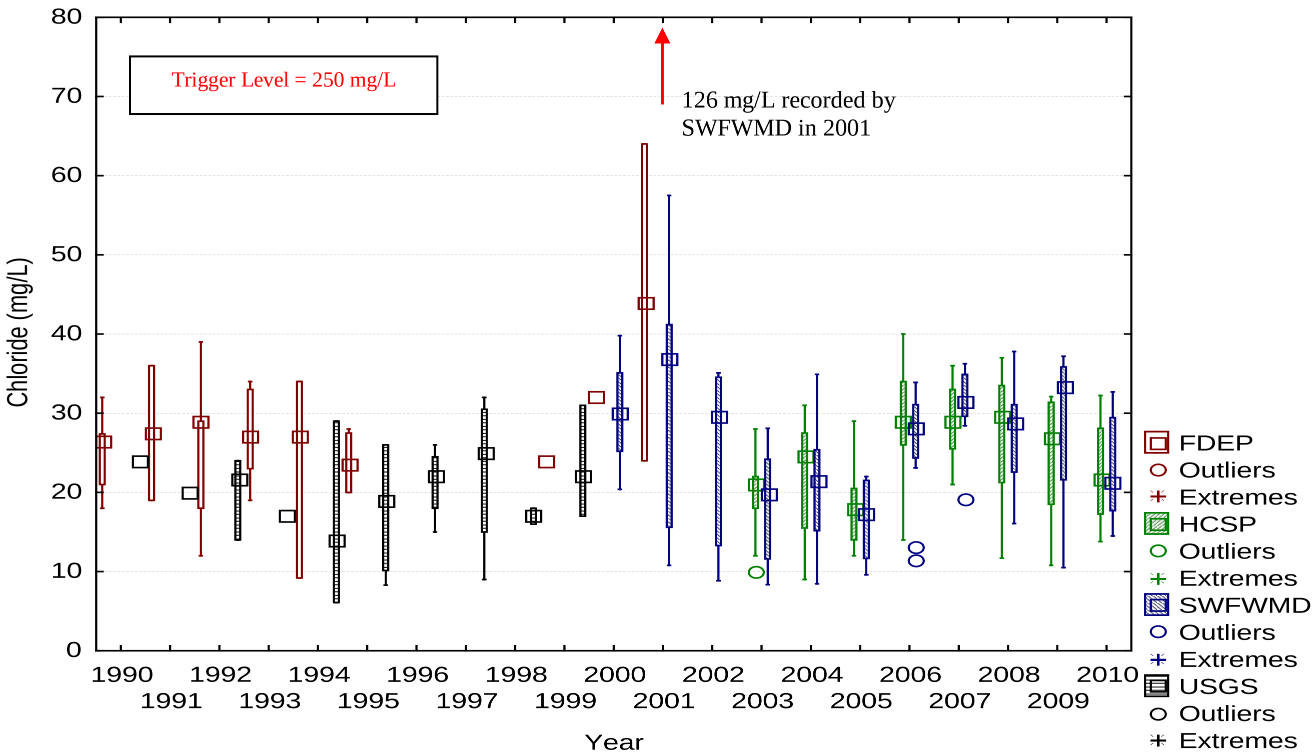

Figure 63. HCSW-4 Values of Chloride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

Fluoride

Concentrations of fluoride were well below the trigger levels of 4.0 mg/L established for HCSW-1, HCSW-2, and HCSW-3, as well as the 1.5 mg/L trigger level for HCSW-4 (Figure 64). Brushy Creek had similar concentrations to the Horse Creek stations. After dramatic changes with the MDL for fluoride in 2007, the MDLs have now been minimized and did not change from April 2008 through 2010. The fluoride concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Figures 65 and 66). The fluoride concentrations at HCSW-1 and HCSW-4 measured by the HCSP could not be analyzed for monotonic trends or correlations with water quantity because of changes in MDL's over the course of the HCSP. Based on an alternative trend analysis performed on data collected by SWFWMD from 2003-2010, there is a slightly increasing monotonic trend at HCSW-1 (Seasonal Kendall Tau with LOWESS, Tau = 0.43, $p = 0.01$, Sen slope = 0.01 mg/L per year), but there was no increasing or decreasing trend exhibited at HCSW-4 for fluoride (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 15). As with other dissolved ion parameters, the slope of the trend for fluoride at HCSW-1 is small compared to differences between primary and field duplicate samples (≤ 0.14 mg/L). The trend for fluoride and other ions may have been influenced by changes in mining practices, but the current concentrations are stable and not biologically harmful (Appendix I).

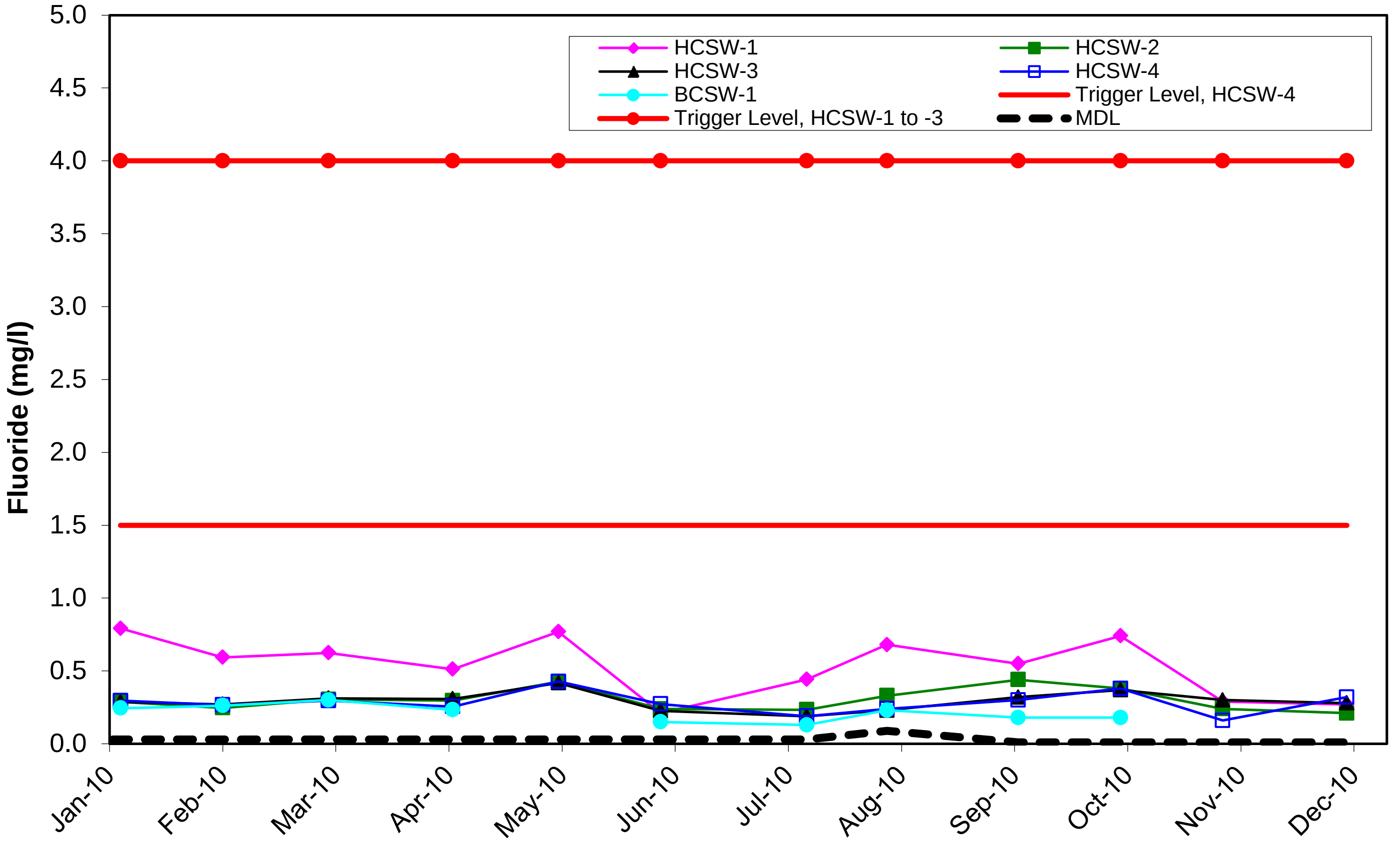

Figure 64. Fluoride Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2010.

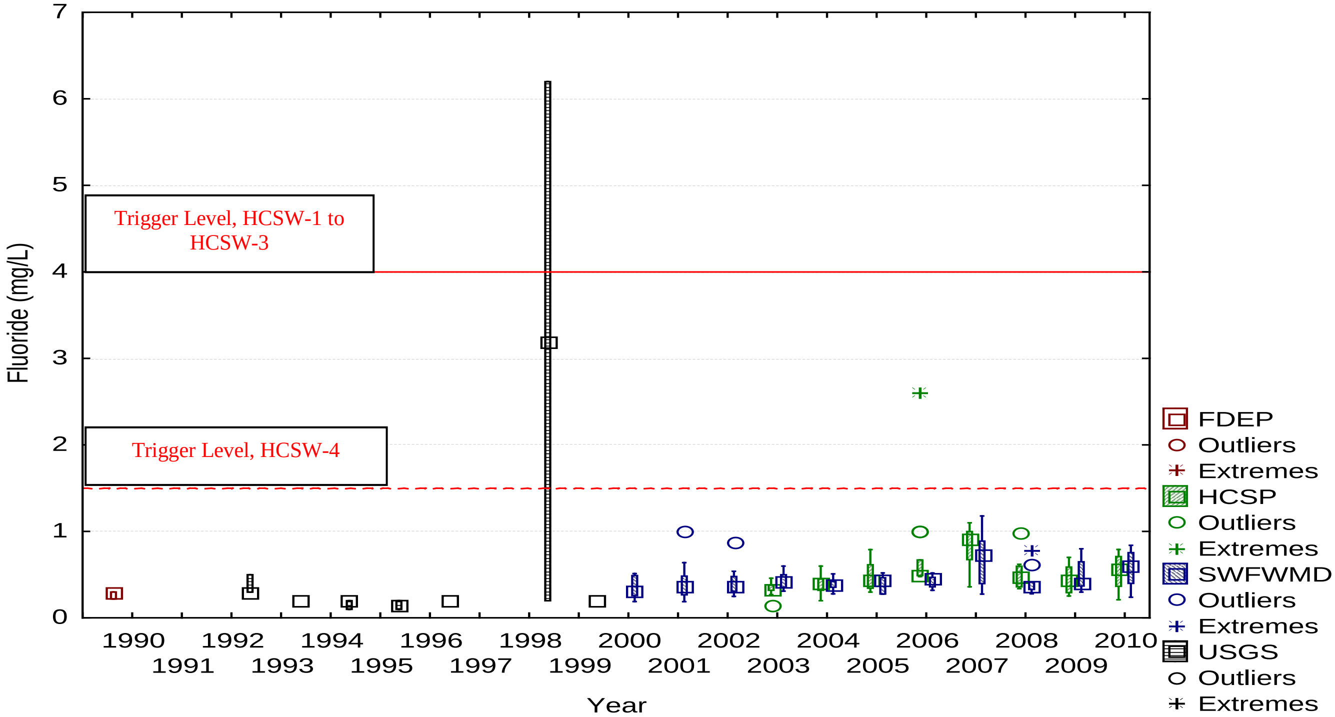

Figure 65. HCSW-1 Values of Fluoride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

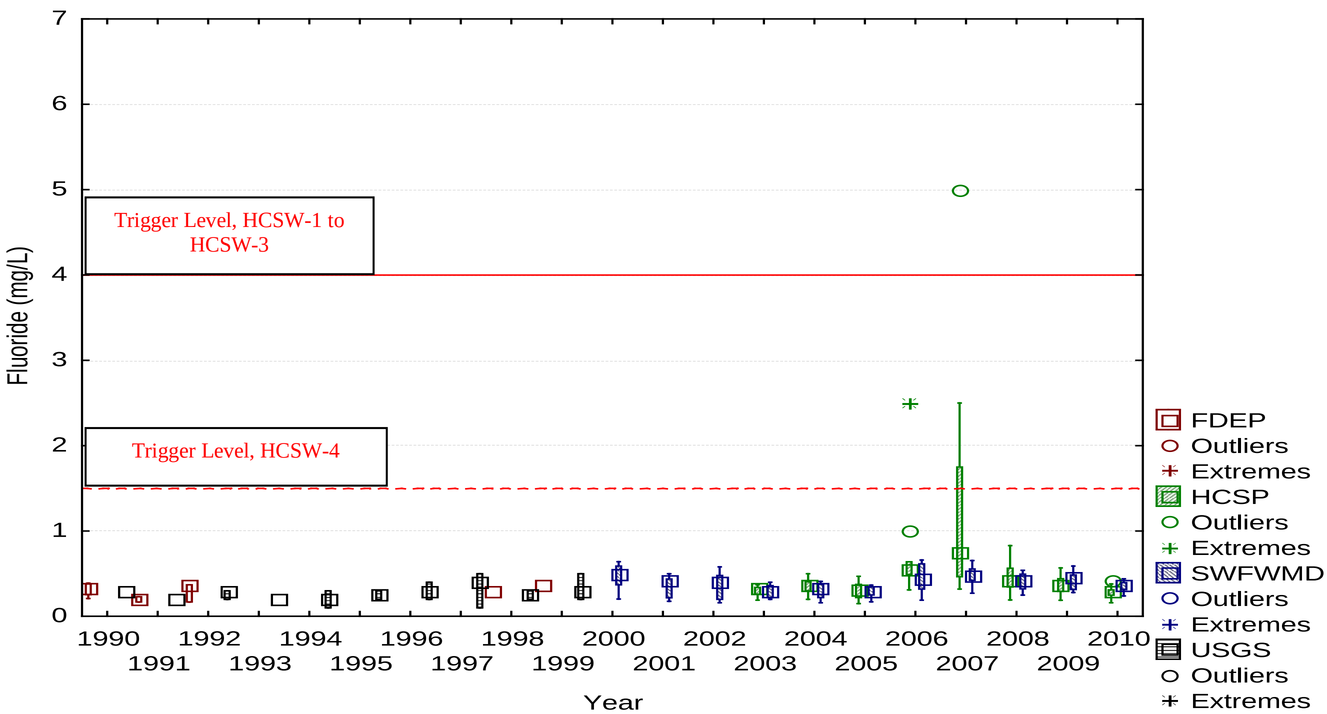

Figure 66. HCSW-4 Values of Fluoride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

Sulfate

Sulfate concentrations were below the trigger level of 250 mg/l at all stations during all sampling events in 2010 with the exception of HCSW-4 in November 2010 (Figure 67). 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 trends since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Figures 68 and 69, Table 15). In 2003 - 2010, levels of sulfate were significantly different among stations (ANOVA, $F = 37.80$, $p < 0.0001$, Table 16), 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, especially during the dry years of 2006 to 2007. Sulfate was negatively correlated with streamflow, rainfall, and NPDES discharge at HCSW-4 (Spearman's rank correlation $-0.33 > r > -0.78$ $p < 0.05$, Table 17), but was positively correlated with NPDES discharge ($r_s = 0.34$) at HCSW-1. Brushy Creek concentrations were lower than at Horse Creek stations.

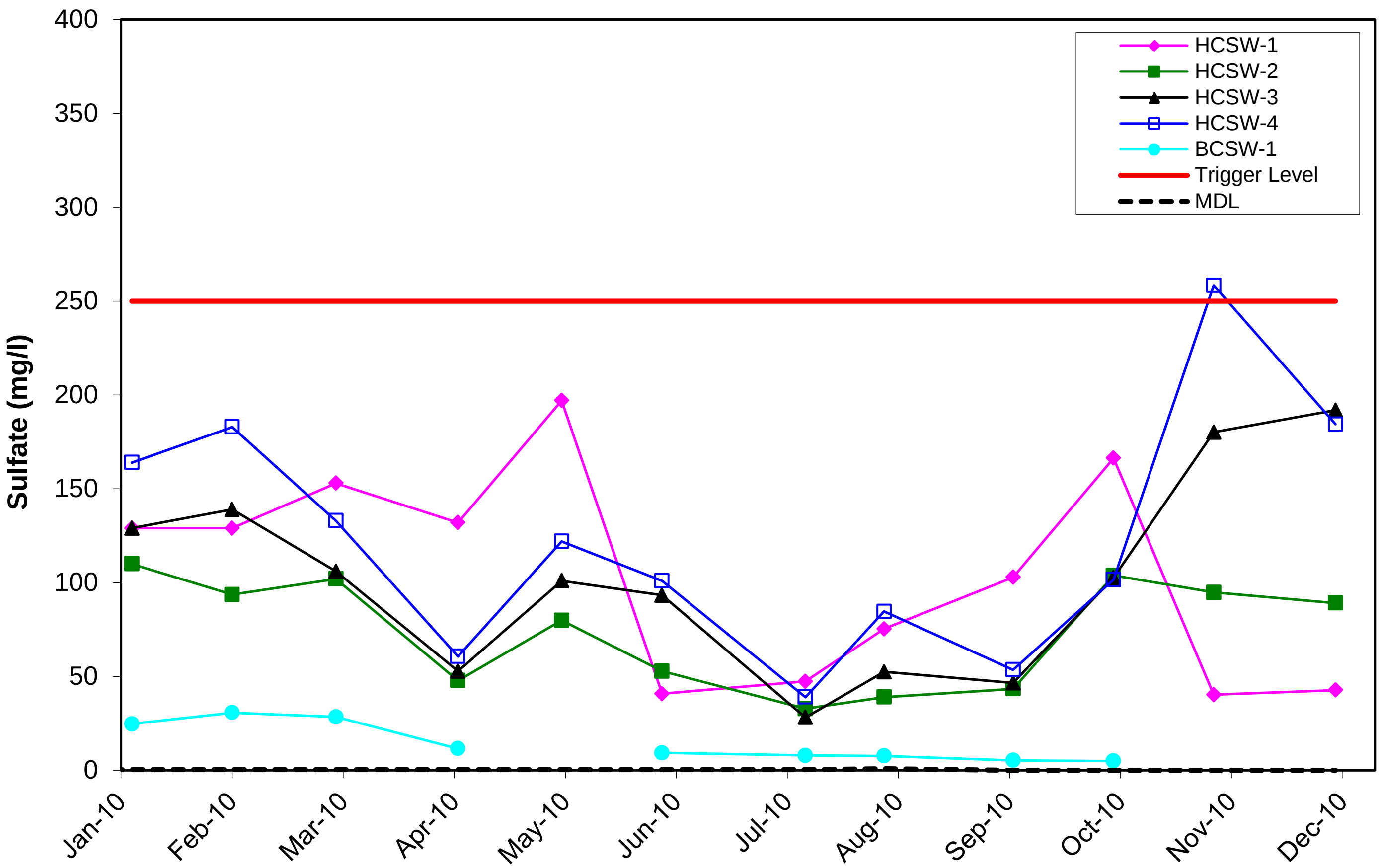

Figure 67. Sulfate Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2010.

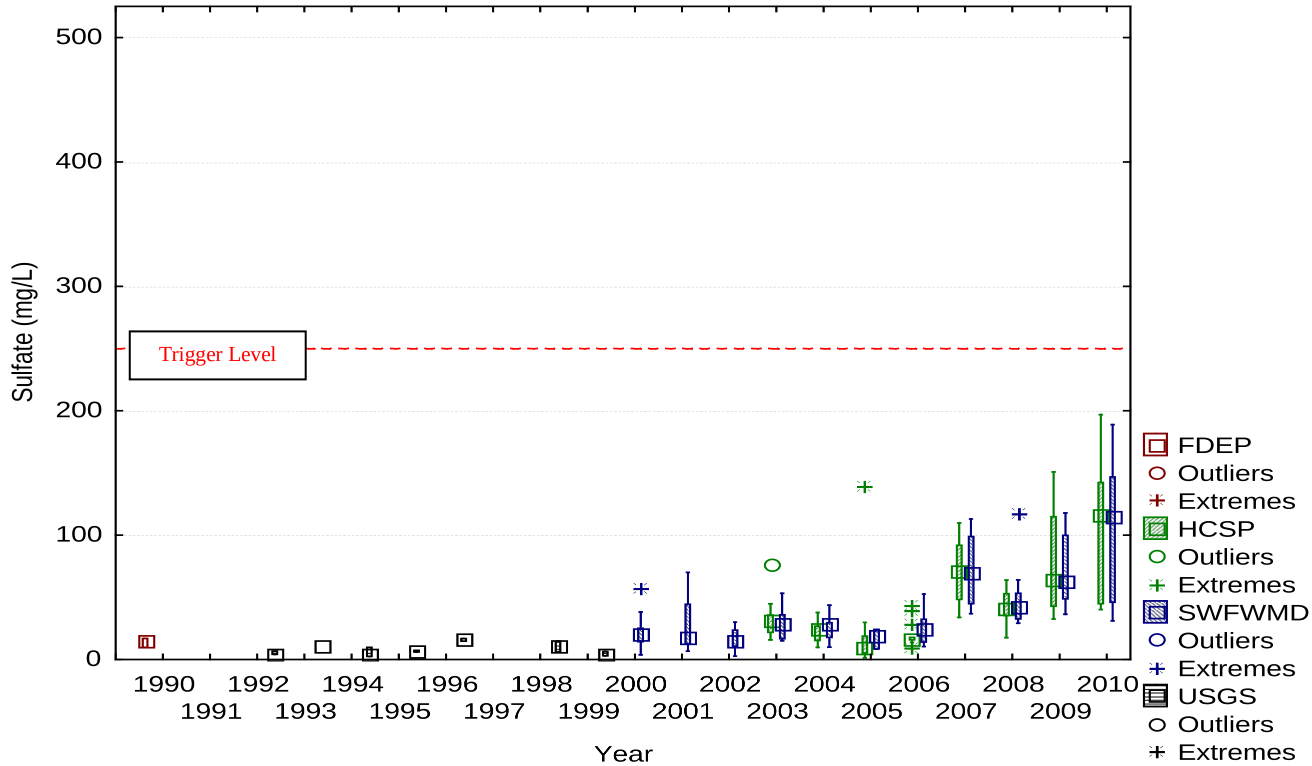

Figure 68. HCSW-1 Values of Sulfate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

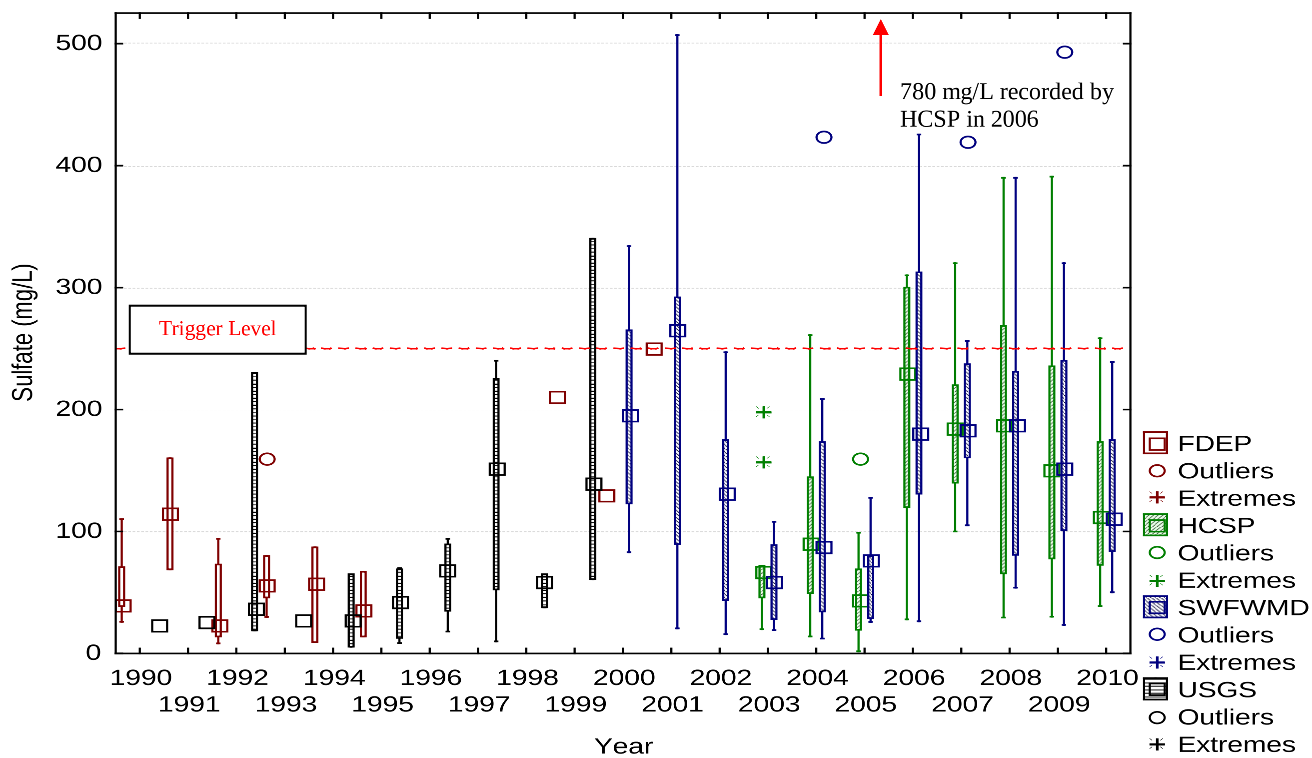

Figure 69. HCSW-4 Values of Sulfate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

Total Dissolved Solids

Total dissolved solids levels were below the trigger level of 500 mg/l during all sampling events at all stations with the exception of HCSW-4 in November 2010 (Figure 70). The TDS concentrations at HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$), however HCSW-1 exhibited an increasing trend since 2003 (Seasonal Kendall Tau with LOWESS, Tau = 0.38, $p = 0.03$, Sen slope = 10.66 mg/L per year, Figures 71 and 72, Table 15). The slope of the trend for HCSW-1 is small compared to differences between primary and field duplicate samples (≤44 mg/L). This potential trend is discussed in Appendix I.

As with sulfate concentrations, total dissolved solids levels over the course of the entire period of record were lowest at HCSW-1 and HCSW-2 and highest at HCSW-4 (ANOVA, F = 32.20, $p < 0.0001$, Table 16; Duncan's multiple range test, $p < 0.05$, Figure 70). Total dissolved solid levels were negatively correlated with streamflow, rainfall, and NPDES discharge at HCSW-4 (Spearman's rank correlation $-0.26 > r > -0.73$, $p < 0.05$), but positively correlated with NPDES discharge at HCSW-1 ($r_s = 0.37$, Table 17). Both sulfate and total dissolved solids at downstream stations are probably affected by agricultural irrigation return flows and groundwater seepage downstream in the same manner as discussed above for conductivity and calcium. Brushy Creek concentrations were lower than at Horse Creek stations. Dissolved ion concentrations at HCSW-1 have been affected by recent changes in mining practices, but the new levels appear to be stable and not biologically harmful (Appendix I).

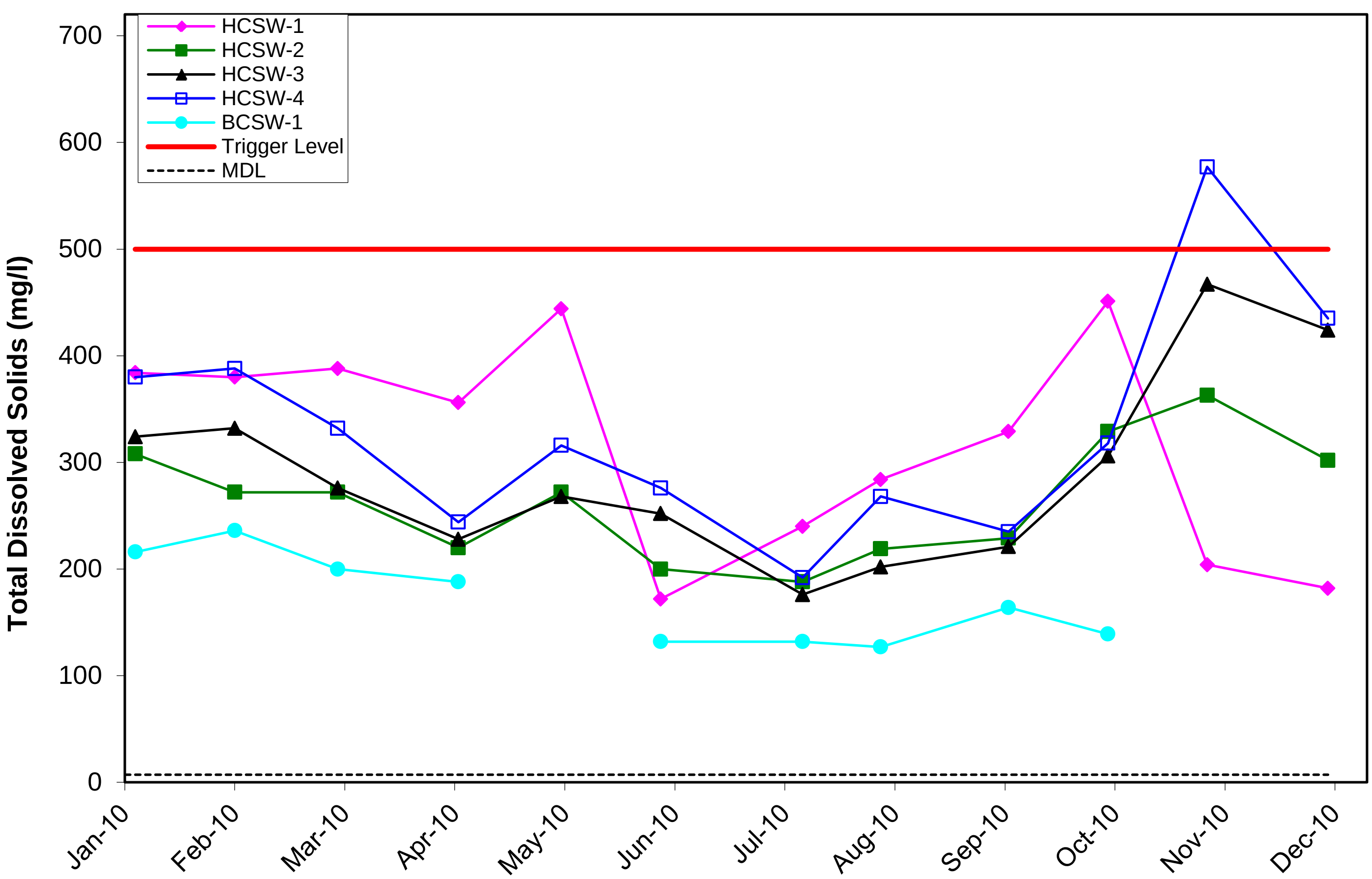

Figure 70. Levels of Total Dissolved Solids Obtained During Monthly HCSP Water Quality Sampling in 2010.

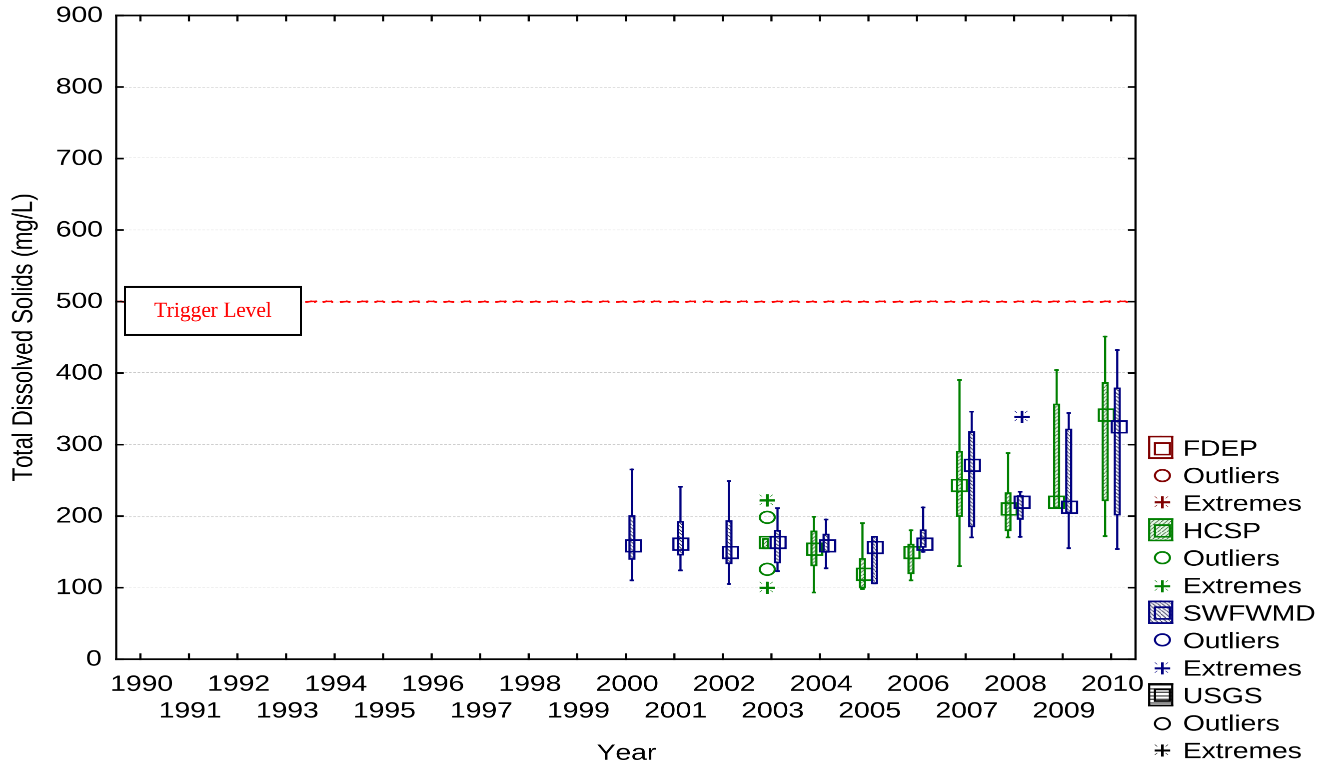

Figure 71. HCSW-1 Values of Total Dissolved Solids Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

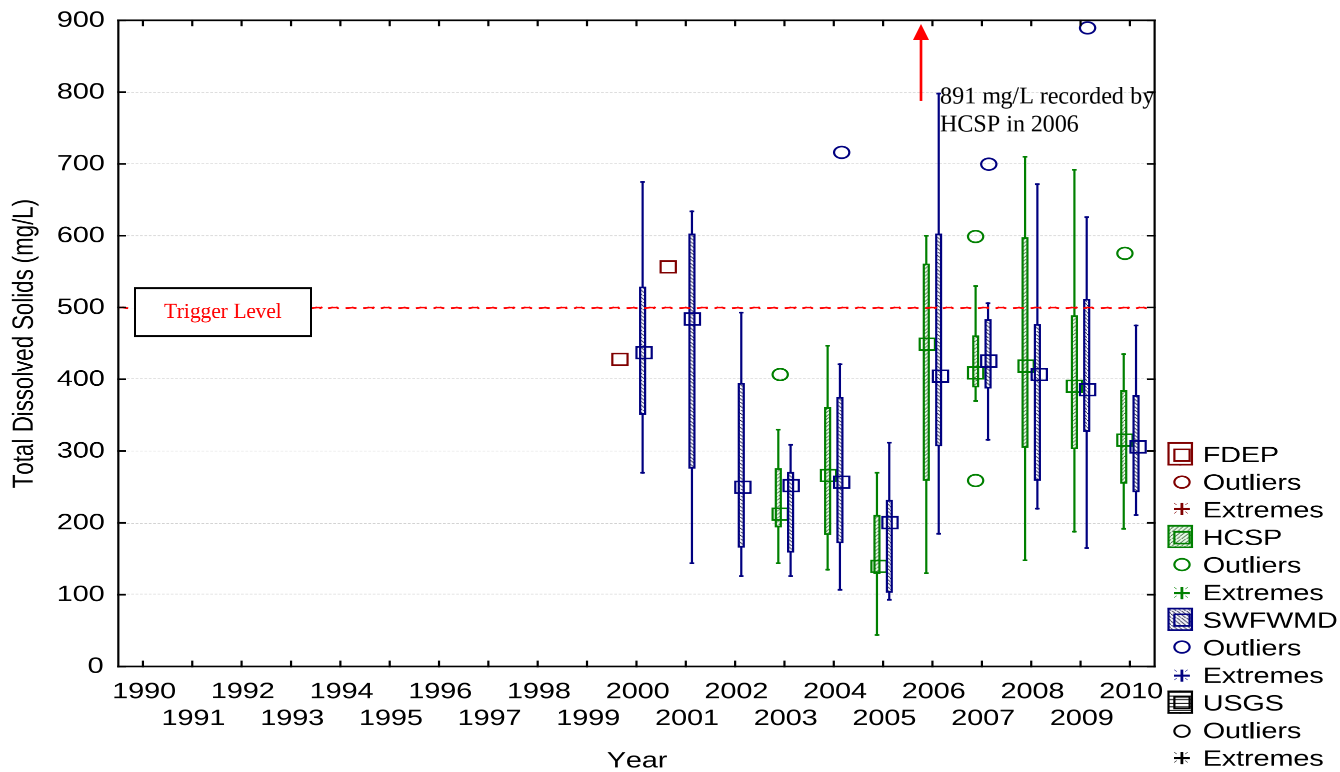

Figure 72. HCSW-4 Values of Total Dissolved Solids Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) for Years 1990 – 2010.

Total Fatty Acids, FL-PRO, and Total Amines

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). FL-PRO, fatty acid and amines all degrade biologically and/or photochemically within mine recirculation waters and clay settling areas (Patel and Schreiber 2001). 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.

In September 2009, these three parameters were removed from the HCSP based on recommendations from Mosaic, the TAG, and the PRMRWSA because they were seldom detected but may be added later should conditions warrant the addition.

Total Radium

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). 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). The study also found that general radiochemical concentrations in groundwater from the surficial aquifer were greater below unmined lands than reclaimed lands.

In Horse Creek during 2010, total radium[9] levels were below the trigger level of 5 pCi/L (Figure 73). There were no monotonic trends observed since 2003 for total radium at HCSW-1 or HCSW-4 (Seasonal Kendall Tau, $p > 0.05$, Table 15). Total radium levels during 2003-2010 were not significantly different among stations (ANOVA, $F = 2.25$, $p = 0.08$) (Figure 73, Table 16). Total radium was negatively correlated with NPDES discharge at HCSW-1 and HCSW- 4 (Spearman's correlations $-0.36 > r > -0.38$, $p < 0.05$), but not correlated with streamflow or rainfall at either station (Spearman's correlations, $p > 0.05$, Table 17). indicating that radium was higher when NPDES discharge was low. Brushy Creek concentrations were similar to Horse Creek stations.

9 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 as part of a calculated constituent is contrary to both laboratory and DEP SOPs.

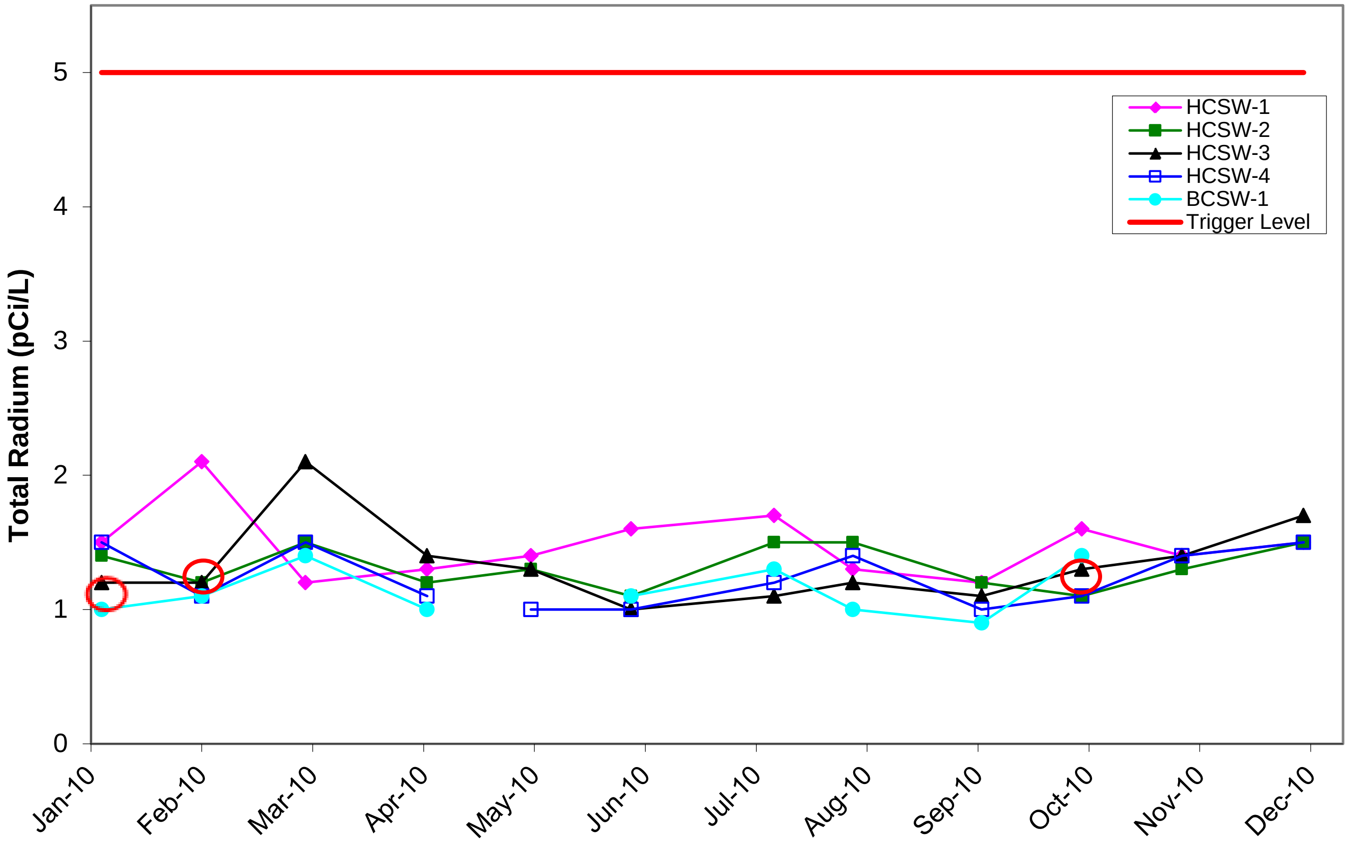

Figure 73. Levels of Total Radium Obtained During Monthly HCSP Water Quality Sampling in 2010. (Data from samples where both Radium 226 and Radium 228 were undetected are circled in red. All but three of the samples were undetected for one of the components.)

5.2.5 Summary of Water Quality Results

Water quality parameters in 2010 were almost always within the desirable range relative to trigger levels and water quality standards at the station closest to mining (HCSW-1, Table 18). Trigger levels were exceeded only twice at HCSW-1 in 2010: alkalinity in January and chlorophyll *a* in February. At HCSW-2, trigger levels were exceeded for dissolved oxygen during most of the year (Table 18). 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. HCSW-3 exceeded trigger levels for dissolved oxygen in April and July through September. HCSW-4 exceeded trigger levels for dissolved oxygen (July), sulfate (November), TDS (November), and iron (4 months). Dissolved oxygen triggers were exceeded during summer wet months of 2010, when high temperatures reduce the oxygen carrying capacity of the stream. Sulfate and TDS were exceeded in the dry season, when low rainfall and streamflow likely led to increased groundwater inputs from baseflow and agricultural runoff. Dissolved iron concentrations consistently exceeded the trigger value set at HCSW-4, but Mosaic and the PRMRWSA agree that the trigger value at that station has been set too low given historical and upstream concentrations of dissolved iron. Based on impact assessments already completed, none of the observed exceedances can be attributed to mining.

Several of the trends detected during the statistical analysis either have an estimated slope that 1) was not in the direction of an adverse trend (color, ammonia) or 2) was very small compared to limits in laboratory prediction or the observed differences between primary and duplicate field samples (pH, fluoride). For the trends with higher estimated rates of change (orthophosphate and various dissolved ions), the potential trends are discussed in Appendix I. Appendix I shows that the apparent trend in orthophosphate from 2003-2010 is caused by a data bias, and that extending the period of record eliminates this trend. The trend for specific conductivity and other ions may have been influenced by changes in mining practices, but the current concentrations are stable and not biologically harmful.

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 dissolved ions (specific conductivity, calcium, chloride, 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).

Water quality parameters were compared with water quantity variables recorded during the same month: average daily streamflow for the month, average daily NPDES discharge for the month, and total monthly rainfall (Figure 74). In general, pH, dissolved oxygen, and most dissolved ions are higher when the overall quantity of water in the Horse Creek system is low. (In 2010, specific conductivity, sulfate, and TDS showed the opposite pattern with NPDES discharge at HCSW-1; this is discussed as part of the trend analysis in Appendix I.) Conversely, turbidity, color, iron, and some nutrients are high when the water quantity is also high (Figure 74). When water quantity in Horse Creek is low, the stream may be pooled or slow-moving, leading to algal blooms that may increase pH and chlorophyll a. In addition, the majority of water in the stream during low quantity periods may be from groundwater (seepage or agricultural runoff); groundwater has a higher concentration of dissolved ions than surface water. When water quantity is high, an increased amount of sediment and organic debris is washed into the stream, leading to increases in turbidity, color, iron, and nitrogen.

Table 18. Instances of Trigger Level Exceedance Observed in 2010 HCSP Monthly Monitoring.

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at Goose Pond	HCSW-2	2/2/2010	Dissolved Oxygen (mg/l)	2.67	5
Horse Creek at Goose Pond	HCSW-2	3/3/2010	Dissolved Oxygen (mg/l)	3.75	5
Horse Creek at Goose Pond	HCSW-2	4/6/2010	Dissolved Oxygen (mg/l)	1.42	5
Horse Creek at Goose Pond	HCSW-2	5/5/2010	Dissolved Oxygen (mg/l)	0.56	5
Horse Creek at Goose Pond	HCSW-2	6/2/2010	Dissolved Oxygen (mg/l)	0.6	5
Horse Creek at Goose Pond	HCSW-2	7/12/2010	Dissolved Oxygen (mg/l)	0.62	5
Horse Creek at Goose Pond	HCSW-2	8/3/2010	Dissolved Oxygen (mg/l)	0.56	5
Horse Creek at Goose Pond	HCSW-2	9/8/2010	Dissolved Oxygen (mg/l)	0.72	5
Horse Creek at Goose Pond	HCSW-2	10/6/2010	Dissolved Oxygen (mg/l)	0.93	5
Horse Creek at Goose Pond	HCSW-2	11/3/2010	Dissolved Oxygen (mg/l)	1.28	5
Horse Creek at State Road 70	HCSW-3	4/6/2010	Dissolved Oxygen (mg/l)	4.74	5
Horse Creek at State Road 70	HCSW-3	7/12/2010	Dissolved Oxygen (mg/l)	3.67	5
Horse Creek at State Road 70	HCSW-3	8/3/2010	Dissolved Oxygen (mg/l)	4.61	5
Horse Creek at State Road 70	HCSW-3	9/8/2010	Dissolved Oxygen (mg/l)	4.09	5
Horse Creek at State Road 72	HCSW-4	7/12/2010	Dissolved Oxygen (mg/l)	4.31	5
Horse Creek at State Road 64	HCSW-1	2/2/2010	Chlorophyll a (mg/m^3)	15.4	15
Horse Creek at State Road 72	HCSW-4	4/6/2010	Dissolved Iron (mg/L)	0.615	0.3
Horse Creek at State Road 72	HCSW-4	7/12/2010	Dissolved Iron (mg/L)	0.719	0.3
Horse Creek at State Road 72	HCSW-4	8/3/2010	Dissolved Iron (mg/L)	0.321	0.3
Horse Creek at State Road 72	HCSW-4	9/8/2010	Dissolved Iron (mg/L)	0.421	0.3
Horse Creek at State Road 64	HCSW-1	1/5/2010	Alkalinity (mg/L)	109	100
Horse Creek at State Road 72	HCSW-4	11/3/2010	Sulfate (mg/L)	258	250
Horse Creek at State Road 72	HCSW-4	11/3/2010	TDS (mg/L)	577	500

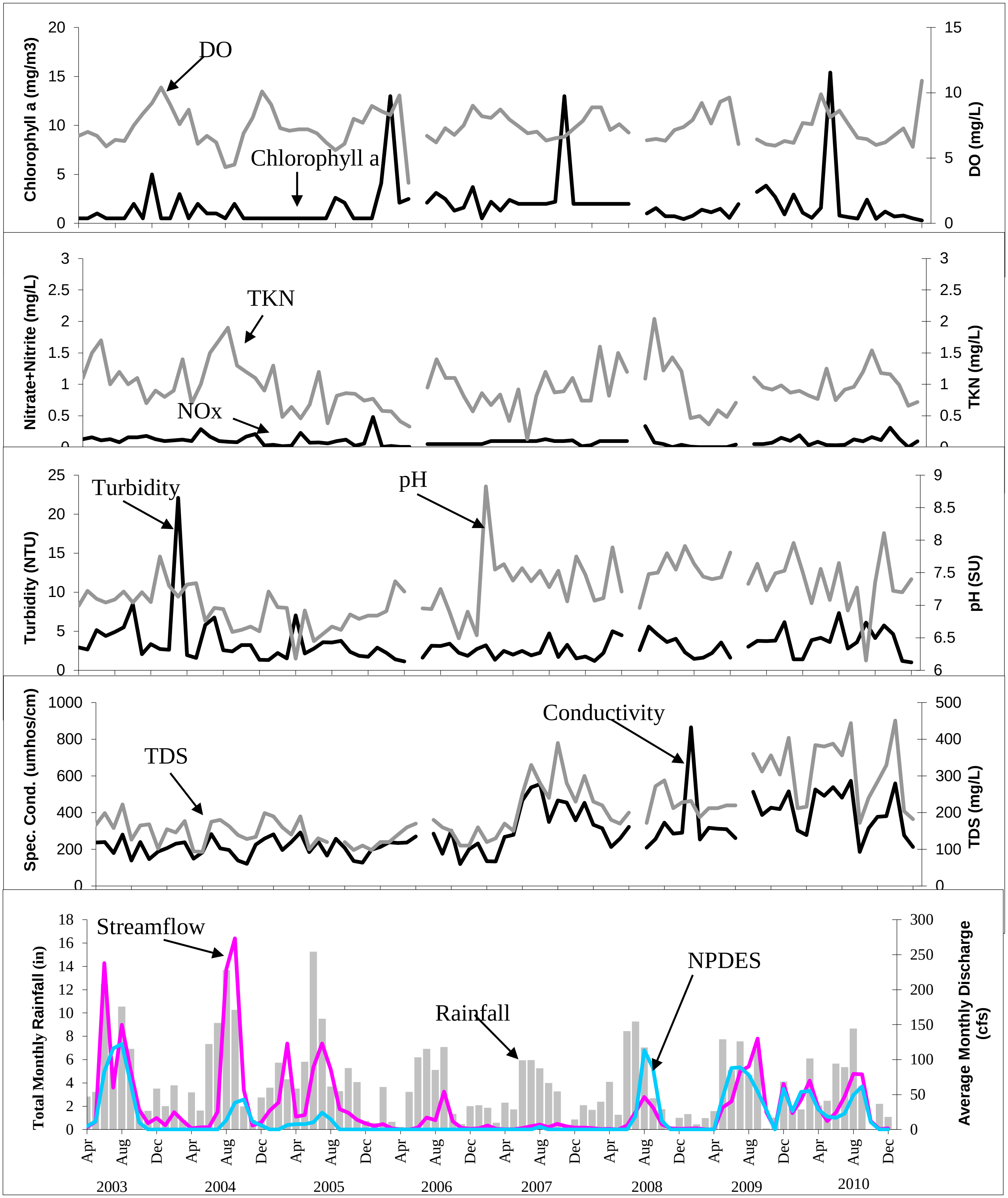

Figure 74. HCSP Water Quality Correlations With Average Monthly NPDES Discharge, Average Monthly Streamflow, and Total Monthly Rainfall at HCSW-1 in 2003 – 2010.

5.3 Benthic Macroinvertebrates

Benthic macroinvertebrate sampling was conducted at each of the four sampling stations on 20 April 2010, 28 September 2010 and HCSW-1 on 4 November 2010 and the remaining three downstream stations on 11 November 2010. In November 2010, there was a significant rainfall event that occurred the day prior to the scheduled sampling event, causing water levels to rise significantly at the three downstream stations. Since water levels did not appear to have been affected at HCSW-1, sampling occurred on 4 November 2010. Cardno ENTRIX waited a week for water levels to decrease to pre-rainfall levels before sampling the other stations on 11 November 2010.

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. Since the turbidity of the NPDES discharge in 2010 was low, it is unlikely that suspended particles within the discharge made a significant contribution to sediment deposition in the stream. Habitat smothering in 2010 was fairly high at most stations, because stream velocity was very low during the dry season followed by high runoff during the wet season.

The habitat quality of Horse Creek was within the optimal or sub-optimal range during all sampling events in 2010 (Table 19), as it was for 2003 to 2009 (Figures 75 - 78[10]). Some of the minor variation among the sampling events for a given station primarily reflects differences in habitat quality and quantity 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.

[10] An asterisk (*) represents a sampling event that did not meet the required SOP. See Appendix J for more details.

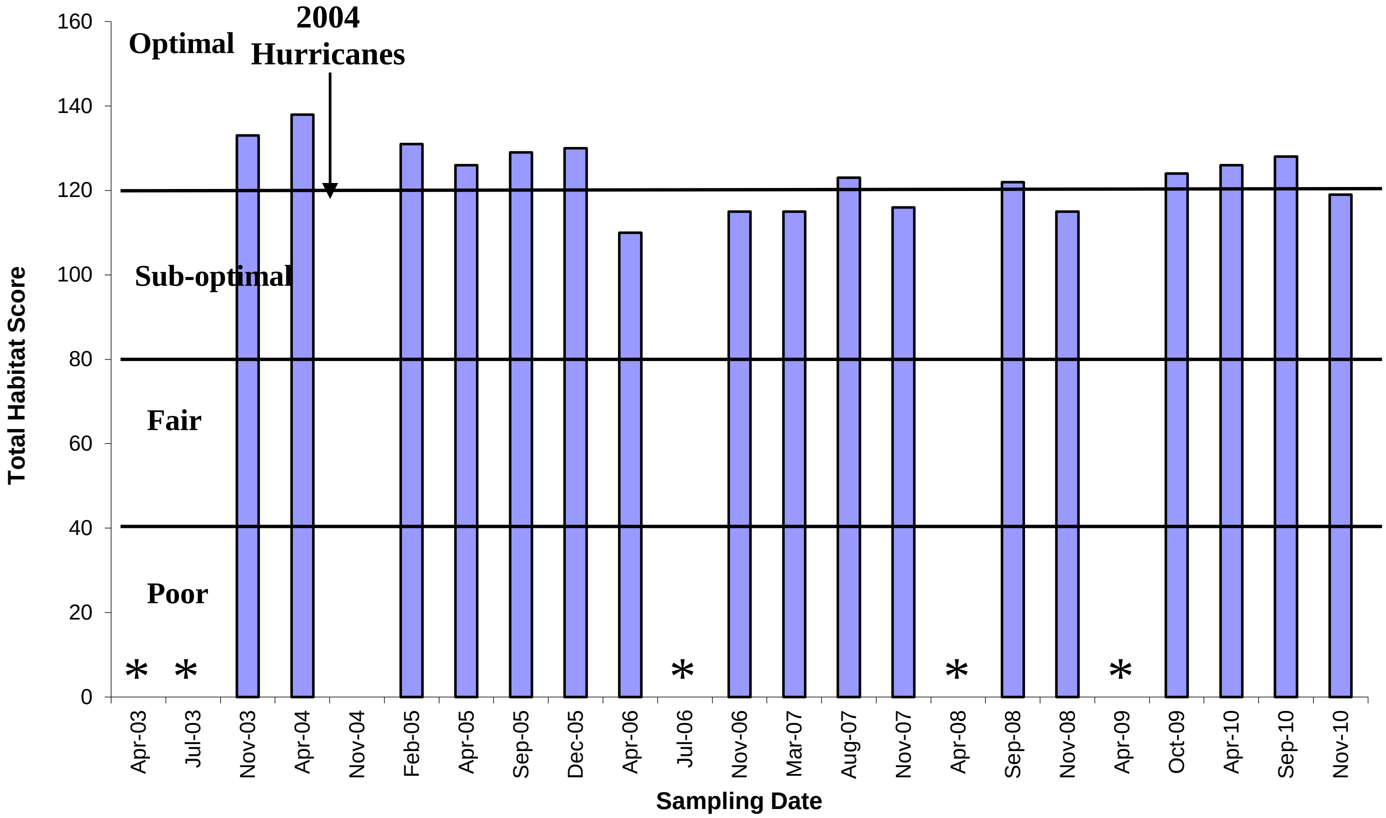

Figure 75. Total Habitat Scores Obtained During HCSP Biological Sampling Events at HCSW-1 from 2003-2010. (HCSW-1 November 2004 score omitted because of sampler oversight.)

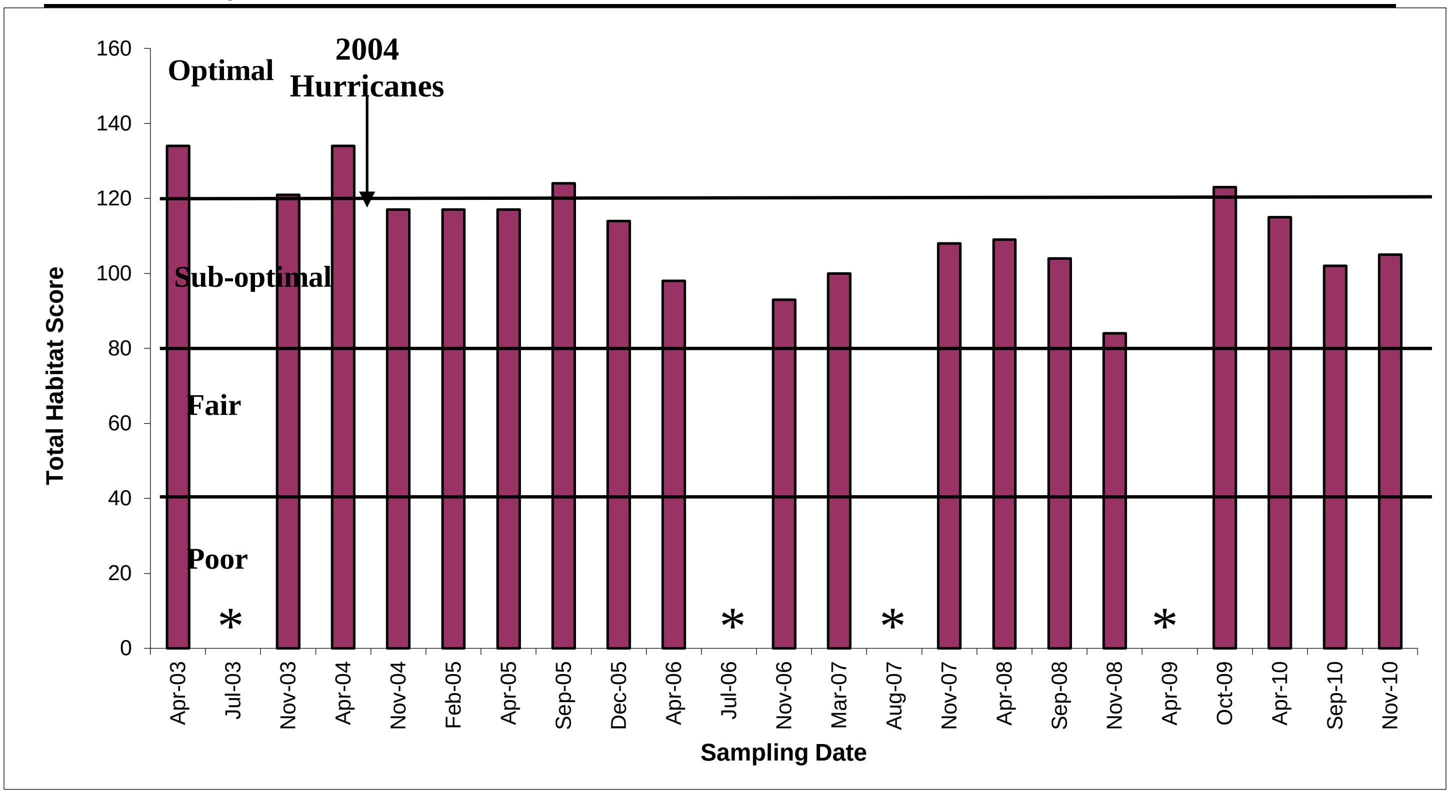

Figure 76. Total Habitat Scores Obtained During HCSP Biological Sampling Events at HCSW-2 from 2003-2010.

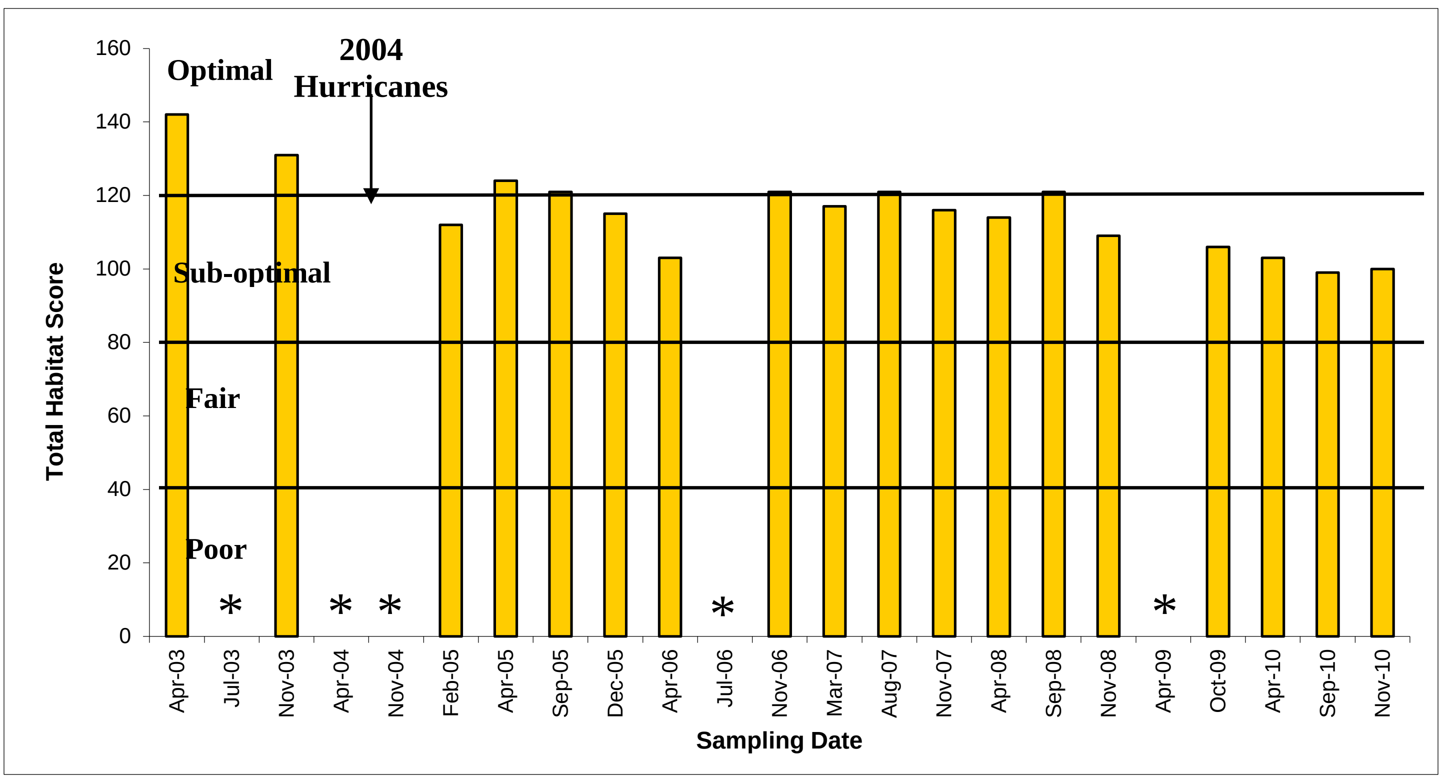

Figure 75. Total Habitat Scores Obtained During HCSP Biological Sampling Events at HCSW-3 from 2003-2010.

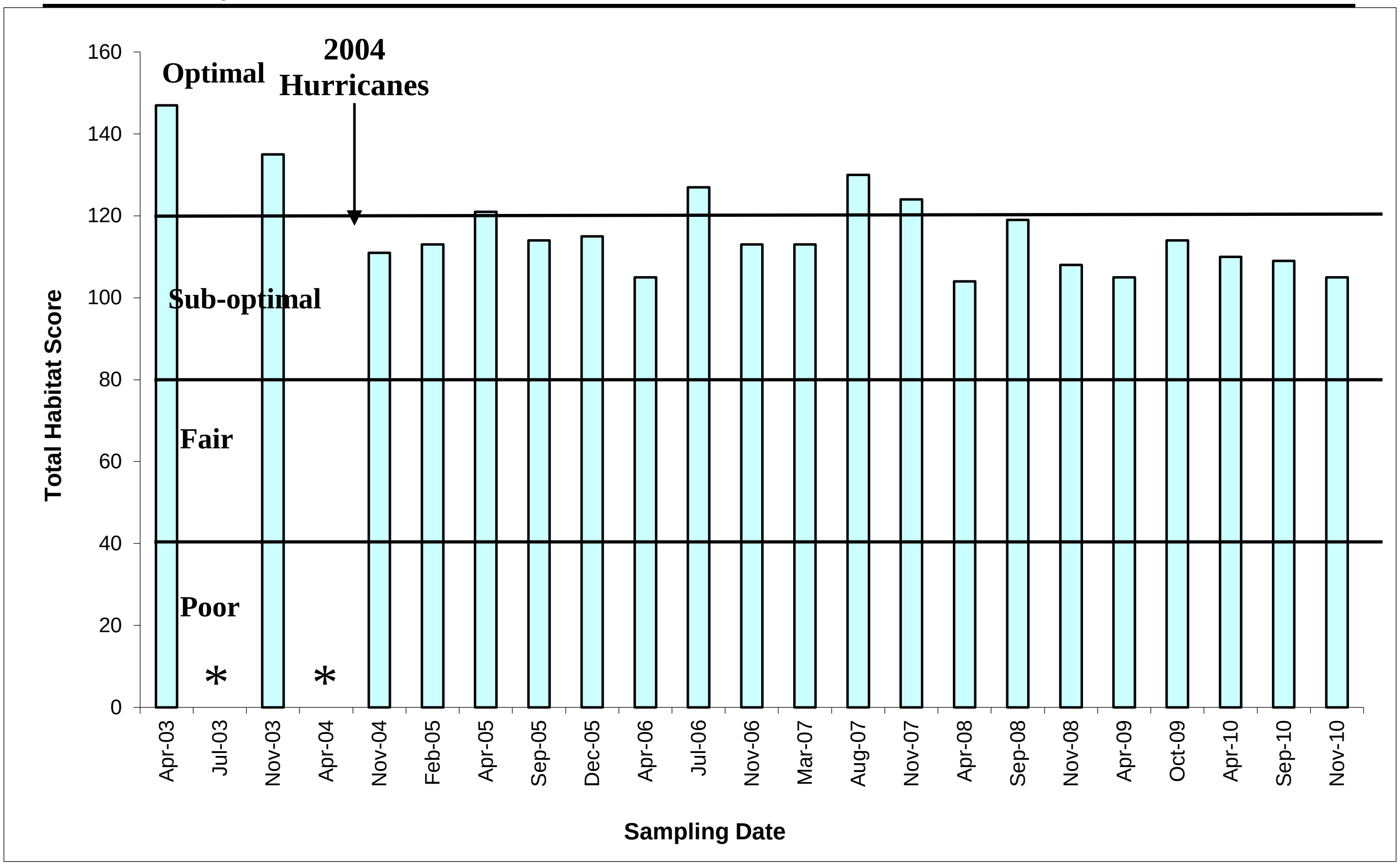

Figure 78. Total Habitat Scores Obtained During HCSP Biological Sampling Events at HCSW-4 from 2003-2010.

5.3.2 Stream Condition Index

A database containing a list of the benthic macroinvertebrate taxa collected during 2003 - 2010 is on the attached CD-ROM[11]. Table 20 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 2010. The numbers of individuals included in Table 20 represent the number extracted from the whole sample for identification (i.e., all 20 dipnet sweeps), which were 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.

[11] For the 2010 annual report, we have reevaluated the HCSP SCI data with strict interpretation of FDEP SOP guidance (Appendix J), including the upper and lower limits of the SOP target number of individuals, the SOP target of 90 days of previous flow, and the SOP target of less than a 0.5 m water level increase in the previous 30 days. As a result of this evaluation, some SCI scores have been removed from the 2010 analysis (Appendix J, *red italics*). In addition, some SCI results with more than the target number of individuals were randomly resampled to provide an unbiased result. In future reports, those samples with less than the SOP target range of individuals may be revaluated if sufficient material can be resorted from stored samples.

Table 19. Habitat Scores Obtained During HCSP Biological Sampling Events in 2010

	HCSW-1			HCSW-2			HCSW-3			HCSW-4		
	20 April 2010	**28 September 2010**	**4 November 2010**	**20 April 2010**	**28 September 2010**	**11 November 2010**	**20 April 2010**	**28 September 2010**	**11 November 2010**	**20 April 2010**	**28 September 2010**	**11 November 2010**
Substrate Diversity	15	14	16	8	7	8	11	7	7	10	9	5
Substrate Availability	12	9	9	13	8	5	5	3	4	4	3	3
Water Velocity	17	19	13	13	11	13	16	18	17	18	18	17
Habitat Smothering	14	18	13	15	10	13	11	11	12	10	11	12
Artificial Channelization	20	20	20	20	20	20	20	20	20	20	20	20
Bank Stability												
Right Bank	5	5	5	9	9	9	5	5	5	5	5	5
Left Bank	5	5	5	7	7	7	5	5	5	5	5	5
Riparian Buffer Zone Width												
Right Bank	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
Riparian Zone Vegetation Quality												
Right Bank	9	9	9	5	5	5	5	5	5	9	9	9
Left Bank	9	9	9	5	5	5	5	5	5	9	9	9
Total Score*	126	128	119	115	102	105	103	99	100	110	109	105
Habitat Descriptor	Optimal	Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-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 20. SCI Metrics Calculated for Benthic Macroinvertebrates Collected at Four Locations on Horse Creek for the HCSP During 2010

SCI Metric	HCSW-1						HCSW-2					
	20 April 2010		28 September 2010		4 November 2010		20 April 2010		28 September 2010		11 November 2010	
	Raw	SCI Value	Raw Score	SCI	Raw	SCI Value	Raw	SCI Value	Raw	SCI Value	Raw	SCI Value
Total Taxa	19.5	1.4	25.5	3.8	25.0	3.6	28.5	4.8	21.0	2.0	34.0	7.2
Ephemeropteran Taxa	1.5	3.0	3.5	7.0	3.5	7	1.0	2.0	1.0	2.0	1.0	2.0
Trichopteran Taxa	2.0	2.9	3.5	5.0	4.0	5.7	0.5	0.7	0	0	0	0
Percent Filterer Taxa	8.4	1.9	7.0	1.5	2.0	0.3	5.3	1.1	0.8	0	6.7	1.5
Long-lived Taxa	1.5	3.8	2.0	5.0	1.0	2.5	1.0	2.5	0	0	1.0	2.5
Clinger Taxa	6.0	7.5	5.5	6.9	5.0	6.3	0	0	0	0	0.5	0.6
Percent Dominant Taxon	47.1	1.6	31.7	5.1	51.0	0.7	23.0	7.1	34.0	4.5	20.7	7.6
Percent Tanytarsini	2.5	3.8	2.5	3.7	1.3	2.4	9.0	7.0	0.8	0.9	6.6	6.1
Sensitive Taxa	2.0	2.2	4.0	4.4	3.0	3.3	0	0	0	0	0	0
Percent Very Tolerant Taxa	6.2	5.2	2.2	7.2	2.7	8.4	34.0	1.3	74.1	0	41.8	0.9
Total SCI Score	36.9		55.2		44.6		29.4		10.5		31.5	
Interpretation	Healthy		Healthy		Healthy		Impaired		Impaired		Impaired	
Total Number of Individuals	163		162		152		150		129*		130*	
SCI Metric	HCSW-3						HCSW-4					
	20 April 2010		28 September 2010		11 November 2010		20 April 2010		28 September 2010		11 November 2010	
	Raw	SCI Value	Raw	SCI Value	Raw	SCI Value	Raw	SCI Value	Raw	SCI Value	Raw	SCI Value
Total Taxa	31.0	6.0	32.0	6.4	38.0	8.8	28.0	4.8	37.5	8.6	23.5	3.0
Ephemeropteran Taxa	5.0	10.0	4.5	9.0	5.0	10.0	4.5	9.0	3.5	7.0	3.5	7.0
Trichopteran Taxa	3.0	4.3	4.5	6.4	3.5	5.0	4.0	5.7	3.0	4.3	4.5	6.4
Percent Filterer Taxa	26.2	6.5	16.2	3.9	8.8	2.0	33.0	8.1	5.3	1.1	18.3	4.4
Long-lived Taxa	0	0	2.0	5.0	2.0	5.0	0.5	1.3	2.0	5.0	1.5	3.8
Clinger Taxa	6.0	7.5	4.5	5.6	5.5	6.9	7.5	9.4	6.0	7.5	7.0	8.8
Percent Dominant Taxon	27.1	6.1	12.3	9.5	22.2	7.2	24.7	6.7	14.9	8.9	44.8	2.1
Percent Tanytarsini	10.6	7.2	4.2	5.0	6.0	5.8	17.3	8.8	1.7	3.0	0.7	1.5
Sensitive Taxa	2.0	2.2	3.0	3.3	2.5	2.8	3.5	3.9	4.0	4.4	4.0	4.4
Percent Very Tolerant Taxa	17.2	3.0	9.5	4.3	9.3	4.3	14.3	3.5	23.7	2.2	1.3	7.9
Total SCI Score	58.7		64.9		64.2		67.9		57.8		54.9	
Interpretation	Healthy		Healthy		Healthy		Exceptional		Healthy		Healthy	
Total Number of Individuals	158		143		151		150		148		151	

* < recommended 150 individuals, acceptable range 140 - 160

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. Figures 79-82[12] illustrate the number of taxa collected at each of the HCSP stations during the monitoring events. 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). When considered over time from 2003 to 2010, the total taxa were variable over time at each station, but their scores did not increase or decrease over time (Kendall Tau, $p > 0.05$) and were not significantly different between stations (ANOVA: $F = 1.13$, $p = 0.34$).

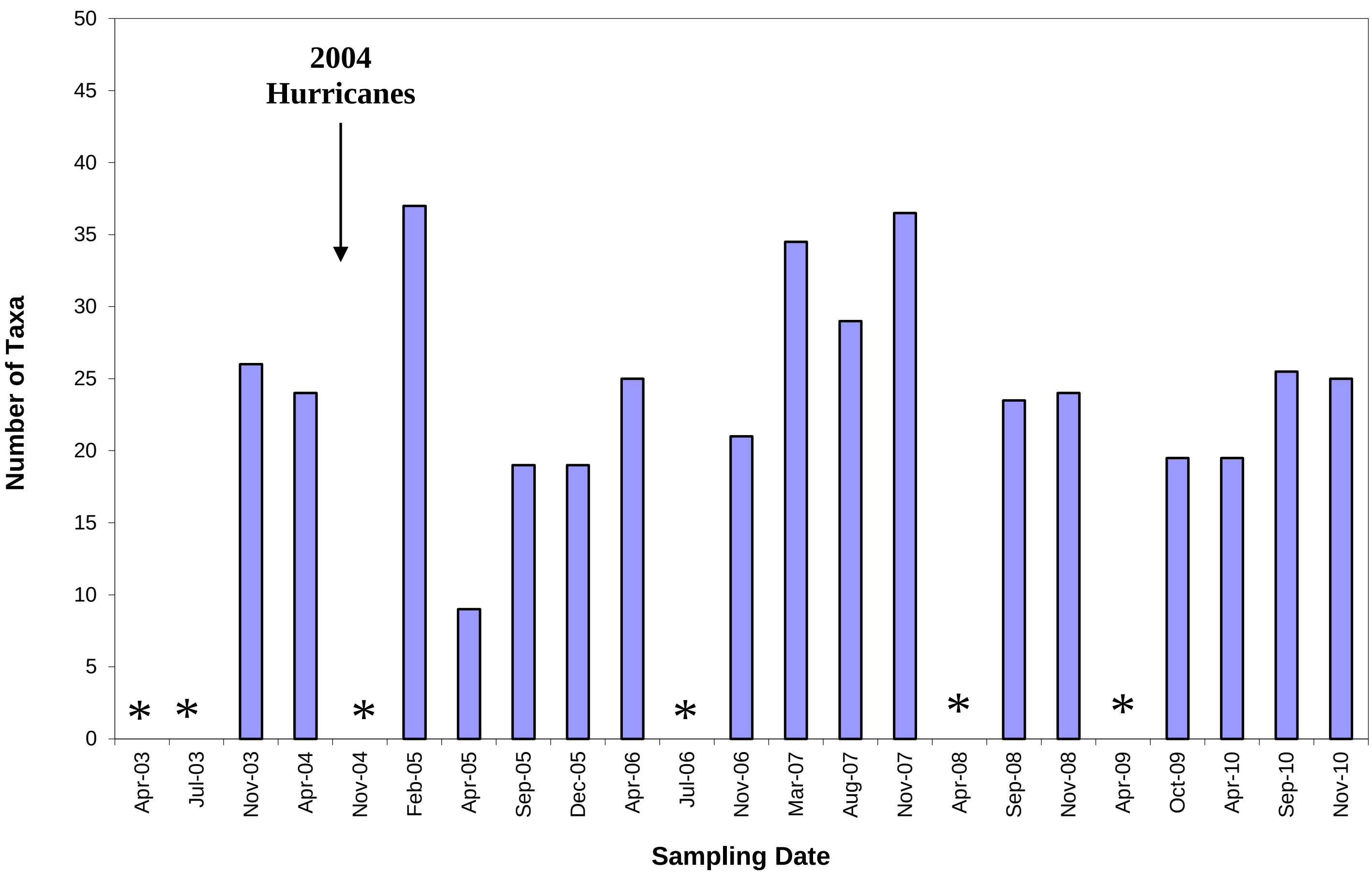

Figure 79. Number of Invertebrate Taxa Collected from HCSW-1 for the HCSP in 2003 – 2010.

[12] An asterisk (*) represents a sampling event that did not meet the required SOP. See Appendix J for more details.

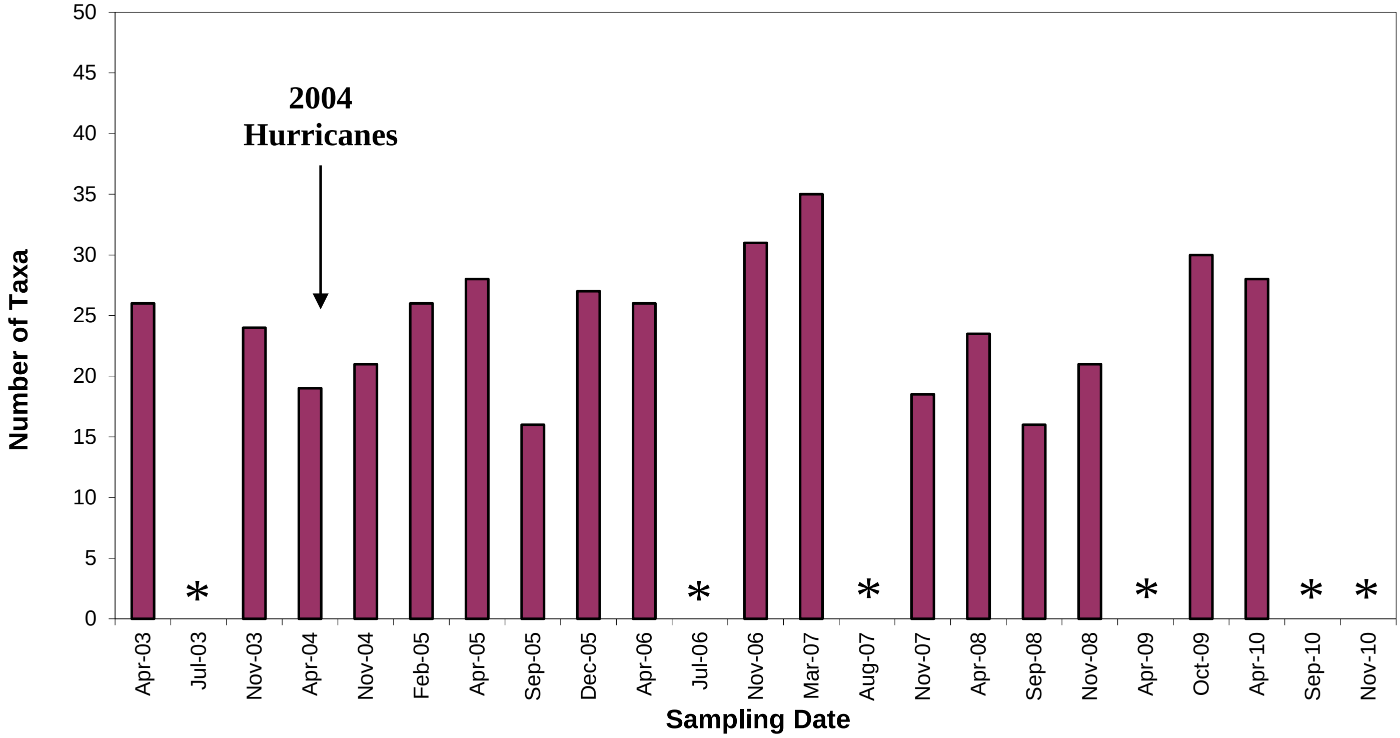

Figure 80. Number of Invertebrate Taxa Collected from HCSW-2 for the HCSP in 2003 - 2010.

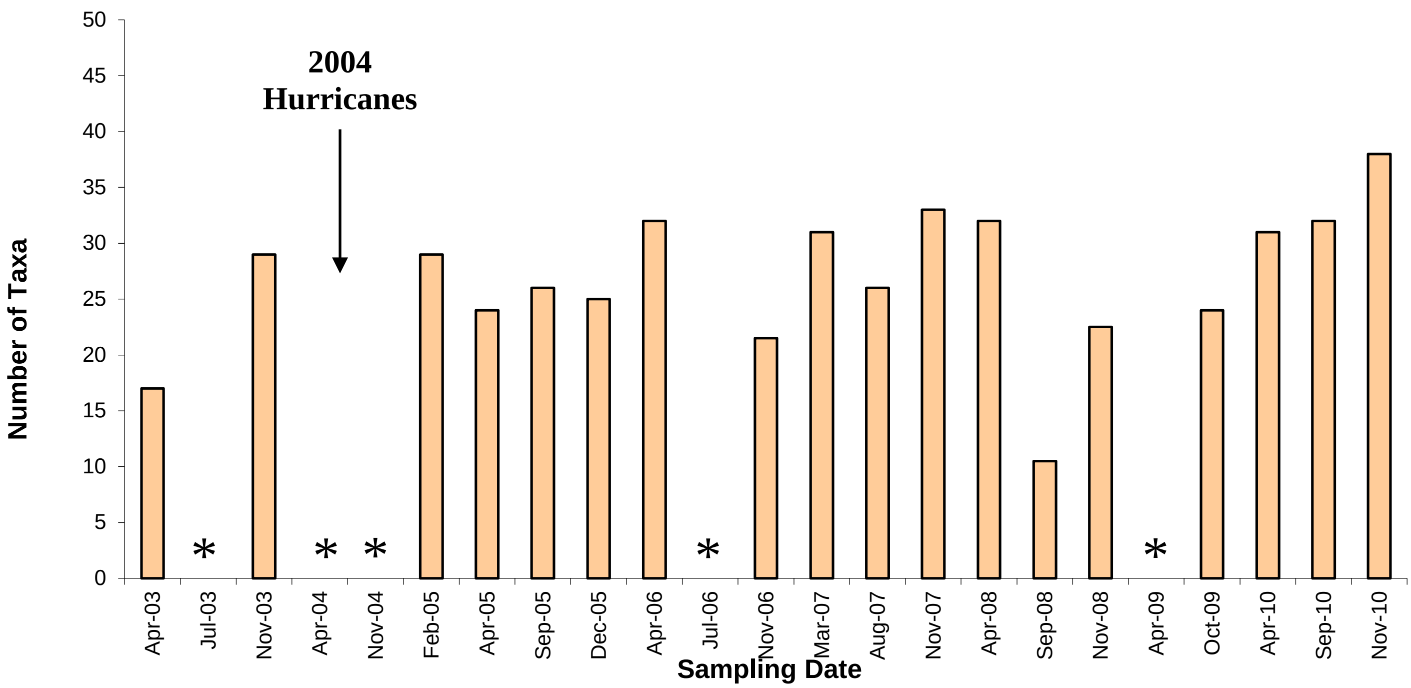

Figure 81. Number of Invertebrate Taxa Collected from HCSW-3 for the HCSP in 2003 – 2010.

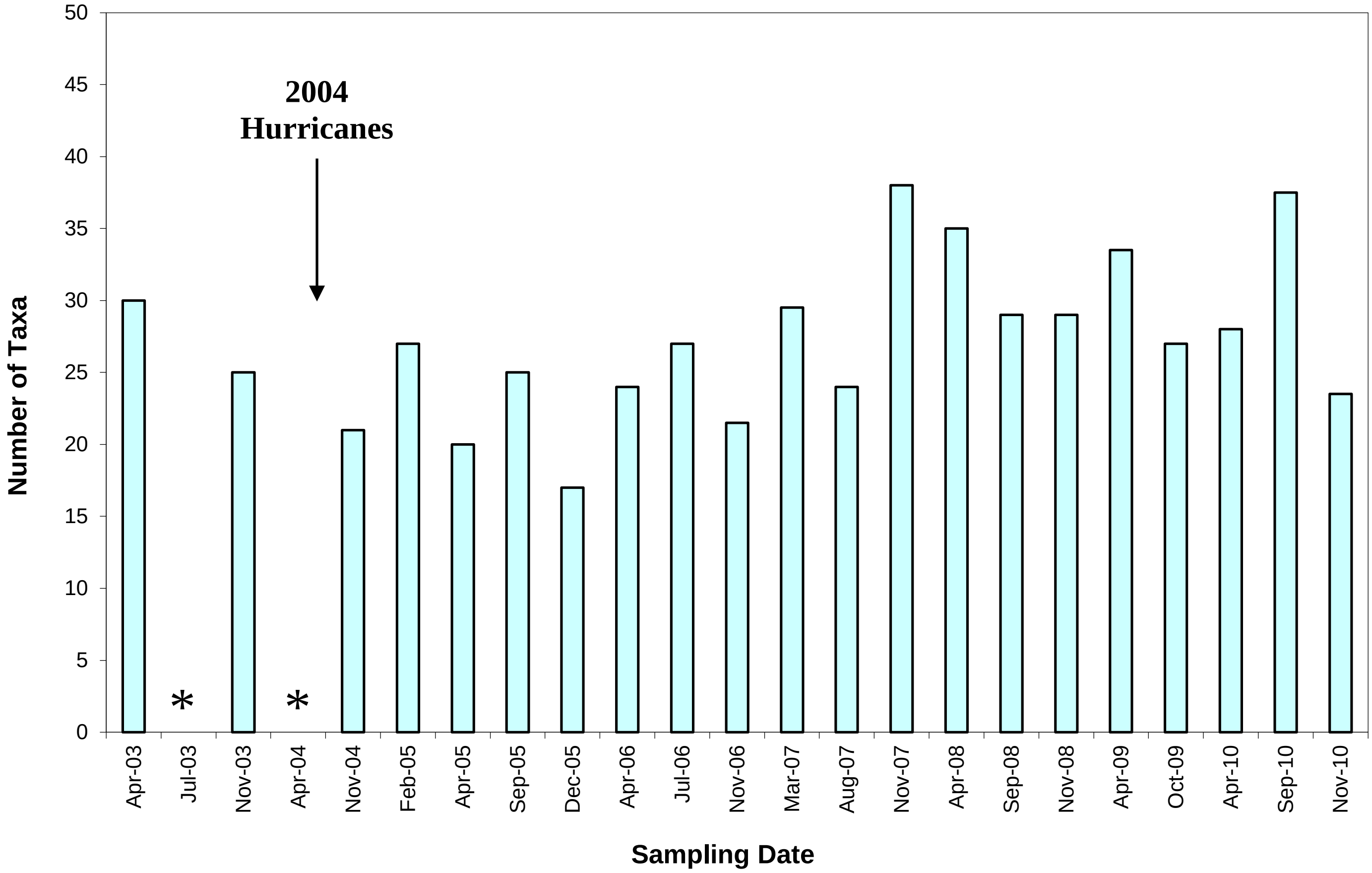

Figure 82. Number of Invertebrate Taxa Collected from HCSW-4 for the HCSP in 2003 – 2010.

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. This metric was never zero in 2010. The greatest number of mayfly taxa collected at any station during any event in 2010 was 5.0 (at HCSW-3 in April and November). 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 20). When considered over time from 2003 to 2010, Ephemeroptera taxa were variable over time at each station, but their scores did not increase or decrease over time (Kendall Tau, $p > 0.05$); scores were significantly lower at HCSW-2 than other stations (ANOVA: $F = 12.23$, $p < 0.0001$, Duncan's multiple range test: $p < 0.05$). Examples of common mayfly species collected in 2010 were *Caenis diminuta*, *Caenis hilaris*, *Tricorythodes albilineatus*, and *Maccaffertium exiguum.*

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 twice at HCSW-2 in 2010. The greatest number of caddisfly taxa in any sample in 2010 was 4.5 (vial average) (in September at HCSW-3 and in November at HCSW-4). 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 2010 (Table 20). When considered over time from 2003 to 2010, Trichoptera taxa were variable over time at each station, with their scores increasing over time (Kendall Tau = 0.27, $p < 0.05$). Trichoptera scores also increased at HCSW-4 from 2003 to 2010 (Kendall Tau = 0.69, $p < 0.05$). Overall, scores were significantly lower at HCSW-2 than other stations (ANOVA: F = 9.95, $p < 0.0001$, Duncan's multiple range test: $p < 0.05$). Examples of common caddisfly species found in Horse Creek in 2010 were *Cheumatopsyche* sp., *Hydrophyche rossi*, *Neotrichia* sp.

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 2010 event were composed of zero to just over eight percent collector-filterers (Table 20). This is within the range reported by Fore (2004) in developing the SCI calculation protocol. When considered over time from 2003 to 2010, collector-filterers taxa were variable over time at each station, and their scores had a slight decrease over time (Kendall Tau = -0.28, $p < 0.05$). The percent collector-filterer taxa also decreased at HCSW-1 (Kendall Tau = -0.57, $p < 0.05$). However, scores were not significantly different among stations (ANOVA: F = 0.80, p = 0.50). Examples of filter feeder species collected in 2010 were *Cheumatopsyche* sp., *Rheotanytarsus pellucidus*, and *Hydropsyche rossi*.

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. In 2010, the number of long-lived taxa ranged from zero to 7.5. The observed range of long-lived taxa (0 - 5 taxa) in samples collected from Horse Creek in 2010 (Table 20) corresponds with the range used to develop the SCI methodology (Fore 2004). When considered over time from 2003 to 2010, long-lived taxa were variable over time at each station, but their scores did not increase or decrease over time (Kendall Tau, $p > 0.05$); scores were also not significantly different among stations (ANOVA: F = 2.07, p = 0.11). Examples of long-lived species collected in 2010 were *Corydalus cornutus*, Palaemonetes *paludosus*, and *Corbicula fluminea*.

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. Clinger taxa were not found at HCSW-2 during April or September of 2010 (Table 20); this was 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 in 2010, with the most in any sample being 7.5 at HCSW-4 in April (Table 20). 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. When considered over time from 2003 to 2010, clinger taxa were variable over time at each station, but their scores did not increase or decrease over time (Kendall Tau, $p > 0.05$); scores were significantly lower at HCSW-2 than other stations (ANOVA: F = 24.37, $p < 0.0001$, Duncan's multiple range test: $p < 0.05$). Common clinger species found in Horse Creek in 2010 were *Stenelmis hungerfordi*, *Cheumatopsyche* sp., *Hydropsyche rossi*, *Neotrichia sp.*, *Stenelmis sp.*, and *Maccaffertium exiguum*.

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. Overall, five of the twelve samples in 2010 had a single taxon representing more than one fourth of the invertebrate community (Table 20). Even though the amphipod *Hyalella azteca* complex was present at all stations and has been a dominant species in the past, it was not the dominant species for all stations in 2010; instead each station was dominated by a different order of invertebrates. The coleopterans (beetles) dominated HCSW-1, with *Microcylloepus pusillus*. HCSW-2 was dominated by a dipteran (fly) *Chironomus* sp. and the amphipod *Hyalella azteca* complex. Dipterans *Polypedilum flavum* and amphipods *Hyalella azteca* complex also dominated HCSW-3 and HCSW-4. The dominant taxa vary from year to year, with the 2010 samples dominated by dipterans, amphipods, and coleopterans. When considered over time from 2003 to 2010, percent dominant taxa were variable over time at each station, but their scores did not increase or decrease over time (Kendall Tau, $p > 0.05$); scores were also not significantly different among stations (ANOVA: $F = 2.09$, $p = 0.11$).

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; the percent Tanytarsini ranged from 0.9 % to 8.8 % in 2010. When considered over time from 2003 to 2010, Tanytarsini taxa were variable over time at each station, but their scores did not increase or decrease over time (Kendall Tau, $p > 0.05$). Tanytarsini taxa were not significantly different between stations (ANOVA: $F = 0.94$, $p = 0.42$). Common chironomids found in 2010 were various *Tanytarsus* and *Rheotanytarsus* species.

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 2010 ranged from zero to four (Table 20). No sensitive taxa were collected from HCSW-2 in 2010, 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. When considered over time from 2003 to 2010, sensitive taxa were variable over time, but there were no increasing or decreasing trend observed (Kendall Tau, $p > 0.05$); scores were significantly lower at HCSW-2 (ANOVA: $F = 11.99$, $p < 0.0001$, Duncan’s multiple range test: $p < 0.05$). Examples of common sensitive species found in 2010 were *Hydropsyche rossi*, *Tricorythodes albilineatus* and *Maccaffertium exiguum*.

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 occurred only once in 2010 - at HCSW-2 during the September sampling event (Table 20). When considered over time from 2003 to 2010, percent very tolerant taxa were variable over time at each station but did not increase or decrease over time (Kendall Tau, $p > 0.05$). Very tolerant taxa scores decreased at HCSW-2 from 2003 to 2010 (Kendall Tau = -0.71, $p < 0.05$). Scores were significantly lower at HCSW-2 and higher at HCSW-1 than other stations (ANOVA: F = 8.70, $p < 0.0001$, Duncan's multiple range test: $p < 0.05$). Common very tolerant taxa found in Horse Creek in 2010 included *Chironomus* sp., *Helobdella elongate*, *Melanoides tuberculata*, *Polypedilum illinoense* group, and *Goeldichironomus* spp.

5.3.2.11 SCI Overall Score

Final SCI scores for the samples (with the recommended range of individuals in the sorted portion) ranged from 11 to 68 in 2010, similar to other years (Table 20 and Figures 83 - 86[13]). When considered over time from 2003 to 2010, the overall SCI scores were variable at each station but did not increase or decrease over time (Kendall Tau, $p > 0.05$); scores were significantly lower at HCSW-2 than other stations (ANOVA: F = 10.38, $p < 0.0001$, Duncan's multiple range test: $p < 0.05$).

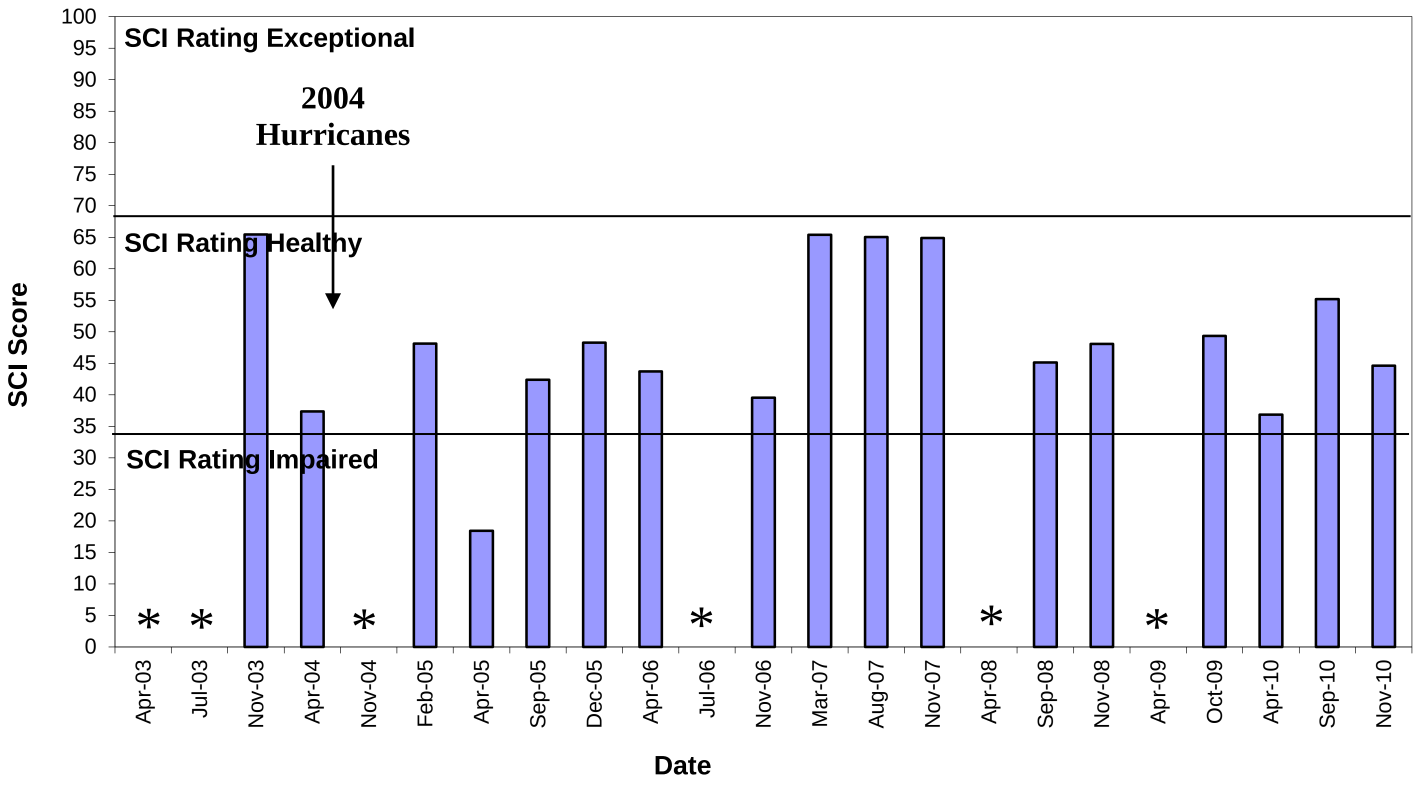

Figure 83. SCI Scores for Samples Collected at HCSW-1, 2003 - 2010.

13 An asterisk (*) represents a sampling event that did not meet the required SOP. See Appendix J for more details.

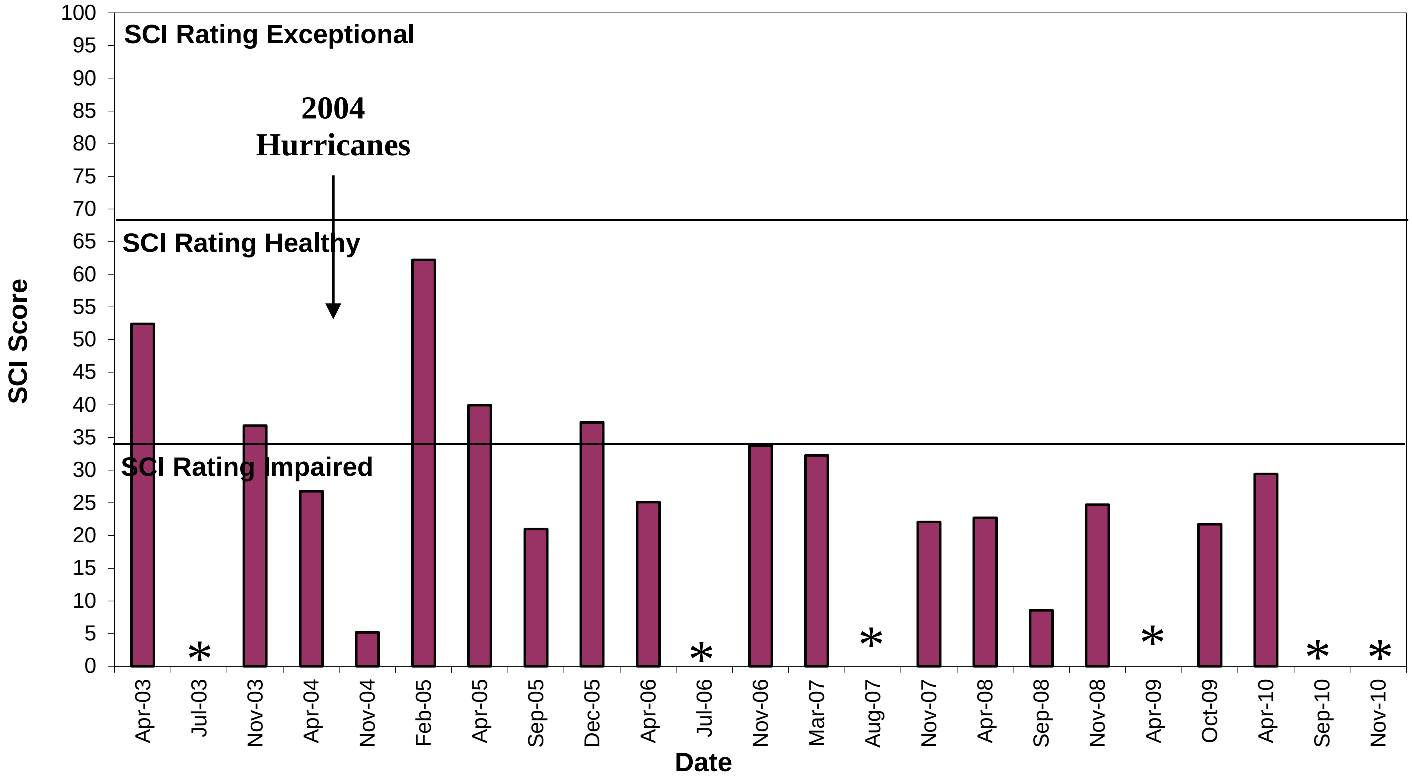

Figure 84. SCI Scores for Samples Collected at HCSW-2, 2003 - 2010.

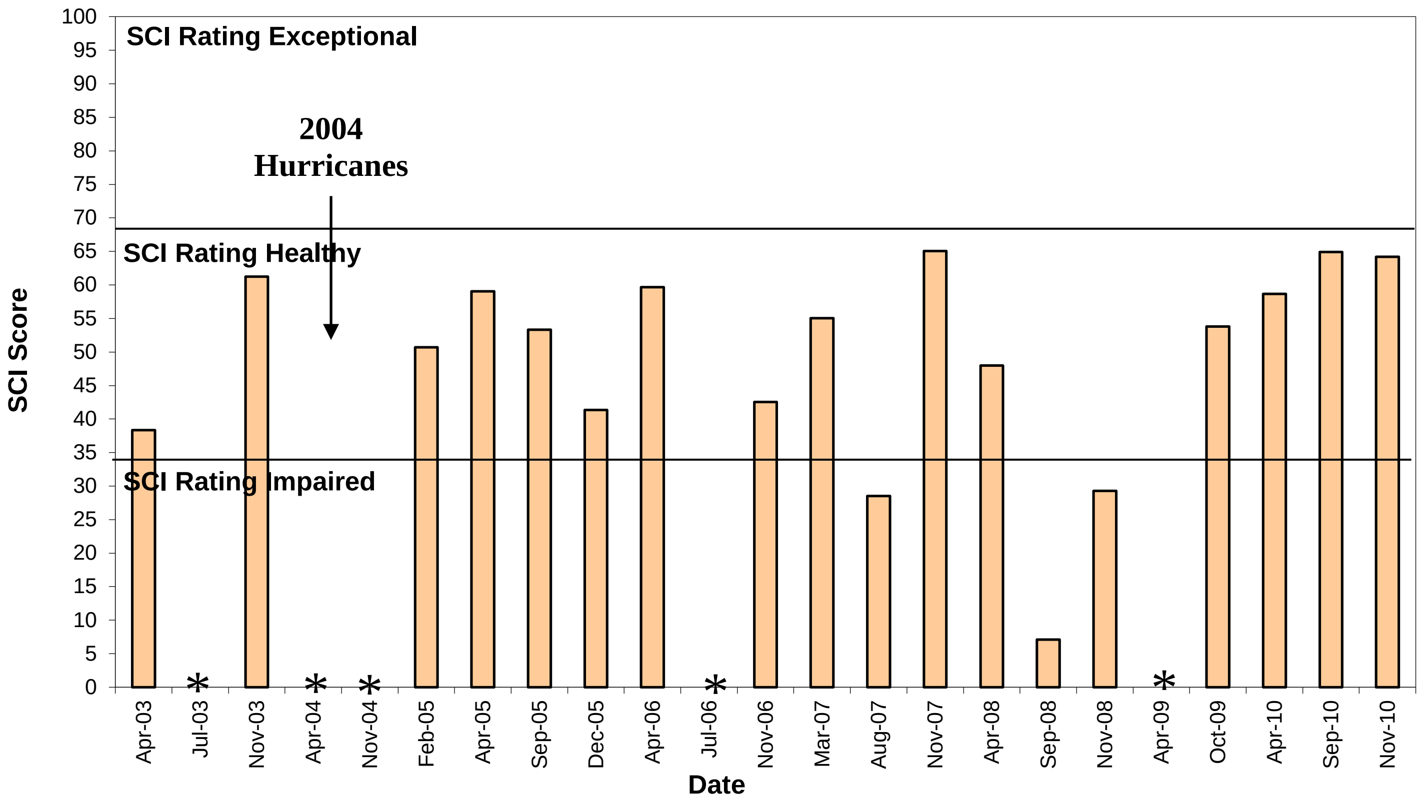

Figure 85. SCI Scores for Samples Collected at HCSW-3, 2003 - 2010.

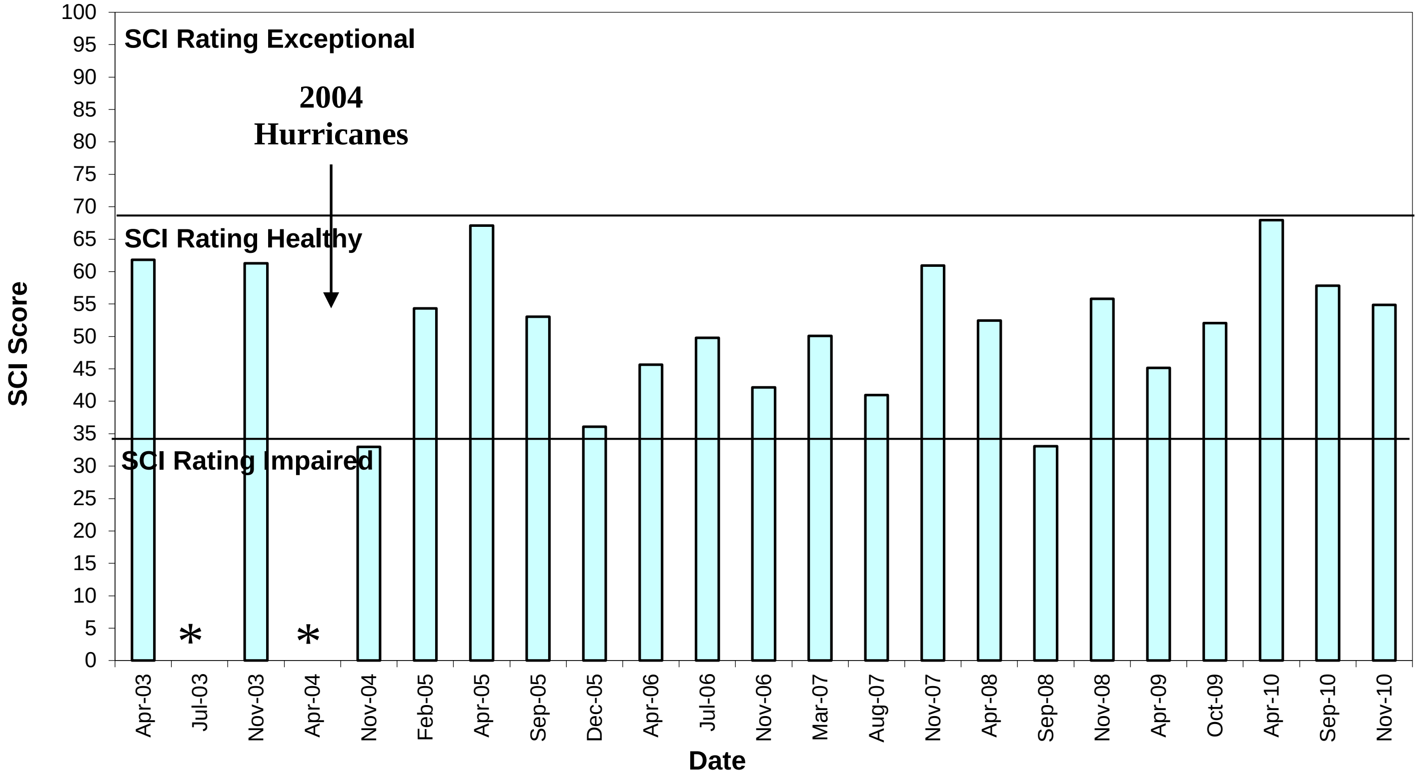

Figure 86. SCI Scores for Samples Collected at HCSW-4, 2003 - 2010.

5.3.3 Shannon-Wiener Diversity Index

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

S = Number of taxa, and

p_i = Proportion of total sample belonging to ith taxa.

The Shannon-Wiener Index, H', increases with the number of taxa 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 taxa and their relative abundance; a greater number of taxa and a more even distribution of individuals across taxa both increase diversity as measured by H'. For example, consider two communities, each with 100 individuals of 10 taxa captured. Community A is dominated by one taxa (91 of 100 individuals), while only one individual was captured for each of the other nine taxa. Community B, however, is even, with 10 individuals captured for each of the ten taxa. 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 taxa.

For the Horse Creek data, generic diversity, rather than species diversity, was used to account for the high variability of species present from year to year. In Horse Creek in 2010, the Shannon-Wiener Diversity Index ranged from 2.31 (April, HCSW-1) to 4.23 (September, HCSW-4, Figures 87-90[14]). When considered over time from 2003 to 2010, the diversity was variable at each station but showed no increase or decrease for any station (Kendall Tau, $p > 0.05$). When stations and dates within years were combined, diversity was statistically different among years (ANOVA: $F = 2.16$, $p < 0.05$) with the lowest diversity observed in 2004 (Duncan's multiple range test, $p < 0.05$, Figure 91). When results from all events in 2003 - 2010 were combined by station (Figure 92), there was a significant difference between stations (ANOVA: $F = 2.81$, $p < 0.05$), with HCSW-4 being significantly higher than HCSW-2 and HCSW-1, and similar to HCSW-3 (Duncan's multiple range test, $p < 0.05$).

[14] An asterisk (*) represents a sampling event that did not meet the required SOP. See Appendix J for more details.

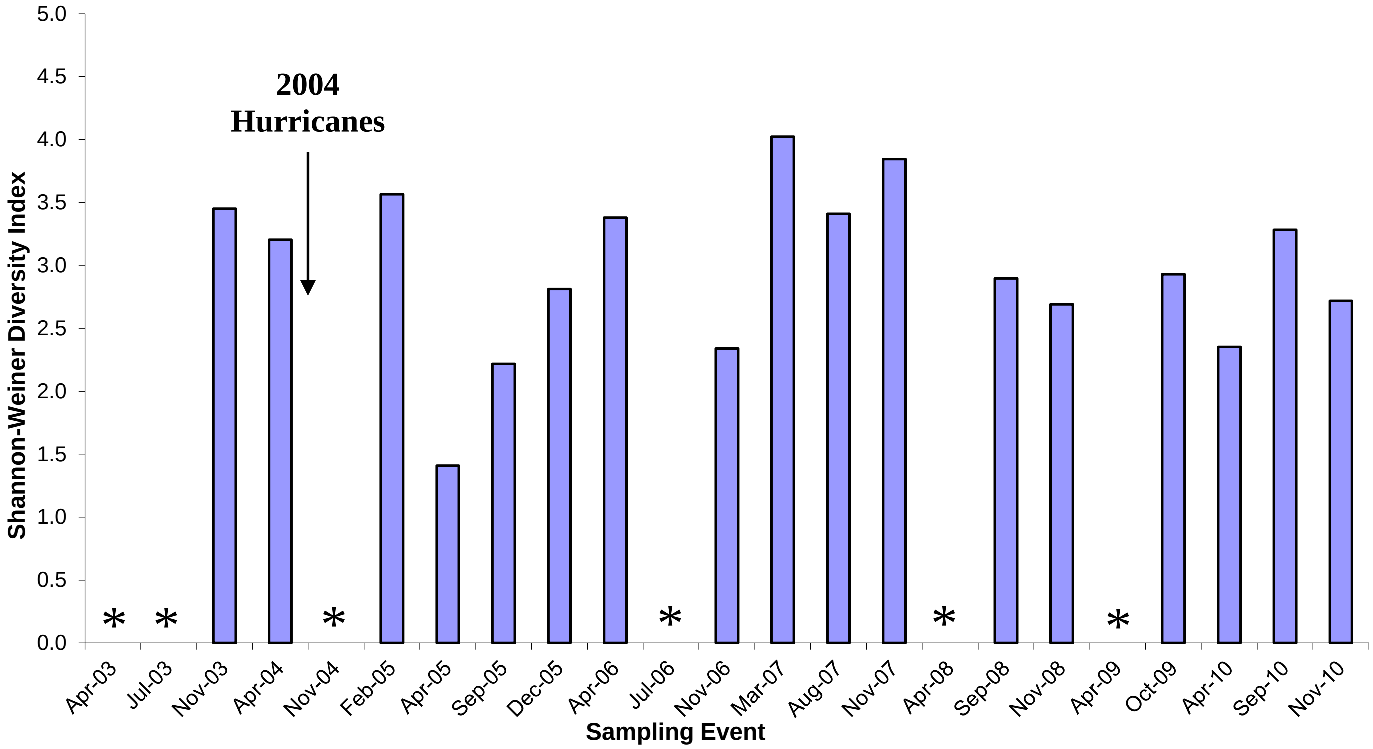

Figure 76. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrate Genera from HCSW-1 on Horse Creek from 2003 - 2010.

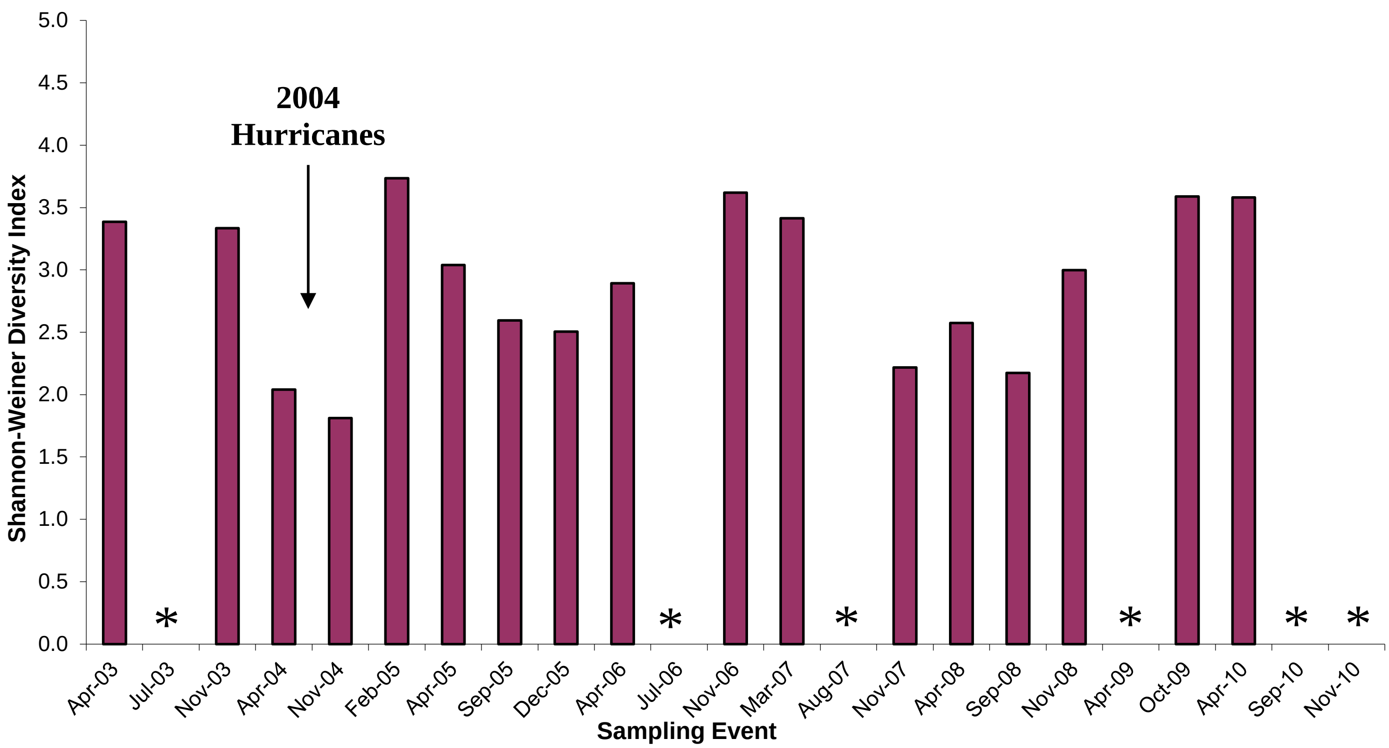

Figure 88. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrate Genera from HCSW-2 on Horse Creek from 2003 - 2010.

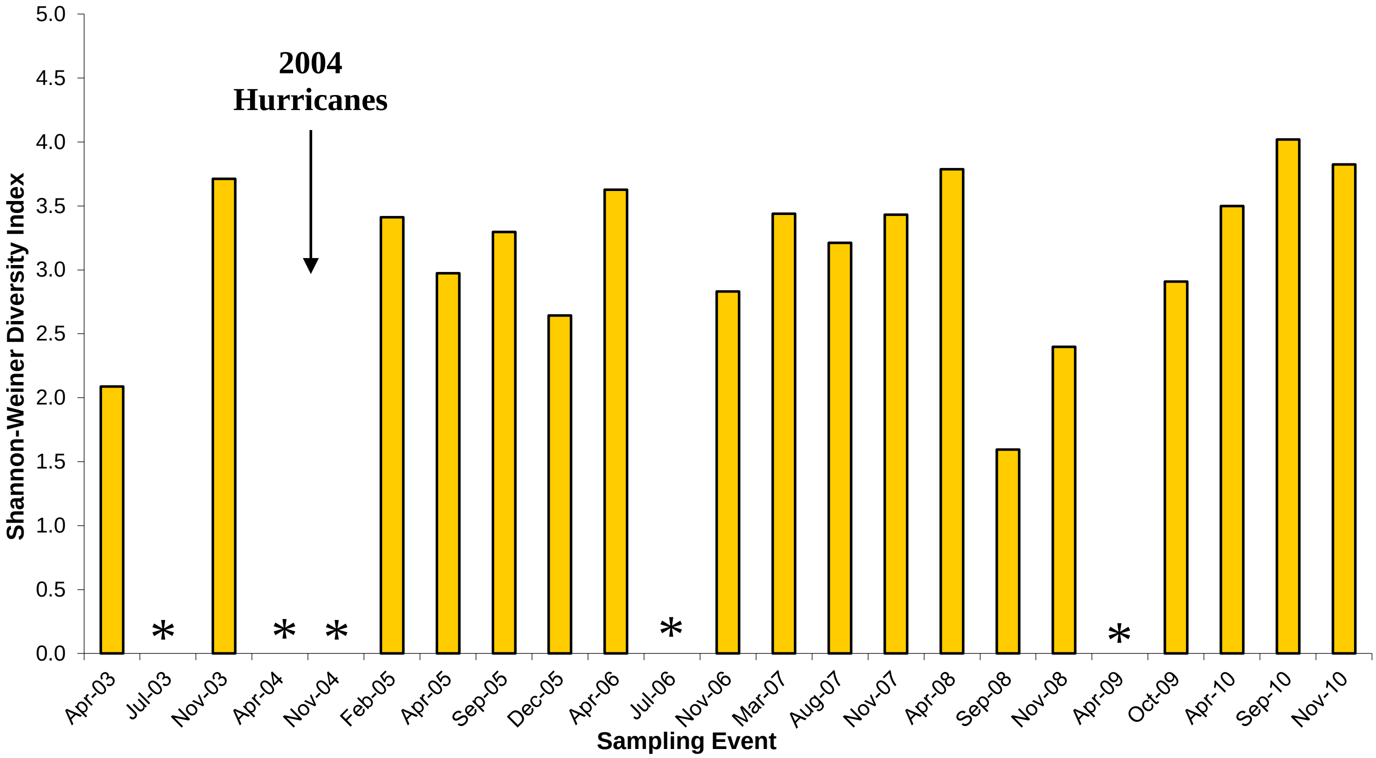

Figure 89. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrate Genera from HCSW-3 on Horse Creek from 2003 - 2010.

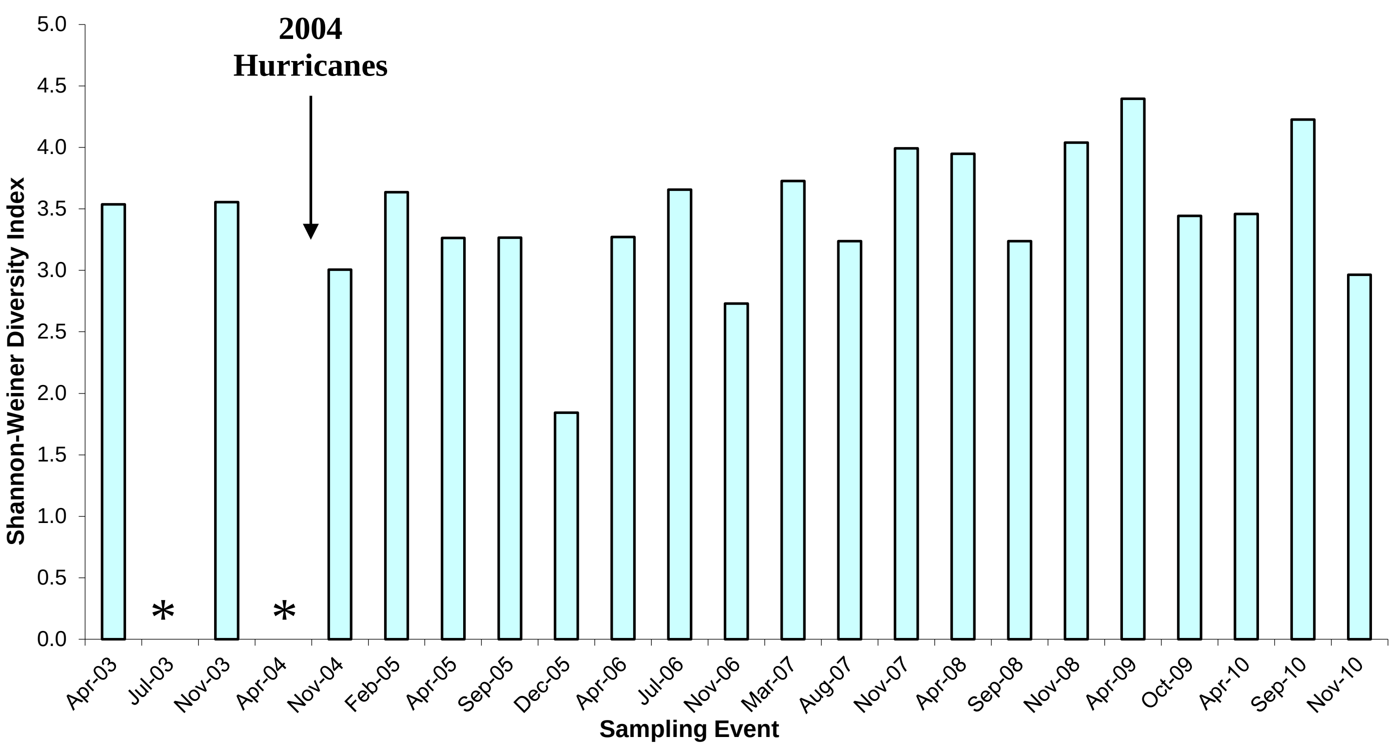

Figure 90. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrate Genera from HCSW-4 on Horse Creek from 2003 - 2010.

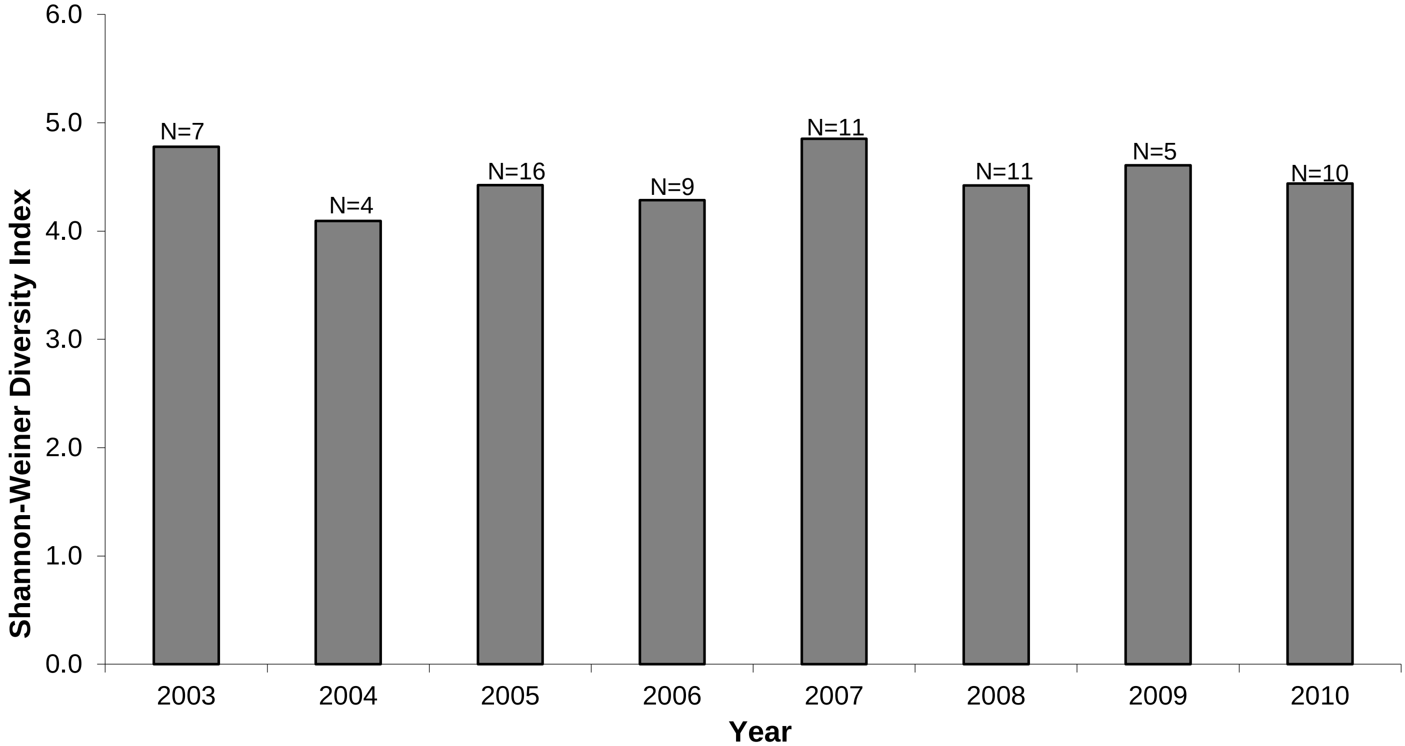

Figure 91. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrates Genera per year from Horse Creek for combined sample dates and stations.

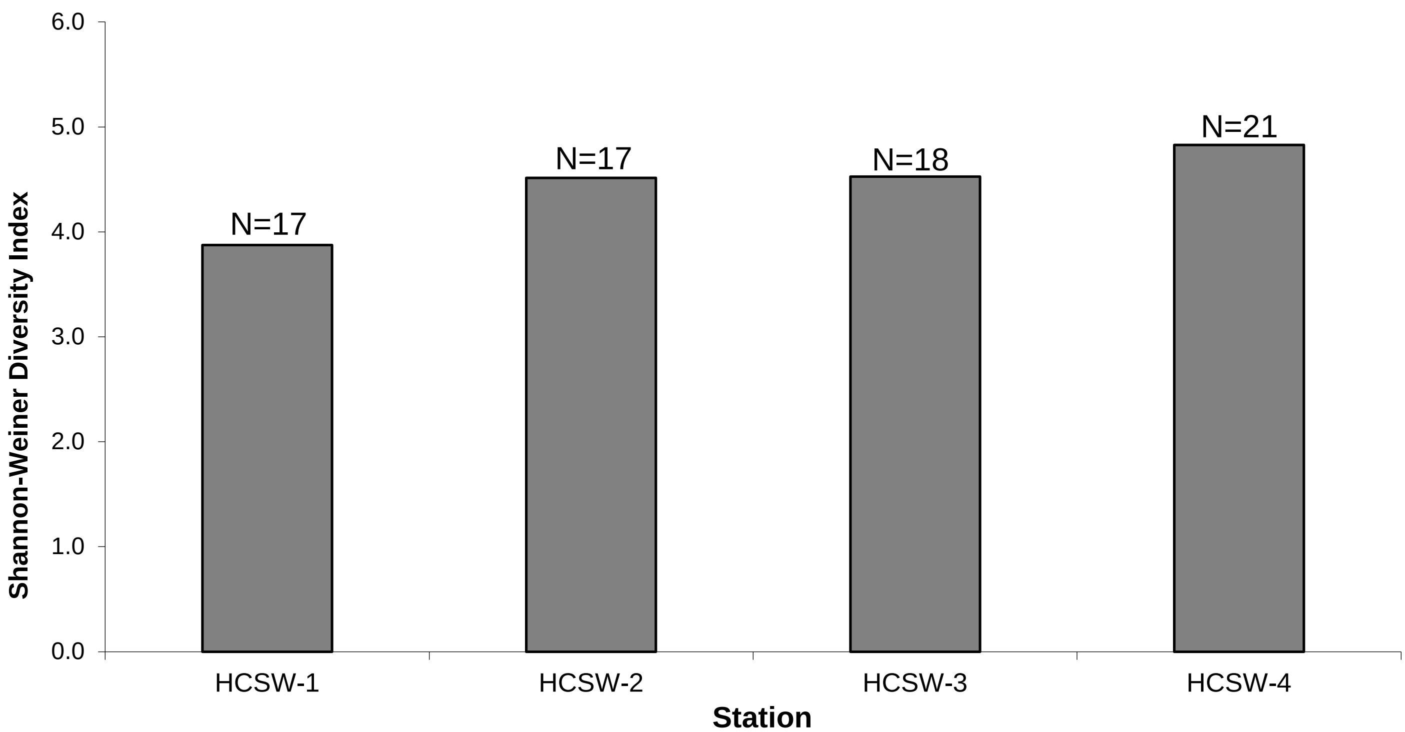

Figure 92. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrates Genera per Station on Horse Creek for combined sample dates.

5.3.4 Summary of Benthic Macroinvertebrate Results

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 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 Cardno ENTRIX in similarly-sized natural streams in this region of Florida. Recent SCI scores at three of the four stations are consistently rated as Healthy, with stations HCSW-2 having Impaired SCI scores because of unique, natural upstream conditions. 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 Healthy. 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 in 2007, DEP found that the majority of the reference/background stations it had sampled fell into the Healthy category when calculated under the new SCI (R. Frydenbourg, pers. comm.). This indicates that the sampled segments of Horse Creek are considered healthy and thus comparable in quality (as determined via the SCI) to other reference streams in Florida.

Benthic invertebrate taxa diversity and SCI metrics in Horse Creek exhibit both seasonal and year-to-year variation. Overall, taxa diversity indices and SCI metrics show few monotonic trends over time and are very similar between sampling events and stations. However, HCSW-2 has slightly lower diversity and significantly lower SCI metrics than other stations. Habitat conditions at HCSW-2 are consistently poor, with lower streamflow, dissolved oxygen, and pH than other Horse Creek stations. The source of the poor conditions are related to the lower than average streamflow and rainfall of the previous few years and the presence of Horse Creek Prairie, the large marsh located upstream of the biological sampling station.

5.4 Fish

Fish sampling was conducted at each of the four stations on 20 April 2010, all but HCSW-2 on 28 September 2010, HCSW-1 on 4 November 2010 and the remaining three downstream stations on 11 November 2010. No fish sampling occurred at HCSW-2 in September 2010 due to high water levels and inability to access much of the stream and suitable habitats. In November 2010, there was a significant rainfall event that occurred the day prior to the scheduled sampling event, causing water levels to rise significantly at the three downstream stations. Since water levels did not appear to have been affected at HCSW-1, sampling occurred on 4 November 2010. Cardno ENTRIX waited a week for water levels to decrease to pre-rainfall levels before sampling the other stations on 11 November 2010.

During 2010, 25 species of fish were collected from the four Horse Creek sampling stations; they are listed in Table 21 (the attached CD-ROM provides all data). In 2010, no new fish species were collected. However, fifteen species of fish that had been collected in 2003-2009 were not collected in 2010.

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. Seven of the 40 species collected from 2003 to 2010 are not native to Florida: the walking catfish (*Clarias batrachus*), African jewelfish (*Hemichromis letourneuxi*), brown hoplo (*Hoplosternum littorale*), vermiculated sailfin catfish[15] (*Pterygoplichthys disjunctivus*), oriental weatherfish (*Misgurnus anguillicaudatus*), sailfin catfish[6] (*Pterygoplichthys pardalis*), and blue tilapia (*Oreochromis aureus*).

5.4.1 Taxa Richness and Abundance

Most of the individuals collected at each 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 the 2010 sampling events. Spotted sunfish (*Lepomis punctatus*), bluefin killifish (*Lucania* goodei), least killifish (*Heterandria formosa*), coastal shiners (*Notropis petersoni*), and sailfin mollies (*Poecilia latipinna*) were collected at all four sampling stations the majority of the time in 2010. Small numbers (as few as one) of individual fish were collected for most of the species found in 2010 (Table 21). Fewer fish species were collected at HCSW-1 in 2010 than the other three stations because of sampling conditions (either very low or high flow) (Table 21, Figures 93 - 96). In addition, water levels and streamflow were very high during biological sampling at all stations in September 2010 which led to HCSW-2 not being sampled; high water levels and flow during sampling were not ideal because some habitats could not be reached by our sampling equipment. Taxa richness showed no monotonic trend over time at any station (Kendall Tau of annual median, $p > 0.05$).

[15] Previously identified in 2004 Annual Report as *Hypostomus plecostomus* (suckermouth catfish). Confirmation identification as *P. disjunctivus* by Florida Museum of Natural History (FLMNH).

Table 21. Fish Collected from Horse Creek during HCSP Sampling in 2010

		HCSW-1			HCSW-2			HCSW-3			HCSW-4		
	Common Name	20 April 2010	28 Sept 2010	4 Nov 2010	20 April 2010	28 Sept 2010	11 Nov 2010	20 April 2010	28 Sept 2010	11 Nov 2010	20 April 2010	28 Sept 2010	11 Nov 2010
Hemichromis letourneuxi	African jewelfish *						1			3			17
Lucania goodie	Bluefin killifish				4		13	9	10	6	1	12	18
Lepomis macrochirus	Bluegill										1		
Amia calva	Bowfin				1								
Labidesthes sicculus	Brook silverside								14		6	2	3
Ameiurus nebulosus	Brown bullhead			1						1			
Hoplosternum littorale	Brown hoplo*												2
Notropis petersoni	Coastal shiner			4				23	24	62	1	11	22
Gambusia holbrooki	Eastern mosquitofish	22	103	200	891		553	417	1525	615	975	538	581
Elassoma evergladei	Everglades pygmy sunfish										4		
Jordanella floridae	Flagfish						7		9	5		12	47
Lepisosteus platyrhincus	Florida gar												1
Fundulus chrysotus	Golden topminnow						6	7	2			1	4
Trinectes maculatus	Hogchoker							2	4	6	11	10	4
Micropterus salmoides	Largemouth bass							16		1	2		2
Heterandria formosa	Least killifish		1		42		78	12	82	3	4	14	97
Misgurnus anguilllicaudatus	Oriental weatherfish *				1			3	1				
Aphredoderus savanus	Pirate perch				7								
Lepomis microlophus	Redear sunfish								1	7			
Poecilia latipinna	Sailfin molly			2	5		127	32	104	84	2	19	193
Fundulus seminolis	Seminole killifish							1	5	7	2	19	4
Lepomis punctatus	Spotted sunfish	3	1	2	1			13	26	9	11	11	9
Etheostoma fusiforme	Swamp darter				5		6	10	7	1		4	6
Notropis maculates	Taillight shiner									1			
Lepomis gulosus	Warmouth		1					3	2				2
	Total Taxa	2	4	5	9		8	13	15	15	12	12	17
	Total Individuals	25	106	209	957	0**	791	548	1816	811	1020	653	1012

* - Non-native species

** - Samples not collected at HCSW-2 in September due to high water conditions.

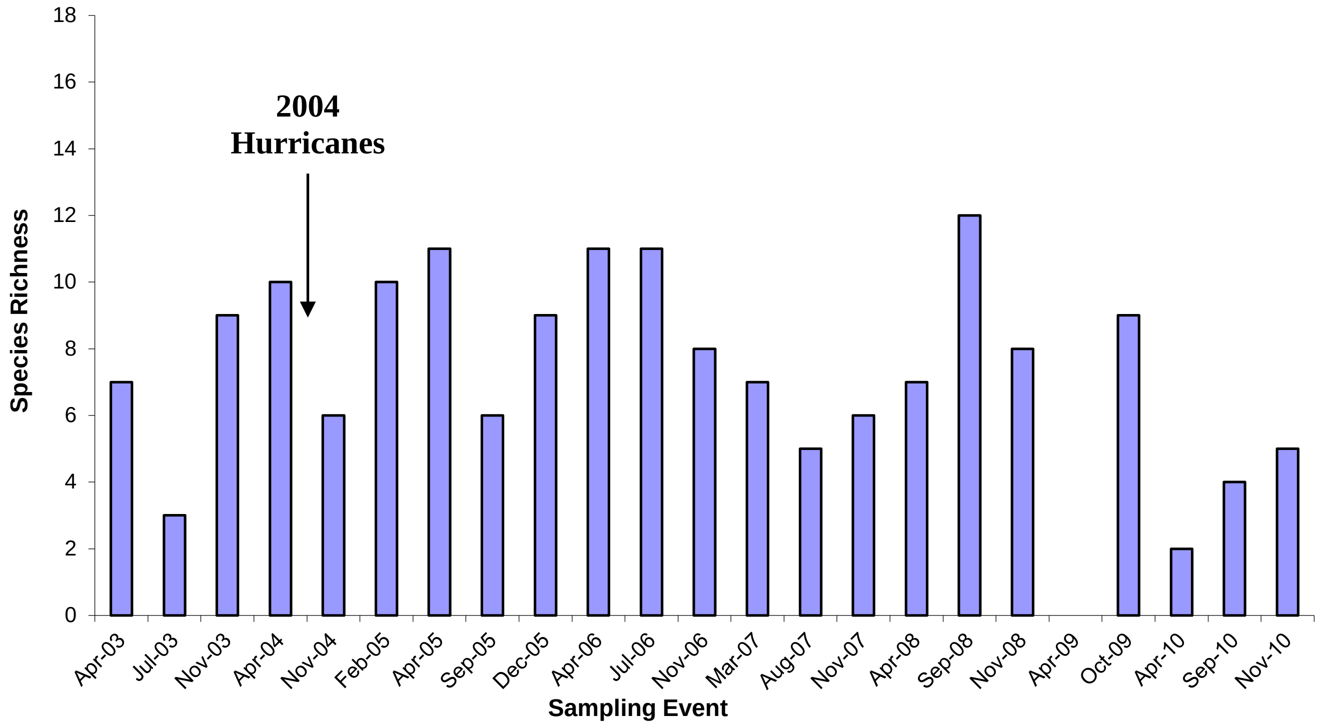

Figure 93. Species Richness for Fish from HCSW-1 on Horse Creek from 2003 - 2010.

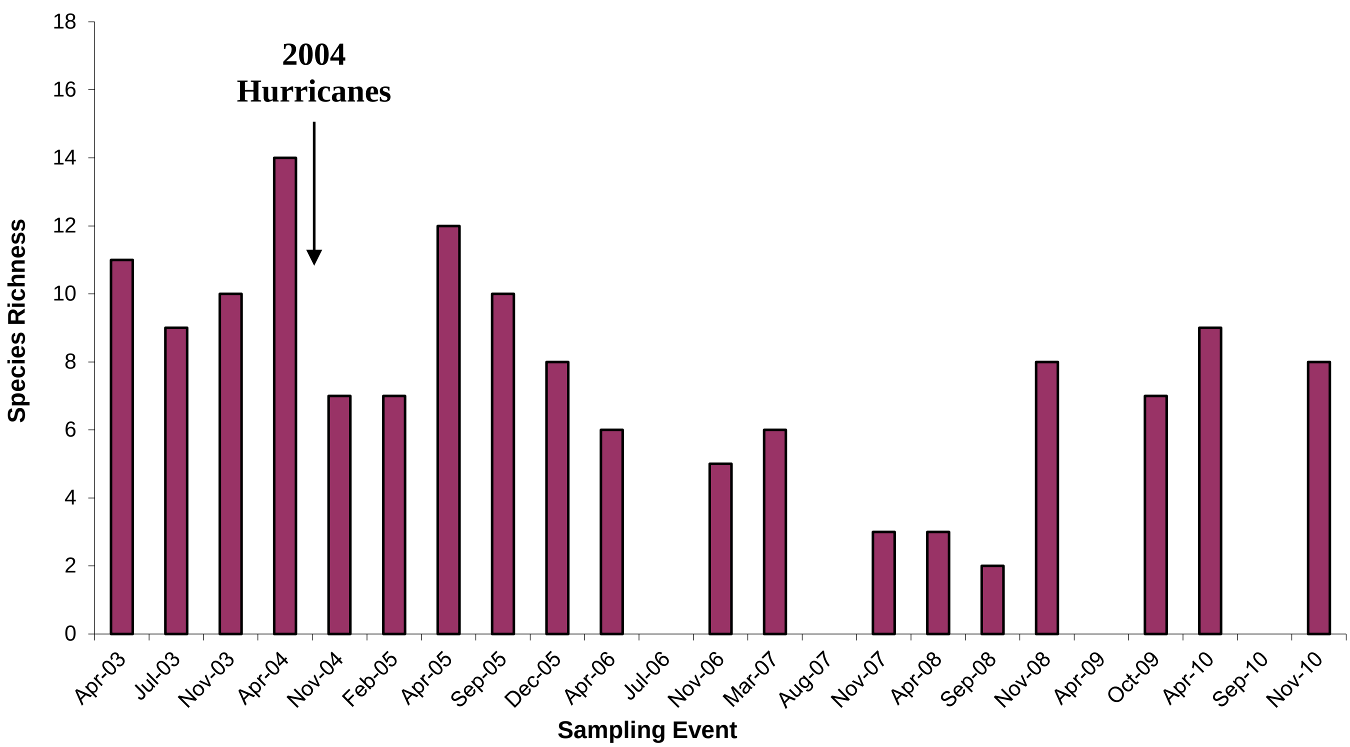

Figure 94. Species Richness for Fish from HCSW-2 on Horse Creek from 2003 - 2010.

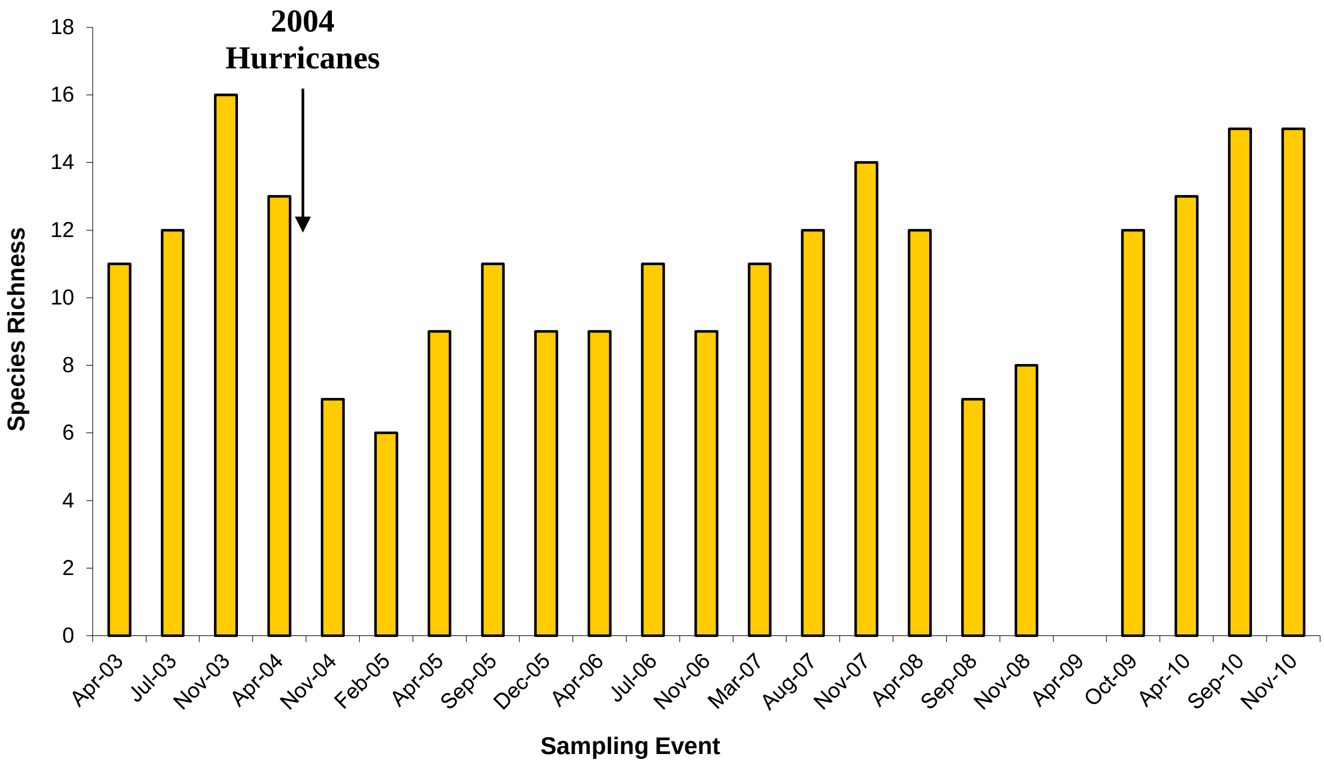

Figure 95. Species Richness for Fish from HCSW-3 on Horse Creek from 2003 - 2010.

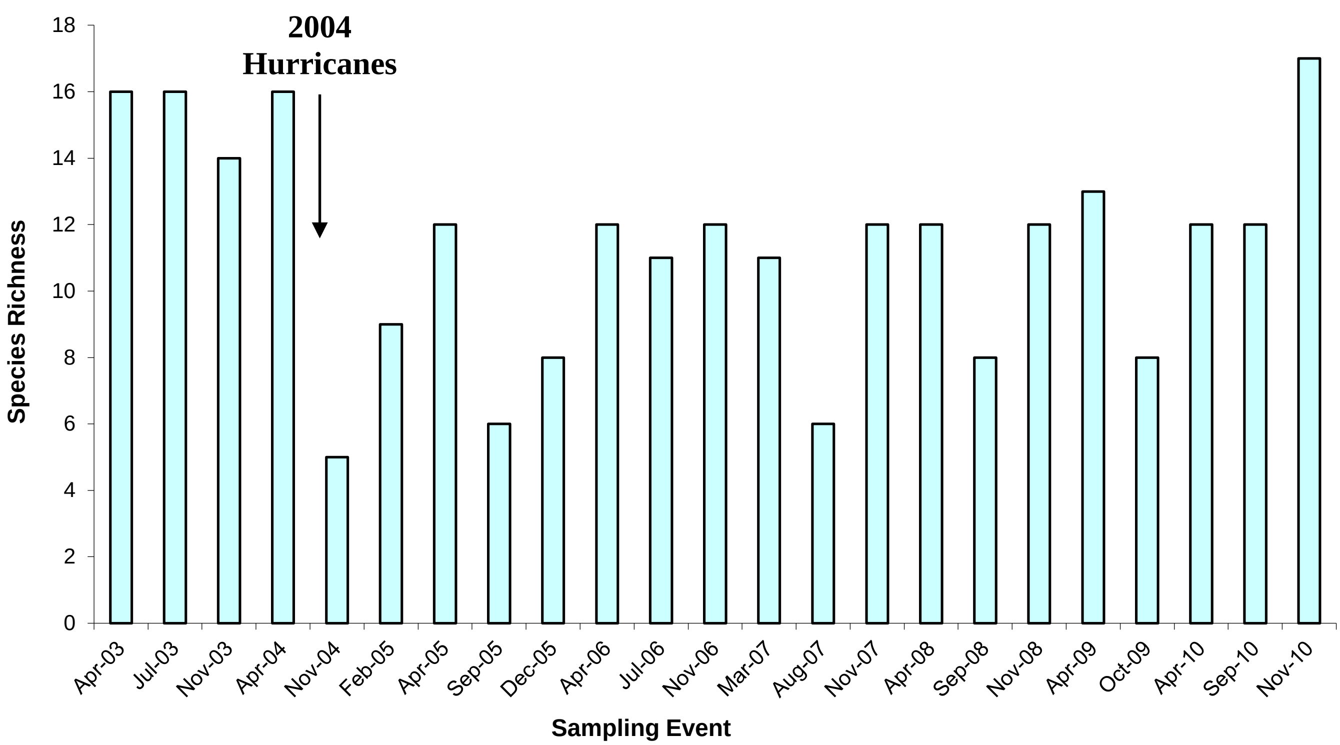

Figure 96. Species Richness for Fish from HCSW-4 on Horse Creek from 2003 - 2010.

5.4.2 Shannon-Wiener Diversity Index

Diversity of individual fish samples in 2010 ranged from 0.14 (HCSW-1, September) to 2.04 (HCSW-4, November) (Figures 97-100), similar to 2003 to 2009 ranges. When fish samples were combined across all sampling events, HCSW-1 had the highest species diversity in 2004 – 2006 (after the hurricanes), but it had lower diversity in 2003 and 2007 – 2010 than other stations (Figure 101). HCSW-4 had high diversity in 2003, lower diversity in 2004 and 2005 after the hurricanes, high diversity in 2006 through 2009, with slightly lower diversity in 2010. HCSW-3 followed the same pattern as HCSW-4 until 2008 and 2009; the lower diversity in late 2008 and 2009 may be related to difficulties in accessing fish habitats at this station when stream stage is high. The diversity for HCSW-3 increased slightly in 2010. Fish diversity at HCSW-2 has been decreasing over time, because of changes in the amount of fish and fish habitat available for sampling, related to climate changes that affected flow and dissolved oxygen concentrations and physical changes to the stream segment where biological sampling occurs.

Diversity was significantly different between dates when stations were combined, with September 2010 having the lowest diversity score and April 2004 the highest (ANOVA $F = 1.76$, $p = 0.04$, Duncan's multiple range test: $p < 0.05$, Figure 102). Diversity showed no monotonic trend over time at any station (Kendall Tau of annual median, $p < 0.05$). Over all sampling dates combined (Figure 103), fish diversity was significantly lower at HCSW-2 than at the other stations (ANOVA $F = 5.77$, $p = 0.001$). Over all stations combined (Figure 104), fish diversity has been slightly decreasing since 2006, but the differences were not significant (Kendall Tau of medians, $p > 0.05$).

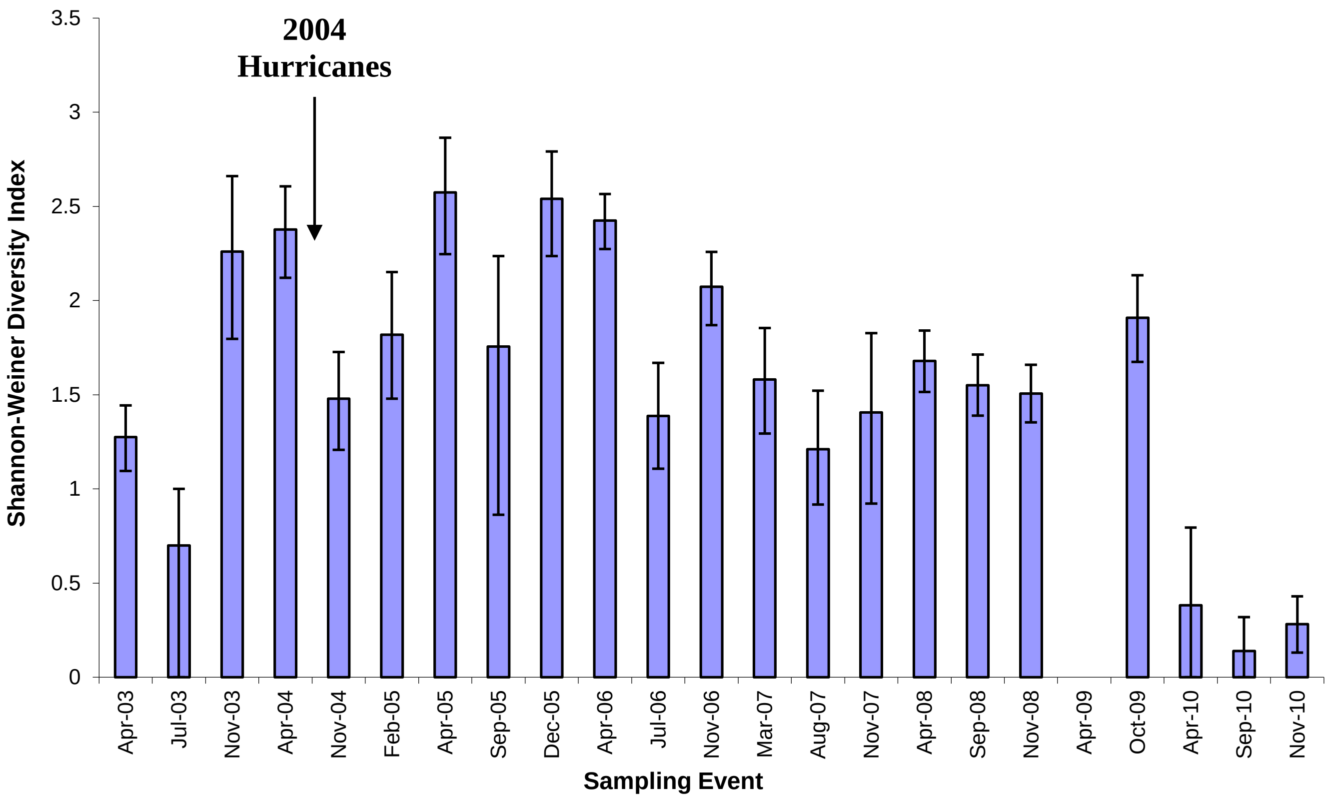

Figure 97. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from HCSW-1 on Horse Creek in 2003 – 2010.

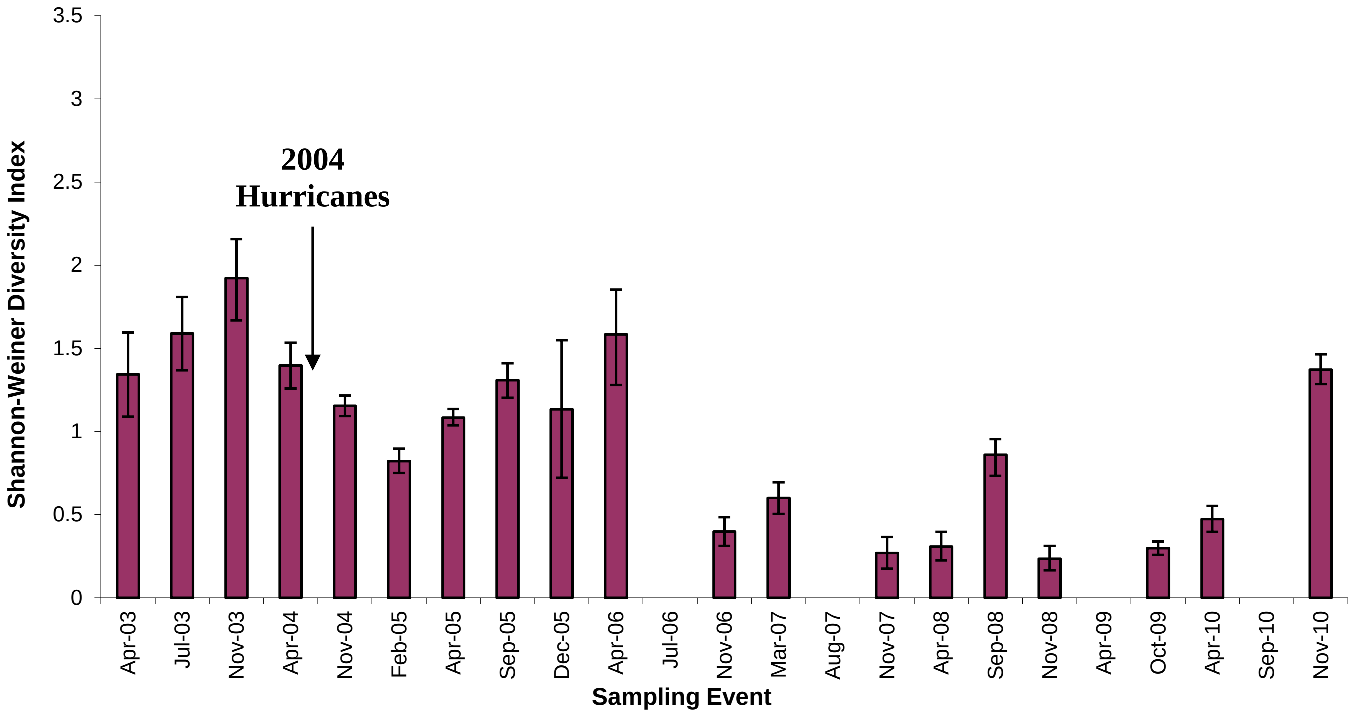

Figure 98. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from HCSW-2 on Horse Creek in 2003 – 2010.

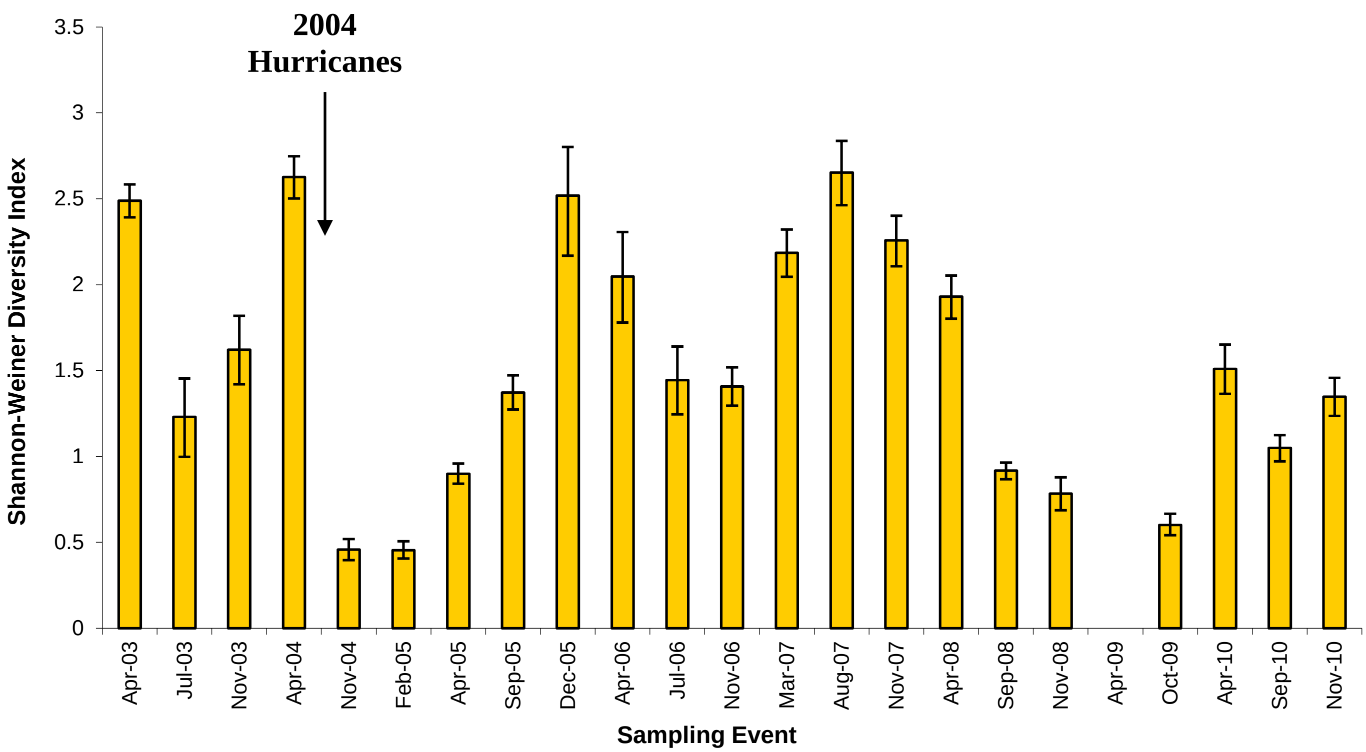

Figure 99. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from HCSW-3 on Horse Creek in 2003 – 2010.

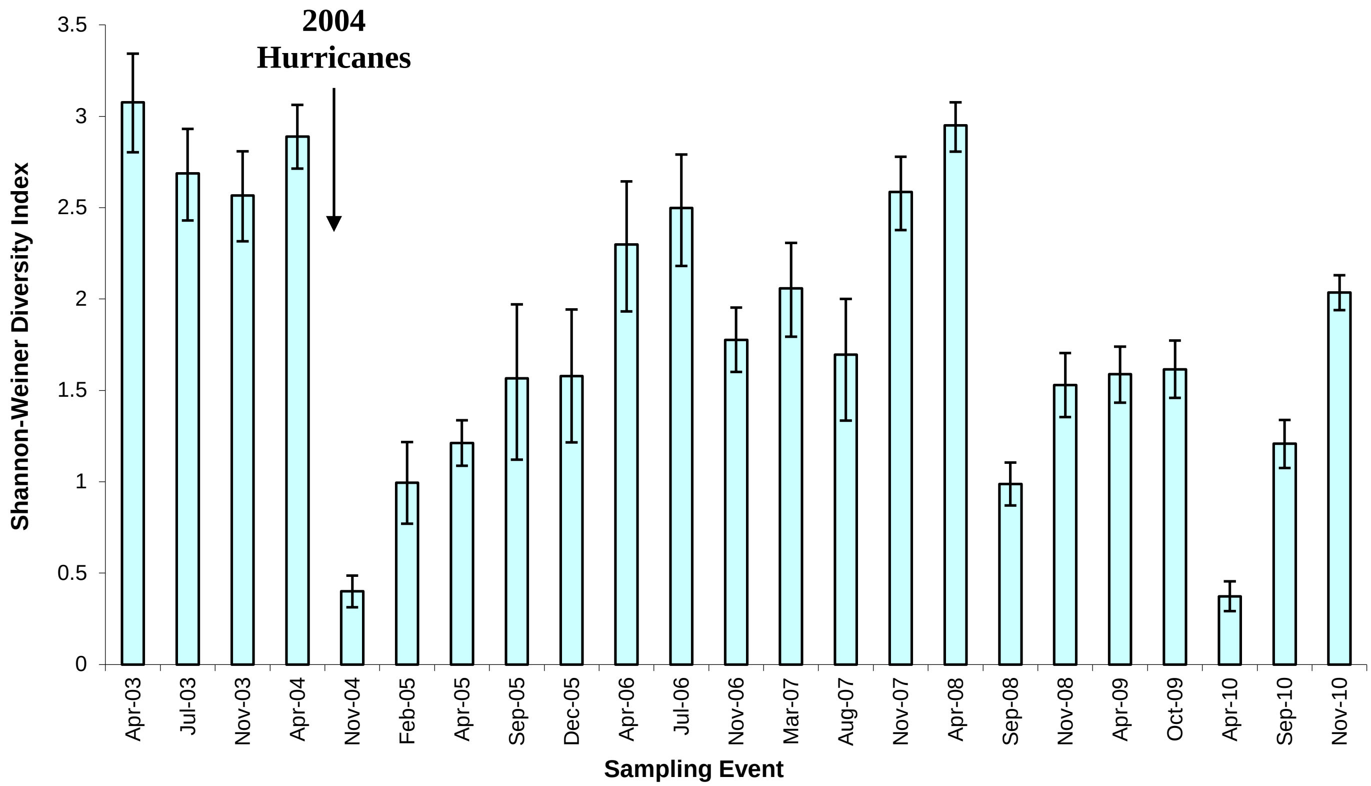

Figure 100. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from HCSW-4 on Horse Creek in 2003 – 2010.

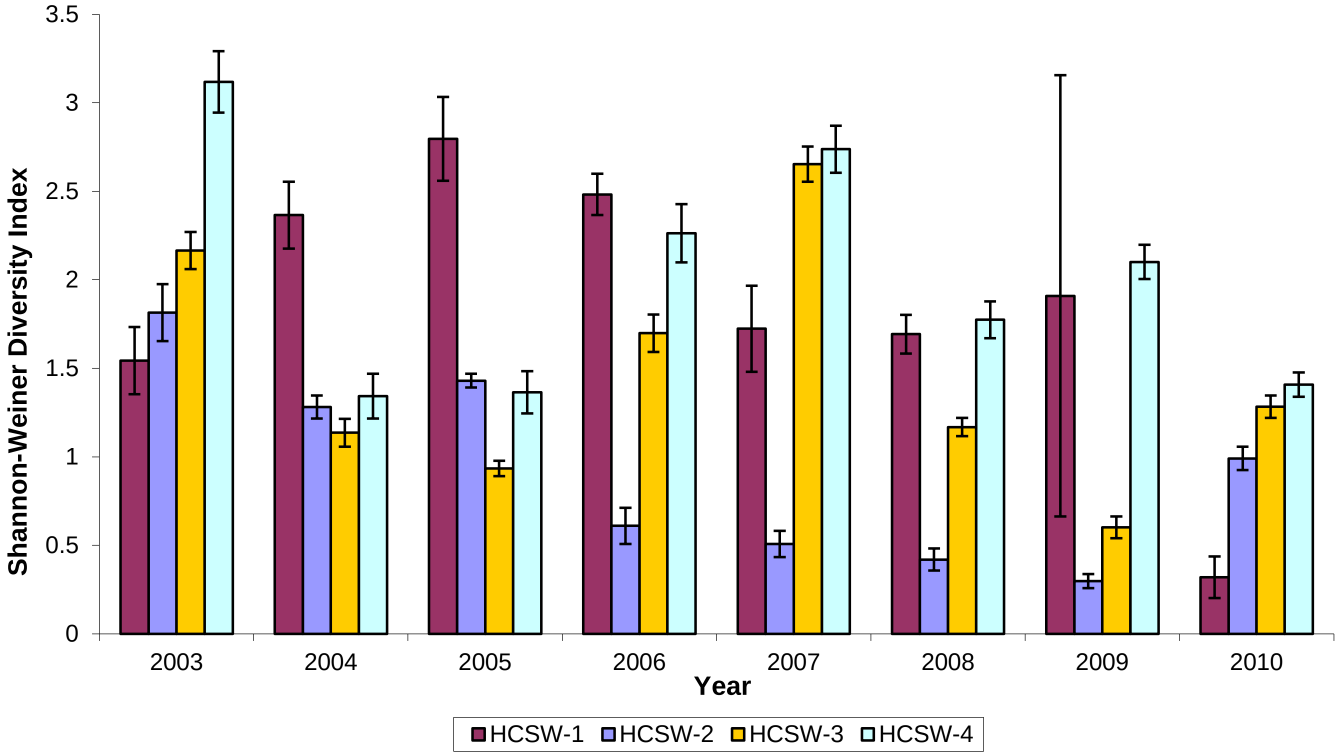

Figure 101. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from Four Stations on Horse Creek summarized over sampling events within each year.

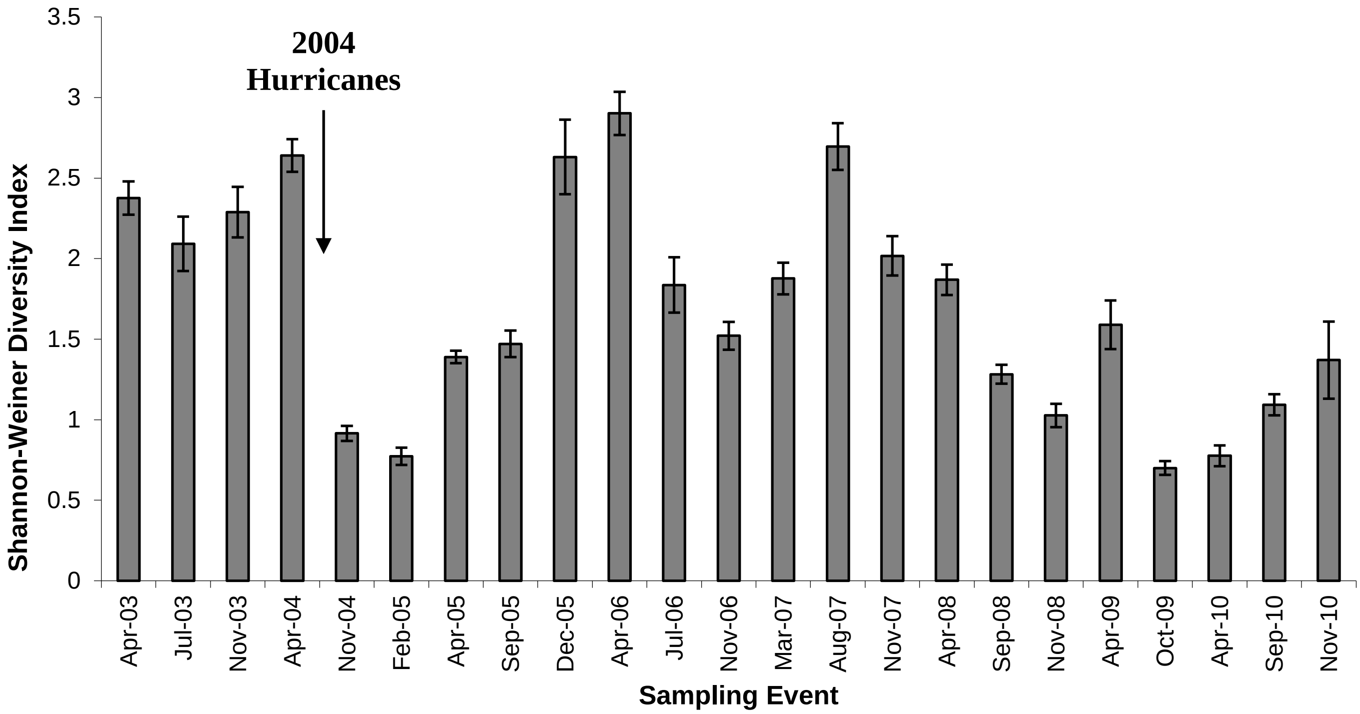

Figure 102. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from Horse Creek summarized over all stations per sampling event.

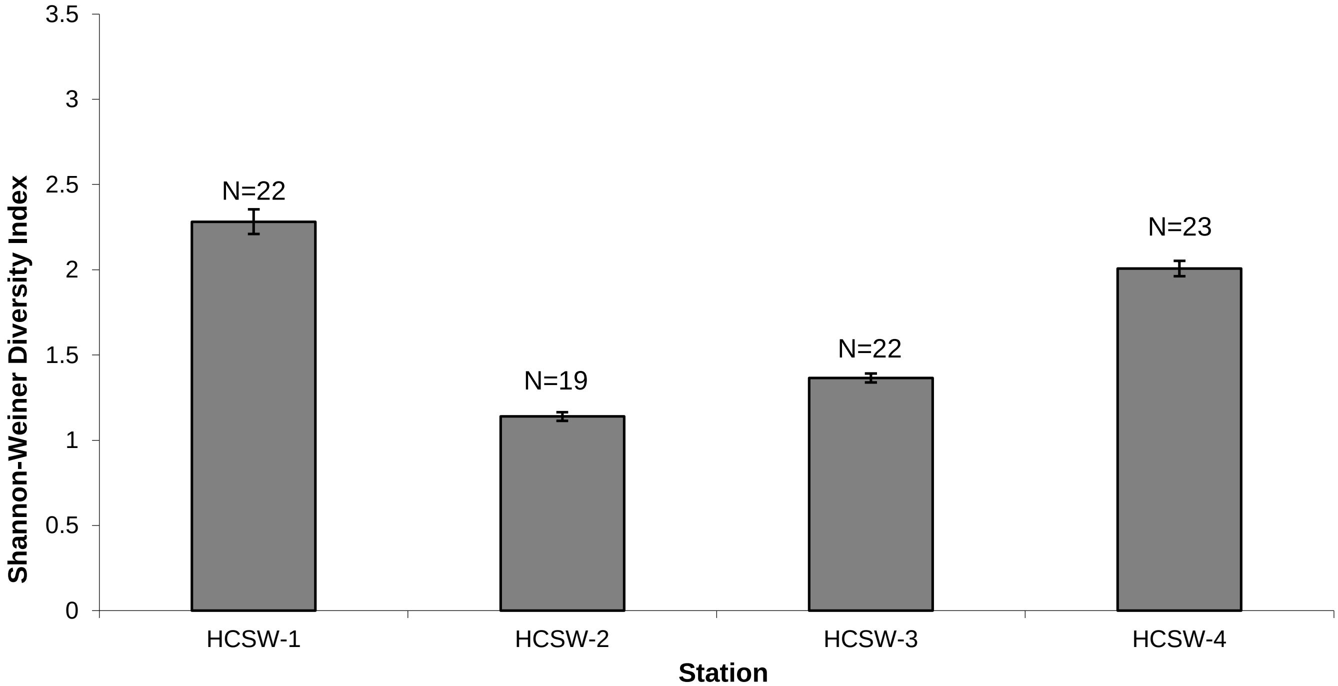

Figure 103. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from Four stations on Horse Creek summarized over all sampling dates.

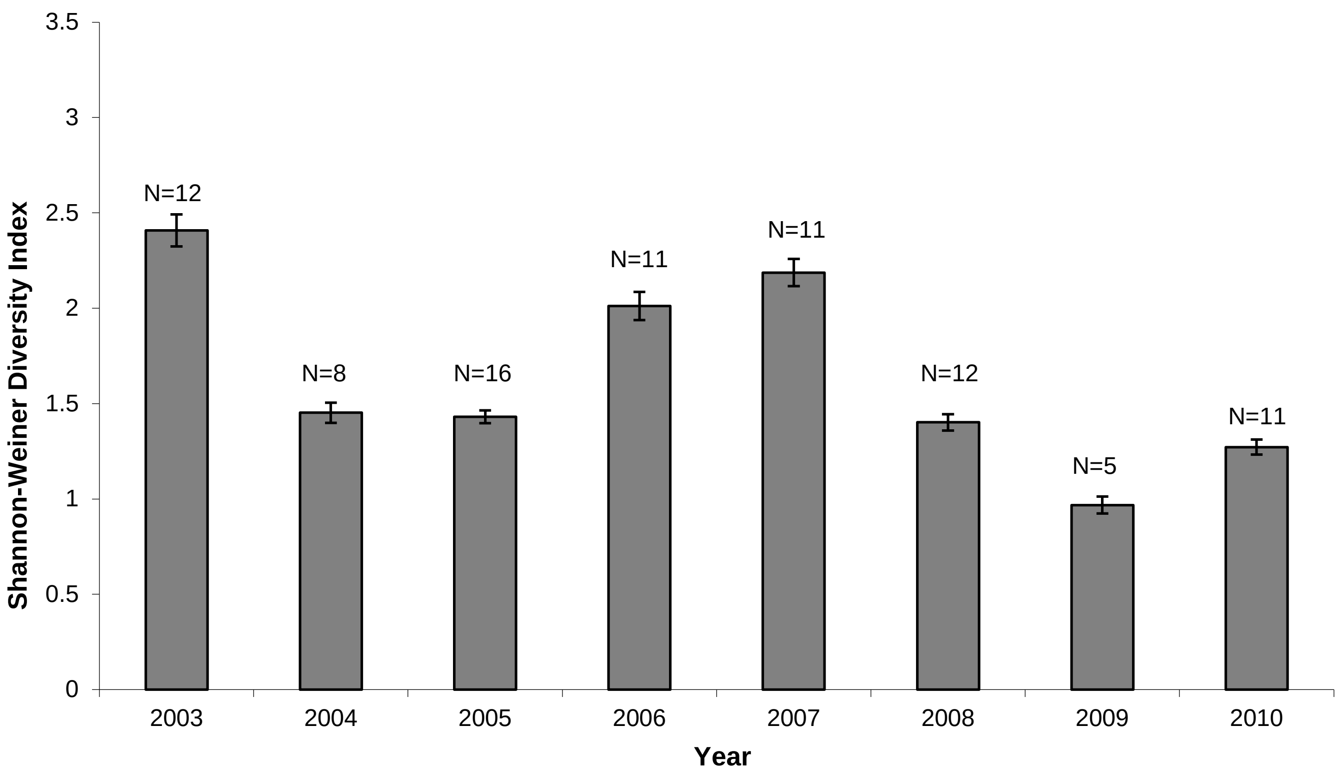

Figure 104. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from Eight Years on Horse Creek summarized over all stations combined.

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 = ΣX_{ij} = Total number of individuals in sample *j*

N_k = ΣX_{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 22 includes Morisita's Index values combined by year or station. When all sampling locations for a given year or station are combined, fish communities were very similar (87%-99%) (Table 22).

Table 22. Morisita's Similarity Index Matrix Comparing Sampling Dates within Stations or within Years for 2003 to 2010 Samples.

	HCSW-1	**HCSW-2**	**HCSW-3**	**HCSW-4**				
HCSW-1	1	0.87	0.89	0.94				
HCSW-2		1	0.99	0.97				
HCSW-3			1	0.99				
HCSW-4				1				
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
2003	1	0.96	0.96	0.99	0.99	0.96	0.92	0.94
2004		1	0.98	0.99	0.95	1	0.99	1
2005			1	0.98	0.94	0.97	0.94	0.97
2006				1	0.99	0.99	0.97	0.98
2007					1	0.96	0.93	0.94
2008						1	0.99	1
2009							1	1
2010								1

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 very few new species with subsequent sampling events, and the curves shown have also leveled off for each station (Figure 105). This suggests that very few, if any additional species will be collected in the future.

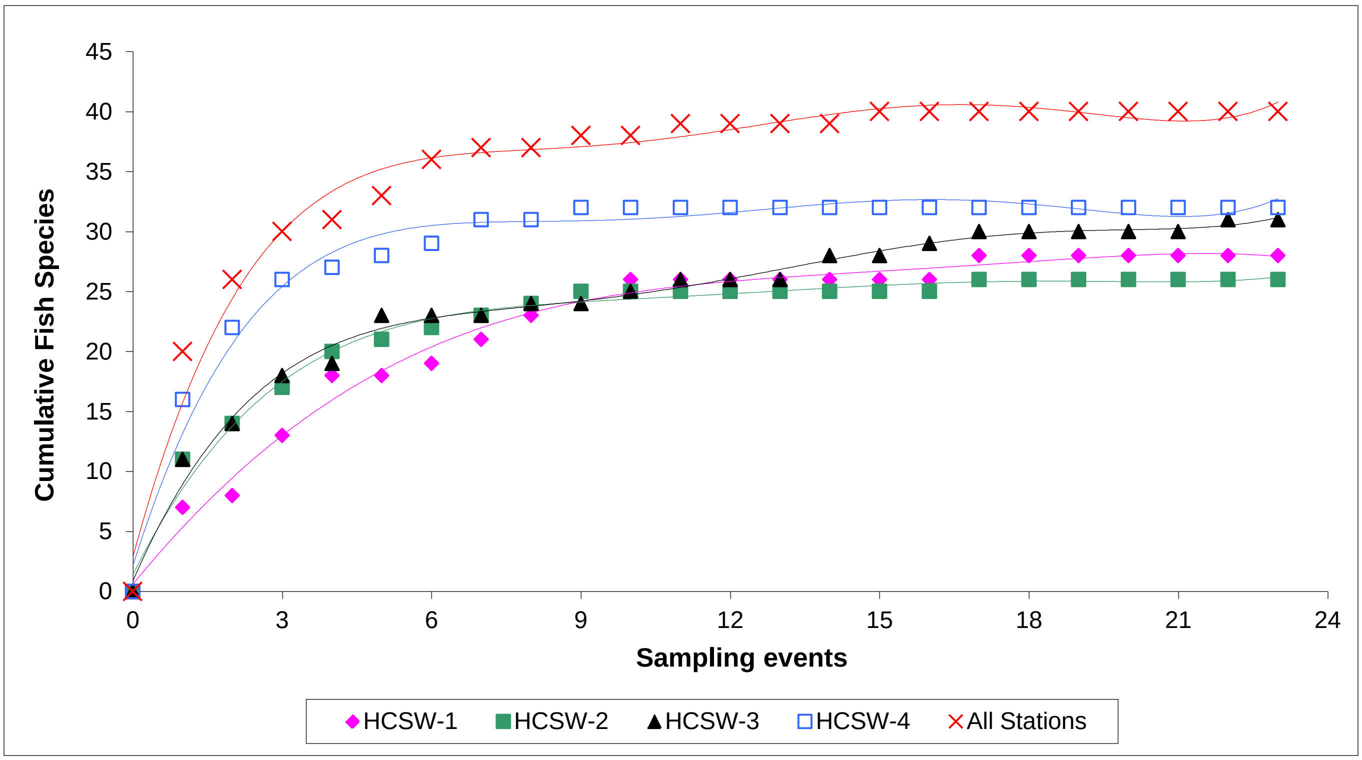

Figure 105. Cumulative Numbers of Fish Species Collected at Horse Creek Stations During 2003 -2010. (Species accumulation curves were fit for visual purposes only.)

5.4.5 Catch Per Unit Effort Analysis

Because of inconsistent sampling conditions during the biological sampling events, fish sampling effort may vary slightly between stations or sampling dates. To give a better representation in possible changes in sampling success over time, we have standardized the fish seining and electroshocking results to the number of individuals (Figures 106-109) and number of species (Figures 110-113) per 500 seconds of electroshocking or 5 seine hauls.

From Figures 106-109, it is clear that the standard number of individuals collected during seining is often greater than the number collected during electrofishing. This is expected because the seine technique is more likely to catch many small fish (such as mosquitofish or sailfin molly) in one haul; these small fish are often found in schools, which increase the likelihood of capturing a large group at one time. The figures also indicate that more fish are captured per unit effort at HCSW-2 and HCSW-3 than at other stations. At these two stations, the water levels are generally lower than at HCSW-4, leaving more habitats accessible for fish sampling; this is especially true for areas where seining is most effective. HCSW-1, which has the lowest catch per unit effort is the most narrow station, which can lead to higher velocity and water levels during some sampling events that will interfere with fish sampling. In addition, HCSW-1 has less fish refuge habitat (areas isolated from main channel, snags, large roots, aquatic vegetation) than other stations, making it more difficult to sample fish without them being alerted. All stations show some variability over time, with a noticeable decrease in individuals per unit effort at HCSW-2 and HCSW-3 during the dry years of 2006-2007.

Fish richness per sampling effort is more similar between sampling methods (seine vs shock), between stations, and over time (Figures 110-113). Richness per sampling effort is generally 12 species or less for each technique, station, and sampling event combination, with HCSW-1 and HCSW-2 on the lower end and HCSW-3 and HCSW-4 on the higher end of the spectrum. Given that the larger Peace River is a potential source of recruitment to the downstream stations of Horse Creek, this outcome is not surprising. In addition, HCSW-2 often has very low dissolved oxygen concentrations because of its proximity to a large wetland area; therefore, often only hypoxia-tolerant fish species are present at that station.

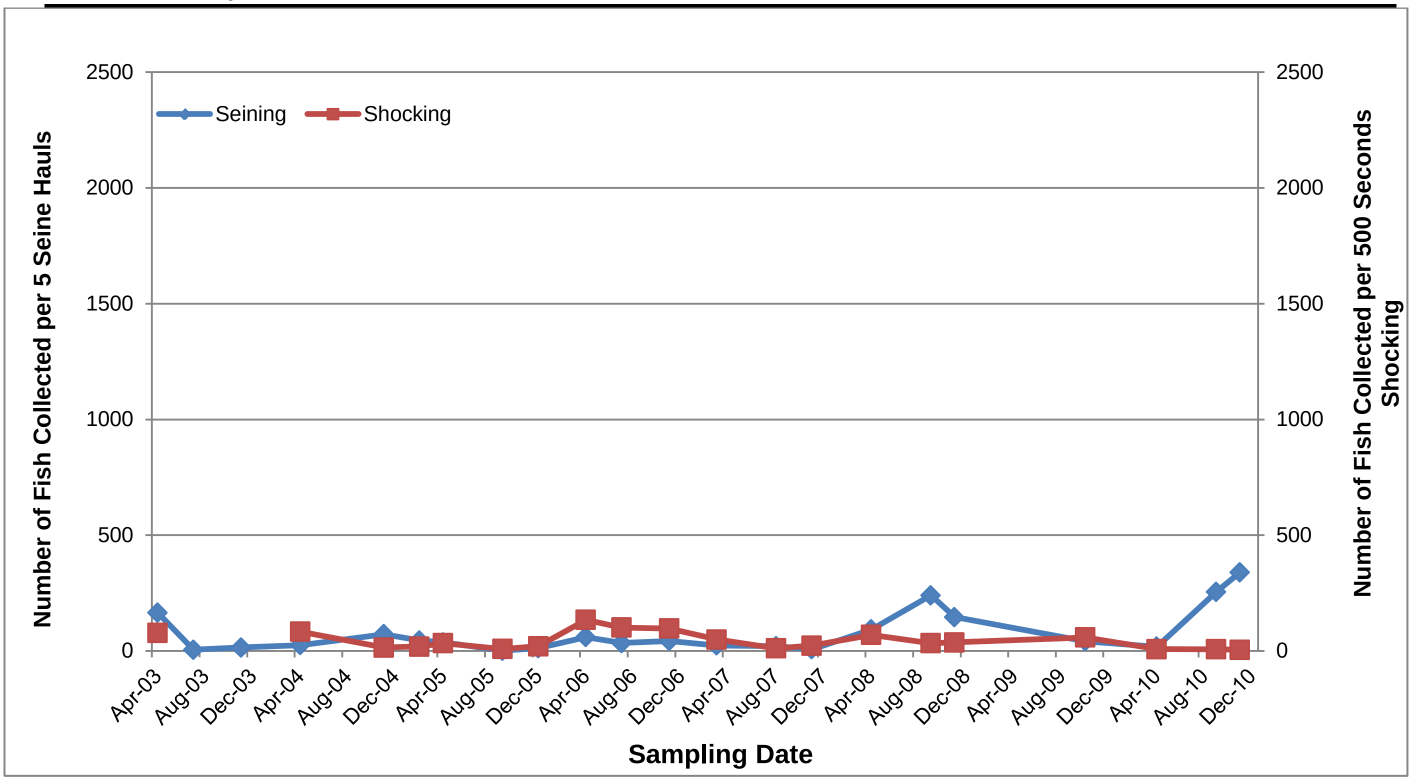

Figure 106. Number of fish individuals per unit effort at HCSW-1from 2003 – 2010 (total fish collected standardized to 5 seine hauls and 500 seconds shocking).

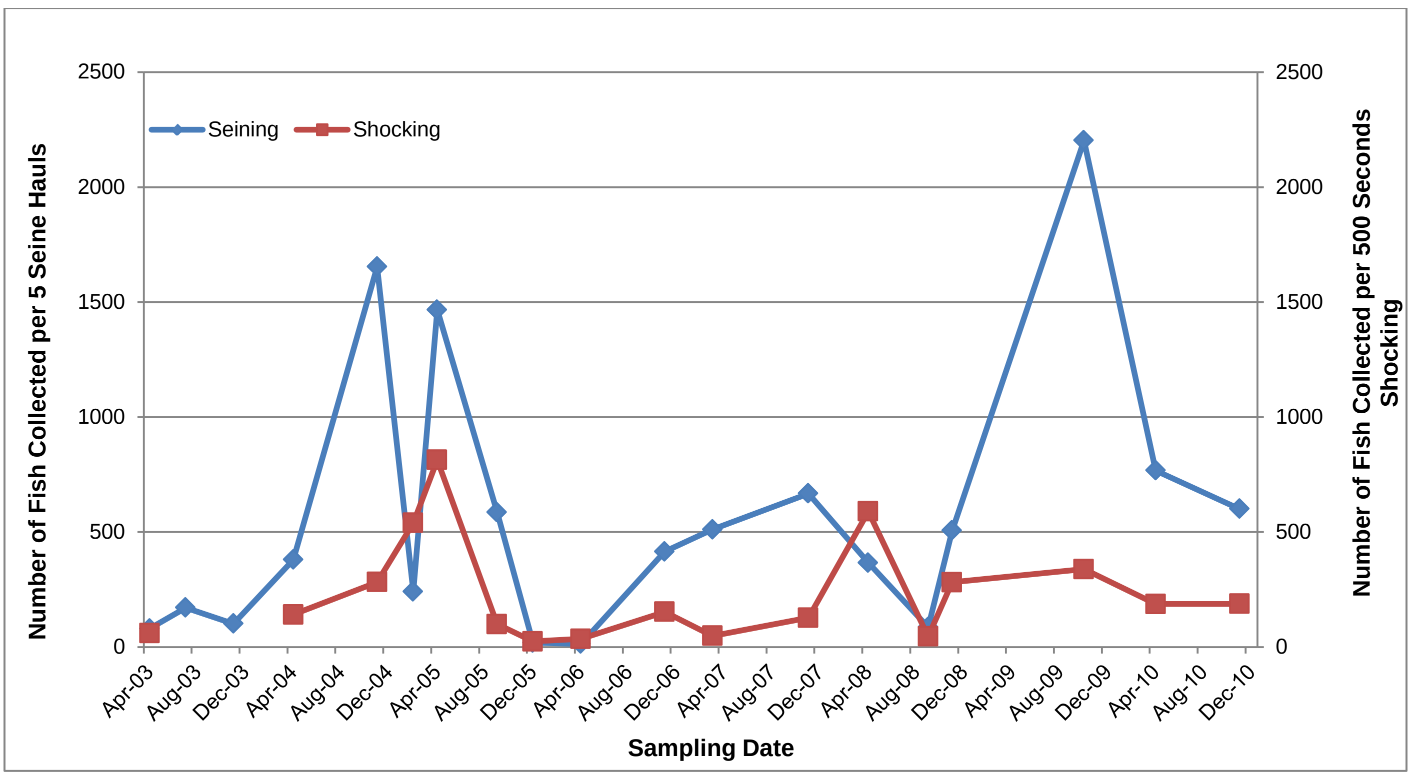

Figure 107. Number of fish individuals per unit effort at HCSW-2 from 2003 – 2010 (total fish collected standardized to 5 seine hauls and 500 seconds shocking).

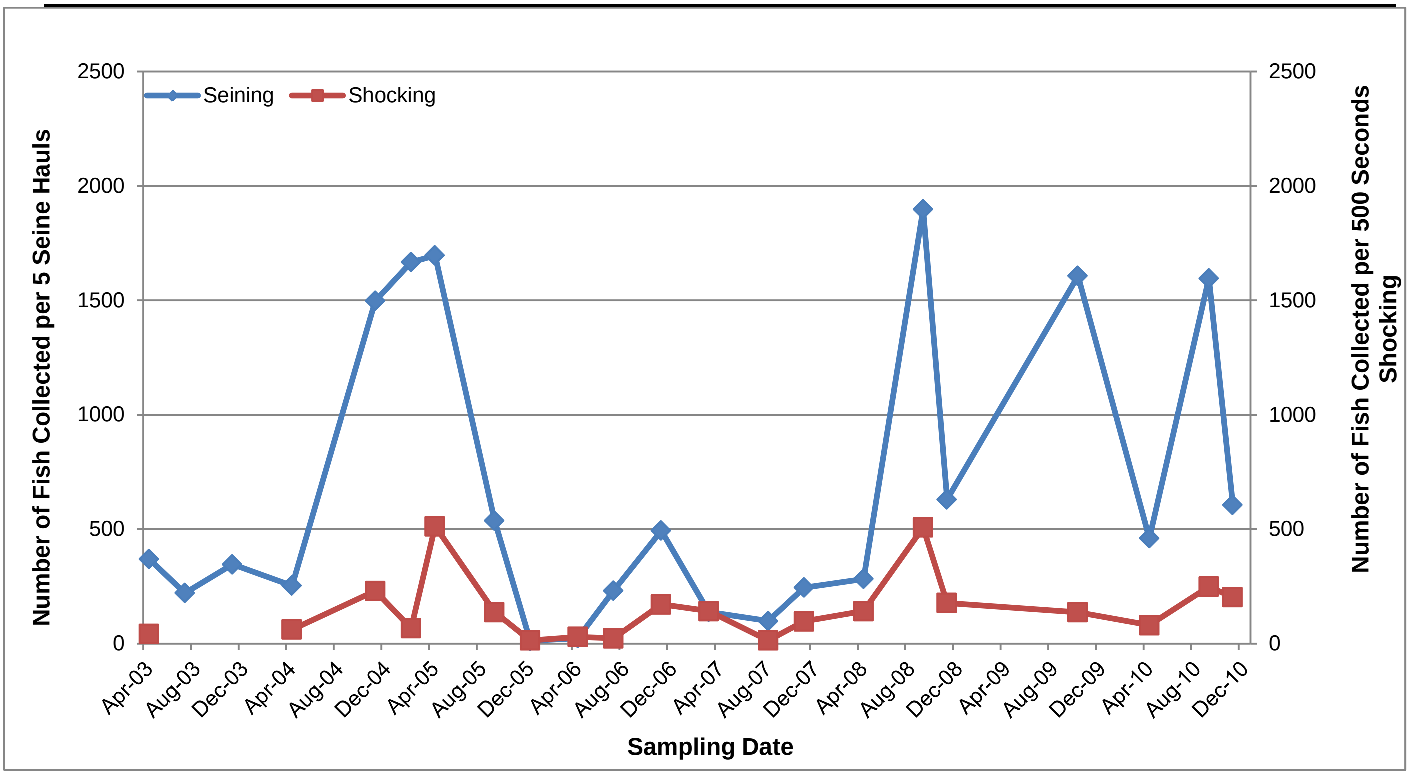

Figure 108. Number of fish individuals per unit effort at HCSW-3 from 2003 – 2010 (total fish collected standardized to 5 seine hauls and 500 seconds shocking).

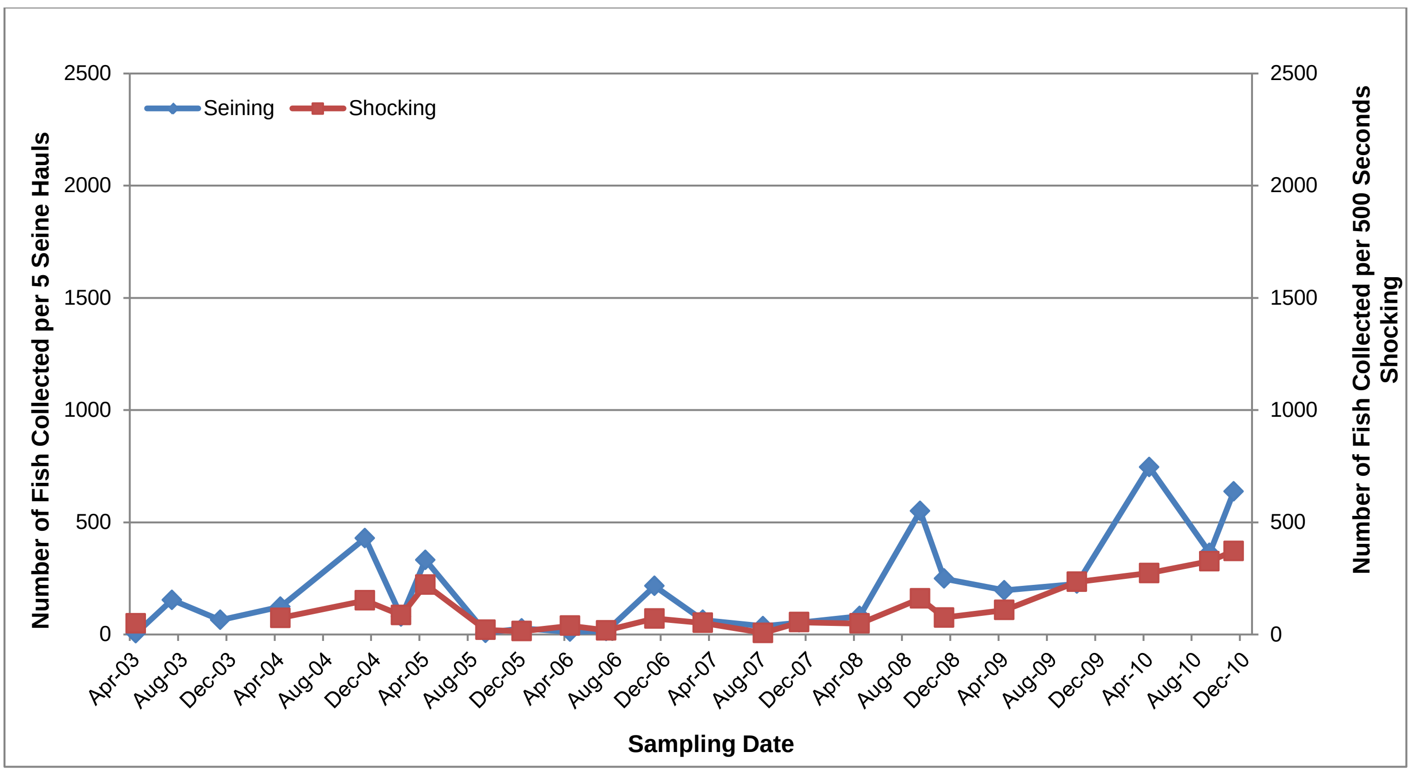

Figure 109. Number of fish individuals per unit effort at HCSW-4 from 2003 – 2010 (total fish collected standardized to 5 seine hauls and 500 seconds shocking).

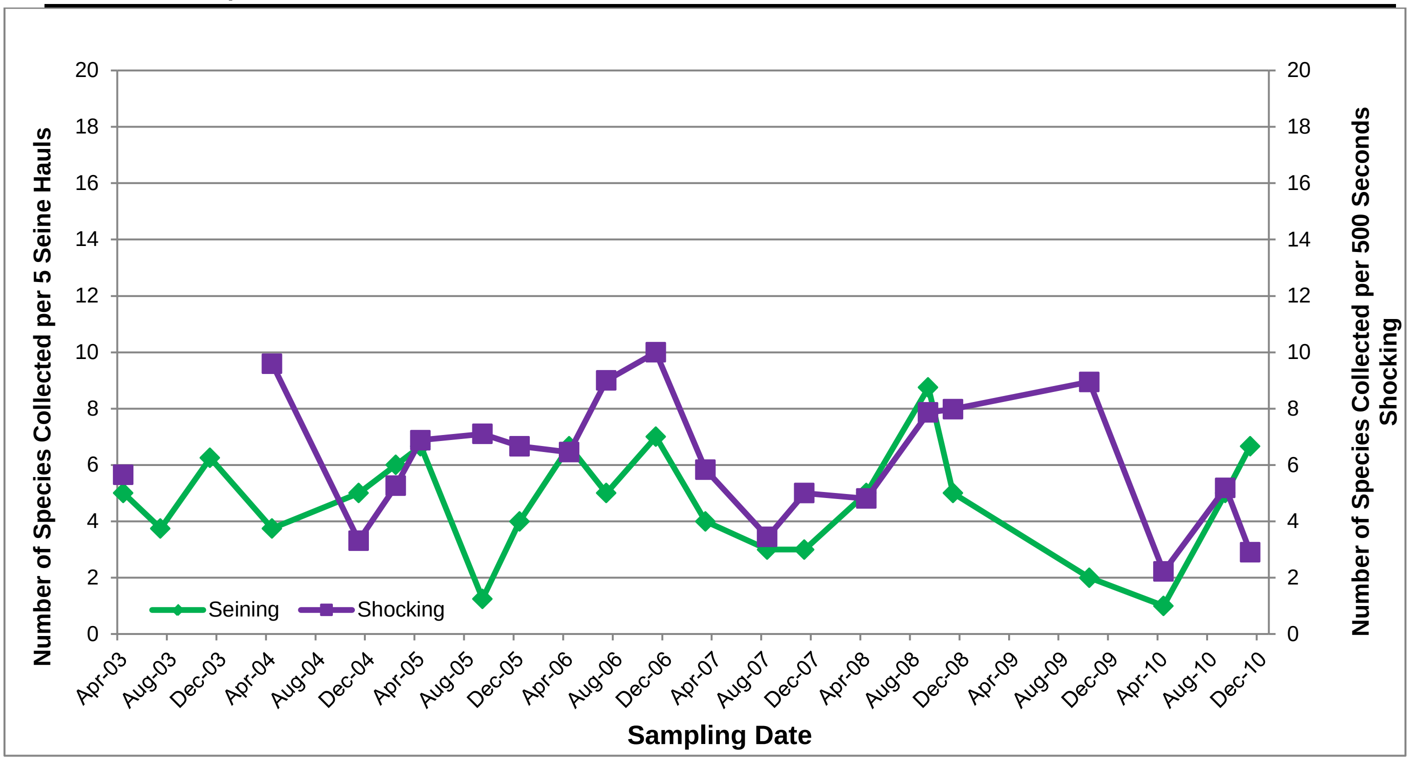

Figure 110. Fishing richness per unit effort at HCSW-1 from 2003 – 2010 (fish species collected standardized to 5 seine hauls and 500 seconds shocking).

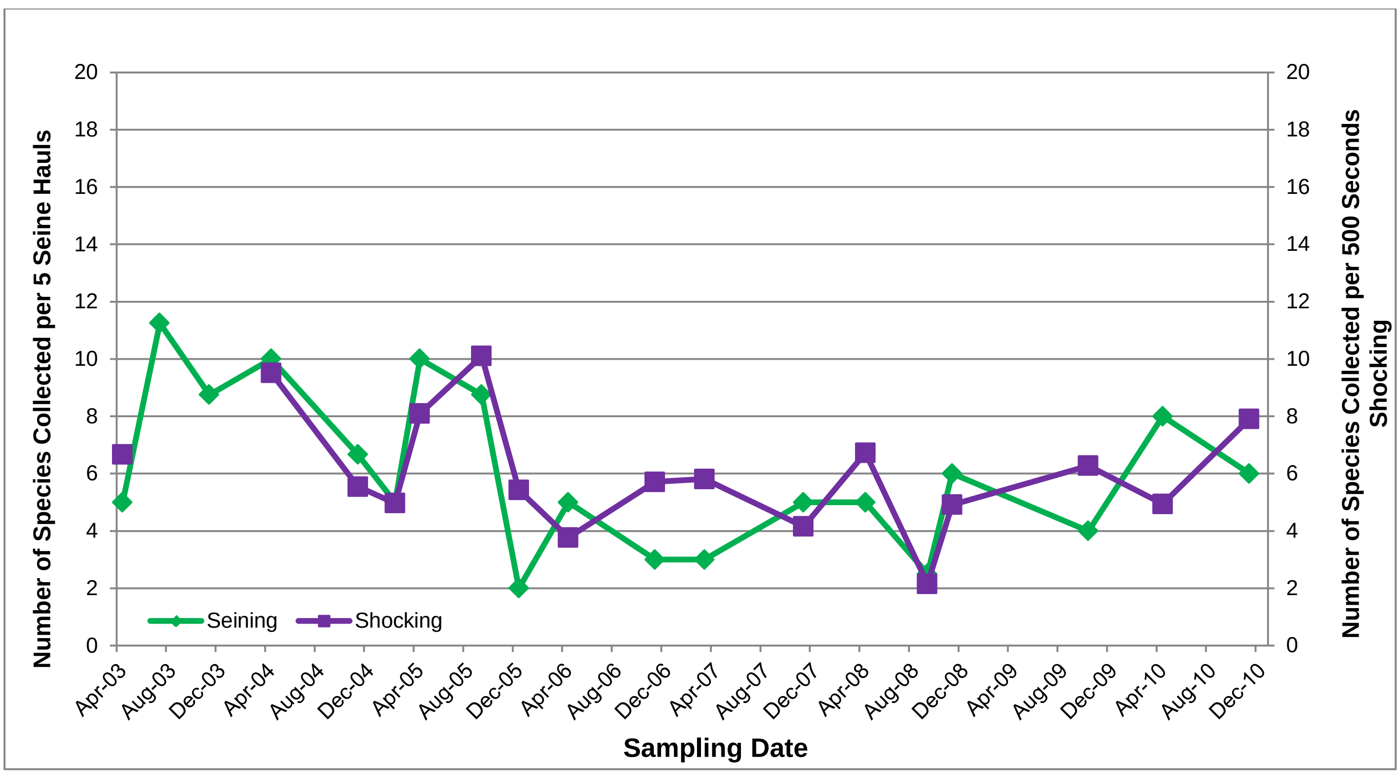

Figure 111. Fishing richness per unit effort at HCSW-2 from 2003 – 2010 (fish species collected standardized to 5 seine hauls and 500 seconds shocking).

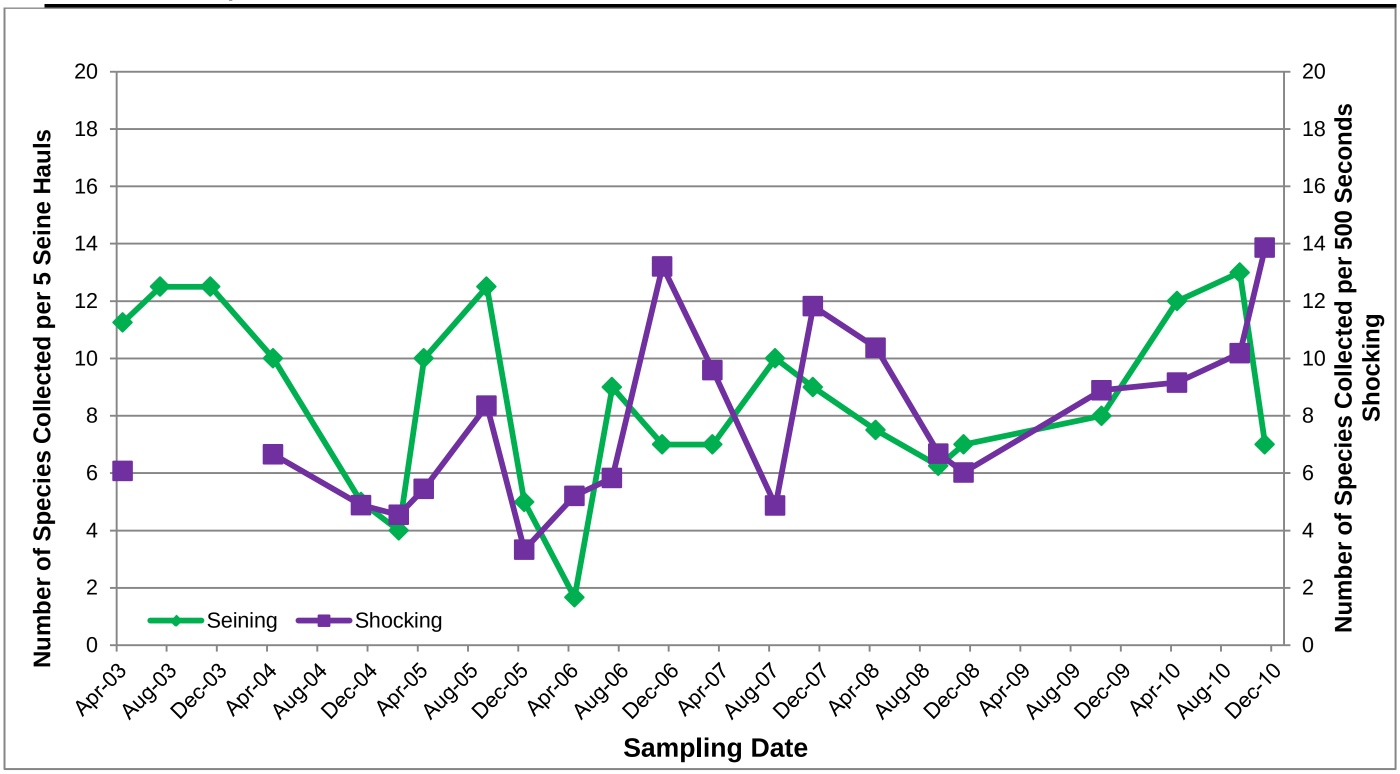

Figure 112. Fishing richness per unit effort at HCSW-3 from 2003 – 2010 (fish species collected standardized to 5 seine hauls and 500 seconds shocking).

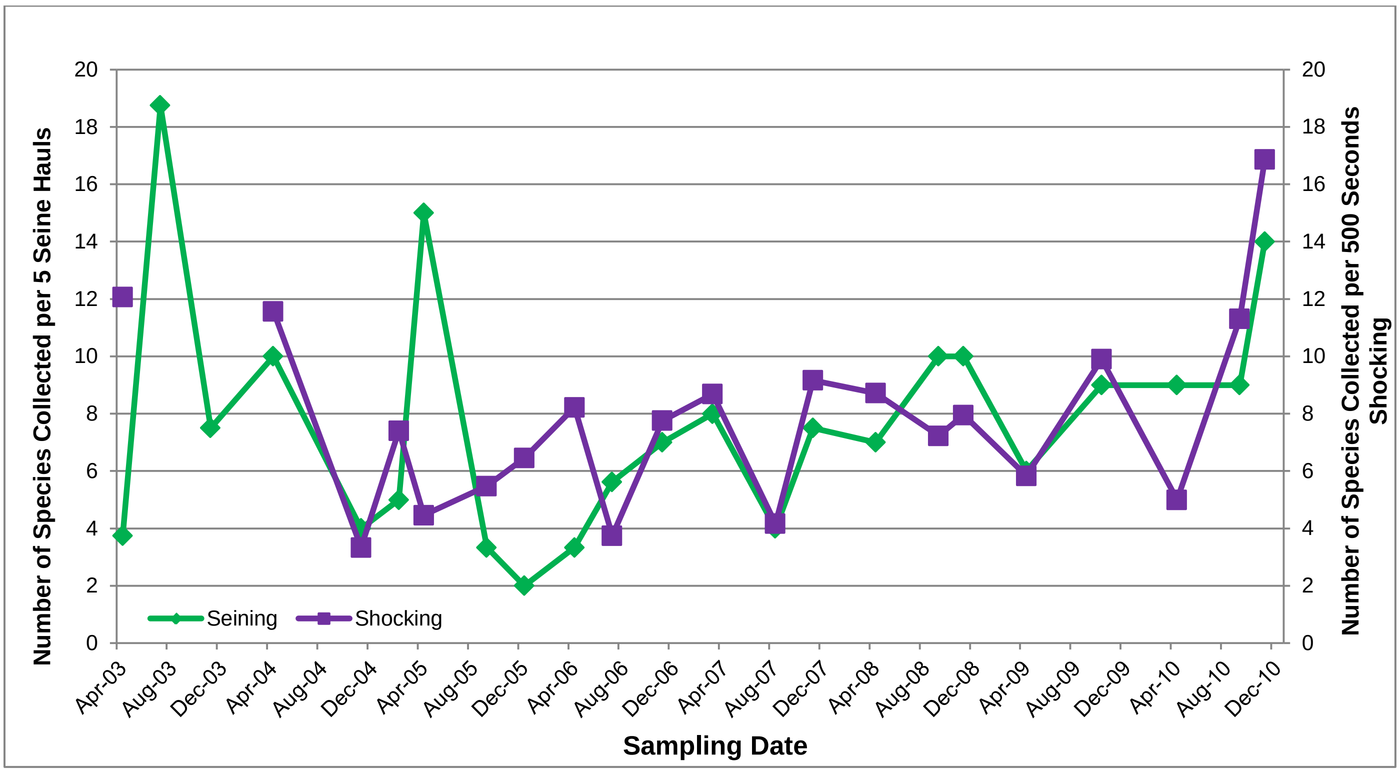

Figure 113. Fishing richness per unit effort at HCSW-4 from 2003 – 2010 (fish species collected standardized to 5 seine hauls and 500 seconds shocking).

5.4.6 Summary of Fish Results

Forty species of fish were collected in 2003 to 2010, with most captured individuals belonging to one of five families (Table 23). 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 2010 have leveled off. Several native species are almost certainly present in Horse Creek but were not collected in 2003 to 2010. These include the American eel (*Anguilla rostrata*) and black crappie (*Pomoxis nigromaculatus*). Samples collected included seven introduced species: walking catfish, African jewelfish, brown hoplo, suckermouth catfish, oriental weatherfish, sailfin catfish, and blue tilapia. 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 23. Percentage of individual fish captured per year for most abundant fish families/groups in Horse Creek during 2003 – 2010 as part of the Horse Creek Stewardship Program.

Fish Family	HCSW-1	HCSW-2	HCSW-3	HCSW-4	Total
Poeciliidae	60%	97%	91%	78%	89%
Cyprinidae	24%	0.02%	3%	7%	4%
Centrarchidae	8%	1%	2%	5%	2%
Cyprinodontidae	1%	1%	1%	4%	2%
Atherininidae	3%	0%	1%	2%	1%
Exotics	1%	1%	1%	2%	1%

Table 24 presents a summary of the number of individual fish captured for several major fish groups at each station per year, including exotic fish species. At each station, the number of individuals per fish groups varies considerably over time and is heavily influenced by sampling conditions. The inherent variability of the data, as well as the change in sampling effort between years and stations, makes it difficult to look for trends in fish group abundance over time, but a visual examination shows no general trends of increase or decrease in the exotic group or the native fish groups.

Fish diversity showed no significant trends over time at any station or over all stations combined. Fewer fish species were collected at HCSW-1 in 2010 than the other three stations because of sampling conditions (either very low or high flow). In addition, water levels and streamflow were very high during biological sampling at all stations in September 2010 which led to HCSW-2 not being sampled; high water levels and flow during sampling were not ideal because some habitats could not be reached by our sampling equipment. In addition, when fish sampling was corrected for catch per unit effort, fish abundance and richness in 2010 was not different that previous years.

Table 24. Number of individual fish captured per year for major native and exotic fish groups in Horse Creek during 2003 – 2010 as part of the Horse Creek Stewardship Program.

HCSW-1								
	2003	2004	2005	2006	2007	2008	2009	2010
Native Poecilids	181	78	75	341	25	275	47	328
Native Sunfish	46	26	33	20	23	24	14	7
Native Catfish	5	9	3	4	3	2	0	0
Native Other	77	104	92	164	103	294	49	12
Exotics	0	1	2	3	0	1	5	0
Total Fish	309	218	205	532	154	596	115	347
Sampling Events	3	2	4	3	3	3	1	3
HCSW-2								
	2003	2004	2005	2006	2007	2008	2009	2010
Native Poecilids	363	1735	3093	568	908	1335	2519	1696
Native Sunfish	41	15	9	13	2	1	1	1
Native Catfish	1	2	0	0	0	0	0	0
Native Other	63	80	52	14	8	48	5	50
Exotics	4	0	22	1	4	5	3	2
Total	472	1832	3176	596	922	1389	2528	1749
Sampling Events	3	2	4	2	2	3	1	2
HCSW-3								
	2003	2004	2005	2006	2007	2008	2009	2010
Native Poecilids	669	1606	4125	727	489	3122	1677	2874
Native Sunfish	49	24	35	31	44	19	5	78
Native Catfish	1	0	0	0	4	1	0	1
Native Other	230	138	58	179	250	130	16	294
Exotics	1	14	37	9	17	19	53	7
Total	950	1782	4255	946	804	3291	1751	3254
Sampling Events	3	2	4	3	3	3	1	3
HCSW-4								
	2003	2004	2005	2006	2007	2008	2009	2010
Native Poecilids	172	713	705	280	62	794	409	2423
Native Sunfish	52	27	5	67	54	68	65	38
Native Catfish	6	2	2	0	0	1	0	0
Native Other	136	81	22	123	228	242	376	245
Exotics	16	6	28	17	4	6	6	17
Total	382	829	762	487	348	1111	856	2723
Sampling Events	3	2	4	3	3	3	2	3

Section 6.

Conclusions

6.1 Water Quantity Results

For 2010, 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 October). The winter dry season (November to December) was extremely dry, resulting in periods of little to no flow. Mosaic's NPDES-permitted discharges upstream of HCSW-1 discharged for portions of ten months of the year. Although low and median discharge in 2010 was average for the region, rainfall in 2010 was below the long-term average annual rainfall of 52.72 inches (1908-2010)[16].

With no rainfall in October 2010 and very little rainfall in November and December 2010, streamflow at HCSW-1 and NPDES discharge was essentially zero. During other months, NPDES discharge accounted for the majority of the streamflow at HCSW-1, except for some peak streamflow events during the wet season.

6.2 Water Quality Results

Water quality parameters in 2010 were almost always within the desirable range relative to trigger levels and water quality standards at the station closest to mining. Trigger levels were exceeded only twice at HCSW-1 in 2010: alkalinity in January and chlorophyll *a* in February. At HCSW-2, trigger levels were exceeded for dissolved oxygen during most of the year as the result of natural conditions (proximity to hypoxic segment of stream – Horse Creek Prairie) and are not related to mining activities. HCSW-3 exceeded trigger levels for dissolved oxygen in April and July through September. HCSW-4 exceeded trigger levels for dissolved oxygen (July), sulfate (November), TDS (November), and iron (4 months). Dissolved oxygen triggers were exceeded during summer wet months of 2010, when high temperatures reduce the oxygen carrying capacity of the stream. Sulfate and TDS were exceeded in the dry season, when low rainfall and streamflow likely led to increased groundwater inputs from baseflow and agricultural runoff. Dissolved iron concentrations consistently exceeded the trigger value set at HCSW-4, but Mosaic and the PRMRWSA agree that the trigger value at that station has been set too low given historical and upstream concentrations of dissolved iron. Based on impact assessments already completed, none of the observed exceedances can be attributed to mining.

Several of the trends detected during the statistical analysis either have an estimated slope that 1) was not in the direction of an adverse trend (color, ammonia) or 2) was very small compared to limits in laboratory prediction or the observed differences between primary and duplicate field samples (pH, fluoride). For the trends with higher estimated rates of change (orthophosphate and various dissolved ions), the potential trends are discussed in Appendix I. Appendix I shows that the apparent trend in orthophosphate from 2003-2010 is caused by a data bias, and that extending the period of record

[16] Historical rainfall information came from the following stations and years: 1908-1943 NOAA station 148, 1944-2010 average of NOAA station 148 and 336

eliminates this trend. The trend for specific conductivity and other ions may have been influenced by changes in mining practices, but the current concentrations are stable and not biologically harmful.

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 dissolved ions (specific conductivity, calcium, chloride, sulfate) had higher concentrations downstream in Horse Creek, probably because of increased groundwater seepage and agricultural runoff in the lower Horse Creek basin.

Water quality parameters were compared with water quantity variables recorded during the same month: average daily streamflow for the month, average daily NPDES discharge for the month, and total monthly rainfall (Figure 74). In general, pH, dissolved oxygen, and most dissolved ions are higher when the overall quantity of water in the Horse Creek system is low. (In 2010, specific conductivity, sulfate, and TDS showed the opposite pattern with NPDES discharge at HCSW-1; this is discussed as part of the trend analysis in Appendix I.) Conversely, turbidity, color, iron, and some nutrients are high when the water quantity is also high.

6.3 Benthic Invertebrate Results

Benthic invertebrate habitat scores were "Optimal" to "Sub-optimal" and SCI scores were "Healthy" or "Impaired" at all stations in 2010; 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. When considered over time from 2003 to 2010, the SCI scores were variable over time at each station, but showed no monotonic trend. SCI scores and invertebrate diversity was significantly lower overall at HCSW-2.

6.4 Fish Results

Twenty-five species of fish were collected in 2010. In 2010, fish richness and diversity was lowest at HCSW-2, with no annual trends at any station. Fish communities were similar for all years when stations were combined and for all stations when years were combined. Catch per effort is variable over time and dependent on sampling technique, a station's physical characteristics, water levels, and available recruitment sources. No trends were evident in the abundance of fish from exotic and native fish groups.

Section 7.
Recommendations

7.1 Previous Annual Report Recommendations

During the 4 August 2010 meeting of the HCSP TAG for the 2009 annual report (Robbins, et. al. 2011), the TAG made several recommendations for modifications to the existing program. These recommendations and their current status are as follows:

In the 2010 HCSP Annual Report and subsequent reports, the report will:

- Clarify the steps of reclamation, including reconnection and release. The mining and reclamation figures in the reports will be clarified to detail what stage of reclamation is depicted.
- Include a brief summary of the Brushy Creek basin landuse above the new sampling collection point on State Road 64.
- Provide a table and discussion on the native versus exotic fish population found in Horse Creek.
- Provide a catch per unit effort (CPUE) analysis for fish sampling.
- Review potential additional analyses to examine the relationships between streamflow, rainfall, and mining and reclamation in the Horse Creek basin.

7.2 Current TAG Recommendations

During the TAG meetings for the 2010 Annual Report draft (February 29, 2012) and the 2010 Impact Assessment (August 20, 2013), the following recommendations were made:

- In the 2010 HCSP Annual Report and subsequent reports, Cardno ENTRIX will add the report year’s median water quality concentrations to the water quality trend summary table for context.
    - Included in final 2010 HCSP Annual Report and Appendix H.
- In the 2010 HCSP Annual Report and subsequent reports, Cardno ENTRIX will add a table, graphic, or text depicting major mine operation changes or alterations both during and prior to the HCSP.
    - Included in final 2010 HCSP Annual Report, Appendix I, and will be a separate appendix in the 2011 HCSP Annual Report.
- In the 2010 HCSP Annual Report and subsequent reports, Cardno ENTRIX will add a paragraph to explain the NPDES discharge make-up in the past and how it has changed in both water quantity and quality.

  - Included in final 2010 HCSP Annual Report, Appendix I.

- In the 2010 HCSP Annual Report, Cardno ENTRIX will include reference to the Streamflow Analysis Report that was prepared for SWFWMD (which was part of the EMP for Mosaic's WUP).

  - Included in final 2010 HCSP Annual Report.

- In the 2010 report and subsequent reports Cardno ENTRIX will add a sentence stating that all graphs within the report contain data collected only during the HCSP period-of-record unless otherwise noted.

  - Included in final 2010 HCSP Annual Report.

- In the 2010 report and subsequent reports Cardno ENTRIX will provide a discussion of the table showing native versus exotic fish species.

  - Included in final 2010 HCSP Annual Report.

- Cardno ENTRIX and Mosaic will research total pumpage (removal) and the number of SWFWMD Water Use Permits (WUPs) within the Peace River Basin. This may be incorporated into the 2012 Annual Report, if appropriate.

- Cardno ENTRIX will provide a milestone section (as an appendix) in the 2011 report and all future reports.

- Cardno ENTRIX will expand flow discussion in 2012 Annual Report.

7.3 Current Annual Report Recommendations

- Cardno ENTRIX will add new 2012 FDEP SCI SOP and NNC language to 2012 or 2013 Annual Reports.

- Cardno ENTRIX will add a discussion of current to previous stream conditions in Section 4 of the 2012 and future reports.

- Cardno ENTRIX will add the outfall locations to Figure 3 (Mining and Reclamation) in the 2011 and future reports.

Section 8.

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