WY06 ANALYSIS OF C-139 BASIN PHOSPHORUS SOURCES, TRANSPORT, CYCLING, AND EXPORT

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Prepared For

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EVERGLADES REGULATION DIVISION

Prepared By

COMMUNITY WATERSHED FUND
"Clean Water, Healthy Watersheds"

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TABLE OF CONTENTS

LIST OF FIGURES

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telephone: 321.639.4982 • fax: 321.631.3169 • www.cwfund.org • 365 Gus Hipp Road, Rockledge, FL 32955

LIST OF TABLES

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EXECUTIVE SUMMARY

Agricultural Best Management Practices (BMPs) are an integral part of efforts to reduce phosphorus impacts to the Everglades Protection Area (EPA). The C-139 Basin goal is to maintain total phosphorus (TP) loads at or below historical levels. The Everglades Forever Act mandates that, collectively, the basin landowners not exceed the average annual TP load observed between 1 October 1978 and 30 September 1988 adjusted for rainfall. However, TP load and P concentration have increased in recent decades. Discharge from the C-139 Basin exceeded its mandated target load and concentration in each of its first four years of compliance determination.

In a previous study, Community Watershed Fund (CWF) and DB Environmental reviewed phosphorus data (10 May 1999 through 10 May 2004) for the C-139 Basin. Much of the phosphorus exported from the basin appeared to come from relatively few sites in the central and southern basin. An exploratory investigation of phosphorus cycling and transport focused on the Deerfence and S&M Canals (31 May through 23 June 2005) found the S&M Canal to be a more significant source of phosphorus than the Deerfence Canal. Phosphorus transported down the Deerfence and S&M Canals was primarily dissolved.

The focus of this report was to evaluate the WY06 data. The South Florida Water Management District (SFWMD) has three sampling programs in the C-139 Basin: C139B, C139D, and C-139 Compliance Points. The C139B Program provides a snapshot of TP concentrations throughout the watershed during the wet season. The C139D and the C139 Compliance Points Programs provide water quality and flow data for the sub basins and basin discharge points, respectively. CWF evaluated the WY06 phosphorus concentration, flow, and load data to assess basin phosphorus sources, transport, cycling, and export.

Based upon the evaluation of WY06 data, amending the existing sampling programs would facilitate developing an effective BMP program. Most important is completing installation of the C139D Program autosamplers. Phosphorus concentration (TP, total dissolved phosphorus [TDP], and soluble reactive phosphorus [SRP]) and flow data, and improved understanding of G150-associated flow, would enable comparison of sub basin loads.

Ideally, TDP, SRP, chlorophyll *a*, total suspended solids (TSS), and floating aquatic vegetation (FAV) would be sampled at each station. Collectively, this information elucidates phosphorus sources, transport, and cycling throughout the C-139 Basin. For example, measurement of SRP and calculation of PP from TP and TDP help to identify the predominant phosphorus species. Predominant SRP suggests phosphorus from soil amendments or sediment flux. Predominant PP suggests phosphorus from soil erosion, plant decomposition, or plankton. Chlorophyll *a*, TSS, and FAV help us discern between

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various PP sources. Sampling during quiescent periods elucidates phosphorus transport and cycling.

Flow is also a critical measurement parameter for each station because it facilitates calculation of average daily and cumulative loads. A high phosphorus concentration is meaningless if the phosphorus is not conveyed downstream. Flow should be measured concurrent with water quality sampling to determine phosphorus conveyance.

Despite the aforementioned constraints, the WY06 sampling data elucidates some aspects of C-139 Basin phosphorus sources, transport, cycling, and export. TP concentration for SM-01 was four times greater than the combined DF-01/02 sub basins, a finding consistent with previous studies (CWF and DBE 2004, 2005). This suggests that the SM-01 Basin may be a relatively significant source of phosphorus in the C-139 Basin. However, flow measurements and load calculations are required to precisely define sub basin export. Moreover, collection of phosphorus and flow data at other C139D program locations is necessary to place SM-01 and DF-01/02 sub basins phosphorus export in a basin-wide context.

Differences in TP concentration were apparent within several sub basins, and may be indicative of source contributions. The significance of differences in TP concentration cannot be evaluated without flow data and load calculation. That said, in the SM-01 sub basin, TP concentrations were greatest at SM02.2TW02 and SM02.1TN01. A non-sampled canal discharging downstream of the SM05.0TN and SM05.0TW stations and upstream of SM02.2TW02 may be contributing significant phosphorus to the S&M Canal and should be investigated. In the DF-02 sub basin, station DF11.3TW01 had an average TP concentration three times greater, and a peak concentration nine times greater, than station DF12.3TS. In the L3-01 sub basin, TP concentration was greater at L207.6TW02 than L206.0TW02, and greater at L206.0TW02 than L206.0TW01. Finally, in the L2-01 sub basin, TP and SRP concentrations were greater at L209.1TW01 than L212.1TW13.

Transport mechanisms were suggested in two instances by the WY06 data. In the SM-01 sub basin, TP concentration was less upstream of SM02.1TW, and again upstream of SMWeir. A reduction in TP concentration was also evident in the L3-01 sub basin. TP concentration was less at the downstream station (L206.0TW01) than at one, and perhaps both, of the upstream stations. These finding suggests that phosphorus was being removed as it was transported through the sub basin. Alternatively, phosphorus was being diluted by greater flow from one of the upstream stations, a non-sampled canal/ditch, or overland runoff. In either instance, the changes in TP concentration should be investigated, beginning with flow measurements and load calculations.

Elucidating phosphorus cycling in the C-139 Basin was hindered by inconsistent measurement of TDP and SRP, qualitative observations of FAV, and the lack of chlorophyll *a* or TSS data. SRP was the predominant phosphorus species in both the SM-01 and DF-01/02 sub basins. PP may play a more prominent role in phosphorus transport

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in the L3-01, L2-01, and L2-02 sub basins than the SM-01, DF-01, and DF-02 sub basins. At stations in the L3-01 sub basin, and at the L2-01 station, SRP was the predominant phosphorus species until April, when PP becomes the predominant species. The change was coincident with generally lower TP concentrations. Conversely, PP was the predominant phosphorus species in the L2-02 sub basin until the last sampling event in early November.

The WY06 C139 Compliance Points Program data provide a general picture of phosphorus export from the C-139 Basin. Average daily WY06 load was greatest at G406 (416 kg) and least at G136 (44 kg). The average daily load was greater at G342A, B, and C than at G342D. One hundred six metric tons of phosphorus were exported from the C-139 Basin during WY06. Cumulative load was greatest at G406 (44 metric tons) and least at G342D (10 metric tons). Fifty percent of the C-139 Basin annual load was exported to STA-5, and 41 percent to the L-3 Canal via G406.

Phosphorus export increased in response to increasing flow, increasing TP concentration, or an increase in both. Determining the cause of increased loads can inform future BMP development and implementation. For example, increasing loads due to increased flow suggest that water storage would be an effective BMP. Conversely, increasing loads due to increased TP concentration suggest a BMP centered on phosphorus source control, vegetation management, or canal sediment removal (if high phosphorus sediments are detected within the basin).

According to C139 Compliance Points Program data, phosphorus export patterns varied among structures. Some structures (e.g., G136, G406) exhibited relatively discrete phosphorus discharge events. Other structures (e.g., G342) discharge more consistently, although peaks are evident. Phosphorus was discharged predominantly as SRP. PP was a more significant proportion of phosphorus during quiescent periods, when TP concentrations are 30 to 50 percent less than flow concentrations. The relative increase in PP during quiescent periods may reflect the growth of FAV or plankton.

CWF offers the following recommendations to facilitate the SFWMD's elucidation of C-139 Basin phosphorus source, transport, cycling, and export, and ultimately optimizing the BMP program.

1. Each monitoring program should attempt to sample all stations within a single day. If this is not possible, then all sub basin stations should be sampled on the same day.
2. Each monitoring program should sample TP, TDP, and SRP whenever water is present, even in the absence of flow. Identification of phosphorus species is essential for discerning phosphorus sources and understanding transport and cycling.

3. Each monitoring program should measure TSS and chlorophyll *a* concurrent with phosphorus sampling. Measurement of TSS, chlorophyll *a*, and FAV facilitates understanding of PP source and phosphorus transport and cycling.
4. Each monitoring program should sample TP, TDP, SRP, TSS, chlorophyll *a*, and FAV during quiescent periods. Quiescent data compared with flow data contribute to our understanding of phosphorus transport and cycling.
5. Each monitoring program should measure flow coincident with sampling of TP, TDP, and SRP. 'No flow' events should recorded as 0 (zero) cfs. The Marsh-McBirney Flo-Mate Flowmeter (www.marsh-mcbirney.com) seems to be well suited for C-139 Basin flow measurement. Flow measurement allows for calculation of phosphorus load and contributes to our understanding of transport and cycling.
6. Each program should estimate floating aquatic plant coverage at the time of sampling, and include this information on the data worksheet(s). The occurrence of floating aquatic plants, and changes in coverage, help to explain the relative concentrations of phosphorus species and contribute to our understanding of phosphorus transport and cycling. One method for recording floating aquatic plant coverage (percent) is to visually estimate species-specific percent coverage for a defined quadrat (e.g. shore to shore for a 25 m length of the canal) encompassing the water quality sampling station.
7. The installation of autosamplers at stations DF11.3TW01, L202.0TN, L207.0TN, and G-151 should be completed.
8. The relative contribution of sub basins DF-02&01, SM-01, L3-01, L2-01, and L2-02 to discharge structures G342A-D and G406 cannot be discerned. This constrains application of BMPs related to gate operation. Dye tests could be used to evaluate the relative contribution of the sub basins to each discharge structure. Dye tests could be accomplished with a single dye applied to each sub basin at a separate time, or multiple dyes applied simultaneously to the sub basins. Dye should be applied to each sub basin at least once during a flow event, and preferably twice – once during the first significant flow event of the rainy season and again mid to late rainy season.
9. Defining L2-01 phosphorus and flow when G151 and G150 are open and discharging might be simplified by placing a structure on the L-2 Canal south of the L-2W Canal.
10. Discharge from the SM-01 sub basin canal downstream of the SM05.0TN and SM05.0TW stations and upstream of SM02.2TW02 should be investigated as a potentially significant source of phosphorus.
11. The apparent removal or dilution of phosphorus upstream of SM02.1TW and upstream of SMWeir should be investigated. Understanding changes in phosphorus concentration will clarify transport and cycling mechanisms, and suggest effective BMPs.
12. The apparent removal or dilution of phosphorus upstream of L206.0TW01 should be investigated. Understanding changes in phosphorus concentration will clarify transport and cycling mechanisms, and suggest effective BMPs. The

investigation should include contemporaneous measurement of TP, TDP, and SRP in the Devil's Garden, South Boundary, and Knowles Canals during a quiescent period and during flow.

13. The sediments should be investigated at L209.1TW01 to determine if they are a potential source of SRP to the water column. Sediments should be sampled during both quiescent and flow conditions.

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INTRODUCTION

Agricultural Best Management Practices (BMPs) are an integral part of efforts to reduce phosphorus impacts to the Everglades Protection Area (EPA). The Everglades Agricultural Area (EAA) BMP Program has exceeded mandates and expectations, achieving twice the regulatory program goal of a 25 percent reduction in phosphorus (South Florida Water Management District [SFWMD] 2005).

The C-139 Basin (Figure 1) goal is to maintain total phosphorus (TP) loads at or below historical levels. The Everglades Forever Act mandates that, collectively, the basin landowners not exceed the average annual TP load observed between 1 October 1978 and 30 September 1988 adjusted for rainfall. However, TP load and P concentration have experienced an increase in recent decades. Discharge from the C-139 Basin exceeded its mandated target load and concentration in each of its first four years of compliance determination (Adorisio et al. 2006).

Options for optimizing BMP effectiveness in the C-139 Basin could be applied at the basin, sub-basin, or farm level. Evaluations to determine where and how BMPs might best be applied have been initiated. In a previous study, Community Watershed Fund (CWF) and DB Environmental (DBE) reviewed phosphorus data encompassing the period 10 May 1999 through 10 May 2004 for the C-139 Basin (CWF and DBE 2004). The review concluded that much of the phosphorus exported from the basin appears to come from relatively few sites in the central and southern basin. Phosphorus was exported as total dissolved phosphorus, although there was some evidence of significant particulate phosphorus transport in the Deerfence Canal and at the southern inflow to STA-5 (CWF and DBE 2004).

CWF and DBE (2005) conducted an exploratory investigation of phosphorus cycling and transport in the Deerfence and S&M Canals. Based upon a small data set covering a limited period, the S&M Canal appeared to be a more significant source of phosphorus to the L3 Canal and STA-5 than the Deerfence Canal. Phosphorus transported down the Deerfence Canal was primarily dissolved. Phosphorus transported down the S&M Canal was dissolved, and to a lesser extent, particulate phosphorus (probably phytoplankton) and floating aquatic plants. Sediment was not a significant source or sink for phosphorus in the Deerfence and S&M Canals.

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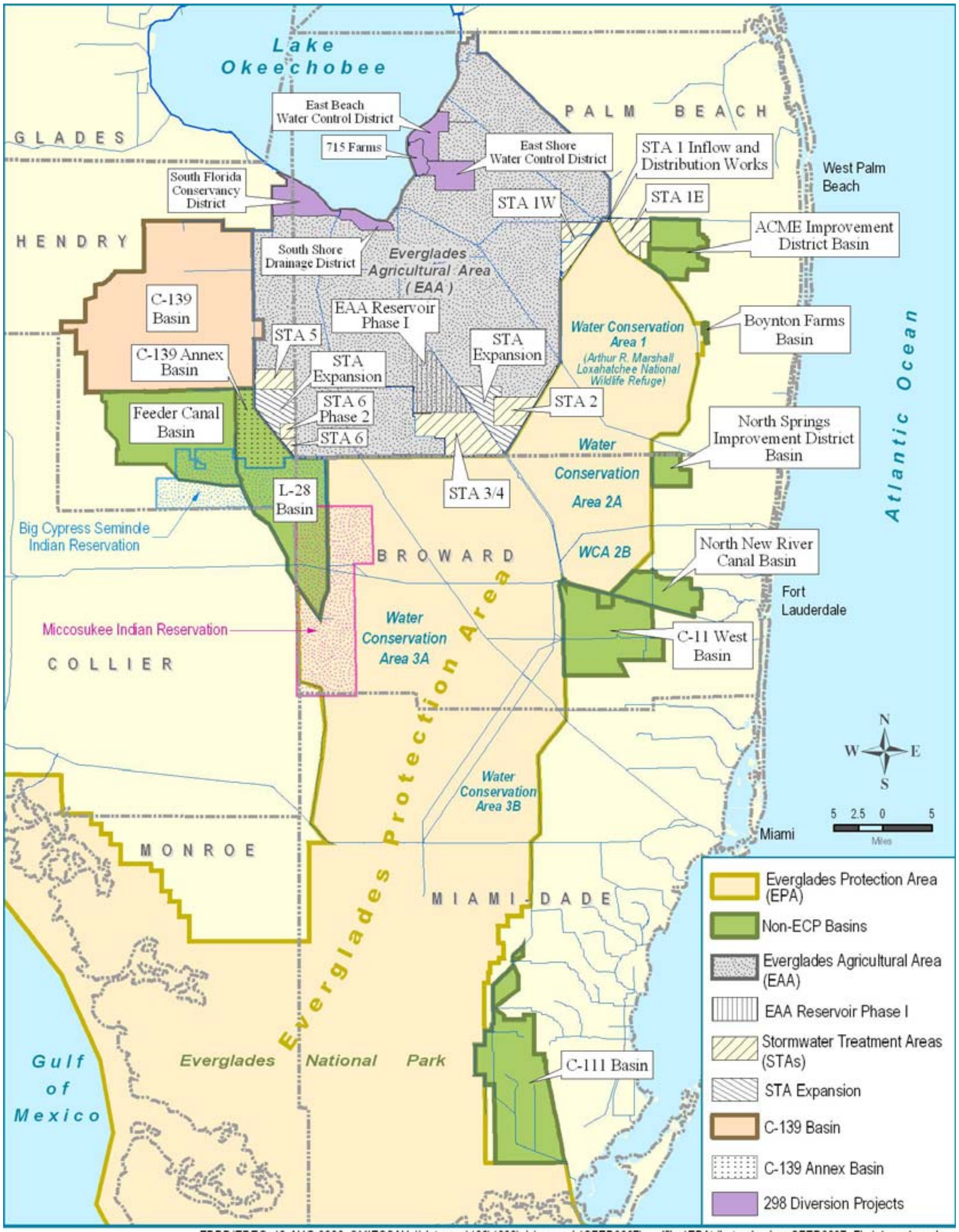

Figure 1. The C-139 Basin is located southwest of Lake Okeechobee and northwest of the Everglades Protection Area. Figure courtesy of the South Florida Water Management District.

Subsequent to the CWF and DBE studies (2004, 2005), the SFWMD defined sub basins and expanded its C-139 Basin sampling programs. Three programs are the primary source of basin data for the analyses in this report: 1) C139B Program, 2) C139D Program, and 3) C139 Compliance Points Program. Figure 2illustrates the location of program stations and basin features. Table 1 summarizes station names, sample parameters, collection methods, and number of Water Year 2006 (WY06) samples. Figure 3 illustrates the relationship between sampling stations, sub basins, and compliance points (basin discharge structures).

The SFWMD Everglades Regulation Division C139B Program encompasses 18 stations representing locations upstream of regulatory compliance points (Figure 2). The sampling locations provide a snapshot of phosphorus concentrations throughout the watershed in the wet season (generally April through October). Grab samples are collected weekly if water is flowing. Parameters of interest include TP, total dissolved phosphorus (TDP), and orthophosphorus (soluble reactive phosphorus, SRP).

The SFWMD Everglades Regulation Division C139D Program will, when complete, have seven autosamplers for determining water quality and flow data from C-139 Basin sub basins (Figure 2). Three autosamplers were installed in WY06: G150, SM00.2TW, and DF02.1TW. TP, TDP, and SRP were measured bi-weekly during the wet season. No flow data were collected in WY06.

Lastly, the C-139 Compliance Points Program collects water quality data at the C-139 Basin discharge structures to determine compliance with the Everglades Forever Act and Rule 40E-63, (F.A.C.). Compliance Point Program water quality data includes TP, TDP, and SRP. The Autosampler Composite Flow Proportional (ACF) data encompass weekly TP concentration and daily flow. In addition, grab samples are collected weekly at the C-139 Basin discharge structures for phosphorus analysis. Grab samples are collected during both flow and quiescent (no flow) conditions.

CWF was retained by the SFWMD to develop analysis templates, and evaluate WY06 and WY07 phosphorus concentration, flow, and load data. This report describes CWF's evaluation of WY06 C-139B, C-139D, and C-139 Compliance Points data to assess C-139 Basin phosphorus sources, transport, cycling, and export. Source assessment refers to where in the basin the phosphorus is originating. Transport assessment refers to the capacity for the phosphorus to move from its source, through the basin, and to be exported. Cycling assessment refers to changes in predominant species (SRP, DOP [dissolved organic phosphorus], PP) as phosphorus is conveyed through the basin. Export assessment refers to both the quantity and location of phosphorus leaving the basin.

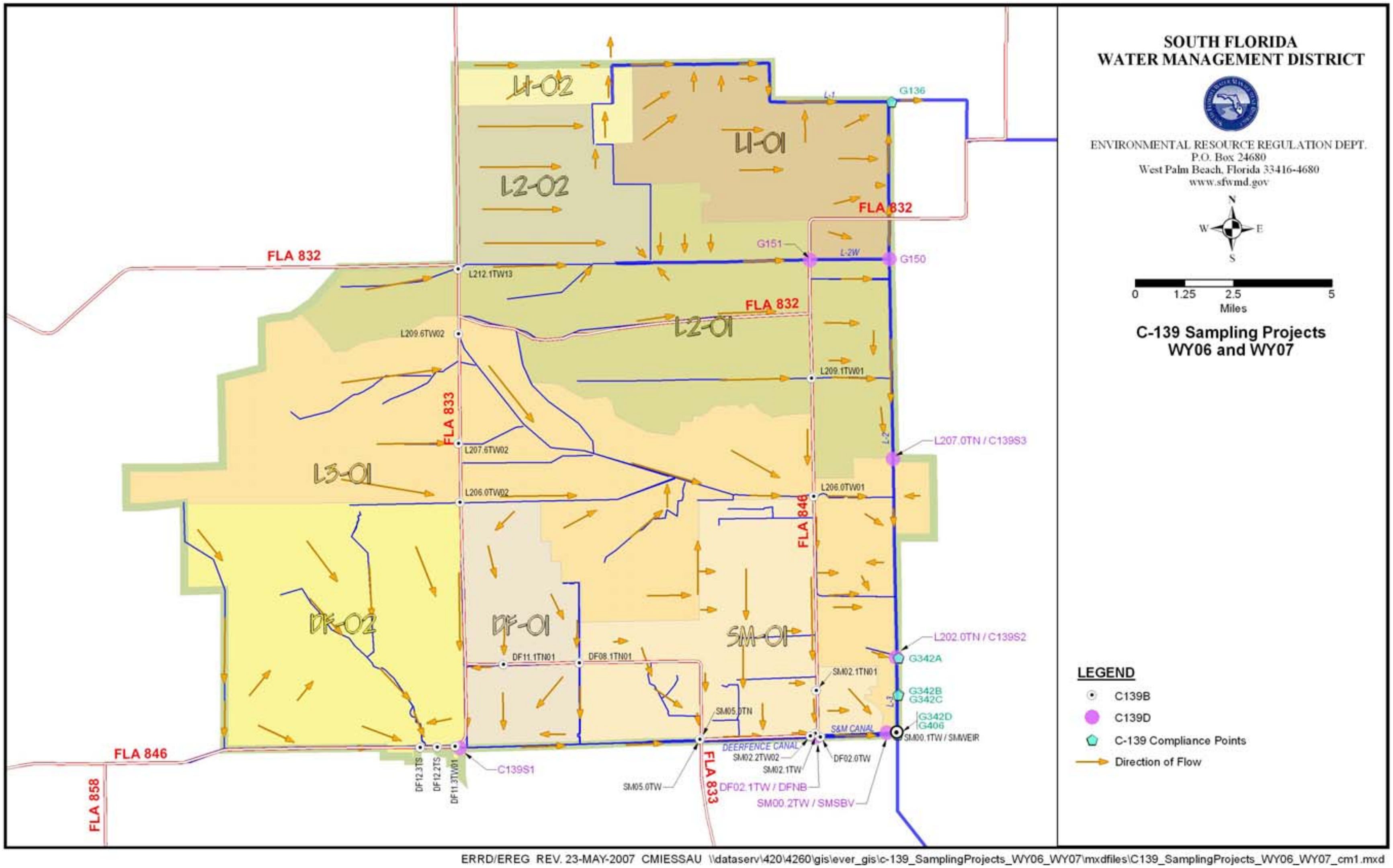

Figure 2. C-139 Basin C139B, C139D, and C-139 Compliance Points sampling program stations, sub basin boundaries, flow patterns, and prominent geographical features.

Table 1. WY06 C-139 Basin programs, stations, parameters, collection methods, and number of samples.

Program	Water Quality Station Name	Flow Station Name	Parameters	Collection Method	# Samples	Comments
C139B						
	L212.1TW13		TP, TDP, SRP	Grab	8	
	L209.1TW01		TP, TDP, SRP	Grab	15	
	L209.6TW02		TP, TDP, SRP	Grab	0	
	L207.6TW02		TP, TDP, SRP	Grab	1	
	L206.0TW02		TP, TDP, SRP	Grab	9	
	L206.0TW01		TP, TDP, SRP	Grab	17	
	SM05.0TW		TP, TDP, SRP	Grab	5	
	SM05.0TN		TP, TDP, SRP	Grab	7	
	SM02.2TW02		TP, TDP, SRP	Grab	6	
	SM02.1TN01		TP, TDP, SRP	Grab	7	
	SM02.1TW		TP, TDP, SRP	Grab	3	
	SMWeir		TP, TDP, SRP	Grab	10	To be replaced by SMSBV, Actual location is SM00.1TW
	DF12.3TS		TP, TDP, SRP	Grab	10	
	DF12.2TS		TP, TDP, SRP	Grab	0	
	DF11.3TW01		TP, TDP, SRP	Grab	12	To be replaced by C139S1
	DF02.0TW		TP, TDP, SRP	Grab	12	To be replaced by DFNBV
	DF11.1TN01		TP, TDP, SRP	Grab	10	
	DF08.1TN01		TP, TDP, SRP	Grab	11	
C139D						
	G150	Same	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	48	
	G151	Same	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	0	No Data WY06
	C139S3	Same	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	0	No Data WY06, Actual location is L207.0TN
	C139S2	Same	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	0	No Data WY06, Actual location is L202.0TN
	SM00.2TW	SMSBV	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	12	No Flow Data WY06
	DF02.1TW	DFNBV	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	12	No Flow Data WY06
	C139S1	C139S1	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	0	No Data WY06
Compliance Points						
	G136	Same	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	19/19/18	
	G342A	Same	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	14/13/22	
	G342B	Same	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	21/21/16	
	G342C	Same	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	21/19/5	
	G342D	Same	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	19/18/7	
	G406	Same	TP, TDP, SRP, Flow	Autosampler/Grab Flow/Grab No Flow	6/6/6	

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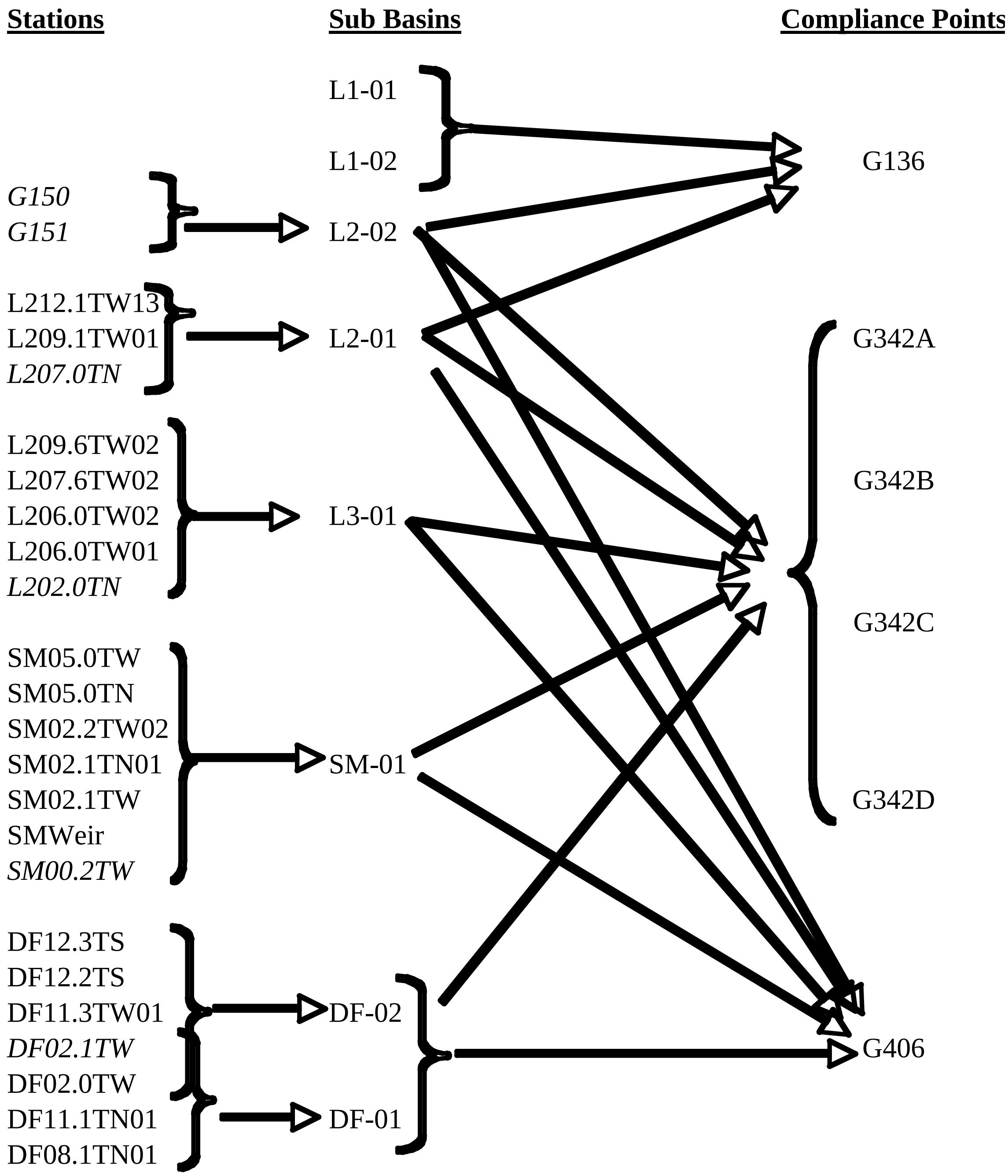

Figure 3. Relationship between upstream sampling stations, sub basins, and basin discharge structures in the C-139 Basin. Stations in italics are part of the C139D sampling program. All other stations are part of the C139B sampling program.

Analysis of different phosphorus species is an important aspect of the C-139 Basin assessment. The phosphorus species at headwater stations suggests the proximal source. For example, predominant SRP suggests conveyance of soil amendments in stormwater runoff to the canals, whereas predominant PP suggests movement of soil, plant detritus, or plankton. Measuring species throughout the canals provides information about whether phosphorus is transported through the basin in the form in which it enters the canals, or is converted to other forms. For example, SRP could be moved through the basin, without conversion into other forms, during flow events. Alternatively, SRP could be converted into aquatic plants and plankton, which in turn could decay and settle or be transported out of the basin during flow events. Finally, the phosphorus species at the point of export helps us to assess treatment potential and downstream effects. In total, understanding phosphorus species at headwaters, throughout conveyance canals, and at export points facilitates development of effective on-farm, in-canal, and post-basin BMPs.

METHODS

The WY06 evaluation includes graphical and statistical analyses, identification of data deficiencies, and recommendations. At the SFWMD's direction, the assessment begins at the sub basin level, and proceeds upstream to individual stations. Compliance Point data were also evaluated. Phosphorus concentrations and loads at the sub basin and individual stations cannot in most instances be directly related to specific basin discharges because of uncertainties about flow patterns (Figure 3).

Sub Basins

SFWMD's consultant, ADA Engineering, Inc., identified eight C-139 Basin sub basins (2006; Figure 2, Figure 3, and Table 2). The C139D autosampler locations are designed to facilitate measurement of water quality and flow in six sub basins. Some sub basins are represented by measurement at a single autosampler (e.g., DF-02), and other sub basins require calculation (e.g., DF-01). The combined water quality and flow of sub basins L1-01 and L1-02 can be measured at the G136 structure. Measurements at G136 must be adjusted for contributions from L2-02 and L2-01 when structure G150 is open.

Autosamplers were not installed at stations DF11.3TW01, L202.0TN, L207.0TN, and G-151 in WY06. Consequently, no WY06 data were available to directly evaluate phosphorus concentration, flow, or load emanating from the DF-01, DF-02, L3-01, L2-01, and L2-02 sub basins. G150 could have been used as a surrogate for G-151 if both structures were open and discharging, flow was equivalent at each structure, and mixing of L-2W Canal and L2 Canal water was negligible. No information was available to determine if these criteria were satisfied.

Stations DF02.1TW and SM00.2TW of the C139D Program were sampled for TP. The stations can be used to estimate phosphorus discharge concentration from the combined DF-01 and DF-02 sub basins and the SM-01 sub basins, respectively. C139B Program Stations DF02.0TW and SMWeir are located proximal to C139D Program stations DF02.1TW and SM00.2TW. Sampled for TP, TDP, and SRP, DF02.0TW and SMWeir also provide an estimate of phosphorus discharge from the DF-01/DF-02 and SM-02 sub basins. Flow was not measured at any of the stations.

Table 2. Measurement calculation for sub basins equipped with autosamplers.

Sub Basin	Estimator
DF-02	DF11.3TW01
DF-01	DF02.1TW - DF11.3TW01
SM-01	SM00.2TW
L3-01	L202.0TN - L207.0TN
L2-01	L207.0TN - G151 if G150 is closed; L207.0TN + G150 if G151 is closed and G150 is open; proportional estimation required if both G151 and G150 are open.
L2-02	G-151

Compliance Points

The C-139 Basin compliance points coincide with its six discharge structures: G136, G342A-D, and G406 (Figure 2) G136 is located in the northeast corner of the C-139 Basin and discharges to the L-1E Canal. The G342A-D structures are the inflow structures for STA-5. G406 is located in the southeast corner of the C-139 Basin and manages discharge south along the L-3 Canal.

One or more sub basins contribute to each basin discharge; phosphorus loads cannot be traced from discharge structures to sub basins to stations (see Figure 3). The L1-01 and L1-02 sub basins always contribute to the G136 structure. The L2-02, and less certainly the L2-01, likely contribute to the G136 when the G150 structure is open and discharging. Basin discharge structures 342A-D and G406 likely receive contributions from sub basins L2-02, L2-01, L3-01, SM-01, DF-02, and DF-01. The relative contribution to any discharge structure from each sub basin is unknown and likely varies with upstream release schedules and discharge structure operation.

The Autosampler Composite Flow Proportional (ACF) data are weekly TP and daily flow. Flow, TP concentration, and calculated load were compared among stations, and examined intra-station over time.

Grab sample TP, TDP, and SRP were collected weekly during both flow and quiescent (no flow) conditions at the C-139 Basin discharge structures. DOP and PP were calculated from TP, TDP, and SRP. TDP was not measured at G136, and TDP and SRP were not measured at G406. TP, SRP, DOP, and PP were compared among stations separately for flow and quiescent samples. In addition, intra-station differences in TP, SRP, DOP, and PP were examined over time.

Analyses

Column charts were used to illustrate station-specific TP, SRP, DOP, PP, flow, and load average daily value $\pm$ standard deviation. The charts facilitate inter-station comparisons. Phosphorus, flow, and load data were examined and found to best approximate the log normal distribution. Consequently, statistical comparisons were performed on log-transformed data. Differences were examined using *t*-Test (2 stations), and Analysis of Variance (> 2 stations). Significant differences detected by Analysis of Variance were further evaluated using pair wise Student's t Tests. A probability value $\leq$ 0.05 was considered indicative of a significant difference.

Line and marker charts were used to illustrate TP, SRP, DOP, PP, flow, and TP load over time. Empty Excel worksheet cells i.e., data gaps, are not plotted. All line and marker charts are set to encompass the WY06 period 1 May 2005 – 30 April 2006. The period of record charts facilitate discernment of intra-station temporal patterns, inter-station differences, recognition of predominant P species, and correspondence between TP, SRP, DOP, and PP. In instances where data is only collected when water is flowing (e.g., C-139B program), the line charts also facilitate understanding of station and sub basin discharge characteristics. Used in combination, intra-station line charts and inter-station column charts elucidate phosphorus transport and cycling.

Combination area/marker charts were used to illustrate station flow and TP concentration over the WY06 period. The charts facilitate examination of flow/TP relationships. Area charts were used to illustrate TP load. TP load (kg) was calculated from flow and TP concentration.

RESULTS AND DISCUSSION

Sub Basins

Sub basin SM-01 average discharge TP concentration was significantly greater than that of the combined DF-01 and DF-02 sub basins according to both C-139D program data[1] (0.173 ± 0.096 mg/L vs. 0.044 ± 0.014 mg/L; Figure 4) and C-139B program data[2] (0.414 ± 0.214 mg/L vs. 0.108 ± 0.069 mg/L; Figure 5). SRP[3] (0.332 ± 0.210 vs. 0.061 ± 0.055) and PP[4] (0.071 ± 0.0.039 vs. 0.033 ± 0.016) concentrations were greater in discharge from the SM-01 sub basin than the combined DF-01 and DF-02 sub basins. SRP constituted 80 percent of the TP from SM-01and 56 percent of the TP from the DF-01/DF-02 sub basins. PP constituted 17 percent of SM-01 TP and 31 percent of DF-01/DF-02 TP.

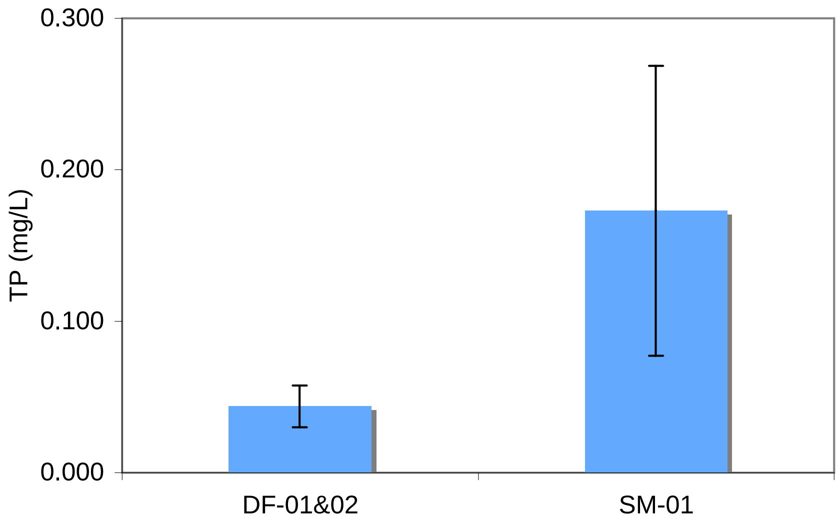

Figure 4. WY06 C139D program total phosphorus (TP) concentration (mean ± s.d.) for the C-139 Basin DF-01/02 and SM-01 sub basins.

1 $t_{19df} = 7.87$, $p < 0.0001$
2 $t_{20df} = 5.17$, $p < 0.0001$
3 $t_{20df} = 3.48$, $p < 0.0003$
4 $t_{20df} = 3.38$, $p < 0.0003$

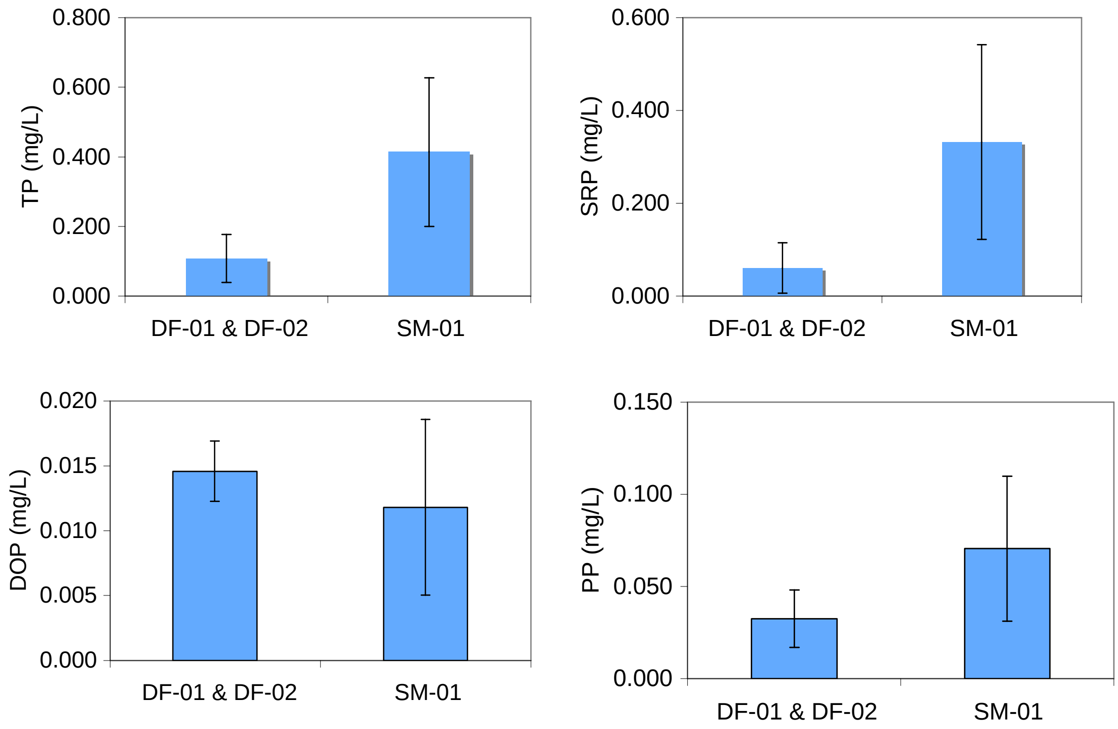

Figure 5. WY06 C139B program total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations (mean $\pm$ s.d.) for the C-139 Basin DF-01/02 and SM-01 sub basins.

Sub Basin SM-01

The C139D program sampled station SM00.2TW from 7 February - 25 April 2006. TP concentration varied widely, ranging from 0.071 - 0.432 mg/L (Figure 6). The maximum TP concentration did not correspond with peak monthly rainfall or a sharp increase in cumulative rainfall total (Figure 7). Nor does the maximum TP concentration coincide with the occurrence of floating aquatic vegetation (FAV) or algae according to C139D program field notes (Appendix A).

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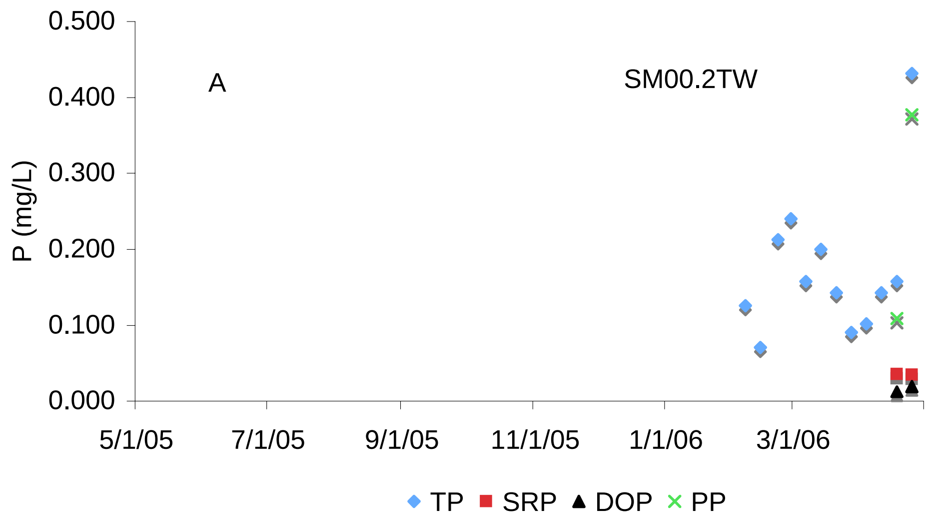

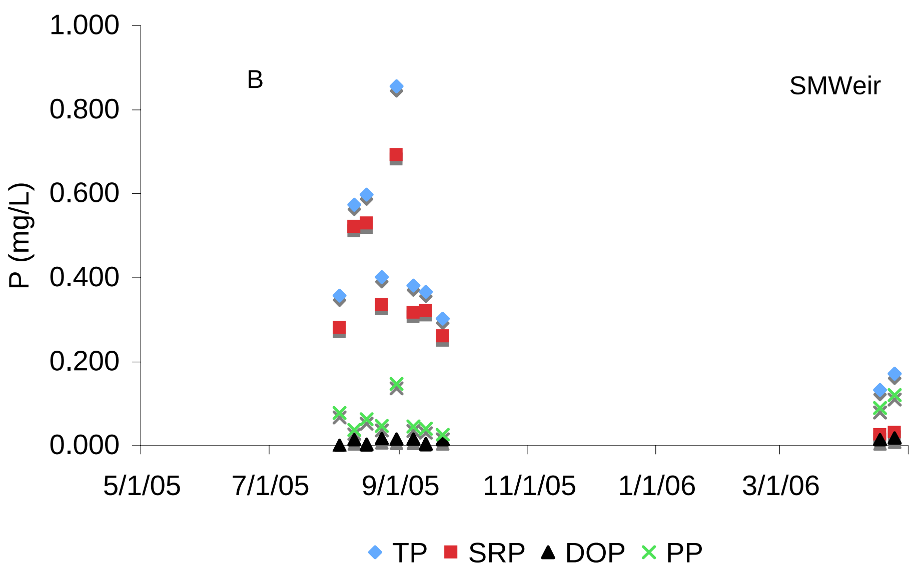

Figure 6. Chart A illustrates C139D Program WY06 total phosphorus (TP) concentrations emanating from the SM-01 sub basin as measured at station SM00.2TW. Chart B illustrates C139B Program WY06 TP, soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations emanating from the SM-01 sub basin as measured at station SMWeir. SM00.2TW and SMWeir are proximally located.

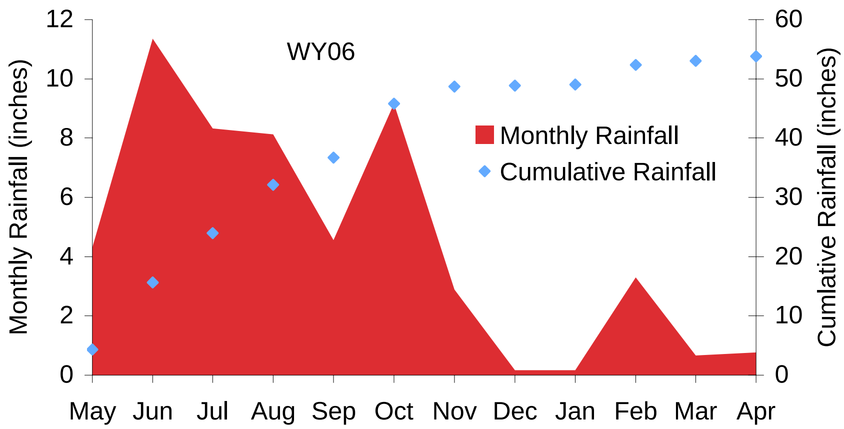

Figure 7. WY06 monthly and cumulative rainfall for the C-139 Basin.

SRP, DOP, and PP were sampled at SM00.2TW late April 2006. PP was the dominant species, and varied in concert with TP. FAV and algae were not recorded at SM00.2TW in April 2006.

The C139B Program sampled station SMWeir from 3 August 2005 – 24 April 2006. As with the C139D Program, TP concentrations varied widely, ranging from 0.133 - 0.856 mg/L (Figure 6). Concentrations were generally higher in August 2005, peaking 30 August. High TP concentrations generally correspond with higher monthly rainfall and sharply increasing cumulative rainfall totals. FAV, notably water lettuce (*Pistia stratiotes*), was present in August according to the field notes (Appendix A). TP concentrations declined in September 2005 and were lowest in April 2006. No sampling occurred between 21September 2005 and 17 April 2007.

Much of the C139B Program station SMWeir TP in 2005 was SRP. SRP concentrations corresponded with TP concentrations throughout August and September 2005. To a lesser extent, PP contributed to the peak in TP 30 August 2005. Again, FAV was noted at the site throughout much of August. In April 2006, PP was the predominant P species. The field notes indicate surface algae 17 and 24 April 2006. DOP was very low at all times (0.003 – 0.019 mg/L).

C139D and C139B Programs TP concentration data overlapped in mid to late April 2006. The correspondence was good 17/18 April 2006 (0.133 and 0.158 mg TP/L), but on 24/25 April 2006, C139B program TP concentration was 2.5 times lower than C139D program TP concentration. The latter finding suggests the two programs do not produce comparable results at proximal stations SM00.2TW and SMWeir.

If differences between the two programs persist, then it may be beneficial to determine if both programs are warranted. The C139B Program provides instantaneous measurements and could potentially identify short-term spikes in P concentration. Conversely, the infrequent sampling of the C139B Program is likely to miss discrete spikes in P concentration, and to exaggerate the importance of any spikes that are sampled. The C139D Program, which provides weekly composite samples, is less likely to miss spikes in P concentration or to exaggerate discrete P discharge events. Ideally, the C139D Program could supplant C139B Program at overlapping stations, and be amended to effect occasional sampling during quiescent periods.

Sub Basin SM-01 Stations

The C139B program has seven SM-01 sampling stations, six of which were sampled in WY06. SM05.0TN and SM05.0TW discharge into the western end of the S&M Canal. SM02.2TW02 is downstream of stations SM05.0TN and SM05.0TW and a non-sampled discharge canal draining the center of the SM-01 sub basin. SM02.1TN01 drains the eastern part of the SM-01 sub basin and discharges south to the S&M Canal. The western and northern branches combine at SM02.1TW, and flow east to the L3 Canal. Station SMWeir is immediately upstream of a corrugated metal structure separating the S&M Canal from the L3 Canal.

WY06 average TP concentrations were greatest[5] at stations SM02.2TW02 and SM02.1TN01, and lowest at SM05.0TN, SM05.0TW, and SM02.1TW (Figure 8). SRP was the predominant P species at all SM-01 sub basin stations. SRP[6] concentrations were greatest at SM02.2TW02 and SM02.1TN01. PP[7] concentrations were greatest at SM02.2TW02, SM02.1TN01, and SMWeir. FAV or algae were observed during many of the sampling events at each of these stations (see Appendix A). FAV was also observed at SM05.0TN during many of the sampling events, but PP concentrations were not especially high.

The average TP concentration (0.616 $\pm$ 0.202 mg/L) at SM02.2TW02 was four to five times that of upstream stations SM05.0TN and SM05.0TW. The area drained by the non-sampled discharge canal between SM05.0TN/SM05.0TW and SM02.2TW02 may be contributing significant phosphorus to the S&M Canal. The canal draining the eastern SM-01 sub basin also may be a significant P contributor to the S&M Canal. Average TP concentration at station SM02.1TN01 was 0.611 $\pm$ 0.269 mg/L. P load from each of the contributing drainages should be determined through concurrent flow measurement.

[5] $F = 11.25$, 37 df, $p < 0.0001$
[6] $F = 4.46$, 37 df, $p < 0.003$
[7] $F = 9.83$, 36 df, $p < 0.0001$

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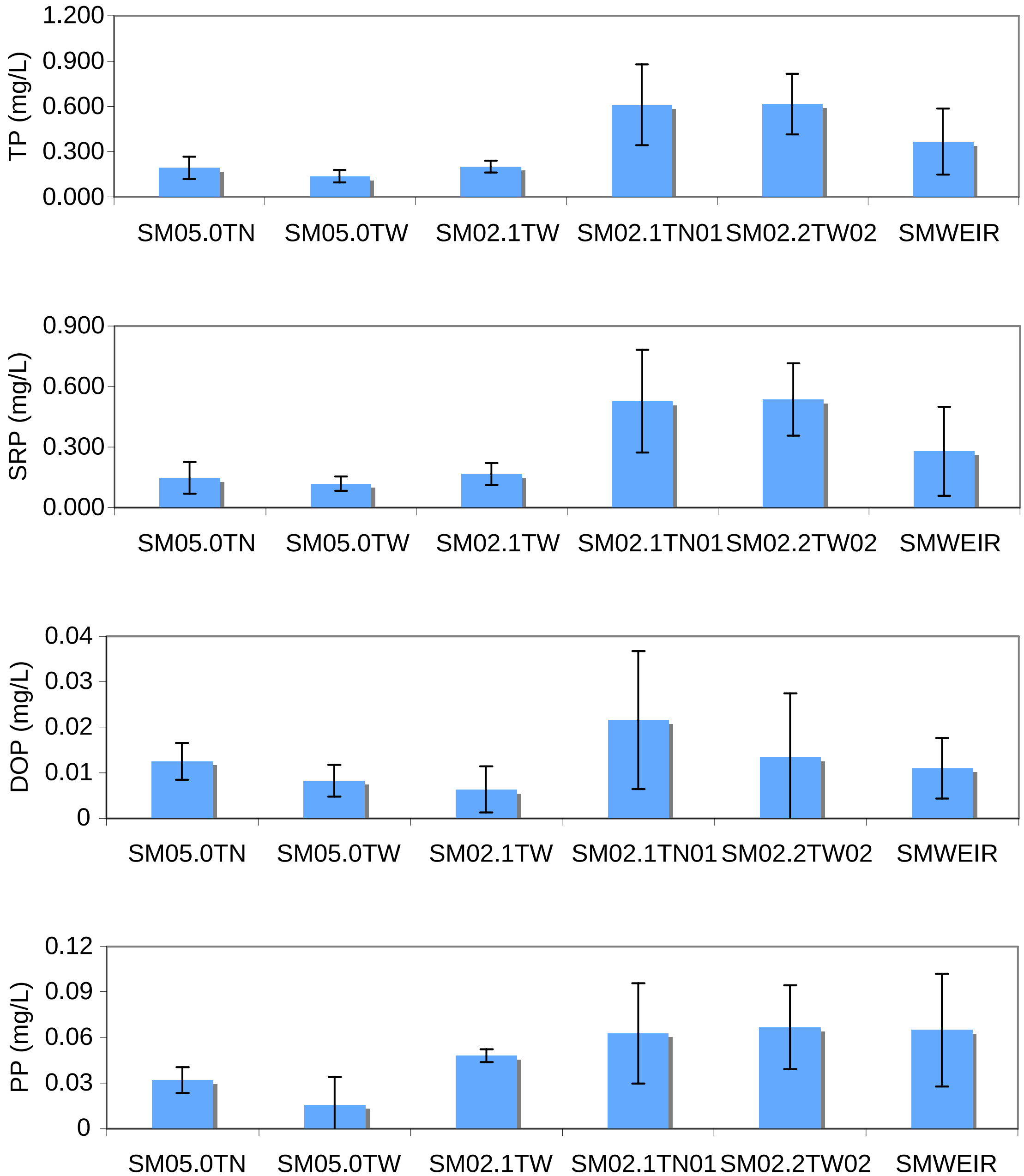


Figure 8. Total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations at stations in the C-139 Basin SM-01 sub basin.

The average TP concentration was 0.202 ± 0.040 mg/L at the confluence of the western and northern branches of the S&M Canal (SM02.1TW). This value is about one third of the concentrations in each of the contributing canals. The apparent reduction in TP concentration suggests TP removal or dilution upstream of the station. PP might be removed in the recently excavated sediment basins (see CWF and DBE 2005). However, PP is not significantly lower at SM02.1TW than the upstream stations. SRP and DOP are significantly lower at SM02.1TW than the upstream stations, suggesting that dissolved P might be converted into FAV. No FAV were ever observed at SM02.1TW according to C139B program field notes, and algae were observed on only one occasion (see Appendix A). FAV were noted during 47 percent of the sampling events at SM02.1TN01 and 30 percent of events at SM02.2TW02. The canals upstream of SM02.1TW should be investigated to determine the reason(s) for the reduction in, or dilution of, TP, SRP, and DOP.

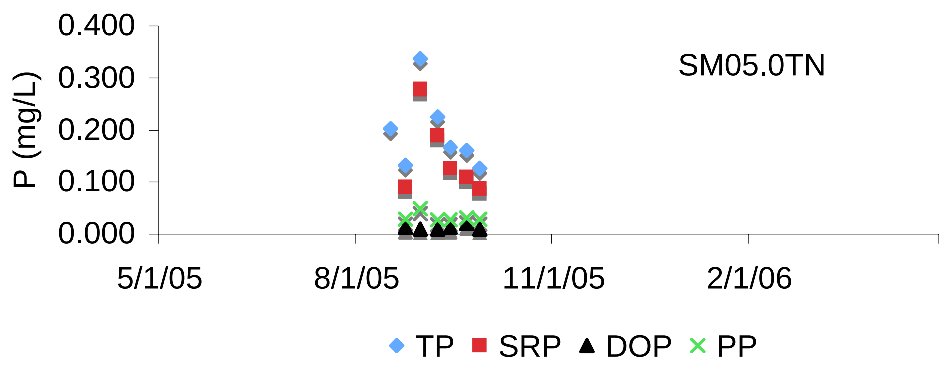
Temporal changes in TP, SRP, DOP, and PP were examined using line charts (Figure 9, Figure 10). Samples were only collected at the SM-01 stations when flow was observed. Consequently, the distribution of data points indicates when water was discharged from the tributary canals to the S&M Canal and from the S&M Canal to the L-3 Canal.

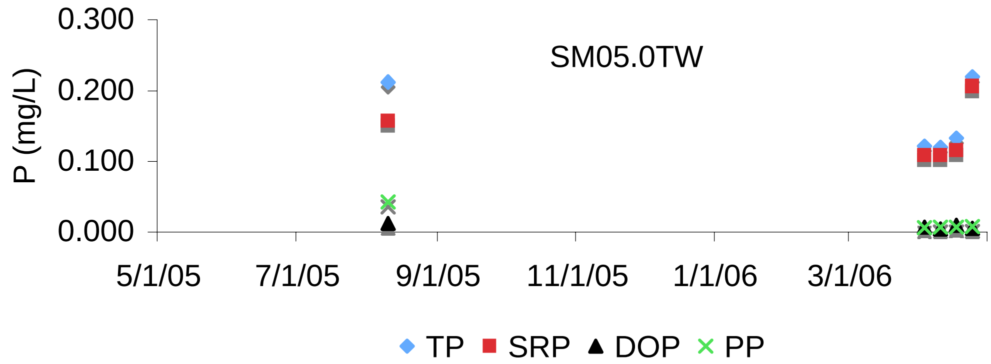
SM05.0TN discharged to the western end of the S&M Canal mid August through September 2005. SMO5.0TW discharged into the western end of the S&M Canal on one occasion mid August 2005 and in April 2006. Flow at the downstream station (SM02.2TW02) reflects August and September upstream discharge. Discharge from SM05.0TW in April 2006 was apparently insufficient to induce flow downstream at SM02.2TW02.

Peak discharge concentrations at stations SM05.0TN and SM05.0TW ranged from 0.212 – 0.337 mg TP/L, which was substantially less than peak TP concentration downstream at SM02.2TW02 (0.947 mg/L). This finding reinforces the earlier conclusion that the central part of the SM-01 sub basin, drained by a non-sampled canal, is contributing significant phosphorus to the S&M Canal.

The northern tributary represented by SM02.TN01 also discharged August through mid September 2005. Peak discharge TP concentration (0.977 mg/L) was 2 – 3 times greater than discharge concentrations into the western part of the S&M Canal.

Station SM02.1TW was sampled once in November 2005 and then again mid to late April 2006. This is a substantially different pattern than flow at upstream stations SM02.2TW02 and SM02.TN01. Moreover, peak TP concentration at SM02.1TW (0.278 mg/L) was a third the peak concentrations at stations immediately upstream. These findings suggest that flow is being modified and phosphorus is being removed upstream of SM02.1TW and downstream of SM02.2TW02 and SM02.TN01. Flow measurements should be conducted concurrent with water quality sampling, and factors modifying phosphorus and flow upstream of SM02.1TW should be investigated.





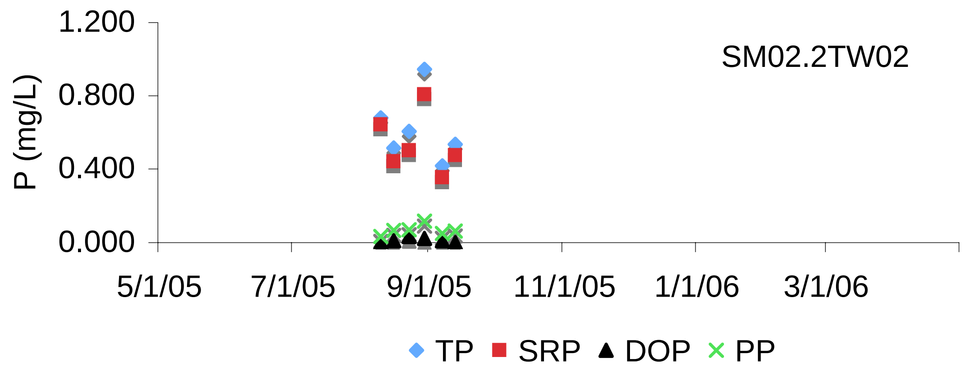


Figure 9. Total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations at C139B program stations SM05.0TN, SM05.0TW, and SM02.2TW02 in C-139 Basin sub basin SM-01.

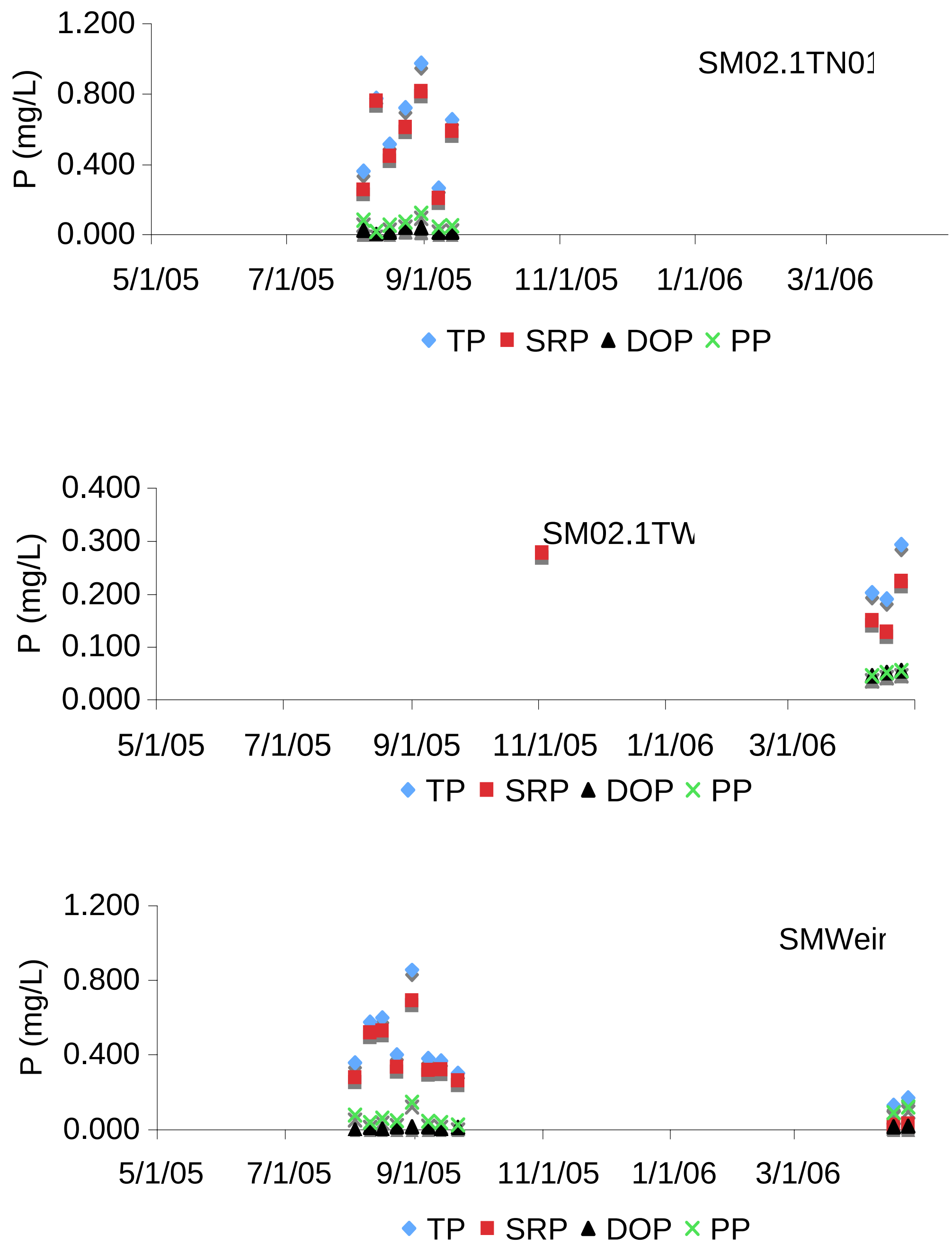


Figure 10. Total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations at C139B program stations SM02.1TN01, SM02.1TW, and SMWeir in C-139 Basin sub basin SM-01.

At the discharge end of the S&M Canal (station SMWeir), flow was observed in August and September 2005 and again mid to late April 2006. This pattern is substantially different than flow at upstream station SM02.1TW suggesting contributory flow from non-sampled tributaries or nonpoint runoff. Peak TP concentration at SMWeir (0.856 mg/L) was three times greater than that at SM02.1TW. Non-sampled sources may be contributing to S&M Canal discharge TP concentrations. Alternatively, phosphorus is being generated within the canal upstream of SMWeir and downstream of SM02.1TW. One possible source is flux from sediments, which is unlikely given the previous finding of low sediment phosphorus and low flux (CWF and DBE 2005). FAV, algae, and plankton may also be a source of elevated TP at SMWeir, although much of the TP is SRP and not PP.

With one exception, SRP is the predominant P species at the SM-01 stations. SRP increases and decreases in synchrony with TP. By exception, PP is the predominant P species at SMWeir in April 2006. TP concentrations are relatively low during this period, and algae were noted in the field records 17 and 24 April.

Sub Basins DF-01 & DF-02

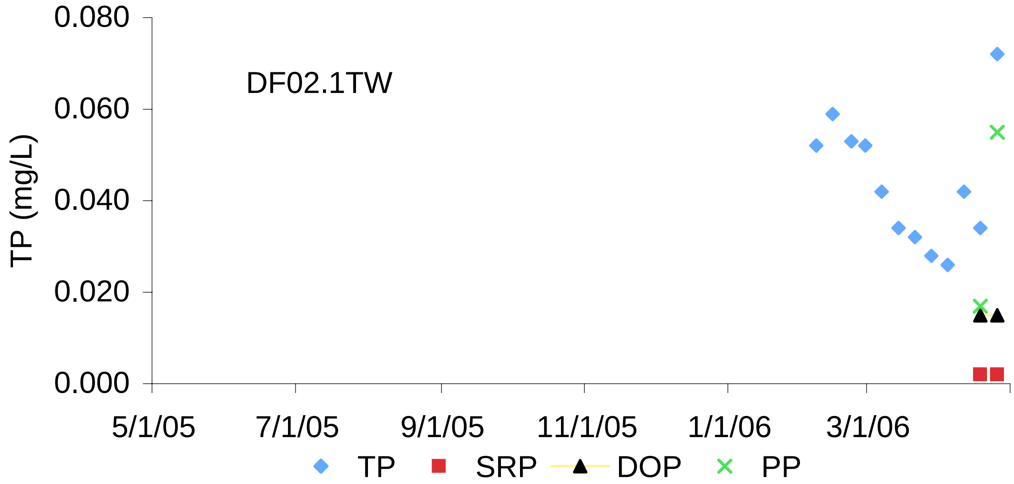
Phosphorus concentrations emanating from the combined DF-01 and DF-02 sub basins are represented by stations DF02.1TW of the C139D program (TP) and DF02.0TW of the C139B program (TP, SRP, DOP, and PP). The C139D program sampled station DF02.1TW from 2 February - 25 April 2006. TP concentration varied little, ranging from 0.026 - 0.072 mg/L (Figure 11). The maximum TP concentration does not correspond with peak monthly rainfall or a sharp increase in cumulative rainfall total (Figure 7). Nor does the peak coincide with the occurrence of FAV or algae according to C139D program field notes (Appendix A).

SRP, DOP, and PP were sampled at DF02.1TW 18 and 25 April 2006. PP and DOP exceeded SRP on these dates. PP increased markedly in concert with TP on 25 April 2006, although TP concentrations were relatively low. Again, FAV and algae were not recorded at DF02.1TW in April 2006.

The C139B program sampled station DF02.0TW from 4 August 2005 – 24 April 2006. TP concentrations varied more widely than measurements of the C139D program, ranging from 0.029 - 0.268 mg/L (Figure 11). Concentrations were relatively high in August and September 2005, reached a maximum 2 November 2005, and were low in April 2006. High August and September TP concentrations generally correspond with higher monthly rainfall and sharply increasing cumulative rainfall totals. FAV was only observed at the site 30 August 2005 (Appendix B).

SRP was the predominant P species at DF02.0TW in August, September, and November 2005. SRP varied in concert with TP during this period. In April, when TP concentrations were relatively low, PP and DOP were the predominant concentrations.

C139D and C139B Programs TP concentration data overlapped in mid to late April 2006. The correspondence was good 3/4, 10/11, and 17/18 April 2006. On 24/25 April 2006, C139B program TP concentration was half the C139D Program TP concentration. The two programs may not produce comparable results. As noted above, the C139D Program may be better suited to representative monitoring of basin P discharge, especially if amended to include sampling during quiescent periods.



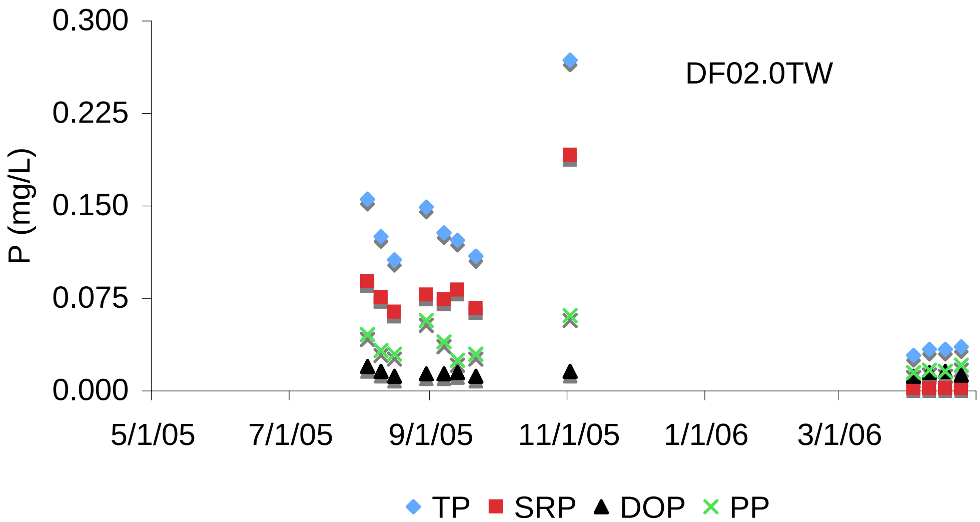


Figure 11. Total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations emanating from the DF-01 and DF-02 sub basins in the C-139 Basin. DF02.1TW is part of the South Florida Water Management District C139D program and DF02.0TW is part of the C139B program.

Sub Basin DF-02 Stations

The DF-02 sub basin has three stations: DF11.3TW01, DF12.2TS, and DF12.3TS. Each station is located in the southeast corner of the DF-02 sub basin. DF11.3TW01 discharges south to the Deerfence Canal, and DF12.2TS and DF12.3TS discharge north to the canal (Figure 2). No data were collected at DF12.2TS in WY06.

WY06 average TP concentration was nearly three times greater and much more variable at DF11.3TW01 (0.135 mg/L) than DF12.3TS (0.048 mg/L; Figure 12) [8]. Similarly, SRP[9], DOP[10], and PP concentrations were greater at DF11.3TW01 than at DF12.3TS[11]. FAV, algae, and other vegetation were commonly noted at both stations.

Temporal changes in TP, SRP, DOP, and PP were examined using line and marker charts (Figure 13). Again, samples were only collected when flow was observed providing indirect information about discharge to the Deerfence Canal. Station DF11.3TW01 discharged to the Deerfence Canal 11 August through 3 November 2005, and again 17 April 2006. The DF12.3TS station discharge period was more limited - 11 August through 20 October 2005. Peak TP concentration was about nine times greater at DF11.3TW01 than at DF12.3TS.

SRP and PP were the predominant phosphorus species at DF11.3TW01 when the TP concentration was relatively low (about $\leq$ 100 mg/L). FAV was commonly observed during this time. The elevated TP concentration 3 November 2005 was accompanied by an increase in SRP. By contrast, PP was the predominant phosphorus species at DF12.3TS. Weeds and algae were commonly observed. Chlorophyll *a* measurement would elucidate whether PP was plankton or phosphorus associated with other particulate matter (e.g., soil).

[8] $t = 5.50$, 12 df, $p < 0.0001$
[9] $t = 6.51$, 16 df, $p < 0.0001$
[10] $t = 2.42$, 15 df, $p < 0.03$
[11] $t = 3.74$, 17 df, $p < 0.002$

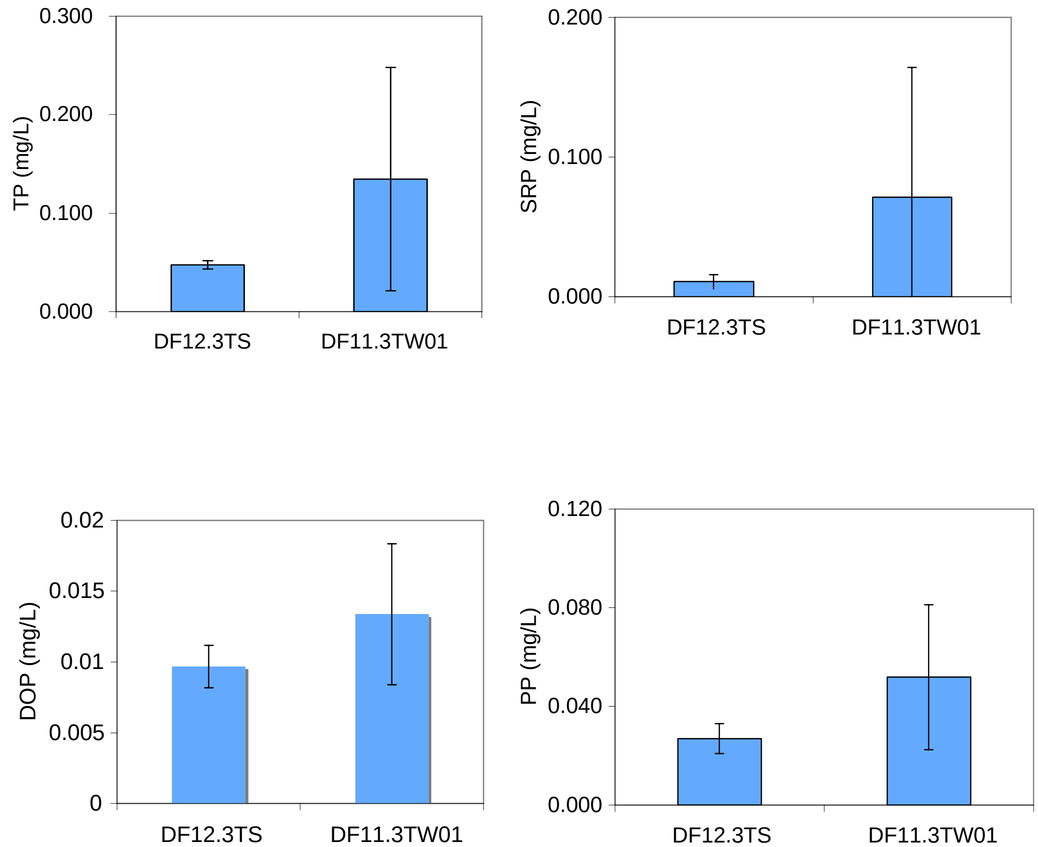
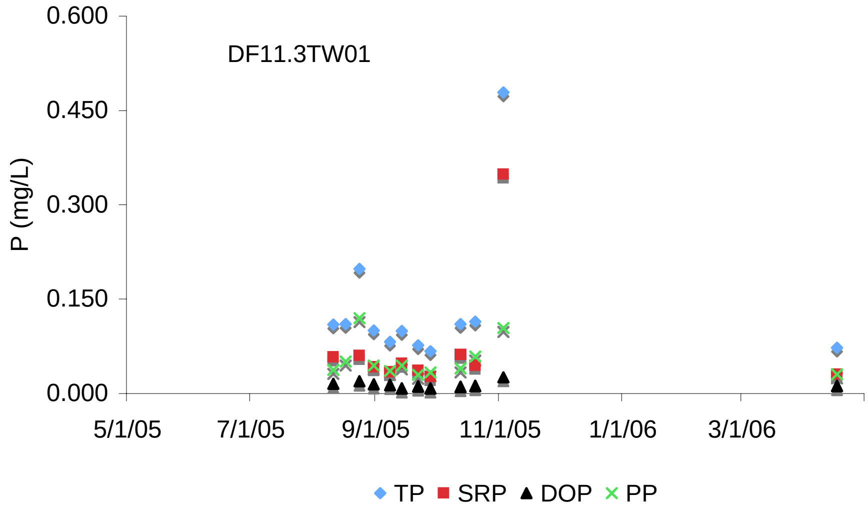


Figure 12. C139B program WY06 total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations (mean ± s.d.) at C-139 Basin sub basin DF-02 stations.



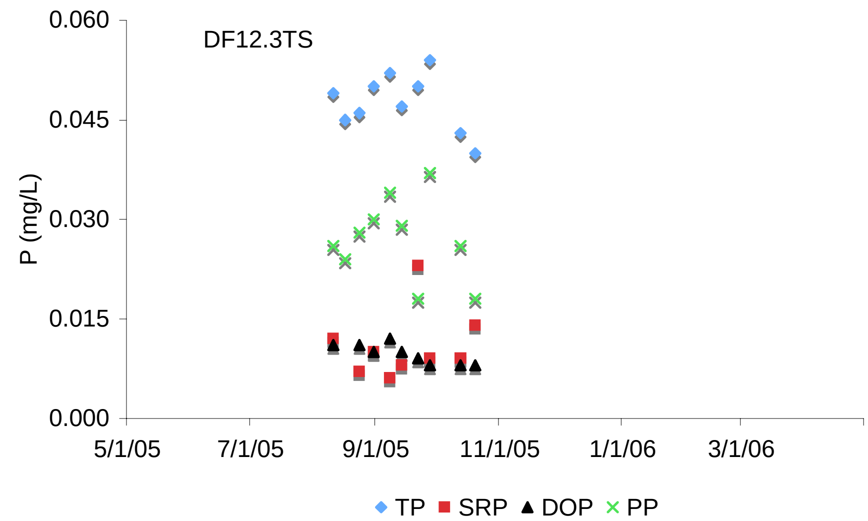


Figure 13. C139B program total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations at C-139 Basin sub basin DF-02 stations.

Sub Basin DF-01 Stations

The DF-01 sub basin has two stations: DF11.1TN01 and DF08.1TN01 (Figure 2). Both stations are located in the center of the DF-01 sub basin and discharge south to the Deerfence Canal. DF11.1TNO1 discharges to the Deerfence Canal upstream of DF08.1TN01.

WY06 average TP concentration was comparable at DF11.1TN01 (0.215 $\pm$ 0.090 mg/L) and DF08.1TN01 (0.165 $\pm$ 0.085 mg/L; Figure 14)[12]. Similarly, there were no differences between sites for SRP[13], DOP[14], and PP[15] concentrations. Phosphorus concentrations were more variable at DF11.1TN01 than DF08.1TN01. FAV, algae, and other vegetation were commonly noted at both stations.

Station DF08.1TN01 discharged to the Deerfence Canal 12 August through 4 November 2005, and again 24 April 2006 (Figure 15). The DF11.1TN01 station discharge period was more limited: 11 August through 20 October 2005. Maximum TP concentrations were comparable, but occurred on different dates. Both stations experienced noticeable increases in phosphorus 24 August 2005.

SRP was generally the predominant phosphorus species at station DF08.1TN01 when concentrations were about $\leq$ 100 mg TP/L. PP was the predominant phosphorus species during increases 24 August 2005 and 24 April 2006. PP was also elevated at the time of TP maximum concentration 4 November 2005. SRP, and to a lesser extent PP, was the predominant phosphorus species at station DF11.1TN01. DOP concentrations were low at both stations. FAV and weeds were commonly observed at both stations August through October 2005, and at DF08.1TN01 24 April 2006.

[12] $t = 1.31$, 19 df, p = 0.21
[13] $t = 1.52$, 17 df, p = 0.15
[14] $t = 1.74$, 14 df, p = 0.10
[15] $t = 0.29$, 16 df, p = 0.77

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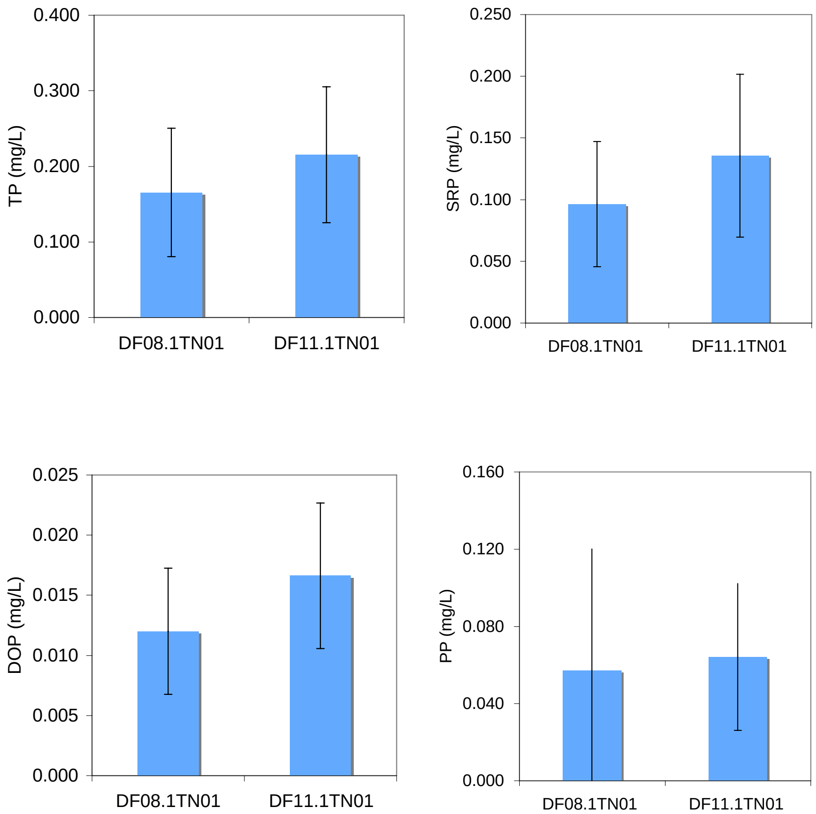
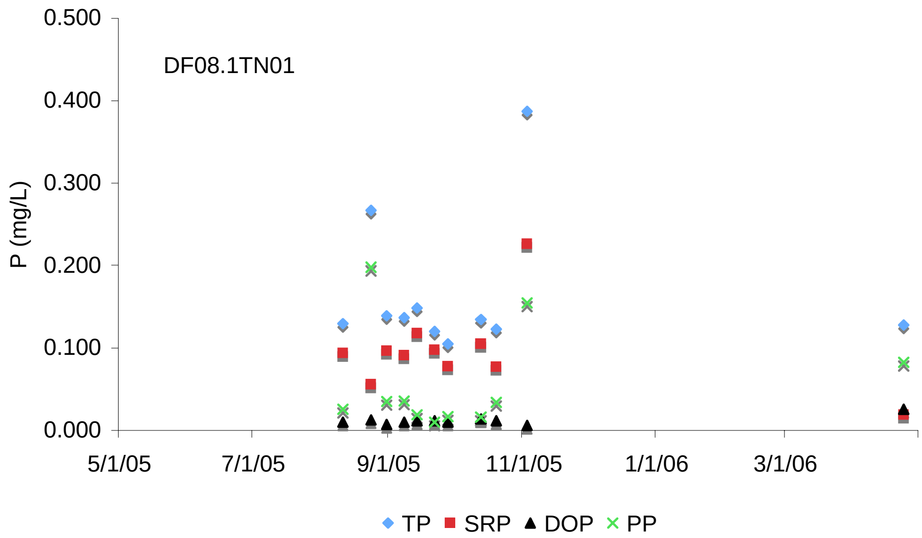


Figure 14. C139B program WY06 total phosphorus concentrations (mean $\pm$ s.d.) at C-139 Basin sub basin DF-01 stations.



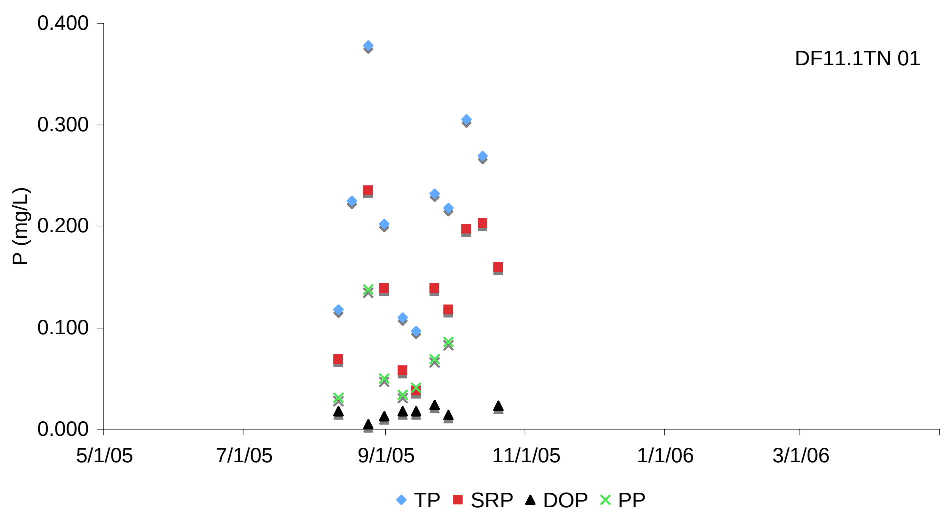


Figure 15. C-139B program total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations at C-139 Basin sub basin DF-01 stations.

Sub Basin L3-01

Phosphorus and flow emanating from the L3-01 sub basin can be calculated as the difference between stations L207.0TN and L202.0TN. No data were collected at these stations in WY06.

Sub Basin L3-01 Stations

The L3-01 sub basin has four stations: L209.6TW02, L207.6TW02, L206.0TW02, and L206.0TW01 (Figure 2). Station L209.6TW02 discharges into the western end of the Devil's Garden Canal. The station was not sampled in WY06. Stations L207.6TW02 discharges into the South Boundary Canal, and was sampled only once in WY06. Station L206.0TW02 also discharges into the South Boundary Canal. The Devil's Garden and South Boundary Canals merge to form the Knowles Canal, which is the site of station L206.0TW01. The Knowles Canal discharges to the L2 Canal.

WY06 average TP concentration was greatest at station L207.6TW02 (1.450 mg/L)[16], although this finding is based upon only one sampling event (Figure 16). TP concentration was greater at station L206.0TW02 (0.395 $\pm$ 0.138 mg/L) than at station L206.0TW01 (0.139 $\pm$ 0.041 mg/L). A similar pattern was observed for SRP[17] and DOP[18]. PP concentration was greater at L207.0TW02, and apparently greater at L207.6TW02, than the downstream station L206.0TW01[19]. This finding suggests that phosphorus is removed or diluted along the Devil's Garden Canal and South Boundary Canal, or along the Knowles Canal upstream of L206.0TW01. The mechanism(s) for the apparent phosphorus removal or dilution should be investigated.

Station L207.6TW02 was sampled only once in WY06 on 11 August 2005, although TP (1.450 mg/L) and SRP (1.250 mg/L) concentrations were very high. If the lack of sampling reflects an absence of flow, the drainage area represented by station L207.6TW02 likely had little significance on sub basin and basin phosphorus discharge. Flow measurements should be taken concurrent with water quality sampling, and load calculated.

Stations L206.0TW02 and L206.0TW01 exhibited flow (as evidenced by sampling events) August through early November 2005 (Figure 17). Maximum TP concentrations among the stations did not correspond perfectly, although TP concentrations were high at all stations 13 September 2005.

[16] $F = 47.68$, 26 df, $p < 0.0001$
[17] $F = 17.89$, 25 df, $p < 0.0001$
[18] $F = 18.81$, 25 df, $p < 0.0001$
[19] $F = 6.78$, 25 df, $p < 0.004$

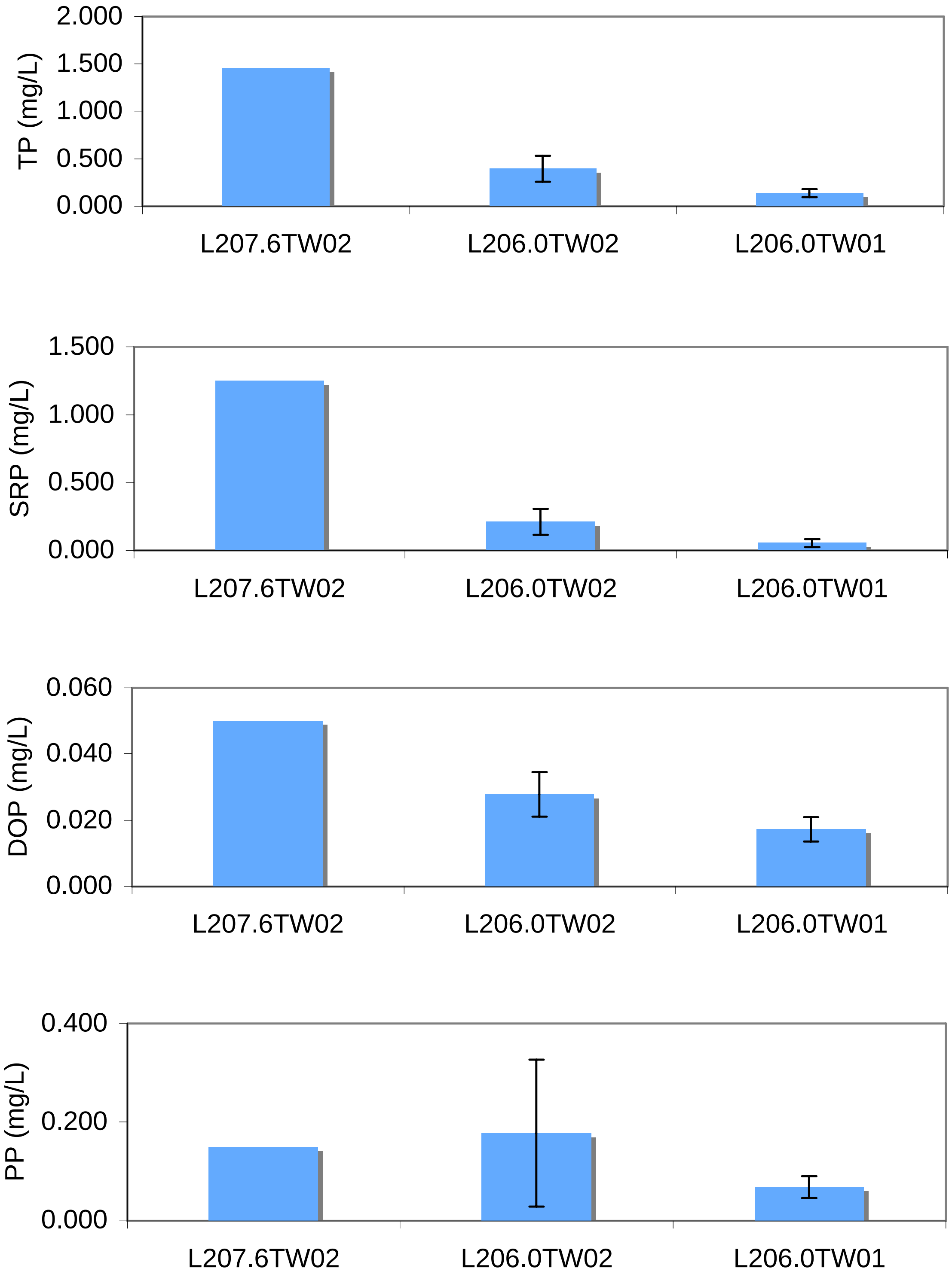


Figure 16. C139B program WY06 total phosphorus concentrations (mean ± s.d.) for C-139 Basin sub basin L3-01 stations.

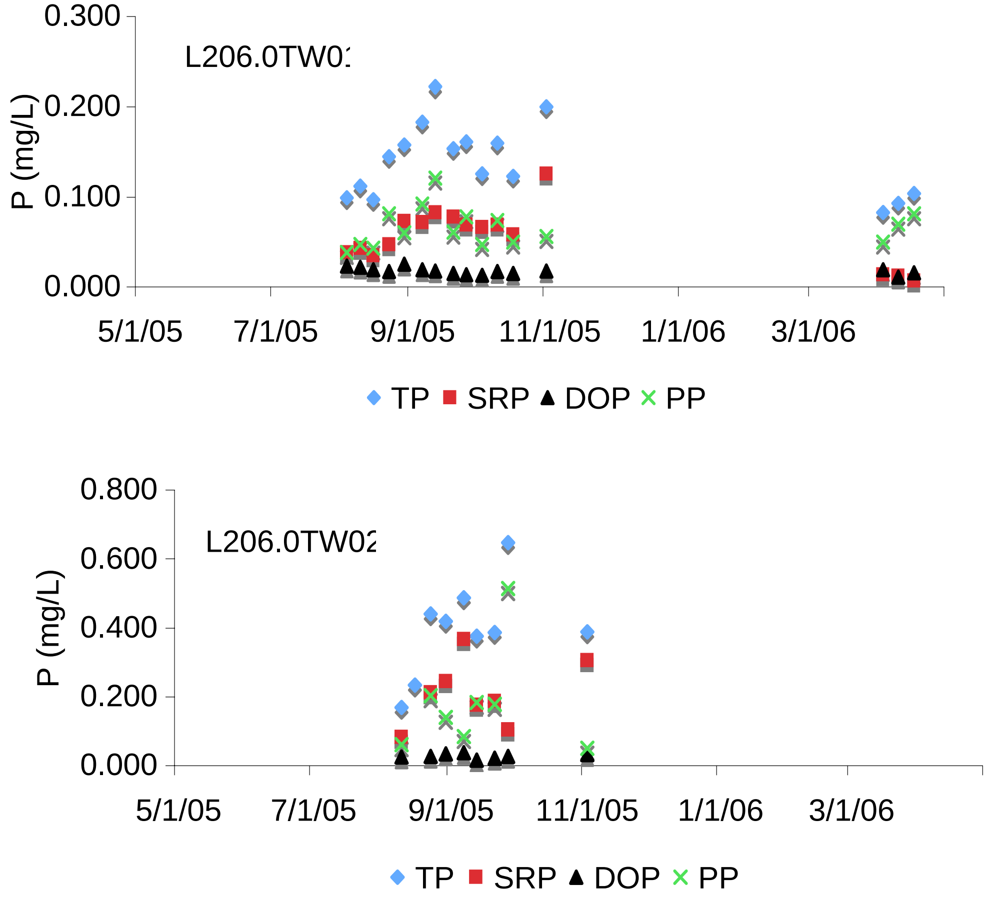


Figure 17. C139B program total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations at C-139 Basin sub basin L3-01 stations.

SRP was generally the predominant phosphorus species at L206.0TW02. SRP concentrations increased and decreased in concert with TP concentrations. PP concentration increased substantially at L206.0TW02 28 September 2005 coincident with an increase in TP concentration. No FAV or algae were observed at the station on this date. The increase in PP may have been the result of soil erosion, plankton, or sampling/measurement error.

At L206.0TW01, both SRP and PP were predominant phosphorus species and varied in synchrony with TP concentration during 2005, and PP was predominant and varied with TP in 2006. FAV and other vegetation were regularly observed at this station (Appendix B), perhaps contributing to PP.

L209.1TW01 and L206.0TW01 also exhibited flow in April 2006. PP was the predominant phosphorus species in April, and increased at both stations when TP concentration increased. No FAV, algae or other vegetation were observed at either station in April 2006.

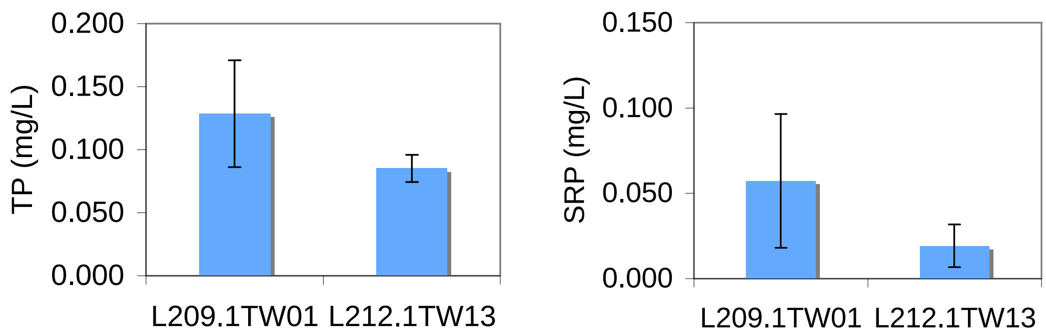
Sub Basin L2-01

Phosphorus and flow emanating from the L2-01 sub basin is represented by L207.0TN if G151 and G150 are closed. Alternatively, phosphorus and flow from the sub basin can be calculated as the difference between stations L207.0TN and G151 if G150 is closed, or cumulative stations L207.0TN and G150 if G151 is closed. If G151 and G150 are open and discharging, defining sub basin L2-01 phosphorus and flow requires understanding mixing of L-2W Canal and L-2 Canal waters. No data were collected at L207.0TN in WY06.

Sub Basin L2-01 Station

Sub basin L2-01 has two stations: L212.1TW13 and L209.1TW01. L212.1TW13is located at the western end of the L-2W Canal, and L209.1TW01is located along the Midway Canal. The L-2W Canal and Midway Canal discharge into the L2 Canal (Figure 2).

WY06 average TP[20] and SRP[21] concentrations were higher at L209.1TW01 (TP 0.128 ± 0.042, SRP 0.057 ± 0.039) than L212.1TW13 (TP 0.085 ± 0.011, SRP 0.019 ± 0.013)



[20] $t_{21df} = 3.05$, $p = 0.006$
[21] $t_{18df} = 2.96$, $p = 0.008$

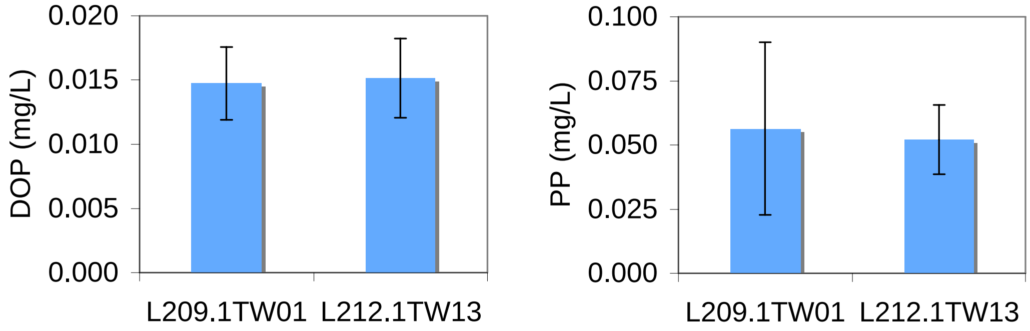
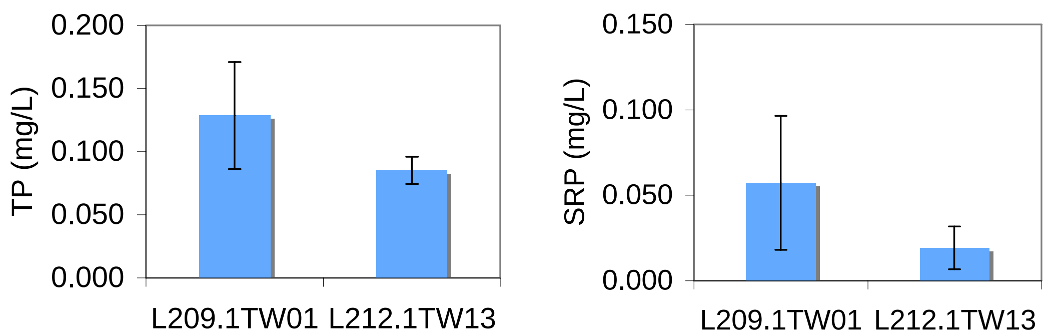


Figure 18). There were no differences between the stations for DOP[22] or PP[23]. Aquatic vegetation was frequently located at or near L212.1TW13 (see Appendix B).

Station L209.1TW01 was sampled 4 August - 2 November 2005 and 3 – 24 April 2006 (Figure 19). TP concentrations ranged from a low of 0.082 mg/L 3 April to a maximum of 0.201 mg/L 24 April 2006. SRP was the predominant phosphorus species 4 August – 2 November 2005. SRP concentration varied in concert with TP concentration during this period. SRP could have come from soil amendment runoff or flux from the sediments. Sediment P should be investigated at L209.1TW01, preferably during both quiescent and flow conditions.



[22] $t_{11df} = 0.30$, $p = 0.77$
[23] $t_{19df} = 0.12$, $p = 0.90$

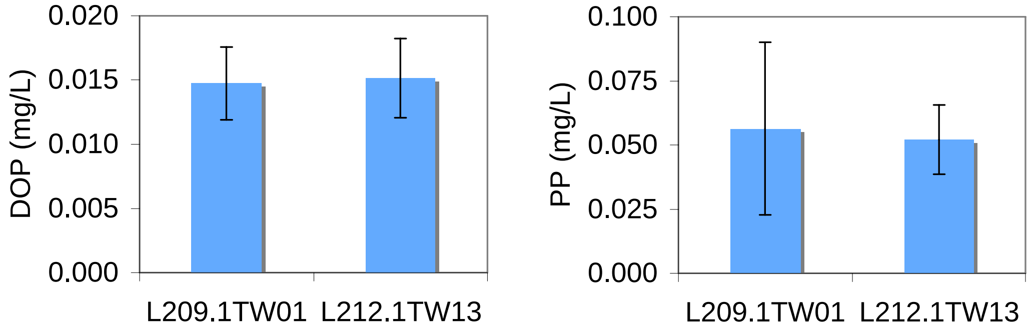
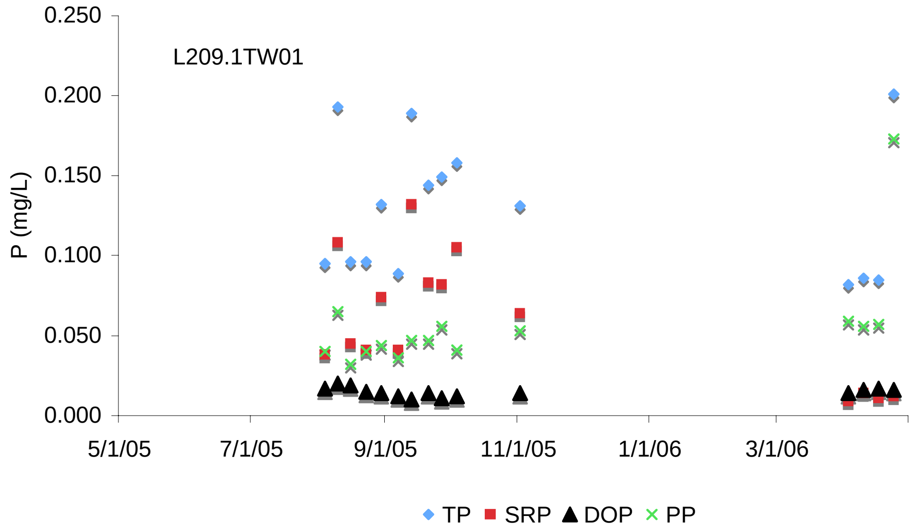


Figure 18. C139B program WY06 total phosphorus concentrations (mean ± s.d.) at C-139 Basin sub basin L2-01stations L209.1TW01 and L212.1TW13.

PP was the predominant phosphorus species in April 2006. PP concentration varied in concert with TP concentration. SRP and DOP concentrations were very low in April 2006. FAV was not observed at the site during April 2006 (Appendix B). PP could be associated with plankton or suspended solids. Chlorophyll *a* and TSS were not measured.

Station L212.1TW13 was sampled 11 August through 3 November 2005. TP concentrations varied little, ranging from 0.069 - 0.099 mg/L. PP concentrations generally increased and decreased coincident with TP concentrations. FAV and other plants were commonly observed at the site and may explain the predominance of PP. Chlorophyll *a* and TSS were not measured. On 3 November 2005, PP concentration declined as TP increased, and was offset by an increase in SRP concentration suggesting a change in phosphorus source. SRP and DOP concentrations had been low throughout September and October.



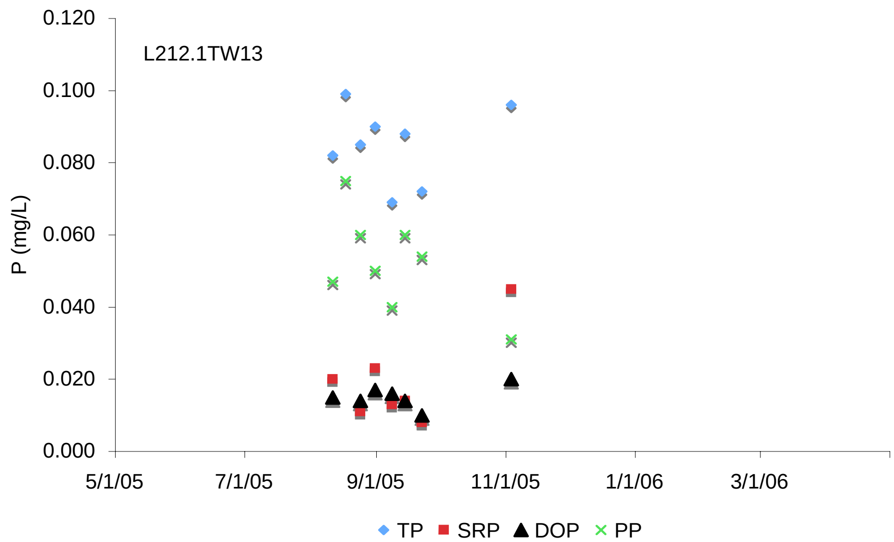


Figure 19. C139B program total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations at the C-139 Basin sub basin L2-01 station.

Sub Basin L2-02

No sampling stations are located within this sub basin.

Sub Basin L1-01

No sampling stations are located within this sub basin.

Sub Basin L1-02

No sampling stations are located within this sub basin.

C139 Compliance Points

Autosampler Composite Flow Proportional (ACF)

WY06 average daily TP concentrations were greatest at G406 (0.364 mg/L) and least at G136 (0.159 mg/L, Figure 20)[24]. Concentrations were greater at G342C than G342A, B, and D, and greater at G342D than G342A and B.

WY06 average daily flow was greatest at G406 (410 cfs) and least at G136 (69 cfs, Figure 20)[25]. Average daily flow was greater at G342A and B than at G342 C and D, and greater at G342C than G342D.

Average daily WY06 load was greatest at G406 (416 kg) and least at G136 (44 kg tons, Figure 20)[26]. Day to day variability was high as evidence by standard deviations. The average daily load was greater at G342A, B, and C than at G342D.

The C-139 Basin exported 107 metric tons of phosphorus during WY06 (Figure 21). Cumulative load was greatest at G406 (44 metric tons) and least at G342D (9 metric tons). Fifty percent of the C-139 Basin annual load was exported to STA-5, and 41 percent to L-3 via G406.

[24] $F = 68.96$, 1,178 df, $p < 0.0001$
[25] $F = 105.59$, 1,178 df, $p < 0.0001$
[26] $F = 118.90$, 1,178 df, $p < 0.0001$

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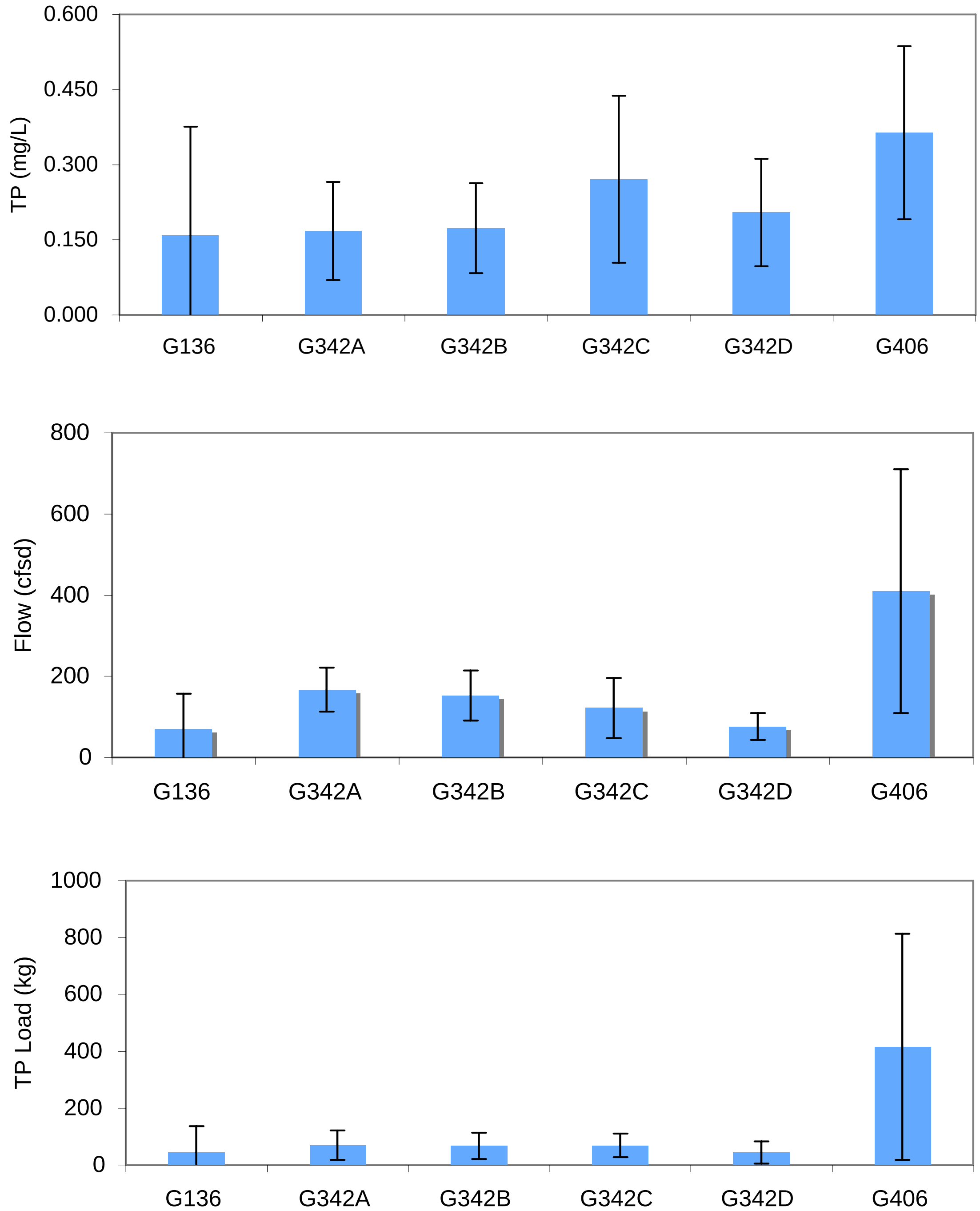


Figure 20. ACF average daily total phosphorus (TP) concentrations, flow, and load for C-139 Basin discharges structures.

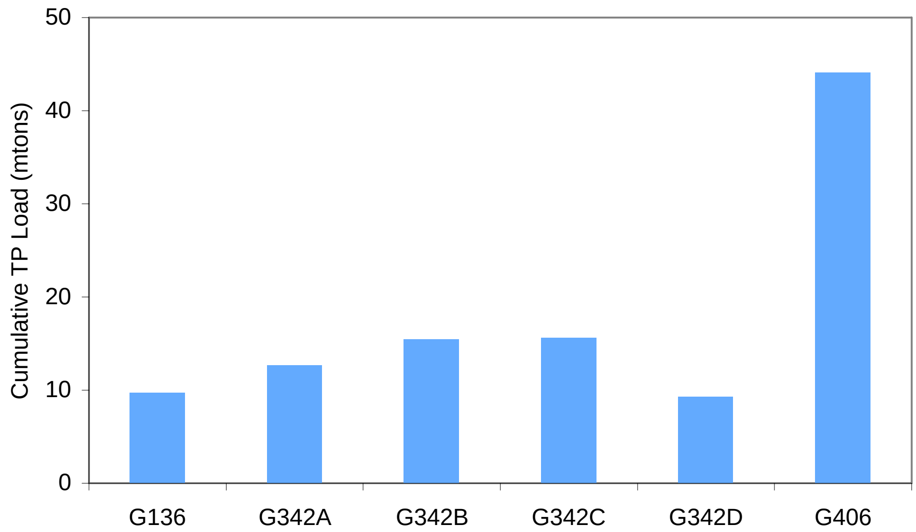
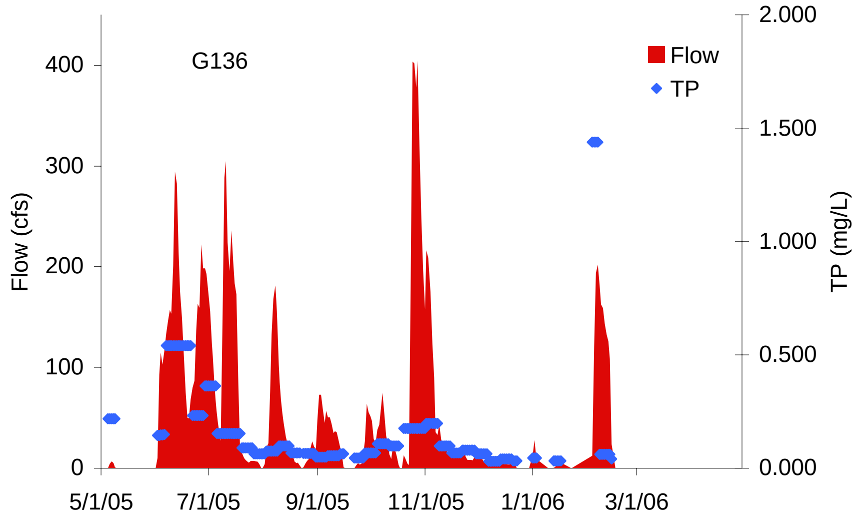


Figure 21. ACF program cumulative WY06 TP loads at the C-139 Basin discharge structures.

G136

G136 flow spiked on eight occasions during WY06, with peak flows ranging from 47 – 405 cfs (Figure 22). TP concentrations were generally less than 0.361 mg/L, except for an increase to 0.539 8 – 20 June 2005, and a second, larger peak of 1.440 4 – 7 February 2006.

G136 daily load peaked in June and late October/early November 2006, and early February 2007 (Figure 22). Flow and TP concentration produce the June elevation in daily load, which peaks at 372 kg. The late October/early November increase in load is coincident with increased flow following Hurricane Wilma. The maximum load occurred in early February 2006, and is a result of a dramatic increase in TP concentration and a substantial increase in flow. Monthly rainfall in February 2006 was 3.3 inches, significantly more than in December 2005 (0.17 inches) and January 2006 (0.16 inches; see Figure 7). If the rainfall occurred in early February, sub basin runoff may have conveyed accumulated phosphorus to G136. On farm water storage or a downstream stormwater treatment BMP are options for reducing peak loads.



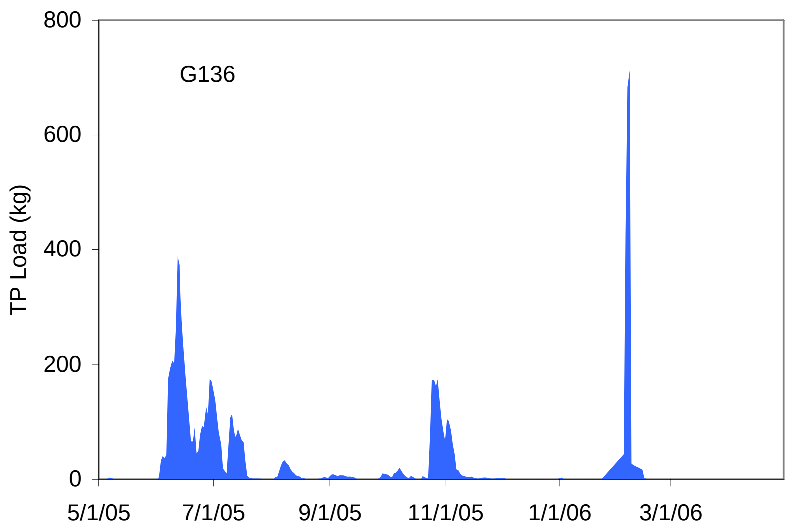


Figure 22. WY06 flow, total phosphorus (TP) concentration, and load at structure G136 in the C139 Basin.

G342A

G342A flow was moderately consistent from May through November 2005, with peaks ranging from about 190 - 260 cfs (Figure 23). Flows appeared to increase slightly in response to Hurricane Wilma. TP concentration varied widely, ranging from 0.059 – 0.509 mg/L, with peak concentrations occurring in early November. TP concentrations increased substantially one to two weeks after the Hurricane. Peak loads are attributed to periodic increases in flow and TP concentration, with the maximum load of 344 kg in early November attributed largely to a sharp increase in TP concentration. The latter finding suggests that phosphorus was initially retained somewhere in the basin.

G342B

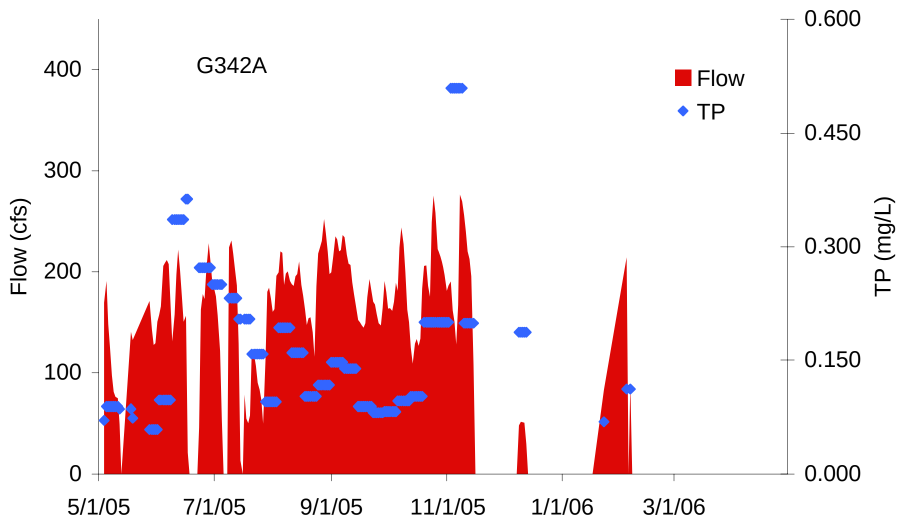
G342B flows were greatest late October through early December 2005 (about 220 – 270 cfs), reflecting in part Hurricane Wilma runoff (Figure 24). TP concentrations ranged from 0.066 – 0.523 mg/L, with the maximum concentrations recorded early to mid October 2005. TP concentrations did not increase in response to Hurricane Wilma, and may have been diluted by relatively high flows. Peak daily loads (239 – 263 kg) occurred coincident with peak TP concentrations, but not with substantial increases in flow. The possible cause of increased TP concentrations in the absence of increased flow is unknown. Earlier in WY06, loads were moderate and the result of periodic increases in flow and TP concentration.

G342C

G342C flow was greatest (299 – 344 cfs) in December 2005, more than a month after Hurricane Wilma (Figure 25). Prior to December, flow ranged from about 50 – 220 cfs. TP concentration varied widely, ranging from 0.059 – 0.786. Maximum TP concentrations occurred mid November 2005, with a secondary peak early to mid October. The peak daily load (320 kg) occurred coincident with the November spike in TP concentration. Daily loads prior to the November spike were generally 100 – 200 kg. Daily load was relatively low in December, despite high flows.

G342D

Maximum observed flow at G342D was 160 cfs, with values frequently less than 100 cfs (Figure 26). TP concentrations ranged from 0.034 – 0.561 mg/L, peaking late June 2005. Values were less than 340 mg/L at other times. TP daily load peaked on several occasions, attaining a maximum load of 220 kg 28 June 2005. Load peaks are primarily the result of elevated TP concentrations, and secondly modest increases in flow.



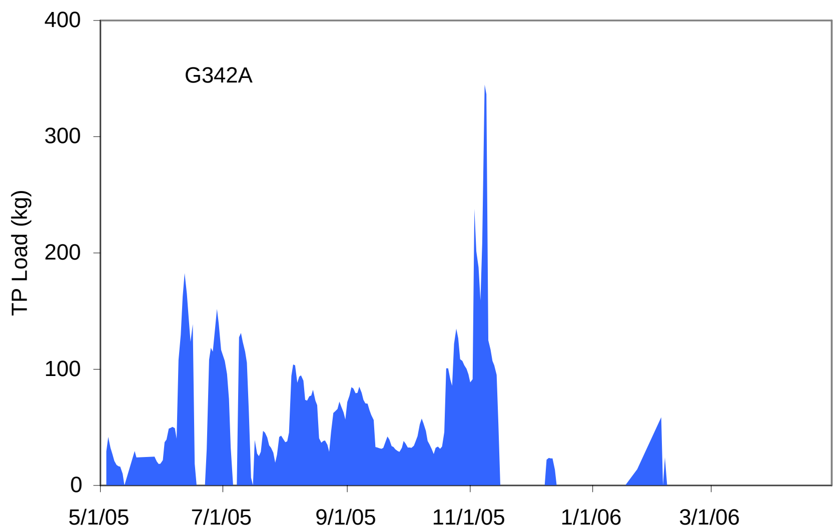
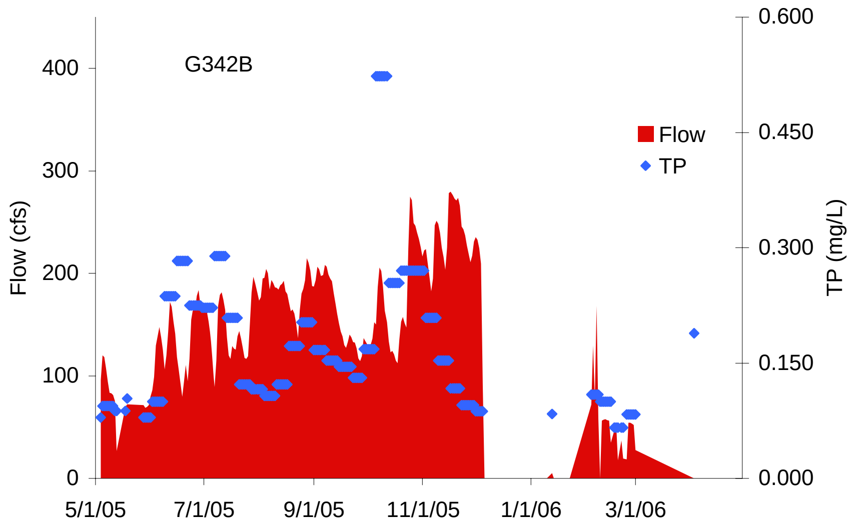


Figure 23. WY06 flow, total phosphorus (TP) concentration, and load at G342A in the C139 Basin.



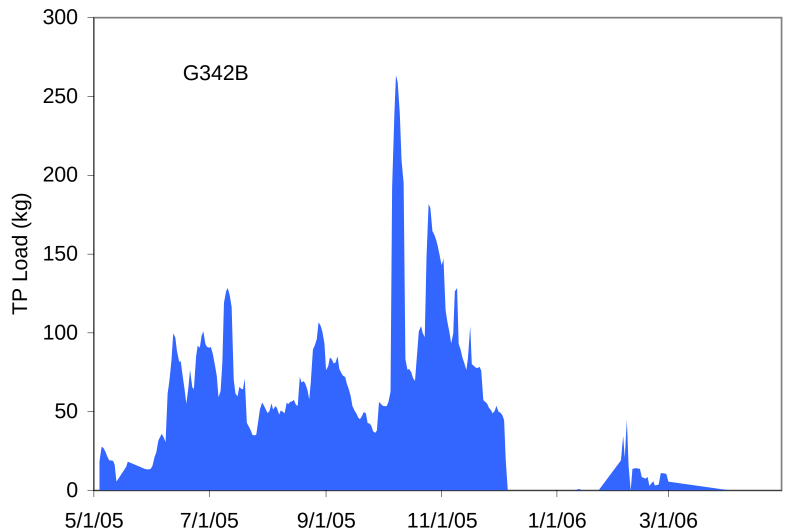
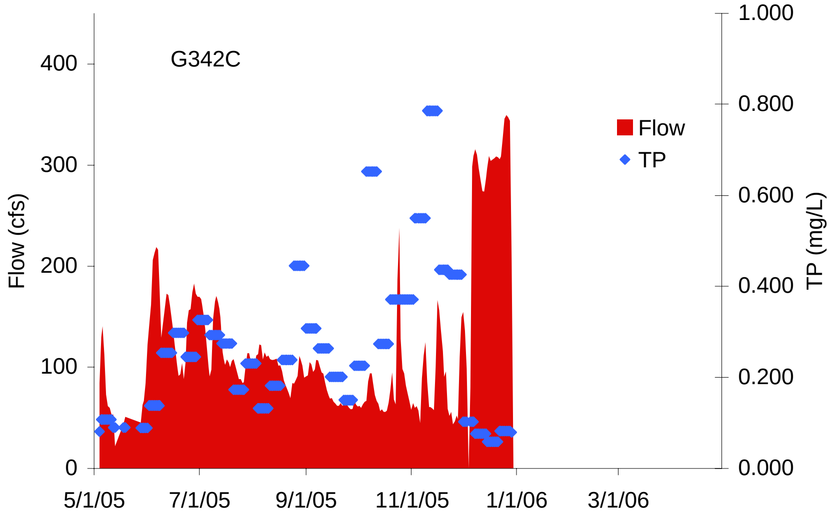


Figure 24. WY06 flow, total phosphorus (TP) concentration, and load at G342B in the C139 Basin.



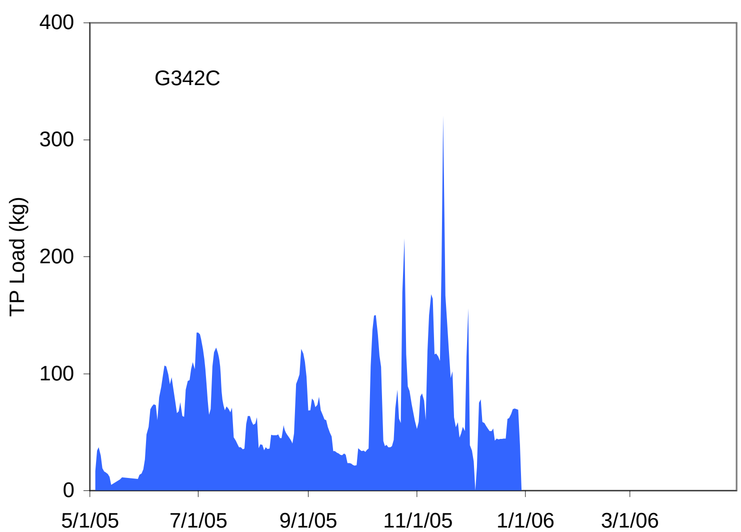


Figure 25. WY06 flow, total phosphorus (TP) concentration, and load at G342C in the C139 Basin.

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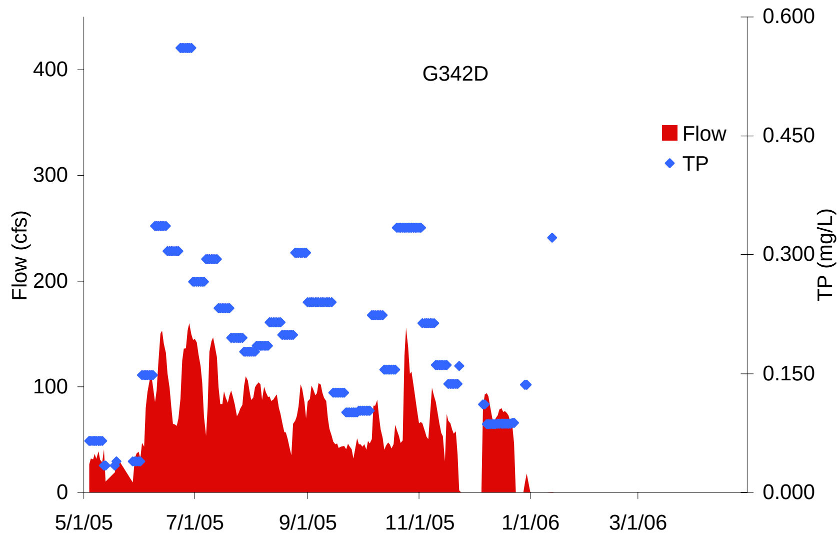

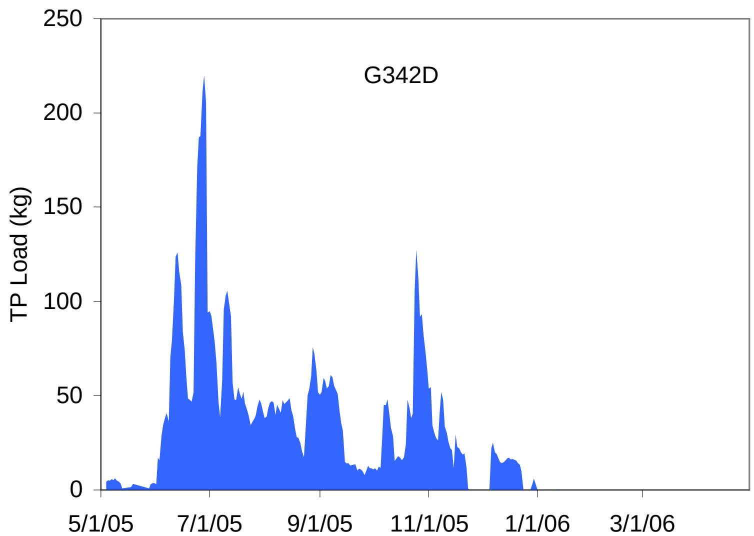

Figure 26. WY06 flow, total phosphorus (TP) concentration, and load at G342D in the C139 Basin.

G406

Discharge through G406 was less frequent than other C-139 Basin structures (Figure 27). Peak flows occurred late June through early July 2005 (808 – 969 cfs), and late October 2005 (725 – 829 cfs). The latter likely reflects Hurricane Wilma runoff. TP concentration ranged from 0.164 - 882 mg/L, with peak concentrations occurring was in late June. Daily loads peaked in late June through early July, and again in late October. The June/July peak was due to a substantial increase in TP, followed closely by a substantial increase in flow. The late October increase in load coincides with a substantial increase in flow and a moderate increase in TP concentration.

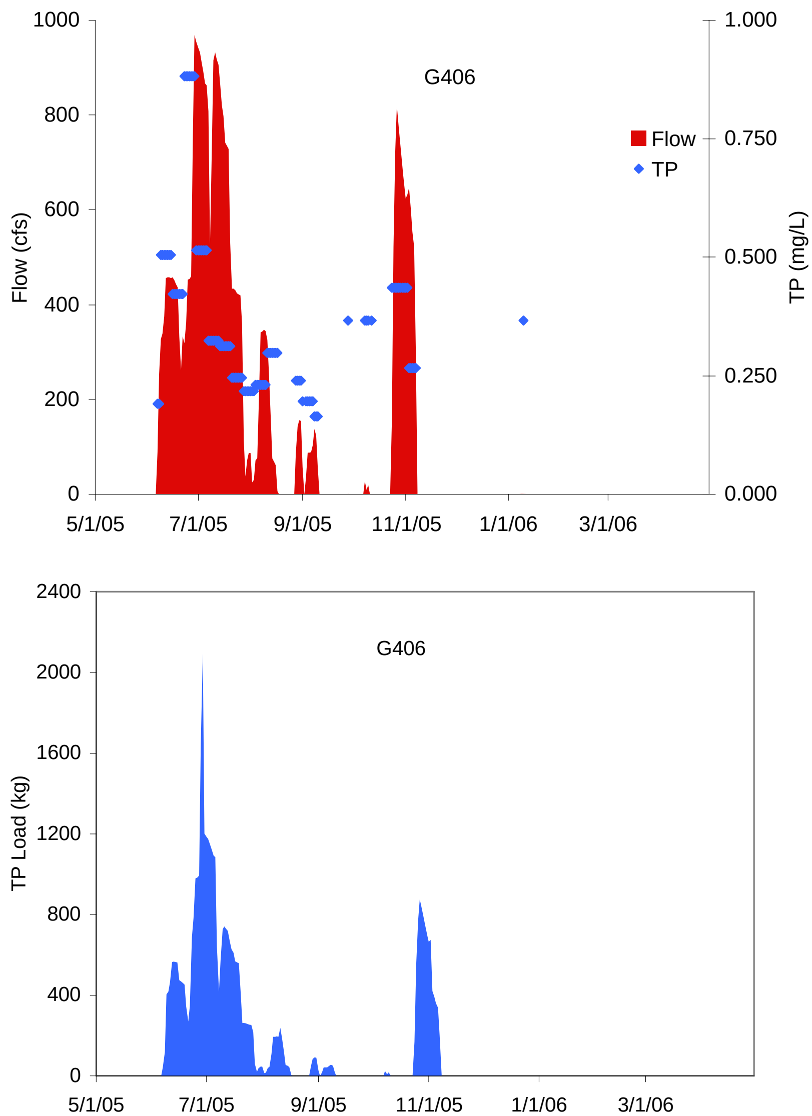

Figure 27. WY06 flow, total phosphorus (TP) concentration, and load at G406 in the C139 Basin.

Grab Samples

Flow Samples

WY06 average daily TP concentrations ranged from 0.076 at G136 to 0.195 mg/L at G342C (Figure 28). TP concentration was greater at G406 and G342C than G342A and G136, and comparable among G342A, B, and D[27]. G136 had the lowest TP concentration.

SRP was the predominant phosphorus species (49 – 72 percent of phosphorus) at the stations, and was greater at G342B, C, and D than at G342A and G136[28] (Figure 28). PP comprised the next largest percentage of phosphorus (26 – 35 percent of phosphorus), but did not vary among stations[29]. DOP was a relatively minor component of phosphorus (7 – 16 percent).

G136

TP concentrations ranged from 0.031 – 0.276 mg/L, with the maximum value occurring 1 November 2005 (Figure 29). TP concentration generally varied in concert with flow except for 7 February 2006. Thirty percent of G136 TP consisted of SRP, which generally increased and decreased in concert with TP concentrations. TDP was not sampled; DOP and PP could not be calculated.

G342A

G342A TP concentrations ranged from 0.072 – 0.175 mg/L. SRP was generally the predominant phosphorus species, although PP was predominant 7 September 2005 and comparable to SRP 2 November 2005. SRP and PP concentrations generally varied in concert with TP concentration, although SRP concentration did not increase with TP concentration 7 September 2005.

[27] $F = 9.95$, 90 df, $p < 0.0001$
[28] $F = 11.59$, 76 df, $p < 0.0001$
[29] $F = 0.24$, 65 df, $p = 0.87$

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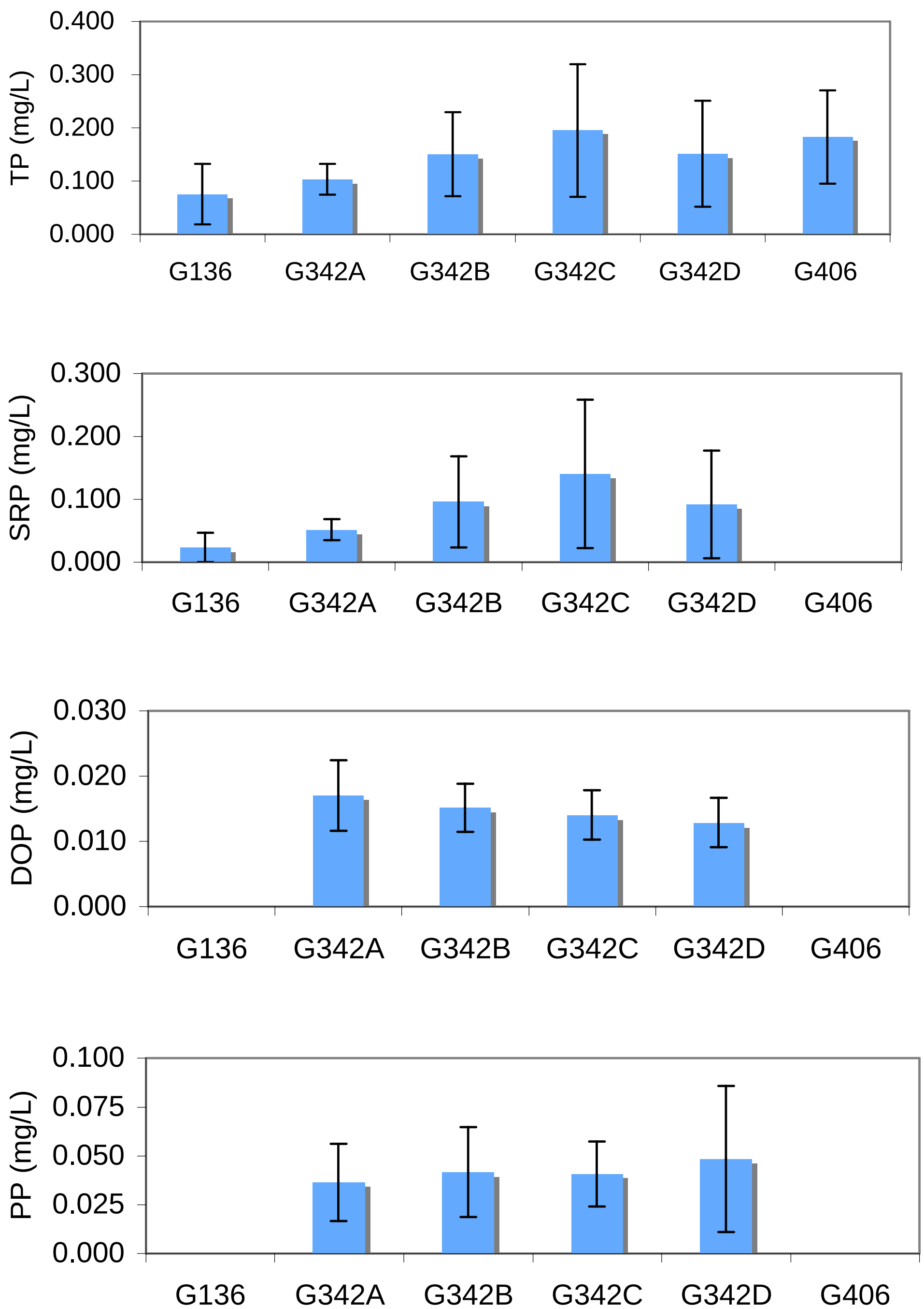

Figure 28. WY06 average (± s.d.) grab sample total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus at C-139 Basin discharge structures during flow events. TDP was not measured at G136 and G406.

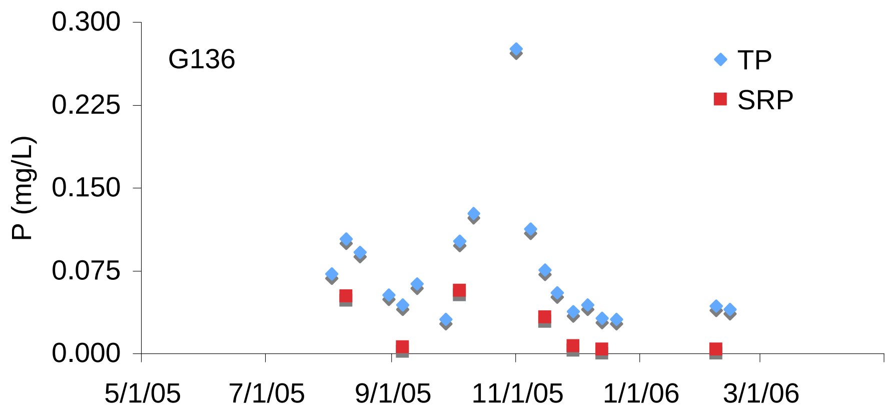

Figure 29. WY06 grab sample total (TP) and soluble reactive phosphorus (SRP) concentrations at G136 in the C-139 Basin during flow events.

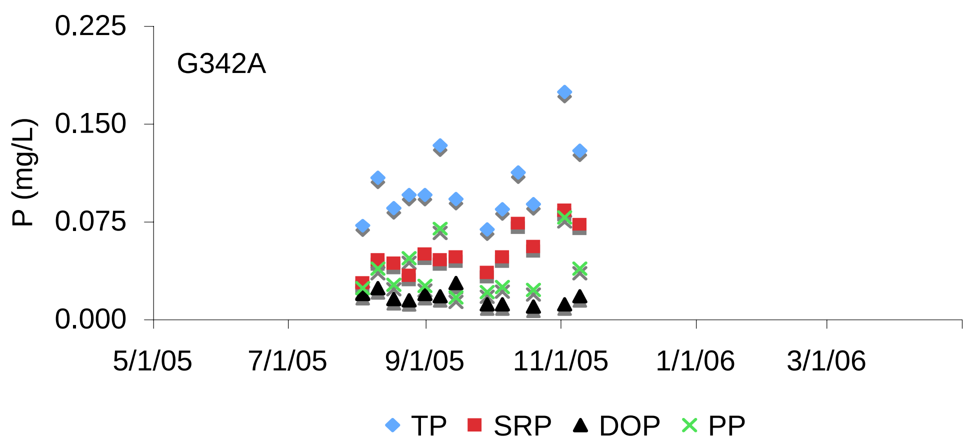

Figure 30. WY06 grab sample total (TP), soluble reactive (SRP), dissolved organic (DOP), and particulate (PP) phosphorus concentrations at G342A in the C139 Basin during flow events.

G342B

TP concentrations ranged from 0.071 – 0.429, and did not always vary in concert with flow (Figure 31). SRP was generally the predominant phosphorus species through November 2005, and again 8 February 2006. SRP concentrations varied in concert with TP concentrations during these periods. SRP and PP concentrations were similar mid February through early March 2006.

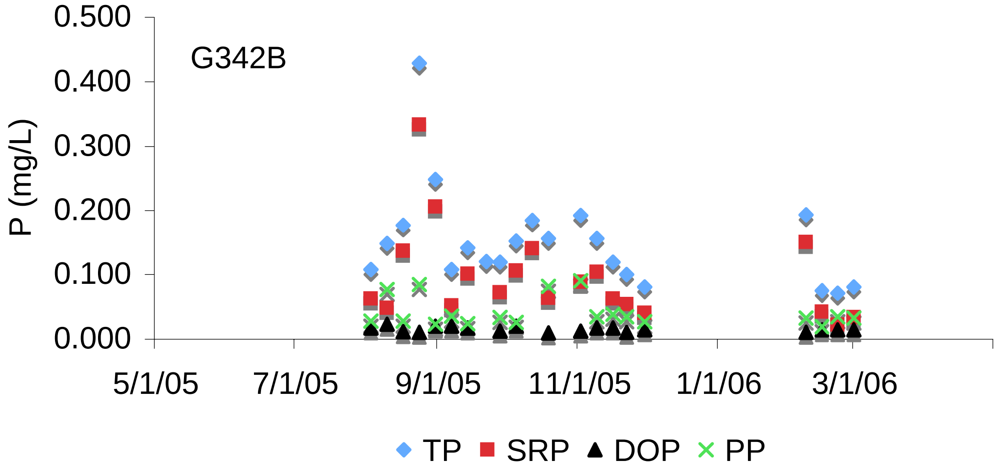

Figure 31. WY06 grab sample total (TP), soluble reactive (SRP), dissolved organic (DOP), and particulate (PP) phosphorus concentrations at G342B in the C139 Basin during flow events.

G342C

G342C TP concentrations ranged from 0.064 – 0.544 mg/L, peaking 31 August 2005 (Figure 32). SRP was the predominant phosphorus species throughout November 2005. SRP varied in concert with TP concentrations during this period. In December 2005, TP concentration was low and SRP and PP concentrations were similar.

G342D

G342D TP concentration ranged from 0.078 – 0.517 mg/L, with a maximum value occurring 31 August 2005 (Figure 33). SRP was the predominant phosphorus species. SRP concentration generally varied in concert with TP concentration.

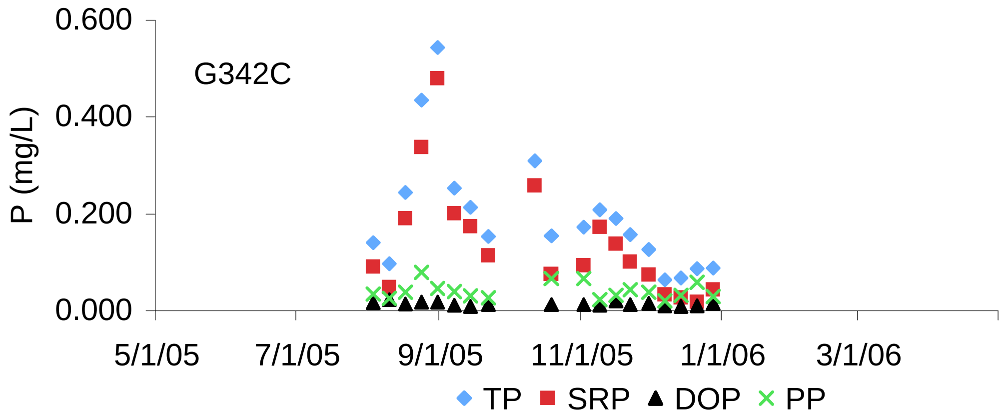

Figure 32. WY06 grab sample total (TP), soluble reactive (SRP), dissolved organic (DOP), and particulate (PP) phosphorus concentrations at G342C in the C139 Basin during flow events.

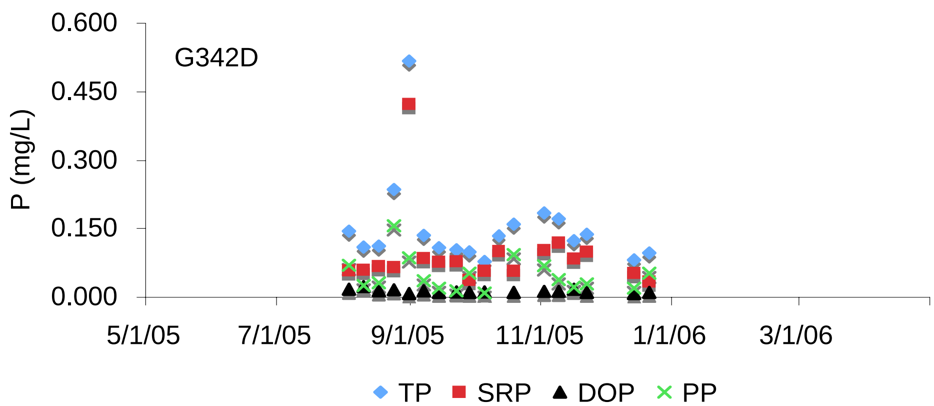

Figure 33. WY06 grab sample total (TP), soluble reactive (SRP), dissolved organic (DOP), and particulate (PP) phosphorus concentrations at G342D in the C139 Basin during flow events.

G406

G406 had few sample events and an abbreviated period of record. TP concentration ranged from 0.108 to 0.339 mg/L. Neither TDP nor SRP were sampled, precluding comparison of phosphorus species (Figure 34).

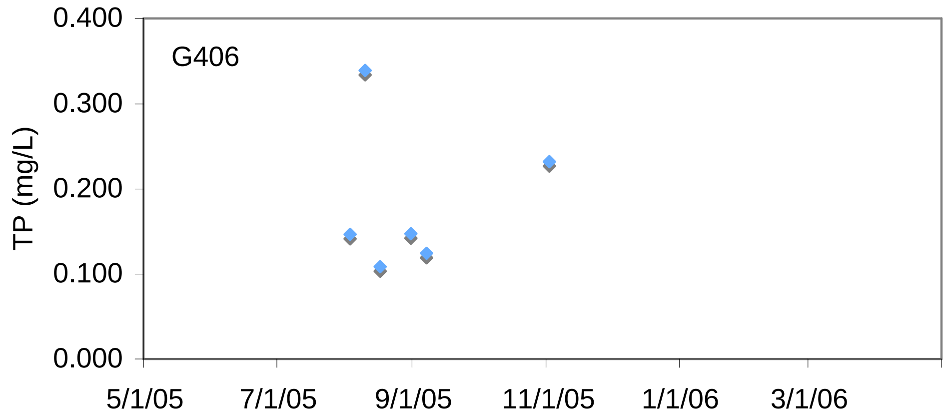

Figure 34. WY06 grab sample total phosphorus (TP) concentration at G406 in the C139 Basin during flow events.

Quiescent (No Flow) Samples

WY06 average daily TP concentrations during quiescent periods were 30 to 50 percent lower than concentrations during flow. Quiescent concentrations ranged from 0.039 mg/L at G136 to 0.094 at G342C (Figure 35). TP concentration was greater at G342C than 342A and D, and was least at G136[30]. There was no difference between 342A, B, D, and G406 TP concentrations.

PP was the predominant phosphorus species at G342A and B. PP and SRP were roughly comparable at G342C, and SRP was the dominant phosphorus species at G342D. SRP was a relatively small fraction (12 percent) of the phosphorus at G136. TDP was not sampled so DOP and PP could not be calculated). TDP and SRP were not sampled at G406.

Average SRP concentration was greater at G342D than at G342A or B, and greater at G342C than at 342A[31]. Average PP concentration was lower at G342D than at G342A, B, and C[32]. Average DOP concentrations did not vary among structures.

[30] $F = 18.87$, 73 df, $p < 0.0001$
[31] $F = 8.59$, 59 df, $p < 0.0001$
[32] $F = 12.03$, 49 df, $p < 0.0001$

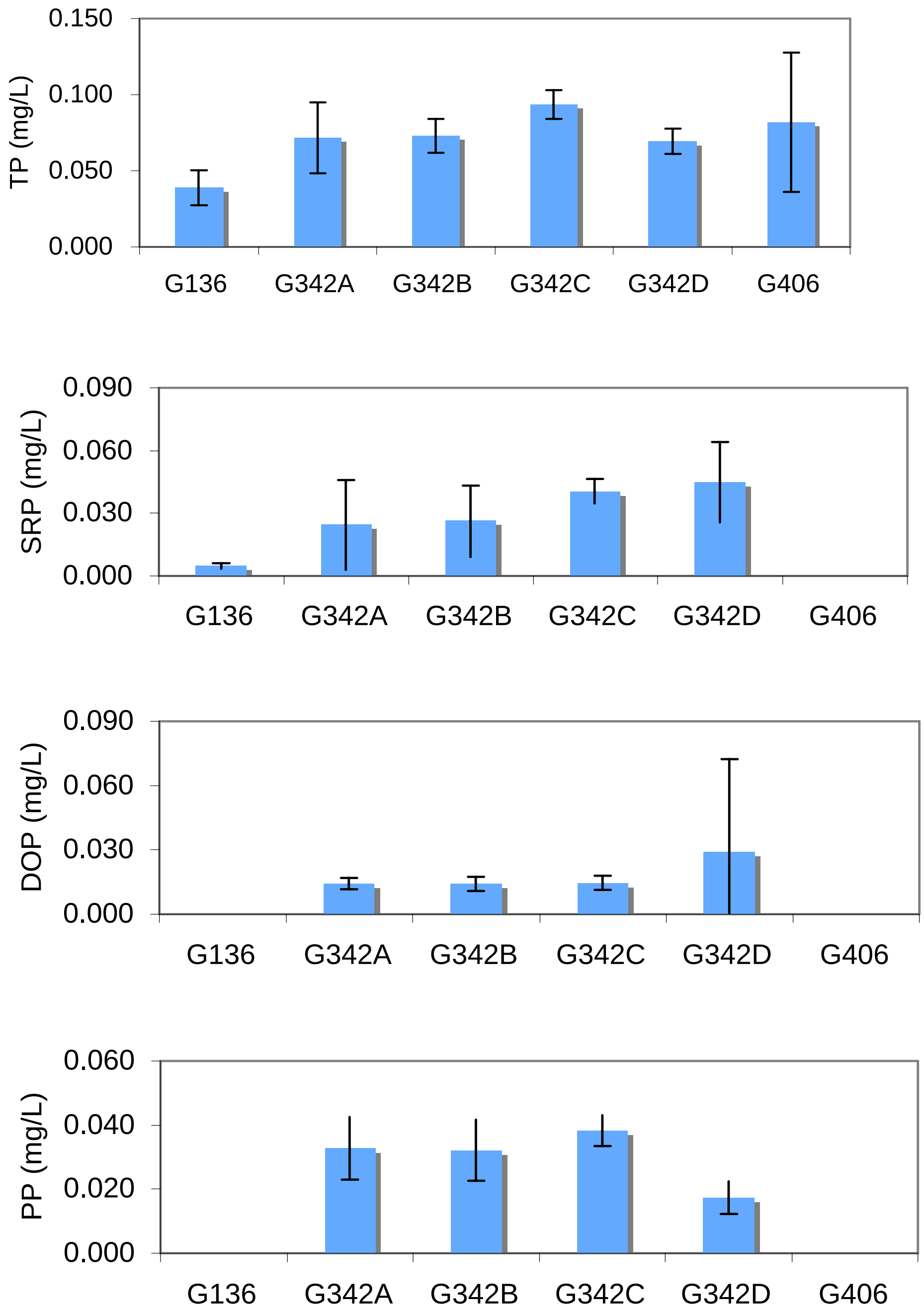

Figure 35. WY06 average (± s.d.) grab sample total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus at C-139 Basin discharge structures during quiescent periods.

G136

TP concentration varied throughout WY06, ranging from 0.027 mg/L 24 January to 0.066 mg/L 11 April 2006 (Figure 36). Concentrations were relatively high in August, September, and October 2005 and mid April 2006. By contrast, SRP concentrations were relatively invariant, ranging from 0.004 – 0.007 mg/L. TDP was not sampled, precluding evaluation of DOP and PP.

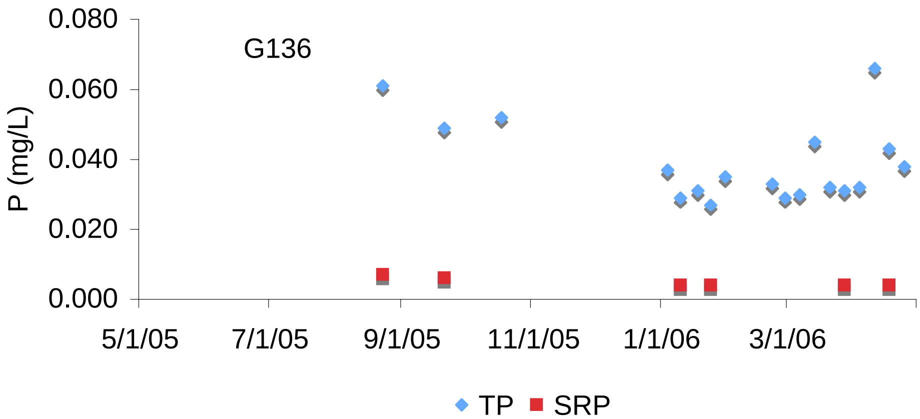

Figure 36. Total phosphorus (TP) and soluble reactive phosphorus (SRP) concentrations over time at C-139 Basin discharge structure G136 during quiescent periods.

G342A

TP concentration varied throughout WY06, ranging from 0.043 – 0.154 mg/L (Figure 37). The maximum value was achieved 8 February 2006. SRP and PP were significant contributors to TP. SRP concentration varied in concert with TP concentration from 22 September 2005 through 18 February 2006. Thereafter, PP concentration varied with TP concentration and SRP concentration decreased and remained low.

G342B

Quiescent TP concentrations varied little, ranging from 0.051 – 0.092 mg/L (Figure 38). SRP and PP were the largest contributors to TP. SRP concentration varied in concert with TP concentration from 7 December 2005 through 22 March 2006. Thereafter, PP concentration varied with TP concentration and SRP concentration decreased and remained low.

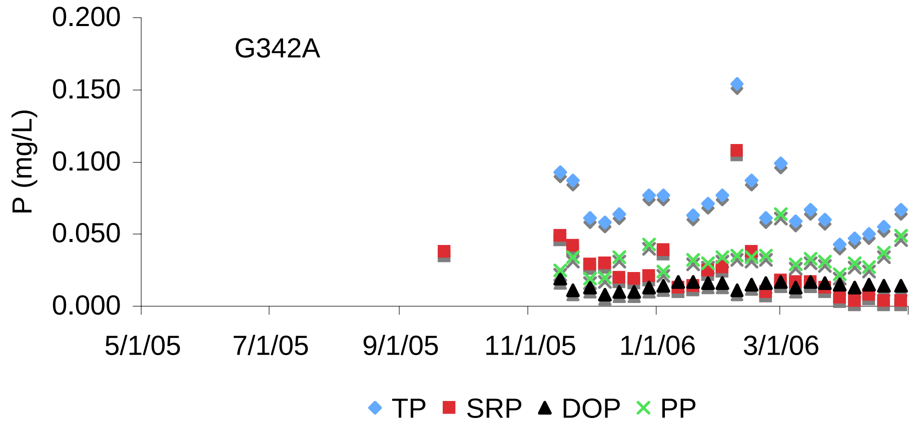

Figure 37. Total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations over time at C-139 Basin discharge structure G342A during quiescent periods.

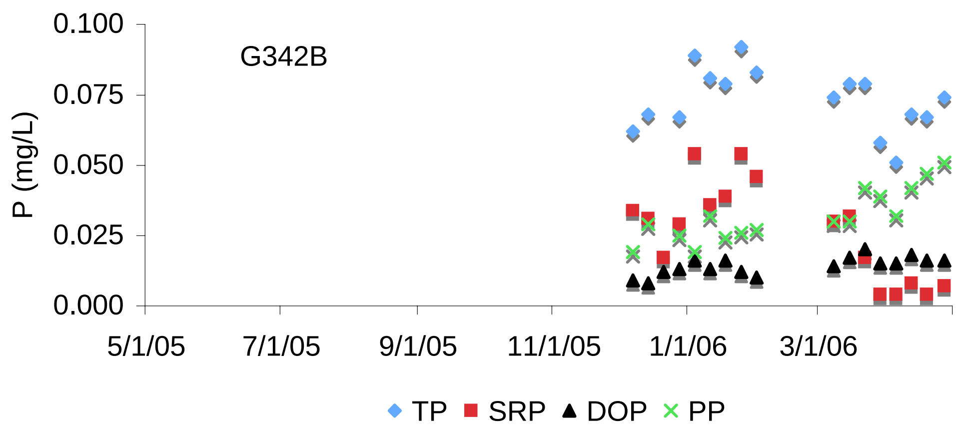

Figure 38. Total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations over time at C-139 Basin discharge structure G342B during quiescent periods.

G342C

Quiescent sampling at G342C was confined to a brief period encompassing 4 January through 1 February 2006 (Figure 39). SRP and PP were equal contributors to TP.

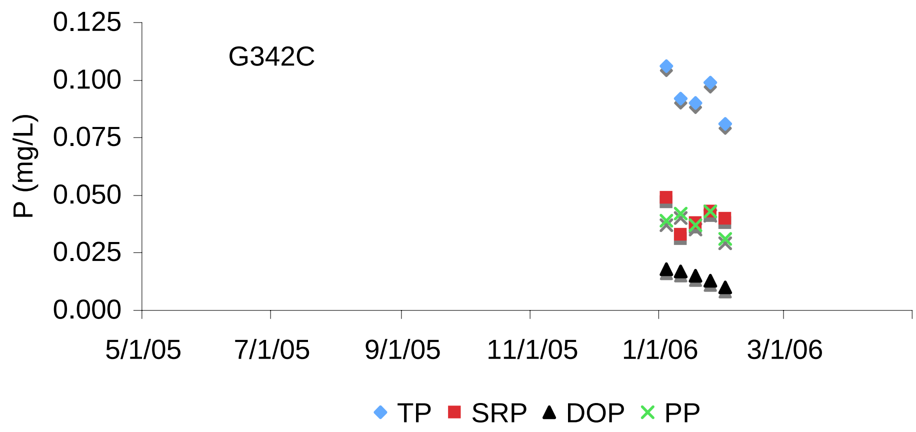

Figure 39. Total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations over time at C-139 Basin discharge structure G342C during quiescent periods.

G342D

Quiescent sampling at G342D was confined to 30 November 2005 through 1 February 2006 (Figure 40). TP concentration varied little, ranging from 0.058 – 0.083 mg/L. SRP appears to be the predominant phosphorus species, and to vary in concert with TP concentration. An elevated SRP sample and an extraordinary DOP sample 28 December 2005 cannot be properly evaluated in the absence of a TP sample value.

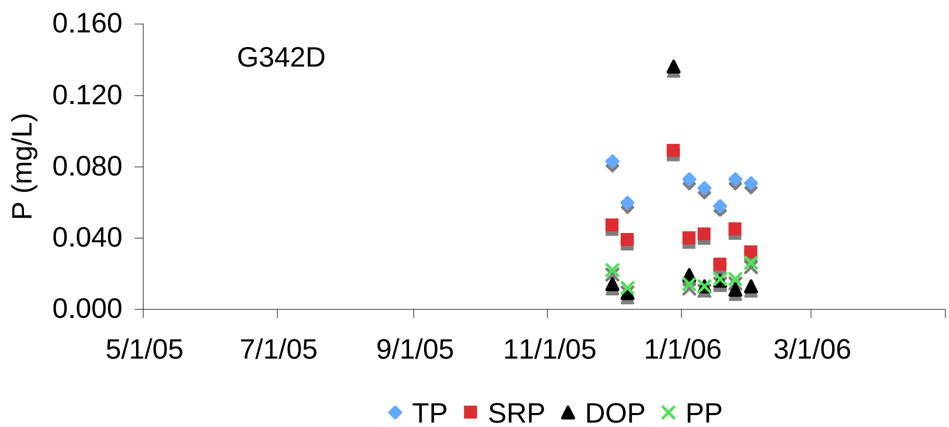

Figure 40. Total phosphorus (TP), soluble reactive phosphorus (SRP), dissolved organic phosphorus (DOP), and particulate phosphorus (PP) concentrations over time at C-139 Basin discharge structure G342D during quiescent periods.

G406

G406 was sampled on six occasions from 14 September 2005 through 15 February 2006 (Figure 41). TP concentration ranged from 0.053 – 0.166 mg/L, and was less than 0.060 mg/L from 7 December 2005 until 15 February 2006. TDP and SRP were not sampled, precluding evaluation of phosphorus species.

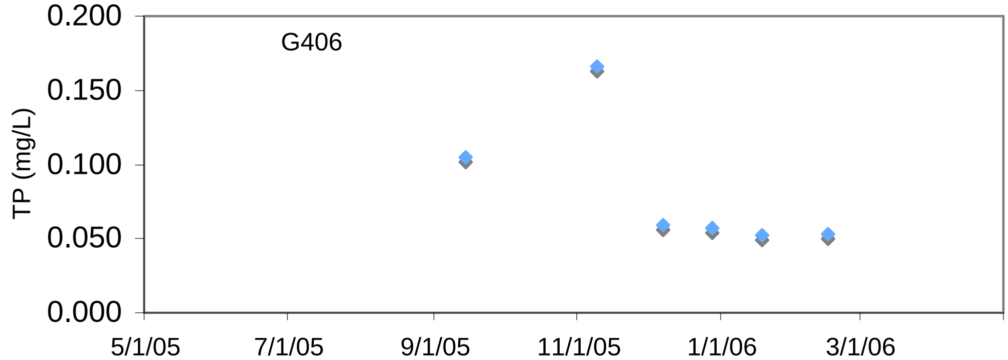

Figure 41. Total phosphorus (TP) over time at C-139 Basin discharge structure G406 during quiescent periods.

SUMMARY AND CONCLUSIONS

Amending the existing sampling programs would facilitate developing an effective BMP program. Most important is completing installation of the C139D program autosamplers. Phosphorus concentration (TP, TDP, and SRP) and flow data, and improved understanding of G150-associated flow, would enable comparison of sub basin loads.

Ideally, TDP, SRP, chlorophyll *a*, TSS, and FAV would be sampled at each station. Collectively, this information elucidates phosphorus sources, transport, and cycling throughout the C-139 Basin. For example, measurement of SRP and calculation of PP from TP and TDP help to identify the predominant phosphorus species. Predominant SRP suggests phosphorus from soil amendments or sediment flux. Predominant PP suggests phosphorus from soil erosion, plant decomposition, or plankton. Chlorophyll *a*, TSS, and FAV help us discern between various PP sources. Sampling during quiescent periods elucidates phosphorus transport and cycling.

Flow is also a critical measurement parameter for each station because it facilitates calculation of average daily and cumulative loads. A high phosphorus concentration is meaningless if the phosphorus is not conveyed downstream. Flow should be measured concurrent with water quality sampling to determine phosphorus conveyance.

Despite the aforementioned constraints, the WY06 sampling data elucidates some aspects of C-139 Basin phosphorus sources, transport, cycling, and export. TP concentration for SM-01 was four times greater than the combined DF-01/02 sub basins, a finding consistent with previous studies (CWF and DBE 2004, 2005). This suggests that the SM-01 Basin may be a relatively significant source of phosphorus in the C-139 Basin. However, flow measurements and load calculations are required to precisely define sub basin export. Moreover, collection of phosphorus and flow data at other C139D program locations is necessary to place SM-01 and DF-01/02 sub basins phosphorus export in a basin-wide context.

Differences in TP concentration were apparent within several sub basins, and may be indicative of source contributions. The significance of differences in TP concentration cannot be evaluated without flow data and load calculation. That said, in the SM-01 sub basin, TP concentrations were greatest at SM02.2TW02 and SM02.1TN01. A non-sampled canal discharging downstream of the SM05.0TN and SM05.0TW stations and upstream of SM02.2TW02 may be contributing significant phosphorus to the S&M Canal and should be investigated. In the DF-02 sub basin, station DF11.3TW01 had an average TP concentration three times greater, and a peak concentration nine times greater, than station DF12.3TS. In the L3-01 sub basin, TP concentration was greater at L207.6TW02 than L206.0TW02, and greater at L206.0TW02 than L206.0TW01. Finally, in the L2-01 sub basin, TP and SRP concentrations were greater at L209.1TW01 than L212.1TW13.

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Transport mechanisms were suggested in two instances by the WY06 data. In the SM-01 sub basin, TP was reduced upstream of SM02.1TW, and again upstream of SMWeir. A reduction in TP concentration was also evident in the L3-01 sub basin. TP concentration was less at the downstream station (L206.0TW01) than at one, and perhaps both, of the upstream stations. These findings suggest that phosphorus was being removed as it was transported through the sub basin. Alternatively, phosphorus was being diluted by greater flow from one of the upstream stations, a non-sampled canal/ditch, or overland runoff. In either instance, the changes in TP concentration should be investigated, beginning with flow measurements and load calculations.

Elucidating phosphorus cycling in the C-139 Basin was hindered by inconsistent measurement of TDP and SRP, qualitative observations of FAV, and the lack of chlorophyll *a* or TSS data. SRP was the predominant phosphorus species in both the SM-01 and DF-01/02 sub basins. PP may play a more prominent role in phosphorus transport in the L3-01, L2-01, and L2-02 sub basins than the SM-01, DF-01, and DF-02 sub basins. At stations in the L3-01 sub basin, and at the L2-01 station, SRP was the predominant phosphorus species until April, when PP becomes the predominant species. The change was coincident with generally lower TP concentrations. Conversely, PP was the predominant phosphorus species in the L2-02 sub basin until the last sampling event in early November.

The WY06 data provide a general picture of phosphorus export from the C-139 Basin. Average daily WY06 load was greatest at G406 (416 kg) and least at G136 (44 kg). The average daily load was greater at G342A, B, and C than at G342D. Almost 100 metric tons of phosphorus were exported from the C-139 Basin during WY06. Cumulative load was greatest at G406 (44 metric tons) and least at G342D (9 metric tons). Fifty percent of the C-139 Basin annual load was exported to STA-5, and 41 percent to the L-3 Canal via G406.

Phosphorus export increased in response to increasing flow, increasing TP concentration, or an increase in both. Determining the cause of increased loads can inform BMP development and implementation. For example, increasing loads due to increased flow suggest that water storage would be an effective BMP. Conversely, increasing loads due to increased TP concentration suggest a BMP centered on phosphorus source control, vegetation management, or canal sediment removal (if high phosphorus sediments are detected within the basin).

Phosphorus export patterns varied among structures. Some structures (e.g., G136, G406) exhibited relatively discrete phosphorus discharge events. Other structures (e.g., G342) discharge more consistently, although peaks are evident. Phosphorus was discharged predominantly as SRP. PP was a more significant proportion of phosphorus during quiescent periods, when TP concentrations are 30 to 50 percent less than flow concentrations. The relative increase in PP during quiescent periods may reflect the growth of FAV or plankton.

RECOMMENDATIONS

1. Each monitoring program should attempt to sample all stations within a single day. If this is not possible, then all sub basin stations should be sampled on the same day.
2. Each monitoring program should sample TP, TDP, and SRP whenever water is present, even in the absence of flow. Identification of phosphorus species is essential for discerning phosphorus sources and understanding transport and cycling.
3. Each monitoring program should measure TSS and chlorophyll *a* concurrent with phosphorus sampling. Measurement of TSS, chlorophyll *a*, and FAV (see below) facilitates understanding of PP source and phosphorus transport and cycling.
4. Each monitoring program should sample TP, TDP, SRP, TSS, chlorophyll *a*, and FAV during quiescent periods. Quiescent data compared with flow data contribute to our understanding of phosphorus transport and cycling.
5. Each monitoring program should measure flow coincident with sampling of TP, TDP, and SRP. 'No flow' events should recorded as 0 (zero) cfs. The Marsh-McBirney Flo-Mate Flowmeter (www.marsh-mcbirney.com) seems to be well suited for C-139 Basin flow measurement. Flow measurement allows for calculation of phosphorus load and contributes to our understanding of transport and cycling.
6. Each program should estimate floating aquatic plant coverage at the time of sampling, and include this information on the data worksheet(s). The occurrence of floating aquatic plants, and changes in coverage, help to explain the relative concentrations of phosphorus species and contribute to our understanding of phosphorus transport and cycling. One method for recording floating aquatic plant coverage (percent) is to visually estimate species-specific percent coverage for a defined quadrat (e.g. shore to shore for a 25 m length of the canal) encompassing the water quality sampling station.
7. The installation of autosamplers at stations DF11.3TW01, L202.0TN, L207.0TN, and G-151 should be completed.
8. The relative contribution of sub basins DF-02&01, SM-01, L3-01, L2-01, and L2-02 to discharge structures G342A-D and G406 cannot be discerned. This constrains application of BMPs related to gate operation. Dye tests could be used to evaluate the relative contribution of the sub basins to each discharge structure. Dye tests could be accomplished with a single dye applied to each sub basin at a separate time, or multiple dyes applied simultaneously to the sub basins. Dye should be applied to each sub basin at least once during a flow event, and preferably twice – once during the first significant flow event of the rainy season and again mid to late rainy season.
9. Defining L2-01 phosphorus and flow when G151 and G150 are open and discharging might be simplified by placing a structure on the L-2 Canal south of the L-2W Canal.

10. Discharge from the SM-01 sub basin canal downstream of the SM05.0TN and SM05.0TW stations and upstream of SM02.2TW02 should be investigated as a potentially significant source of phosphorus.
11. The apparent removal or dilution of phosphorus upstream of SM02.1TW and upstream of SMWeir should be investigated. Understanding changes in phosphorus concentration will clarify transport and cycling mechanisms, and suggest effective BMPs.
12. The apparent removal or dilution of phosphorus upstream of L206.0TW01 should be investigated. Understanding changes in phosphorus concentration will clarify transport and cycling mechanisms, and suggest effective BMPs. The investigation should include contemporaneous measurement of TP, TDP, and SRP in the Devil's Garden, South Boundary, and Knowles Canals during a quiescent period and during flow.
13. The sediments should be investigated at L209.1TW01 to determine if they are a potential source of SRP to the water column. Sediments should be sampled during both quiescent and flow conditions.

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LITERATURE CITED

A.D.A. Engineering. 2006. C-139 Basin Phosphorus Water Quality and Hydrology Analysis. Deliverable 5.4 – Phase 1 Report. Prepared for the South Florida Water Management District. West Palm Beach, Florida.

Adorisio, C., C. Bedregal, J. Gomez, J. Madden, C. Miessau, D. Pescatore, phosphorus. Sievers, S. Van Horn, T. van Veen, and J. Vega. 2006. Chapter 4: Phosphorus source controls for the basins tributary to the Everglades Protection Area. Draft 2007 South Florida Environmental Report. South Florida Water Management District and Florida Department of Environmental Protection.

Community Watershed Fund and DB Environmental. 2004. C-139 Basin particulate phosphorus and sediments. Memorandum to the South Florida Water Management District. 5 August.

Community Watershed Fund and DB Environmental. 2005. C-139 Basin Deerfence and S&M Canals Phosphorus Transport and Cycling. Final Report to the South Florida Water Management District. 8 November.

SAS Institute. 2005. JMP Start Statistics. Third edition. Brooks/Cole –Thomson Learning. Belmont, California, U.S.

APPENDIX A

SUMMARY OF C139D PROGRAM FLOATING AQUATIC VEGETATION (FAV) AND ALGAE OBSERVATIONS

Station	Days With FAV/Algae	Days Without FAV/Algae	Total Days
DF02.1TW	0	13	13
G150	0	49	49
SM00.2TW	3	12	15

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Station	Date	FAV/Algae Comments
DF02.1TW	2/7/06	
DF02.1TW	2/14/06	
DF02.1TW	2/22/06	
DF02.1TW	2/28/06	
DF02.1TW	3/7/06	
DF02.1TW	3/14/06	
DF02.1TW	3/21/06	
DF02.1TW	3/28/06	
DF02.1TW	4/4/06	
DF02.1TW	4/11/06	
DF02.1TW	4/18/06	
DF02.1TW	4/25/06	
DF02.1TW	4/25/06	

G150	5/18/05	
G150	5/23/05	
G150	5/23/05	
G150	6/2/05	
G150	6/8/05	
G150	6/16/05	
G150	6/22/05	
G150	6/29/05	
G150	7/7/05	
G150	7/14/05	
G150	7/20/05	
G150	7/27/05	
G150	8/3/05	
G150	8/10/05	
G150	8/16/05	
G150	8/23/05	
G150	8/30/05	
G150	9/7/05	
G150	9/13/05	
G150	9/21/05	
G150	9/27/05	
G150	10/4/05	
G150	10/11/05	
G150	10/18/05	
G150	11/8/05	

G150	11/15/05	
G150	11/22/05	
G150	11/29/05	
G150	12/6/05	
G150	12/13/05	
G150	12/20/05	
G150	12/28/05	
G150	1/4/06	
G150	1/10/06	
G150	1/18/06	
G150	1/24/06	
G150	1/31/06	
G150	2/7/06	
G150	2/14/06	
G150	2/22/06	
G150	2/28/06	
G150	3/7/06	
G150	3/14/06	
G150	3/21/06	
G150	3/28/06	
G150	4/4/06	
G150	4/11/06	
G150	4/18/06	
G150	4/25/06	
SM00.2TW	2/7/06	
SM00.2TW	2/14/06	
SM00.2TW	2/22/06	
SM00.2TW	2/28/06	heavy water lettuce
SM00.2TW	3/7/06	some water lettuce
SM00.2TW	3/14/06	some water lettuce at sample site
SM00.2TW	3/21/06	
SM00.2TW	3/28/06	
SM00.2TW	4/4/06	
SM00.2TW	4/11/06	
SM00.2TW	4/18/06	
SM00.2TW	4/25/06	

APPENDIX B

SUMMARY OF C139B PROGRAM FLOATING AQUATIC VEGETATION (FAV) AND ALGAE OBSERVATIONS

Station	Days With FAV/Algae	Days Without FAV/Algae	Total Days
DF02.0TW	1	19	20
DF08.1TN01	11	5	16
DF11.1TN01	8	8	16
DF11.3TW01	10	6	16
DF12.2TS	1	14	15
DF12.3TS	8	8	16
L206.0TW01	11	5	16
L206.0TW02	6	10	16
L207.6TW02	1	14	15
L209.6TW02	1	16	17
L212.1TW13	7	10	17
SM02.1TN01	8	9	17
SM02.1TW	1	13	14
SM02.2TW02	6	10	16
SM05.0TN	8	8	16
SM05.0TW	3	15	18
SMWEIR	9	8	17

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Station	Date	FAV/Algae Comments
DF02.0TW	8/4/05	
DF02.0TW	8/4/05	
DF02.0TW	8/4/05	
DF02.0TW	8/4/05	
DF02.0TW	8/10/05	
DF02.0TW	8/16/05	
DF02.0TW	8/23/05	
DF02.0TW	8/30/05	light vegetation; water lettuce, weeds
DF02.0TW	9/7/05	
DF02.0TW	9/13/05	
DF02.0TW	9/21/05	
DF02.0TW	9/27/05	
DF02.0TW	10/4/05	
DF02.0TW	10/11/05	
DF02.0TW	10/18/05	
DF02.0TW	11/2/05	
DF02.0TW	4/3/06	
DF02.0TW	4/10/06	
DF02.0TW	4/17/06	
DF02.0TW	4/24/06	
DF08.1TN01	8/11/05	water lettuce, weed growth upstream
DF08.1TN01	8/17/05	
DF08.1TN01	8/24/05	heavy vegetation; lilies and weeds upstream and downstream
DF08.1TN01	8/31/05	weeds and water lettuces upstream and downstream
DF08.1TN01	9/8/05	heavy vegetation upstream; water lettuces, weeds, grass
DF08.1TN01	9/14/05	water lettuce and algae upstream
DF08.1TN01	9/22/05	weed choked upstream
DF08.1TN01	9/28/05	vegetation upstream
DF08.1TN01	10/6/05	
DF08.1TN01	10/13/05	weed choked upstream
DF08.1TN01	10/20/05	heavy vegetation upstream; water lettuces, weeds (choked), grass
DF08.1TN01	11/3/05	heavy vegetation downstream; weeds, water lettuces choked, grass
DF08.1TN01	4/3/06	
DF08.1TN01	4/10/06	
DF08.1TN01	4/17/06	
DF08.1TN01	4/24/06	algae, vegetation particulates

DF11.1TN01	8/11/05	weed growth upstream
DF11.1TN01	8/17/05	weeds upstream
DF11.1TN01	8/24/05	weeds and lilies upstream and downstream
DF11.1TN01	8/31/05	weeds and lilies upstream
DF11.1TN01	9/8/05	heavy vegetation upstream; water lettuces, weeds, grass
DF11.1TN01	9/14/05	
DF11.1TN01	9/22/05	weed choked upstream
DF11.1TN01	9/28/05	
DF11.1TN01	10/6/05	weed choked upstream
DF11.1TN01	10/13/05	weed choked upstream
DF11.1TN01	10/20/05	
DF11.1TN01	11/3/05	
DF11.1TN01	4/3/06	
DF11.1TN01	4/10/06	
DF11.1TN01	4/17/06	
DF11.1TN01	4/24/06	
DF11.3TW01	8/11/05	water lettuce, weed growth upstream
DF11.3TW01	8/17/05	weeds and water lilies upstream and downstream, lilies suspended on fence
DF11.3TW01	8/24/05	weeds and lilies upstream and downstream
DF11.3TW01	8/31/05	weeds and water lettuces upstream and downstream
DF11.3TW01	9/8/05	vegetation by sample point; weeds, water lettuces
DF11.3TW01	9/14/05	water lettuce upstream and downstream
DF11.3TW01	9/22/05	
DF11.3TW01	9/28/05	
DF11.3TW01	10/6/05	
DF11.3TW01	10/13/05	heavy vegetation downstream; weeds, water lettuces, grass
DF11.3TW01	10/20/05	heavy vegetation downstream
DF11.3TW01	11/3/05	light amount of water lettuces downstream
DF11.3TW01	4/3/06	
DF11.3TW01	4/10/06	
DF11.3TW01	4/17/06	weed choked with water lettuce
DF11.3TW01	4/24/06	
DF12.2TS	8/11/05	
DF12.2TS	8/17/05	
DF12.2TS	8/24/05	
DF12.2TS	8/31/05	
DF12.2TS	9/8/05	

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DF12.2TS	9/14/05	water lettuce upstream and downstream
DF12.2TS	9/22/05	
DF12.2TS	9/28/05	
DF12.2TS	10/6/05	
DF12.2TS	10/13/05	
DF12.2TS	10/20/05	
DF12.2TS	11/3/05	
DF12.2TS	4/10/06	
DF12.2TS	4/17/06	
DF12.2TS	4/24/06	
DF12.3TS	8/11/05	
DF12.3TS	8/17/05	weeds upstream and downstream
DF12.3TS	8/24/05	weeds upstream
DF12.3TS	8/31/05	weeds upstream and downstream
DF12.3TS	9/8/05	cattail and weeds upstream by sample point
DF12.3TS	9/14/05	algae upstream
DF12.3TS	9/22/05	weeds upstream
DF12.3TS	9/28/05	
DF12.3TS	10/6/05	
DF12.3TS	10/13/05	grass upstream
DF12.3TS	10/20/05	grasses upstream on sides of bank
DF12.3TS	11/3/05	
DF12.3TS	4/3/06	
DF12.3TS	4/10/06	
DF12.3TS	4/17/06	
DF12.3TS	4/24/06	
L206.0TW01	8/4/05	heavy weed, water lettuce upstream
L206.0TW01	8/10/05	heavy water lettuce, grasses, Nymphaea or water hyacinth (purple flowers) upstream
L206.0TW01	8/16/05	weed and water lettuce growth
L206.0TW01	8/23/05	vegetation growth; weed and water lettuce
L206.0TW01	8/30/05	heavy vegetation; water lilies, weeds
L206.0TW01	9/7/05	
L206.0TW01	9/13/05	heavy vegetation upstream; water lettuces, weeds, grass
L206.0TW01	9/21/05	
L206.0TW01	9/27/05	heavy vegetation upstream; water lettuces, weeds
L206.0TW01	10/4/05	heavy vegetation upstream; water lettuces, weeds
L206.0TW01	10/11/05	heavy vegetation upstream; water lettuces, weeds, grass
L206.0TW01	10/18/05	

L206.0TW01	11/2/05	weeds 10 yards from collection point
L206.0TW01	4/3/06	
L206.0TW01	4/10/06	
L206.0TW01	4/24/06	algae
L206.0TW02	8/11/05	
L206.0TW02	8/17/05	weeds upstream
L206.0TW02	8/24/05	weeds upstream
L206.0TW02	8/31/05	weeds upstream and downstream
L206.0TW02	9/8/05	vegetation by sample point; weeds, water lettuces
L206.0TW02	9/14/05	
L206.0TW02	9/22/05	some weeds upstream
L206.0TW02	9/28/05	
L206.0TW02	10/6/05	
L206.0TW02	10/13/05	
L206.0TW02	10/20/05	
L206.0TW02	11/3/05	some water lettuces and weeds upstream
L206.0TW02	4/3/06	
L206.0TW02	4/10/06	
L206.0TW02	4/17/06	
L206.0TW02	4/24/06	
L207.6TW02	8/11/05	
L207.6TW02	8/17/05	
L207.6TW02	8/24/05	
L207.6TW02	8/31/05	
L207.6TW02	9/14/05	vegetation upstream
L207.6TW02	9/22/05	
L207.6TW02	9/28/05	
L207.6TW02	10/6/05	
L207.6TW02	10/13/05	
L207.6TW02	10/20/05	
L207.6TW02	11/3/05	
L207.6TW02	4/3/06	
L207.6TW02	4/10/06	
L207.6TW02	4/17/06	
L207.6TW02	4/24/06	
L209.6TW02	8/11/05	
L209.6TW02	8/17/05	
L209.6TW02	8/24/05	

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L209.6TW02	8/31/05	
L209.6TW02	9/8/05	
L209.6TW02	9/8/05	
L209.6TW02	9/14/05	vegetation upstream and downstream
L209.6TW02	9/22/05	
L209.6TW02	9/28/05	
L209.6TW02	10/6/05	
L209.6TW02	10/13/05	
L209.6TW02	10/20/05	
L209.6TW02	11/3/05	
L209.6TW02	4/3/06	
L209.6TW02	4/10/06	
L209.6TW02	4/17/06	
L209.6TW02	4/24/06	
L212.1TW13	8/11/05	
L212.1TW13	8/17/05	lilies in water
L212.1TW13	8/24/05	weeds and lilies upstream and downstream
L212.1TW13	8/31/05	weeds and water lettuces upstream and downstream
L212.1TW13	8/31/05	
L212.1TW13	9/8/05	heavy vegetation upstream; water lettuces, weeds
L212.1TW13	9/14/05	heavy vegetation upstream
L212.1TW13	9/22/05	heavy vegetation upstream
L212.1TW13	9/28/05	
L212.1TW13	10/6/05	
L212.1TW13	10/13/05	
L212.1TW13	10/20/05	
L212.1TW13	11/3/05	heavy vegetation upstream; water lettuces, weeds
L212.1TW13	4/3/06	
L212.1TW13	4/10/06	
L212.1TW13	4/17/06	
L212.1TW13	4/24/06	
SM02.1TN01	8/4/05	heavy water lettuce growth upstream
SM02.1TN01	8/10/05	heavy water lettuce, grass upstream
SM02.1TN01	8/16/05	heavy vegetation
SM02.1TN01	8/23/05	heavy vegetation; water lettuce
SM02.1TN01	8/30/05	heavy water lettuce
SM02.1TN01	9/7/05	water lettuce upstream
SM02.1TN01	9/13/05	heavy vegetation upstream; water lettuces
SM02.1TN01	9/21/05	upstream weed chocked and water lettuce

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SM02.1TN01	9/27/05	
SM02.1TN01	10/4/05	
SM02.1TN01	10/11/05	
SM02.1TN01	10/18/05	
SM02.1TN01	11/2/05	
SM02.1TN01	4/3/06	
SM02.1TN01	4/10/06	
SM02.1TN01	4/17/06	
SM02.1TN01	4/24/06	

SM02.1TW	8/10/05	
SM02.1TW	8/16/05	
SM02.1TW	8/23/05	
SM02.1TW	8/30/05	
SM02.1TW	9/7/05	
SM02.1TW	9/13/05	
SM02.1TW	9/21/05	
SM02.1TW	9/27/05	
SM02.1TW	10/18/05	
SM02.1TW	11/2/05	
SM02.1TW	4/3/06	
SM02.1TW	4/10/06	
SM02.1TW	4/17/06	some algae
SM02.1TW	4/24/06	

SM02.2TW02	8/10/05	
SM02.2TW02	8/16/05	heavy vegetation; water lilies, water lettuce, weeds
SM02.2TW02	8/23/05	heavy vegetation; water lilies, water lettuce, weeds
SM02.2TW02	8/30/05	heavy vegetation; water lilies, water lettuce, weeds
SM02.2TW02	9/7/05	
SM02.2TW02	9/13/05	heavy vegetation upstream; water lettuces, weeds, grass
SM02.2TW02	9/21/05	
SM02.2TW02	9/27/05	
SM02.2TW02	10/4/05	
SM02.2TW02	10/11/05	
SM02.2TW02	10/18/05	
SM02.2TW02	11/2/05	
SM02.2TW02	4/3/06	
SM02.2TW02	4/10/06	
SM02.2TW02	4/17/06	water lettuce around culverts and upstream
SM02.2TW02	4/24/06	weed choked

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SM05.0TN	8/10/05	heavy water lettuce, duck weed, various grasses, weeds upstream
SM05.0TN	8/17/05	weeds upstream
SM05.0TN	8/24/05	water lilies upstream
SM05.0TN	8/31/05	weeds and lilies upstream
SM05.0TN	9/8/05	heavy vegetation upstream; weeds, grass
SM05.0TN	9/14/05	water lettuce
SM05.0TN	9/22/05	heavy vegetation upstream; water lettuces, weeds, grass
SM05.0TN	9/28/05	water lettuce
SM05.0TN	10/6/05	
SM05.0TN	10/13/05	
SM05.0TN	10/20/05	
SM05.0TN	11/3/05	
SM05.0TN	4/3/06	
SM05.0TN	4/10/06	
SM05.0TN	4/17/06	
SM05.0TN	4/24/06	
SM05.0TW	8/10/05	
SM05.0TW	8/17/05	
SM05.0TW	8/24/05	
SM05.0TW	8/31/05	
SM05.0TW	9/8/05	
SM05.0TW	9/14/05	water lettuce and algae upstream
SM05.0TW	9/22/05	
SM05.0TW	9/28/05	
SM05.0TW	10/4/05	
SM05.0TW	10/6/05	
SM05.0TW	10/11/05	
SM05.0TW	10/13/05	
SM05.0TW	10/20/05	
SM05.0TW	11/3/05	
SM05.0TW	4/3/06	vegetation particulates
SM05.0TW	4/10/06	
SM05.0TW	4/17/06	water lettuce
SM05.0TW	4/24/06	
SMWEIR	8/3/05	water lettuce around the weir
SMWEIR	8/10/05	water lettuce around the weir
SMWEIR	8/16/05	slight vegetation on vegetation barrier
SMWEIR	8/23/05	vegetation on vegetation barrier

SMWEIR	8/30/05	light vegetation; water lettuce
SMWEIR	9/7/05	water lettuce
SMWEIR	9/13/05	light vegetation near sample point; water lettuce
SMWEIR	9/21/05	
SMWEIR	9/27/05	
SMWEIR	10/4/05	
SMWEIR	10/11/05	
SMWEIR	10/18/05	
SMWEIR	11/2/05	
SMWEIR	4/3/06	
SMWEIR	4/10/06	
SMWEIR	4/17/06	some algae
SMWEIR	4/24/06	algae