JEFFERSON PATTERSON PARK AGRICULTURAL PONDS III:

SEASONAL WATER COLUMN NUTRIENT CYCLING AND

EFFECTS OF STORM WATER FLOW

ON NUTRIENT PARTITIONING

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EXECUTIVE SUMMARY

Seasonal sampling from Ponds A and B at Jefferson Patterson Park during the period November 1997- August 1998 confirmed that nutrient cycling within these ponds is predictable from year-to-year. For example, nitrite+nitrate concentrations between the stream leading to pond A and the concentrations in pond A are substantially reduced (20-90%, depending on the season) and are even further reduced upon entering Pond B. The uptake of readily available inorganic N compounds by the plant/microbial community present in the ponds emphasizes the value of the two pond system in removing these nutrients which would otherwise directly enter the Patuxent River.

The predominant form of phosphorus is the particulate fraction throughout the year and discharge of water rich in phosphorus from the ponds is event specific.

Two major storm events were monitored; one during January 1998 and the other in May 1998. Discharge rates of 1200 liters/minute were measured during the winter event. Immediately after an event, declining rates of flow were noted. For Pond A, a decline of 3.8 liters/minute/hour was calculated. Nearly twice that (6.3 liters/minute/hour) was determined for Pond B. This assumes a linear hourly rate reduction when no precipitation occurred. It was also noted that the most dramatic changes in nutrient concentrations occurred in the stream leading to Pond A and in Pond A itself. Drought conditions during the summer and fall prevented storm event sampling for those seasons.

It appears that the particulate parameters are most affected by winter storm events.The most striking feature of this field survey was the significant and rapid decrease of particulate nitrogen, particulate phosphorus and total suspended solids in the stream after 48 hours, followed by the subsequent return to "ambient" concentrations after 96 hours. It appears that stream flow and immediate runoff as a result of the storm clears loosely bound particulate material from most of the immediate area surrounding the stream, thereby reducing the particulate material in the water. Subsequent sampling indicates that concentrations return to those that were present during the event.

Particulate nitrogen concentrations in Pond A also show some changes with time at both stations as a result of the storm. For example, during the event, the concentration of particulate nitrogen at the center station of Pond A was 0.276 mg N/L. Forty eight hours later, the concentration dropped to 0.199 mg N/L and by 96 hours after the initial collection, the concentration at this surface station had decreased to 0.143 mg N/L. This trend was not evident in particulate N concentrations collected from the second pond. Particulate N concentrations at the center station of Pond B increased slightly from 0.234 to 0.286 mg N/L.

During the time period that samples were collected from the two ponds, no substantial changes in concentration of dissolved nitrogen and phosphorus were noted. It

appears, then, that the rainfall and associated runoff had little effect on the dissolved portion of N and P. The greatest storm event impact was seen in the particulate phase.

Increased frequency of sampling occurred during the May rainfall event showed particulates were again most affected by the storm. Particulate nitrogen concentrations in the stream increased from 0.357 to 1.288 mg N/L during the first eight hours of the onset of rain. This is nearly a four fold increase. Particulate P concentrations demonstrated a three fold increase (0.122 to 0.363 mg P/L) during the same period. This increase in both parameters was followed by unusually low concentrations which then returned to pre-storm values within 72 hours; very similar to what occurred in the stream during the January event. It appears that runoff water carries most of the particulate material away in an initial flush. It then takes the watershed system approximately 72 hours to return to pre-storm concentrations. This flushing pattern was noted in the total suspended solids concentrations, as well.

Nitrate concentrations in the stream actually decreased (0.565 to 0.336 mg N/L) during the first eight hours of the onset of rain. Within 24 hours, nitrate concentrations were at pre-rainfall levels, where they remained for the duration of sampling. This indicates that this is a "gaining" (spring fed) stream where nitrate concentrations are fairly constant during specific seasons. The runoff associated with the storm actually dilutes the ambient nitrate concentrations associated with this spring-fed stream.

During the 72 hour period that samples were collected from the two ponds, no substantial changes in concentration of either particulate or dissolved nitrogen, phosphorus or chlorophyll were noted. It appears, then, that the rainfall and associated runoff had little effect on the nutrient chemistry or dynamics of the ponds. Where an effect from the storm was noted in Pond A during the January storm, no effect was noted in May. The actively growing duckweed population present in Pond A in May might be responsible for utilizing the increased load of particulate nitrogen and particulate phosphorus entering the pond.

Discharge from Ponds A and B during the May storm event were ~1500 and 2500 liters/minute, respectively. Within 24 hours after the storm, both ponds were discharging less than 1000 liters/minute. Stream speed and water height were also directly related to rainfall.

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SECTION I: STUDY SITE

The pond/marsh system located at Jefferson Patterson Park (Calvert County, MD.) is an ideal system to measure the effectiveness of the ponds in reducing the amounts and types of nitrogen and phosphorus compounds prior to reaching the Patuxent River. These ponds are quite different from each other in surface area, depth and watershed (Figure 1).

Pond A is located farthest east on the complex and is the smallest of the three. It is roughly circular in shape and the circumference is fringed with hardwood trees. It was constructed in the late 1940's or early 1950's, has a surface area of approximately 0.6 acres and services a drainage area of approximately 142 acres (DNR, 1993, unpublished). It is the deepest fo the three ponds (3m). A discharge pipe releases water from the pond into a hardwood forest/marshy area approximately 180 m long and 50 m wide. Water discharging from this pond eventually drains into pond B.

Pond B is the middle of the three ponds. It is roughly rectangular in shape with a depth of ~2m throughout much of the center of the pond. The eastern shore of this pond is comprised of marsh which drains from a hardwood forest. the northern and southern shorelines have grass buffer strips after which the land is in agricilutural production. This pond has a surface area of approximately 3.8 acres and services a drainage area of approximately 177 acres. A discharge pipe from pond B releases water into a wetland/marsh system approximately 215 m long and 50 m wide from which the water eventually drains into pond C.

Pond C is the most westerly of the three ponds and borders the Patuxent River. A narrow berm approximately 3 m wide separates the pond from the river. there is also an opening to this pond from the river, thus the pond is tidally influenced. The surface area of this pond is approximately 4 acres.

Ponds A and B underwent major renovations during the period Ocotber-December 1995. The ponds were drained, new discharge pipes were installed and much of the silt material from pond B was removed. A wetland area on the south side of pond B was also constructed.

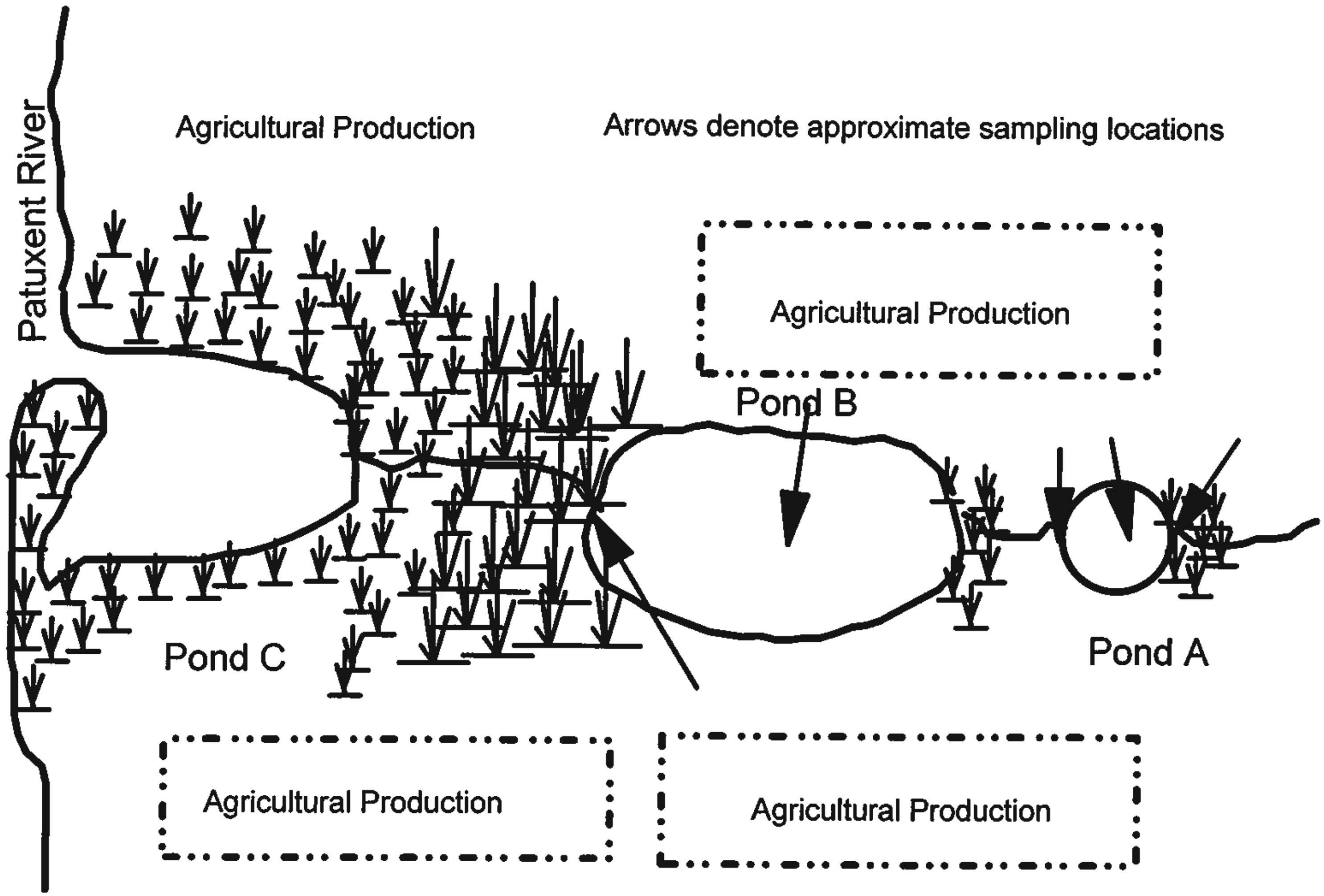


Figure 1-1 Jefferson Patterson Park Pond/Marsh System

SECTION II: QUARTERLY STREAM/POND SURVEYS

FORMS AND DISTRIBUTION OF NITROGEN AND PHOSPHORUS IN QUARTERLY MONITORING SURVEYS

PURPOSE: The purpose of these surveys was to compare nutrient and other data collected during this time period with data from previous years studies. These data can help determine any changes in nutrient cycling and/or patterns.

MATERIALS AND METHODS: Routine seasonal water quality sampling was performed on 21 November 1997 (Fall), 16 March 1998 (Winter), 3 July 1998 (Late Spring/early Summer) and 31 August 1998 (Summer) at the creek flowing into pond A and at the approximate centers and outflows of ponds A and B (Figure 1-1). The grab samples collected from the center of both ponds were subsurface samples; collected beneath any surface algal growth that may have been present. Samples were immediately placed on ice and partitioned into various fractions within two hours of the last sample that was collected. Samples for inorganic nutrients (NO2, NO23, NH4, PO4), total dissolved N and P, particulate C, N and P, total suspended solids (TSS) and chlorophyll a were analyzed by the University of Maryland's Chesapeake Biological Laboratory's Nutrient Analytical Services Laboratory. Their analytical methods are found in D'Elia, et al. 1997. Temperature and pH were also measured in the field.

Discharge measurements of water flowing from the outlets at ponds A and B were also taken, as were estimates of stream speed and height. Measurements from the outlets of the two ponds consisted of placing a 10 gallon bucket beneath the culvert and counting the time necessary to fill the tub. During periods of low flow, the tub was placed beneath the culvert for a specific time period after which the amount of water collected in the bucket was measured. Rates are reported in liters/minute.

Stream height was determined by measuring the height of water from a fixed reference point. Stream sped was measured by determining the time necessary for a 3" twig to traverse 10 feet of creek. Replicate measurements were usually performed.

Seasonal base flow surveys were defined as surveys conducted after a period of at least six days after the last significant rainfall. It should be noted that the July/August period was extremely dry; only a little more than two inches of rain fell during that time period (See section III for a more detailed description of precipitation patterns in the study area).

RESULTS

STREAM NUTRIENT CHARACTERISTICS

Nitrogen: Dissolved inorganic nitrogen (DIN) predominantly in the form of nitrate+nitrite comprised most of the nitrogen pool in November (60%), March (88%), July (63%) and August (37.5%) in samples collected from the stream leading to pond A. Dissolved organic nitrogen (DON) constituted nearly 30% of the total N in November, then declined sharply in March where DON comprised only 5%. In early July only 13% of the total N pool was dissolved organic nitrogen with little change (15.5%) occurring in August. Particulate nitrogen comprised less than 10% of the total N pool in November and March while in July, 24% of the total N was particulate. In August, nearly 47% of the total N was in the particulate form. Figure 2-1 illustrates the above description.

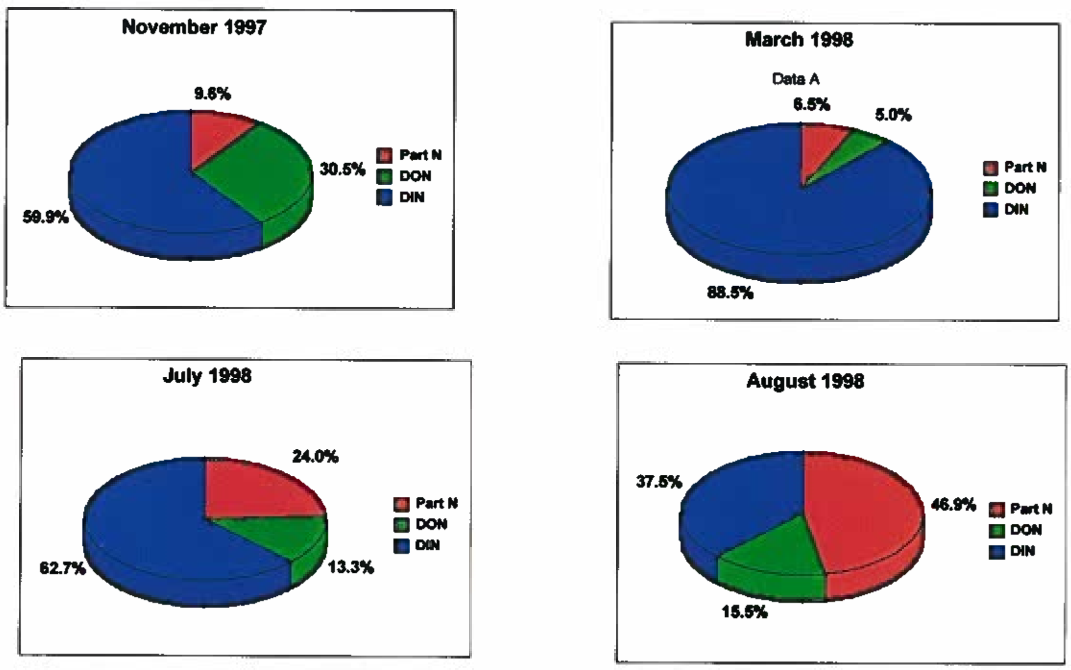


Figure 2-1. Seasonal stream base flow nitrogen partitioning.

Total nitrogen concentrations found in the stream leading to pond A was 0.509 mg N/L in November, 0.973 mg N/L in March, 1.05 mg N/L in July and 0.999 mg N/L in late August, 1998.

Phosphorus: Dissolved inorganic phosphorus (DIP) as phosphate accounted for 37% of the total P in November and then remained fairly constant at approximately 25% in March and July 1998. By the end of August, DIP accounted for approximately 17% of the total P in the stream sample. This is a much lower percentage than the inorganic nitrogen component. Dissolved organic phosphorus (DOP) comprised less than 20% of the toal P fraction during the four seasonal surveys. Particulate P, unlike particulate N, comprised the major portion of the total phosphorus pool. In November, 47.3%; in March, 66%; in July, 58% and August, 70% of the total P was in the particulate form. Typical stream baseflow concentrations of particulate phosphorus in November and March was 0.05 mg P/L while in July the concentration was 0.12 mg P/L and August 0.222 mg P/L. This distribution is shown in Figure 2-2.

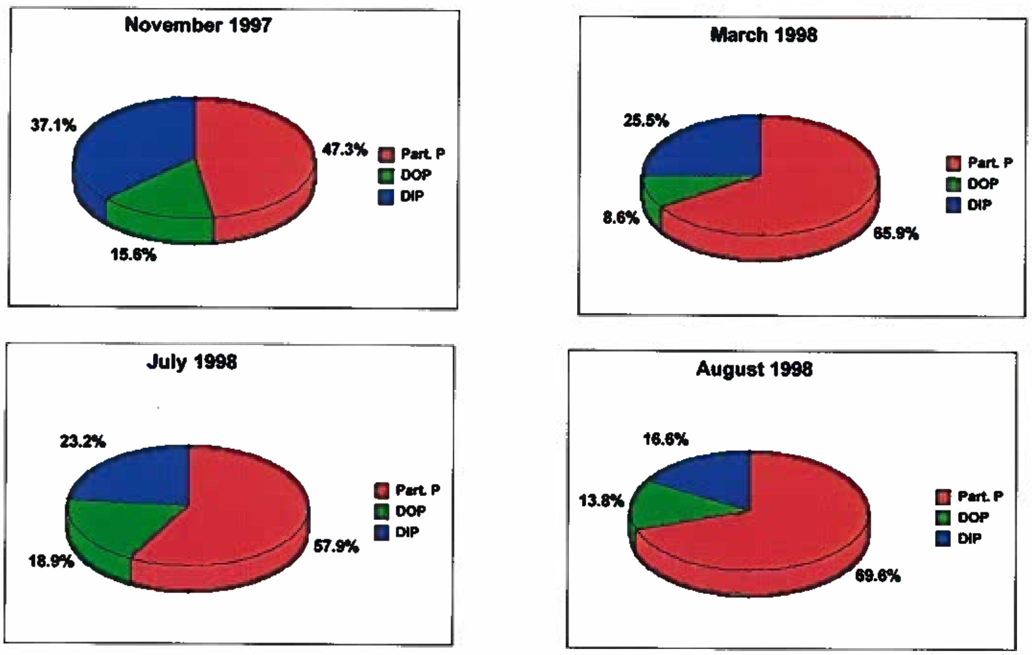


Figure 2-2. Seasonal stream base flow phosphorus partitioning.

PONDS:

Nitrogen: In November, substantial differences in the distribution of nitrogen in the two ponds was noted. In pond A, only 16% of the total N was particulate while more than 55% was dissolved organic nitrogen. The remainder, (~29%) was comprised of readily available dissolved inorganic N (Nitrite+nitrate). Pond B nitrogen partitioning showed nearly a three fold increase in particulate N (44%) compared to pond A. Another 40% was DON while only about 15% of the total was DIN.

March data showed low particulate N (<5% of the total N), approximately 17% of the N as DON and nearly 80% of the N pool comprised of inorganic N, primarily NO23 in pond A. A nearly equal distribution of particulate N and DIN (20% for each component) was noted in pond B. The remaining 60% was inorganic N.

By July, the entire distribution of N had shifted. Inorganic N was no longer the predominant N species. In fact, in both ponds, inorganic N comprised less than 2% of the total. Particulate N comprised nearly 60% of the N in pond A and 47% of the N in pond B. Nearly 25% of the total was DON in pond A and 52% in pond B. This same nitrogen distribution occurred in August, as well; where 55% of the N was particulate in both ponds and the DON portion was more than 30% in pond A and 44% in pond B. The percentage of total nitrogen that was DIN comprised less than 2% at the center surface stations of both ponds, and 21% at the discharge site of pond A.

Typical total N concentrations in pond A were 0.7 mg N/L in November; 0.84 mg N/L in March, and July. In August, the mean concentration was nearly 1.0 mg N/L. Pond B total N concentrations were approximately 1.0 mg N/L during all four surveys. What is important to note is that the total nitrogen concentrations in the ponds did not change appreciably through the year. What did change with time was the composition of the various nitrogen fractions. These changes in nitrogen components for pond A is shown in Figure 2-3. A similar distribution occurred in pond B.

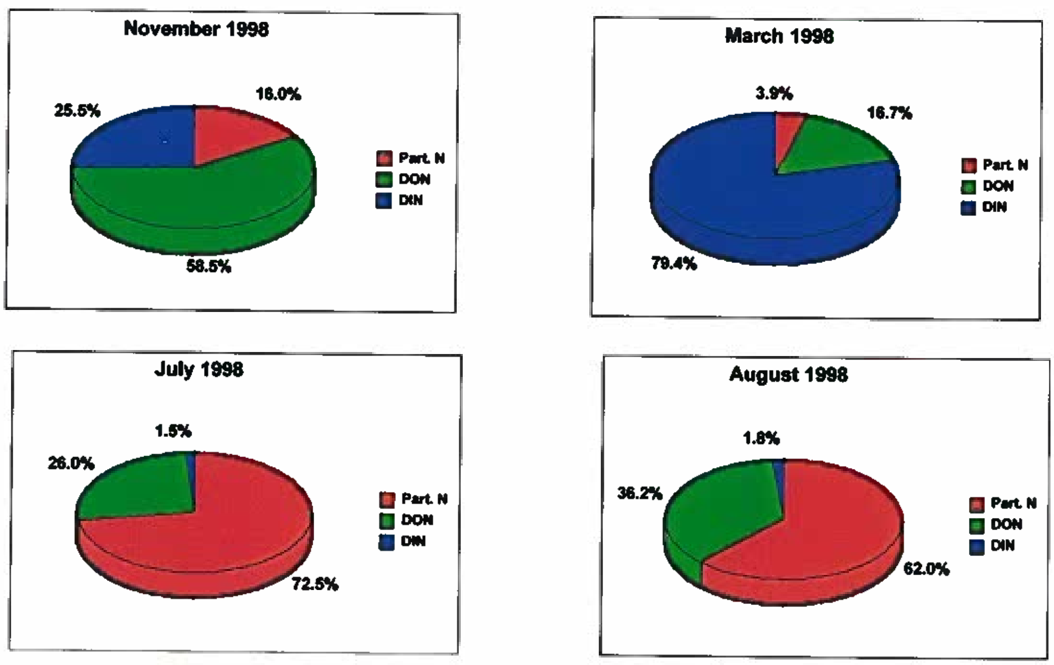


Figure 2-3. Seasonal nitrogen partitioning at pond A.

For example, nitrate concentrations remained consistent between ponds but varied greatly with seasons. Figure 2-4 provides data showing this similarity between ponds, but dynamic variation between seasons. Center station data were used.

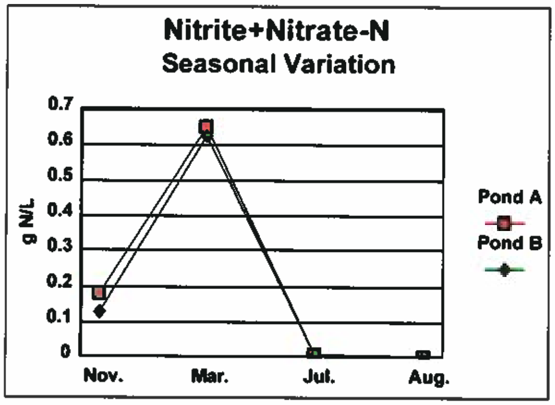


Figure 2-4. Seasonal nitrite+nitrate-N variation in ponds A and B.

Phosphorus: As was the case for phosphorus in the stream, particulate P also dominated the phosphorus pool in both ponds during the seasonal sampling. In November, more than 60% of the total P was particulate with a nearly even distrbution of 20% DOP and 20% DIP comprising the remainder of the phosphorus total. There was also little variation in these percentages between surface samples and those collected from the discharge pipes.

This same trend occurred in March, except that the percentage of DIP in pond B was lower (approximately 12.5%) and the particulate fraction higher (~70%). By July, the particulate fraction comprised more than 80% of the total P pool in both ponds while less than 10% was present in the inorganic form. By late August, particulate phosphorus continued to comprise nearly 80% of the total P while DIP made up 10-15% of the total.

Total P concentrations in pond A averaged 0.065 mg P/L in November, 0.048 mg P/L in March, 0.045 mg P/L in July and 0.17 mg P/L in late August. Pond B total P concentrations were 0.075 mg P/L, 0.062 mg P/L and 0.022 mg P/L for November, March and July, respectively. The August total P value at the center station of pond B was 0.07 mg P/L. Figure 2-5 illustrates this seasonal partitioning of phosphorus in the pond A. Although the total P concentrations are significantly different between ponds in the August samples, the relative distribution of phosphorus components is very similar. The higher concentrations noted in pond A is probably due to the duckweed population beginning to senesce.

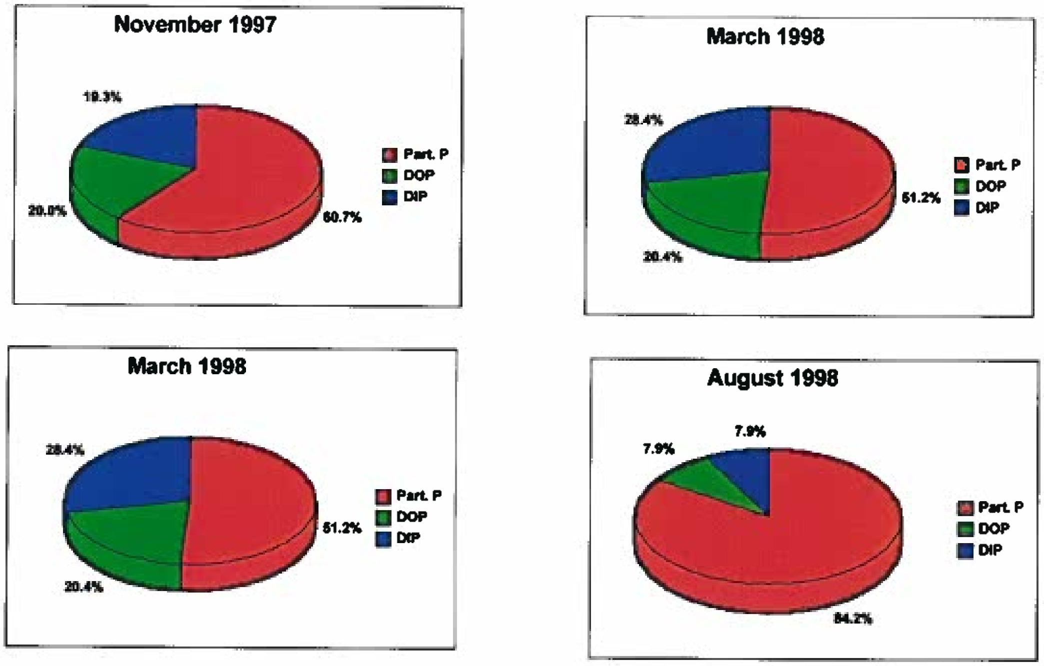


Figure 2-5. Seasonal phosphorus partitioning at Pond A.

Chlorophyll as an estimate of Algal Biomass:

Chlorophyll concentrations of samples collected from the stream leading to pond A were consistently less than 5 ug/L throughout the four seasonal surveys. These low concentrations suggest little algal biomass, primarily as a result of the very shallow/fairly swiftly moving water.

Pond A exhibited a more seasonal pattern where chlorophyll values in November and March were less than 5 ug/L at both sampling locations. In July and August, however, chlorophyll concentrations averaged more than 40 ug/L for each month. It should be noted that this pond is covered with duckweed for a large portion of the year and that the samples are collected below the surface, thereby eliminating much of the duckweed from the sample. These concentrations, then, are probably an underestimate of the actual chlorophyll values found during the summer months in this pond.

Where pond A demonstrated a seasonal pattern of algal biomass, pond B showed atypical patterns. Chlorophyll was present in pond B surface samples at a concentration of 92.5 and 32.4 ug/L at the center and discharge pipe, respectively in November 1997. Even in Winter (March 1998) a mean concentration of 18 ug/L was found. In July and

August, concentrations were approximately 40 ug/L; very similar to pond A. A review of field notes indicated that pond B had small algal cells present in November that clogged our filtration apparatus. This pond was also 1/3 covered with macroalgae in July. While not located specifically at our sampling site, this was an indication of another type of algal population. By the August survey, a large portion of the pond was also covered with duckweed. It appears, then, that pond B has varied algal populations at different times of the year, while duckweed predominates at pond A.

Discharge From Ponds: Results from the quarterly monitoring of water discharging from ponds A and B is found in Figure 2-6. Discharge rates reflected weather conditions, the wetter the season, the more discharge. There was essentially no flow in August 1998. Particularly dramatic is data from the wet winter and dry summer months. The substantial rates and duration of the winter and spring discharge is discussed in detail in Section VI of this report.

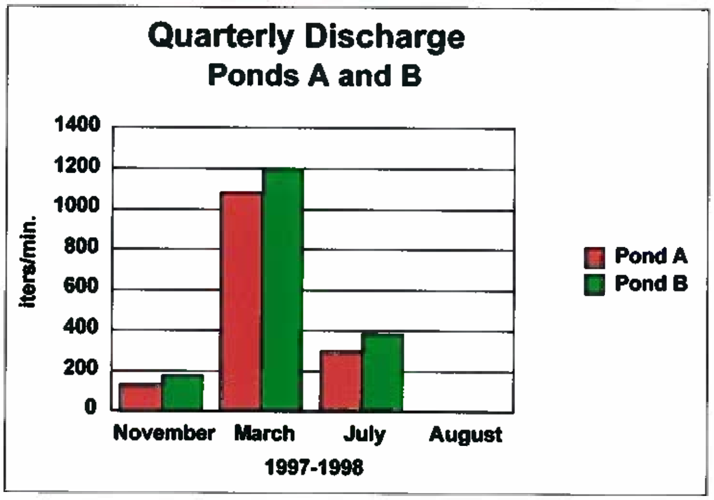


Figure 2-6. Seasonal discharge from ponds A and B.

<u>Comparison With Previous Years:</u> Probably one of the most important conclusions resulting from this and past monitoring efforts (Zimmermann, 1995; Zimmermann, 1996) at the agricultural ponds at Jefferson Patterson Park is the substantial reduction of nitrite+nitrate as water makes its way through the system. Table 2-1 compares this reduction of nitrite+nitrate.

Table 2-1. Percent reduction of nitrite+nitrate (mg N/L) at J. Patterson Park agricultural ponds; 1996 and 1997-1998.			
Date	Inflow (mg N/L)	Pond A (mg N/L)	Percent Reduction
January 1996	.37	.15	60
March 1996	.81	.58	28
April 1996	.70	.50	29
June 1996	.65	.15	77
July 1996	.55	.01	98
November 1997	.29	.18	38
March 1998	.82	.65	21
July 1998	.59	.01	98
August 1998	.34	.004	98

Were these ponds and their associated algal/microbial populations not present, significant amounts of readily available inorganic nitrogen in the form of nitrite+nitrate would enter the Patuxent River. The biological plant community in the ponds act as a filter to remove nitrite+nitrate.

The percentage of particulate phosphorus to the total P of the ponds is substantial throughout the year. Particulate nitrogen is more variable, with significant percentages occurring mainly in the summer months. Table 2-2 illustrates this fact.

Table 2-2. Comparison of Particulate N and P percentages of the total for 1996 and 1997-1998.

	Pond A			Pond B	
Date	% Part. N	% Part. P		% Part. N	% Part. P
Jan. 1996	50	74		40	80
Feb. 1996	30	67		40	77
Mar. 1996	67	89		60	79
Apr. 1996	10	65		--------	41
Jun. 1996	50	42		50	67
July 1996	50	74		50	55
Nov. 1997	16	61		49	66
Mar. 1998	4	51		20	72
July 1998	72	87		58	80
Aug. 1998	62	84		54	82

Nutrient cycling within these ponds is predictable from year-to-year.

SECTION III. PRECIPITATION PATTERNS AT J. PATTERSON PARK; OCTOBER 1997- SEPTEMBER 1998

Rainfall data was obtained from the weather station at Chesapeake Biological Laboratory, Solomons, MD. This facility is located approximately ten miles south of the Jefferson Patterson Park study site. In some cases, such as thunderstorm activity, there may be some inconsistencies between the two areas. As an example, August rainfall data was provided by a private citizen who lives close to the study site. Significant rainfall that occurred in Solomons as a result of a large thunderstorm simply did not occur at Patterson Park. Results are provided in Figure 3-1.

The study period exhibited extremely wet conditions in Fall [Oct.-Dec] (~ 13") and Winter [Jan.-Mar.] (~22"), normal Spring [April-June] conditions (~12") and very dry conditions during the Summer [July-Sept.] months (~4.2"). October 1997 rainfall was 2.44". In November, nearly 8.5" of rain fell in the area, with more than an inch of rainfall on November 7, 10, 14 and 24. December precipitation was a little more than 2" with more than an inch falling on 31 December 1997. More than one inch of rain fell on January 23 and 3.15" of rain fell on the 28th. The total for January was 7.17". In February, nearly 9.24" of rainfall occurred with a total of four inches falling on the 4th and 5th of February and more than an inch of rain occurring on the 23rd. March rainfall was more than 5.5" with significant amounts of more than one inch occurring on 9, 19 and 21 March. April precipitation was slightly more than 4" with only oneevent providing more than an inch of rain. May rainfall was 3.16". Precipitation in June was 5.3" where 1.35" fell on 29 June. July was extremely dry with less than 1.5" total rainfall. Only an inch of rain occurred at Patterson Park during August and only 1.73" of rain fell in September.

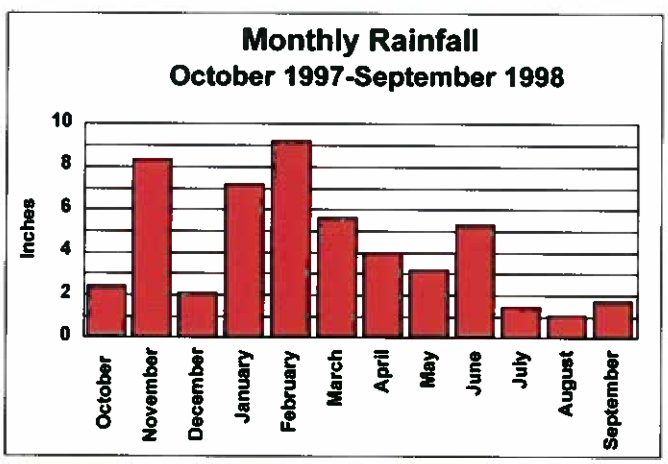


Figure 3-1. Monthly rainfall from October 1997-September 1998.

SECTION IV: WINTER PRECIPITATION EVENT

FORMS AND DISTRIBUTION OF NITROGEN AND PHOSPHORUS DURING AND AFTER A MAJOR PRECIPITATION EVENT.

PURPOSE: The purpose of this sampling sequence was to document the time necessary for nutrient concentrations to return to baseflow conditions after a substantial rainfall event.

MATERIALS AND METHODS: On Thursday, January 15, 1998, a low pressure system riding a low lying Jet Stream moved from the South-eastern United States through Maryland. Precipitation began to fall at approximately 0700 hours. Although forecasters called for a "wintry mix", rain was the only type of precipitation noted. Steady moderate to heavy rainfall occurred from approximately 1000-1900 hrs. Nearly one inch of rain fell during this event. Temperatures were in the low forties (Fahrenheit). Actual sampling was conducted during moderate rainfall from 1500-1630 hours. Post storm event sampling was conducted between 0930 and 1100 hours on January 17, 1998 and between 0930 and 1100 hours on January 19, 1998. Weather conditions were generally dry six days prior to the fifteenth. Rain ceased on the night of 15 January 1998.

Samples were collected at one location from the creek flowing into pond A and at the approximate centers and outflows of ponds A and B (Figure 1-1). The grab samples collected from the center of both ponds were subsurface samples; collected beneath any surface algal growth that may have been present. Samples were immediately placed on ice and partitioned into various fractions within two hours of the last sample that was collected. Samples for inorganic nutrients (NO2, NO23, NH4, PO4), total dissolved N and P, particulate C, N and P, total suspended solids (TSS) and chlorophyll a were analyzed by the University of Maryland's Chesapeake Biological Laboratory's Nutrient Analytical Services Laboratory. Their analytical methods are found in D'Elia, et. al., 1997. Temperature and pH were also measured in the field.

RESULTS

STREAM NUTRIENT CHARACTERISTICS:

Nitrogen: The most striking feature of this field survey was the significant and rapid decrease of particulate nitrogen after 48 hours followed by the subsequent return to "ambient" concentrations after 96 hours (Figure 4-1). Concentrations of particulate N in the stream during the rainfall event were 0.789 mg N/L. Forty eight hours later, the concentration had decreased to 0.108 mg N/L and values ninety six hours later after the rainfall event were 0.633 mg N/L.

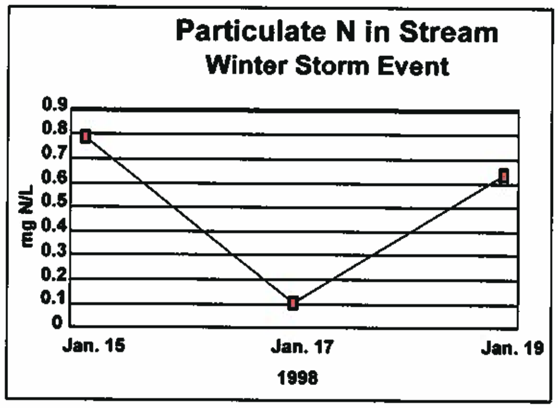
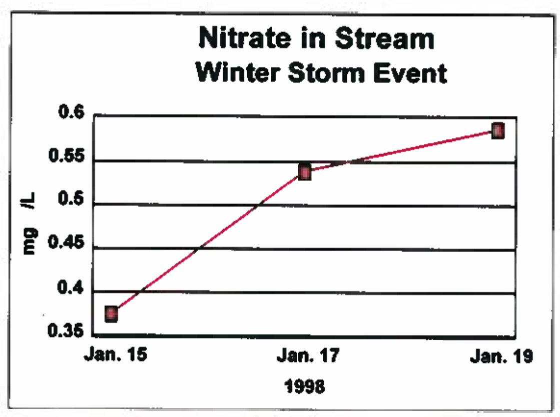


Figure 4-1. Particulate nitrogen changes in the stream with time.

Dissolved inorganic nitrogen (DIN) concentrations were primarily nitrite+nitrate and increased during all three sampling events (Figure 4-2). The most dramatic increase occurred 48 hours after time 0. These concentrations(0.5 mg N/L) were also substantially higher than those present in either ponds A (0.3 mg N/L) or B (0.25 mg N/L).

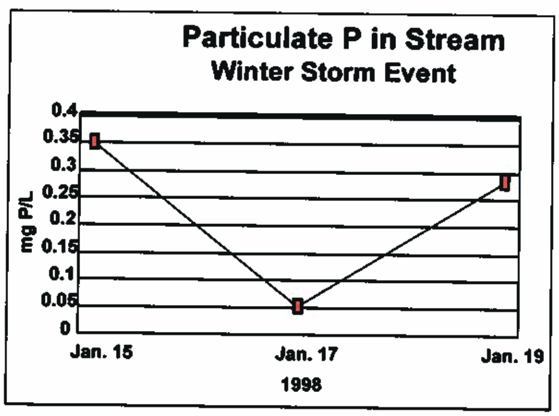
Figure 4-2. Nitrate changes in the stream with time.



During the rainfall event, the total nitrogen pool was dominated by particulate N (55%) and DIN (32%). The second sampling period which occurred 48 hours after the first saw a significant altering of this distribution. The large decrease in particulate N accounted for only a 13% share of the total N pool while DIN comprised 73%. Another 48 hours later and the particulate N and DIN fractions are nearly the same (45% and 47%, respectively) (Table 4-1).

Table 4-1. Nitrogen partitioning in the stream with time.			
Time (hours)	Percent Particulate	Percent DIN	Percent DON
0	55.2	31.6	13.2
48	13.0	13.8	73.2
96	45.1	8.2	46.7

Phosphorus: Particulate phosphorus dominated the phosphorus pool during and after the rainfall event. Percentages of the total were 93%, 74% and 94% particulate phosphorus for this sampling series. Concentration ranges were 0.3779, 0.0695 and 0.2978 mg P/L. The significant decrease in particulate P during the second survey (48 hours) parallels the particulate nitrogen decrease. DIP concentrations also decreased with time (Figure 4-3).



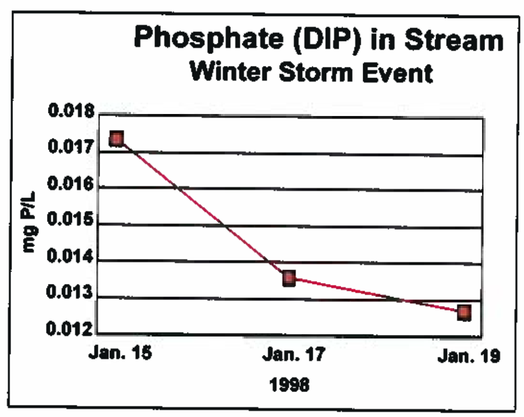


Fig. 4-3. Particulate P and phosphate changes in concentration in the stream with time.

PONDS:

Nitrogen:

Pond A: Total nitrogen concentrations at both stations in Pond A varied little during and up to 96 hours after the storm event. Concentrations at the center station averaged approximately 0.735 mg N/L while the concentration at the discharge pipe was approximately 0.664 mg N/L. Nearly 45% of this total was comprised of dissolved inorganic nitrogen (DIN); primarily in the nitrite+nitrate form, while 25% was in the dissolved organic nitrogen (DON) fraction. Particulate nitrogen showed some changes with time at both stations. Samples collected during the rain were considerably higher than those collected 48 and 96 hours later (Figure 4-4). For example, during the event, concentrations of particulate nitrogen at the center station of pond A was 0.276 mg N/L. Forty eight hours later, the concentration dropped to 0.199 mg N/L and by 96 hours after their initial collection, the concentration of this surface station had decreased to 0.143 mg N/L. This trend was not evident in particulate N concentrations collected from the second pond.

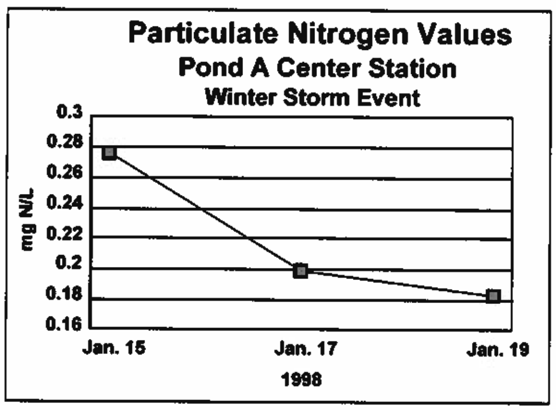


Figure 4-4. Change in particulate N concentrations with time at Pond A.

What did change dramatically at this station were concentrations of TSS and Chlorophyll (Figure 4-5). The substantial decrease in these two parameters after 48 hours is indicative of flushing the pond with a return to normal values after 96 hours. No significant changes in particulate phosphorus at this station were noted.

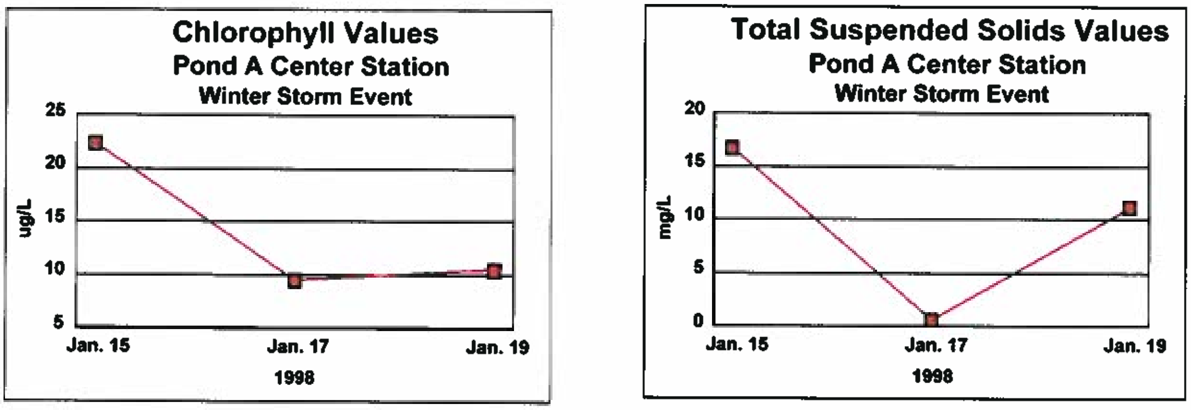


Figure 4-5. Changes in chlorophyll and TSS concentration in Pond A with time.

Pond B: Concentrations of total nitrogen at both stations of pond B were nearly double those of pond A and indicated little variation both in concentration and percentages of nitrogen components during the 96 hours of sampling. Percent DIN remained at 50% while DON comprised 28% of the total.

The difference in total nitrogen concentrations between the two ponds is largely due to the much higher ammonium and dissolved organic nitrogen concentrations found in pond B (Figure 4-6). Ammonium concentrations were more than an order of magnitude greater than those from pond A while DON concentrations were more than twice as high.

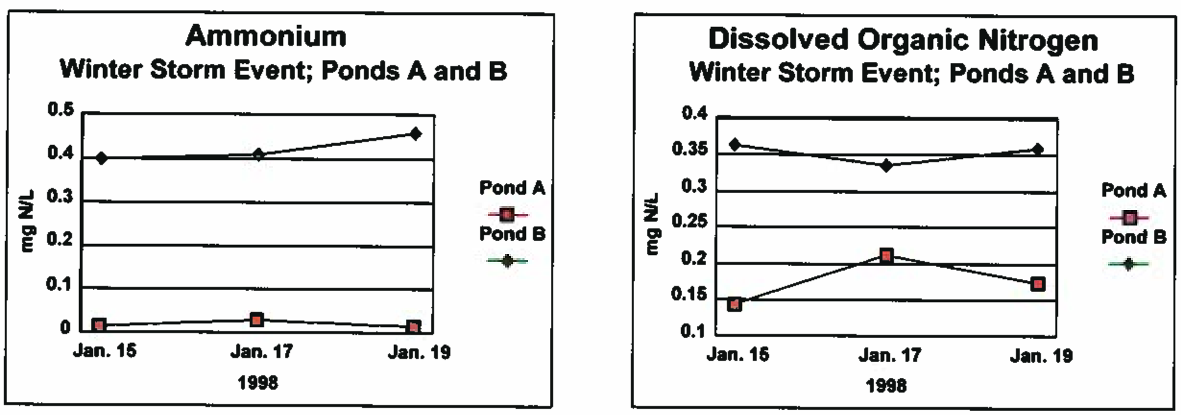
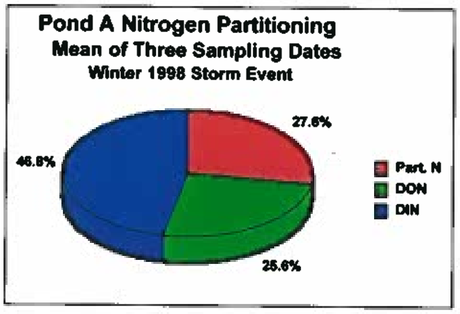


Figure 4-6. Changes in ammonium and DON concentrations in Ponds A and B with time.

Even with these differences in concentrations between the two ponds, the percent distribution of particulate nitrogen, dissolved inorganic nitrogen and dissolved organic nitrogen from both ponds were quite similar (Figure 4-7).



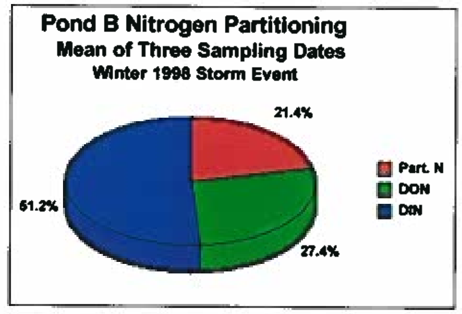


Figure 4-7. Nitrogen partitioning at Ponds A and B.

<u>Phosphorus</u>:

Pond A: Total phosphorus concentrations at pond A averaged 0.0636 mg P/L for the entire field survey. Inorganic phosphorus (phosphate) concentrations increased as a function of time at both stations (Figure 4-8) while dissolved organic phosphorus (DOP) values were variable for the same time period.

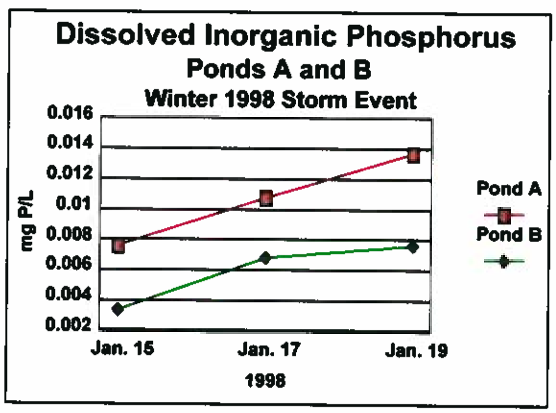


Figure 4-8. Dissolved inorganic phosphorus changes at Ponds A and B with time.

The particulate phosphorus component accounted for more than 70% of the total at both stations (Figure 4-9).

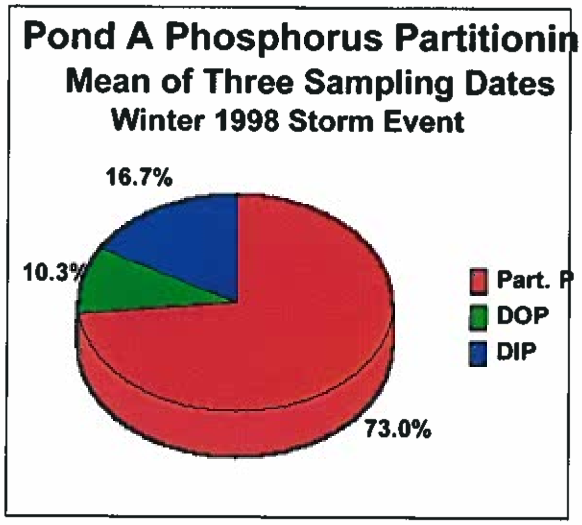


Figure 4-9. Phosphorus partitioning at Pond A.

Pond B: The average total phosphorus concentration at pond B was 0.0716 mg P/L and total values from the center station increased with time. The same increase in phosphate values noted in pond A during the study also occurred here; particularly at the discharge station. This increase in phosphate also accounted for an increase with time in the percent DIP comprising the total phosphorus pool (5.8, 8.9 and 11.5%, respectively). Phosphate concentrations at Pond B (0.0059 mg P/L) were nearly three times lower than those at pond A(0.01 mg P/L). Dissolved organic phosphorus values were somewhat higher than those corresponding values from pond A. Particulate phosphorus comprised more than 75% of the total at both stations while less than 10% was DIP and approximately 15% was DOP (Figure 4-10).

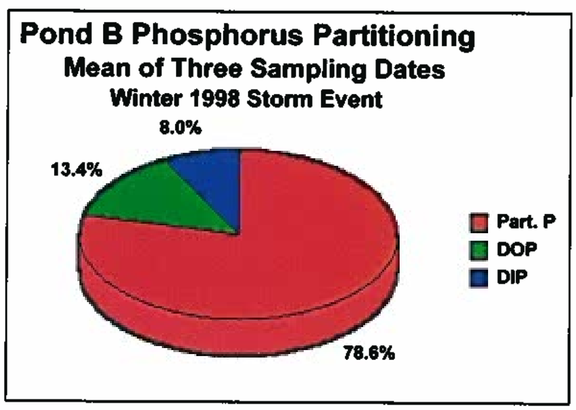


Figure 4-10. Phosphorus partitioning at Pond B.

CONCLUSIONS OF WINTER RAINFALL EVENT

- The rapid decrease in particulate N and P occurring in the stream 48 hours after the rainfall, followed by a return to concentrations present during the rain is also documented in the Total Suspended Solids (TSS) results for the stream and also for pond A. TSS concentrations in the steam during the rain was 126 mg/L, then decreased five fold to 26 mg/L after 48 hours. Ninety six hours after the event, TSS values approached rainfall concentrations at 116 mg/L. It may be that stream flow and immediate runoff as a result of the storm cleared particulate material from most of the immediate area into the stream, thereby reducing the particulate material in the water. Subsequent sampling indicated that concentrations returned to those that were present during the event.

- During the time period that samples were collected from the two ponds, no substantial changes in concentration of dissolved nitrogen and phosphorus were noted. It appears, then, that the rainfall and associated runoff had little effect on the dissolved portion of N and P. The greatest impact was seen in the particulate phase.

- Conclusions That Are Not A Result Of The Storm Event

    - Ammonium concentrations in pond B were an order of magnitude greater than either pond A or concentrations found in the stream. Ammonium concentrations in pond B were greater than 0.4 mg N/L while concurrently collected samples at pond A were approximately 0.02 mg N/L and those from the stream approximately 0.07 mg N/L. Differences in algal populations between the two ponds is thought to be the reason for this.

    - However, phosphate concentrations in pond B are nearly three times lower (0.006 mg P/L) than the corresponding values found in pond A (0.01 mg P/L) and the stream (0.014 mg P/L).

    - Nitrate concentrations were similar between ponds (~0.25 mg N/L) but values in the stream were substantially higher (~0.5 mg N/L).

SECTION V: SPRING PRECIPITATION EVENT

FORMS AND DISTRIBUTION OF NITROGEN AND PHOSPHORUS DURING AND AFTER A MAJOR PRECIPITATION EVENT

PURPOSE: The purpose of this series of monitoring events is to attempt to trace changes in nutrient concentrations and partitioning of nutrients between particulate and dissolved fractions in the stream and discharge pipes leading from ponds A and B as a function of time, rainfall and drier weather conditions

MATERIALS and METHODS: A low pressure system located in the Atlantic Ocean off the mid-Atlantic coast caused damp, cloudy and showery conditions for several days in early May. The ground was saturated. The forecast for May 12, 1998 was rainfall, heavy at times with clearing and the remainder of the week generally fair. Temperatures were in the low fifties (Fahrenheit).

Actual sampling commenced on 12 May 1998 during a heavy shower from 0700-0800 hours. Sampling was repeated from 1645-1745 that afternoon during a heavy shower. Post storm event sampling was conducted between 1630 and 1700 hours on 13, 14 and 15 May 1998. Weather conditions were clear and warm on those dates.

Samples for nutrient analyses were collected from the creek flowing into pond A and at the outflows of ponds A and B (Figure 1-1) for the above five time periods. Samples were immediately placed on ice and partitioned into various fractions within two hours of the last sample that was collected. Samples for inorganic nutrients (NO2, NO23, NH4, PO4), total dissolved N and P, particulate C, N and P, total suspended solids (TSS) and chlorophyll a were analyzed by the University of Maryland's Chesapeake Biological Laboratory's Nutrient Analytical Services Laboratory. Their analytical methods are found in D'Elia, et al., 1997. Temperature and pH were also measured in the field.

RESULTS

STREAM NUTRIENT CHARACTERISTICS

Nitrogen: Particulate nitrogen concentrations in the stream increased nearly four fold (from 0.357 to 1.28 mg N/L) during the first eight hours of the rainfall event. Twenty four hours after the event, the particulate nitrogen concentrations were at their lowest (0.44 mg N/L) and then gradually increased with time to pre rainfall concentrations.

Nitrate was the predominant inorganic nitrogen species present in the stream. Where particulate nitrogen concentrations increased during the first two sampling events, nitrate concentrations decreased from 0.565 to 0.336 mg N/L. Within 24 hours, nitrate values returned to pre-rainfall conditions where they remained fairly constant for the remainder of the sampling surveys.

Dissolved organic nitrogen (DON) concentrations from the stream increased by a factor of two (0.156 to 0.285 mg N/L) from pre-storm to during storm and then continually decreased with time.

Total nitrogen concentrations increased substantially in the stream during the first eight hours of the storm event (1.14 to 1.97 mg N/L). This increase is largely due to the increase in particulate nitrogen that most likely occurred as a result of increased runoff into the stream. Twenty four hours later, this nearly 2 mg N/L total N value had decreased to 0.854 mg N/L, after which values began to increase to pre-storm concentrations as a function of time. Figure 5-1 illustrates this sequence for particulate, dissolved inorganic and dissolved organic nitrogen.

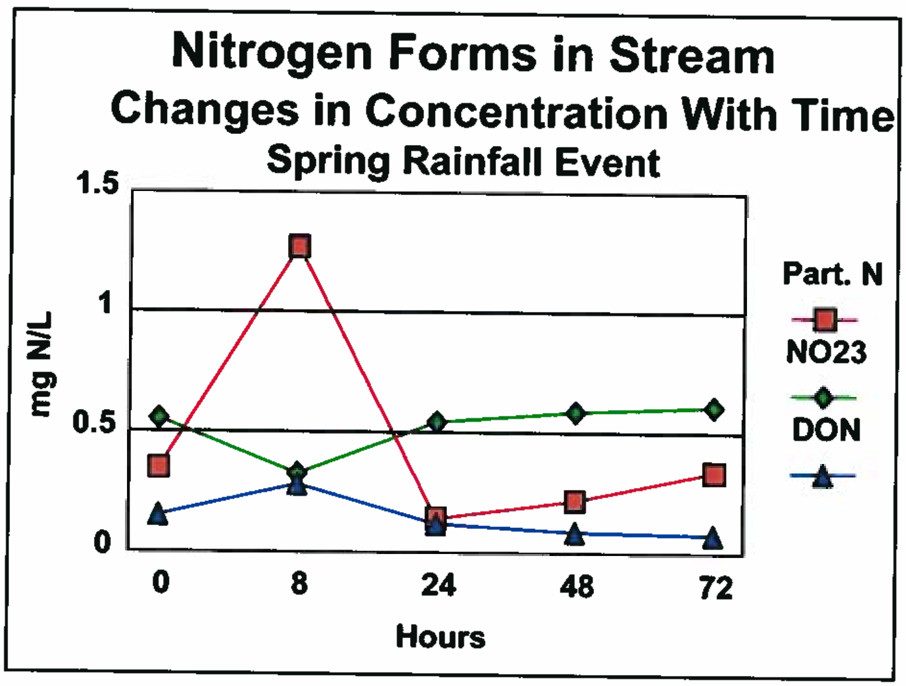


Figure 5-1. Nitrogen concentration changes with time in stream.

Phosphorus: Dissolved phosphate (DIP) concentrations in the stream did not increase as a result of storm induced runoff. Concentrations in the stream actually decreased somewhat during the entire sampling series.

Dissolved organic phosphorus (DOP) concentrations increased more than two fold (0.0126 to 0.0355 mg P/L) during the first eight hours of the storm but within 24 hours, concentrations returned to pre-rainfall values (mean concentration of 0.0070 mg P/L). Particulate phosphorus (Part. P) concentrations in the stream increased three fold (from 0.122 to 0.363 mg P/L) during the rainfall event. After the rainfall event ended, the trend in concentration was the same as particulate N. Lowest concentrations occurred 24 hours after the event and then gradually increased to pre-storm concentrations with time. Figure 5-2 provides the data showing the concentrations in the stream with time for DIP, DOP and particulate P.

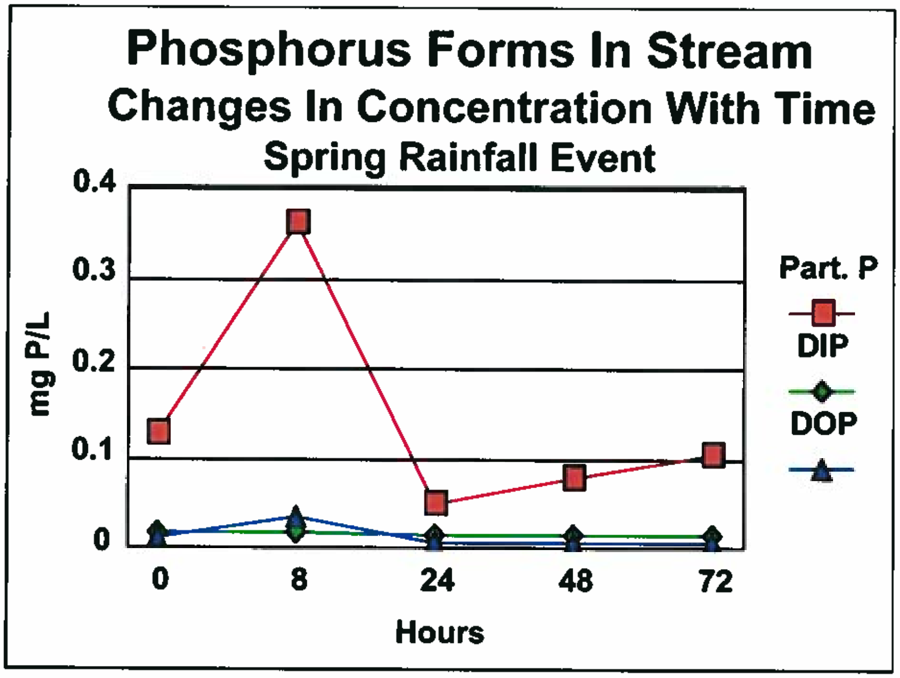


Figure 5-2. Phosphorus concentration changes with time in stream.

PONDS:

Nitrogen: Nitrate concentrations in pond A were almost half (0.25 mg N/L) that of the stream with no noticeable effect of the storm on concentration. Nitrate concentrations at Pond B (Mean 0.062 mg N /L) were nearly an order of magnitude less than those from the stream.

Dissolved organic nitrogen concentrations in ponds A and B also remained quite constant through this experimental time period. Concentrations of ~0.25 mg N/L (very similar to nitrate concentrations) were noted in pond A while in pond B, these DON values were slightly higher at ~0.31 mg N/L. In both ponds, no obvious trends were noted.

Particulate nitrogen values showed a slight drop in concentration during the first few hours of the storm. In pond A, concentrations decreased from 0.249 to 0.181 mg N/L and in pond B, concentrations decreased from 0.218 to 0.184 mg N/L. For the remaining time periods, no obvious trends were observed at either pond. It is also interesting to note that the particulate nitrogen concentrations were quite similar at both ponds for this series of sampling events. In pond A the mean concentration was 0.225 mg N/L and in pond B, the mean concentration was 0.200 mg N/L. Figure 5-3 describes the changes in the particulate N, dissolved inorganic N and dissolved organic N concentrations with time at ponds A and B.

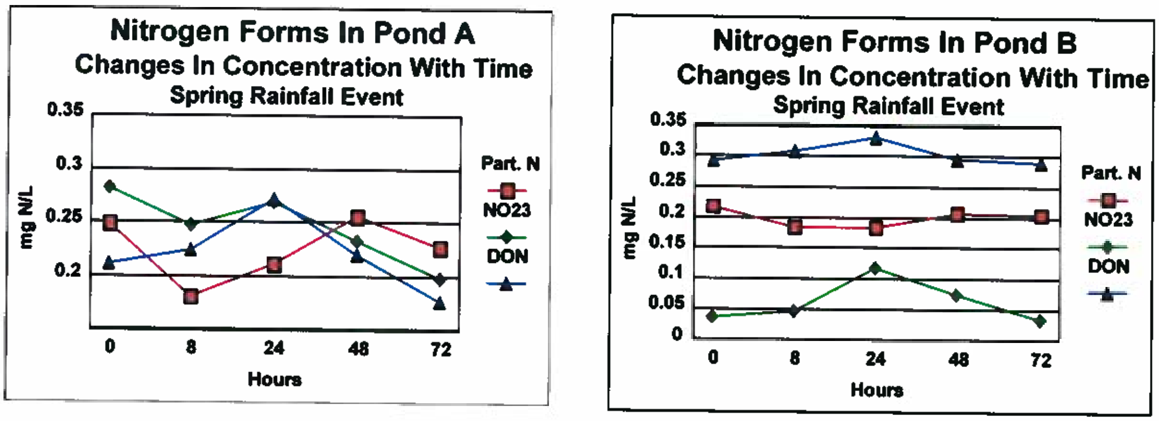
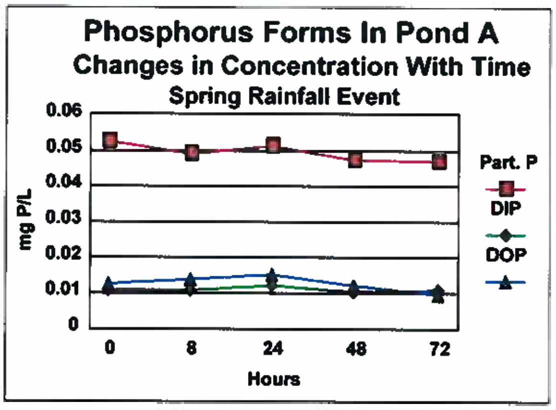


Figure 5-3. Nitrogen concentration changes in Ponds A and B with time.

Phosphorus: DIP concentrations in pond A showed little variation with time (mean value of 0.0112 mg P/L) and approximately the same concentration as found in the stream. Concentration of DIP in pond B were half that of pond A (0.0063 mg P/L) and showed no large changes or trends with time. Dissolved organic phosphorus concentrations in both ponds were very similar. Again, no obvious trends in either pond were noted and the mean concentration in pond A was 0.0130 mg P/L and in pond B, the mean concentration was 0.0115 mg P/L. Particulate phosphorus concentrations also showed no dramatic changes in the ponds as a result of the storm. Concentrations between the ponds were different (pond A mean value, 0.0497 mg P/L; pond B mean value, 0.0253 mg P/L). Particulate phosphorus also comprised a majority of the total phosphorus pool in the stream as well as the two ponds. Figure 5-4 provides DIP, DOP and Part. P data illustrating the concentration changes in ponds A and B with time.



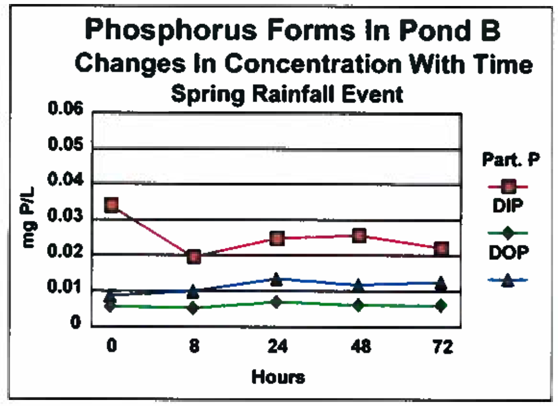


Figure 5-4. Phosphorus concentration changes in Ponds A and B with time.

SUMMARY

1. Particulate nitrogen concentrations in the stream increased from 0.357 to 1.288 mg N/L during the first eight hours of the onset of rain. This is nearly a four fold increase. Particulate P concentrations demonstrated a three fold increase (0.1217 to 0.363 mg P/L) during the same period. This increase in both parameters was followed by unusually low concentrations which then returned to pre-storm values within 72 hours. It may be that runoff water has carried most of the particulate material away in an initial flush. It then takes the watershed system approximately 72 hours to return to pre-storm concentrations. This occurrence was noted in the total suspended solids results, as well.

2. Nitrate concentrations in the stream actually decreased (0.565 to 0.336 mg N/L) during the first eight hours of the onset of rain. Within 24 hours, nitrate concentrations were at pre-rainfall levels, where they remained for the duration of sampling. It is believed that this is a "gaining" (spring fed) stream where nitrate concentrations are fairly constant during specific seasons. It is thought that the runoff associated with the storm actually diluted the ambient concentrations associated with this spring-fed stream.

3. During the 72 hour time period that samples wree collected from the two ponds, no substantial changes in concentration of nitrogen, phosphorus or chlorophyll were noted. It appears, then, that the rainfall and associated runoff had little effect on the nutrient chemistry or dynamics of the ponds.

4. The relationship between nitrate and dissolved organic nitrogen (DON) and the stream and two ponds is interesting. Nitrate concentrations in pond A are half of what

they are in the stream (0.247 vs 0.53 mg N/L). Concentrations of nitrate in pond B are an order of magnitude less than pond A. (0.062 mg N/L) DON trends are just the opposite, although not nearly as dramatic. DON concentrations are lowest in the stream (0.148 mg N/L) and highest in pond B (0.303 mg N/L). Differences in algal populations at each pond utilizing inorganic nitrogen compounds is the most probable explanation for these huge differences in concentration.

5. A comparison of three fractions (percent particulate, percent dissolved organic N and percent dissolved inorganic N) indicated that in the stream, DIN species predominated the total N pool; comprising 54% of the total with the particulate fraction accounting for 33.6%. In pond A, the three pools were nearly identical; each comprising 30-35% of the total. Pond B exhibited a complete reversal of what occurred in the stream; where 52% of the total was comprised of DON and only 13.6% was comprised of DIN (Figure 5-5).

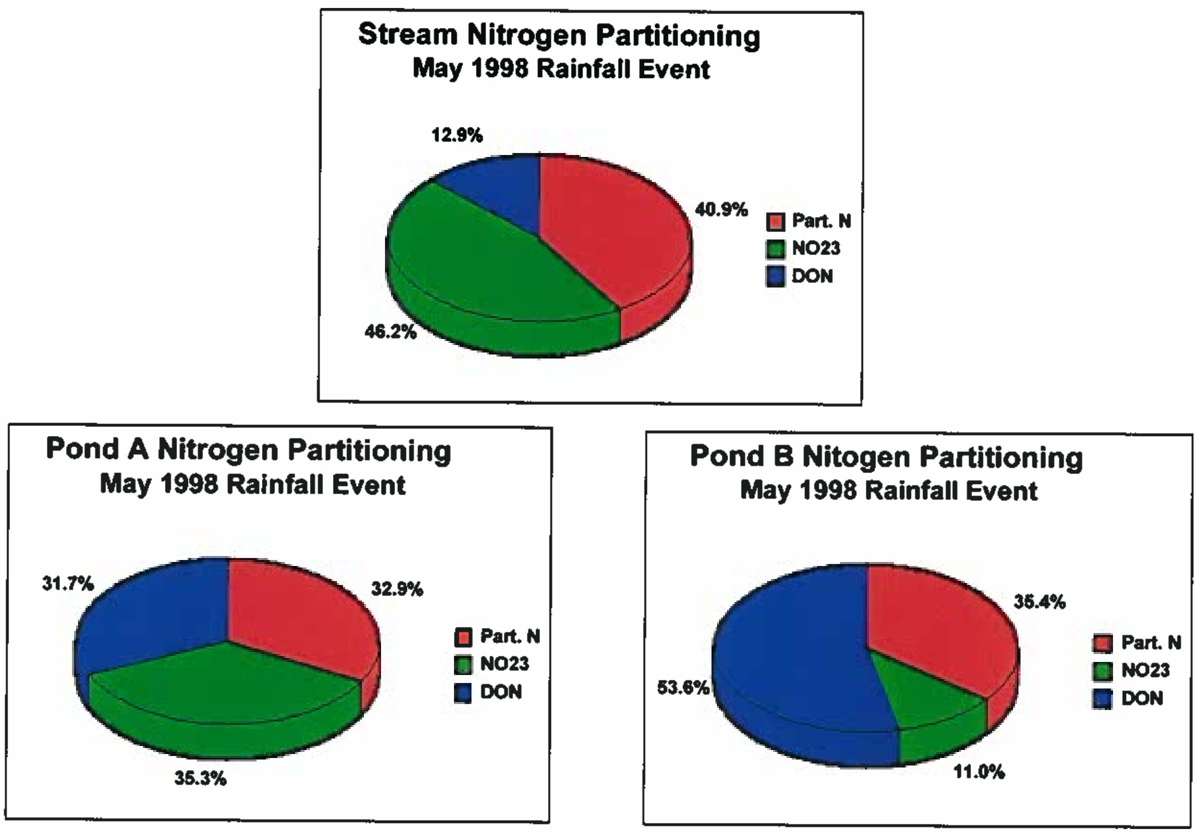


Figure 5-5. Mean percentages of various nitrogen fractions; May 1998 rainfall event.

6. A comparison of three phosphorus fractions (percent particulate, percent dissolved organic P and percent dissolved inorganic P) indicated that in the stream, particulate P species predominated the total P pool; comprising 82% of the total with the dissolved inorganic fraction accounting for nearly 10%. In ponds A and B, particulate P continued as the predominant P fraction, although not nearly as high as in the stream. The percent DOP was nearly 10% higher in pond B than in pond A. Figure 5-6 provides the various P fractions from the stream and the two ponds.

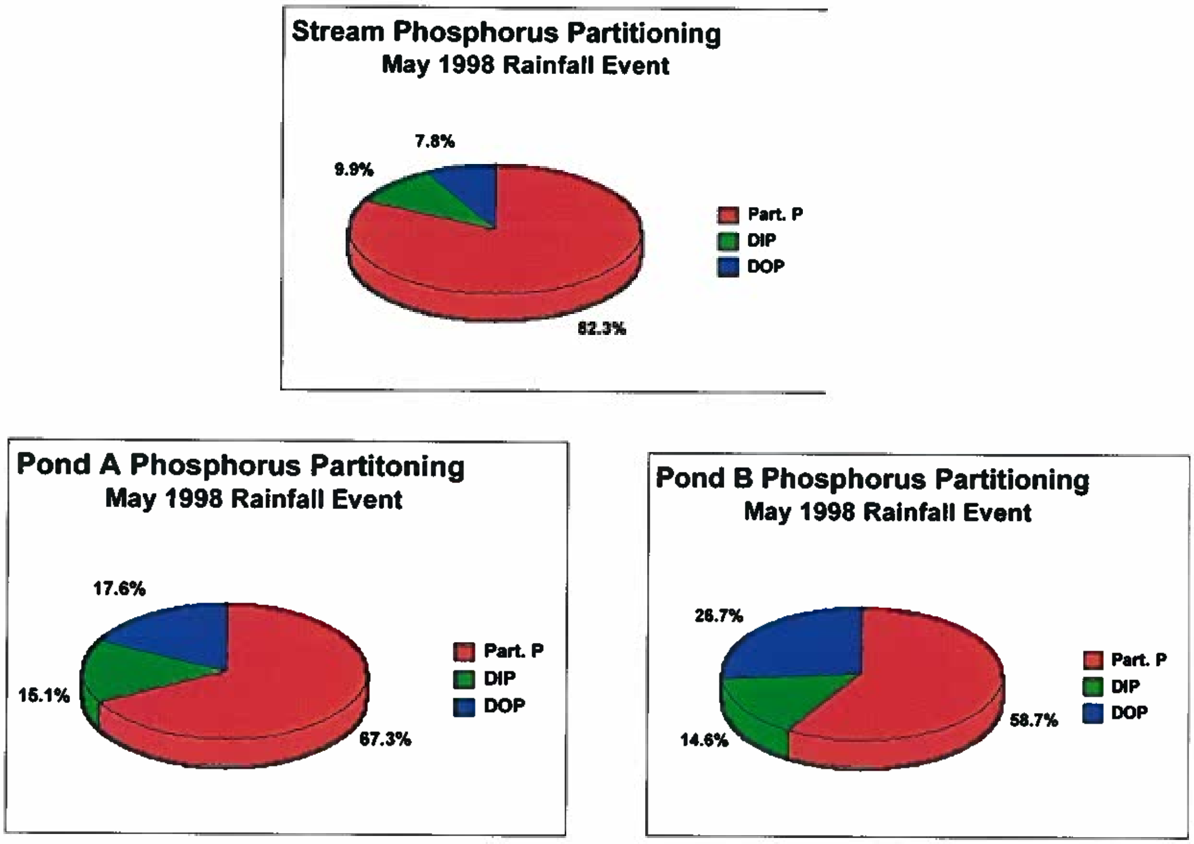


Figure 5-6. Mean percentages of various phosphorus fractions; May 1998 rainfall event.

SECTION VI: WINTER AND SPRING STORM EVENTS

Pond Discharge and Stream Speed and Height Measurements

Purpose: Discharge measurements from the culverts of ponds A and B were measured on several occasions during January, 1998. Variation with time as well as determining a relationship between rainfall and discharge was the major purpose of this experiment. Stream speed and height measurements were made on several dates in February 1998 in an effort to document stream response to large storm systems. In May, discharge measurements and stream height and speed estimates were performed at 24 hour intervals during a four day period. The purpose was to document short term changes in response to a storm event.

Materials and Methods: Measurements from the outlets of the two ponds consisted of placing a 10 gallon bucket beneath the culvert and using a stopwatch to note the precise time required to fill the bucket. During periods of low flow, the tub was placed beneath the culvert for a specific time period after which the amount of water collected in the bucket was measured. Rates are reported in liters/minute. Discharge of water from ponds A and B were monitored on nine occasions in all sorts of weather conditions during January 1998.

Stream height was determined by measuring the height of water from a fixed reference point. Stream sped was measured by determining the time necessary for a 3" twig to traverse 10 feet of creek. Replicate measurements were usually performed

A powerful storm passed through the area on 4-5 February 1998 and again on 23 February. A total of 4.0" of rain fell during the first storm and 2.07" rain fell as a result of the second storm. The landscape was already saturated prior to these storms. Three stations in the stream were established and occupied a total of seven times during February 1998 and were continued to be monitored for the duration of this project. Stream water height and stream speed measurements were made at each of these stations.

RESULTS OF WINTER STORM EVENT

Rates of water discharging from ponds A and B during January 1998 are found in Table VI-1.

Table VI-1. Rates of water (L/min.) discharging from Ponds A and B during January 1998 storm event.

Date	Pond A (L/min.)	Pond B (L/min.
01/06/98	300	282
01/10/98	300	282
01/13/98	369 **	417 **
01/15/98	292.9	616
01/17/98	401	470
01/18/98	360	432
01/19/98	385.6	382.7
01/24/98	855 **	1200 **
01/27/98	579	746

** = mean of two replicates.

On 22-23 January, 1.78" of rainfall occurred in the Solomons/St. Leonard area. This, in addition to the rainfall of 15 and 19 January left the ground saturated and run-off through the culverts was quite impressive, as the data suggest.

Since no rain fell 24-27 January 1998, estimates of declining rates of flow were calculated. For Pond A, a decline of 3.8 L/min./hour was noted. Nearly twice that, 6.3 L/min./hour was determined for pond B. This assumes a linear hourly rate reduction where no precipitation occurred. The 28 hour period between17 and 18 January noted only a 1.5 L/min./hour rate reduction for both ponds.

It should be noted that for the period 22 January - 05 February 1998, 10.73" rain fell in the Solomons area (CBL data, personal communication).

<u>Stream Current Speed:</u> Estimates of current speed were performed in the stream draining to Pond A on four occasions during January 1998.

The first estimates were made on 17 January 1998 at two different locations within the stream. The first section indicated fairly rapidly moving water while the second section appeared slower moving. Results are shown below:

Table VI-2. Stream current speed (feet/sec.) in the stream draining to pond A during January 1998.

Date		01/17/98	01/18/98	01/19/98	01/24/98
Section 1	Replicate 1	0.94	1.00	0.87	0.98
	Replicate 2	0.92			
Section 2	Replicate 1	0.77	0.73	0.71	
	Replicate 2	0.75			
Section 3	Replicate 1				0.89
	Replicate 2				0.97
Section 4	Replicate 1				1.22
	Replicate 2				1.23

Units are in feet/second

Although preliminary, these data indicated that stream current speed is positively influenced by rainfall. Also, the width and depth of water moving through the stream bed increases with rainfall.

<u>Stream Monitoring Stations:</u> One outcome from these preliminary measurements was the establishment of three stations in mid-February 1998 in the creek leading to pond A. Water height and speed were measured at each station. These measurements were made during significant seasonal rainfall events as well as during routine water quality field surveys.

Station X is located closest to the pond. The stream bed is approximately 3-5' wide with no particularly well defined banks; perhaps 12" high on each side. Station Y is approximately 100 ' upstream from station X. The width of the stream bed is approximately 4.5' and the height of the stream bed on the south side is 12" but had poorly defined northern banks. Station Z is located 100 ' upstream from station Y. It has a stream bed width of 3'3" with well defined banks of 2' on the south side and 1'3" on the North side.

Stream gauges were installed at each site as were stakes which defined 10' sections of stream bed. Water height and speed could then be determined at each site by measuring the water height and determining the time for an object to travel the 10'. Replicate stream speed measurements were almost always performed.

These stations were surveyed on seven occasions during February 1998 and encompassed pre-, during, and post rainfall events on two separate occasions.

The first occurred on 17 February 1998 where nearly an inch of rainfall occurred between 0830 and 1640 hours. The amount of water in the stream bank nearly doubled from 5" to nearly 10" at all three stations (Figure VI-1). Water current increased substantially from 1.0 to 1.7 ft./second at two of the three stations.

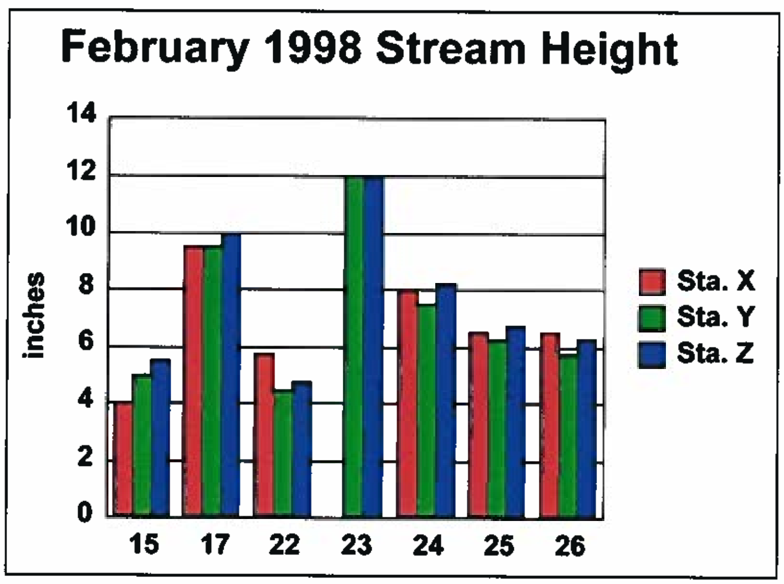


Figure VI-1. Changes in water depth at three stations in the stream leading to Pond A.

To further document the time necessary for the creek to return to "ambient" physical conditions after a significant rainfall event, the three stations were monitored for five consecutive days on 22-26 February 1998. On 23 Feb. 1998, 2.07" of rain fell during a ten hour period (0830-1830). By 1600 on 23 Feb., the creek had overflowed its banks at all three station; to the point that the water level was above the installed measuring devices. Figure VI-2 illustrates the effects of this rainfall event on the stream.

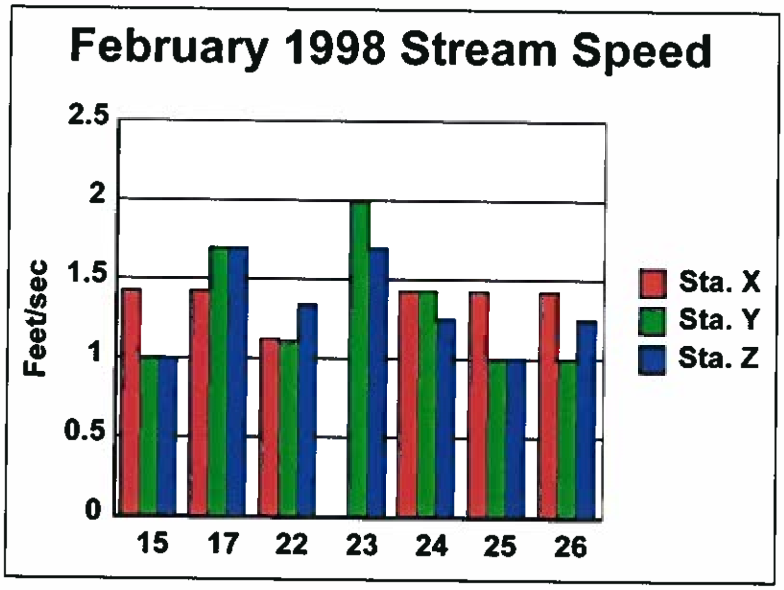


Figure VI-2. Changes in stream velocity at three stations in the stream leading to Pond A.

Between 15 and 17 February 1998, current speed increased from 1.0 to 1.7 feet/sec. Current speed during the rain event of 23 February was more than 2.5, 2.0 and 1.7 feet/sec. For stations X, Y and Z, respectively. Current speed returned to pre storm flow within 48 hours (Figure VI-2).

RESULTS OF SPRING STORM EVENT

Event monitoring in May consisted of sampling twice on May 12; both times during heavy showers. Additional measurements for discharge and current velocity were made at approximate 24 hour intervals for an additional 72 hours.

Discharge from both ponds decreased substantially during the first 24 hours, followed by slight increases at the discharge from pond A and slsight decreases from Pond B (Figure VI-3).

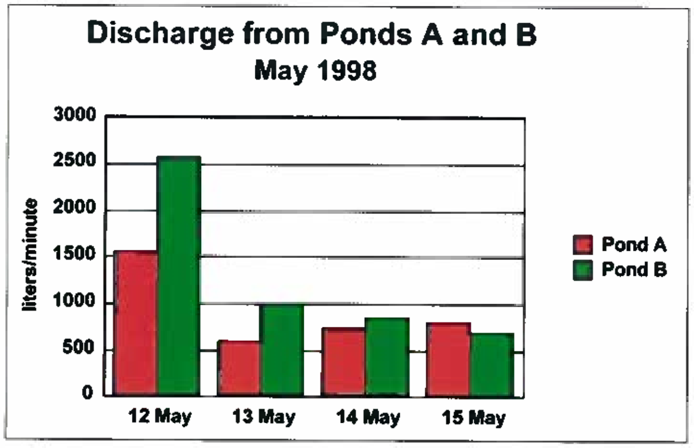


Figure VI-3. Short-term measurements of discharge from Ponds A and B, May 1998.

These data also demonstrate the efficiency of the culverts to move large amounts of storm water through the system.

Current speed (Figure VI-4) generally decreased with time from the afternoon of 12 May to 15 May 1998.

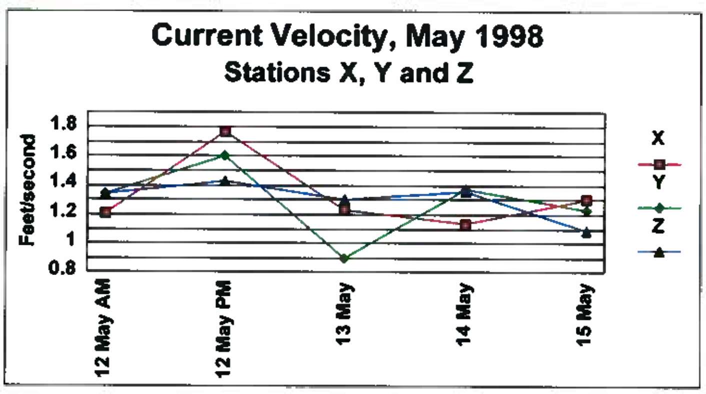


Figure VI-4. Current velocity during and immediately after a major rainfall event.

The use of automated measuring devices was attempted, but lack of operator experience and drought conditions during the summer and fall months prevented the use of this instrumentation.

General Comments and a Look to Future Research at Jefferson Patterson Park

Actual water quality sampling and direct stream velocity and height measurements as well as direct measurement of discharge from the ponds worked extremely well. Detailed field reports and some preliminary data reduction increased the efficiency of preparing the final report.

The severe drought from July-October prevented two field surveys that might have otherwise provided important additional data. The automated system was tested in May, but the weather didn't cooperate in the implementation of this system.

Adding two additional important components to this multi-year project is a suggestion that should be considered. The first component would be an intensive "event" sampling of the same five stations during late summer or early fall. A tropical depression would be nice.

The second component would be an in-depth analysis of the data. More sophisticated data reduction is beyond the scope of this report and it is felt that there are some extremely useful and worthwhile data that could be refined to make additional statements concerning the importance of this system.

Lastly, I believe much of the data presented in these three reports are publishable in refereed journals and I think this should be pursued.

ACKNOWLEDGMENTS:

Mr. William Clark (Calvert Soil Conservation District) and Mr. Mike Smolek (Jefferson Patterson Park) have supported this project from its inception. Thank you. My thanks also to Mike Quigley, Leigh and Katy Zimmermann for their assistance in the field.

The Nutrient Analytical Services Laboratory at the Chesapeake Biological Laboratory provided quality data in a timely manner.

Also, thanks to the U.S. EPA Chesapeake Bay Program, who funded this study.

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