Three Design Alternatives For Stormwater Detention Ponds

1990-91

1993-94

1994-95

Southwest Florida
Water Management District

June 1997

COVER: Aerial views of the three design configurations for the pond studied during this project.

> **TOP PHOTO:** The pond as it appeared during the dry season for the first year of the study. The view is looking from north to south with the outflow instrument trailer, the white rectangle, in the foreground. Also seen in the background are experimental research ponds which are not a part of this report.
>
> **MIDDLE PHOTO:** The pond as it appeared during the second year of the study. The view is looking from south to north with the inflow instrument trailer in the foreground. Also shown is the industrial area that is part of the air shed.
>
> **BOTTOM PHOTO:** The pond as it appeared immediately after reshaping for the final year of the study. The view is from south to north with the brown wooden inflow instrument shelter in the foreground.

TITLE PAGE PHOTO: The pond during construction right before the final year of the study. The view is from north to south with the outflow instrument trailer in the foreground. It also shows part of the drainage basin which includes a parking lot, a vehicle storage compound, equipment storage areas, grassed ditches/swales and experimental ponds (not a part of this report). Some of the canal system which received the effluent from the wet detention pond is seen in the upper left hand corner.

COVER DESIGN: Mary Ann Ritter

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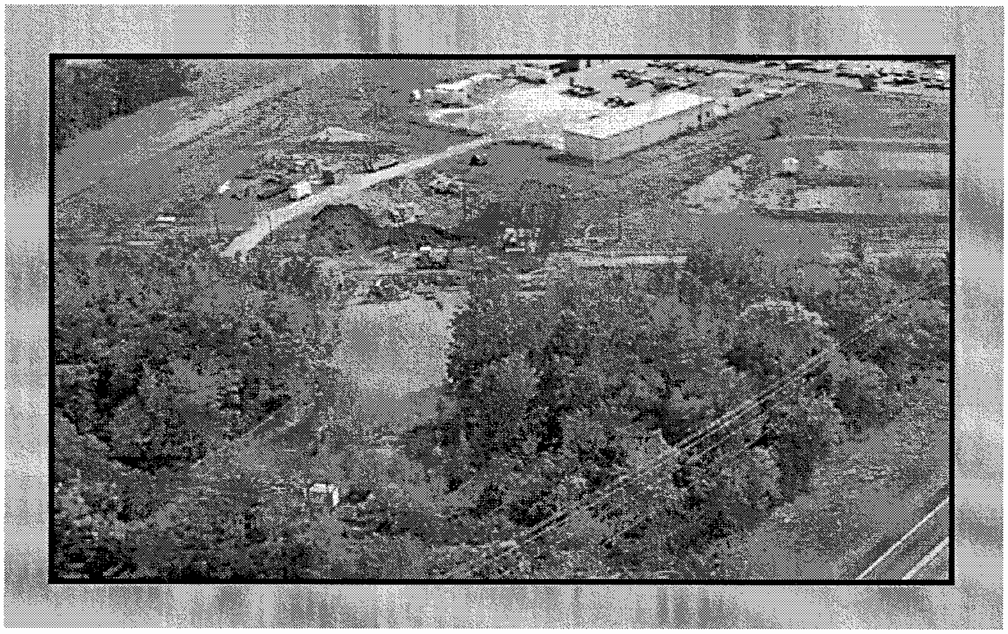
Three Design Alternatives For Stormwater Detention Ponds



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JUNE 1997

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF TABLES

LIST OF TABLES (continued)

EXECUTIVE SUMMARY

The most common method for stormwater management in Florida is the construction of wet detention ponds. As new information has become available, senior technical staff at the Southwest Florida Water Management District (SWFWMD) has modified their Surface Water Management Rules (MSSW) to improve the performance of these systems. To determine the effect of some of these rule modifications, one wet detention pond was reshaped to replicate three configurations representing different rule criteria and each configuration was monitored for an eight month period.

In general, detention attenuation systems are designed to reduce water pollution as well as flooding. The major components of wet detention ponds consist of a permanent water pool, an overlying zone in which the stormwater fluctuating volume temporarily increases the depth, and a shallow littoral zone to act as a biological filter. The purpose of this research was to determine how much improvement in water quality can be expected by increasing residence time of the water in the permanent pool. Specifically, the Conservation Wet Detention criteria, which includes a 14-day residence time, was compared to earlier rule criteria. Other objectives included measuring the hydrologic response to rainfall, analyzing peak flow, measuring pollutant loading from rainfall, correlating relationships between constituents, determining compliance with state water quality goals, recording the reaction of field parameters to changing environmental conditions, measuring pollutants in the sediments, documenting vegetation and insect colonization, and making recommendations for improvements in stormwater systems.

Site Description

A wet detention pond located at the SWFWMD Service Office in Tampa was used to study the effectiveness of the various design alternatives. The drainage basin is 6.5 acres with about 30 percent of the watershed covered by roof tops and asphalt parking lots, 6 percent by a crushed limestone storage compound and the remaining 64 percent as a grassed storage area. The impervious surfaces discharge to ditches which provide some pre-treatment before stormwater enters the pond. During the first year of the study (1990), the pond was shallow and completely vegetated with a permanent pool less than one foot deep and an average wet season residence time of two days. In the second year (1993), the vegetated littoral zone covered 35% of the pond area and the volume of the permanent pool was increased to include a five day residence time by excavating the pond to five feet. For the final year (1994), the vegetated littoral zone was planted with desirable species, the depth of the pond was kept at five feet and the area of the permanent pool was enlarged for a calculated wet season residence time of 14 days. This final year tested the Conservation Wet Detention design.

The major emphasis of the study was to compare the pollutant removal efficiency of the pond by collecting flow-weighted composite samples for over 20 storm events occurring from June through January of each year. Automated equipment recorded rainfall amounts, measured water levels and calculated flow rates using standard formulas. For mass loading calculations, rainfall directly on the pond was included as an input. Some parameters affected by diurnal cycles were monitored *in situ* at two hour intervals.

Hydrology

Rain events were compared for the same eight month period of each year. Although equipment at the study site measured much different rainfall amounts for the three years (28" in 1990, 34" in 1993 and 44" in 1994), the averages for each storm were similar, for example, rain amount (0.53-0.57 inches), intensity (0.26-0.30 in/hr) and duration (2.61-2.72 hrs). Drought years did decrease the amount of direct discharge from the pond and increased the amount lost by exfiltration and evapotranspiration (ET). Water losses from seepage and ET were estimated as: 40 percent in 1990, 30 percent in 1993 and 18 percent in 1994. The runoff coefficient was the only significantly different rainfall characteristic between years with the rainfall deficit in 1990 reducing the coefficient to 0.19 compared to 0.36 for the other two more normal years.

Water Quality

The efficiency of the pond to remove pollutants was dramatically improved in 1994 when the Conservation Wet Detention design was in place. The percent efficiency for pollutant load removal is at least 20 percent better when 1994 is compared to 1990. The specific removal rates from 1990 to 1994 are: Total suspended solids from 71 percent to 94 percent, ammonia from 54 percent to 90 percent, nitrate+nitrite from 64 percent to 88 percent, ortho-phosphate from 69 percent to 92 percent, total phosphorus from 62 percent to 90 percent, total zinc from 56 percent to 87 percent, total iron from 40 percent to 94 percent and total cadmium from 55 percent to 87 percent. In 1994, the mass loading efficiencies always met the 80 percent reduction goal of the State Water Policy (Chapter 62-40 FAC) except for total organic nitrogen which was reduced by only 30 percent in 1990 and 51 percent in 1994. Organic nutrients will always be difficult to remove in wetlands such as this one where high primary productivity generates organic matter.

Load removal efficiency was not necessarily improved between 1990 and 1993, although the residence time had been increased from two to five days. The lower efficiencies in 1993 were caused by one extreme storm event with 3.89 inches of rain. This one storm accounted for 28 percent of the total stormwater outflow for the sampling year and an even larger percentage of total constituent loads. For example, outflow loads for this one event as a percentage of total outflow loads for all 22 events were: ammonia (77%), nitrate+nitrite (56%), organic nitrogen (44%), ortho-phosphate (45%), total phosphorus (39%) suspended solids (38%), zinc (32%), and copper (46%). Another measurement to determine if water discharged from stormwater systems meet state water quality goals is to compare the data to state water quality standards (Chapter 62-

302 FAC). In 1993 and 1994, except for iron in one sample, no metals were discharged from the wet detention pond that did not meet standards, while from 5 to 69 percent of metal concentrations at the inflow did not meet standards. This demonstrates the effectiveness of wet detention ponds in reducing pollutants to acceptable levels before discharge to our rivers, lakes and estuaries.

Although no numerical state water quality standards have been set for nitrogen and phosphorus, these constituents are of concern since excessive levels cause algal problems. Threshold levels for eutrophication suggested by some limnologists are 0.3 mg/l for inorganic nitrogen and 0.01 mg/l for ortho phosphorus. Although average concentrations in rainfall and at the inflow were high enough to cause eutrophication, the averages at the outflow for inorganic nitrogen (0.158 mg/l in 1990, 0.082 mg/l in 1993 and 0.098 mg/l in 1994) were low enough to cause no problems. Phosphorus concentrations in the Tampa Bay region are more difficult to evaluate since the region is naturally enriched in phosphate, but approach 0.01 mg/l with longer residence times. Averages for ortho-phosphorus at the outfall were 0.108 mg/l in 1990, 0.084 mg/l in 1993, and 0.027 mg/l in 1994.

Rainfall directly on the pond is a significant source for some pollutants. Depending on the area of the pond, which was increased from 0.30 acres to 0.57 acres over the course of the study, rainfall accounted for 14 to 26 percent of the hydrologic input, while 20 to 30 percent of inorganic nitrogen and 9 to 10 percent of copper entered directly in rainfall. Zinc concentrations were variable between years but perhaps as much as 38 percent entered the pond in rain during the 1993 sampling period. Much higher concentrations of inorganic nitrogen (>0.4 mg/l) were measured in storms with less than an inch of precipitation while storms greater than 1.25 inches never had levels this high, indicating that precipitation tends to contain contaminants at higher concentrations in short storms. This suggests that rainfall traps pollutants in the early part of the storm while longer duration rain events dilute samples.

Field Parameters

Measurements of dissolved oxygen (DO), pH, temperature, oxidation reduction potential (ORP) and conductivity fluctuate on a daily cycle and are perturbed by rainfall events. Rain decreased temperature and conductivity for all stations, but a much sharper drop occurred at the inflow station. Also rainfall decreased both pH and dissolved oxygen in the permanent pool where they were measured higher than at the outflow. In contrast pH and DO increased at the outflow which usually had low measurements. During quiescent periods between rain events, the wide littoral shelf concentrated at the outflow, ameliorated temperature, reduced dissolved oxygen and decreased pH in the water flowing through the vegetation. The different conditions in the permanent pool compared to the littoral shelf allow pollution removal using both aerobic and anaerobic processes as well as different pH regimes. A circumneutral pH helps immobilize metals and improves nitrification-denitrification while alternating oxidizing and reducing conditions enhance nitrogen removal.

Discrete Samples

To determine some of the processes taking place, three individual storm events were evaluated by taking up to 24 individual samples. These were composited together to represent the rising limb, the top, the falling limb and the tail of the hydrograph. Almost all constituents demonstrated a reduction after the peak of the storm had passed, although there were considerable differences between storms. The most consistent results were demonstrated by a storm with an intense opening burst of high intensity rain which also had high initial pollutant concentrations.

Sediments

The sediments were classified as mineral soils and generally had a sand content between 75 and 95 percent. Organic content showed a reduced percentage with depth, and the surface layer generally ranged between 2 and 5 percent organic matter except for the east ditch and an area on the littoral shelf, both of these areas were vegetated with cattails and measured over 7 percent. Nitrogen concentrations (TKN) were much lower in the permanent pool and the grassed pre-treatment swale than in the vegetated east ditch and outflow littoral shelf. Also, the concentration of both inorganic nitrogen and TKN in the water column exhibited the same pattern as that in the sediments indicating an exchange between the sediment water interface during quiescent no flow conditions. Phosphorus concentrations showed more accumulation in the pond sediments and the vegetated east ditch than at the inflow swale or the outflow of the pond. This could be the result of several processes: 1) sedimentation in the permanent pool, 2) enrichment as a result of the higher aluminum content associated with some soils, or 3) the more anaerobic conditions at the outflow. Unlike nitrogen, phosphorus concentrations in the water column exhibited no consistent pattern with concentrations in the sediments, but a negative correlation existed with dissolved oxygen during quiescent conditions. None of the metal concentrations measured in these newly constructed ponds reached toxic levels and only a few measurements were considered in the range that could potentially be associated with adverse biological effects.

Sediment samples were tested for over 100 organic pollutants at 4 to 5 locations in the pond and two locations in the ditches but only a few were detected. In 1990 the pond had been receiving stormwater runoff for four years and both the inflow and outflow had some detectable levels of organic pollutants. In 1993, four months after the newly constructed pond had been receiving runoff, no organic pollutants were detected in the pond, but measurable concentrations of polycyclic aromatic hydrocarbons (PAH) were measured in the pre-treatment swale near the parking lot. In 1995, the concentrations in the swale had increased several fold and the pond, which had been reshaped for the last time six months earlier, already showed trace levels of PAHs.

Statistical Relationships

Correlation analysis for constituents measured at the inflow and outflow demonstrated the same general patterns but relationships were much weaker at the outflow in part because of the much lower concentrations of constituents measured there. The one exception was total suspended solids compared to total phosphorus (r=0.71 at the outflow and r=0.47 at the inflow) indicating a transformation of suspended solids in the pond from inorganic particles to organic forms. A tendency also existed for more phosphorus to be measured with larger storms (r=0.48 at the inflow and r=0.45 at the outflow). The correlation analysis also emphasized the importance of iron as a controlling mechanism for pollution removal. Since it forms particles that settle easily it represents a process leading to sedimentation. Positive correlations of constituents with iron at the inflow included: lead (r=0.74), suspended solids (r=0.68), phosphorus (r=0.63), manganese (r=0.42), copper (r=0.35), and ammonia (r=0.39).

Vegetation Analysis

Shallow areas in ponds and lakes, suitable for colonization by emergent wetland plants, are referred to as littoral zones and, since they help provide for the biological assimilation of pollutants, at least 35 percent of the area of wet detention ponds constructed using SWFWMD rules must consist of a littoral shelf. The effect of planting the littoral zone with desirable species was documented in this study by making percent cover estimates right before planting and again two years later. The most striking differences in the littoral zone between the six month old pond in 1994 and two years later in 1996 included the large reduction in open water (from 62% to 30%) and the increase in plant species diversity (from 3.67 to 6.70 species per meter square). Some other trends were also noted. Factors which influenced the colonization of cattail included exposed soils after construction. Also much greater species diversity and survival of desirable planted species occurred on the large (45 x 45 sq ft) and relatively shallow (<1ft avg depth) littoral shelf which was concentrated at the outflow compared to the steeper littoral zone surrounding the edge of the rest of the pond. Planting desirable species on the wide shelf reduced the invasion of torpedo grass while the steep slopes favored the expansion of torpedo grass into deep water and may indicate that a 3.5 maximum depth for a littoral zone is too deep. Also none of the planted pickerel weed survived on the deeper part of the narrow littoral shelf surrounding the pond and none of the planted arrowhead survived anyplace except on the wide shelf.

Macroinvertebrate Sampling

The diversity and abundance of aquatic macroinvertebrates can be used as a measure of environmental quality. This limited study indicated that stormwater ponds were not dominated by an abundant number of individuals representing a few tolerant taxa, as might be expected, but instead were quite diverse including some species intolerant of pollution. More detailed studies of insects in wet detention ponds would provide useful information for making these systems better wildlife habitat, and more information is needed about the bioaccumulation of toxic pollutants in species that use these systems.

Pollutant Removal Mechanisms

The Tampa Office pond in 1994, which used the Conservation Wet Detention design, performed well for removing pollutants during the first eight months after construction. Factors which likely contributed to this result were pre-treatment opportunities in the watershed, increased residence time with good flushing characteristics, a wide vegetated littoral shelf concentrated at the outfall, aerobic conditions in the permanent pool, alternating anaerobic aerobic processes on the littoral shelf, mineral soils for the substrate, increased iron in runoff and a circumneutral pH. Features which might help the pond even more would be a better landscape design incorporating trees to lessen the impact of rain drops and reduce runoff, a sediment sump in front of the pond to collect large particle pollutants as well as aid in maintenance, plants selected specifically for their proven ability to remove stormwater pollutants by pumping oxygen to the rhizosphere, and better control of fertilizers and herbicide use. In addition, incorporating the entire drainage basin into the stormwater design would help reduce runoff to pre-developments levels.

RECOMMENDATIONS

1. The Conservation Wet Detention criteria should be encouraged for all stormwater management systems possible. In this study the effluent which resulted from using this criteria met almost all state water quality standards and this design can reduce the need for fill material and produce other economic benefits.

2. Stormwater designs that utilize the entire drainage basin and reduce discharge to pre-development levels should be encouraged and credit given to developers who use these techniques. Although stormwater ponds reduce peak flows, only a watershed approach will significantly reduce the volume of water discharged downstream. Another method to reduce flow downstream as well as improve water quality is to incorporate a stormwater reuse component into the stormwater system.

3. The impact on the receiving waters needs more study. Unlike wastewater, stormwater pollution is delivered in pulses and extreme events especially need to be assessed. During 1993 in this study, from 32 to 77 percent of all the pollutants measured during the 22 storms monitored that year were discharged during one storm.

4. Concentrations of polycyclic aromatic hydrocarbons (PAH) showed a progressive increase in the pre-treatment swale near the parking lot and they were beginning to be detected in the pond within eight months after construction. Since they are a known carcinogen their accumulation and disposal needs further study.

5. Inorganic nitrogen and some metals enter the system directly as anthropogenic air pollution. Reduction at the source is necessary to improve surface water pollution.

6. Iron appears to be a controlling mechanism for pollution removal and should be studied in more detail.

7. Vegetation in the littoral zone plays a vital role in the processes which remove pollutants. More study is needed to determine which species enhance these processes.

8. A wide littoral shelf with shallow relief is the most effective means for providing conditions to remove pollutants and increase diversity. Planting the littoral shelf proved successful for replacing torpedo grass, a nuisance species, but successful cattail removal is not as easy.

9. Wet detention ponds are suitable for a diverse macro invertebrate and fish community and more information is needed about the bioaccumulation of toxic pollutants in species that use these systems.

10. Aerobic bottom sediments and a circumneutral pH in a permanent pool with adequate residence time are necessary conditions for stormwater ponds and designs which provide these conditions should be incorporated in stormwater systems.

11. More information on maintenance of stormwater systems is an urgent need.

12. A watershed approach using a variety of techniques throughout the basin could greatly improve stormwater treatment.

INTRODUCTION

Although stormwater runoff is a natural component of the hydrologic cycle, its quality has been degraded by modern technology to the detriment of rivers, streams, lakes and coastal waters. Alteration of natural drainage patterns, the addition of man-induced pollutants and changes in hydroperiod have caused declines in fisheries, restrictions on swimming, contamination of shellfish and accelerated eutrophication of lakes and rivers. In recognition of these problems governmental agencies began to regulate surface runoff in the early 1980s. Water management systems constructed in Florida are under the jurisdiction of five water management districts. The Southwest Florida Water Management District (SWFWMD) regulates systems in new developments under Chapter 40-D4 and 40D-40 F.A.C., Rules for the Management and Storage of Surface Waters (MSSW).

With the accumulation of more data and the insight from practical experience, the MSSW rules have been modified and new technical procedures developed to try to increase pollutant removal capabilities and thereby reduce the downstream impacts. To determine the effect of some of these rule modifications, one wet-detention pond was recontoured to replicate three configurations representing different rule criteria. The purpose of this research was to determine how much improvement in water quality can be expected by increasing residence time (the average amount of time that water remains in a system before it is replaced). Specifically the Conservation Wet Detention guidelines (TP/SWP-022, alternative 3) which include a 14-day residence time were compared to earlier rule criteria. Other objectives of the study included measuring the hydrologic response to rainfall, analyzing peak flow, measuring pollutant loading from rainfall, correlating relationships between constituents, determining compliance with state water quality goals, recording the reaction of field parameters to daily cycles and rainfall events, and measuring organic priority pollutants, metals and nutrients in the sediments.

Development of the Conservation Wet Detention Criteria

Guidelines for the Conservation Wet Detention design, which were tested during the final year of this study (1994), evolved over a period of time. The original concept for wet detention was sediment entrapment and early designs were little more than sedimentation basins. As more data became available it was obvious that sedimentation alone was not sufficient to remove the pollutants present, especially those in the dissolved form. Another approach was suggested which viewed detention basins as a lake achieving a controlled level of eutrophication. It incorporated more processes for treatment and therefore more pollution removal (Hartigan 1989). The key parameter in the eutrophication model is average hydraulic residence time (the average amount of time water is detained in the pond). At SWFWMD this concept developed into a technical procedure suitable for wet detention ponds constructed in west central Florida. To be effective calculations must be based on local rainfall records. The specifications for the Conservation Wet Detention design with some examples can be found in Appendix A.

Design Components

The most common method for stormwater management in Florida is the construction of detention basins. Detention attenuation systems use ponds which discharge stormwater over a period of several days and reduce water pollution as well as flooding. Wet detention ponds consist of a permanent water pool, an overlying zone in which the stormwater fluctuating volume temporarily increases the depth, and a shallow littoral zone to act as a biological filter. Extended detention times have long been recognized as a best management practice for treating urban runoff pollution, since the longer detention times allow for increased sedimentation and biological uptake. The major components for designing wet detention ponds are described below.

Permanent Pool

The most important feature of a wet-detention basin is the permanent pool. It allows for stormwater treatment between rain events before new stormwater displaces the treated water in the pond. Therefore, the size and the shape of the permanent pool should be one of the first considerations in design development. The design should provide for good circulation, mixing and residence time. This can be accomplished by creating maximum separation between the inflow and outflow, locating inflow inverts below the control elevation, using multi-cell ponds or flow baffles and eliminating dead areas. For permanent pool storage volume, solids settling design curves usually assign more than 90 percent of the total pollutant removal to quiescent conditions between storms (Hartigan 1989). The size of the permanent pool to watershed area should be 4 to 6 percent of the drainage basin to achieve this amount of pollutant removal. Residence time in the permanent pool has to be balanced with the amount of time needed to enhance sedimentation and ensure adequate nutrient uptake without the risk of thermal stratification and anaerobic bottom waters, two weeks has been determined as an optimal residence time (Hartigan 1989). The depth of the permanent pool should be shallow enough to minimize the risk of thermal stratification, but deep enough to reduce algal blooms and prevent sediment resuspension.

Fluctuating Pool

The volume above the permanent pool that is slowly released within five days after a storm event is the fluctuating pool. This feature reduces peak flows downstream and provides some solids settling and nutrient removal. This zone assures freeboard for closely spaced rain events which enhances mixing by providing additional time for mixing to occur. The fluctuating pool was referred to in earlier design criteria as "treatment volume". The bottom of the fluctuating pool, the lowest elevation at which water can be released through the outfall structure, is referred to as the control elevation which usually coincides with seasonal high water levels.

Littoral Zone

The littoral zone is a shallow shelf around the perimeter of the pond or in some other configuration which promotes suitable conditions for plants to improve water quality by biological uptake and transformations. In turn, nutrient uptake in the littoral zone helps minimize the proliferation of free-floating algae by limiting the amount of nutrients available for phytoplankton (Hartigan 1989). Macrophytes have also been know to excrete chemicals that inhibit algal growth and thus competition for light and nutrients.

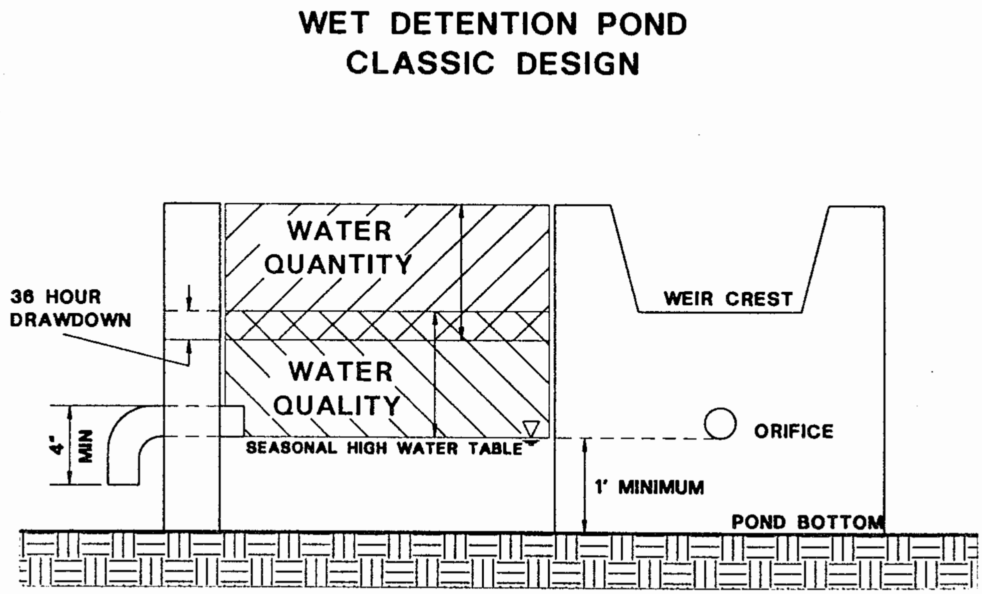
Outfall Weirs

The outflow weir configuration controls how the pond operates. Typical outfall weir configurations and some requirements for the permanent pool are shown in Figure 1 which compares the classic or older design to the Conservation Wet Detention requirements. Not only does the conservation design provide more treatment but it also can save land area. As an example, Boyer (1995) calculated the amount of pond area required for both the classic design (1.826 ac) and the Conservation Wet Detention design (1.448 ac) for a golf course and found that the conservation design saved 0.38 acres of buildable land. The smaller pond size was attributed to the conservation design's permanent wet pool that includes water quality treatment volume stored below the control elevation.

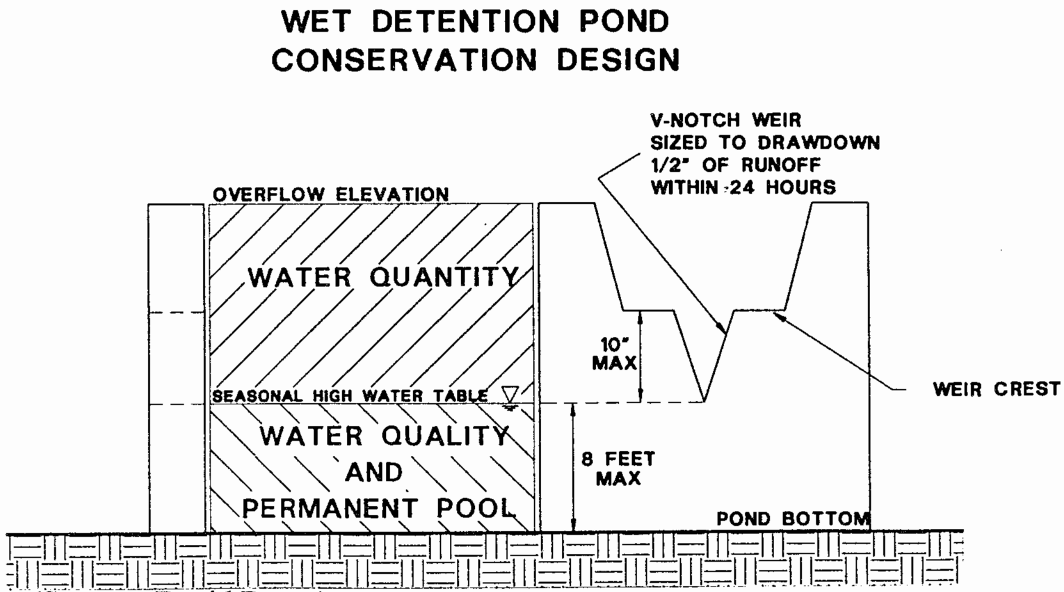
Site Description

A wet-detention pond at the SWFWMD Service Office in Tampa has been studied since 1990 to document the effectiveness of various rule criteria and design alternatives. The 6.5 acre drainage basin receives runoff from a rooftop, a parking lot, a vehicle storage compound and grassed areas which are kept mowed. About 30 percent of the site is covered by roof tops and asphalt parking lots, 6 percent by a crushed limestone storage compound, and 64 percent grassed areas. The impervious surfaces discharge to ditches which provides some pre-treatment before stormwater enters the pond. The bathymetrical contours of the pond for each year studied indicate the differences between years (Figure 2) and pertinent data for each pond configuration are compared in Table 1.

Wet detention ponds are designed to detain stormwater flow and remove pollutants prior to discharge to downstream waters. As described above, the major components for these systems consists of a design pool (permanent standing water) and a fluctuating pool in association with water-tolerant vegetation. Pollutants are primarily removed through settling, absorption by soils and nutrient uptake by vegetation and associated biota. To increase the time for these processes to take place, residence time becomes an important aspect of the design scheme.



(Source: David Boyer)



(Source: David Boyer)

Figure 1. Some differences in outflow weir design and elevations between the classic or older design and the conservation wet detention design.

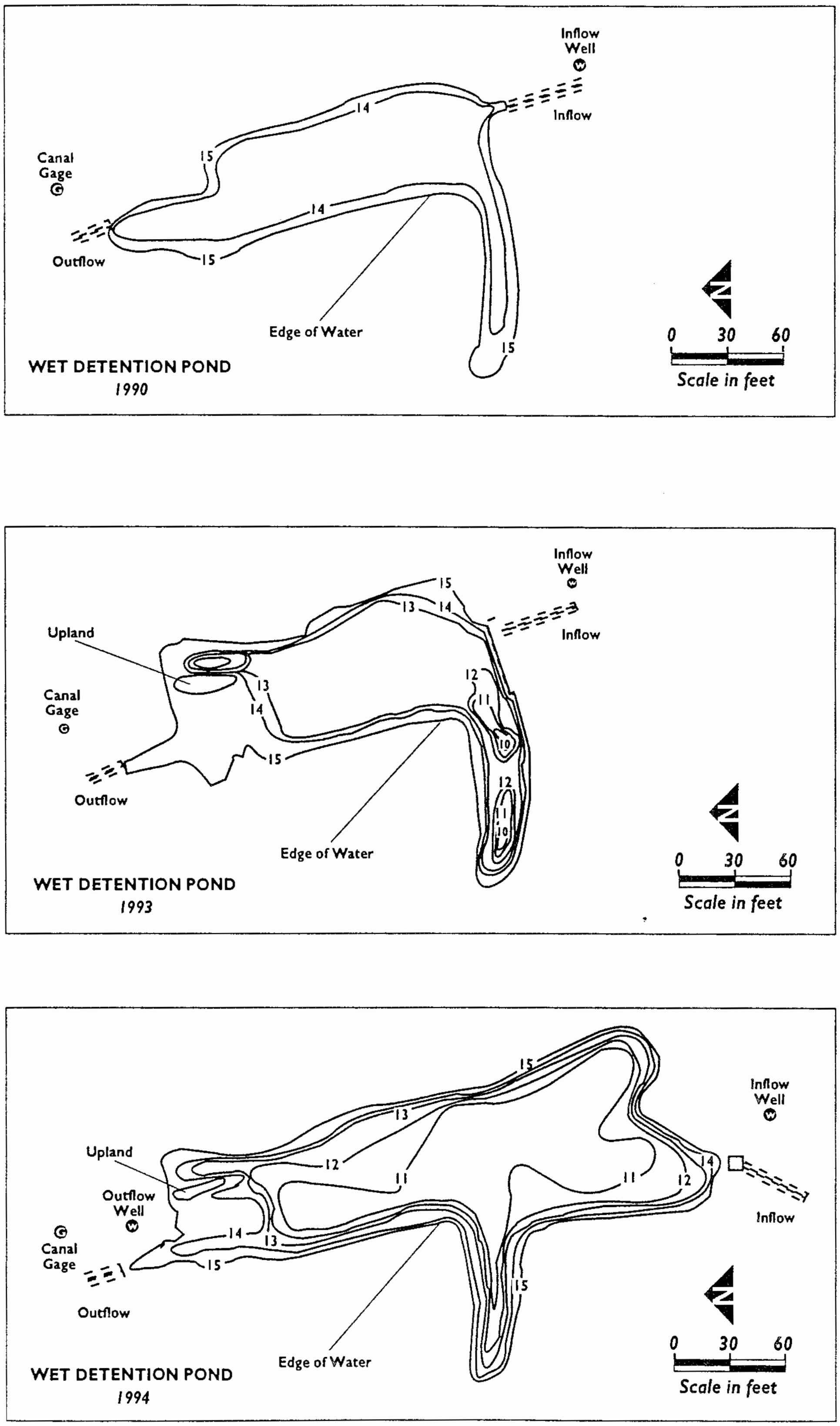


Figure 2. The bathymetric contour lines are shown for the three pond configurations. The control elevation is 15.08 (NGVD in feet) for all years and the contour intervals are one foot apart.

Table 1. Pond characteristics for the year studied.

	Units	1990	1993	1994
General Information				
Construction Date	year	1986	1993	1994
Fluctuating Pool	inches	8	10	10
Bleed down Time	in/day	>0.5/5	>0.5/1	>0.5/1
Area of pond	acre	0.30	0.35	0.57
Summer Rainfall *	inches	20.36	24.50	34.12
Length of grass conveyances Swale Ditches	feet	1000 500 500	1000 500 500	1100 350 750
Residence Time	days	2	5	14
Permanent Pool (volume of water below the outflow control structure or bleeder)				
Maximum Depth	feet	1	5	5
Average Depth	feet	0.22	1.3	2.8
Volume	cu ft	2 796	19 487	70 907
Littoral Zone (shallow zone suitable for wetland plants)				
Area of Littoral Shelf	percent	100	35	35
Dominant Vegetation	scientific common	*Typha latifolia* cattail	*Chara* sps** musk-grass	*Panicum repens* torpedo grass

* Average summer rainfall is 31.04 inches for the 122 day rainy season
** This submerged alga occupied about 70% of the pond volume including the permanent pool.

During the first year of the study, 1990, the pond design represented the rules as written in 1985. The MSSW criteria at that time required that a wet detention pond be sized to detain a "fluctuating pool (treatment volume)" equal to at least one-half inch of runoff from the contributing area. It also specified that the pool include a minimum of 35 percent planted littoral zone with a depth of less than three and one half feet below the overflow elevation. The criteria further stated that the fluctuating pool not cause the pond level to rise more than eight inches above the control elevation (bleeder). Additionally the volume between the control device and the overflow elevation (fluctuating pool) should be discharged in no less than five days with no more than one-half the total volume being discharged within the first 2.5 days. In the four years since the pond was constructed vegetation had colonized the entire pond area and the permanent pool had decreased from a maximum depth of one foot to less than half a foot as decaying vegetation and sediments filled in the pond.

During the second year of the study, 1993, revised rules were used to configure the pond. Although many of the criteria remained the same, the rule changes made in 1988 allowed an 18 inch fluctuation above the control elevation (fluctuating pool) which was sized to "treat" one inch of runoff from the contributing area instead of one-half inch. The new rules also allowed an unplanted littoral zone. Not all of these criteria were incorporated in the new design excavated for this study, for example, the fluctuating pool was only ten inches instead of the eighteen allowed, but of importance for the purposes of the study, the residence time was increased from two to five days and the average depth of the pond was increased from one to two feet. The unplanted littoral zone was quickly colonized by torpedo grass (*Panicum repens*) and the volume of the pond was occupied by a submerged macroalga, a *Chara* species, typical of hard water.

For the final year of the study, 1994, the Conservation Wet Detention technical procedure, written by SWFWMD staff, was followed for the pond design (See Appendix A). The new criteria require a permanent pool with a capacity of one inch of runoff from the drainage area plus the calculated volume based on an average residence time of 14 days. The procedure allows treatment credit for residence time below the seasonal high water table in the permanent pool which by these criteria can be as deep as eight feet. It also reduces flood elevations which result from stacking flood volume on top of treatment volume and therefore makes it feasible for developers to use less fill for elevating building pads to assure flood protection.

Under normal circumstances, it would not have been necessary to increase the area of the pond to use these criteria. However, a confining layer separating a deeper artesian aquifer was close to the surface and in order not to breach this confining layer, the pond could only be excavated to a depth of five feet instead of the eight feet allowed by the guidelines. Therefore, the area of the pond had to be increased in order to provide the necessary volume for a 14-day residence time.

METHODS

Automated equipment at the site collected composite flow proportional water samples, recorded rainfall amounts, measured water levels and calculated flow rates for all storm events from June through January of 1993 and 1994. Similar instruments and methods were used in 1990 and that information is available in an earlier report (Rushton and Dye 1993). In addition rainfall water quality samples were collected, field parameters measured, and water table levels recorded.

Water Quantity

Water levels at the inflow and outflow were measured using float and pulleys connected to data loggers and also with bubbler flowmeters recording to strip charts. Flow was calculated from water levels using standard weir equations. Omnidata™ model 900 loggers scanned data at one minute intervals and reported results to a storage pack every 15 minutes. ISCO™ Model 3230 flowmeters signaled the refrigerated water quality samplers during storm events and recorded the exact time of each sample collected on a hydrograph. It was also programed to print a summary for each day.

Inflow

Flow at the inflow station was measure by a sharp-crested 90° V-notch weir. The official survey drawings giving all of the dimensions are shown in Appendix B. Water levels measured by the data logger and flowmeter were compared to actual readings from the staff gauge during all site visits, but in addition, special care was taken to measure accuracy when water levels were high and rapidly changing, a much more difficult measurement. The average standard deviation using both the program written in the data logger and a calculated regression equation was 0.02 feet, about the same accuracy as reading the staff gauge in the field. See appendix B for calculations and regression graphs. The ISCO™ flowmeter which comes pre-calibrated from the factory usually agreed with the staff reading with discrepancies less than 0.01 feet. Since the accuracy of reading the staff gauge is 0.02 feet, we feel confident that the water level measurements are fairly accurate, at least for the amount of variation typical of natural systems.

The standard equation for a V-Notch weir was used to calculate flow from water levels (head) above the V-notch..

$$Q = 2.5 * (HEAD^{2.5})$$

where: Q = Flow in cubic feet per second
HEAD = Water level above the bottom of the V-notch in feet.
C = 2.5 = A constant dependent on the angle of the V-notch and units of measurement.
K = 2.5 = A constant for V-notch weirs.

Several problems were encountered in trying to accurately measure flow. During 1993 it was discovered a water pipe had broken and was leaking potable water into the inflow swale during December. Storms occurring during this time period were removed from the data set, although calculations both with and without this information are included in Appendices I and J. Leaks around the inflow weir resulted in some unmeasured flow during June of 1994. For both 1993 and 1994 the water table was much closer to the surface than in 1990. In fact, during 1994, the water table was consistently measured above the inflow level indicating a substantial gradient which may have increased subsurface flow into the pond, although it was not evident by a close inspection of water level measurements. Some unmeasured flow from a low area entered the pond during large storms in 1994.

Outflow

Flow at the outfall was calculated from a two part formula using standard weir equations with some modifications. A 20° V-notch discharged water from the fluctuating pool while a rectangular weir with end contractions most accurately described the overflow discharge during large storms. Engineered drawings from the official survey show all of the dimensions (Appendix C). Trash in the narrow V-notch created a problem for measuring flow by keeping water levels artificially elevated some of the time. This potentially overestimated flow since trash was removed from the V-notch during 42 percent of site visits when flow was occurring. But since high flows almost always completely flushed the notch, this probably did not result in a serious overestimation. The V-notch was also manually calibrated and a coefficient calculated for determining flow rates (Appendix C). Field measurements and calculations were made for the outflow in a similar manner as those described for the inflow. Results showed a standard deviation between 0.01 and 0.02 feet.

The compound weir at the outflow required two equations to calculate flow. For water levels less than 0.83 feet above the V-notch, the following formula was used to measure flow.

Q=0.623*HEAD^2.5

Where: Q=Flow rate (cubic feet per second (CFS))
HEAD=Water level above the V-notch in feet.
C=0.623=Coefficient calculated from measuring flow with a bucket and stop watch (see Appendix C for calculations).
K= 2.5= A constant for V-notch weirs.

For heads greater then 0.83 feet, the maximum value of the V-notch at 0.83 feet was added to flow over an improvised rectangular weir with end contractions. The 0.83 feet was determined from actual field observations as the difference between the bottom of the V-notch and the overflow for the weir. The weir configuration is slightly different from the surveyed figure (Appendix C). The actual weir was divided in the middle to make two weir plates and posts were installed to make the overflow into a rectangular weir configuration. Since the corners of each weir served as a drag the overflow was treated as two separate weirs and flow was measured with the following formula:

$$Q = (2*C*(L-(0.2*WH))*(WH^{1.5}))$$

Where: Q = Flow rate over weir (cubic feet per second (CFS))
C=3.13=Coefficient calculated using the method of Kindsvater and Carter (1959).
L=2.47=Crest length of each weir.
WH=Head over the weir structure.

The flow through the V-notch appeared to give reasonable results, but the calculations for flow over the weir seemed to over-estimate flow unless large flows also created unmeasured flow into the pond. Also, Backwater conditions held the pond at artificially high levelsduring extreme rain events.

Rainfall

Rainfall amount was the average of two tipping bucket rain gauges located at the inflow and outflow. Precipitation was collected for water quality analysis by using an Aerochem Metics^{TM} model 301 wet/dry precipitation collector. A sensor detected precipitation and activated a motor which removed the lid from the wet bucket and transferred it to the dry bucket. When the rain stopped, the cycle was reversed. A small refrigerator was mounted under the collector to store the sample immediately until it was fixed with appropriate reagents and transported to the laboratory. Dryfall was not measured.

Water Quality

Water quality samples were collected with American Sigma ^{TM} refrigerated samplers located at the inflow and the outflow weirs. The refrigerated samplers were programmed to take samples for up to 75 specific intervals based on volume as measured by the ISCO^{TM} flow meters. All water quality samples were retrieved from the samplers, preserved as required, placed on ice and transported to the SWFWMD laboratory for analysis using standard methods (Table 2) and in accordance with SWFWMD's Comprehensive Quality Assurance Plan (SWFWMD 1993). Samples for total organic carbon cannot be collected with automatic samplers and this constituent was collected as a grab sample after storm events.

One problem encountered when analyzing the water quality data was the large number of measurements below the laboratory detection limit (left censored data). When possible the actual laboratory value was substituted as recommended by Gilbert (1987). When a value was not reported but listed as below the limit of detection (LOD) then one-half the detection limit was used. Cadmium and lead had the greatest number of censored data points (75 to 90%). Rainfall often had values below the detection limit for organic nitrogen (40%), phosphorus (50%) and hardness (40%); while the inflow and outflow stations had less than 5 percent censored data for these constituents. From 8 to 21 percent of nitrate was measured below the detection limit, most of these at the outflow. Zinc and ammonia were censored at all stations for less than 10 percent of samples. All other constituents were never censored.

Table 2. Description of laboratory analyses for parameters measured in stormwater study. Reference refers to section in Standard Methods (APHA 1985).

Parameter	Method	Det. Limit	Ref.
Total Suspended Solids	Total filterable residue dried at 103-105 oC	0.05 mg/l	209C
Total lead	Electrothermal atomic absorption spectrometry	0.01 mg/l	304
Total copper	Electrothermal atomic absorption spectrometry	0.01 mg/l	304
Total cadmium	Electrothermal atomic absorption spectrometry	0.002 mg/l	304
Total chromium	Electrothermal atomic absorption spectrometry	0.01 mg/l	304
Total zinc	Direct aspiration into air-acetylene flame	0.005 mg/l	303A
Total iron	Direct aspiration into air-acetylene flame	0.02 mg/l	303A
Ammonia-N	Automated phenate	0.01 mg/l	417G
Organic nitrogen	Macro-kjeldahl - NH_3	0.01 mg/l	420A
Nitrate-nitrite-N	Cadmium reduction	0.01 mg/l	418F
Total and ortho-phosphorus	Colorimetric automated block digester	0.01 mg/l	424
Total Organic carbon	Combustion-infrared	0.50 mg/l	505A
Calcium	AAS/Flame	0.04 mg/l	215.1
Magnesium	AAS/Flame	0.0006 mg/l	242.1
Potassium	AAS/Flame	0.07 mg/l	258.1
Chloride	Argentometric	1.0 mg/l	SM 17th Ed.
Sulfate	Turbidimetric	5.0 mg/l	375.4

For quality assurance, deionized water (D.I.) samples were taken in the same manner as stormwater samples to determine if the method of collection led to any contamination (Appendix D). Copper, iron and total Kjeldahl nitrogen appeared to be detected above the detection limit on numerous occasions. Iron could be explained by the fact that iron was measured in the D.I. water when that water was tested for another program at the District as well as for one sample in this study. The detection limit may be set too low for TKN, 0.3 mg/l appears more reasonable. None of the detections were high enough to affect the overall results of the study. The fact that the levels were above the detection limit may mean that some residual pollutant stays on the instruments even after the tubing is changed. Sample 530B in Appendix D appears to be contaminated.

Water quality concentrations were compared to State Standards for class III waters (Ch 62-302) to determine how water at this site compared to water quality goals set to protect fish and wildlife. The standards were changed in 1992 which make the results from this report different from previous reports that have been published by the District (Kehoe 1992, Rushton and Dye 1993, and Kehoe, Dye and Rushton 1994). A comparison of pre-1992 and current water quality standards shows the differences (Table 3).

Field Parameters

Some parameters affected by diurnal cycles were measured in the field. Dissolved oxygen, pH, oxidation reduction potential, temperature and conductivity were monitored *in situ* with fully submersible automated water quality DataSonde IIH samplers (manufactured by Hydrolab™) which were programmed to sense and record data at two hour intervals. Post calibration measurements were comparable to test standards for at least seven days, therefore, the units were usually deployed for a week at a time. One to three identical instruments measured conditions at up to three locations in the wet-detention pond: 1) at the inflow about five feet beyond the weir, 2) in the open water pool about ten feet before the water crossed the littoral shelf near the outflow, and 3) at the outflow right before the water was discharged from the pond. The probes were placed 4 to 6 inches above the bottom sediments and water depths varied between 0.5 and 1.0 feet. Data were summarized in graphs for each of the weekly measurements and averages for each week were calculated to compare water quality characteristics between stations and between years. Averaged values for pH data are not strictly accurate since this is the negative log of the hydrogen ion concentration, however, the differences within stations were small and the resolution of the average value seemed sufficient to describe the patterns and processes taking place. This is especially true since all the data were skewed and non-parametric statistics were used for most analyses.

Table 3. A Comparison of Class III State Surface Water Quality Standards. Standards are exceeded when pollutant concentrations were ≥ the values given below. Units in ug/l unless Indicated.

Constituent	July 1991 FAC Ch. 62-302	February 1992 FAC Ch. 62-302
Cadmium	0.8 or 1.2 Hardness dependent	$e^{(0.7852[\ln H]-3.49)}$
Copper	30	$e^{(0.8545[\ln H]-1.465)}$
Iron	1000	1000
Lead	30	$e^{(1.273[\ln H]-4.705)}$; 50 max
Manganese	100 (mg/l) (Class II)	100 (mg/l) (Class II)
Zinc	30	$e^{(0.8473[\ln H]+0.7614)}$; ≥ 1000
Dissolved oxygen (DO)	5000; Normal daily and seasonal fluctuations above these levels shall be maintained (see rules).	5000; complex, see rules
pH	6.0 min. 8.0 max; +/- 1.0 NB (standard units)	6.0 min 8.0 max; +/- 1.0 NB (standard units)
Conductivity	≤ 50% increase or 1275 umhos/cm max whichever is greater.	Shall not be increased > 50% of NB or to 1275 (umhos/cm), whichever is greater.

lnH = natural logarithm of total hardness expressed as mg/l of $CaCO_3$. NB = Natural background.

Discrete Samples

Most water quality samples collected at the site were measured using flow-weighted composite samples. However, for three storm events up to 24 discrete samples were collected across the hydrograph. Automated refrigerated samplers linked to recording flow meters identified the exact time on the hydrograph when each sample was taken. These were then composited on a flow-weighted basis to represent the different stages of the hydrograph (rising limb, top, falling limb, the end of the falling limb and the tail). The same amount of flow was used for each stage of the hydrograph for each storm, but because of the differences in magnitude of each storm, the same amount of flow was not represented between storms.

Sediment Samples

Sediment Samples were collected at four to five locations within the wet detention pond and two locations in the inflow ditches during October of 1993 and again in January of 1995 (Figure 3). Samples were extracted intact from the sediments using a two inch diameter hand driven acrylic or stainless steel corer and analyzed for particle size, nutrient and metals. Four to six replicate cores in close proximity to each other were composited together into one sample for two depths at each location. The two strata selected for measurement represented the sediments from one to two inches and a deeper strata from four to five inches. The top organic layer, which never exceeded an inch, was discarded. Each sub-sample was deposited in a Pyrex or stainless steel mixing tray and composited with stainless steel utensils into one sample using the "four corners" method (SWFWMD 1993). Samples were placed in EPA approved ICHEM glass jars supplied by the Department of Environmental Protection (DEP) laboratory, then covered with ice in insulated coolers and transported to Tallahassee for analysis. One replicate sample was taken each year.

Particle size and organic content analyses were conducted by the marine geology laboratory at Eckerd College. The standard wet sieve and pipette methods (Folk 1965) were used for particle size analysis. The wet sieve method determined percent sand and the pipette method measured percent silt and clay. Total organic content was analyzed using the method of Dean (1974).

Priority pollutants were evaluated for all three years of the study. These samples were collected with an Ekman dredge or a hand-held stainless steel scoop, and included only the one to two inch depth. In 1990, samples were analyzed by the University of Florida's Environmental Engineering Sciences laboratory. A combination of the Environmental Protection Agency (USEPA 1986, Method 3350) and Marble and Delfino (Method Amer. Lab. 1988, 20, 265) was used to analyze samples. In 1993 and 1995, samples were analyzed using EPA approved methods in the DEP laboratory in Tallahassee.

Statistical Analysis

Statistical computations were performed using the Statistical Analysis System (SAS 1990) to determine significant differences and to analyze relationships between variables. Most statistical tests assume the variables are from an independent and normally distributed population and that the variances are homogeneous. This is rarely the case in nature, and even log transformations did not improve the distribution enough to make at least half of the samples suitable for parametric procedures according to the Shapiro-Wilk Statistic (W).

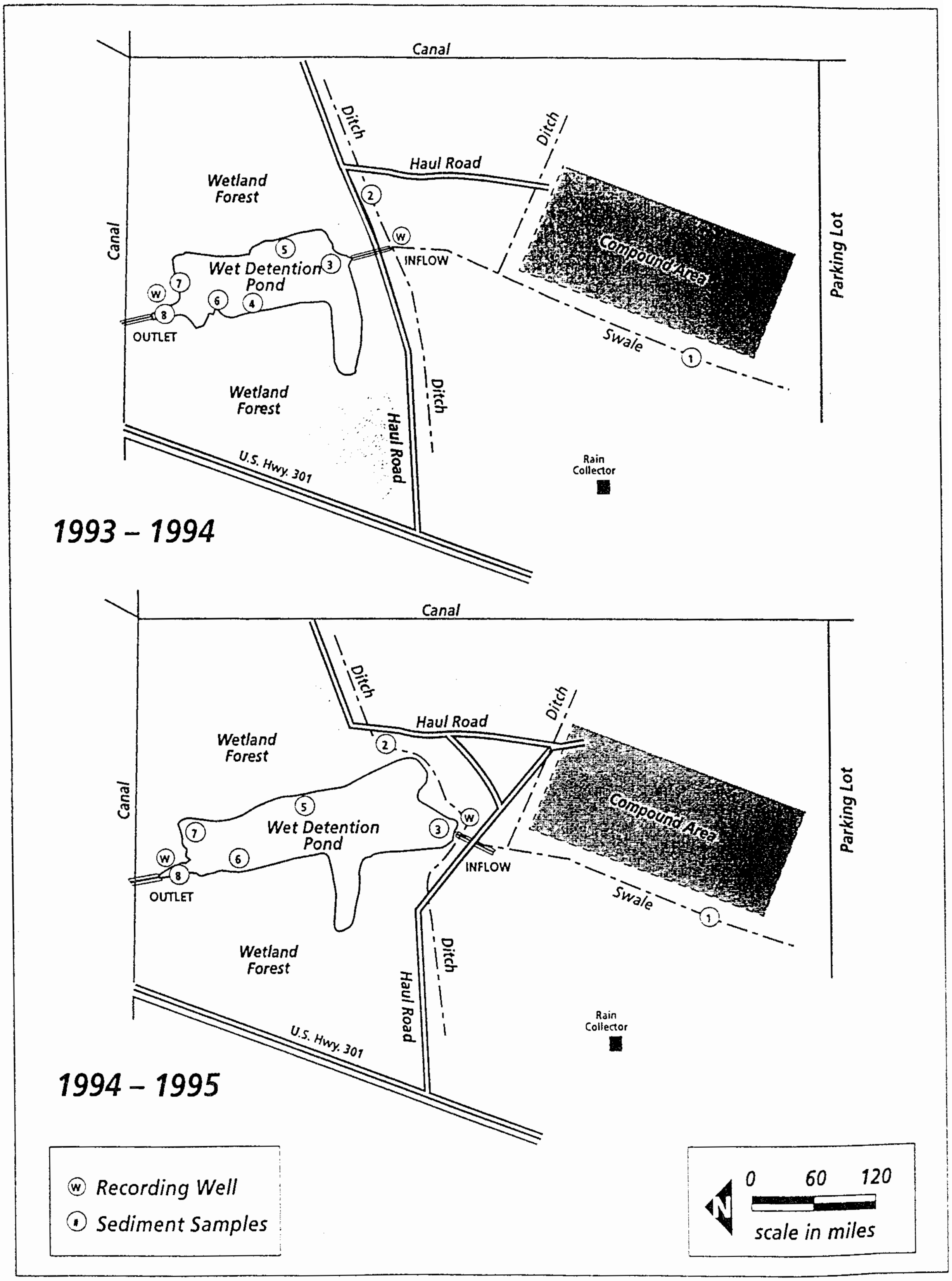


Figure 3. Site plans with location of sediment sampling sites.

To investigate the relationship between variables, nonparametric correlations were run using the Spearman rank correlation procedure. With Spearman's method differences between data values ranked further apart are given more weight, similar to the signed-rank test. It is perhaps easiest to understand as the linear correlation coefficient computed on the ranks of the data (Helsel and Hirsch 1992). Spearman's rho is best suited for large sample sizes (n>20) and the 50 to 80 data points in this study met these criteria.

To determine significant differences between years, the Wilcoxon Rank Sum Test was used to test whether concentrations of constituents in one year were consistently larger (or smaller) than those from the year before. This test has two advantages over the independent-sample t-test: a) the two data sets need not be drawn from normal distributions, and b) the test can handle a moderate number of not detected (ND) values by treating them as ties (Gilbert 1987).

Evaluation of the Data

The raw data were summarized using various mathematical and statistical techniques.

Efficiency

Efficiency of the system, i.e. the pollutant reduction from the inflow to the outflow, was calculated by two methods (concentrations and loads) using flow weighted composite samples for each storm. For load efficiency, rain falling directly on the pond was considered an input and added to the inflow data. Load efficiency gives greater weight to large storms and takes into account the reduction in pollutants retained in the pond because more water enters than leaves at the outflow. These losses are attributed to evapotranspiration and sub-surface flow.

Load efficiency (%) = ((SOL in - SOL out)/(SOL in))*100

where: SOL = the sum of loads in cubic feet for all the storms sampled from June through
January of each year.
SOL in = sum of loads at the inflow plus rain falling directly on the pond.
SOL out = the sum of loads at the outfall.

For missing data (about 3%) the median value for the constituent was substituted. Loads were calculated by multiplying the constituent concentration by volume and converting to cubic feet.

The Event Mean Concentration (EMC) efficiency was calculated by averaging the inflow and outflow concentrations for each storm from June through January of each year. This method gives equal weight to both small and large storms and does not consider water volume.

EMC efficiency (%) = (conc in - conc out/conc in)*100

where: EMC = event mean concentration from flow weighted samples
Conc in = average of EMC at inflow
Conc out = average of EMC at outflow

Residence Time

Residence time was based on calculations used for permanent pool volume below the control elevation which is computed using average total wet season rainfall. The wet season is defined as the 122 day period from June through September.

$$R = (V/(A*c*P)) *(1 \text{ ft.}/12 \text{ in.})$$

where: R = Residence time (days)
V = Volume of water below the control elevation (cu.ft.)
A = Area of pond (sq.ft.)
P = Historic average wet season rainfall rate for area = (31.04 in./122 days)
c = Composite Rational runoff coefficient

Rainfall Characteristics

Rainfall conditions were calculated from the hydrology data to determine their effect on pollutant concentrations using the following formulas:

Average rainfall intensity (in/hr) = total rain / duration of storm.

Maximum 15 min intensity (in/hr) = avg. max. rain during 15 min. interval * 4

Runoff coefficient = inflow volume /(total rain * basin area)

Inter-event dry period (antecedent conditions) = days since the previous rainfall.

Vegetation Analysis

The emergent vegetation in the littoral zone was measured using percent cover in 54 systematically located 10 ft square quadrats spaced about 25 feet apart around the perimeter of the pond (Figure 4). Quadrat locations were determined from survey stakes installed during a topographic survey which identified the upper and lower boundary of the littoral zone. The stakes marked the area to be planted with pickerel weed and arrowhead later in the summer. The quadrat frame was placed parallel to the shoreline with its lower left hand corner around one of the survey stakes. When the littoral zone was wide enough (> 6ft) one quadrat was analyzed near the shore (a) and an adjacent quadrat was analyzed in deeper water (b). Percent cover of each

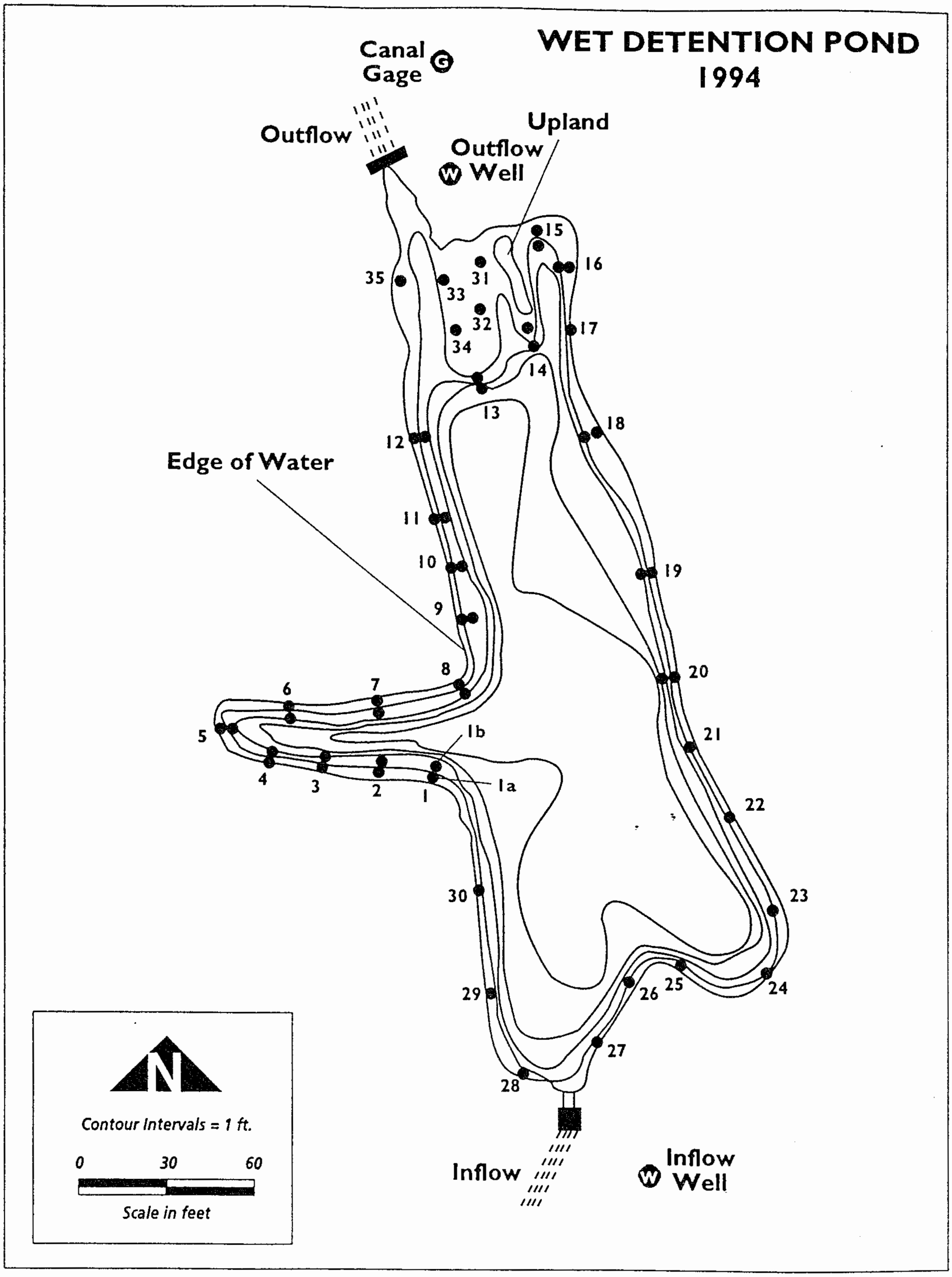


Figure 4. Location of Vegetation Quadrats. Each Dot Represents One Quadrat.

species as well as the percent of open water was estimated and recorded. Maximum and minimum water levels were also noted for each quadrat. Voucher specimens were archived and field identifications were later verified using Dressler *et al.* (1987), Godfrey and Wooten (1979) and Wunderlin (1982).

The purpose of the first survey was to document the vegetation that colonizes from natural recruitment and the later survey was made to document the competitive effect that results from planting the littoral zone. Measurements were made on June 24, 1994, about a month before the littoral zone was planted and again two years later on June 18, 1996, to document changes in species composition.

Aquatic Macroinvertebrate Measurements[1]

Macroinvertebrates were sampled using a dip net with a three foot handle for water samples and an Ekman Dredge for the sediments. Five sweeps of the dip net were taken in the littoral zone near the inflow, the outflow and the edges of the pond (Figure 5). Collections were made weekly from June 18 to August 16, 1994. Specimens were preserved in a solution of 70 percent ethanol and transported to the lab for identification. Bottom sampling was done systematically, with an Ekman Dredge along three transects. Six samples were taken with the dredge along each transect, two near the beginning of the transect, two in the middle, and two at the end, for a total of eighteen sediment samples on each date. Samples near the littoral zone were taken where the vegetation and water met, but not in the vegetation. Sediments were placed in two gallon containers and transported to the lab where they were rinsed through both an 18 gauge sieve and a 35 gauge sieve before being preserved in a 70 percent ethanol solution. Also a comparison site, a ten year old pond, was sampled on August 18, 1994. The open water and the littoral zone were sampled with equal intensity and all pond environments were lumped together and reported in one table by date.

Preliminary identification was done using McCafferty (1981) and Merritt and Cummins (1979). The bottom fauna, more specifically the chironomids and the oligochaetes, were identified with a dissecting microscope after being mounted on slides and fixed with CMC-10. For many specimens, identification was only possible to the genus level. Chironomidae identification is from Epler (1992) and oligochaetes from Brigham *et al.* (1982). The rest of the macro invertebrates were identified with a compound microscope and selected specimens were photographed. Various keys were used for species and genus identification (Berner 1950, Blatchley 1926, Young 1954) and many knowledgeable professionals provided advice with

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[1] Marnie Ward, an undergraduate student in the Department of Zoology at the University of Florida, collected and identified the insects as an independent study project. The information in this section was taken from her report

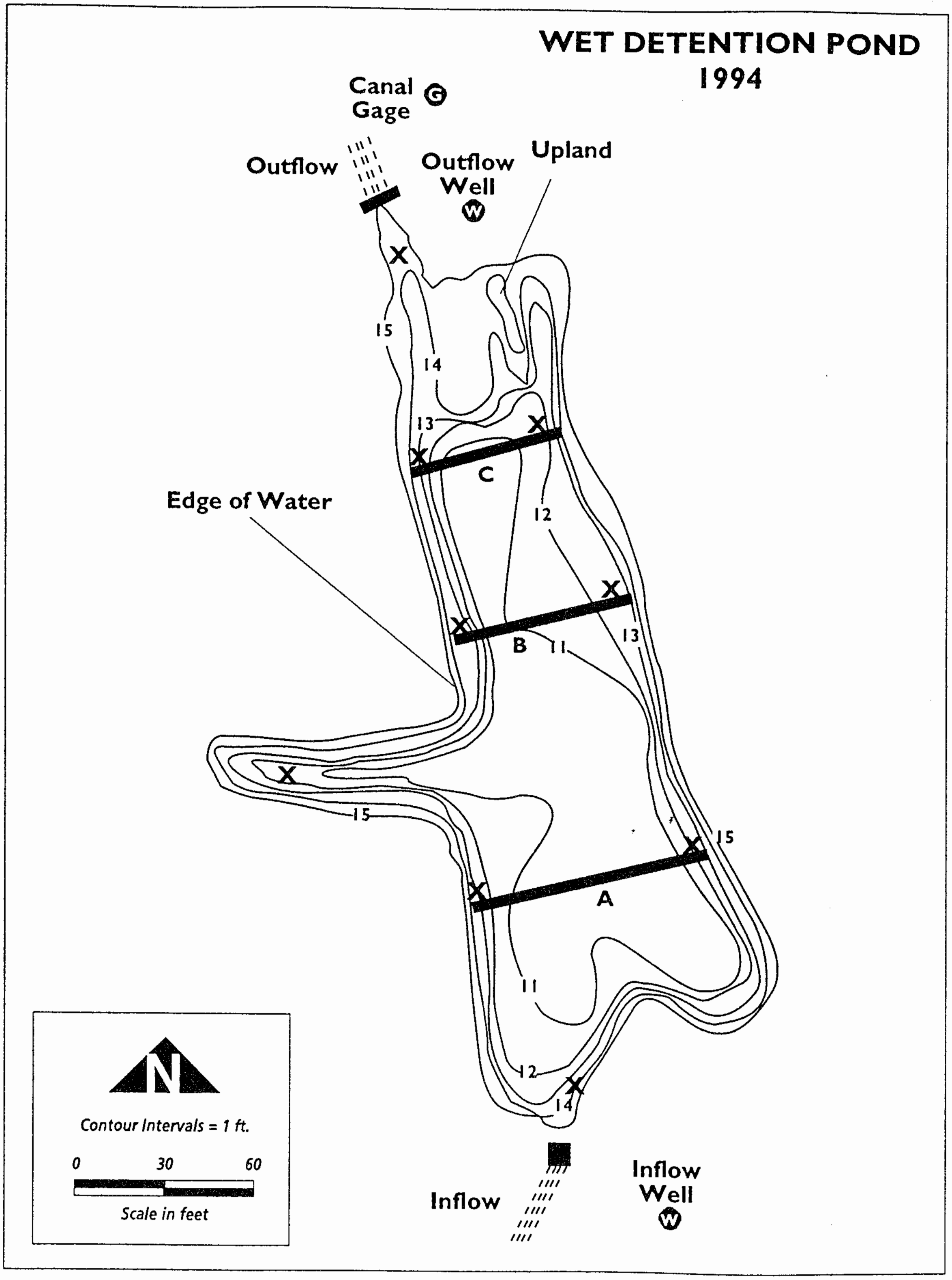


Figure 5. Location of Sediment Transects (A,B, & C) and Sweep Sampling Sites (X) Used for Insect Surveys.

problem species. Since not all individuals could be identified to the species level, the number of taxa was used for diversity measurements when species identification was not possible.

The Shannon-Weaver Diversity Index (USEPA 1973) is based on information theory and includes components of both species diversity and diversity due to the distribution of individuals among species, thereby, making species that are less common contribute more diversity:

$$\text{Diversity} = C/N\,(N \log_{10} N - \textstyle\sum n_i \log_{10} n_i)$$

Where: C=3.321928 (converts base 10 log to base 2)
N=total number of individuals
n_i=total number of individuals in the i^{th} species

The equitability measurement was devised to compare the number of species in the sample with the number of species expected (USEPA 1973). It is based on MacArthur's broken stick model which results in a distribution quite frequently observed in nature i.e. one with a few relatively abundant species and increasing numbers of species represented by only a few individuals:

$$\text{Equitability} = S'/S$$

Where S'=number of species expected (from a table using Shannon Weaver diversity to determine S').
S=number of taxa in the sample.

Many forms of stress tend to reduce diversity by making the environment unsuitable for some species or by giving other species a competitive advantage. Diversity measurements were used in this study to help evaluate these phenomena.

RESULTS AND DISCUSSION

One stormwater wet-detention pond was altered to compare its efficiency for removing pollutants using three different designs. Each pond configuration was studied for an eight month period (June through January) which covered representative conditions for both wet and dry seasons. Hydrology and water quality were analyzed for each year separately and the averaged results compared to each other. Also investigated were some of the other processes taking place such as sedimentation, groundwater interactions, vegetation colonization and insect species diversity. This section discusses the results of these measurements.

Hydrology of the System

Graphs of water levels were made to visually analyze relationships and detect problems (Appendix E and F). Continuous recorders reported rainfall, inflow, outflow and groundwater levels at 15 minute intervals. Only the 1993 and 1994 data are included for the detailed figures and tables in the appendices, but similar data are available for 1990 (Rushton and Dye 1993) and the results for the period of interest are summarized in this report. Storm numbers are placed on graphs for easy cross reference with water quality and other data.

Rainfall Characteristics

Rainfall characteristics are relevant not only to water quantity issues where they affect flooding and peak discharge but also to water quality results where they may influence constituent concentrations and removal efficiency. Antecedent conditions (inter-event dry period) and rainfall intensity increase pollutant concentrations by providing time for accumulation on land surfaces as well as the rain energy to flush pollutants through the system. Also wet and dry years affect input and output concentrations by changing subsurface flow and evapotranspiration. When conditions for the three years are compared (Table 4), the amount of rain and the number of rain events are markedly different, but for many characteristics the averaged values between years are surprisingly similar. For example, with more rainfall and more storms the number of dry days between storms are reduced, but the average amount of rain as well as intensity and storm duration are almost the same.

A key component in the study of rainfall-runoff relationships is rainfall excess, the amount of rain that runs off after depression storage and infiltration by soils. It is measured by the runoff coefficient, a ratio of rainfall excess (runoff) to precipitation volume, which ranges from 0.0 to 1.0. This coefficient represents runoff from the drainage basin and in this study ranged from 0.00 representing small storms and dry soil conditions to 0.91 measured during large storms in the wet season when soils are saturated (See Appendix G). Urban development greatly increases runoff, for example, natural woodlands and meadows with little topographic relief, typical of Florida, have coefficients that range from 0.05 to 0.20; while fully developed commercial and industrial sites range from 0.50 to 0.95 (MSSW 1988 and others).

Table 4. Comparison of rainfall characteristics between years (June through January). Abbreviations: NA=Not applicable, NS=Not significant. Values with the same letter are not statistically different.

Parameter	1990	1993	1994	significant differences
Total for each year				
Total rain (inches) *	28.00	34.21	44.38	NA
Number of rain events (>0.05 in)	53	60	83	NA
Averaged values for all storm events				
Average Rain amount (inches)	0.53	0.57	0.53	NS
Average intensity (in/hr)	0.26	0.27	0.30	NS
Inter-event dry period (days) **	4.40	3.56	2.67	NS
Duration of storm (hrs)	2.67	2.61	2.72	NS
Runoff coefficient	0.19 a	0.36 b	0.36 b	P>0.0001
Maximum values for each year				
Largest storm event (inches)	2.34	3.91	2.28	NA
Maximum duration (hrs)	15.88	16.50	13.00	NA
Maximum intensity (in/hr)	0.85	0.81	0.96	NA
Max. inter-event dry period (days)	25.77	20.45	24.89	NA
Maximum runoff coefficient	0.91	0.85	0.81	NA

* The long term average for the area from June through January is 39.95 inches. The average for an entire year is 52 inches.

** Also referred to as antecedent dry conditions.

At the study site, runoff was reduced because it was directed through ditches instead of having flow from the impervious surfaces discharging directly into the pond. This is measured by the runoff coefficient. The runoff coefficient is relevant to stormwater management systems since it is used to make estimates for pollutant loading (Harper 1994) and to make calculations for sizing systems to improve water quantity control by some methods (Wanielista and Yousef 1993, and others).

The effect caused by the amount of rainfall can be seen by comparing the runoff coefficient between years. When the pond was studied in 1990 drought conditions existed with rainfall almost 12 inches less than the long-term average of 39.95 inches. This rainfall deficit contributed to a lowered ground water level and a much reduced runoff coefficient of 0.19 compared to 0.36 for the other two more normal years. It should be noted that in 1990, a more reasonable 0.32 average coefficient is calculated when only those storms that produced flow are used. The 0.32 to 0.36 range is consistent with book values for low density developments located in flat sandy areas (MSSW 1988 and others).

Extreme events represented by maximum values have great impact on stormwater pollution. One large event, such as the 3.91 inches that fell in one day during August of 1993, can flush out the system and contribute the majority of pollutant loads measured for the entire year. This will be discussed in greater detail later. The maximum runoff coefficient for each year ranges from 0.81 to 0.91 and represents conditions when the ground is saturated caused by intense daily thunderstorms. During the summer rainy season, maximum pollutant loads can be delivered directly to the wet-detention pond with little depression storage or percolation by the drainage basin and then discharged with minimum treatment by the wet-detention pond. In contrast, it is common to have two to three weeks with no rain during the dry season in November as shown by the maximum inter-event dry period. This allows more time for pollutant accumulation on land surfaces and subsequent transport of pollutants to the wet-detention pond when it does rain.

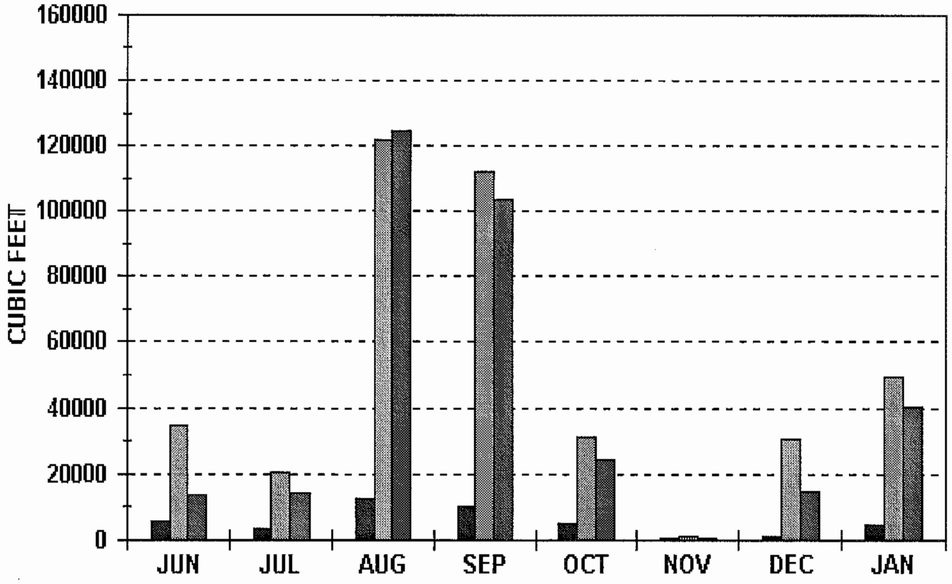
Stage and Flow Measurements

Flow amounts calculated from stage measurements using weir and pipe equations estimated hydrologic budgets and determined pollutant loads. The amount of water entering and leaving the wet-detention pond for each storm are listed in Appendix H. The monthly rainfall volumes show the seasonal and yearly patterns of similarities and differences (Figure 6). Much more flow occurs in summer and considerably more flow was measured in 1994 than 1993. The effect of dry antecedent conditions are evident from the reduced outflow in June and December of 1993 as stormwater filled available storage space in the wet-detention pond before levels were high enough for discharge. It is also noteworthy that rainfall directly on the pond contributed a significant portion of the input. For 1993, when the pond area was 0.35 acres, 14 percent of the total input was from rainfall; in 1994, the pond surface area was increased to 0.57 acres and the total rainfall input was 26 percent.

An analysis of rainfall characteristics in Florida helps explains the variation in flow amounts. June through September is considered the rainy season in the Tampa Bay region a period when over 70 percent of annual rainfall occurs (Winsberg 1990). This is the season for convective storms which form when a parcel of air near the ground is warmed by conduction to a higher temperature than the air that surrounds it. As this heated air expands and rises it is cooled forming clouds and rain. This type of rain is highly localized and often produces short but

HYDROLOGIC INPUTS AND OUTPUTS

JUNE THROUGH JANUARY 1993-4



JUNE THROUGH JANUARY 1994-5

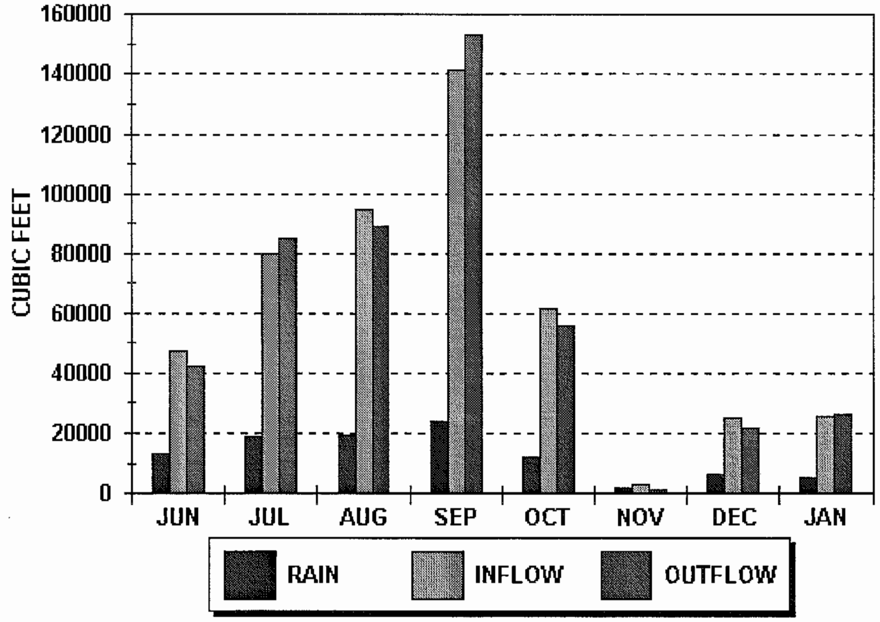


Figure 6. The monthly volumes show the seasonal and yearly patterns of similarities and differences between years for surface hydrologic inputs and outputs in rainfall on the pond, at the inflow and at the outflow.

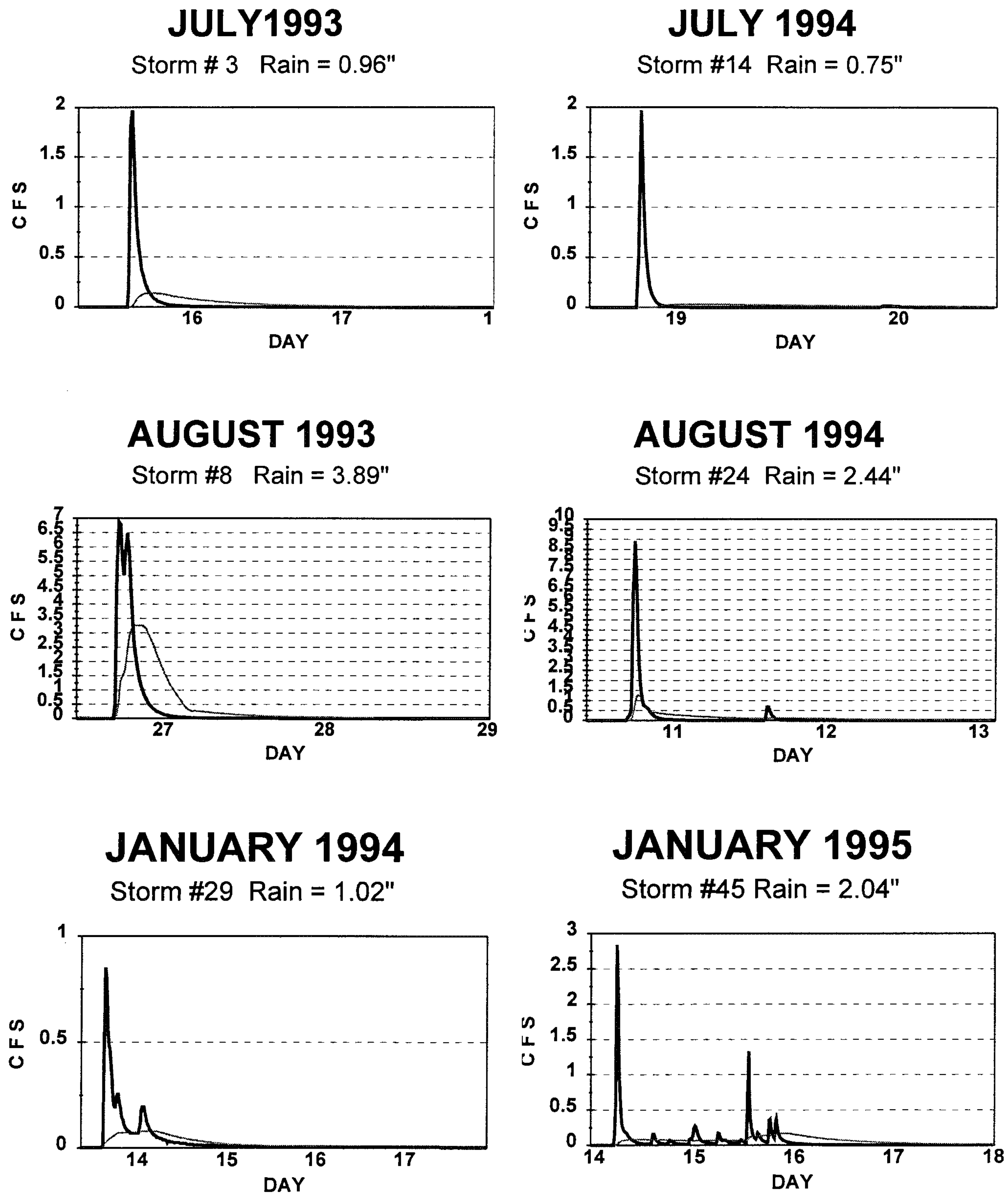
intense storms. No other part of the nation has more thunderstorm activity than the Tampa Bay region (an average of 85 days per year). The rest of the year, October through May, is the dry season and rainfall is more dependent on cold fronts reaching the state from the north. The fall and spring have little rain since frontal systems seldom make it this far south during those seasons. About 12 percent of annual precipitation falls during December, January and February (Winsberg 1990) when storms of long duration and low intensity can produce a few large storms. Other types of precipitation which occur are caused by low pressure systems (tropical depressions) and hurricanes.

One purpose of wet-detention ponds is to reduce the peak flows and rapid runoff caused by urban development, usually to a rate no greater than the predevelopment peak discharge rate. This process is called hydrograph attenuation and is accomplished by increasing watershed time of concentration by adding water storage facilities such as detention ponds in the transport system. In this study a comparison of large storms (> 0.50 inches) showed maximum peak flow rates were greatly reduced between the inflow and outflow for both years (Table 5). The wet-detention pond reduced peak flows measured at the outflow by an average of 1.3 cfs (61%) in 1993 and 2.4 cfs (86%) in 1994. The time to peak was also lengthened with the peak flow at the outflow taking about 3 hours (67%) longer than the inflow in 1993 and 3.5 hours (75%) longer in 1994. It should be noted that the differences between years are not statistically different (P>0.05 Wilcoxon Rank Sum Test). This is not surprising since the fluctuating pool is designed to attenuate peak flows and this was about the same for both designs. The permanent pool which was made larger in 1994 is primarily used for pollution removal, however, when the permanent pool level is below the control elevation, storage is available to help reduce peak flows which accounts for slightly lower levels in 1994. The volume and timing of peak flows and the moderating influence of the wet-detention pond is obvious when seen by viewing a few of the larger storm events (Figure 7). In most cases the magnitude of the outflow is so much less, that when viewed on the same scale as the inflow, it is often difficult to detect the low outflow hydrograph even for these large storms.

Considerable attention has been directed toward detention basin designs that reduce peak flow, and although the ponds are proven effective for moderating and delaying hydrograph peaks, the additional runoff caused by urban development still increases the amount of runoff. A watershed approach needs to be implemented to increase the value of detention ponds in reducing flooded conditions. The typical detention basin will not be able to significantly reduce the volume of water by seepage and evapotranspiration (see Figure 6). Much of this excess volume is released after the peak of the discharge hydrograph, thus causing an extended period of relatively high flow (Nix and Tsay 1988). Also the extra discharge and the change in timing of release often causes a series of detention basins placed at upstream locations in the watershed to be ineffective in reducing peak flows in a downstream channel (James *et al.* 1987). It was also determined that when runoff from lower portions of the watershed are delayed they often coincide with arrival of runoff from upper portions causing peak flows higher than those for no detention conditions (Curtis and McCuen 1977). On the other hand, the gradual replacement of

Table 5. Comparison of peak flows and time to peak flow 1993 vs 1994. The data includes storms >0.50" only. Antecedent head refers to water levels when the storm began. The average maximum rainfall for 15 minute periods is also included. The delay time represents the amount of time from the beginning of the storm until the peak discharge.

MO	DA	YEAR	Total Rain (in)	Max for 15 min (in)	Inflow Ante Head (feet)	Inflow Max Head (feet)	Inflow Max Flow (cfs)	Inflow Delay Time (hours)	Outflow Ante Head (feet)	Outflow Max Head (feet)	Outflow Max Flow (feet)	Outflow Delay Time (hours)
1993 using 5 day residence time												
6	24	1993	0.94	0.4	0.02	0.78	1.34	0.5	-0.4	0.23	0.02	6.25
7	12	1993	1.05	0.34	-0.04	0.81	1.48	1.25	-0.1	0.38	0.06	3.75
7	15	1993	0.96	0.46	0.01	0.91	1.97	1	0.12	0.63	0.2	3.75
8	25	1993	2.18	0.94	-0.18	1.22	4.11	0.5	0	0.81	0.37	3.25
8	26	1993	3.95	1.04	0.05	1.47	6.55	2.25	0.94	1.49	8.22	3.25
8	29	1993	1.66	0.41	0.2	1.23	4.19	1.5	0.3	1.03	1.73	2
9	5	1993	0.94	0.62	0.02	0.79	1.39	0.75	0.12	0.56	0.15	3.75
9	6	1993	2.41	0.93	0.06	1.51	7	0.5	0.3	1.15	3.1	1.25
9	11	1993	0.92	0.4	0.05	0.84	1.62	1.25	0.17	0.74	0.29	3
9	14	1993	0.66	0.22	0.04	0.77	1.3	1.25	0.12	0.56	0.15	3.75
9	21	1993	1.49	0.71	-0.09	1.13	3.39	0.5	0.05	0.84	0.39	2.25
9	27	1993	0.8	0.39	-0.18	0.47	0.38	1	0.07	0.32	0.04	5
10	6	1993	0.82	0.13	-0.11	0.38	0.22	2.5	0.01	0.25	0.02	5.25
10	9	1993	0.5	0.07	0.09	0.17	0.03	2	0.13	0.15	0.01	5
10	30	1993	1.34	0.25	0.02	0.45	0.34	3.25	0.01	0.18	0.01	4.5
1	2	1994	0.85	0.24	0.19	0.65	0.85	0.75	0.29	0.61	0.18	4
1	13	1994	1.06	0.24	0.06	0.65	0.85	1	0.09	0.48	0.1	4.25
1	17	1994	1.18	0.39	0.07	0.95	2.2	1	0.12	0.81	0.37	4.25
Average			**1.32**	**0.45**	**0.02**	**0.84**	**2.18**	**1.26**	**0.13**	**0.62**	**0.85**	**3.81**
Std. Dev.			**0.8**	**0.28**	**0.1**	**0.36**	**2.02**	**0.75**	**0.25**	**0.35**	**1.94**	**1.19**
Variance			**0.61**	**0.61**	**6.54**	**0.42**	**0.93**	**0.6**	**1.93**	**0.56**	**2.27**	**0.31**
Maximum			**3.95**	**1.04**	**0.2**	**1.51**	**7**	**3.25**	**0.94**	**1.49**	**8.22**	**6.25**
Minimum			**0.5**	**0.07**	**-0.18**	**0.17**	**0.03**	**0.5**	**-0.4**	**0.15**	**0.01**	**1.25**
# obs			**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**
1994 using 14-day residence time												
6	14	1994	0.78	0.5	-0.18	0.71	1.06	0.5	-0.02	0.12	0	5.75
6	15	1994	1.4	0.61	0.03	1.08	3.03	0.5	0.1	0.62	0.19	6.75
6	27	1994	0.76	0.5	-0.22	0.65	0.85	1	0	0.16	0.01	2.75
7	1	1994	1.57	0.69	0	1.2	3.94	0.5	0.17	0.83	0.39	2.5
7	2	1994	0.57	0.19	-0.02	0.63	0.79	1.75	0.1	0.25	0.02	5.75
7	10	1994	0.57	0.19	-0.02	0.63	0.79	1.75	0.1	0.25	0.02	5.75
7	18	1994	0.9	0.64	0.11	0.9	1.92	0.75	0.02	0.28	0.03	2.25
7	20	1994	1.12	0.64	0.05	1.2	3.94	0.5	0.18	0.63	0.2	2.5
7	21	1994	0.51	0.26	0.18	1.1	3.17	0.5	0.38	0.57	0.15	4.25
8	10	1994	2.25	0.81	0.04	1.66	8.88	1.75	0.17	1.15	3.1	2.25
8	13	1994	0.79	0.23	0.02	0.59	0.67	1.25	0.21	0.48	0.1	5
8	24	1994	0.73	0.45	0.02	0.95	2.2	1	0.15	0.45	0.08	3.25
8	26	1994	1.17	0.34	0.25	1.15	3.55	0.5	0.24	0.83	0.39	2
9	2	1994	0.72	0.59	-0.07	0.66	0.88	0.5	0.08	0.22	0.01	2
9	15	1994	1.23	0.21	0.04	0.61	0.73	0.75	0.12	0.69	0.25	8
9	16	1994	2.03	0.52	0.06	0.96	2.26	0.5	0.42	1.01	1.53	4.25
9	17	1994	0.73	0.65	0.07	1.13	3.39	0.75	0.53	0.84	0.4	1.5
9	19	1994	1.66	0.76	0.03	1.5	6.89	0.5	0.24	0.97	1.17	1.5
9	24	1994	1.13	0.43	0	1.12	3.32	0.5	0.09	0.63	0.2	3.25
9	27	1994	0.85	0.33	0.11	1.18	3.78	0.5	0.44	0.86	0.45	2.75
10	26	1994	1.6	0.35	-0.06	1.03	2.69	0.75	-0.01	0.44	0.08	3.75
10	29	1994	1.61	0.72	0.04	1.52	7.12	0.5	0.18	0.95	1.01	1.25
11	15	1994	0.69	0.07	-0.02	0.31	0.13	5	0.01	0.14	0	13.5
12	1	1994	1.63	0.82	-0.72	1.4	5.8	0.5	0	0.68	0.24	3.25
12	20	1994	0.84	0.04	-0.1	0.24	0.07	3	0.07	0.3	0.03	15.25
1	14	1995	1.11	0.41	-0.05	1.05	2.82	1.25	0.02	0.44	0.08	3.75
1	15	1995	0.65	0.18	0.18	0.35	0.18	2.75	0.42	0.54	0.13	4
Average			**1.1**	**0.45**	**-0.01**	**0.94**	**2.77**	**1.11**	**0.16**	**0.57**	**0.38**	**4.4**
Std. Dev.			**0.46**	**0.22**	**0.17**	**0.37**	**2.25**	**1.02**	**0.15**	**0.29**	**0.65**	**3.28**
Variance			**0.42**	**0.5**	**-19.73**	**0.39**	**0.81**	**0.92**	**0.93**	**0.51**	**1.71**	**0.75**
Maximum			**2.25**	**0.82**	**0.25**	**1.66**	**8.88**	**5**	**0.53**	**1.15**	**3.1**	**15.25**
Minimum			**0.51**	**0.04**	**-0.72**	**0.24**	**0.07**	**0.5**	**-0.02**	**0.12**	**0**	**1.25**
# obs			**27**	**27**	**27**	**27**	**27**	**27**	**27**	**27**	**27**	**27**


JULY1993
Storm # 3 Rain = 0.96"

JULY 1994
Storm #14 Rain = 0.75"

AUGUST 1993
Storm #8 Rain = 3.89"

AUGUST 1994
Storm #24 Rain = 2.44"

JANUARY 1994
Storm #29 Rain = 1.02"

JANUARY 1995
Storm #45 Rain = 2.04"

Figure 7. Some typical hydrographs showing patterns for different seasons. Inflow is represented by the dark solid line and outflow by the thin line. The July data represent the highly localized short intense convection storms typical of the rainy season. The August storms depict the largest storm measured during each year. The January hydrographs show frontal storms when rain events of longer duration and less intensity occur.

detention areas immediately upstream of culverts was shown by a computer model to reduce peak flows throughout the watershed (Malcom 1978). A watershed approach using a variety of techniques would greatly improve stormwater management.

Another method to reduce flow downstream and improve water quality is to incorporate a stormwater reuse component into the wet detention pond system. Additional benefits derived from stormwater reuse are conservation of rainfall water, reduced demand for potable water for irrigation and enhanced groundwater recharge. To help engineers develop creative designs to capture and reuse runoff, water reuse volume charts (REV) have been developed for southwest Florida (Harrison 1993) and other geographical areas (Wanielista and Yousef 1993). Another advantage of stormwater reuse is the ability to increase annual treatment efficiency to meet the 80 percent pollution removal goal of the state water policy. For example, using the REV charts a wet detention pond with 60 percent treatment would require the reuse of 50 percent of its average annual runoff to obtain a total average annual treatment efficiency of 80 percent (Harrison 1993).

Water Quality for Potential Pollutants

To compare the efficiency of the three different designs for removing pollutants, composite flow weighted water quality samples were collected at the inflow, outflow, and rainfall for almost all storms from June through January of each year. Pollution removal was calculated by two methods, one using concentrations and the other using mass loads. Concentrations for each storm were also compared to State of Florida water quality standards.

Concentrations

Concentrations of constituents for every storm sampled during the three years with summary statistics are listed in Appendix I. Average values for the three pond designs are shown in Table 6. When the average concentrations for each constituent are compared by year, there is almost always less concentration at the outflow when compared to the previous year in spite of the fact that concentrations often increased at the inflow. The increase at the inflow can be attributed to construction activities during 1993 and 1994. Other aspects which increased pollutant concentrations at the inflow were the removal of part of the ditch that provided pre-treatment before stormwater enters the pond plus fertilizer and weed control applications to the grassed areas.

Although in most cases the amount of pollution in the effluent was reduced by increasing the residence time from two to five days, the changes were not statistically significant with the possible exception of inorganic nitrogen. Nitrate plus nitrite showed a large reduction at the inflow, so this may have also improved concentrations at the outflow. The reduction at the inflow may have been caused by a leak in a water transmission line which may have diluted stormwater samples during part of the study. The significant increase in zinc measured in rainfall is attributed to the fact that the rainfall collector was moved closer to the highway in a more exposed location after 1990.

Table 6. A wet detention pond was altered to test three residence times. Water quality samples were collected on a flow weighted basis for the majority of storms that occurred from June through January of each storm year. Rain is the average concentration found in rainfall, inflow represents the average concentration measured at the inflow, and the outflow is the average concentration at the outflow.

CONSTITUENTS	UNITS	1990 2-DAY RESIDENCE TIME (1)			1993 5-DAY RESIDENCE TIME (2)			1994 14-DAY RESIDENCE TIME (3)		
		RAIN	INFLOW	OUTFLOW	RAIN	INFLOW	OUTFLOW	RAIN	INFLOW	OUTFLOW
AMMONIA-N	MG/L	0.224	0.083	0.068	0.156 --	0.077 --	0.05 *	0.202 --	0.123 *	0.035 --
NITRATE+NITRITE-N	MG/L	0.289	0.24	0.09	0.283 --	0.096 **	0.032 *	0.344 --	0.396 *	0.062 --
ORTHO-PHOSPHORUS	MG/L	0.033	0.336	0.108	0.01 --	0.248 --	0.084 --	0.01 --	0.305 --	0.027 **
TOTAL PHOSPHORUS	MG/L	0.072	0.4	0.176	0.07 --	0.651 --	0.164 --	0.012 *	0.497 --	0.053 **
ORGANIC NITROGEN	MG/L	0.305	1.025	1.002	0.341 --	1.089 --	0.823 --	0.188 --	1.09 --	0.62 *
T. SUSPENDED SOLIDS	MG/L	ND	28	11	ND n	45 --	14 --	ND n	131 **	7 **
TOTAL ZINC	uG/L	45	51	31	93 *	25 --	21 --	72 --	81 *	14 *
TOTAL IRON	uG/L	51	555	396	70 --	1517 --	463 --	71 --	3200 *	220 *
TOTAL CADMIUM	uG/L	0.3	0.5	0.6	0.44 n	BD n	BD n	BD --	BD *	BD **
TOTAL COPPER	uG/L	ND	ND	ND	1.68 n	2.59 n	2.83 n	4.01 **	6.52 **	3.96 --
TOTAL LEAD	uG/L	ND	ND	ND	BD n	BD n	BD n	BD --	5 *	BD --
TOTAL MANGANESE	uG/L	ND	ND	ND	2.2 n	33.4 n	10.2 n	2.4 --	31.1 --	10.3 --
T. ORGANIC CARBON	MG/L	ND	ND	ND	ND n	15.23 n	10.9 n	ND n	14.78 --	8.65 **
HARDNESS	MG/L	ND	ND	ND	1 n	175 n	143 n	1 --	197 --	214 **

(1) 20 to 22 storm events sampled. Below normal rainfall.
(2) 18 to 22 storm events sampled. Below normal rainfall.
(3) 37 to 42 storm events sampled. Average rainfall.
ABBREVIATIONS: Significant differences compared to the previous year.
-- = not significantly different from the year before
* = significant difference at the 0.05 level
** = significant difference at the 0.01 level
n = test not performed
BD = Below laboratory detection limit
ND = Data not available

The most impressive results were seen using the 14-day residence time criteria. Despite greater concentrations at the inflow, almost all the major pollutants at the outflow were reduced by significant levels from those measured during the previous year when the residence time was five days. The exception was nitrogen. High inflow levels of inorganic nitrogen from the fertilizer application apparently increased levels at the outflow, although concentrations are still lower than in 1990. Lead, copper and cadmium were measured at such low concentrations that differences were difficult to quantify reliably (BDL = 75 to 95% of samples).

The treatment efficiency of constituent removal was improved by the 14-day residence time design (Figure 8). Using these criteria, the reduction of pollutants from the inflow to the outflow usually met the 80 percent reduction goal specified by the State Water Policy (Chapter 62-40 FAC). These efficiencies are even better when calculated for loads which is the method recommended in the state water policy and those load reductions will be discussed below.

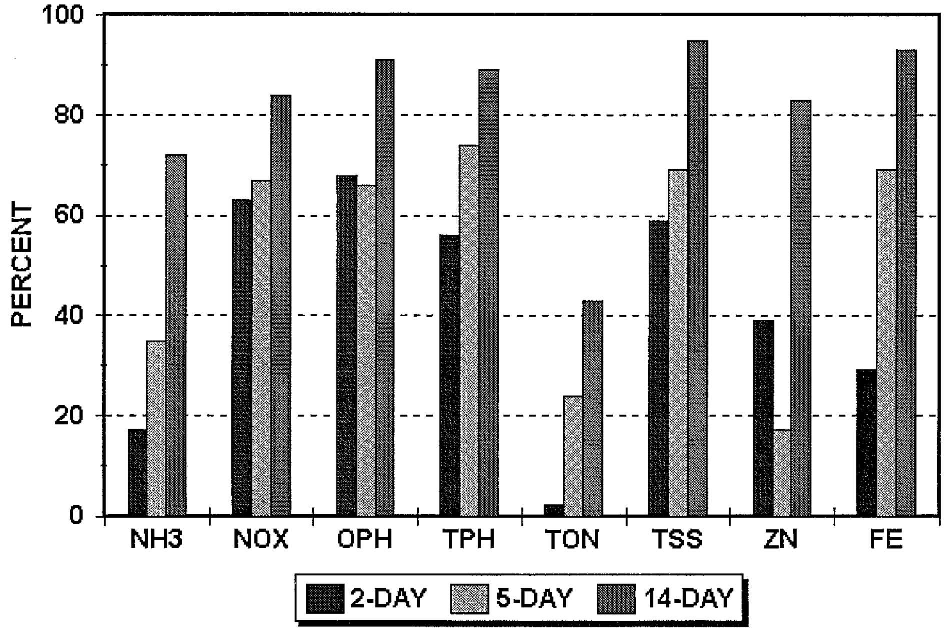


Figure 8. Comparison of percent reduction of pollutants for three residence times. Removal efficiency is calculated from event mean concentration measured at the inflow and outflow during storm events. Abbreviations are identified in Appendix R.

Mass Loading

Load removal gives greater weight to large storms as well as improvements caused by additional time for water losses through seepage and evapotranspiration; while reduction in pollutants calculated from concentrations gives equal weight to all storms and indicates the average removal of pollutants by sedimentation and physico-chemical processes. The event mean concentration is appropriate for many applications such as estimating the impact of specific storm events in rivers and lakes, but when cumulative effects are important, mass loading is more appropriate. Mass loading was calculated over the time period of this study for each year and includes stormwater volume in the calculations. Data for all the storm events sampled can be found in Appendix J and the summarized data are in Table 7. Storm volumes demonstrate the differences observed between years depending on the amount of rainfall.

Storm volumes and thus loads for each year were quite different with over twice as much flow in 1994 as in 1990. According to SWFWMD's Data Collection Department, 1990 was the third driest one-year period based on records going back to 1915. The severe drought conditions in 1990 and the below average rainfall in 1993 affected evapotranspiration and groundwater movement. The percent efficiency for storm volumes (Table 7) represents the amount lost by evapotranspiration and net seepage. The samples collected during December of 1993 were not used because of a leak in a broken water pipe which helps explain the discrepancies between total volumes and the volume for storms sampled in 1993. Some explanations for the reduction in water lost to the system from over 38 percent in 1990 to around 17 percent in 1994 include the following:

1. More vegetation in the pond in 1990 resulted in greater losses by evapotranspiration which can exceed evaporation.

2. The higher water table measured during 1993 and 1994 reduced the radial groundwater loss since this is greater when the water table is low and relatively small or reversed when the ground is saturated.

3. Two low areas contributed some unmeasured inflow to the pond during extreme events in 1994.

4. Backwater from the receiving waters (>15.08 NGVD the control elevation) may have held levels high and thus affected flow calculations for storms 8, 9 and 12 in 1993; and storms 13, 24 and 33 in 1994 (see appendices E and F). The receiving waters were never measured higher than 15.00 NGVD in 1990.

Table 7. Total loads and storm volumes for each year (June through January). RAIN=constituent load falling directly on the wet-detention pond. Percent Efficiency includes rainfall plus inflow as an input. INFL=inflow loads, OUFL=outflow loads, ND=no data. Less than (<) indicates averages below the detection limit and efficiencies are not exact.

JUNE THROUGH JANUARY CONSTITUENT LOADS	1990 (1)				1993 (2)				1994 (3)			
	RAIN	INFL	OUFL	%EFF	RAIN	INFL	OUFL	%EFF	RAIN	INFL	OUFL	%EFF
STORM VOLUMES												
Total Volume (cu ft) *	37733	222194	173657	41	52297	401359	336374	30	100727	478526	474033	18
Volume for storms used(cu ft)	24068	178628	140632	38	34755	332231	307367	17	76383	384498	386919	16
% Sampled **	64	80	81		66	83	91		76	80	82	
CONSTITUENT LOADS												
Total Suspended Solids (grms)	1701	134505	39641	71	2121	402167	133999	67	ND	2060220	130662	94
Total Organic Nitrogen (grms)	172	4738	3455	30	384	10813	9551	15	389	14169	7129	51
Ammonia Nitrogen (grms)	138	404	251	54	145	578	947	-31	373	2683	291	90
Nitrate+nitrite (grms)	154	1084	440	64	244	940	465	61	684	3262	469	88
Ortho-phosphate (grms)	15	2086	641	69	7	2230	1354	39	18	5315	437	92
Total Phosphorus (grms)	39	2465	941	62	42	4947	2121	57	31	8369	835	90
Total Zinc (grms)	29	208	104	56	76	198	186	32	127	1015	149	87
Total Iron (grms)	37	2379	1443	40	72	15017	3777	76	130	53164	3445	94
Total Cadmium (grms)	0.2	2.9	1.4	55	0.48	<1.76	<1.31	~42	<0.40	<4.21	<0.61	~87
Total Copper (grms)	ND	ND	ND	ND	2.08	23.96	25.66	1	7.85	80.32	39.6	55
Total Manganese (grms)	ND	ND	ND	ND	1.95	264.8	103.3	61	4.5	464	100	79
Total Lead (grms)	ND	ND	ND	ND	ND	ND	ND	ND	<1.15	82.96	<6.97	~92
Total Hardness (grms)	ND	ND	ND	ND	658	1255483	1139818	9	191	190079	210195	-10
Total Organic Carbon (grms)	ND	ND	ND	ND	ND	ND	ND	ND	ND	144477	83750	42

* Percent efficiency for water volumes represents the amount of rain and flow measured entering the wet-detention pond which was not measured leaving the pond at the outflow. These losses represent evapotranspiration and net seepage.

** Not all inflows and outflows were sampled caused by missed storm events and storms which didn't produce enough flow to constitute a sample. This was especially true for rainfall directly on the pond, which often didn't produce enough rain to cause flow but the amount is included here as part of the total "volume" of rainfall and accounts for including only about 60% of total rainfall during drought years.

(1) 20 to 22 storms sampled. Low rainfall. (2) 18 to 22 storms sampled. Low rainfall. (3) 37 to 42 storms sampled. Average rainfall.

The percent efficiency for pollutant removal shows at least a 20 percent improvement by using the Conservation Wet Detention criteria as shown by the 1994 data when compared to the earliest design represented by 1990 (Table 7). Load efficiency was not improved between 1990 and 1993, although the residence time had been increased from two to five days and the average depth and thus the volume of the permanent pool had been increased from 3,000 to 20,000 cubic feet. The lower efficiencies in 1993 were caused by one extreme storm event (storm #8) where 3.89 inches of rain fell during one week which had a total of 7.68 inches. At the outflow of the pond, this enormous washout effect, where stormwater had little time for treatment, produced 28 percent of the total flow for the entire study period (from June through January) and an even larger percentage of total constituent loads. For example, at the outflow, loads from this one storm compared to total loads from all 22 storms were: ammonia (77%), nitrate + nitrite (56%), organic nitrogen (44%), ortho-phosphate (45%), total phosphorus (39%), suspended solids (38%), zinc (32%), and copper (46%). The years 1990 and 1994 had no comparable extreme rain events. This indicates the need for examining stormwater impacts using extreme events which may be much more devastating to the ecosystem than is shown by using averaged values.

Mass loading efficiency using the Conservation Wet Detention criteria almost always met the 80 percent removal goal set by the State Water Policy (Chapter 62-40 FAC). Two exceptions which failed to meet the goal were total organic nitrogen (51%) and total organic carbon (42%). Total organic carbon results are not comparable since those samples were collected as a grab sample after storm events while other samples were composite samples. It will always be difficult to remove organic nutrients in wetlands such as this one where high primary productivity generates organic matter. It should be noted that the greater pollutant removal for most constituents was accomplished in spite of the fact that the volume of water lost through evaporation and seepage out of the pond decreased in 1994. Water loss is usually an important mechanism for the net reduction of pollutant loads and the fact that removal for most pollutants was still over 80 percent reflects the fact that concentrations in 1994 were usually significantly lower.

Comparison to Water Quality Standards

Another measurement to determine if water discharged from stormwater systems met state water quality goals is to compare the data to state standards. In February of 1992, the Florida Department of Environmental Protection (DEP) changed the method for determining the surface water standards considered safe for fish and wildlife. The major change incorporated the use of water hardness to compute the new standard since soft water increases the toxicity of some metals to organisms. For these metals, new rules produce a unique standard for each individual sample dependent on the natural logarithm of water hardness. The concentration of each sample (value) is listed with its unique standard in Tables 8 and 9. If a concentration is above the standard, laboratory or other tests have demonstrated it is detrimental for the propagation of aquatic species or the maintenance of a healthy, well-balanced population of fish and other aquatic organisms. All standards express the maximum

Table 8. Water quality results compared to State of Florida Class III Water Quality Standards (Chapter 62-302.530) in 1993. D.L.=Laboratory Detection Limit, na=data not available. Numbers in bold lettering exceed standards considered safe for fish and wildlife. Data are for June 1993 through January 1994. The standard for iron is <1000 ug/l.

1993	Cadmium (ug/l) D.L.=0.3				Copper (ug/l) D.L.=0.1				Lead (ug/l) D.L.=2.0				Zinc (ug/l) D.L.=10				Iron (ug/l) D.L.=30		Hardness (mg/l) D.L.=0.02	
Storm Number	inflow value	inflow std.	outflo value	outflo std.	inflow value	inflow std.	outflo value	outflo std.	inflow value	inflow std.	outflo value	outflo std.	inflow value	inflow std.	outflo value	outflo std	inflow value	outflow value	inflow value	outflow value
1	0	1.6	0	1.4	2.3	20.5	6	16.9	0	7.2	0	5.4	24	183	5	151	**1844**	15	190	152
2	0.5	1.1	0.2	1.6	9.8	13.1	2.6	20.1	**12.6**	3.7	0	7	64	118	29	179	**6648**	792	113	186
3	0	1.2	0	1.5	4	14.9	4	18.3	0	4.5	0	6.1	39	133	22	164	**3082**	**2834**	131	167
4	0	1.5	0.3	1.2	5.6	19	2	14.9	4.6	6.4	0	4.5	46	169	21	133	**1581**	456	174	131
5	0.1	1.7	na	na	2.8	20.8	na	na	1	7.4	na	na	32	186	na	na	**1205**	na	194	na
6	0	1.7	na	na	0.7	20.8	na	na	0.6	7.4	na	na	8	186	na	na	533	na	194	na
7	0.6	1.2	0.2	0.8	3	14.2	4	8.6	**5**	4.2	1.4	2	25	127	25	77	**2569**	922	124	69
8	0.2	0.7	0.1	1.1	3	7.6	4.8	13.2	0.7	1.7	1.1	3.8	2	69	24	118	**1474**	415	60	114
9	0.2	1.1	0.2	1.3	3	12.9	2.3	16.1	**3.6**	3.6	1.7	5.1	23	116	26	144	**1898**	352	111	144
11	0.3	1.9	0.2	1.4	0	24.2	3.1	16.9	0	9.2	0.7	5.4	12	215	23	151	872	283	231	152
12	0.2	1.5	0.3	1.2	0	19.3	0.1	14.1	0	6.6	2.2	4.1	18	172	17	126	642	367	177	123
13	0.1	1.2	0	1.3	2	13.9	1.4	16	**4.6**	4.1	0.8	5	20	125	39	143	**1823**	389	121	142
14	0.1	1.2	0.2	1.3	4.3	14.4	4.8	16.1	3.4	4.3	1.4	5	34	129	34	144	**2026**	352	126	143
15	0.1	0.8	0.1	1	2.4	9.4	2.9	12.2	**2.2**	2.2	0.6	3.3	28	84	15	110	**1257**	458	76	104
16	1	1.3	0.1	1.2	3.5	16.4	1.7	14.1	2.4	5.2	0.9	4.1	36	147	15	126	905	205	147	123
17	0.1	1.6	0.1	1.1	2.2	20	0.3	13.4	1.9	7	1.1	3.8	24	179	9	120	379	177	185	116
18	0	2	0.1	1.3	0	25.8	7	15.3	1.2	10.2	2	4.7	21	230	6	137	711	117	249	135
19	0	2	0.1	1.2	2	25.5	1.3	14.9	1.4	10	1	4.5	19	227	5	133	597	165	246	131
20	0.1	1.4	0.2	1.6	2.1	17.8	1	20.5	0	5.8	0	7.2	21	159	23	183	356	149	161	190
21	0.1	3.6	0.3	1.9	1	50.2	2	23.9	0	27.4	0	9.1	20	444	68	213	213	161	543	228
22	0	2.2	na	na	1.3	28.9	na	na	0.2	12.1	na	na	28	257	na	na	166	na	285	na
23	0	1.9	na	na	2.8	24.9	na	na	0.2	9.6	na	na	14	222	na	na	112	na	239	na
24	0	1.9	0	1.5	0.1	24.1	0	18.7	0	9.2	0	6.3	20	215	10	167	82	101	230	171
25	0.1	1.9	0	1.5	0	24.9	0	19.1	0	9.6	0.2	6.5	22	222	20	170	70	95	239	175
26	0	1.9	0	1.6	0	25	0	19.8	0.1	9.7	0.2	6.9	25	223	17	177	43	93	240	183
27	0.2	2	0	1.6	0	25.2	0	19.8	0.1	9.9	0.3	6.9	19	225	15	177	50	134	243	183
28	0	2	0.1	1.7	0	26.4	0	21.5	0.5	10.5	0	7.7	26	235	16	192	98	97	256	201
29	0	1.9	0	1.6	1	24	1	20	0.8	9.1	0.2	7	17	214	4	179	417	140	229	185
30	0.1	1.1	0.1	1.4	2.3	12.7	4.4	16.7	**5.5**	3.6	1.2	5.3	28	114	14	149	**2351**	508	109	150

Table 9. Water quality results compared to Class III Water Quality Standards (Chapter 62-302.530) in 1994. D.L.= Laboratory Detection Limit. Numbers in bold lettering exceed standards considered safe for fish and wildlife. Data are for June 1994 through January 1995. The standard for iron is a constant 1000 uG/l.

1994	Cadmium (ug/l) D.L.=0.3				Copper (ug/l) D.L.=0.1				Lead (ug/l) D.L.=2.0				Zinc (ug/l) D.L.=10				Iron (ug/l) D.L.=30		Hardness (mg/l) D.L.=0.02	
Storm Number	inflow value	inflow std.	outflo value	outflo std.	inflow value	inflow std.	outflo value	outflo std.	inflow value	inflow std.	outflo value	outflo std.	inflow value	inflow std.	outflo value	outflo std.	inflow value	outflow value	inflow value	outflow value
2	0.3	3.6	0.1	2.7	4.6	41.3	1.4	39.6	0	20.5	0	19.2	25	366	12	351	723	255	432	411
3	0.3	1.3	0	2.6	3.8	14	1.2	30.8	**5.9**	4.1	0	13.3	37	125	12	274	**4616**	207	122	307
4	0.1	2.3	0.1	2.7	3.4	25.1	3.5	28.8	0.1	9.7	0	12	30	223	10	257	851	135	241	284
5	0	2.3	0	2.6	3.2	25.7	1.2	30.3	0.6	10.1	0.1	12.9	48	229	32	270	**1159**	185	248	301
6	0.4	1.4	0.1	2.5	3.5	14.5	1.9	29.4	3.9	4.3	0	12.3	40	130	13	261	**3375**	165	127	290
7	0.1	1.6	0.1	2.6	5.4	17.3	4.4	28.4	0	5.6	1.4	11.7	56	154	17	253	**6511**	151	156	279
9	0.2	1.5	0.1	2.3	7.7	16.1	0.5	29	2.7	5.1	1.3	12.1	40	144	15	258	253	268	144	286
12	0.1	2.4	0	2.4	2.7	26.2	3.7	25.3	1.9	10.4	1.1	9.9	39	234	20	226	820	196	254	244
13	0.2	1.6	0	2.2	4	17	4.4	26.1	2.3	5.5	0.4	10.4	43	152	19	233	**1091**	299	153	253
14	0.4	1.1	0.1	2.1	5.4	11.9	4.4	24.4	7.4	3.2	0	9.4	71	107	14	218	**3176**	156	101	234
15	0.3	1.2	0.4	2	9.1	12.6	7.4	23.3	**10.5**	3.5	0	8.7	68	113	25	208	**5707**	233	108	221
16	0.4	1.4	0	2.1	7.4	14.3	5.4	22.4	**9.6**	4.2	0	8.2	65	128	13	200	**6358**	276	125	211
17	0.2	2.3	0.05	2.1	7.3	26	6.7	23.2	0.9	10.3	0	8.7	40	231	17	207	404	347	251	220
18	0.3	1.6	0	1.9	10.1	16.7	12.6	22.7	**6**	5.3	0	8.4	**615**	149	15	202	**4354**	184	150	214
19	0.4	2.1	0	2.1	6.2	22.9	12.5	21.3	5.2	8.5	0	7.6	**545**	204	12	190	**8174**	148	217	199
20	0.2	1.1	0	2	**11.9**	11.7	3.1	23.1	**3.6**	3.1	0	8.6	70	105	11	206	**1096**	156	99	219
21	0.2	1.6	0	2	5.9	17.8	9.4	22.4	1.7	5.8	0	8.2	46	159	10	200	**1539**	135	161	211
22	0.1	2.4	0	2	16.9	27.2	8.1	21.7	0.9	11	0	7.8	48	242	6	193	778	101	265	203
23	0.2	1.9	0.2	1.7	7.3	20.2	2.7	21.9	4.8	7.1	0	8	7	180	3	196	**3008**	69	187	206
24	0.9	1	0	1.6	**17.7**	10	8.1	18.9	**23**	2.5	0.3	6.4	**111**	90	25	169	**16175**	987	82	173
25	0.3	1.8	0.1	1.7	6.8	19.4	3.4	17.3	**8.3**	6.6	2.5	5.6	50	173	12	154	**4127**	500	178	156
26	0.4	1.6	0	1.9	6.5	17.1	2.1	17.9	4.3	5.5	1	5.9	29	153	10	160	**2190**	258	154	162
27	0.2	3.7	0	1.9	3.4	42.8	1.4	20.3	1.8	21.6	0	7.1	41	380	4	181	718	207	451	188
29	0.1	2.1	0	1.9	2.9	23.4	2.2	20.2	2	8.8	0.1	7.1	27	208	7	180	**1265**	145	222	187
30	0.5	1.8	0	1.9	8.7	19	1	20.7	**16.9**	6.4	0	7.3	79	169	5	185	**9084**	150	174	193
31	0.4	1.6	0.1	1.8	3.4	16.7	4.8	20.5	**10.7**	5.3	0.1	7.2	37	149	17	183	**4722**	169	150	190
32	0.6	2.2	0.1	1.8	11.5	24.6	3.2	20.1	0.4	9.5	0.4	7	49	219	19	179	683	224	236	186
33	0	2.6	0	1.6	7.2	29.5	1.7	19.5	0	12.4	0	6.7	66	262	15	174	858	466	291	180
34	0.26	1.5	0.09	1.6	4.4	16.1	2.6	17	**5.8**	5	2.1	5.5	**202**	144	10	152	**3433**	29	143	153
35	0.2	1.6	0.2	1.6	4.6	16.6	3.3	16.7	4.8	5.3	0.6	5.3	29	149	9	149	**2085**	137	149	150
36	1.05	1.5	0.1	1.8	11.1	15.5	3.2	16.8	**18.2**	4.7	1.7	5.4	88	138	8	150	**11127**	511	137	151
37	0.2	1.9	0.1	2	4	20.6	4.7	19.7	2.5	7.3	0.8	6.8	41	184	12	176	**1347**	152	192	182
38	0.5	2.2	0	1.8	4.3	24.3	3.4	21.7	4.1	9.3	0.5	7.8	7	216	22	193	**11189**	245	232	203
39	0.1	2.3	0	1.8	3.3	26	1.9	19.9	3.2	10.3	0.3	6.9	74	232	5	178	**1626**	132	252	184
40	0.2	1.4	0	2	4.1	15	0.6	19.1	**5.5**	4.5	0.7	6.5	59	134	6	170	**2104**	192	132	175
41	0.2	1.8	0	2.1	7.8	19.3	2.6	22.4	2.5	6.6	0.4	8.2	32	172	12	200	229	62	177	211
42	0	3.6	0.1	2	12.5	41.1	5.4	22.9	3.3	20.4	1.5	8.5	111	365	14	204	444	104	430	217
43	0.2	2.5	0.1	2.1	1	27.6	5.2	21.8	3.6	11.3	1	7.9	90	246	31	195	4	97	270	205
44	0.2	1.9	0	1.8	12.6	21.3	4.6	23.1	3.7	7.6	0.9	8.6	87	190	21	206	336	84	199	219
45	0.34	1.3	0	1.7	3.5	13.7	2.7	19.4	**8.6**	4	0.3	6.6	76	123	8	173	**3578**	114	119	178
46	0.3	1.9	0	1.8	4.3	20.4	0.4	17.9	2.8	7.2	0.8	5.9	50	182	12	160	580	449	189	162
47	0.1	1.7	0.1	0	2.5	18.7	3.6	19.9	5.6	6.3	2.3	6.9	47	167	29	178	**2521**	171	171	184

concentrations which are not to be exceeded at any time (Chapter 62-302). Except for iron in one sample, no metals were discharged from the wet detention pond above the standard for 1993 or 1994, however, stormwater entering the pond exceeded standards for copper (5%), lead (33%), zinc (69%) and iron (66%) in 1994; and for lead (21%) and iron (41%) in 1993. This demonstrates the positive effect that both configurations of the wet detention pond had on downstream biota.

The result for percent exceedences of standards measured discharging from the wet detention pond is markedly different from previous studies conducted by the District which used the old state water quality standards (Kehoe 1992, Rushton and Dye 1993, and Kehoe, Dye and Rushton 1994). Using the old criteria, the zinc standard was lower at a constant 30 ug/l than the present calculated standard using hardness as part of the formula. In contrast, the lead and copper standards were higher at a constant 30 ug/l than the new calculated standard. Using the older criteria none of the water quality samples at the inflow would have exceeded standards for lead or copper in 1993 and 1994 but a higher percentage of samples would have exceeded standards for zinc. The iron standard stayed the same under both rules at 1000 ug/l, however, iron at the inflow was measured at much higher levels in 1993 and 1994 than in 1990.

Nutrient Levels and Eutrophication

Although no numerical water quality standards have been set for nitrogen and phosphorus, these constituents are of concern since excessive levels cause algal problems in receiving waters. When compared to samples collected from 781 Florida lakes (Friedemann and Hand 1989), discharge water from the wet detention pond during all three years had average values reported for total nitrogen lower than 60 to 80 percent of the monitored lakes. In contrast, phosphorus concentrations measured at the outflow of the pond in this study during 1990 and 1993 were lower than only 20 percent of the values reported for the Florida lakes measured, while during 1994, using the Conservation Wet Detention design, phosphorous levels were lower than 55 percent of the Florida lakes.

Some limnologists have tried to determine realistic concentrations for nitrogen and phosphorus that should provide acceptable water quality. According to Sawyer and Vollenweider (In Hall 1988, Daniel *et al.* 1994) nuisance blooms of algae can be expected to grow when levels of inorganic nitrogen (ammonia, nitrate and nitrite) exceed 0.3 mg/l and inorganic phosphorus (primarily ortho-phosphorus) exceeds 0.01 mg/l. For this study these values (see Table 6) were exceeded for nitrogen in rainfall for 1990 (0.513 mg/l), 1993 (0.439mg/l), and 1994 (0.546 mg/l). Although the averages in rainfall and at the inflow were higher than desired, the averages at the outflow of the pond were well below the threshold level for eutrophication of 0.30 mg/l during all three years (1990=0.158, 1993=0.116 and 1994=0.097 mg/l). Phosphorus concentrations in the Tampa Bay region are more difficult to evaluate since the region is naturally enriched in phosphate, but concentrations of ortho-phosphorus at the outflow are decreased to near the target level of 0.01 mg/l with increasing residence time. Specifically, average concentrations for each year at the outflow were 1990=0.108, 1993=0.084 and 1994=0.027 mg/l. Another way to evaluate the data is to compare the levels recommended for healthy streams by the U.S. Environmental Protection Agency (1986). The EPA suggests that a limit below 0.1 mg/l for total P should be low enough to maintain a healthy diverse ecosystem in flowing waters. This target level was achieved at the outflow for the 14-day residence time design (1990=0.176, 1993=0.164 and 1994=0.053). Nitrogen has been identified as the limiting nutrient in local waters and dilution from the better quality water discharged from permitted wet detention ponds is a good management strategy, since it reduces unacceptable nutrient levels to acceptable levels before discharge to the receiving waters and ultimately Tampa Bay.

Major Ions

In most open lake systems located in the humid regions of the world, the principal anion is carbonate. For waters with a pH range between 7 and 9, carbon is present primarily as the bicarbonate ion. This is the situation for both the inflow waters and the water in the pond in this study (Table 10). Another measure of ion concentrations is total dissolved solids (TDS) which include salts and organic residue. Livingstone (1963) suggests that the world's rivers contain an average of 120 mg/l of TDS, however, a much wider range exists for lakes. For example, oligotrophic (low nutrient) lakes average about 1.7 mg/l while eutrophic (high nutrient) lakes contain over 185 mg/l. Total dissolved solids were measured much higher than these levels in this study (Table 10) indicating highly productive eutrophic conditions which cause high levels of ions and salts. Total dissolved solids are not much affected by wetland processes and cannot be effectively reduced (Kadlec and Knight 1996) and this was the condition measured in this study with a similar range of concentrations measured at the inflow and outflow. Rainfall had low levels of TDS. In fresh water TDS can be inferred from conductivity (specific conductance) and the results of these measurements are also shown in Table 10. Although Chromium is a metal and not a major ion, it is also reported in Table 10 with its calculated standard since the results were reported from the laboratory along with the ions. It was never a problem pollutant at this particular site.

The ionic composition of inland waters is dominated by four major cations, calcium (Ca), magnesium (Mg), sodium (Na), potassium (K); and three major anions, carbonate (CO_3), sulfate (SO_4), and chlorides (Cl) (Wetzel 1975 and others). This ionic salinity is governed by runoff from parent rock material, atmospheric precipitation and the balances between evaporation and precipitation. Over large regions of the temperate zone, calcium bicarbonate dominance prevails in open lake systems, a pattern which is also consistent with the average concentrations found in the world's rivers (Wetzel 1975).

Table 10. Carbonates, dissolved solids, conductivity and chromium concentrations for selected storm events from June 1994 through January 1995. The chromium standard is given for comparison.

1994 MDL=MIN.DETECTION LIMIT=			DISSOLVED SOLIDS TDS=1.0 mg/l			HYDROXIDE mg/l as CaCO3			BICARBONATES mg/l as CaCO3			CARBONATES mg/l as CaCO3			CONDUCTIV. CND=1.0		CHROMIUM CR=4.7 ug/l value		CHROMIUM CR=ug/l Standard	
STORM NO	DATE	SAMP NO	TDSR	TDSI	TDSO	HYDR	HYDI	HYDO	BICR	BICI	BICO	CARR	CARI	CARO	CNDI	CNDO	CRIN	CROU	CRIN	CROU
2	6-14-94	40,050,406	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
3	6-15-94	40,070,809	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4	6-16-94	40,101,112	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5	6-17-94	40,131,415	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
6	6-20-94	40,171,816	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
7	6-21-94	40,192,021	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
9	6-29-94	10,262,527	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
12	7-06-94	10,434,241	•	•	•	•	•	0	•	•	•	•	•	•	•	•	•	•	•	•
13	7-10-94	10,454,644	25		343	•	•	•	•	•	83	•	•	0	•	•	•	•	•	•
14	7-18-94	10,504,948	75	169	346	•	0	•	0	61	81	0	0	0	•	•	•	•	•	•
15	7-20-94	10,535,152	15	148	163	•	0	0	•	79	75	•	0	0	226	230	4.4	5.8	220	396
16	7-21-94	10,545,556	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
17	7-24-94	10,575,859	•	•	343	•	•	0	•	•	94	•	•	0	•	472	•	0.0	•	•
18	7-28-94	10,636,465	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
19	7-30-94	10,686,667	100	225	305	•	0	0	•	218	76	•	0	0	320	443	44.2	1.8	390	364
20	8-03-94	10,717,069	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
21	8-06-94	10,747,372	19	236	306	•	0	0	•	117	92	•	0	0	326	432	7.9	0.6	306	382
22	8-07-94	10,777,675	•	•	•	•	0	•	•	172	•	•	0		521		1.9		460	•
23	8-08-94	10,807,879	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
24	8-10-94	10,838,182	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
25	8-11-94	10,858,486	•	206	214	•	0	0	•	172	85	•	0	0	296	326	29.5	5.6	295	307
26	8-13-94	10,898,788	•	217	217	•	0	0	•	109	89	•	0	0	312	344	•	3.7	•	347
27	8-16-94	10,909,291	•	•	245	•	•	0	•	•	103	•	•	0	•	380	•	1.6	•	•
29	8-23-94	10,969,897	•	301	269	•	0	0	•	137	103	•	0	0	442	400	6.3	1.4	326	355
30	8-24-94	10,990,001	•	240	251	•	0	0	•	239	99	•	0	0	252	383	56.1	2.8	289	350
31	8-25-94	11,040,203	•	194	225	•	0	0	•	123	94	•	0	0	200	404	27.7	3.7	418	344
32	9-16-94	11,080,709	•	325	252	•	0	0	•	104	97	•	0	0	483	388	4.9	1.5	496	335
33	9-17-94	11,111,210	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
34	9-19-94	1116,dd,dd	•	189	205	•	0	0	•	93	91	•	0	0	294	311	22.0	2.3	287	289
35	9-25-94	11,242,325	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
36	9-27-94	1129,dd,dd	•	291	212	•	0	0	•	158	100	•	0	0	429	319	10.4	3.9	353	338
37	10-02-94	11,363,435	13	247	229	•	0	0	•	138	114	•	0	0	390	366	10.9	1.7	412	370
38	10-10-94	11,414,342	•	292	343	•	0	0	•	175	74	•	0	0	470	438	11.9	1.0	441	341
39	10-12-94	11,464,544	•	•	269	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
40	10-26-94	11,484,947	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
41	11-15-94	11,545,253	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
42	12-21-94	11,565,557	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
43	12-22-94	11,605,859	•	392	268	•	0	0	•	138	71	•	0	0	545	397	10.4	1.0	467	373
44	1-07-95	11,656,364	•	285	•	•	0	•	•	66	•	•	0	•	435	•	3.7	•	364	•
45	1-14-95	1173,dd,72	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
46	1-15-95	11,767,577	•	286	•	•	0	•	•	91	•	•	0	•	429	•	3.4	•	349	•

Distribution Patterns

The proportion of the major cations of surface waters of the world tend towards Calcium > Magnesium > Sodium > Potassium (Hutchinson 1975). This pattern was usually the same as measured in this study with average concentrations (mg/l) as follows (see Appendix K for all the data):

	1993	1994
	Ca > Mg > Na > K	Ca > Mg > Na > K
Inflow:	53 > 4.4 > 3.3 > 4.4	68 > 6.7 > 4.4 > 2.4
Outflow:	46 > 4.4 > 4.1 > 2.3	76 > 5.8 > 3.9 > 1.6

The averages for 1993 removed the data for storms 21 through 28 because of a leak from a potable water source. This different water quality input is clearly identified in Appendix K by the elevated concentrations of sodium, sulfur, magnesium, calcium, chlorides and the reduction of potassium.

The major anions are usually dominated by carbonates which appear mainly as bicarbonate > sulfate > Chloride. No carbonate data was collected for 1993, but in 1994 the wet detention pond appeared to follow the norm at the inflow and it is characterized as a bicarbonate water with average concentrations as follows:

	$HCO_3 > SO_4 > Cl$
Inflow:	132 > 90 > 6.8
Outflow:	90 > 126 > 3.9

For 1994, the data in Appendix K and L are graphed in figures 9 and 10 to determine patterns and processes which might be taking place. Figure 9 shows the flow-weighted concentrations for each storm and Figure 10 depicts the storms on a mass loading basis. Rainfall loads directly on the pond are also graphed, but are such an insignificant input that they are impossible to detect at this scale. Concentrations (Fig 9) demonstrate the wide fluctuations at the inflow and the much more constant values at the outflow. It appears that high concentrations of calcium and sulfate measured for the pond at the beginning of the study may be caused by construction activity which resulted in the release of constituents from the sediments since values are high at the beginning of the summer in July and August but show a lower concentration with time.

When mass loading, which relates concentrations to flows, are calculated the total mass is relatively constant between the inflow and outflow except for sulfates at the beginning of the summer (Fig 10). A useful property of some ions is their conservative nature which allows them to be used as tracers for estimating the infiltration of groundwater or indicate unmeasured inflow or outflow. The concentrations of magnesium, sodium, potassium and chlorides are relatively conserved and usually undergo only minor spatial and temporal

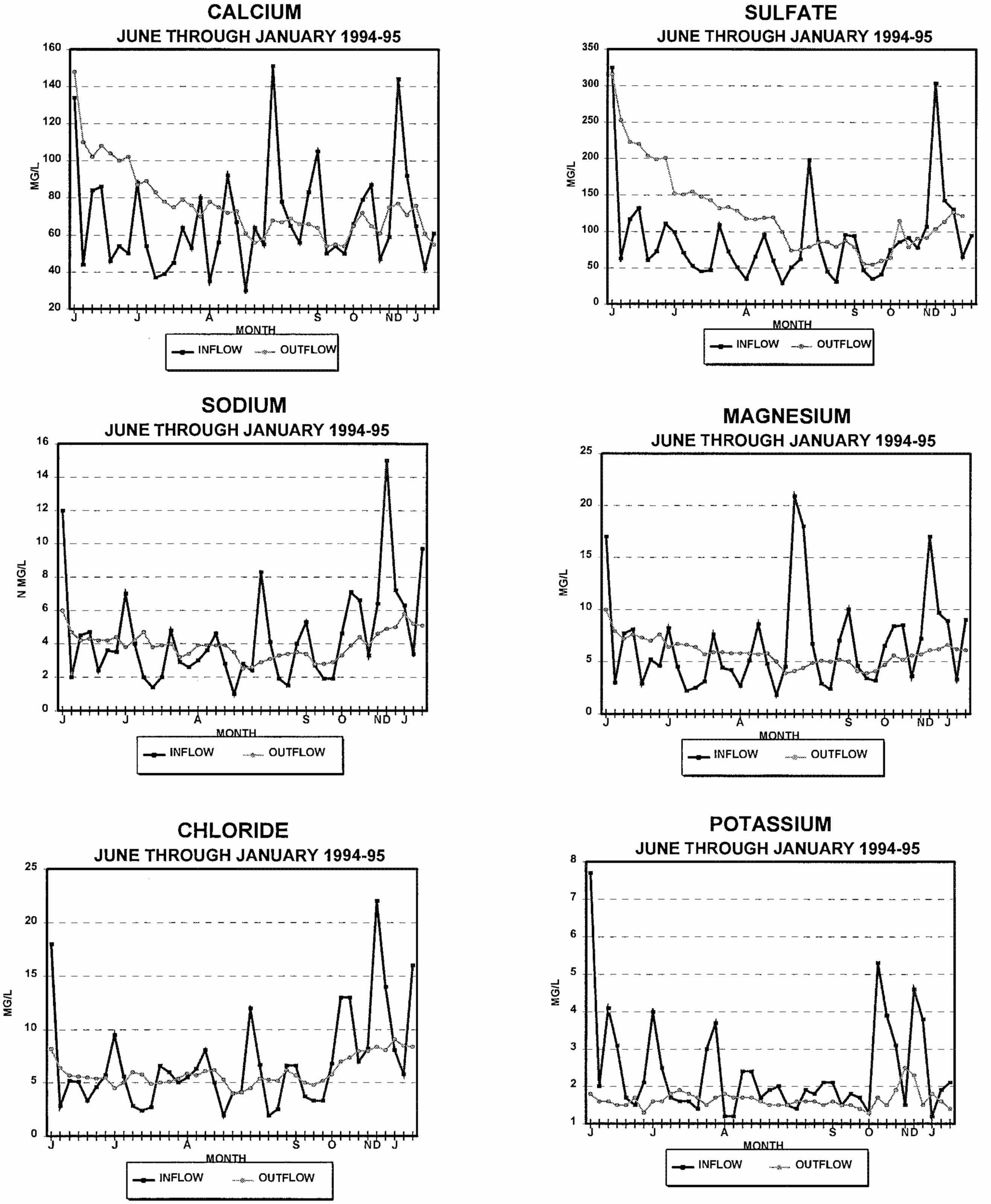


Figure 9. Comparison of flow-weighted concentrations for the major ions measured at the inflow and outflow for each storm event from June through January 1994-95.

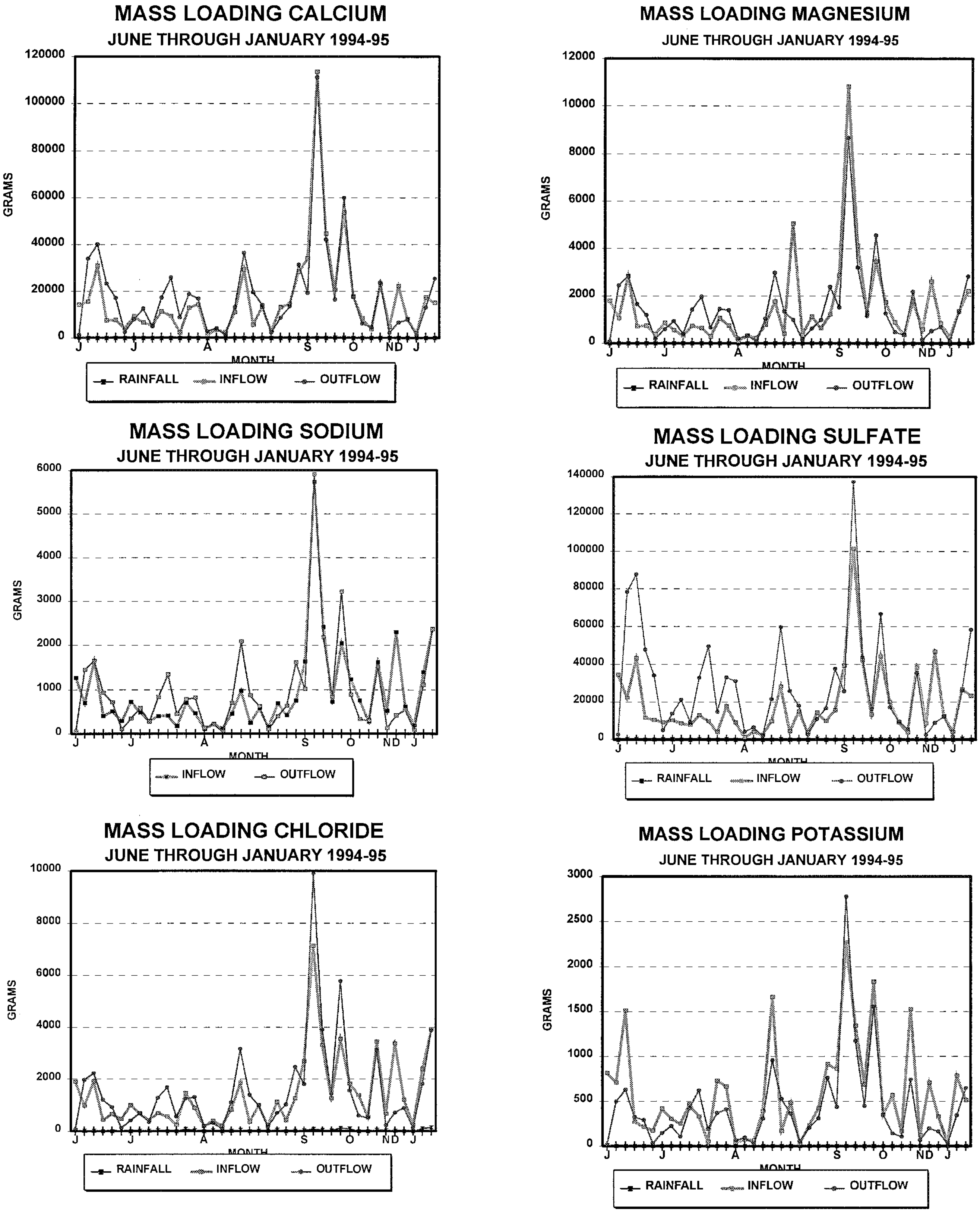


Figure 10. Comparison of mass loading for the major ions measured at the inflow, outflow, and in rainfall for each storm event from June through January 1994-95.

fluctuations (Wetzel 1975). Except for potassium, this pattern was observed in this study (Appendix L). For example when measured on a mass loading basis a variation of less than 15 percent was measured for magnesium, sodium and chloride. In contrast, potassium was reduced by about 30 percent and was apparently utilized by the rapidly colonizing plant community. These results indicate flow measurements are accurate to at least a precision of 15 percent and that groundwater inflow is not a major input to the system. A consistent discrepancy in the mass loading data for the first storm in December may indicate an error in measurement. Brief descriptions of processes affecting individual ion concentrations are discussed in the following sections.

Calcium (Ca)

Calcium and magnesium are the major ions causing water hardness. Florida hardwater lakes are calcium bicarbonate systems. These lakes ($>$20 mg Ca/l) undergo seasonal dynamics with lower calcium concentrations in summer as a result of the precipitation of calcium carbonate (Wetzel 1975). Calcium is biologically active providing nutrients for the biota, especially the shells of mollusks and bones of animals (Kadlec and Knight 1996). It is also important in the carbonate cycle where calcium is removed during photosynthesis along with carbon-dioxide and released during respiration in conjunction with carbonic acid. For systems in equilibrium the net effect is usually zero (Kadlec and Knight 1996). In addition calcium carbonate co-precipitates inorganic nutrients such as phosphorus and removes humic and other organic compounds by adsorption (Wetzel 1975). Calcium concentrations in inland waters range between 0.3 and 70 mg/l (Kadlec and Knight 1996). In this study the average concentrations of about 50 mg/l in 1993 and 72 mg/l in 1994 are at the high end of this range, probably explained by the unconsolidated sand laid down by high seas that once covered the area (Leighty *et al.*, 1958).

Certain algae have been correlated with differing concentrations of calcium and the relatively high levels of calcium in this system were thought responsible for the observed calcification of the alga *Chara* sp. observed in the pond during 1993. During this period calcium was reduced by 25 percent, while in 1994 with little *Chara* there was a net increase of 11 percent.

Magnesium (Mg)

Magnesium is much more soluble than calcium and rarely precipitates, as a result, the concentrations of magnesium are relatively conserved and fluctuate little (Wetzel 1975). Also since magnesium concentrations in surface water almost always exceed the requirements for plants and animals, wetlands can act as either a source or a sink. Inland surface waters have a magnesium concentration between 0.4 and 40 mg/l (Kadlec and Knight 1996). The yearly averages of 4.4 to 6.7 mg/l in this study fall near the low end of this range. Magnesium was reduced in the pond by 4 percent in 1993 and 15 percent in 1994.

Sodium (Na)

The monovalent cations sodium and potassium are involved primarily in ion transport and exchange (Wetzel 1975). Although they are functionally analogous in some of their properties, sodium is usually more important for the growth of marine organisms (Kadlec and Knight 1996). A threshold level of 4 mg Na/l is required for near optimal growth of several species, a concentration that is about the mean for numerous hard-water lakes (Wetzel 1975). The yearly averages for this study ranged from 3.3 to 4.4 mg/l which is close to the threshold level. Because most freshwater wetland species have low sodium requirements, sodium concentrations can be used as a conservative tracer for tracking groundwater discharges into wetlands. Concentration reductions of less than 11 percent and mass reductions of less than 7 percent in this study indicate very little groundwater influence.

Potassium (K)

Of the ions that are usually conserved (i.e., showing little change from the inflow to the outflow) potassium was the one exception with a reduction on a mass loading basis of 33 percent in 1993 and 27 percent in 1994. Potassium concentrations in surface waters typically range between 0.2 and 33 mg/l with an average for world rivers of about 3.4 mg/l (Kadlec and Knight 1996). This average is slightly above the 1.6 to 4.4 range found in this study.

One explanation for the reduction of potassium in the pond might be the rapid colonization of plants immediately after construction each year. Potassium ions are assimilated rapidly by plants but become available for re-solution when the plants mature and die, or when leaves and other parts are shed during the growing season (Hem 1985). Values may stabilize in future years after the pond reaches equilibrium. Also measurements in this study were made primarily during the growing season, before any massive die backs caused by freezing temperatures could have released potassium back to the water column.

Sulfate (SO_4)

The greatest difference between years as well as increases between the inflow and outflow occurred with the concentration of sulfates. The average concentration of sulfate increased from an average of 32 to 52 mg/l in 1993, to over twice that amount, an average of 90 to 126 mg/l in 1994. Also the concentrations were considerably higher than the 5 to 30 mg/l range reported as normal (Wetzel 1975). One probable source of sulfate is the sedimentary substrate which was disturbed when the pond was constructed. Often high-sulfate waters reflect the presence of old marine sediments and this is especially true when present as calcium sulfate (Cole 1979). Since both calcium and sulfate exhibit steadily declining concentrations during the first two months after construction in 1994 (Figure 9) this is a logical explanation.

Another source might be explained by the high concentrations of iron measured entering the pond at the inflow compared to the iron leaving the pond (see Table 6). This suggests the possibility of a chemical reaction producing sulfuric acid in the water column and the precipitation of ferric hydroxide. For 1994 this reaction would help explain the following differences in concentrations between the inflow and outflow: 1) Concentrations for iron were reduced 93 percent, 2) average sulfate concentrations increased 50 percent, and 3) as will be discussed later median pH at the inflow was 8.01 compared to 7.19 at the outflow.

Chloride (Cl)

Chloride ions do not enter into any significant oxidation/reduction reactions, form no important solute complexes at normal concentrations, produce few salts of low solubility, are not significantly adsorbed on mineral surfaces and play few vital biogeochemical roles (Hem 1985). The circulation of chloride ions in the hydrologic cycle are through physical processes, therefore the total mass of chloride is relatively constant, a characteristic that makes them the best ion to use as a tracer provided no significant atmospheric input from oceans or salt lakes. Since chlorides are a conservative ion they can be used to analyze some of the processes taking place in the pond (Figure 11).

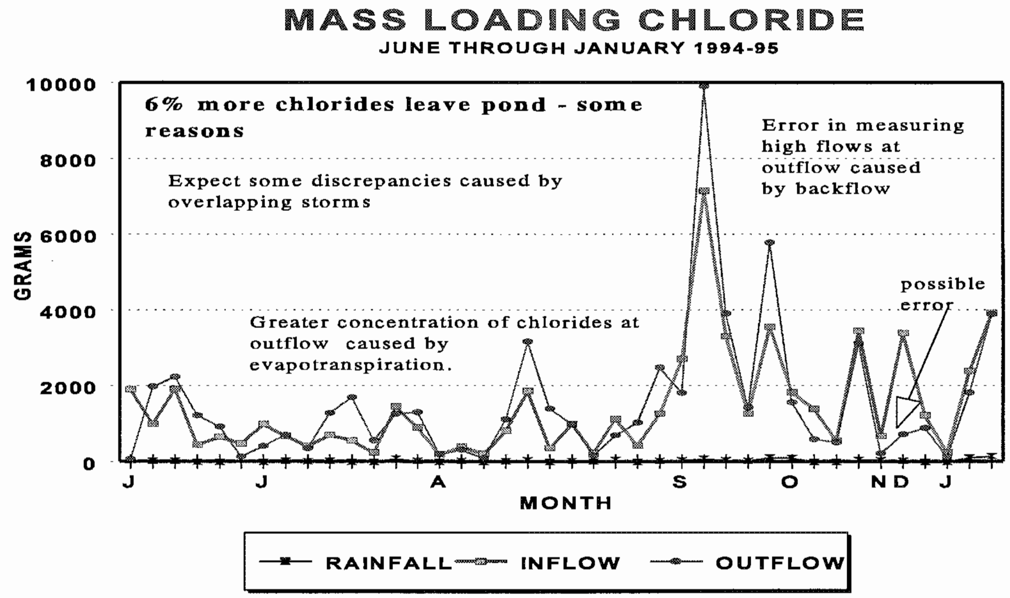


Figure 11. Comparison of chloride loads for each storm event from June through January 1994-5.

Although the study site is within 10 miles of salt water, it did not affect concentrations. Rainfall close to the ocean contains from 1 to 20 mg/l of chloride, but the concentration decreases rapidly as storms move over land. In the United States concentrations in rain are a few tenths of a milligram per liter (Junge and Werby 1958). In this study chloride in rainfall ranged from 0 to 4.0 mg/l indicating influence from the Gulf of Mexico during some storms. This small amount would explain about 2 percent of the input of chlorides to the wet-detention pond on a mass loading basis. About 6 percent more chlorides were measured leaving the wet-detention pond than entering at the inflow and in rainfall. And about 16 percent less water was measured leaving the pond. This mass balance suggests measurements for flow were fairly accurate and very little subsurface water entered the pond.

Field Parameters

Measurements of dissolved oxygen (DO), pH, temperature, oxidation reduction potential (ORP) and conductivity fluctuate on a daily cycle and are perturbed by rainfall events. These parameters were measured in this study using instruments that recorded data at two hour intervals for a week at a time. For comparison, data were collected in the wet detention pond near the inflow weir (INFLOW), in the permanent pool (MIDPOND) and immediately before water was discharged at the outflow (OUTFLOW). In the following section, an example of daily fluctuations as well as storm effects on field parameters is presented first and then individual parameters and differences between years are discussed. Graphs of all the actual measurements are shown in Appendix M.

Daily Fluctuations

The measurements for one week in September of 1994 demonstrates typical responses of field parameters to daily cycles and rainfall (Figure 12). Measurements responded to diurnal patterns by tracking the daily progress of light, temperature, respiration and related processes. In general, temperature, pH, dissolved oxygen and conductivity are similar at both the inflow station and the midpond station indicating relatively well mixed conditions in the permanent pool. During quiescent periods, before the rains began on September 24th, temperatures were measured much lower at the outflow station which is attributed to water flowing across 45 feet of littoral shelf. Dissolved oxygen is depleted and hydrogen ions increased (pH decreased) after flowing through the vegetation to the outfall station. The pH demonstrated less fluctuation at the outflow until influenced by stormwater, the former pattern is typical of areas with dense vegetation (Kadlec and Knight 1996). The data indicate two entirely different conditions in the pond which may have improved pollution removal by using both aerobic and anaerobic processes and different pH regimes. All three stations demonstrated large diurnal fluctuations for dissolved oxygen which is commonly associated with increased biological activity indicative of productive (eutrophic) systems. Some of the increased fluctuation can be attributed to the greater consumption of carbon dioxide and release of oxygen by algae.

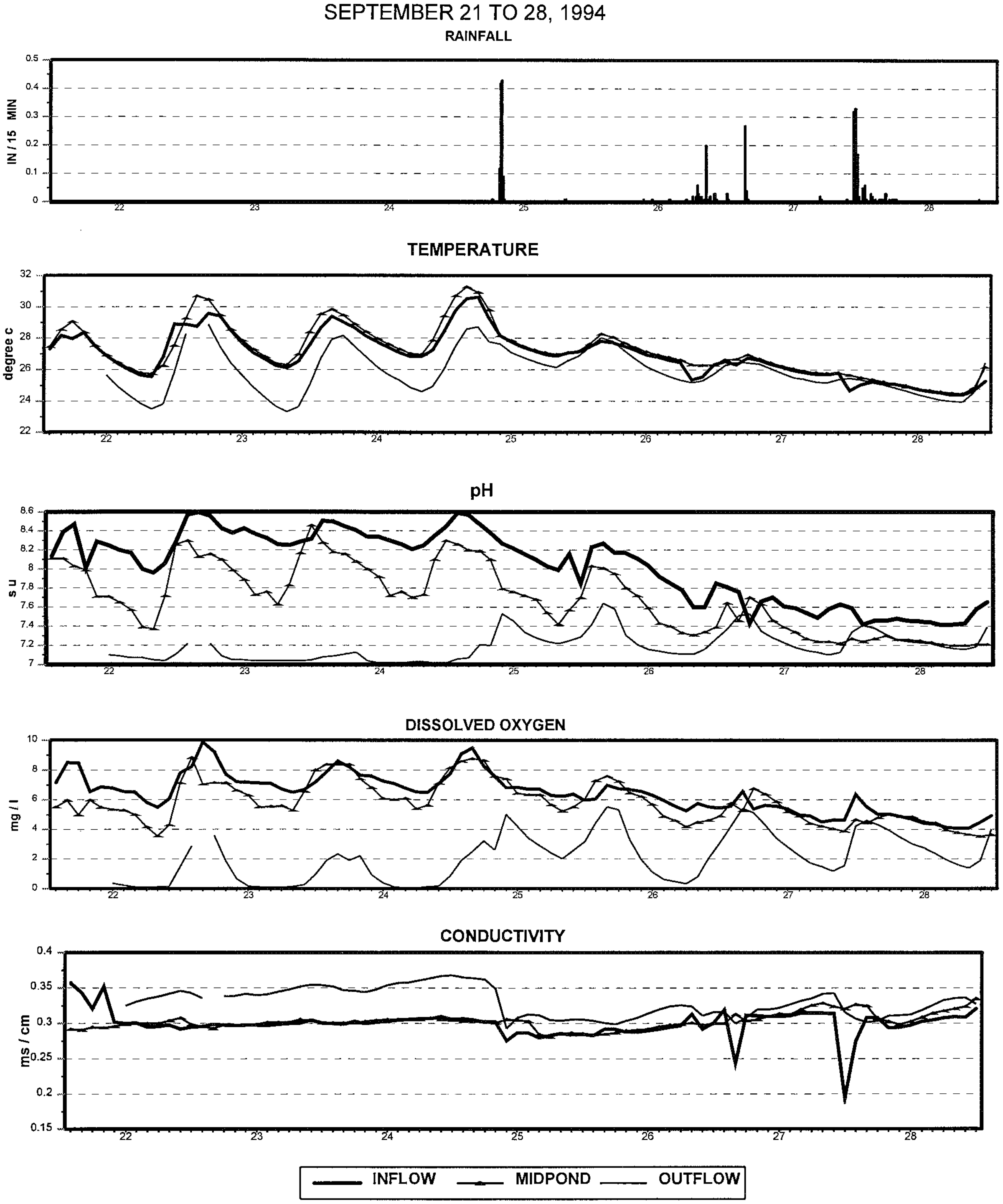


Figure 12. *In situ* measurements recorded for one week in September 1994 demonstrated typical responses to daily cycles and rainfall. Readings were made at two-hour intervals in the wet detention pond near the inflow, in the deep pool and at the outflow. See Appendix M for additional data.

Rainfall Effects

Rainfall decreased temperature and conductivity for all stations. In fact a sharp drop in conductivity is often seen during rain events, this pattern is especially apparent at the inflow station where the dilution by low conductivity rainfall is most obvious. During dry periods, the metabolism of the biota and evapotranspiration gradually raise conductivity levels. Rainfall decreased both pH and dissolved oxygen at the inflow and in the permanent pool where levels were higher; while rain events increased pH and DO at the outflow, presumably the effect of the stormwater passing through the system.

To look at individual parameters, the data for each week were summarized in Table 11 for all of the data presented in Appendix M. The averaged data compares the differences between stations and between years.

Temperature

In summer, temperatures at the outflow are two to four degrees centigrade cooler than in the pond or at the inflow but winter values appear to be higher demonstrating the moderating influence of vegetated wetlands on climate. Differences between years are caused by the fact that fewer measurements were taken during the winter in 1994.

pH

Wetland water chemistry and biology are affected by pH. For example, denitrifiers operate best in the range $6.5 < pH < 7.5$, while nitrifiers prefer $pH > 7.2$ (Kadlec and Knight 1996). This target range for denitrification was never met at the inflow or in the pond during this study, but average values between 7.0 and 7.5 were usually measured at the outflow. This indicates that most of the loss of nitrates in the system occurred on the littoral shelf. The pH values tended to be lower at the outfall station by about 0.5 pH unit (Table 11).

One strategy for improving stormwater systems may be designs which include a series of conditions featuring different pH and DO levels. Some factors to consider are those which change the concentration of dissolved carbon dioxide which affects pH. These include biological activities caused by photosynthesis and respiration, as well as physical phenomena produced by turbulence and mixing. Planted littoral zones in the flow path can accomplish the former while open water expanses with favorable wind fetches enhance the latter. These conditions were a part of the stormwater pond in this study. Chemical reactions in the pond also reduce pollutants. For example, the precipitation of iron hydroxide and the production of sulfuric acid, as mentioned earlier, may have accounted for the reduction in pH at the outflow. Other precipitation reactions which are pH dependent include aluminum phosphate ($pH = 6.3$) and iron phosphate ($pH = 5.3$) (Kadlec and Knight 1996).

Table 11. Hydrolab data. Measurements were taken at two hour intervals and the data averaged for the designated period.
Units = Degree C for Temperature, Standard units for pH, ms/cm for conductivity, mg/l for dissolved oxygen, volts for oxidation reduction potential.

1993		INFLOW					OUTFLOW					MID-POND				
START	STOP	TEMP	pH	COND	DO	ORP	TEMP	pH	COND	DO	ORP	TEMP	pH	COND	DO	ORP
30-Jul-93	06-Aug-93	32.24	7.97	0.355	8.02	0.280	28.01	6.78	0.392	1.83	0.38	•	•	•	•	•
06-Aug-93	13-Aug-93	32.20	8.06	0.375	7.20	0.307	27.64	7.90	0.379	3.96	0.32	•	•	•	•	•
27-Aug-93	03-Sep-93	27.89	7.70	0.303	5.38	0.410	27.50	7.16	0.320	3.99	0.37	•	•	•	•	•
10-Sep-93	17-Sep-93	28.98	7.73	0.291	6.24	0.413	•	•	•	•	•	•	•	•	•	•
17-Sep-93	24-Sep-93	30.02	8.09	0.261	10.74	0.376	28.45	6.75	0.308	3.34	0.39	29.75	8.17	0.24	12.10	0.22
25-Sep-93	01-Oct-93	28.42	8.46	0.243	7.94	0.342	26.37	7.81	0.282	3.24	0.43	28.02	8.86	0.19	12.73	0.24
08-Oct-93	15-Oct-93	26.42	8.21	0.311	7.51	0.326	24.19	7.27	0.289	2.81	0.44	•	•	•	•	•
22-Oct-93	29-Oct-93	25.99	8.13	0.330	9.98	0.290	23.63	7.29	0.400	2.48	0.40	•	•	•	•	•
19-Nov-93	29-Nov-93	21.48	8.52	0.320	10.36	0.290	•	•	•	•	•	•	•	•	•	•
15-Jan-94	21-Jan-94	15.49	8.04	0.426	10.62	0.309	•	•	•	•	•	15.22	8.12	0.39	8.39	0.26
21-Jan-94	28-Jan-94	17.47	8.60	0.455	13.93	0.326	18.40	•	•	3.30	0.46	•	•	•	•	•
AVERAGE		**26.05**	**8.14**	**0.33**	**8.90**	**0.33**	**25.52**	**7.28**	**0.34**	**3.12**	**0.40**	**24.33**	**8.38**	**0.27**	**11.07**	**0.24**
STD.DEV.		**5.36**	**0.28**	**0.06**	**2.35**	**0.04**	**3.16**	**0.42**	**0.05**	**0.68**	**0.04**	**6.48**	**0.34**	**0.08**	**1.91**	**0.02**
MAXIMUM		**32.24**	**8.60**	**0.46**	**13.93**	**0.41**	**28.45**	**7.90**	**0.40**	**3.99**	**0.46**	**29.75**	**8.86**	**0.39**	**12.73**	**0.26**
MINIMUM		**15.49**	**7.70**	**0.24**	**5.38**	**0.28**	**18.40**	**6.75**	**0.28**	**1.83**	**0.32**	**15.22**	**8.12**	**0.19**	**8.39**	**0.22**
MEDIAN		**25.99**	**8.21**	**0.33**	**9.98**	**0.33**	**24.19**	**7.29**	**0.31**	**3.12**	**0.43**	**24.33**	**8.38**	**0.27**	**11.07**	**0.24**
NO.OBS.		**11**	**11**	**11**	**11**	**11**	**8**	**7**	**7**	**8**	**8**	**3**	**3**	**3**	**3**	**3**

1994		INFLOW					OUTFLOW					MID-POND				
START	STOP	TEMP	pH	COND	DO	ORP	TEMP	pH	COND	DO	ORP	TEMP	pH	COND	DO	ORP
05-Jun-94	10-Jun-94	28.93	8.32	0.790	8.55	0.20	28.89	8.26	0.81	8.18	0.22	•	•	•	•	•
15-Jul-94	22-Jul-94	31.01	8.06	0.470	7.74	0.24	28.40	7.19	0.50	2.74	0.37	31.06	7.88	0.47	7.64	0.27
29-Jul-94	5-Aug-94	30.16	7.96	0.420	7.32	0.28	28.80	7.29	0.45	3.03	0.41	•	•	•	•	•
11-Aug-94	18-Aug-94	27.91	7.85	0.340	6.06	0.30	•	•	•	•	•	27.96	7.66	0.34	5.54	0.36
23-Aug-94	31-Aug-94	29.39	7.99	0.360	6.58	0.34	28.60	7.11	0.35	1.71	0.44	29.33	7.70	0.36	5.86	0.39
03-Sep-94	14-Sep-94	30.02	8.07	0.390	6.97	0.37	27.10	7.06	0.42	1.24	0.48	30.03	7.74	0.39	6.57	0.40
21-Sep-94	28-Sep-94	26.96	8.03	0.300	6.44	0.31	25.87	7.19	0.33	2.09	0.45	27.22	7.70	0.30	5.81	0.40
03-Oct-94	10-Oct-94	•	•	•	•	•	25.94	7.07	0.40	1.63	0.45	28.39	7.92	0.36	6.79	0.40
14-Dec-94	21-Dec-94	19.93	7.96	0.358	13.81	0.29	19.93	8.10	0.36	8.78	0.33	19.93	8.10	0.36	8.71	0.33
AVERAGE		**28.04**	**8.03**	**0.43**	**7.93**	**0.29**	**26.69**	**7.41**	**0.45**	**3.67**	**0.39**	**27.70**	**7.81**	**0.37**	**6.70**	**0.36**
STD.DEV.		**3.29**	**0.13**	**0.14**	**2.34**	**0.05**	**2.81**	**0.45**	**0.14**	**2.83**	**0.08**	**3.39**	**0.15**	**0.05**	**1.06**	**0.05**
MAXIMUM		**31.01**	**8.32**	**0.79**	**13.81**	**0.37**	**28.89**	**8.26**	**0.81**	**8.78**	**0.48**	**31.06**	**8.10**	**0.47**	**8.71**	**0.40**
MINIMUM		**19.93**	**7.85**	**0.3**	**6.06**	**0.20**	**19.93**	**7.06**	**0.33**	**1.24**	**0.22**	**19.93**	**7.66**	**0.30**	**5.54**	**0.27**
MEDIAN		**29.16**	**8.01**	**0.38**	**7.15**	**0.30**	**27.75**	**7.19**	**0.41**	**2.41**	**0.42**	**28.39**	**7.74**	**0.36**	**6.57**	**0.39**
NO.OBS.		**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**7**	**7**	**7**	**7**	**7**

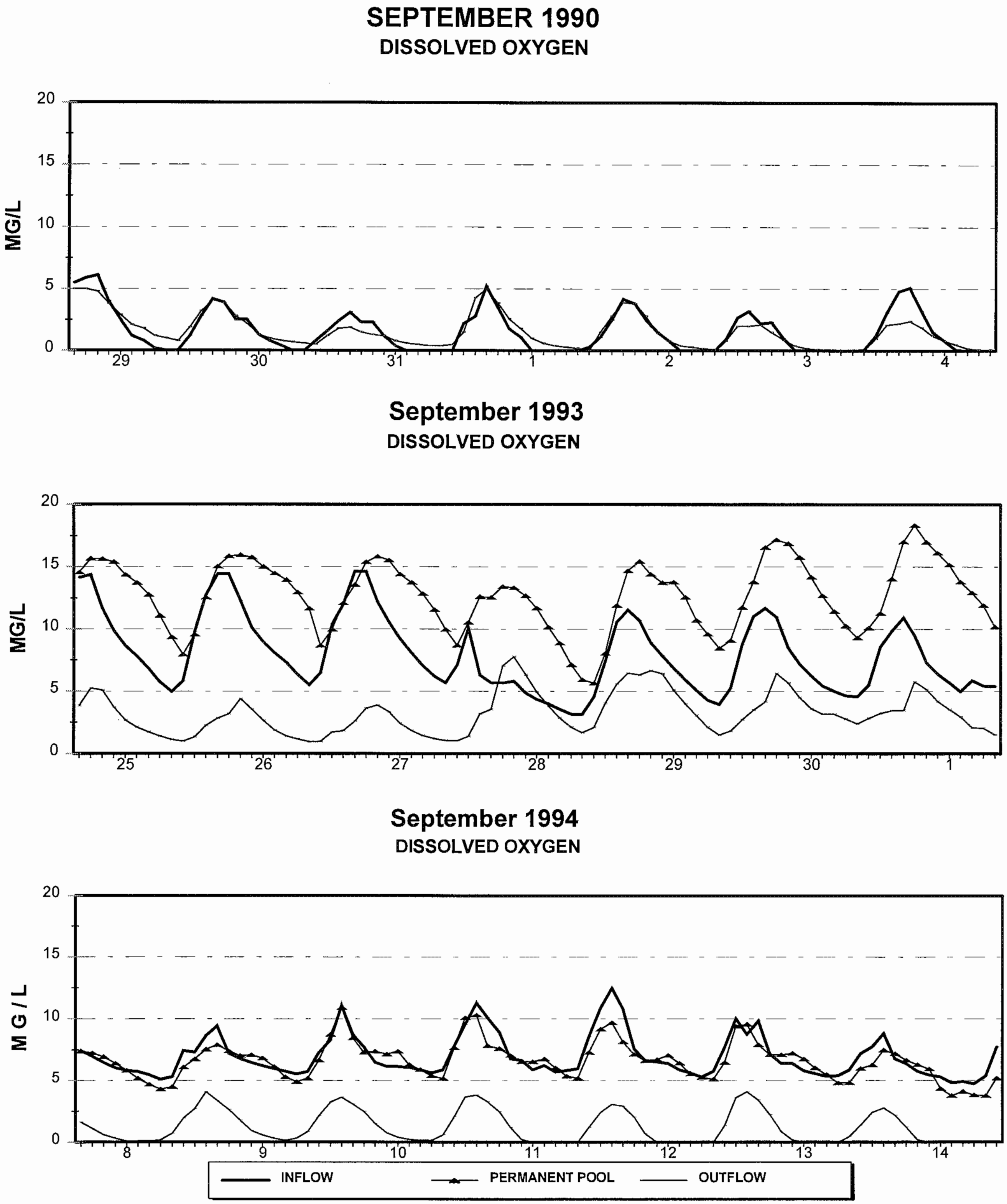
Conductivity (Specific Conductance)

Conductivity levels were fairly consistent for all stations with readings generally between 0.3 and 0.4 ms/cm for 1993 and 0.4 and 0.5 ms/cm in 1995. Specific conductants of most natural inland surface waters range between 0.10 and 0.30 ms/cm. Above average conductivity in the pond and especially in the water table wells were also reported during previous studies at the site (Rushton and Dye 1993, Kehoe 1992) Explanations for higher levels include the fact that the substrate for the drainage basin is spoil material from constructing the adjacent canals in calcareous soils. Also a lime rock parking facility in the drainage basin increased alkalinity. Other conditions which affected the variations in conductivity was the dilution of pond water brought about by rainfall and the concentration effects of evapotranspiration between rain events. As noted in the graphs in Appendix M, a sharp drop in conductivity especially at the inflow occurs in response to rainfall.

Dissolved Oxygen (DO)

Dissolved oxygen can range from zero to more than twice the theoretical solubility in response to ecosystem variables. Wetland surface waters typically have a vertical gradient in DO, with high DO water near the surface and anoxic conditions at the sediment water interface (Kadlec and Knight 1966). Measurements in this study were taken about four inches above the sediment surface. A state standard of 5 mg/l has been set as the lowest level compatible with a healthy ecosystem. Considerable differences were seen between the permanent pool and the outflow. For example, the inflow and permanent pool measurements always met state standards, but water after flowing through the vegetated littoral zone almost never recorded readings above the 5 mg/l target level (Appendix M and Table 11). Low levels of dissolved oxygen are not unusual for vegetated wetlands where the decomposition of decaying plants and microorganisms consume oxygen.

Dissolved oxygen exhibited widely different concentrations in the pond between years caused by the differences in vegetation. Thick emergent vegetation can reduce dissolved oxygen as discussed above while heavy infestations of submerged vegetation can raise DO to high levels during the day caused by the photosynthesizing vegetation. Open water over the submerged vegetation is required for supersaturated condition since dense emergent vegetation blocks the light necessary for algae respiration (Kadlec and Knight 1966). The differences between the three vegetation regimes are exemplified in a comparison of dissolved oxygen concentrations recorded during September of each year (Figure 13). In 1990, the pond was shallow (< 1 foot deep) and was completely covered in cattails resulting in low dissolved oxygen levels (rarely measured above 5 mg/l). In 1993, the pond had a bloom of the submerged macroalga, *Chara* sp, which occupied almost the entire volume of the permanent pool resulting in the pond being supersaturated with oxygen. In 1994, the pond had a deep (about 5 feet) open water permanent pool and a well-established littoral zone and more normal DO conditions were measured.



SEPTEMBER 1990
DISSOLVED OXYGEN

September 1993
DISSOLVED OXYGEN

September 1994
DISSOLVED OXYGEN

Figure 13. Comparison of dissolved oxygen measured for one week in September for each year. In 1990, the pond was less than one foot deep and covered 100% with emergent vegetation. In 1993, the pond was 2 to 5 feet deep and colonized by the submerged alga, *Chara* sp. In 1994, the pond was 5 feet deep with an open water pool and a planted littoral zone concentrated at the outflow.

Oxidation Reduction Potential (ORP)

Redox is a measure of the oxidation potential in the water or sediments. ORP measurements in natural waters show little change as long as the water contains some oxygen, enabling redox potential to remain fairly high and positive (0.3 to 0.5 volts). This was usually the condition measured in this study with average values between 0.29 and 0.40 volts. Of special interest is the fact that although low dissolved oxygen levels were measured at the outflow, the redox potential was usually measured the highest at that location with an average for both years of 0.40 volts and a range between 0.22 and 0.48 volts. When ORP falls below about 0.22 the metabolic demand of organisms use oxygen from other ions as the terminal electron acceptor in a predictable pattern (nitrate, manganese, iron, sulfate, and carbon dioxide) which leads to metal enrichment in the water column by complexing and adsorption to the acid molecule. The fact that reduced conditions were not measured near the bottom of the pond probably means an all important oxidated zone was maintained at the sediment surface which improved the pond's performance for pollution removal. Processes such as temperature, organic matter and pH also influence the rate of the redox reaction. Oxygen pumped to the root zone by vegetation also creates oxidized microsites for use by the plants and other biota. For example, Armstrong (1967) measured the oxygen flux across the roots of swamp plants and found that it is sufficient to meet the oxygen requirements of root cells, to oxidize the rhizosphere, and to ward off the entry of reduced substances.

Discrete Sampling Events

To determine some of the processes taking place, three individual storm events were evaluated using up to 24 discrete samples. Each data point for constituent concentrations included flow-weighted samples composited together to represent different stages across the hydrograph, i.e., rising limb, top, falling limb early, falling limb late and the tail (Figure 14).

First Flush Effects - The initial portion of runoff during a storm event is frequently referred to as the "first flush". Some studies have shown that pollutants are most concentrated early in the runoff process or during the rising limb of the hydrograph; as rainfall continues, the surface pollutant accumulation is depleted and pollutants are diluted (Cullum 1984, Hoffman *et.al.,* 1982, Miller 1979, Stahre and Urbonas 1990). In contrast, other studies have not found an identifiable first flush effect (DRCG 1983,USEPA 1983). In our previous studies, we have found the "first-flush" effect was most consistent for phosphorus and least consistent for nitrogen (Rushton and Dye 1993, Carr and Rushton 1995). Also "first flush" patterns depended on constituent concentrations, especially total suspended solid (TSS) which had to be greater than the 10 to 20 mg/l usually measured. In this present study with TSS always measured above 200 mg/l at the beginning of the three storms sampled, almost all constituents demonstrated a reduction across the hydrograph or at least a large reduction after the peak of the storm had passed (Figures 15 and 16). However, there were considerable differences between storms. For the 9-27-94 storm (#36) the initial peak arrived so rapidly that no samples were taken on the rising limb and the concentrations of most samples were the highest

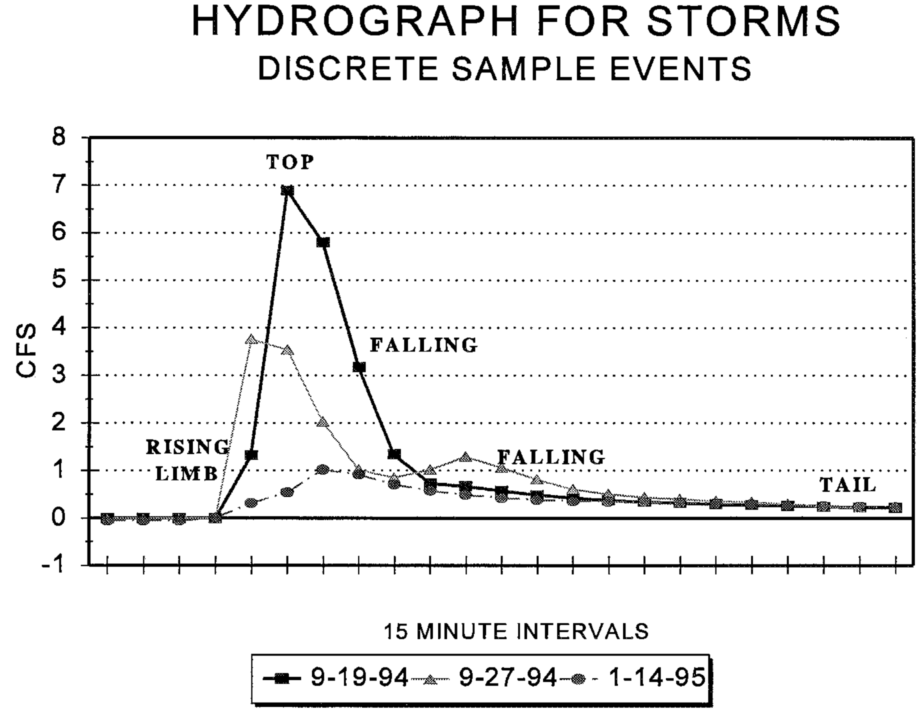


Figure 14. Individual hydrographs for the three storm events evaluated for changes in constituent concentrations indicate the different shapes depending on rainfall characteristics. Also the approximate points between which samples were composited together on a flow-weighted basis are indicated. Rainfall amounts for 9-19-94 (storm # 34) was 1.66 inches, for 9-27-94 (storm # 36) was 1.27 inches and for 1-14-95 (storm # 45) was 1.02 inches.

measured. The largest storm sampled was on 9-19-94 (#34) which usually showed the greatest concentrations at the top of the hydrograph especially for zinc and ortho phosphorus. The 1-14-95 storm (#45) begins the initial flush of a much larger winter storm system (see Figure 7) and demonstrates the least "first flush" effect.

Most constituents follow a similar pattern to that exhibited by total suspended solids, especially when TSS is measured at high concentrations such as the 9-27-94 storm with initial concentrations of 1805 mg/l. Since many pollutants are associated with TSS and large particle suspended solids are removed by sedimentation, these results support the contention that sedimentation is a major mechanism for pollution removal. The exception to the removal of constituents is water hardness which demonstrates an entirely different pattern. Since water hardness is the sum of major ion concentrations, a further analysis of ions, especially those that are conserved, provides some additional insight into patterns of removal.

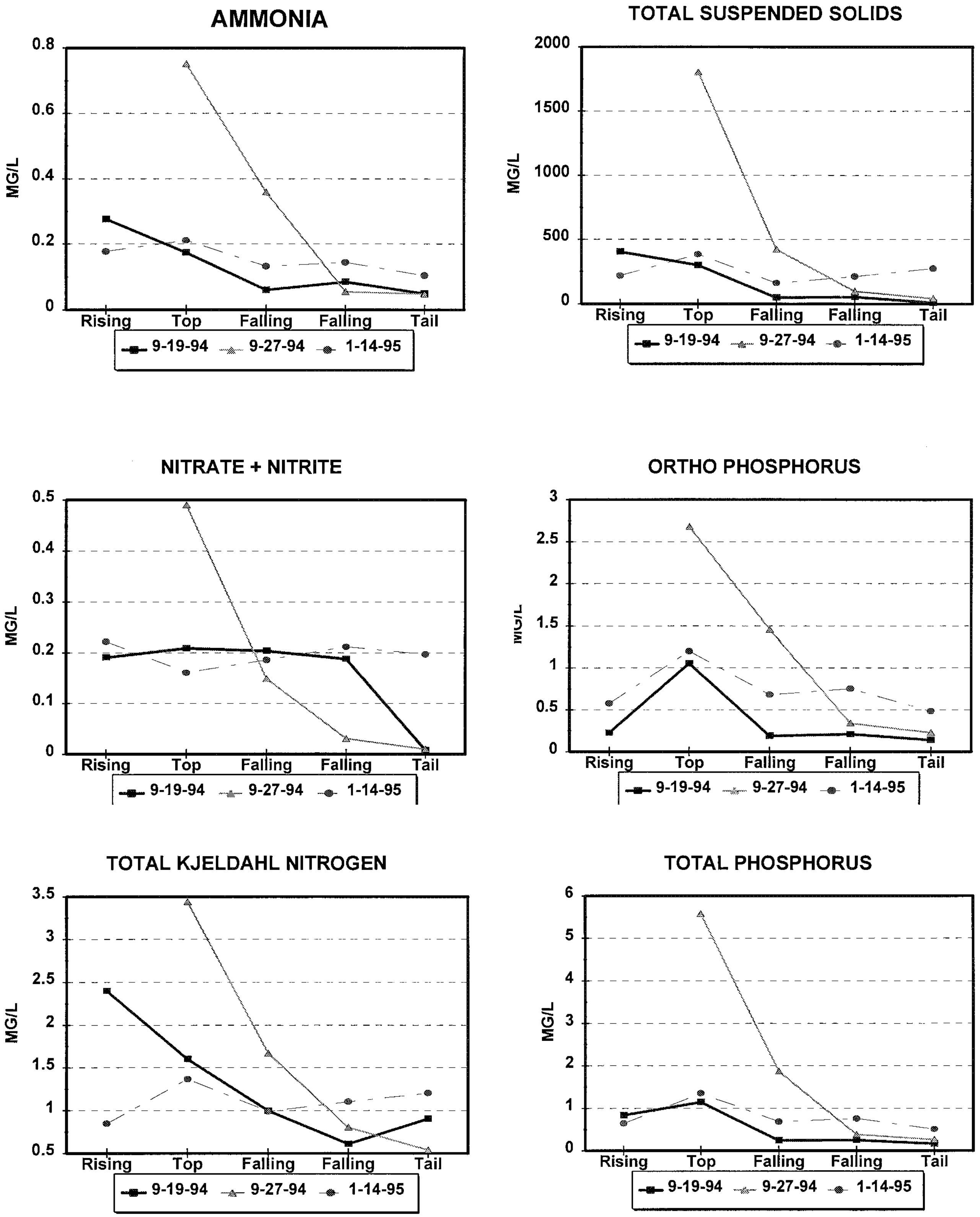


Figure 15. Concentrations of nutrients and total suspended solids measured at the inflow during different stages of the hydrograph for three rain events.

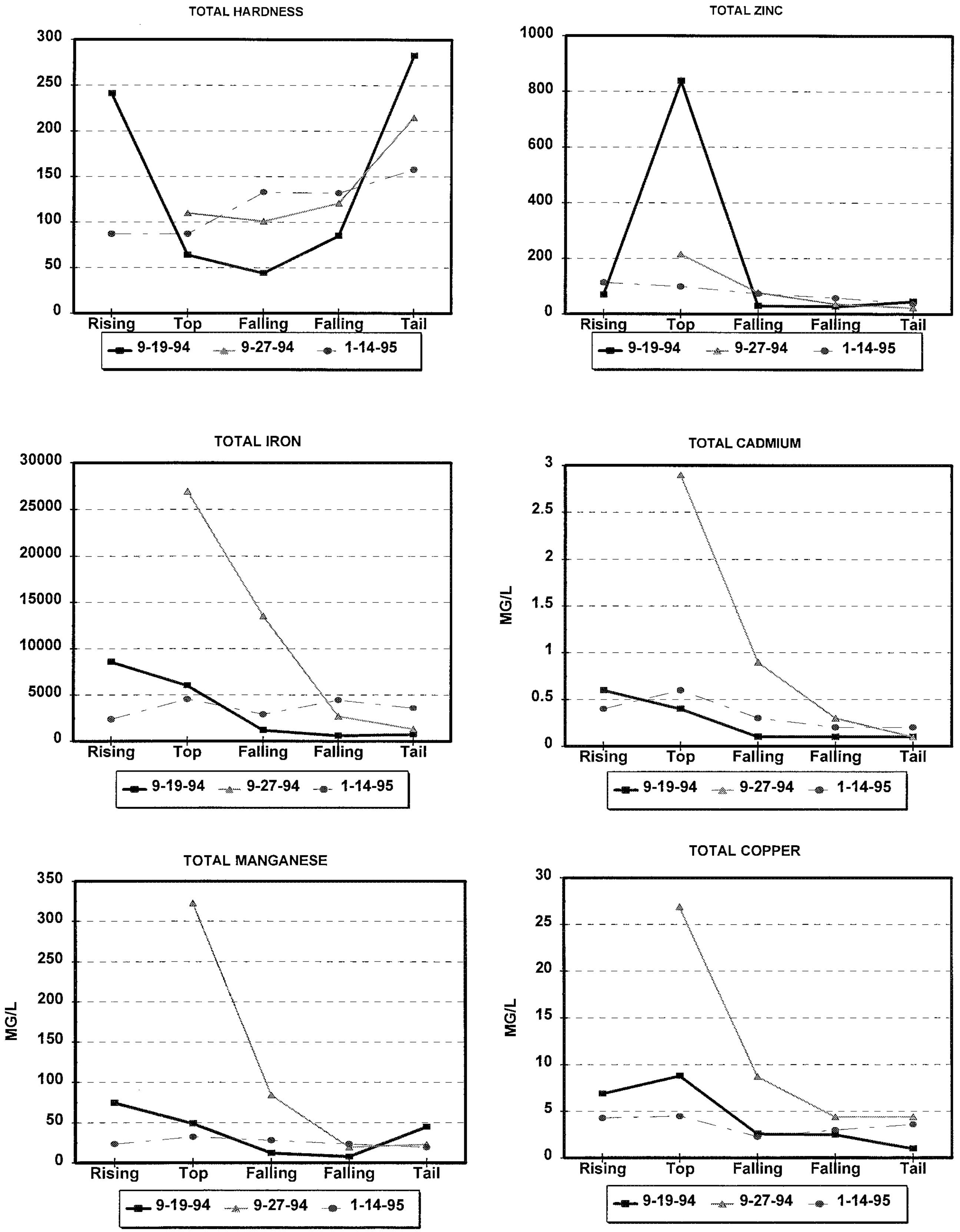


Figure 16. Concentrations of metals and total hardness measured at the inflow during different stages of the hydrograph for three rain events.

Ion Balance

As was discussed in the Major Ion Section, some ions are useful as tracers for determining the proportion of different types of waters present in solution. Sodium, chloride and magnesium were shown to be the best tracers in this study. When one compares the concentrations of these ions over the hydrograph (Figure 17), the influence of rainfall which has much lower concentrations of ions than surface water is seen. The ion concentration demonstrate almost a mirror image of the hydrograph with high flows exhibiting low concentrations and low flows, high concentrations. This is not to infer that the pollutants transported with storm flow are not dominant, but it indicates there is also a dilution effect to be considered, and it helps explain why the largest storm with the greatest intensity did not have the greatest concentration of pollutants. The comparison of ions also demonstrates that for some storms the standing water on the pad in front of the inflow weir, which had high ion concentrations, is often a major component of the samples collected on the rising limb.

Sediments

Sediment cores were collected once during each year of the study. Soils were analyzed for priority organic pollutants during all three years and for particle size, organic matter, nutrients and metals in October of 1993 and January of 1995. Cores to analyze priority pollutants were collected one to two inch deep while most of the other cores represent both the surface layer (1" to 2") and a deeper segment (4" to 5"). Results are discussed with respect to spatial relationship and in comparison to constituent concentrations in the overlying water column. They are also assessed against levels considered toxic or possibly toxic to organisms. See Figure 3 for the soil core sampling locations during 1993 and 1995.

Particle Size Analysis

The soils at the site consist of overburden material dredged up and deposited from construction of the Tampa Bypass Canal in 1981. The drainage basin was originally contoured and the first pond constructed in 1985. By 1993, differential settling was evident with the sandier soils (greater than 90% sand size particles) measured where only shallow excavations had been made such as the swale (site 1) and site 7 (Tables 12 and 13). The more deeply excavated portions of the pond consists of a greater percentage of clay (17 to 24%). This describes what is expected from the soil type in the area which was originally manatee fine sandy loam, consisting of a thin layer of loamy sand over alkaline clay materials and marl (Leighty *et al.*, 1958). Soils were well mixed during construction of the new ponds (in 1993 and again in 1994) resulting in no clear pattern between the top layer and that found 4 inches deeper, in fact particle size often measures about the same at each depth. Patches of clay were sometimes found mixed with the sandy soils explaining the discrepancies seen at site 2 and 6.

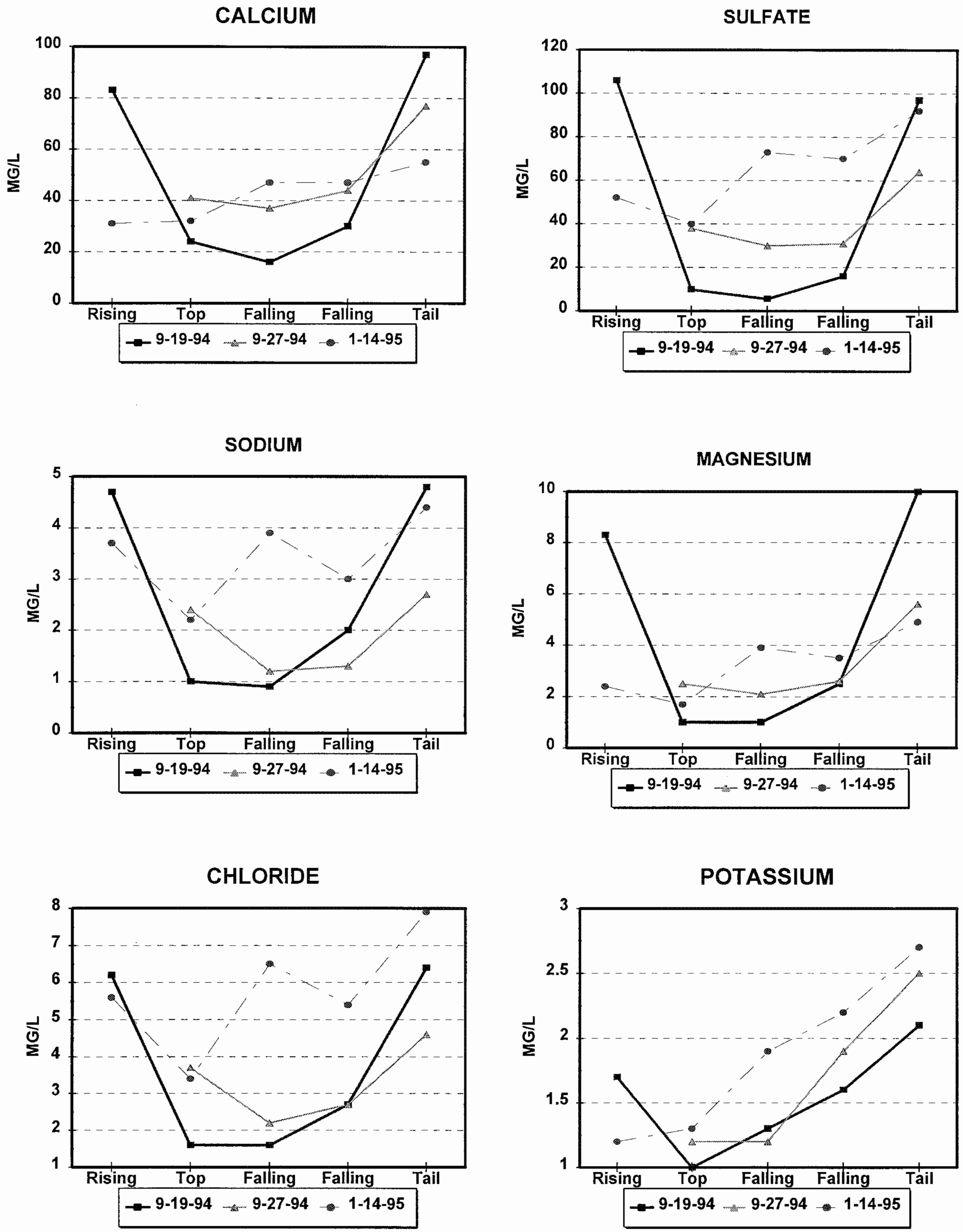


Figure 17. Concentrations of major ions measured at the inflow during different stages of the hydrograph for three rain events.

Table 12. Particle size and organic content of sediment core samples collected in October 1993. DP-Depth of sample and # = sample number. See Figure 3 for sample locations.

Sediment Cores for October 1993						
#	DP (in)	Location	SAND %	SILT %	CLAY %	ORGANIC CONTENT %
1	1	SWALE	92	0	8	2.27
	4		96	3	2	0.43
2	1	N.DITCH	54	12	34	7.74
	4		75	8	17	4.29
3a	1a	INFLOW	81	7	12	2.37
	4a		83	5	13	2.63
3b	1b	DUPLICATE	79	5	17	3.90
	4b		76	0	24	4.56
4	1	MID-POND	72	5	24	5.18
	4		NA	NA	NA	NA
5	1	LITTORAL E	74	12	14	4.83
	4		72	4	24	4.88
6	1	N. POND	61	25	15	10.66
	4		48	29	23	5.89
7	1	DEAD OUT	75	7	18	6.63
	4		98	0	2	0.31
8	1	OUTFLOW	74	8	18	5.21
	4		79	2	19	3.13

Table 13. Particle size and organic content of sediment core samples collected in January 1995. DP-Depth of sample and # = sample number. See Figure 3 for sample locations.

Sediment Cores for January 1995						
#	DP (in)	Location	SAND %	SILT %	CLAY %	ORGANIC CONTENT %
1	1	SWALE	94	3	3	1.14
2	1	N.DITCH	73	15	11	10.03
3	1	INFLOW	75	9	16	3.45
4	1	MID-POND	72	5	24	4.41
5	1	LITTORAL E	74	7	19	4.79
6	1	N. POND	73	6	20	NA
7	1	DEAD OUT	94	2	4	0.88
8	1	OUTFLOW	71	21	8	3.68

Organic content usually shows a reduced percentage with depth. Surface layers in the pond generally ranged between 2 and 5 percent organic matter except in the east ditch which was colonized by a substantial stand of cattails and measured over 7 percent for both years. The grass swale (site 1) had the least organic matter content.

Constituent Concentrations

Nutrients and metals in the sediments are compared to concentrations of constituents in the water columns for October 1993 (Table 14) and January 1995 (Table 15). Field measurements in the water column are included for comparison purposes. Field conditions reflect the different seasons of the collection dates and measured much cooler temperatures and supersaturated conditions for dissolved oxygen in January of 1995. Some spatial relationships as well as comparisons between sediments and the overlying water column are discussed below.

Nitrogen concentrations in the sediments, measured primarily as organic nitrogen (TKN), were much lower in the swale and pond than in the vegetated east ditch and the vegetated littoral shelf at the outflow in 1993 (Table 14). Also the concentration of both inorganic nitrogen and TKN in the water column exhibited the same pattern as that in the sediments indicating an exchange between the sediment water interface during the quiescent no flow conditions in 1993 (Appendix N-1). A similar pattern for the sediments was seen for 1995 except sites 6 and 7 had considerably less TKN in the first inch of the core (Table 15). A shift of nitrogen concentrations in the water column in 1995 can be explained by rainfall patterns. For 1993, no storm with precipitation greater than 0.25 inches had fallen for at least two weeks before sampling took place, while in 1995, the week before the cores were collected, several storms greater than an inch occurred and water was still flowing out of the pond.

Phosphorus concentrations show more accumulation in the pond sediments and the vegetated east ditch than at the inflow swale or the outflow of the pond. Sedimentation is a major pathway for removal of phosphorus and these results show this taking place. Unlike nitrogen, phosphorus concentrations in the water column exhibit no consistent pattern with concentrations in the sediments but a negative correlation exists with dissolved oxygen (DO) concentrations ($R^2=0.40$) during the quiescent conditions of 1993, when wide variations in DO were measured (Appendix N, Figures 3, 4 and 5). The spatial relationship between DO and total phosphorus (TP) also helps explain the lower TP median values in the water column in December 1995 (0.053 mg/l) when DO saturation was over 100 percent compared to October 1993 (0.083 mg/l). This result is consistent with other researchers who have observed a several-fold increase of dissolved P associated with anaerobic sediments (Yousef *et al. 1986*). Phosphorus is not directly altered by changes in redox potential but is indirectly affected in sediments by association with several elements that are reduced (have a valency change).

Table 14. Spatial water quality and sediment concentrations for nutrients and metals in the "Tampa Office" stormwater management system. Samples were collected October 20, 1993, six months after the pond was recontoured. H2O=Water quality sample and SED=Sediment sample. Arsenic, antimony, selenium, silver and thallium were tested for but not found. Sampling locations are in Figure 3. Sediment sample depth (DP) means cores taken from the sediment surface (1) and four inches below the surface (4). Water samples were taken above the same locations. See Appendix R for abbreviations.

OCTOBER 1993			KJELDAHL NITROGEN		INORGANIC NITROGEN		TOTAL PHOSPHORUS		ORTHO PHOS.	TOTAL ZINC		TOTAL COPPER		TOTAL LEAD		TOTAL CADMIUM		BE	NICKEL	CR	IRON	MN	TSS
Constituent => Sediment or Water => #	DP (in)	Location	TKN SED (mg/kg)	TKN H20 (mg/l)	NOx H20 (mg/l)	NH3 H20 (mg/l)	TP SED (mg/kg)	TP H20 (mg/l)	OPH H20 (mg/l)	ZN SED (mg/kg)	ZN H20 (mg/l)	CU SED (mg/kg)	CU H20 (ug/l)	PB SED (mg/kg)	PB H20 (ug/l)	CD SED (mg/kg)	CD H20 (ug/l)	BE SED (mg/kg)	NI SED (mg/kg)	CR SED (mg/kg)	FE H20 (mg/l)	MN H20 (mg/l)	TSS H20 (mg/l)
1	1	SWALE	350	NA	NA	NA	100	NA	NA	8.2 J	NA	U	NA	U	NA	U	NA	0.4 I	U	U	NA	NA	NA
	4		91				54			9.4 J		U		U		U		0.6 I	U	U			
2	1	N. DITCH	2000 J	1.238	0.020	0.101	1200 A	0.163	0.072	132.0 J	0.165	U	0.8	12.0 I	1.16	U	0.04	U	6 I	18 I	0.795	0.036	11.87
	4		700 A				0			5.3 J		U		7.9 I		U		U	5 I	13 I			
3a	1a	INFLOW	150 A	0.578	0.007	0.046	150	0.083	0.020	14.0	0.015	U	0.3	U	0.69	U	0.00	U	U	U	0.278	0.012	6.89
	4a		110				150			8.2		U		U		U		U	U	U			
3b	1b	DUPLICATE	210	NA	NA	NA	940 J	NA	NA	9.2	NA	U	NA	U	NA	U	NA	U	4 I	29 J	NA	NA	NA
	4b		360 A				1100 A			8.3		U		10.0 I		U		U	U	13 I			
4	1	MID-POND	270 A	0.541	0.011	0.054	1400 A	0.054	0.012	9.1 J	0.006	U	0.2	17.0 I	0.85	U		U	5 I	27 J	0.225	0.004	3.16
	4		NA				NA			NA		NA		NA		NA		NA	NA	NA			
5	1	LITTORAL E	300	0.567	0.020	0.055	1000	0.061	0.013	U	0.007	U	3.3	U	0.99	U	0.00	U	4 I	36 J	0.178	0.004	4.86
	4		270				1300			U		U		12.0 I		U		2	4 I	27			
6	1	N. POND	2200	1.435	0.018	0.187	730	0.268	0.037	26.0 J	0.003	U	0.6	14.0 I	0.81	U	0.00	1 I	6 I	8.5 I	0.324	0.026	6.63
	4		380				400			U		U		U		U		1 I	4 I	U			
7	1	DEAD OUT	1400	0.652	0.014	0.058	680	0.090	0.019	10 I	0.006	U	0.7	U	1.58	U	0.09	U	U	10 I		0.007	11.94
	4		110				100 J			U		U		U		U		U	U	U			
8	1	OUTFLOW	990	0.479	0.003	0.067	320	0.063	0.025	24	0.021	U	1.5	U	1.22	U	0.00	U	U	7.6 I	0.161	0.012	4.03
	4		98 J				240 J			U		U		U		U		U	U	U			

FIELD CONDITIONS IN WATER COLUMN WHEN SOIL SAMPLES WERE TAKEN

OCTOBER 1993	Location	SAMPLE DEPTH inches	VEG. TYPE	TIME	TEMP deg C	D.O. mg/l	COND ms/cm	pH su	REDOX volts	%SAT %	T.D.S. g/l
1	SWALE	2	grass	------------ -no samples taken ---------------							
2	N.DITCH	11	cattail	8:11	24.33	2.21	0.54	7.26	358	26	0.35
3	INFLOW	16	none	13:14	28.90	12.15	0.426	7.84	390	158	0.27
4	MID-POND	24	Chara sp	------------ -no samples taken ---------------							
5	LITTORAL E	15	algae	7:40	25.23	8.09	0.291	7.78	415	98	0.19
6	N.POND	12	pickerel	7:55	23.92	1.31	0.372	7.11	371	15	0.24
7	DEAD OUT	31	none	7:32	25.41	8.07	0.304	8.07	396	89	0.20
8	OUTFLOW	15	none	13:51	25.85	2.94	0.359	7.26	408	36	0.23

ABBREVIATIONS FOR SOIL SAMPLES.

J = ESTIMATED VALUE

I = VALUE REPORTED IS LESS THAN THE MINIMUM QUANTITATION LIMIT (REFERENCE ONLY) AND GREATER THAN OR EQUAL TO THE MINIMUM DETENTION LIMIT.

A = VALUE REPORTED IS THE MEAN OF TWO OR MORE DETERMINATIONS.

U = MATERIAL WAS ANALYZED FOR BUT NOT DETECTED.

NA = NOT ANALYZED

ABBREVIATIONS FOR FIELD MEASUREMENTS

TEMP=Temperature

D.O.=Dissolved Oxygen

COND=Sp Conductance

REDOX=Oxidation Reduction Potential

%SAT=Saturation of Oxygen

T.D.S.=Total Dissolved Solids

Table 15. Spatial water quality and sediment concentrations for nutrients and metals in the "Tampa Office" stormwater management system. Samples were collected January 17, 1995, eight months after the pond was recontoured. H2O=Water quality sample and SED=Sediment sample. Arsenic, antimony, selenium, silver and thallium were tested for but not found. Sampling locations are in Figure 3. Sediment sample depth (DP) means cores taken from the sediment surface (1) and four inches below the surface (4). Water samples were taken above the same locations. Duplicate soil cores were taken at site 6. See Appendix R for abbreviations.

JANUARY 1995	KJELDAHL NITROGEN		INORGANIC NITROGEN		TOTAL PHOSPHORUS		ORTHO PHOS.	TOTAL ZINC		TOTAL COPPER		TOTAL LEAD		TOTAL CADMIUM		BE	NICKEL	CR	FE	MN	AL	TSS
Constituent => Sediment or Water => # DP Location (m)	TKN SED (mg/kg)	TKN H20 (mg/l)	NOx H20 (mg/l)	NH3 H20 (mg/l)	TP SED (mg/kg)	TP H20 (mg/l)	OPH H20 (mg/l)	ZN SED (mg/kg)	ZN H20 (mg/l)	CU SED (mg/kg)	CU H20 (ug/l)	PB SED (mg/kg)	PB H20 (ug/l)	CD SED (mg/kg)	CD H20 (ug/l)	BE SED (mg/kg)	NI SED (mg/kg)	CR SED (mg/kg)	FE H20 (mg/l)	MN H20 (mg/l)	AL SED (mg/kg)	TSS H20 (mg/l)
1 1 SWALE	1000 A		0.002	0.025	210 A	0.049	0.038	31 I	0.080	4 I	3.70	16 I	3.30	1.0 U	0.20	0.4 I	4 I	9 I	0.92	0.349	3090	22
4	110 A				76 A			12 U		3 I		6 U		0.3 U		0.0	0	13 I			2560	
2 1 N. DITCH	900	0.940	0.051	0.004	820 A	0.107	0.034	18 J	0.024	2 I	0.8	10 I	1.16	1.0 U	0.20	0.0	0	27	1.37	0.065	10400	21.64
4	1900				320 A			4 I		2 I		5 I		0.9 U		0.0	0	14			4730	
3 1 INFLOW	450 A	1.078	0.002	0.009	260 A	0.053	0.040	13 U	0.023	2 U	0.3	6 U	0.69	0.0	0.40	0.3 I	3 I	16	0.18	0.005	5040	6.09
4	53 A				86 A			11 U		2 U		6 U		1.0 U		0.3 U	2 U	10 I			3400	
5 1 LITTORAL E	360 A	0.921	0.004	0.008	480 A	0.056	0.040	14 I	0.022	2 U	0.2	6 U	0.85	1.0 U	0.00	0.4 I	4 I	26	0.24	0.005	9760	9.96
4	370 A				640 A			23 I		2 U		6 U		1.0 U		0.6 I	6 I	43			13300	
6 1 N. POND	430	0.460	0.004	0.010	1300 J	0.023	0.010	15 J	0.008	2 I	3.3	13 I	0.99	0.8 U	0.00	0.0	0	45	0.48		15400	1.07
4	360				1000 A			14 J		2 U		10 I		1.0 U		0.0	0	39 A			12700	
6b 1 N. POND-D	330				1100 A			14 J		2 U	0.6	11 I	0.81	1.0 U		0.0	0	46			15700	
4	310 A				1300 J			13 J		2 U		14 I		1.0 U		0.0	0	58			19700	
7 1 DEAD OUT	450	0.250	0.012	0.010	230 A	0.020	0.010	9 J	0.010	1 U	0.7	5 U	1.58	1.0 U	0.00	0.0	0	6 I	0.04	0.002	1680	0.41
4	220				200 A			4 I		1 U		5 I		0.9 U		0.0	0	12			3540	
8 1 OUTFLOW	1800 A	0.827	0.004	0.005	450 A	0.104	0.071	94	0.018	5 I	1.5	10 I	1.22	2.0 U	0.20	0.5 I	4 I	19 I	0.44	0.001	6860	3.25
4	92 A				230 A			17 I		2 U		6 U		1.0 U		0.3 I	2 I	13 I			5790	

FIELD CONDITIONS IN WATER COLUMN WHEN SOIL SAMPLES WERE TAKEN

JANUARY 1995 Location	SAMPLE DEPTH inches	VEG TYPE	TIME	TEMP deg C	D.O. mg/l	COND ms/cm	pH su	REDOX volts	%SAT %	T.D.S. g/l
1 SWALE	3	grass	13:00	16.58	13.84	2.56	6.99	501	NA	NA
2 N.DITCH	6	cattail	11:13	14.01	8.90	0.80	7.75	372	88	0.51
3 INFLOW	NA	none	13:45	18.13	11.23	0.43	8.26	414	116	0.27
5 LITTORAL E	9	grass*	14:45	19.27	10.56	0.36	8.41	406	116	0.23
6 N.POND	20	grass*	13:28	18.52	12.66	0.41	8.82	400	134	0.26
7 DEAD OUT	32	Chara	11:41	15.00	10.02	0.42	8.25	423	98	0.27
8 OUTFLOW	11	none	16:01	19.57	10.22	0.43	8.14	422	111	0.28

*Torpedo grass and chara sp. as well as other planted vegetation such as pickerel weed

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(REFERENCE ONLY) AND GREATER THAN OR EQUAL TO THE MINIMUM DETENTION LIMIT.
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ABBREVIATIONS FOR FIELD MEASUREMENTS
D.O.=Dissolved Oxygen
COND=Sp Conductance
REDOX=Oxidation Reduction Potential
%SAT=Saturation of Oxygen
T.D.S.=Total Dissolved Solids

Metal concentrations in the sediments of these newly constructed ponds were usually measured below the quantification limit (I) or not detected at all (U). Chromium was the one metal measured above the quantitation limit. It should be noted that only low levels of chromium were measured in the water column (see Table 10). One explanation for the higher concentrations of chromium in the sediments is that chromium is naturally occurring in the soils. This observation makes use of the fact that a natural relationship exists between metals and aluminum. Therefore, aluminum is sometimes used to normalize sediment metal concentrations when used to identify anthropogenically enriched sediments (Livingston *et al.* 1995). Although the procedure has not been perfected for fresh water systems in Florida and the sediment samples in this study did not receive the rigorous laboratory methods recommended for definite quantification, our results do indicate that the higher concentrations of chromium at sites 5 and 6 are associated with higher levels of aluminum and are probably not enriched from stormwater input.

Comparison to Standards

Since sediments tend to integrate contaminant concentrations over time they may represent a much better method for determining when conditions are toxic to organisms. For this reason, several government agencies are working on standards to assess possible toxic levels detrimental to aquatic organisms. Some of these standards are listed in Table 16. Also compared in Table 16 are standards used to determine safe levels in soils. Soils are considered non-toxic (clean) in Florida (Chapter 62-775 FAC) as long as concentrations do not exceed those listed in column (a). Stormwater pond sediments are considered clean for disposal purposes if they meet these standards (Livingston and Cox 1995). This means that if sediments are removed from wet detention ponds, and they meet these standards, they can be disposed of on site or used for cover material in lined landfills; and thus, do not create a disposal problem.

Table 16. Sediment water quality criteria giving threshold concentrations (mg/kg) where constituents have the lowest effect level (Possible) and the limit of tolerance level (Probable). See text for a more complete explanation.

Constituent	Soil (a)	Freshwater (b)		Estuarine (c)	
		Sediments		Sediments	
	Toxic	Possible	Probable	Possible	Probable
Cadmium	37	1	10	1	8
Lead	108	31	250	21	160
Zinc	na	110	800	68	300
Copper	na	25	114	28	170
Chromium	50	31	111	33	240
Total Phosphorus	na	545	4800	na	na
Kjeldahl Nitrogen	na	600	2050	na	na

(a) Soil Thermal Treatment Facilities, Chapter 62-775 FAC
(b) Development of Sediment Quality Guidelines (Persud *et al.* 1990)
(c) Sediment Quality in Florida Coastal Waters (MacDonald 1993)

Possible biological effects on aquatic animals need more stringent requirements and two levels have been set for aquatic sediment in several states and Canada (Giesy and Hoke 1990). Informal sediment contamination guidelines have been published for freshwater sediments in Canada which identify potentially adverse biological effects (Persuad *et al.* 1990). Possible effects listed in column (b) represent the boundary between the level at which no toxic effects have been observed and the lowest level showing the concentration that can be tolerated by the majority of benthic organisms. The probable effect indicates the level at which a pronounced disturbance to the benthic community occurs. Guidelines for estuarine sediments, column (c), have been established for Florida (MacDonald *et al.* 1993). The lower bounds of the range of concentrations which could potentially be associated with biological effects is the possible effect level while the probable effect level represents concentrations known to be toxic to organisms.

For metals, none of the sediments measured in these newly constructed ponds reached toxic levels and only a few were considered in the range that could potentially be associated with adverse biological effects. These were usually located in the densely vegetated east ditch (2) or the vegetated littoral zone (6) near the outflow. The same pattern was also noted for nutrients where potentially detrimental levels of Kjeldahl nitrogen and total phosphorous were associated with dense vegetation. Entrapment or uptake of these constituents by plants or benthic organisms and burial in the sediments is one process that removes these pollutants from the system. Since these can be released back to the water column under certain conditions more study is needed to establish pond maintenance guidelines or possible removal of sediments once concentrations are a problem.

Organic Priority Pollutants

The increasing dependence of today's society on technology derived from organic chemicals has led to widespread hydrocarbon pollution. Organic compounds are relevant because they can be carcinogenic, bioaccumulate in organisms, cause toxic reactions plus they degrade slowly. Organic priority pollutants are of special concern in stormwater runoff since much of the source material is associated with automobile traffic.

Sediment samples at the site were tested for over 100 organic pollutants, but only those listed in Table 17 were detected. For 1990 only the sediments at the inflow and outflow were sampled while in 1993 and 1995 four to five locations were tested in the pond and two locations were sampled in the inflow ditches. The only locations with detectable concentrations were the inflow swale and the inflow of the pond.

In 1990, the pond had been receiving stormwater runoff for four years and both the inflow and outflow had some detectable levels of organic pollutants. In 1993, four months after the newly constructed pond had been receiving runoff, no organic pollutants were detected in the pond, but measurable concentrations of polycyclic aromatic hydrocarbons (PAH) were measured in the swale near the parking lot which had not been disturbed by construction. In 1995, the concentrations in the swale had increased several fold and the pond, which had been recontoured six months earlier, already showed trace levels of PAHs.

Some PAHs are known to be carcinogenic to man and are formed during the combustion of coal and petroleum. A major source is street dust present as weathered materials of street surfaces, automobile exhaust, lubricating oils, gasoline, diesel fuel, tire particles, and atmospherically deposited materials (Takada *et al.* 1990).

Table 17. Organic priority pollutants (mg/kg) were sampled in the sediments for all three years. Analyses were performed for over 100 pollutants but only the ones listed below were found in any of the three years. (Note 1990 is for Inflow and Outflow while the other years are Swale and Inflow).

	1990		1993		1995	
Constituent	**Inflow**	**Outflow**	**Swale**	**Inflow**	**Swale**	**Inflow**
Polycyclilic Aromatic Hydrocarbons (PAH)						
benzo(a)anthracene	U	U	0.76 I	U	3.90	0.44 T
benzo(a)pyrene	U	U	U	U	2.30 I	U
benzo(b)fluoranthene	U	U	U	U	6.20	0.44 T
benzo(ghi)perylene	U	U	U	U	1.70 I	0.44 T
benzo(k)fluoranthene	U	U	1.50	U	2.00 I	U
benzo(b+k)fluoranthene	0.66 M	U	U	U	U	U
chrysene	U	U	U	U	1.40 I	U
dubebzi(a,h)anthracene	U	U	U	U	5.10 T	U
pyrene	0.22	0.31	1.30	U	5.20	0.44 T
fluoranthene	0.03 M	0.03 M	1.10	U	6.00	0.44 T
indo(1,2,3-c,d)pyrene	U	U	0.49	U	2.40 I	0.44 T
phenanthrene	U	U	0.38	U	2.50 I	0.44 T
Esters						
di-n-butyl phthalate	U	0.23	U	U	U	U
di-n-ocytl phthalate	0.10	U	U	U	U	U
butyl benzyl phthalate	0.16	U	U	U	U	U
Nitrosamine						
1,2-diphenylhydrazine	U	0.24 M	U	U	U	U
Pesticide						
4,4'-DDE	0.20	U	U	U	U	U

ABBREVIATIONS:

I = Value reported is less than the minimum quantitation limit, and greater than or equal to the minimum detection limit.

T= Value reported is less than the criterion of detection

M= Indicates presence of material was verified but not quantified

U=Material was analyzed for but not detected.

The Nationwide Urban Runoff Program (NURP) evaluated the significance of priority pollutants which produced results consistent with our findings (Cole *et al.* 1984). Although the NURP analyses were conducted on water samples, the patterns were the same as in our study. For example, they detected PAHs more often than any other organic priority pollutant with pyrene, phenanthrene and fluoranthene found in at least 10 percent of samples. NURP data also detected phenanthrene and pyrene in concentrations that might pose a risk to human health. Since organic pollutants accumulate in the sediments and they present a potential risk to aquatic life and to human health if ingested, it is suggested that their accumulation rate be monitored in stormwater systems and appropriate action taken if a risk is detected. In this study a definite upward trend in the accumulation of PAHs was noted, especially for pyrene, fluoranthene and phenanthrene.

Relationship Between Variables

Chemical and physical processes in surface waters influence the concentration of pollutants in stormwater systems. One of the purposes of this study was to analyze the interactions of various constituents and identify relationships between variables in order to better understand how to make these systems work more efficiently. To aid in this analysis, statistical tests were run on the data collected for 87 rain events over a three year period. The data were typical for natural systems with values highly skewed to the right and often containing extreme outliers. Nonparametric procedures, especially the Spearman method, were used to compute correlation coefficients (Appendices O and P). The Spearman coefficient not only makes no assumption of a normal or linear distribution but also gives more reliable information if the data possess a distinct curvilinear relationship (Walpole and Myers 1972).

Direct Rainfall

To put the correlations in perspective, a few facts about the importance of rainfall directly on the pond are reviewed. Depending on the area of the pond, rainfall accounted for 14 to 26 percent of the hydrologic input, while 20 to 30 percent of inorganic nitrogen and 9 to 10 percent of copper entered directly in rainfall (see Table 8). Zinc concentrations were variable between years but perhaps as much as 38 percent entered the pond in rain during the 1993 sampling period. Rainfall was an insignificant pathway for other pollutants during all years.

Correlation analysis identified relationships between variables (Figure 18). Some researchers have found that precipitation tends to contain contaminants at higher concentrations in short storms and when precipitation is infrequent (Mitsch and Gosselink 1993). This suggests that the washout effect, with rainfall purifying the air, occurs during the early part of a storm, while longer duration rain events dilute samples. In this study, only weak correlations ($r = -0.19$ to -0.34) were observed when rainfall characteristics were compared to constituent concentrations. However, much higher concentrations of inorganic nitrogen (> 0.4 mg/l) were measured in storms with less than an inch of precipitation while storms greater than 1.25 inches never had high levels (Figure 18). Closely spaced storms and rainfall intensity probably account for the many low concentrations reported during small storms.

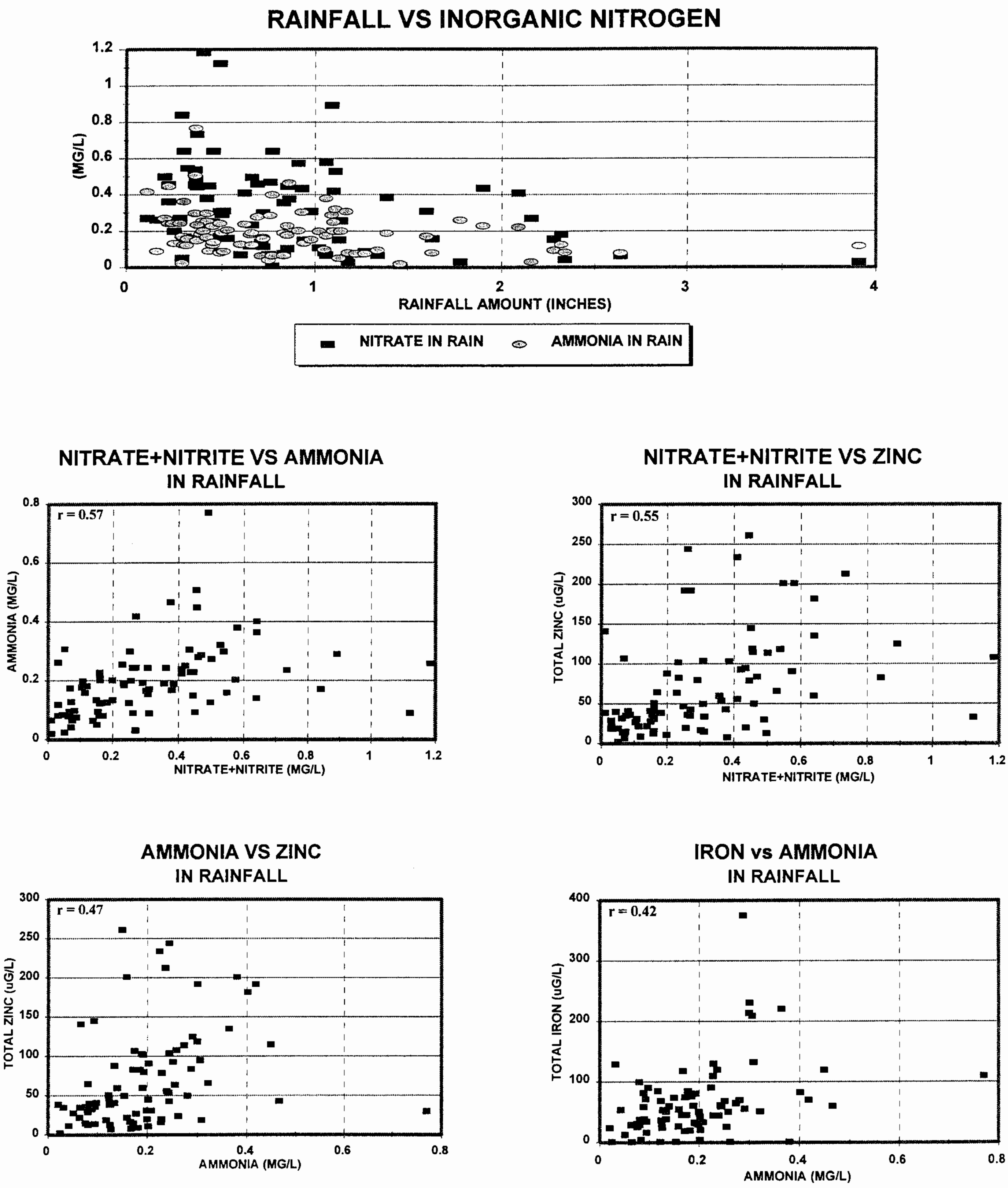

Figure 18. Scatter plots for concentrations of constituents measured in rainfall indicating variables which had a tendency to vary together. r=Spearman correlation coefficient.

The few constituents in rainfall measured in high enough concentrations to analyze statistically are graphed together for descriptive purposes and imply a joint relationship rather than a cause and effect dependency (Figure 18). The Spearman's coefficient of rank correlation identified a few associations demonstrating a tendency for some constituents to increase together. Ammonia, nitrate plus nitrite, zinc and iron showed the strongest positive relationships. Several explanations are discussed below.

A major pathway for the nitrate and ammonia found in rainfall comes from the transformation of nitrogen oxides. Anthropogenic sources of nitrogen oxide contribute a large amount of nitrogen to the atmosphere. In 1985, Florida was listed as the eighth largest nitrogen oxide emitting state based on national rankings of total emissions. Of the total amount of nitrogen oxide discharged, vehicular traffic contributed 50 percent, utilities 35 percent and other industrial sources 5 to 10 percent (Rogers 1990). Another source for the combined nitrogen in the atmosphere is the ammonia released by microbial degradation of terrestrial organic matter that is then partly oxidized to nitrate in the atmosphere (Hutchinson 1944).

It should be noted that rainfall samples at this site had higher concentrations of both zinc and ammonia when compared to two other locations in the Tampa Bay area (Rushton 1993). Explanations include the close proximity of cattle feedlots and industrial activity. Almost 75 percent of the total estimated U. S. Anthropogenic emissions of ammonia come from livestock waste and fertilizer application (Placet *et al.* 1990). The significantly higher zinc levels are attributed to industrial air pollution and the resuspension of particles by highway traffic.

Transport and eventual deposition of aerial pollutants is a complicated process as the ten years of work conducted by the National Acid Precipitation Assessment Program (NAPAP) concluded (Hicks *et al.* 1989). The NAPAP report helps explain the high nitrogen levels found in rainfall. Convective storms remove pollutants efficiently, transform these pollutants into other chemical species, and deposit the products in rainfall. Southwest Florida has the greatest number of convective storms in the United States with 100 per year normal for the region. Gaseous ammonia, due to its high solubility, is rapidly taken up on atmospheric aerosols. Its atmospheric lifetime is short and once deposited it is converted to acidic nitrate in soils. The report further states that urban versus rural studies show urban samples may have up to ten times more sulfates and nitrates for a given storm and about 1.5 times more deposited annually. Wet deposition represents most of the wet plus dry deposition of sulfur and nitrogen while phosphorus is transported primarily as dry deposition (Brezonik *et al.* 1983). It should be noted (see Table 6) that concentrations of inorganic nitrogen in rainfall were always greater than concentrations measured at the inflow of the pond indicating its removal and transformation by overland flow through the large grassed areas in the drainage basin.

Rainfall analysis emphasizes the need to reduce anthropogenic air pollution to help clean up surface water pollution. Nitrogen oxides are emitted into the atmosphere primarily through the combustion processes used in transportation, fossil fuel energy production and waste incineration. The results also points out the importance of vegetated areas in the drainage basin to help utilize and transform nitrogen before it reaches surface waters.

Inflow Data

In a comparison between rainfall, the inflow, and the outflow stations, correlation analysis shows the strongest associations for the inflow data (Appendix O). In general constituents which exhibit a tendency to increase together exhibit much less scatter than the correlations identified in rainfall, although the coefficients are similar. Of all the constituents examined iron and phosphorus proved to be the best predictors for constituent concentrations, although a few of the other metals also varied together. For example, an association exists between zinc and copper ($r = 0.66$). Nitrogen species exhibited the poorest relationships with no coefficients greater than 0.46. Rainfall characteristics were related to each other but were only weakly correlated ($r < 0.50$) to constituent concentrations except for negative correlations with the major ions. Also the major ions show strong relationships to each other (except potassium) and were negatively correlated to some constituents, most often phosphorus, iron and lead.

As mentioned above, some of the best correlations (Figure 19) occurred with iron, the strongest of these are with lead, manganese, suspended solids, and phosphorus (to be discussed later). Although iron is of little direct toxicologic significance, it often controls the concentration of other elements, including toxic heavy metals, in surface waters (Moore 1991). Surface water iron concentrations usually range from 50 to 200 ug/l in aerated aquatic systems (Hutchinson 1975). In this study, iron concentrations increased at the inflow from an average of 555 ug/l in 1990 to 3200 ug/l in 1994, probably caused by the construction activity and resultant soil disturbance. Because iron is so common in the earth's crust, erosion accounts for a majority of the concentrations transported by runoff (Moore 1991). Most iron is present as colloidal particles of ferric hydroxide which is measured here, in part, as suspended solids explaining that relationship (Figure 19). In addition, ions in suspended solids can neutralize the charges on the hydroxide colloidal particles forming a rapidly settling precipitate. Metals, such as copper, can also be adsorbed by and co-precipitated with the ferric hydroxide precipitate (Wetzel 1975). The relationship between iron and copper would undoubtedly have been stronger except for a fertilization and weed control program that occurred at the site between August 1994 and January 1995 and artificially elevated copper and nitrogen levels on some dates during this period. Manganese is chemically similar to iron in its behavior in surface water and similar conditions cause these two elements to vary together. The major ions tend to be inversely correlated with iron and a sodium example is shown in Figure 19.

Phosphorus also shows some significant relationships (Figure 20). It is of considerable environmental concern as a nutrient since, in surface water where it is a limiting factor for growth, inputs of phosphate can result in obnoxious algal blooms. As might be expected since ortho phosphorus is part of total phosphorus, these two constituents vary together (Figure 20). Also in Figure 20 the interrelationship of phosphorus, iron and manganese is evident. This supports the idea that their aquatic transformations (dissolution, transport, distribution, precipitation and accumulation) are interrelated and are interdependent with those of other significant components of natural waters (Stumm and Morgan 1970). Ferric oxides are known to co-precipitate or occlude to phosphorus under aerobic conditions and are, in fact, relatively selective for phosphorus although they also adsorb proportions of metals and other constituents.

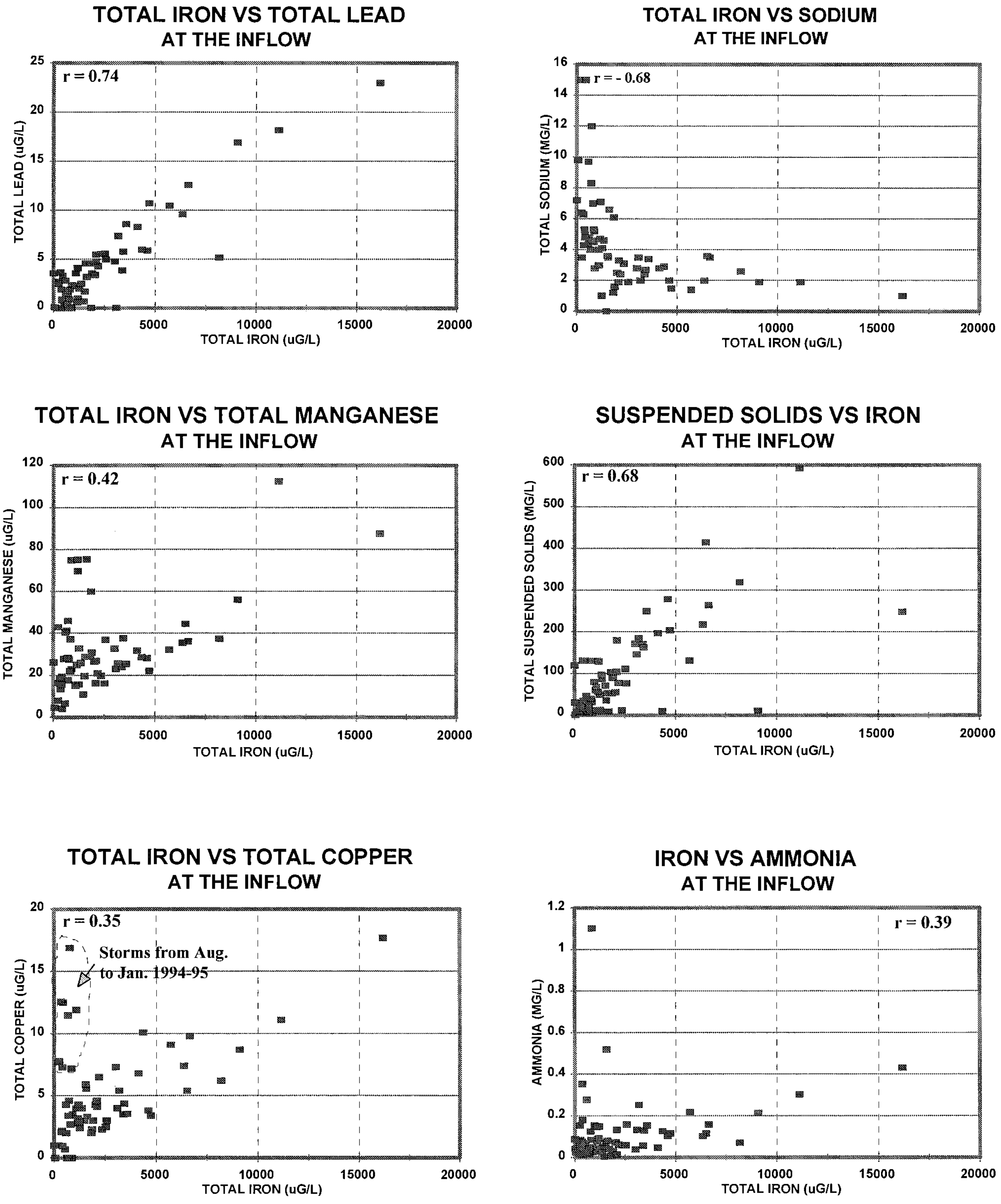

Figure 19. Scatter plots for variables measured at the inflow which had a tendency to vary with iron concentrations. r=Spearman correlation coefficient.

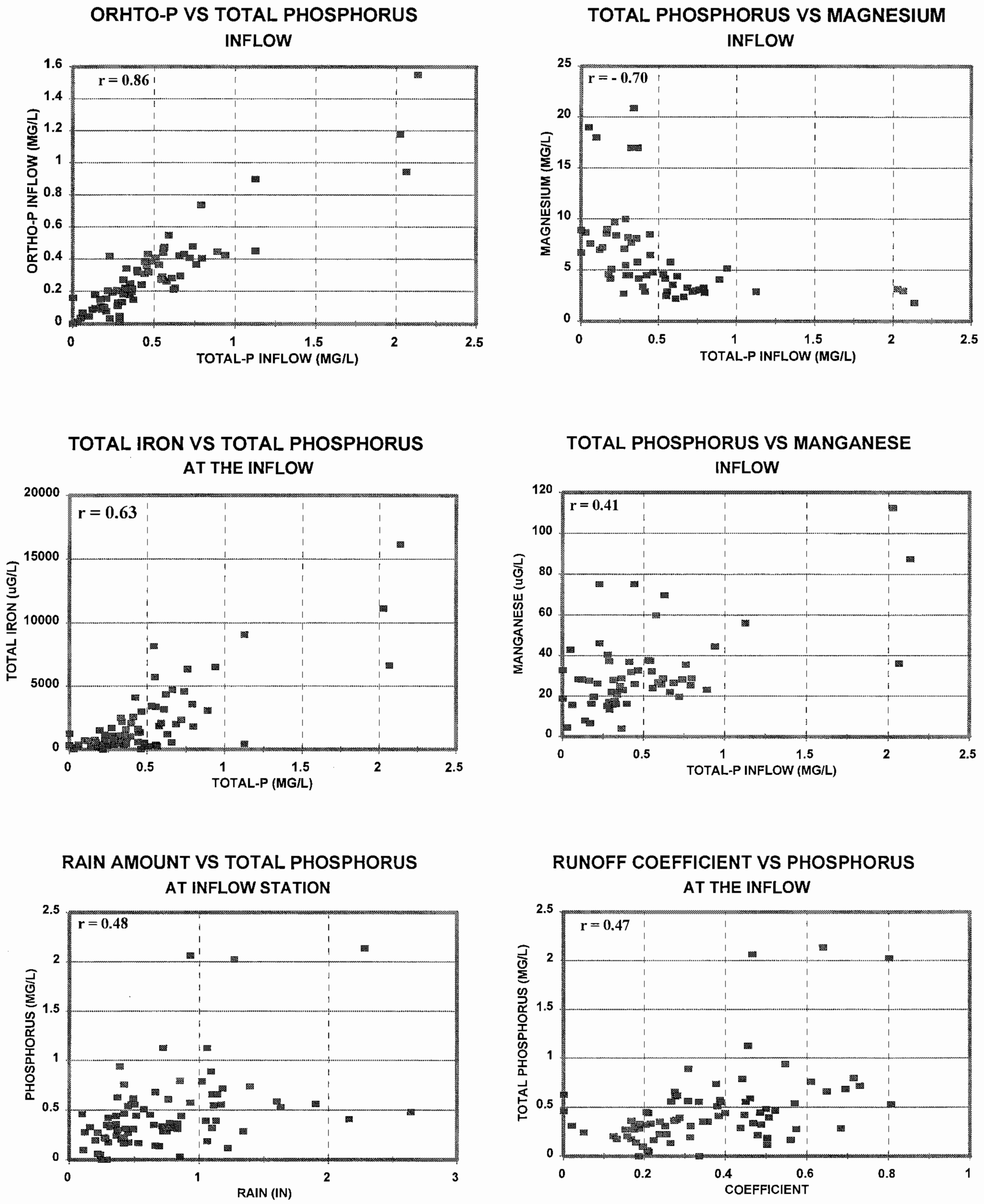

Figure 20. Scatter plots for variables measured at the inflow which had a tendency to vary with total phosphorus. r=Spearman correlation coefficient.

Total phosphorus is also weakly correlated with rainfall amount and negatively correlated with many of the major ions as the example with magnesium demonstrates.

The inflow correlation analysis emphasizes the importance of iron as a controlling mechanism. Since it was measured in above average concentrations, especially in 1994, and since it forms particles that settle easily, it undoubtedly represents an important process leading to the sedimentation and removal of constituents in this study.

Outflow Data

In general the same correlation patterns were seen at the outflow as the inflow (Appendix P), although not as many relationships were identified. Zinc, iron and cadmium were weakly related ($r = 0.45$). Iron was no longer associated with lead, probably because of the extremely low concentrations of lead found in outfall samples with most concentrations below the laboratory detection limit. Nitrogen demonstrated no strong correlations ($r < 0.41$) when compared to other nitrogen species, other constituents, or rainfall characteristics. Major ions were related to each other but demonstrated negative correlations with phosphorus, iron and suspended solids, similar to the patterns found at the inflow.

The most consistent relationships were graphed in scatter plots (Figure 21). As expected, ortho phosphate, which is about 58 percent of total phosphorus, shows good agreement when compared to total phosphorus. One of the major ions, calcium, was plotted as an example of the inverse relationship exhibited by major ions. As discussed above, iron is usually present as ferric oxyhydroxide in aerobic waters, but water at the outflow is sometimes anaerobic after crossing over the wide, heavily vegetated, littoral shelf. Therefore, iron at the outflow may be present in the ferrous form which binds phosphorus and some metals less tightly as was discussed in the sediment section. Also concentrations of iron were significantly less with an average of about 319 ug/l at the outflow compared to 1951 ug/l at the inflow. With a few exceptions, the lower concentrations of constituents make correlations less obvious. One exception, total suspended solids was much better correlated to total phosphorus at the outflow ($r = 0.71$) than at the inflow ($r = 0.47$) indicating a transformation of suspended solids in the pond from inorganic particles to organic forms.

Phosphorus concentrations increased during larger storms at both the inflow and outflow. One explanation for increased concentrations of phosphorus with more intense storms was demonstrated with a study using ^{32}P as a tracer (Ahuja 1990). In that study, rainfall increased the transfer of chemicals from soil solution into surface runoff; with the transfer of phosphorus from the soils likely coming from a pumping action associated with rainfall impacts and accelerated molecular diffusion (Ahuja and Lehman 1983). In our study the effect was much more obvious at the outflow in 1990 when the pond was shallow and often dry (Rushton and Dye 1993).

Correlation analysis provided a basis for drawing conclusions about some of the processes taking place, especially for phosphorus and metals. Phosphorus and iron appear to be controlling factors with increased concentrations of other pollutants increasing with these two constituents. Phosphate species are known to form complexes, chelates and insoluble salts with some metals (Stumm and Morgan 1970).

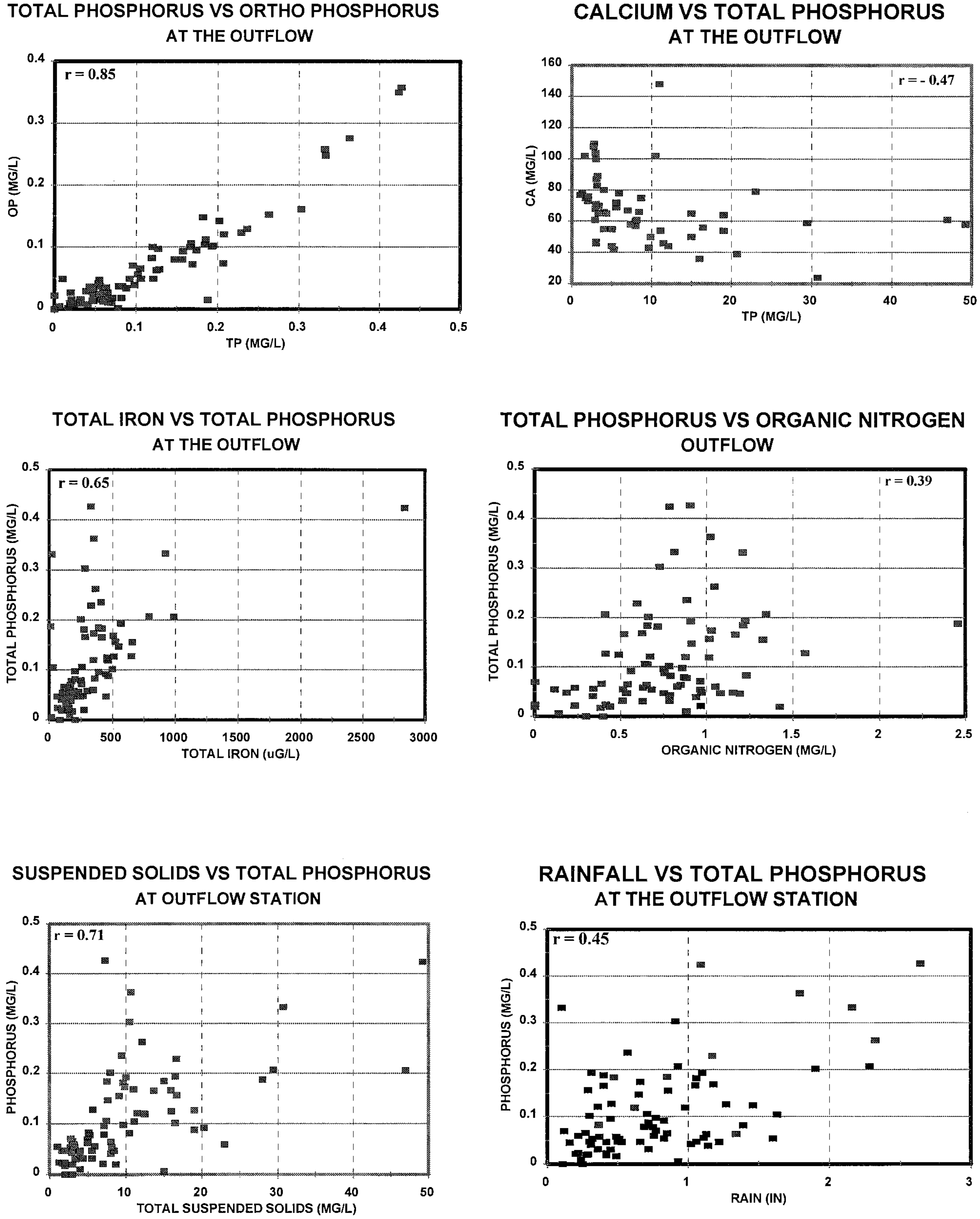

Figure 21. Scatter plots for concentrations of constituents measured at the outflow indicating variables which had a tendency to vary together. r=Spearman correlation coefficient.

Biological Measurements

The preceding sections have investigated the physical and chemical interactions taking place in the wet detention pond. The following section discusses plant and insect measurements made during the final year of the study in 1994 and for vegetation again in 1996.

Vegetation Analysis

Shallow areas, usually around the perimeter of lakes and ponds, which support emergent vegetation are referred to as the littoral zone. They help provide for the biological assimilation of pollutants, and therefore, wet detention ponds built according to SWFWMD rules must include a minimum of 35 percent littoral zone, preferably concentrated at the outfall. The rule also states that the littoral zone shall be no deeper than 3.5 feet below the design overflow elevation. Planting of species is not usually required, but native vegetation that becomes established must be maintained as part of the operation permit. The purpose of this part of the study was to document which plants colonize the littoral zone by natural recruitment and to determine the success of actively planting the littoral zone by increasing the coverage of desirable plants. Also of interest are the processes which allow the invasion of species that tend to form monocultures and have little wildlife value. These are especially serious when they are also aggressive colonizers, such as cattail *(Typha* sp) and primrose willow *(Ludwigia peruviana)* which produce large volumes of organic matter and anaerobic conditions on pond bottoms. Of special concern in this study was the dominance of another noxious species, torpedo grass *(Panicum repen),* which during 1993 and 1994 was a dominant colonizer on the littoral shelf and expanded rapidly into open water by elongated surface runners. This exotic species is difficult to control and is seldom utilized by waterfowl or songbirds (Tarver *et al. 1978).*

A productive littoral zone of desirable plant species helps transform and bury pollutants using a complex variety of biological, chemical and physical processes. For example, Macrophytes remove pollutants by: 1) assimilating them directly into their tissue, 2) providing a suitable environment for microbial activity which in turn remove pollutants, and 3) transporting oxygen into their rhizosphere, thereby stimulating aerobic degradation of organic matter and growth of nitrifying bacteria (Brix 1993, Reddy and DeBusk 1987). Vegetation also slows flow which gives particulates time to settle. In addition a diverse vegetation community attracts macroinvertebrates that also convert constituents and bury them in the sediments. Denitrification, seepage and ammonia volatility are other processes which remove nitrogen. Although senescence of plant parts often release nutrients back to the water column, translocation to the roots essentially removes some nutrients permanently.

Vegetation History at the Site - When first constructed, the original wet detention pond was planted with a variety of species. According to the vegetation plan finalized on January 8, 1987, the following species were to be planted: 206 cypress trees *(Taxodium distichum*), 950 pickerel weed (*Pontederia cordata)*, and 400 cord grass (*Spartina bakeri*). The cord grass and cypress were planted above the littoral zone and the pickerel weed, spaced on 3.3 foot centers, covered the entire pond area. There was no permanent pool in this early design. By 1990, the first year of this study, the cypress and cord grass were well established around the perimeter of the pond, but cattails had invaded the central portion, although some pickerel weed (*Pontederia cordata)*, water lily (*Nymphaea odorata*) and arrowhead (*Sagittaria lancifolia*) still survived, although hidden, among the cattail.

In 1993, the first year the pond was recontoured, an effort was made to save as many of the cypress trees and as much of the cord grass as possible, still many had to be sacrificed to provide sufficient area for the enlarged pond. Almost all of the desirable species in the pond were either transplanted to another site or plowed under. After construction was completed, the littoral zone was quickly colonized by torpedo grass and later almost the entire volume of the permanent pool was invaded by a macroalga, *Chara* sp. Some of the vegetation near the outfall and a few of the pickerel weed and arrowhead in the littoral zone surrounding the pond survived the construction. In July 1994, about six weeks into the final year of collecting data for this study, the littoral zone was planted with 365 bare root pickerel weed seedlings and 265 bare root arrowhead (*Sagittaria latifolia)* plants.

Vegetation Survey - In an effort to quantify the result of natural recruitment on species diversity a vegetation survey of the littoral zone was conducted before planting in June 1994 and again two years after planting in June 1996. Meter square quadrat frames were used to estimate percent cover of emergent vegetation in 54 individual quadrats. Where the littoral zone was wide enough, one quadrat was analyzed near shore, the "a" quadrat, and another measurement was made in the deeper zone, the "b"quadrat (see Figure 4 for the exact location of all sampling sites and Appendix Q for all the measurements). Some of the most striking differences between 1994 and 1996 included the large reduction in open water and the increase in species diversity (Table 18). The dominant species in 1994, torpedo grass *(Panicum repens)* and barnyard grass *(Echinoclloa crusgalli*) occupied about the same area during both sampling events, but many other species had also colonized by 1996. These included not only the planted pickerel weed *(Pontederia cordata)* and arrowhead (*Sagittaria latifolia*) but also *Bacopa monnieri* which grew profusely in the upper part of the fluctuating pool and *Rhynchospora corniculata* which had dispersed from a patch near the outfall to produce isolated individual seedlings throughout the littoral zone. Some nuisance species were also increasing, especially cattail *(Typha* sp.) and willow *(Salix caroliniana)* which, as explained above, have the potential to crowd out more desirable species. Alligator weed (*Alternanthera phloxeroides*) was another noxious weed of concern which showed a 69 percent increase from 1994 to 1996.

Submerged Vegetation - The most noticeable nuisance species in 1996 were large patches of filamentous algae. Since submerged species were not counted in the survey, unless a mat broke the surface of the water, the many large clumps below the surface throughout the littoral zone are not included in Table 18. Also, not included in Table 18 was the macroalga *Chara* which occupied about 40 percent of the volume in the deeper water and appears to be shaded out and killed by the filamentous algae mats. *Chara* had been a dominant vegetation type (about 60 percent of the volume of the permanent pool) during the study in 1993, but was almost totally absent in the pond during the vegetation survey in 1994. By 1996 it was once again a dominant

Table 18. Vegetation analysis of the littoral zone using percent cover. Surveys were conducted June 1994 (shaded columns) and June 1996. Exten=dead end extension on west side, West=West side of original pond, East=East side of original pond, New=part of pond excavated in 1994, Shelf=wide littoral shelf at the outflow. See Figure 4 for locations.

SCIENTIFIC NAME	COMMON NAME	LITTORAL ZONE - PERCENT COVER											
		1994	1996	---------- 1994 ----------					---------- 1996 ----------				
				EXTEN	WEST	EAST	NEW	SHELF	EXTEN	WEST	EAST	NEW	SHELF
Open Water		62.09	29.70	66.1	61.3	50.5	75.1	22.1	40.6	23.7	32.5	22.2	14.6
Panicum repens	Torpedo grass	17.78	23.28	20.1	15.4	20.0	2.4	29.3	33.2	11.3	9.3	32.8	3.9
Echinochloa crusgalli	Barnyard grass	5.30	5.43	0.0	8.1	4.8	0.0	19.4	0.0	13.3	10.6	0.8	1.1
Alternanthera phloxeroides	Alligator weed	2.60	4.39	0.0	0.0	0.0	0.0	0.0	5.8	4.1	4.7	0.4	7.3
Rhynchospora corniculata	Horned-rush	1.57	2.87	0.0	0.0	0.0	0.0	12.1	0.0	5.8	0.3	0.2	11.4
Ludwigia repens		1.50	0.44	4.8	3.6	5.5	0.0	8.6	1.1	0.0	0.0	0.7	0.3
Lolium spp ?		1.20	0.00	0.0	0.0	4.5	0.0	2.1	0.0	0.0	0.0	0.0	0.0
Dichromina colorata	White top sedge	0.93	0.83	2.9	0.1	0.0	0.0	1.3	2.1	0.3	0.7	0.5	0.0
Ludwigia peruviana	Primrose Willow	0.57	0.33	1.4	0.0	1.0	0.0	0.0	0.1	0.1	1.4	0.0	0.1
Pontederia cordata	Pickerel weed	0.48	8.02	0.0	1.7	0.0	0.0	0.7	0.2	10.7	3.7	10.9	21.0
Mikania scandens	Hemp vine	0.46	2.30	1.1	0.3	0.1	0.0	0.7	0.4	0.3	6.2	1.5	4.6
Paspalum distichum	Knot grass	0.46	0.00	0.4	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Spartina bakeri	Cord grass	0.46	0.00	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrocotyle umbellata	Pennywort	0.43	4.83	0.7	0.5	0.2	0.0	0.7	2.1	2.3	6.3	0.4	18.6
Grass (red head)		0.41	0.13	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.7	0.0
Commelina sp.	Dayflower	0.39	0.07	0.0	0.0	1.9	0.0	0.0	0.0	0.1	0.1	0.0	0.3
Polygonium punctatum	Knot weed	0.37	0.56	0.0	1.7	0.0	0.0	0.0	0.0	1.0	0.7	0.0	0.0
Centella asiatica	Coinwort	0.37	0.28	0.4	0.4	0.9	0.0	0.0	0.4	0.5	0.3	0.0	0.1
Ludwigia leptocarpa		0.37	0.09	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1
Cyperus haspens		0.35	0.00	0.0	0.4	0.4	0.0	1.4	0.0	0.0	0.0	0.0	0.0
Sagittaria lancifolia	Arrowhead	0.28	0.11	0.7	0.0	0.0	0.0	0.7	0.1	0.0	0.0	0.0	0.6
Lythrum alatum	Loosestrife	0.28	0.46	0.4	0.5	0.3	0.0	0.1	0.2	0.7	0.3	0.4	0.6
Lippia nodiflora	Carpet weed	0.26	0.22	0.7	0.0	0.4	0.0	0.0	0.0	0.4	0.4	0.0	0.4
Cyperus oderatus		0.24	0.15	0.0	0.8	0.0	0.3	0.0	0.1	0.0	0.0	0.0	1.0
Pluchea purpurascens	Marsh-fleabane	0.17	0.06	0.1	0.7	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Acer rubrum	Red maple seedling	0.11	0.19	0.1	0.0	0.5	0.0	0.0	0.1	0.4	0.3	0.0	0.1
Floating filamentous algae		0.09	6.93	1.6	0.0	0.0	0.0	0.0	6.8	19.4	1.8	1.9	0.0
Sesbania Vesicaria	Bag-pod	0.09	0.00	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Typha sp.	Cattail	0.07	0.63	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	3.0	0.6
Glabrous Grass		0.04	0.31	0.1	0.0	0.0	0.0	0.0	0.0	0.8	0.5	0.2	0.0
Ampelopsis arborea	Pepper vine	0.04	0.07	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0
Eupatorium capillifolium	Dog fennel	0.04	0.02	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Bacopa monnieri	Water-hyssops	0.00	3.37	0.0	0.0	0.0	0.0	0.0	5.8	4.6	4.2	0.0	0.0
Sagittaria latifolia		0.00	1.78	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.8	10.4
Grass	St. Augustine	0.00	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0
Ptilimnium capillaceum	Bishop's weed	0.00	0.41	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	2.4
Cyperus polystachyos		0.00	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Unknown red node		0.00	0.11	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0
Juncus effusus		0.00	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
Salix caroliniana	Willow	0.00	0.07	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0
Juncus megacephalus		0.00	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Cyperus distinctus		0.00	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Galium sp.	Bed straw	0.00	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Ludwigia microcarpa		0.00	0.04	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Unknown alternate leaf		0.00	0.04	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Unknown opposite leaf		0.00	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Mitreola petiolata		0.00	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Ulmus americana var floridana	Elm seedling	0.00	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
AVERAGE NUMBER OF SPECIES PER SQ. METER		3.67	6.70	4.2	5.3	4.3	1.5	5.1	6.4	6.4	6.6	5.3	9.4

species and since it produces major changes in dissolved oxygen and pH (see Figure 13), its effect needs further study. It may also indicate eutrophication levels.

Chara belongs to the Chaophyceae family, a unique group of nonvascular hydrophytes with worldwide distribution commonly known as stoneworts or brittleworts. They grow best in oligotrophic calcareous waters and disappear when water bodies become eutrophic (Vymazal 1995). *Chara* spp. may be physiologically sensitive to high P concentrations (Forsberg 1964) or as Blindow (1988) found not inhibited by P toxicity but reduced by some other factor such as competition from other vegetation. Competition appears to be the case in this study where light limitation or smothering by filamentous algae seems to cause its demise. Inability to tolerate competition was also evident in the littoral zone in this study since *Chara* was seldom seen in plots next to the shore where other vegetation was present in quantity. A study in the Florida Everglades tends to support this hypothesis. Complete disappearance of both *Chara* and *Utricularia* was seen in plots with added phosphorus of 0.26 g - m^{-2} - wk^{-1} (Steward and Ornes 1975). In another study with lower P additions (4.8 g P- m^{-2} - yr^{-1}) the results showed a decline of *Utricularia* and an increase in *Chara* and the authors concluded that an increase in *Chara* may serve as an early indicator of P enrichment in the Everglades (Craft *et al.* 1995).

Spatial Differences - The vegetation data for each year were further subdivided into the area of the pond where it was found (Table 18). The wide littoral shelf near the outflow (SHELF) had the least percentage of open water for both years and showed the best survival rate for the planted pickerel weed and common arrowhead. It also had the greatest reduction in torpedo grass which in this study did not survive shading by other vegetation. The newly excavated zone (NEW) had the greatest percentage of open water and the least diversity in 1994, but by 1996 the open water had been colonized by torpedo grass and the area near shore by the planted pickerel weed. In 1994, with the exception of the newly constructed area, the dead end extension to the west (EXTEN) had the greatest amount of torpedo grass and open water. The sharp drop off and deeper water in both the dead end and the newly constructed portion of the pond especially favored the dominance of torpedo grass which expands by long floating rhizomes from the shore. The east (EAST) and west (WEST) sides of the pond exhibited similar characteristics with about the same amount of open water and torpedo grass. The west side of the pond and the dead end extension to the west had the largest amount of filamentous algae indicating the prevailing wind may blow it in that direction.

Species Diversity - From 1994 to 1996 species diversity increased by 82 percent overall and as might be expected was greatest in the newly constructed portion of the pond where it increased by 253 percent. In contrast, diversity on the littoral shelf increased by 84 percent and in the rest of the pond by 21 to 53 percent. The littoral shelf exhibited the greatest species diversity on both sampling dates demonstrating the effect of its larger size and more uniform water depth on plant colonization as well as survival of planted species. The survey also demonstrated that planting the shelf with pickerel weed and common arrowhead reduced the amount of torpedo grass (87%). The planting of pickerel weed also reduced the amount of torpedo grass in other parts of the pond but not by as great a percentage since the torpedo grass expanded into the deeper water. It should be noted that pickerel weed was planted in two rows around the perimeter of the pond but only those closest to shore survived while torpedo grass continued to expand into the open water zones demonstrating the effect of proper elevations for establishing target species.

Nuisance Species - By 1996, cattails, an invasive species, had begun to colonize two parts of the pond: 1) on the exposed shore of the newly constructed portion and 2) on some of the soil piled up during the pond excavation on the littoral shelf. After the survey was completed, the cattails were cut off below the water surface to see if they can be controlled in this manner. The number of cattail plants removed on the newly constructed part of the pond included 192 individuals and on the littoral shelf at the outflow, 125 individuals. These plots will be followed to determine if this is an effective method for controlling cattail invasions. During our observation period from 1990 to 1996 no cattails were reduced by any planted vegetation or naturally occurring species colonization. However, caterpillars were observed on almost all cattail stalks in 1996 which may be providing some biological control. Alligator weed (*Alternanthera phloxeroides*) was another noxious weed of concern where heavy grazing by insects may be keeping its expansion under some control. All alligator weed plants measured in 1996 showed severe grazing by insects.

In summary, factors which influenced the colonization of nuisance species in this study included exposed soils after construction which produced conditions favorable to cattail invasions. Steep slopes in the littoral zone favored the expansion of torpedo grass and may indicate that a 3.5 foot maximum depth for the littoral zone is too deep. Of importance is the greater species diversity and survival of desirable planted species which occurred on the large (45 x 45 sq. ft.) and relatively shallow (< 1 ft average depth) littoral shelf at the outflow. Planting desirable species reduced the invasion of torpedo grass when water levels were shallow, however, none of the planted pickerel weed survived in the deeper part of the littoral zone and the planted arrowhead only survived on the wide littoral shelf at the outflow.

Macroinvertebrate Sampling[2]

The diversity and abundance of aquatic macroinvertebrates can be used as a measure of environmental quality. It has been well documented that non-polluted water bodies have a significantly greater diversity and a different taxa composition than polluted systems. To document the changes over the summer in this newly recontoured wet detention pond, dip net and sediment samples were collected weekly from June 18 to August 16, 1994. Open water areas and vegetated littoral zones were sampled with equal intensity and the combined data for each date were recorded.

It was expected that the high pollution loads and the wide fluctuations typical of stormwater ponds would result in an abundance of a few tolerant species and therefore low

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[2] Marnie Ward, an undergraduate student in the Department of Zoology at the University of Florida, collected and identified the insects as an independent study project. The information in this section was taken from her report.

species diversity. This was not necessarily the case in this newly constructed pond. Instead the number of species steadily increased while the number of individuals fluctuated sporadically in response to environmental conditions, insect emergence patterns, and disturbance of the littoral zone by the planting of additional vegetation (Table 19). The littoral zone was planted with pickerel weed and other desirable macrophytes on July 20, 1994 (refer to vegetation analysis section), and this disturbance interrupted the upward trend of the number of individuals recorded after this date. No obvious explanation exists for the sudden drop in the number of individuals on August 16th. The greatest abundance of individuals and taxa occurred on August 4th when 165 individuals of 19 taxa were identified and this same pattern continued for the August 11th sampling date. The high number of individuals were the result of one species, *Limnodrilus hoffmeisteri*, which accounted for almost half of the individuals collected on those two dates.

Other taxa collected during the study indicate the stormwater pond is suitable for habitation by aquatic species that are considered pollution intolerant. For example, mayflies have long been classified as an indicator of good water quality, due in part to the large gill surface area they expose to the environment (Fleming 1964, Gaufin 1973). Also studies of heavy metal pollution indicate mayflies are sensitive to heavy metal contamination (Winner 1980). In some studies hydracarinids in the order Arachnida were found to be sensitive to environmental stress because of their low tolerance to physio-chemical changes, especially pH fluctuations (Smith and Cook 1991, Havens 1993). In our study hydracarinids were represented in all collections after July 15th. Also in the order Diptera, *Cryptotendipes* sp. is listed as a taxa intolerant of pollution (Hulbert 1989), although other Diptera in the pond, *Cryptochironomus* spp., *Glyptotendipes paripes, Tanypus* spp. and *Chaoborus punctipennis*, are taxa tolerant of degraded conditions (Hulbert 1989).

Diversity indices are an additional tool for measuring the quality of the environment. Although estimates of diversity improve with increased sample size and are not accurate with less than 100 specimens, they are used here to give an indication of the status of the system. The Shannon-Weaver diversity index measures both richness of species and the distribution of individuals among species. For this study values ranged between 2.74 measured on the first sampling date to 3.49 calculated for July 29. For pooled data which included all sampling dates the diversity index increased to 4.53 (Table 19). When Wihm (1970) evaluated Shannon-Weaver diversity numbers calculated from data collected by numerous authors for a variety of polluted and unpolluted waters, he found that in unpolluted water the diversity index was usually between 3 and 4, but in polluted waters the index was less than 1. Using this yardstick the stormwater pond falls in the slightly polluted category. However, in the southeastern United States, EPA biologists found that where degradation is slight to moderate, the diversity index lacked the sensitivity to detect the differences (USEPA 1973).

Another measurement, equitability (USEPA 1973), is much more sensitive to pollution. Equitability usually ranges from 0 to 1 except in the unusual situations where samples contain only a few specimens represented by several taxa. That situation occurred in this study on collection days with less than 55 individuals and 16 taxa (Table 19). In unpolluted streams equitability generally ranges between 0.6 and 0.8, and even slight levels of degradation have

Table 19 . Insect taxa collected at the Tampa Office Pond - Summer 1994

	Jun 18	Jul 8	Jul 15	Jul21	Jul 29	Aug 4	Aug 11	Aug16	TOTALS
Odonata (dragonflies)									
Crocothemis servilia		1							1
Perithemis tenera		1							1
Brachymesia gravida		1							1
Orethemis ferruginea		2	2	1	4				9
Pachydiplax longipennis			2		3	3	4		12
Erythemis simplicicollis		3		1			1		5
Coryphaeschna ingens					1				1
Analagma doubledaye							2	1	3
Pantala flavescens								1	1
Odonata (damselflies)									
Ishnura posita		18	11	2	3	2	5		41
Ishnura ramburii			6		1				7
Hemiptera (true bugs)									
Belostoma lutarium					1				1
Belostoma testaceum	3	1	7		2		3	1	17
Ranatra nigra							3	1	4
Ranatra fusca						1			1
Pelocoris femoratus		3	9		5	9	8		34
Ephemeroptera (mayflies)									
Cloeon sp.	3								3
Baetis pigmaeus	2					4	3		9
Baetis intercalaris							4		4
Ephemerellidae				6	14				20
Isonychia sp.					2				2
Baetisca sp.					1	1			2
Caenis diminuta				4		15	2		21
Coleoptera (water beetles)									
Lissorhoptrus simplex	7	1	2	1			2	1	14
Derallus altus	1	2						1	4
Stenus sp.	2								2
Tropisternus lateralis	3					1			4
Haliplus mutchleri		1		1	2				4
Haliplus punctatus				3		1	1		5
Dineutus emarginatus		2	43			1			46
Oligochaeta (worms)									
Limnodrilus hoffmeisteri		1	5			80	67		153
Arachnida (water spiders)									
Hydracarina (green)				2		23	8		33
Hydracarina (red)				2	2	2	1	2	9
Tricoptera (stoneflies)									
Oecetis sp.						2	3	4	9
Diptera (midges)									
Odontomyia sp.				1			1	2	4
Chaoborus punctipennis								1	1
Cryptochironomous sp.				1	4	10			15
Cryptotendipes sp.						2			2
Glyptotendipes sp.	1				8	5		2	16
Polypedilum sp.						1		1	2
Procladius sp.							1	1	2
Tanypus sp.			2		1		1	1	5
Tanytarsus sp.						2		14	16
Number of individuals	**22**	**37**	**89**	**25**	**54**	**165**	**120**	**34**	**546**
Number of taxa	**8**	**13**	**10**	**13**	**16**	**19**	**19**	**15**	**43**
Diversity Index	**2.74**	**2.76**	**2.49**	**3.27**	**3.49**	**2.73**	**2.68**	**3.11**	**4.53**
Equitability	**1.14**	**0.71**	**0.75**	**1.06**	**1.01**	**0.48**	**0.47**	**0.83**	**0.79**

been found to reduce the level below 0.5. Polluted water is generally in a range of 0.0 to 0.3. The lowest values (0.47 and 0.48) calculated during early August in this study occurred when an explosion of *Limnodrilus hoffmeisteri* dominated the collection effort. The dominance of this one species may be an indication of increased pollution levels during the height of the rainy season, or more likely, the manifestation of its life cycle and the emergence of its young.

Although relatively high levels of degradation had been expected in the stormwater pond, both species composition and diversity measurements indicate only slightly degraded water quality. Since this was a newly constructed pond, it was reasoned that it may not be representative, therefore, a comparison site which had been receiving stormwater for over ten years was added to the study. It was sampled on August 18, two days after the last collection date at the Tampa Office pond. The purpose was to examine similarities and differences between the old and the new pond. The comparison pond had been included in a previous study conducted by SWFWMD where 24 wet detention ponds that had received permits from the District were compared after storm events for water quality (Kehoe 1992). In that study the pond was identified under the pseudonym GTEDS. The GTEDS pond is 3.69 acres in size with an average depth of 10 feet. It receives runoff from 54 acres covered mostly by paved parking lots and rooftops. Like the Tampa Office pond, the bottom is clayey with a littoral zone of healthy macrophytes around the perimeter. At the time of the invertebrate sampling the water clarity was poor. Sampling was accomplished using the same proportional distances and methods as the Tampa Office pond. The comparison of the species collected at the Tampa Office pond on August 16th with the other much larger wet detention pond GTEDS on August 18th are listed in Table 20. Although only about 24 to 28 percent of the same taxa were found in both ponds, the number of individuals and species are almost the same.

Table 20. Insect taxa at two wet detention ponds during August 1994.

Order	Genus Species	Tampa Office Pond (3 mo old)	GTEDS (10 yrs old)
Odonata	*Pantala flavescens*	1	
	Analagma doubledayi	1	
	Lestes sp. 1		1
	Lestes sp. 2		1
	Ophiogomphus sp		2
	Erythemis simplicicollis.		2
Hemiptera	*Belostoma testaceum*	1	1
	Ranatra nigra	1	
	Ranatra fusca		4
	Pelocoris femoratus		4
	Pelocoris carolinensis		7
Arachnida	*Hydracarina* (green)		7
	Hydracarina (red)	2	1
Tricoptera	*Oecetis* sp.	4	
	Unidentfied Leptoceridae (Family)		1
Coleoptera	*Lissorhoptrus simplex*	1	
	Derallus altus	1	

Table 20 (continued)

Order	**Genus Species**	**Tampa Office Pond (3 mo old)**	**GTEDS (10 yrs old)**
Diptera	*Odontomyia* sp.	2	
	Chaoborus punctipennis	1	
	Glyptotendipes sp.	2	1
	Polypedilum sp.	1	
	Procladius sp.	1	
	Tanypus sp.	1	
	Tanytarusus sp.	14	1
	Unidentified Tanypodinae (Family)		1
	Number of Individuals	**34**	**34**
	Number of Species	**15**	**14**

This limited study spanning a two month period indicates that stormwater ponds are not dominated by an abundant number of individuals representing a few tolerant taxa, as might be expected, but instead are quite diverse including some species intolerant of pollution. Since insects integrate chemical, physical, and ecological aspects of water quality, this implies that stormwater ponds may be relatively good wildlife habitat when properly built and maintained. However, it needs to be emphasized that heavy metals and organic pollutants can be concentrated up the food chain. In a study funded by the St. Johns River Water Management District, fish collected from stormwater ponds contained significantly higher concentrations of heavy metals then fish from a control site (Campbell 1993).

A recent visit to the Tampa Office pond in June 1996 revealed that the pond has an even more diverse insect community than when sampled in 1994. Many different varieties of dragon flies, mayflies and water spiders were seen in abundance. Also several large bass and many other species of fish were evident in the clear water. More detailed studies of insects in wet detention ponds would provide useful information for making these systems better wildlife habitats, although more information is needed about the bioaccumulation of toxic pollutants in species that use these systems.

ANALYSIS

The results of this study clearly demonstrated the improvement in pollution removal made by the Conservation Wet Detention design. Features such as a fourteen day residence time, a permanent pool for maximum mixing and a littoral zone for biological treatment increased mechanisms for pollution removal. This section will discuss some of the processes that help improve water quality.

Pollutant Removal Mechanisms

Whenever site conditions allow, stormwater management systems should be designed to achieve maximum onsite storage (and even reuse) of stormwater by incorporating infiltration practices throughout the remaining natural and landscaped areas (Livingston 1995). Also conditions in the pond should be manipulated if necessary to maximize pollution removal.

Landscape Techniques

Good stormwater management includes strategies for removing pollutants as soon as rainfall reaches the ground and designs should incorporate a series of opportunities for assimilation, transformation and recycling of stormwater. Some of the mechanisms for good stewardship which were used in this project include taking advantage of the entire drainage basin. Various processes which were or could be incorporated into the landscape design at the Tampa Office are illustrated in Figure 22 and discussed below.

Preserving Existing Wetlands - The pond was excavated between two degraded wetlands which had been impacted by construction of the Tampa By-Pass Canal. Although no direct exchange of water between the pond and the wetlands exist during normal rain events, data from the surrounding wells show how the mound of water under the pond also raises the water table under the wetlands after rain events (Rushton and Dye 1993). Placing the two systems in close proximity also increases the potential for wildlife utilization. Additionally, planting cypress trees around the pond shaded the littoral zone reducing algae and other nuisance species and the increased transpiration by trees helped to cleanse and recycle stormwater.

Parking Lot Design - Grassed areas around the parking lot provided some treatment for runoff by acting as grass buffer strips. To be effective the strip must be at least 20 feet wide, have a slope of 5 percent or less and be stabilized (Bell 1995). Under ideal conditions, grass buffer strips can remove 5 to 25 percent of suspended solids provided the flow is kept shallow and slow (Urbonas 1994). It was shown by Wanielista *et al.* (1978) that shoulder areas of highways were very effective for the removal of hydrocarbons, metals, and solids.

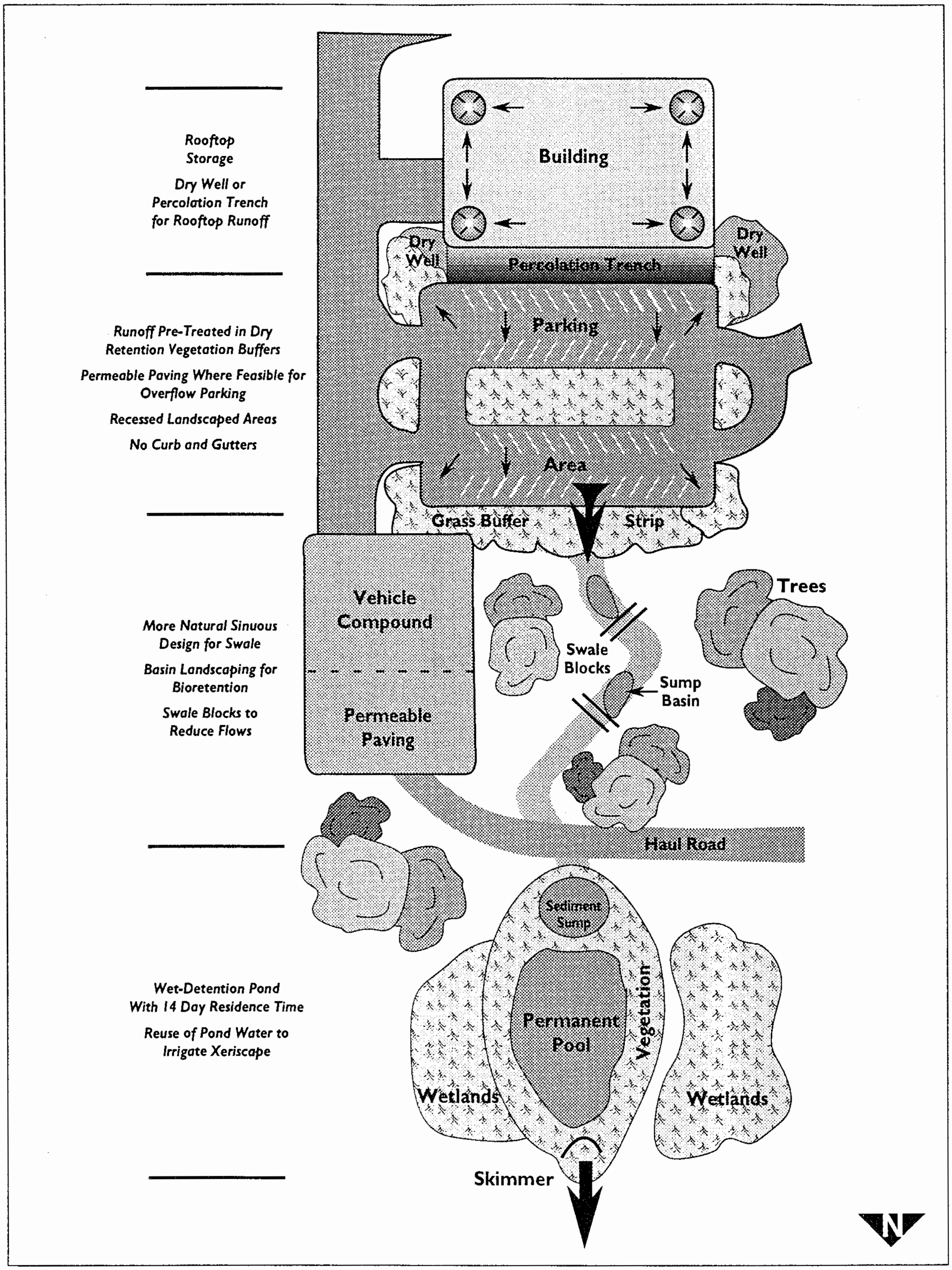


Figure 22. Idealized Basin Design for Stormwater Treatment.

The watershed design in this study would be improved by also including landscaping treatment. Trees and shrubs absorb the energy of falling rain, their roots hold soil particles in place, vegetation helps maintain absorptive capacity of the soils, and vegetation slows the velocity of runoff and acts as a filter to catch sediments. One method being tested to reduce runoff in Maryland, is Rain Gardens. These are shallow landscaped gardens that mimic a forest environment and manage stormwater through bioretention. It is estimated that 19% to 38% of nitrogen loading and 18 to 73% of phosphorus loading could be removed if a mature forest was created for bioretention (Coffman 1993). Rain Gardens can also be designed so that they reduce discharge to predevelopment levels, a condition that is not achieved with wet detention ponds alone (Coffman 1995). All stormwater retained and recycled on site, reduces pollutant loads downstream by allowing more time for infiltration and evapotranspiration. Vegetative control is usually accomplished in parking lots by using recessed landscape areas with raised storm sewer inlets and curb cuts.

Roof Runoff - At the Tampa Office site, roof drains discharge directly to the parking lot surface which increases flow and pollutants to the pond. Bioretention would have been useful in treating the roof runoff, especially if some kind of dry well or infiltration trench had been incorporated into the design to take care of excess runoff. When percolation trenches are properly operating they can remove up to 99% of the particulates (Urbonas 1994). This also reduces surface runoff which, in turn, reduces surface water pollutants. The major concern is groundwater pollution. Studies have shown that possible metal pollution from stormwater which has percolated through soils does not migrate more than a few inches and follows an exponential decline with depth (Harper 1988, Yousef *et al.* 1991). Nitrate-nitrogen, however, is highly mobile and could create higher concentrations in groundwater, this possibility needs further study. A major concern associated with infiltration/exfiltration systems is filter clogging and maintenance.

Pre-Treatment Swales and Ditches - Placing the wet detention pond some distance away from the parking lot increased the potential for stormwater treatment before runoff entered the pond. This minimized the directly connected impervious surfaces such as asphalt parking lots and building rooftops and therefore reduced pollutant loads. Surface runoff from storms less than about 0.15 inches was virtually eliminated because of the opportunity for infiltration and depression storage. Also the runoff that did occur had the opportunity for treatment. Some field measurements showed removal efficiencies of 30 to 50% for metals by swales 200 feet long, although the swales perform poorly in reducing concentrations of nutrients (Harper 1988). This is consistent with data collected during this study. In 1991 composite grab samples for two storm events were collected from parking lot runoff to estimate the amount of treatment given by the ditches (Rushton and Dye 1993). Removal efficiencies were similar or somewhat higher than Harper's (1988) with about 50% removal for total suspended solids and 10 to 30% for nutrients except for organic nitrogen which increased. The higher concentrations of priority pollutants measured in sediment cores collected in the swale compared to concentrations at the inflow of the pond is another indication that the swale is effective for removing petroleum hydrocarbons (see Table 17). Maintenance may present a challenge, however, and sump basins may be a solution.

Sump Basins - Although a few wide places in the swales and ditches collected some water and slowed flow in this study, sump basins designed for this purpose would have been more effective. Sediment sumps, forebays or interceptor basins are depressions in the runoff collection stream which may also be a cost effective maintenance strategy. Maintenance of stormwater systems has not been adequately addressed and the value of collection areas where sediments can be easily removed and the area restored appears to be an attractive alternative. Most stormwater sediments meet State Clean Soil Criteria (Rule 62-775) and can be disposed of in permitted lined landfills and used for landfill cover (Livingston and Cox 1995). Since these sediments also contain elevated concentrations of nutrients, they can also be used on site as a soil amendment. Yousef *et al.* (1991) recommends that sediments accumulating in wet detention ponds be removed every 25 years based on sediment accumulation rates. Fernandez and Hutchinson (1992) indicate that the longer sediments accumulate in wet detention systems the more likely the sediments may exceed clean soil criteria. Cleaning out an entire pond is an expensive proposition and destroys existing ecosystem values. Sump basins would intercept much of the heavier particles and although they would have to be cleaned more often, the process would be less expensive and cause less environmental damage. A sediment sump collecting runoff from a roof top and a parking lot in a commercial development demonstrated its effectiveness in capturing and retaining zinc and copper (Carr and Rushton 1995).

Packed Bed Filters - Packed bed filters use vegetation planted in rock media to filter and treat stormwater. Experiments conducted to determine the efficiency of packed bed filters indicate good removal for metals, organic nutrients and total suspended solids with averages usually between 50 and 90 percent (Egan *et al.* 1995). Dissolved nutrients were not as easily removed, however, and were often increased. Depending on flow rate, nitrate and phosphorus often increased and ranged between -55 percent to +57 percent, and ortho-P ranged between -49 percent to +4 percent. The study showed that low flow was most effective for removing cadmium, chromium, TKN, nitrate, nitrite, total dissolved solids and total suspended solids; while copper, lead, zinc, ammonia, total phosphorus, fecal coliform, and total organic carbon were removed better at higher flow rates (Egan *et al.* 1995).

Pollutant removal in dry systems such as most of those described above are limited by: Resuspension of previously deposited material, short settling times which then export fine-grained particles, and insufficient biological contact time for uptake of soluble nutrients. Therefore they are more suitable for removal of large particle sized pollutants and for reduction in stormwater volume before more intensive treatment. Wet ponds, on the other hand, are effective in removing both small particulates and soluble pollutants provided they have sufficient volume in relation to the contributing watershed and effectively utilize the biogeochemical cycle (Schueler and Helfrich 1989).

Wet Detention Basins

The primary objective of our research project was to analyze the effectiveness of three wet detention designs for pollutant removal efficiency and the following section investigates some of the mechanisms which affected pollution removal. Two main processes are taking place in wet detention ponds to reduce pollutants (Hartigan 1989): One relies on solids settling theory and assumes pollutants are removed by sedimentation, and the other views the wet detention pond as a lake achieving a controlled level of eutrophication in an attempt to utilize biological and physical/chemical processes. Both approaches suggest that pollutant removal efficiency is positively related to hydraulic residence time (Figure 23).

Hydraulic Residence Time (HRT) - One of the main differences between the three design alternatives was an increase in residence time from 2.5 days in 1990, to 5 days in 1993 and finally to 14 days in 1994. HRT is the average amount of time water is stored in the permanent pool, and is the reciprocal of the water renewal rate. Chemical and biotic properties are often influenced by the openness of the system, and the renewal rate is an index of this process since it indicates how rapidly the water in the system is replaced (Mitsch and Gosselink 1993). A model developed by Walker (1987) to determine the optimal residence time necessary to reduce nutrient levels to acceptable levels, calculated that it takes two to three weeks for the removal of dissolved nutrients (Hartigan 1989). Field investigations have also identified residence time as a key parameter as determined in an analysis of several mechanisms studied at a natural wastewater wetland treatment site (Knight *et al.* 1987). Based on the parameters measured in their study, residence time is the primary causative factor influencing the reduction of P concentrations. Residence time was also shown to increase the removal of pollutants in laboratory experiments using both calcareous and organic soils. The nitrate concentration of the water column was decreased by 15 and 54 percent for a residence time of 12 and 24 days respectively for both soil types; and for ammonium the reduction was 75 percent in 12 days compared to 93 percent in 24 days in organic soils, and 53 percent in 12 days and 98 percent in 24 days for calcareous soils (Reddy and Graetz 1981). This shows that under ideal conditions in the laboratory, residence time is an important process for removing nitrogen and phosphorus from the water column. Our field study substantiates these results for wet detention ponds (see Table 7 and Figure 8).

But, infinitely long residence times are not the answer. Apparently in natural systems there is an optimal residence time depending on the size of the system before degraded nutrient enriched water is a problem. Low removal rates of nutrients have been recorded when ponds become stagnant. It is well documented in the limnology literature that increased water residence time leads to higher algal abundances in systems constrained by temporal, rather than nutrient limitations (Soballe and Kimmel 1987). Hvitved-Jacobsen (1990) also noted that algae problems in wet detention ponds were dependent on residence time. He concluded that long residence times supported by external as well as internal nutrient loads may increase algal biomass and that detention pond volume for pollution removal has to be weighed against tolerance for eutrophication levels. Increased algal production was also noted in a study of 24 wet detention ponds where grab samples were collected at the outfall after rain events. In that study, using log transformed data, total suspended solids concentrations were negatively correlated with discharge frequency (r = -0.62) (Kehoe 1992). The 14-day residence time used during our study appears to be of sufficient duration to remove nutrients, but not long enough to affect removal rates (see Table 7).

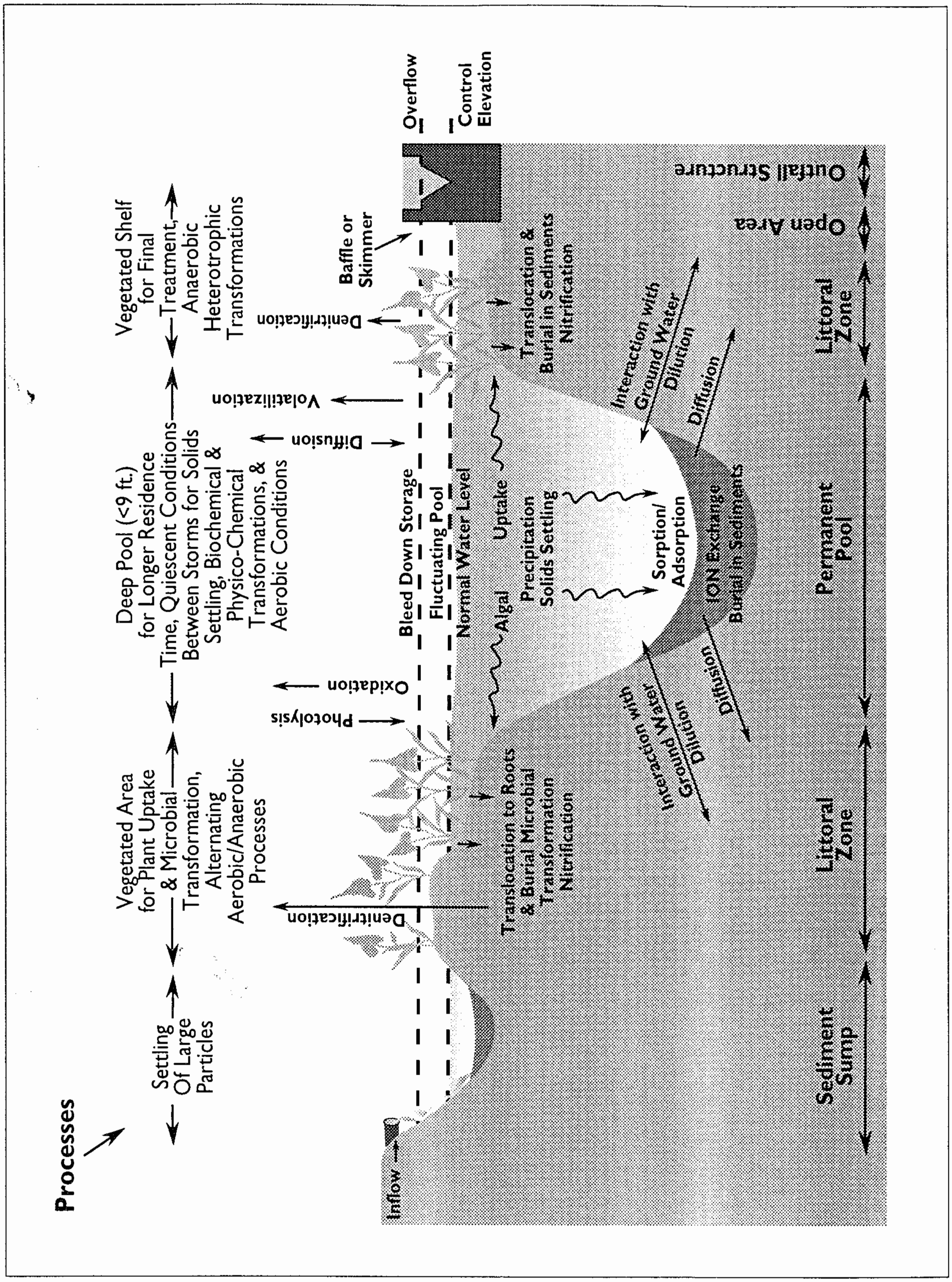


Figure 23. Idealized Wet Detention Pond

Permanent Pool - One of the most important features of a wet detention basin is the permanent pool (Hartigan 1989), and one of its major functions is to allow time for gravitational settling and transformations. Most pollution removal occurs during quiescent periods between storm events therefore the permanent pool must have sufficient volume to treat storm runoff. Ideally the "treated water" from the previous storm will be displaced by the next rain event. During the intervening time the permanent pool provides conditions where sedimentation of particulate matter is most likely to occur. Settleability of particulates has been studied in the laboratory by Whipple and Hunter (1981) and Randall *et al.* (1982). Results show that TSS and lead are the most efficiently removed while about half of BOD and phosphorus were reduced and more than a third of selected metals settled out (Table 21). These values indicate how much pollution removal is theoretically possible by sedimentation alone. During the third year of our study much better removal rates that those in Table 21 were documented (see Table 7) indicating that other processes besides sedimentation were reducing pollutants.

Table 21. Comparative settleability of pollutants in urban runoff as determined by laboratory settling experiments. Percent removal of pollutants.

	TSS	TOC	TP	TN	ZINC	LEAD	COPPER	BOD
(1)	90	34	56	33	44	86	---	64
(2)	68	---	50	---	30	65	42	40

(1) Randall *et al.* 1982 (48 hour settling time)
(2) Whipple and Hunter 1981(32 hour settling time)

Aquatic Plants - Vegetation in a stormwater treatment system is important both for uptake of nutrients and as a carbon and litter source for the sediments. The carbon, in part, fuels the immobilization of phosphorus and nitrogen by microorganisms. Vegetation coverage was a major difference between the three pond designs. In 1990 the entire pond was colonized by cattail and the depth of the pond was about one foot. For 1993 and 1994 only one-third of the pond area included a littoral shelf allowing pollution treatment by both a permanent pool and vegetation. The dominant vegetation was torpedo grass and the maximum depth of the littoral zone was up to three feet. These differences in vegetation cover affect processes in the pond.

Vascular plants are important in pollution removal since they assimilate and store contaminants, transport oxygen to the root zone, and provide a substrate for microbial activity. In a literature review of the role of aquatic plants in the removal of pollutants the following processes were identified (Reddy and DeBusk 1987). Nitrification-denitrification reactions are the dominant mechanism for nitrogen although some quantities of N can be removed by plant uptake. The nitrification process is enhanced beneath stands of plants which transport large quantities of oxygen such as pennywort. Nitrate-N thus formed, diffuses into reduced microenvironments in the pond system, where it is utilized as an electron acceptor by facultative anaerobic bacteria and lost from the system as nitrogen gas, however, differences between plant species is impressive. Denitrification rates in excess of 1 g m^{-2} d^{-1} have been reported in experiments with pennywort. As a comparison, pennywort transported 2.49 to 3.95 mg O_2 g^{-1} hr^{-1} while cattails only transports 0.19 to 1.39 mg O_2 g^{-1} hr^{-1} (Reddy and DeBusk 1987).

Although phosphorus is also removed from water by plant uptake and microbial assimilation, reduction depends mostly on precipitation with cations, such as calcium, magnesium, iron, manganese and adsorption onto clay and organic matter. This helps explain the much better removal of total phosphorus compared to total nitrogen in the Tampa Office pond since higher than average concentrations of calcium and iron were measured.

Removal rates of 13 to 75 percent of total nitrogen and 12 to 75 percent of total phosphorus have been recorded for vegetated plots (Reddy and Debusk 1987). High plant surface area and soil organics are important for the microbial decomposition of oxygen demanding pollutants, petroleum hydrocarbons and synthetic organics (Horner 1995). Plant uptake and microbial transformations at the Tampa Office pond undoubtedly were responsible for removal of pollutants, but plants also affected the amount of dissolved oxygen in the water column which introduces another process which affects pollution removal.

Aerobic/Anaerobic conditions - Biogeochemical cycling in wetlands holds the key to improving designs for pollutant removal efficiency, and dissolved oxygen levels with its associated redox reactions are often implicated in that process. One mechanism for the removal of pollutants in the second and third year of this study, as compared to the first year, was the fact that more than one process for pollution removal was available. These included both aerobic and anaerobic conditions with well oxygenated open water expanses in the permanent pool and more anaerobic vegetated littoral zones (see Table 11). Nitrogen removal is enhanced by alternating oxidizing and reducing conditions which maximize nitrification during the aerobic phase and denitrification during anaerobic (reducing) conditions, however, denitrification is reduced if carbon supplies are low (Hammer and Knight 1994). Ammonium loses were more complicated with an initial increase of ammonium caused by the mineralization of organic nitrogen, followed by a rapid decrease during the 29 day experiment. Ammonium loss (99 percent) in the aerobic water was due to nitrification and ammonia volatilization. The loss in the anaerobic water columns (83%) was due to the ammonia volatilization process alone (Reddy and Graetz 1981). Ammonification needs moderate temperatures and pH, microbial attachment substrates, and adequate supplies of oxygen (Hammer and Knight 1994). These conditions were met using the Conservation Wet Detention design (1994) in our study.

The phosphorus cycle is fundamentally different from the N cycle since there is no valency change, no gaseous phase, and the soil-litter compartment contains the major P pool. Although phosphorus is unaffected by redox reactions anaerobic conditions still releases P to the water column since the adsorbed and occluded P is released when Fe^{3+} is reduced to Fe^{2+} (Faulkner and Richardson 1989). As an example of the effect of redox reactions on P removal, Yousef *et al.* (1986) conducted isolation chamber experiments and measured a decrease of phosphorus in the water column under aerobic conditions, and an increase, under anaerobic conditions. They concluded that soluble phosphorus was decreased because of sorption by the sediments and the control of its release in an aerobic environment. Masscheleyn *et al.* (1992)

found soils equilibrated under oxidized to moderately reduced conditions (+500 to +200mV) removed from 90 to 98 percent of added P depending on P load; but under reduced conditions (0 to -200mV), only 28 percent (low loads) to 74 percent (high loads) of phosphorus was removed by the soil. One explanation for the difference is given by Patrick and Khalid (1974) who found anaerobic soils released more phosphate to soil solutions low in soluble phosphate and sorbed more P from soil solutions high in soluble P than did aerobic soils. They theorized that the greater surface area of the gel-like reduced ferrous compounds in an anaerobic soil results in more soil phosphate being solubilized where solution phosphate is low and more solution phosphate being sorbed where solution phosphate is high. This same tendency was seen during quiescent conditions (one sampling event) at the Tampa Office pond where stations with low dissolved oxygen had higher total phosphorus concentrations (see Appendix N-4). Also, when DO concentrations in the bottom waters were less than 2 mg/l, total phosphorus concentrations were 0.16 and 0.27 mg/l; while DO levels greater than 8 mg/l had P concentrations that ranged from 0.06 to 0.09 (see Table 14).

An anoxic sediment-water interface typically exhibits a negative redox potential and easily releases metals such as iron, copper, zinc and cadmium (Guilizzoni 1991). More research is needed to investigate the interaction between soil redox conditions and soil pH and how it affects metal chemistry. Special attention should focus on the rhizosphere effects where an oxidizing soil environment exists immediately around the root zone and in close proximity to strongly reduced soils, a condition which influences metal chemistry and availability (Gambrell 1994). Reduction of carbon oxygen demand, petroleum hydrocarbons, and synthetic organics are all promoted by aerobic conditions (Horner 1995). The fact that both aerobic and anaerobic conditions existed in the pond during our study (see Appendix M) undoubtedly improved the efficiency of the pond since several processes were available to remove pollutants.

Soil Type - Pollution removal in wetlands works best on a medium to fine textured soil (Horner 1995). Also the soil is the primary removal mechanism for phosphorus which is attributed to soil sorption, biomass and accreting sediments (Kadlec 1994). The type of sediments may determine if wetland soils act as a source or a sink for P. For example, calcareous soils low in organic matter but high in $CaCO_3$ removed more added phosphorus than organic soil (Reddy and Graetz 1981). They further concluded that flooded organic soil may function as a source by increasing the soluble P concentration in the overlying aerobic water column while phosphorus reduction over the calcareous soils was probably a result of precipitation of P with calcium compounds and physical sorption by the underlying soil. Laboratory experiments showed a maximum reduction (65%) in the ortho-P concentration in the water column with a 24-day residence time, whereas for organic soil, maximum reduction (36%) in ortho-P levels was observed with the residence time of 6 days and reduction was less for longer residence times (Reddy and Graetz 1981). Other researchers have also found greater phosphorus sorption potential in predominately mineral swamp forest soils compared to organic freshwater marsh soils (Masscheleyn *et al.* 1992). The calcareous sandy soils with low organic matter content at the Tampa Office pond (see Tables 12 and 13) probably contributed to the 90 percent phosphorus removal rates exhibited with increased residence time.

Since phosphorus is primarily removed by soil sorption processes, the fact that soils have a finite P capacity is of concern. Data indicate that high initial removal rates of phosphorus by freshwater wetlands will be followed by large exports of P within a few years. Sorption is enhanced, as mentioned above, by high calcium concentrations and is also improved by oxalate-extractable iron and aluminum. Therefore, wetland types with predominately mineral soils and high amorphous aluminum content are better P sinks than peatlands but sill retain much less P than terrestrial ecosystems (Richardson 1985). Gale *et al.* (1993) also measured more rapid nitrogen removal in wetlands with mineral soils than organic soils and they concluded that soil type has a significant effect on nitrogen removal from floodwater. In addition dissolved metal adsorption is enhanced by sediments with a high soil cation exchange capacity (Horner 1993).

In the Tampa Office study the higher levels of calcium in the water column (72 mg/ l) in 1994 compared to 50 mg/l in 1993 may have helped account for the increased efficiency for phosphorus removal in 1994 (see Figure 8). Also the increased iron measured at the inflow (555 ug/l in 1990, 1517 ug/l in 1993 and 3,200 ug/l in 1994) may have enhanced precipitation of phosphorus and then incorporation with iron oxide in the sediments. Additionally, the mineral soils and the higher levels of aluminum in the sediments of the permanent pool probably increased the removal of heavy metals, nitrogen and phosphorus (see Table 15). Since attachment sites on soil particles suitable for the uptake of P are finite, the phosphorus potential may decrease over time and this potential needs more study. However, the wetland biogeochemical cycle can operate to accrete new soils and sediments which contain phosphorus and these soil building processes can provide a more permanent storage of phosphorus (Kadlec 1994).

pH - At near-neutral to somewhat alkaline pH levels, metals tend to be effectively immobilized as are metals complexed with large molecular weight organics (Gambrell 1994). A circumneutral pH advances microbially mediated processes such as decomposition and nitrification-denitrification and avoids the mobility of certain pollutants at extreme pH (Horner 1993). The neutral to slightly alkaline pH measured in our study is ideal for metal immobilization and the nitrification-denitrification process (see Table 11) .

In Summary - The Tampa Office pond in 1994 which used the Conservation Wet Detention design (TP/SWP-022) performed well for removing pollutants during the first eight months after construction. Factors which likely contributed to this result were pre-treatment opportunities in the watershed, increased residence time with good flushing characteristics, a vegetated littoral shelf concentrated at the outfall, aerobic conditions in the permanent pool, mineral soils, increased iron runoff and a circumneutral pH. Features which might help the pond even more would be a better landscape design incorporating trees, a sediment sump to collect large particle pollutants, littoral zone plants selected specifically for their proven ability to remove stormwater pollutants by pumping oxygen to the rhizosphere, and better control of fertilizers and pesticide use. Improved use of the entire drainage basin would help reduce runoff to pre-development levels. This is a newly constructed pond and additional research as the pond matures should indicate long term removal capabilities and determine maintenance requirements.

COMPARISON DATA

Additional insight about wet detention ponds can be gained by comparing the data to other studies that have been conducted in the region.

Treatment Efficiencies

A major objective of this study was to determine how well wet detention ponds reduced pollutants from the inflow to the outflow using different residence times. The efficiency of the system is relevant to the State Water Policy (Chapter 62-40 FAC) which has a goal for new stormwater systems of 80 percent reduction in annual loads. The data from this study as well as comparable data from other studies in Florida demonstrate the wide range of efficiencies exhibited by different stormwater management designs (Table 22).

Table 22. Percent reduction of mass loads (efficiency) for various wet detention ponds and natural wetlands in Florida.

	MEAN REMOVAL EFFICIENCIES (%)										
	This Study			Comparative Studies of Wet Detention Treatment							
	1990	1993	1994	a	b	c	d	e	f	g	h
Total Lead	----	----	92	32	90	83	----	----	----	60	85
Total Zinc	56	32	87	10	96	84	----	----	----	85	90
Total Cadmium	55	42	87	----	79	88	----	----	----	----	----
Total Iron	40	76	94	----	92	5	87	85	----	----	----
Total Copper	----	1	55	----	90	79	19	22	----	40	50
Ammonia-N	54	-31	90	54	99	79	89	90	----	----	----
Organic-N	30	15	51	9	96	29	7	-8	----	----	----
Nitrate+Nitrite	64	61	88	----	95	94	92	95	87	50	70
Ortho Phosphate	69	39	92	37	97	67	83	89	82	40	60
Total Phosphorus	62	57	90	33	91	70	75	75	60	60	70
Suspended Solids	71	67	94	16	82	86	77*	69*	64	85	85

Comparative Studies

a Martin 1988 (Mixed Urban) SHORT RESIDENCE TIME, NO PRE-TREATMENT
b Harper 1988 (Residential) NO PRE-TREATMENT, RETENTION 80%
c Carr and Rushton 1995 (Light Commercial) NATURAL WETLAND, PRE-TREATMENT BASINS, RAINFALL 45% OF INPUT, RETENTION 60% OF TOTAL INPUT INC. RAIN.
d Cunningham 1993 (Experimental Pond - Deep (9 feet)) SIMULATED STORM EVENTS
e Cunningham 1993 (Experimental Pond - Shallow (3 feet)) SIMULATED STORM EVENTS
f Cullum 1984 (Low Density Residential) PRE-TREATMENT BY GRASSED SWALES
g Harper and Herr 1993 (Commercial) RESIDENCE TIME 7 DAYS.
h Harper and Herr 1993 (Residential) RESIDENCE TIME 14 DAYS.

This Study

1990 RESIDENCE TIME 2.5 DAYS
1993 RESIDENCE TIME 5 DAYS. RESULTS GREATLY INFLUENCED BY ONE RAIN EVENT.
1994 RESIDENCE TIME 14 DAYS.

* Non-volatile suspended solids

Table 22 also shows that no system achieved the 80 percent reduction goal for all constituents and some fail to achieve it for any pollutants. The purpose of this section is to investigate conditions that lead to greater removal efficiencies. First, some of the best efficiencies in most systems were seen for lead, nitrate+nitrite, and total suspended solids. Poorest removal occurred for organic nitrogen and possibly total phosphorus and total copper. As observed by Harper (1995), organic nitrogen is not readily available for removal through biological or chemical processes, and there are relatively few mechanisms for removal of this species in a wet detention system. In contrast, both nitrate and ammonia are readily taken up in biological processes which accounts for the relatively good removal efficiencies achieved for these species in wet ponds.

Other factors which improve pollution removal include: 1) Residence times, with longer residence times in a permanent pool giving better treatment; 2) Retention of stormwater on site, which gives 100 percent efficiency for the retained stormwater; and 3) Pre-treatment by ditches, sediment sumps and swales, which reduces the amount of some pollutants to levels low enough to make further efficiency difficult. Each of these systems demonstrates at least one of these processes at work.

Residence Time - As has already been discussed in this report, one of the major differences between years in this study was increasing the residence time, and efficiencies using average annual concentrations showed a steady improvement with longer residence times (see Figure 8). Residence time also appeared to be the most common factor for greater pollution removal in the comparison sites. For example, poorest efficiencies were observed at site "a" which had the shortest residence time. Dye studies were conducted by Martin (1989) to determine the short-circuiting and mixing characteristics at site "a". He determined that the median time for 50 percent of the dye recovery from the inflow to the outflow ranged between 47 and 95 minutes for most runs and only 20 minutes for one run. The estimated time to recover 75 percent of the injected dye ranged between 69 and 282 minutes. It is obvious that not much time for treatment took place, but it does indicate that even small sedimentation basins reduce some pollutants and are effective for pre-treatment. Another example using these studies was the improved efficiency (by at least 20%) at site "h" (14 days HRT) compared to site "g" (7 day HRT) except for suspended solids (Harper and Herr 1993). Another observation from the data are the two experimental ponds, "d" (deep pond) and "e" (shallow pond), which showed essentially no differences between the two ponds with the possible exceptions of slightly better removal of organic nitrogen and suspended solids in the deep pond and ortho-phosphorus in the shallow pond (Cunningham 1993).

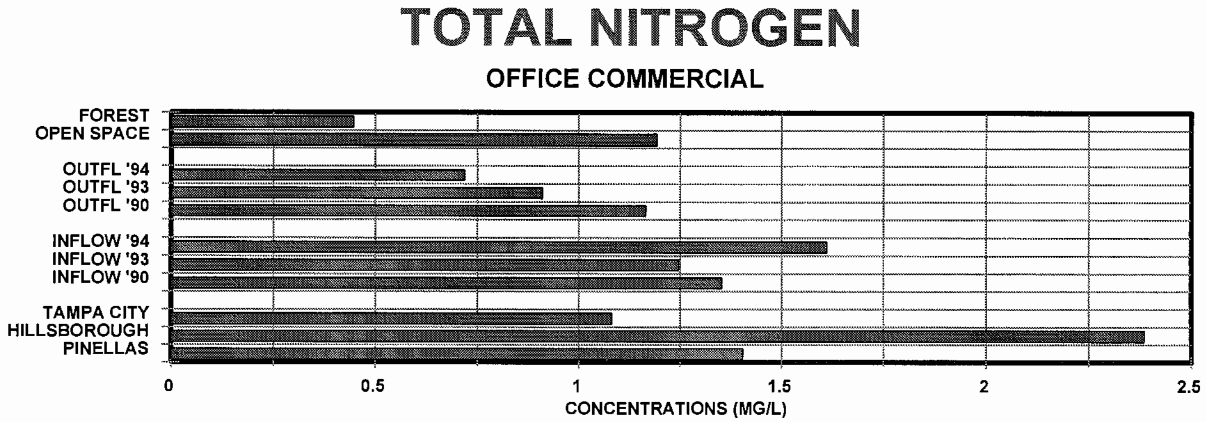
Retention on site - Site "b" retained an estimated 80-90 percent of all stormwater runoff within the system which gives the best removal efficiencies of all sites since water retained on site provides 100 percent load efficiency. Retaining water on site is one of the best strategies for stormwater management since it also provides opportunities to recharge the aquifer. A natural herbaceous marsh used for stormwater treatment, site "c", retained 60 percent of all water entering the system, and also shows good removal efficiencies. It was not effective at removing iron or organic nitrogen which is not surprising since it was a wetland with high levels of these constituents already in the marsh (Carr and Rushton 1995).

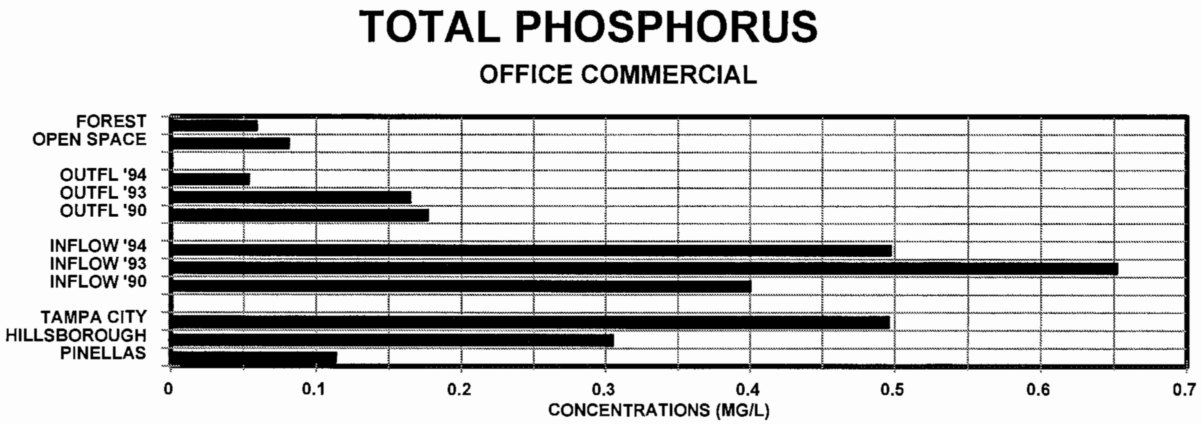
Comparison to Local NPDES Data

The purpose of comparing the data we collected during this study to the data collected by local governments for their NPDES permits was to determine if our untreated stormwater from an office\commercial site was representative of other stormwater from the same type of land use; and also to compare constituent concentrations measured at the outfall of our study to runoff from natural forests and open spaces such as parks. The National Pollutant Discharge Elimination System (NPDES) stormwater permit application is an Environmental Protection Agency (EPA) program authorized by Chapter 40 CFR 122.26(d)(2)(iii)(A). This section of Chapter 40 requires that local governments collect data from five to ten sites for three representative storm events.

When the NPDES data collected from the City of Tampa, Hillsborough County and Pinellas County were compared to the data in this study, there was considerable variability between sites but the overall trends indicate the untreated stormwater concentrations (inflow data) measured in this study were within the same range as urban stormwater measured at commercial sites in the region, except for Pinellas county where low concentrations indicate samples may have been collected downstream of a stormwater treatment BMP (Figure 24). Also when the concentrations measured at the outflow in our study are compared to those from forests and open spaces they were usually in the same range as those measured for open spaces. Especially the concentrations measured during the last year of our study (1994) using the Conservation Wet Detention design. These data indicate that pollutant concentrations can be reduced to levels comparable to forests and open spaces. However, as population increases so will urban pollution because of the increased volume of runoff caused by development. For example, about 65 percent of rain falling on office/commercial sites runs off while only 10 to 15 percent of rain falling on natural forests does (Figure 25).

To reduce nonpoint source pollution, stormwater systems must also reduce the volume of runoff. Unfortunately urban development increases impervious surfaces such as streets, parking lots and rooftops that retard infiltration and increase runoff volume. These "improvements" also increase pollution. Every opportunity to retain and infiltrate runoff within the watershed must be utilized. Forested areas, depression storage, swales and reuse are some mechanisms which can reduce runoff in urban areas.





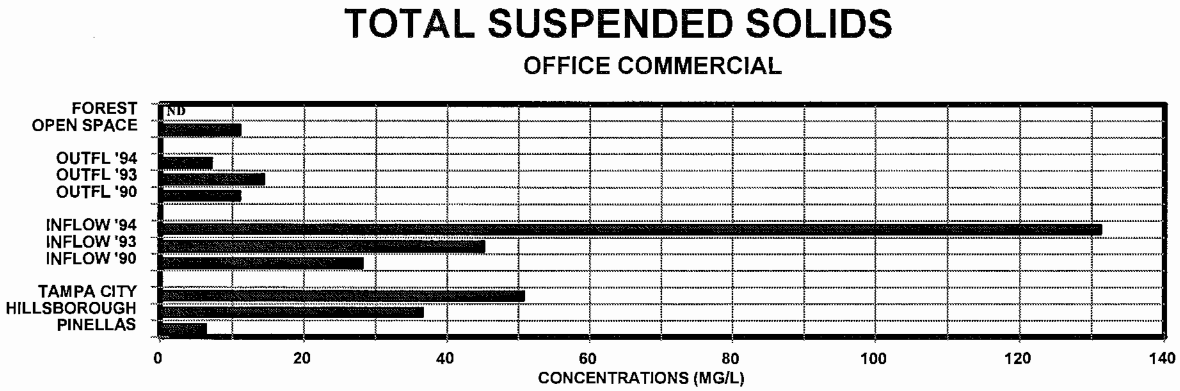


Figure 24. Concentrations (mg/l) of pollutants measured in untreated stormwater during the NPDES program (Pinellas County, Hillsborough County and the City of Tampa) compared to untreated stormwater measured at the inflow in this study. Data at the outflow were compared to runoff from forests and open spaces in the NPDES program.

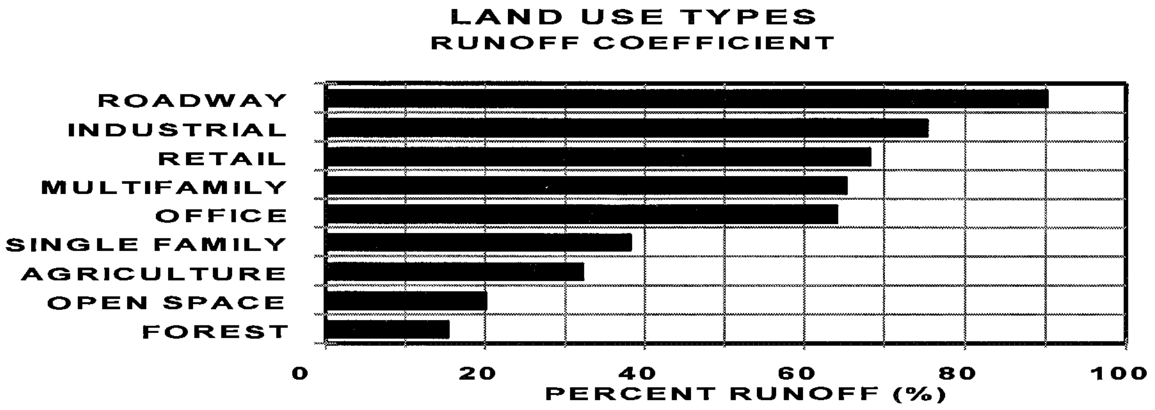


Figure 25. A comparison of different runoff coefficients for various land uses.

CONCLUSIONS

The Conservation Wet Detention criteria, which include a 14-day residence time, not only are superior for removing pollutants, but also provide additional benefits compared to traditional stormwater management design criteria. Projects using the new criteria benefit from reduced development costs, higher quality surface water discharges, and more desirable habitat conditions for aquatic biota.

Florida has little topographic relief and the water table is often near the surface, making flood control a concern of project designers and home builders. Stormwater management facilities are often designed with multiple objectives, combining water quality treatment with flood control. Previous design criteria gave no treatment credit for residence time in the permanent pool, but required detention of stormwater runoff in a fluctuating pool above the seasonal high water table, while slowly releasing this volume in no less than 120 hours. Because of this extended detention time, the storage volume of the fluctuating pool is often not available for flood storage, and flood volumes are stored above the fluctuating pool. This stacking of flood volume on top of "treatment volume" often required minimum floor elevations for buildings to be raised several feet above natural grade. This design required substantial amounts of fill to elevate buildings above flood elevations, a costly component of development in Florida. To generate this amount of fill, stormwater ponds were often excavated to excessive depths, creating anoxic hypolimnetic zones and reducing pollutant removal efficiencies.

Conservation Wet Detention criteria allow treatment credit for residence time below the seasonal high water table in the permanent pool and reduce the flood elevations which resulted from stacking the flood volume on top of the treatment volume. Reducing the flood stage in the pond allows lower minimum floor elevations for buildings and other structures so less fill was required. Reduced fill requirements resulted in less excavation in ponds. Shallower ponds generally have higher dissolved oxygen concentrations, providing better pollutant removal efficiencies and more desirable aquatic habitat.

Previous design criteria allowed a greater range of fluctuation (18") in the fluctuating pool, which had a detrimental effect on the littoral community and promoted the growth of cattails, a species which can be a nuisance in Florida. Reducing the allowed fluctuation range to 10" created more stable littoral conditions and promoted the establishment of a diverse assemblage of more desirable native aquatic vegetation Reducing the allowable range of fluctuation from 18" to 10", coupled with reducing the required detention storage in the fluctuating pool from 1" to ½" of runoff, reduced the land area required for stormwater treatment ponds from nearly 6 percent to about 5 percent, creating additional economic benefit for developers.

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Marnie Ward, a student at the University of Florida, made the macroinvertebrate investigation possible. She collected and identified the insects as an independent study project under the direction of Dr. Frank Maturo in the Department of Zoology. Marnie is especially indebted to the following people for help with identifying species: Marcella Robinson for chironomids, Dr. M. J. Westfall for Odonates, Dr. M. Thomas for confirmation of Curculionidae, and Dr. D. Habeck for Tricoptera. Selected specimens were photographed by Erika Simon. Marcella Robinson also reviewed the final draft and made many useful suggestions and corrections. Marnie is now a graduate student at UF in the Department of Environmental Engineering.

David Boyer from the consulting firm, Tampa Bay Engineering, Inc. provided the data and figures that described how the conservation design saves land area. Jesus Merly of the South Florida Water Management District corrected transcription errors in the calculations for the Conservation Wet Detention design (Appendix A).

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APPENDIX A

Conservation Wet Detention Criteria
Technical Procedure TP/SWP-022 (Alternative 3)

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
RESOURCE REGULATION
TECHNICAL PROCEDURE FOR CONSERVATION WET DETENTION

The design guidelines for the Conservation Wet Detention criteria (14-day residence time) are included here for the convenience of anyone wishing to use them. They include the wet detention design pool guidelines that provided the best water quality treatment during this study. The following section is adapted from the original technical procedure developed by SWFWMD's Technical Services Staff in August 1990. The original draft included three alternatives, but only the third alternative, the conservation wet detention design, is included here since those guidelines were the ones used to construct the pond during the third year of this study (1994). Examples for making calculations for the conservation wet detention design are also provided.

This procedure provides interim guidelines regarding concepts and methods for determining design pool[1] requirements and alternatives for wet detention systems used for stormwater quality treatment..

BACKGROUND: Sections 2.0, 3.2.2, 3.2.3 and 3.2.4 in the Basis of Review (BOR) for the managment and storage of surface water (MSSW)(Reference 1), contain guidelines for wet detention systems to provide water quality treatment using a design pool in association with water tolerant vegetation. If adequate residence time is provided, pollutants can be removed through settling, adsorption to soils and uptake by aquatic biota.

The explanation of a wet detention system in section 2.25 of the BOR includes a requirement that, "...The bottom elevation of the pond must be at least one foot below the control elevation." The intent of this requirement is to maintain a permanent wet pool which supports residual aquatic biota, dilutes influent stormwater runoff and extends the residence time of water passing through the system.

Design guidelines for wet detention systems in section 3.2.2.2 require that wet detention pond discharge structures normally be designed with a gravity drawdown control device (bleeder). The bleeder allows no more than one-half of the detained treatment volume, stored between the overflow elevation down to seasonal high water level (SHWL) or control elevation, to discharge within the first 60 hours. The Conservation Wet Detention criteria changes this "bleeddown" time to 24 hours. Pool volume below the control elevation that intermixes with the SHWL is the permanent wet pool.

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[1] Design pool = treatment volume + permanent wet pool volume.

CONSERVATION WET DETENTION: The following criteria provide acceptable alternative methods of achieving design pool and gravity discharge configuration when it is justified to provide all or part of the treatment volume below SHWL or control elevation, without design pool bleed down[2]. If all other criteria are in compliance with the BOR, monitoring will normally not be required.

a) In the interest of water conservation, discharge devices below SHWL shall be avoided; and

b) Design pool volume below the control elevation[3] to eight feet depth must be equal to one inch of runoff plus the calculated volume based on average residence time of 14 days and average total rainfall during the wet season (122 days, June through September); and

c) The minimum design pool volume below the control elevation to eight feet depth must be no less than 1.667 inches of runoff from the contributing area; and

d) Systems discharging directly into Outstanding Florida Waters (OFW) shall provide treatment and permanent wet pool volume 50 percent more than required for systems discharging to other receiving waters; and

e) The gravity overflow weir shall be multi-stage, first having a "v"-notch[4] or other equivalent drawdown control device sized to discharge one-half inch of detention runoff from the contributing area in 24 hours with ten inches maximum head (refer to Figure 1); and having a broad crested weir for higher discharges, including the 25 year, 24 hour event; and

f) The control elevation ("v"-notch invert) shall be above SHWL in the pond and above wet season tailwater in the receiving water, but no higher than two feet above SHWL; and

g) For gravity discharge systems with treatment volume below SHWL, credit for water quantity (discharge attenuation) storage may be allowed above control elevation and SHWL, if the "v"-notch meets the requirements of 3) e) and BOR Section 3.2.4.2; and

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[2] Please refer to Clarification Memo No. SWP - 51 for further discussion of circumstances when wet detention systems may justify not using a bleeder.

[3] Longer residence time associated with the design pool for a wet detention system without a bleeder is presumed to offset the benefits of extended detention drawdown of treatment volume by a bleeder.

[4] The "v"-notch weir sized as stated creates a minimum pond area and fluctuation to enhance surface aeration, circulation and mixing in the design pool. The minimum pond area is equivalent to five percent of the contributing area, as recommended by reference 2.

h) At least 35 percent of the pond bottom, based on area at control elevation, must extend below SHWL to help sustain the required littoral area; and the 35 percent littoral area shall extend two feet maximum below the control elevation; and

i) Wet detention systems shall be specifically designed to maximize circulation, mixing and residence time of inflow within the design pool by means such as: maximum separation of inflow and outflow points, locating inflow inverts below the control elevation, use of multi-cell ponds or flow baffles and other locally effective means to avoid "dead" storage areas.

AGRICULTURAL EXAMPLE
CALCULATION OF WET DETENTION DESIGN POOL VOLUME

Given: A citrus grove project near Arcadia, Florida; Project area = drainage area = 320 Acres; Composite Rational runoff coefficient = 0.30; Discharge to Class III waters from a wet detention system.

Required: 1. Calculate the treatment volume; and

2. Calculate the permanent wet pool volume to be retained below the control elevation to eight feet depth. It must be the greater of: a) the volume calculated to provide an average residence time of 14 days based on average total wet season rainfall of 31.04 inches; or, b) the volume produced by 0.667 inches of runoff from the contributing area; and

3. Calculate the average minimum pond area.

1. Calculate the treatment volume (Q) as one inch of runoff -

$$\boxed{\begin{aligned}(Q) &= (320\text{ Ac.})(1\text{ inch})(1\text{ ft.}/12\text{ in.})\\ &= 26.67\text{ Ac. - ft. (AF)}\end{aligned}}$$

2. Calculate the permanent wet pool volume (V_R) -

a) Based on 14 day residence volume (V_R) -

$$\boxed{(V_{R)} = (A)\,(C)\,(P)\,(R)\,(1\text{ ft.}/12\text{ in.})}$$

Where, (A) = Project area = drainage area = 320 Ac
(C) = Composite Rational runoff coefficient = 0.30
(P) = Historic average wet season rainfall rate for
(R) = Residence time = 14 days

$$(V_R) = (320)\ (0.30)\ (31.04/122)\ (14)\ (1/12) = 28.50\text{AF}$$

NOTE: Refer to Figure 2 for graphic solution of 14 day residence volumes for various project types and sizes.

b) As 0.667 inches of runoff (V_{min}) -

$$(V_{min}) = (320\text{ Ac.})\ (0.667\text{ inch})\ (1\text{ ft.}/12\text{ in.}) = 17.78\text{ AF}$$

Since (V_R) is more than (V_{min}), 28.50 AF is correct for permanent wet pool volume (V_B) in this case.

Therefore, the wet detention system design pool volume
= (Q) 26.67 AF + (V_B) 28.50 AF = 55.17 AF.

3. Calculate the average minimum pond area (A_S) -

Based on treatment volume below control elevation of "v"-notch weir, ½ inch runoff and 10 in. maximum head or based on design pool volume at maximum depth -

1) Based on 10 in. maximum head on the "v"-notch:

$$(V_W) = (320\text{ Ac.})\ (0.50\text{ inch})\ (1\text{ ft.}/12\text{ in.}) = 13.33\text{ AF}$$

$$(A_S) = (13.33\text{ AF}/0.833\text{ ft.}) = 16.00\text{ Ac.}$$

2) Based on design pool volume [(Q) + (V_B) = 55.17 AF] at maximum depths:

$$55.17\text{ AF} = [(0.35)\ (2\text{ ft.})\ (A_S)] + [(0.65)\ (8\text{ ft.})\ (A_S)]$$

$$(A_S) = (55.17\text{ AF}) / (5.9) = 9.35\text{ Ac.}$$

Check Max. head (H) = $(V_W) / (A_S)$,

$$\boxed{(V_W) = 13.33 \text{ AF}; (A_S) = 9.35 \text{ Ac.}}$$

$$\boxed{(H) = (13.33/9.35) = 1.425 \text{ Ft.} = 17.1 \text{ in.} > 10 \text{ in.}}$$

Therefore, the correct minimum pond area is 16.00 Ac.

COMMERCIAL EXAMPLE
CALCULATION OF WET DETENTION DESIGN POOL VOLUME

Given: A shopping plaza project near Oneco, Florida; Project area = 16 Acres; Drainage area = 18 Acres; Composite Rational runoff coefficients: project site = 0.90; offsite = 0.45; drainage area = 0.85; Discharge occurs to Class III waters from a wet detention system.

Required: 1. Calculate the treatment volume; and

2. Calculate the permanent wet pool volume to be retained below the control elevation to eight feet depth. It must be the greater of: a) the volume calculated to provide an average residence time of 14 days based on average total wet season rainfall of 31.04 inches; or, b) the volume produced by 0.667 inches of runoff from the contributing area; and

3. Calculate the average minimum pond area.

1. Calculate the treatment volume (Q)

a) For project site, as 1 inch of runoff (Q_P) -

$$\boxed{\begin{aligned}(Q_P) &= (16 \text{ Ac.}) (1 \text{ inch}) (1 \text{ ft.}/12 \text{ in.}) \\ &= 1.33 \text{ Ac. -ft. (AF)}\end{aligned}}$$

b) For offsite, as runoff from first inch of rainfall (Q_O) -

$$\boxed{\begin{aligned}(Q_O) &= (2 \text{ Ac.}) (1 \text{ inch}) (0.45) (1 \text{ ft.}/12 \text{ in.}) \\ &= 0.08 \text{ AF}\end{aligned}}$$

Therefore, $(Q) = (Q_P)$ 1.33 AF + (Q_O) 0.08 AF = 1.41 AF

2. Calculate the permanent wet pool volume (V_B) -

a) Based on 14 day residence volume (V_R) -

$$\boxed{(V_R) = (A)\ (C)\ (P)\ (R)\ (1\text{ ft.}/12\text{ in.})}$$

Where, (A) = Project site + offsite = drainage area = 18 Ac.
(C) = Composite Rational runoff coefficient = 0.85
(P) = Historic average wet season rainfall rate for Arcadia, Bradenton, Brooksville, Lakeland and Ocala gauging stations = (31.04 in./122 days)
(R) = Residence time = 14 days

$$(V_R) = (18)\ (0.85)\ (31.04/122)\ (14)\ (1/12)$$
$$= 4.54\text{ AF}$$

NOTE: Refer to Figure 2 for graphic solution of 14 day residence volumes for various project types and sizes.

b) As 0.667 inches of runoff (V_{min}) -

$$\boxed{\begin{aligned}(V_{min}) &= (18\text{ Ac.})\ (0.667\text{ inch})\ (1\text{ ft.}/12\text{ in.})\\ &= 1.00\text{ AF}\end{aligned}}$$

Since (V_R) is more than (V_{min}), 4.54 AF is correct for permanent wet pool volume (V_B) in this case.

Therefore, the wet detention system design pool volume
= (Q) 1.41 AF + (V_B) 4.54 AF = 5.95 AF.

3. Calculate the average minimum pond area (A_S) -

Based on treatment volume below control elevation of "v"-notch weir, ½ inch runoff and 10 in. maximum head or based on design pool volume at maximum depth -

1) Based on 10 in. maximum head on the "v"-notch:

$$\boxed{\begin{aligned}(V_W) &= (18\text{ Ac.})\ (0.50\text{ inch})\ (1\text{ ft.}/12\text{ in.})\\ &= 0.75\text{ AF}\end{aligned}}$$

$$\boxed{(A_S) = (0.75\text{ AF}/0.833\text{ ft.}) = 0.90\text{ Ac.}}$$

2) Based on design pool volume $[(Q) + (V_B) = 5.95 \text{ AF}]$ at maximum depths (i.e., 35% @ 2' and 65% @ 8' depth):

$$\boxed{5.95 \text{ AF} = [(0.35)(2 \text{ ft.})(A_S)] + [(0.65)(8 \text{ ft.})(A_S)]}$$

$$\boxed{\begin{aligned}(A_S) &= (5.95 \text{ AF}) / (5.9)\\ &= 1.01 \text{ Ac.}\end{aligned}}$$

Check Max. head $(H) = (V_W) / (A_S)$,

$$\boxed{(V_W) = 0.75 \text{ AF}; (A_S) = 1.01 \text{ Ac.}}$$

$$\boxed{(H) = (0.75/1.01) = 0.743 \text{ Ft.} = 8.9 \text{ in.} < 10 \text{ in.}}$$

Therefore, the correct minimum pond area is 1.01 Ac.

REFERENCES:

1. "Permit Information Manual, Management and Storage of Surface Waters," March 1988 (Revised), SWFWMD, Brooksville, Florida.

2. "The Florida Development Manual: A Guide to Sound Land and Water Management," June 1988, FDER.

3. "Design of Urban Runoff Quality Controls," Proceedings of an Engineering Foundation Conference held in July 1988, American Society of Civil Engineers, 1989.

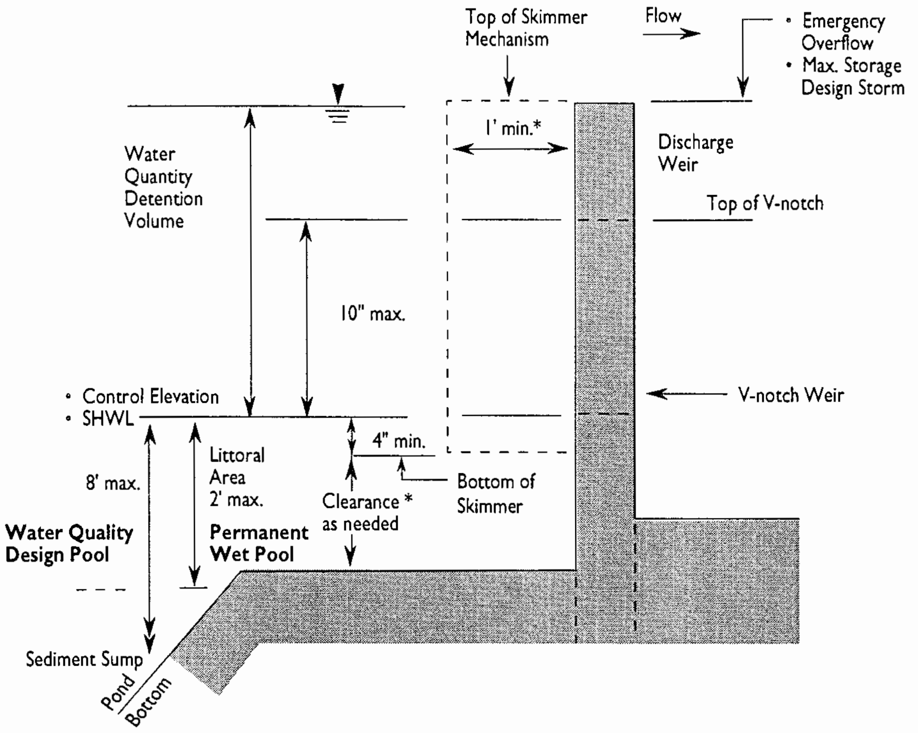
4. "Wet Detention Systems," A paper by Peter J. Singhofen, David W. Hamstra and Martin W. Pawlitkowski; 1990 Stormwater Management: A Designer's Course, the Florida Engineering Society, February 1990.

5. "Management and Storage of Surface Waters, Permit Information Manual, Volume IV," June 1987 (Revised), SFWMD, West Palm Beach, Florida.

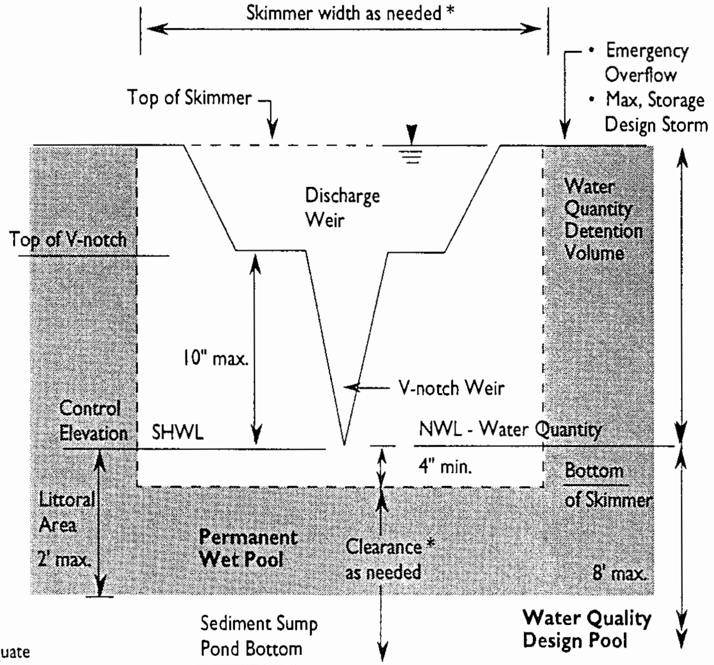
6. Clarification Memo No. CM/SWP-51, "Wet Detention Systems - Use of Gravity Bleeddown Orifices" (SWFWMD).

ATTACHMENTS:

Discharge Structure End View



Discharge Structure Instream View



* Skimmer clearances must be adequate to avoid-excessive constriction of flow during the design storm.

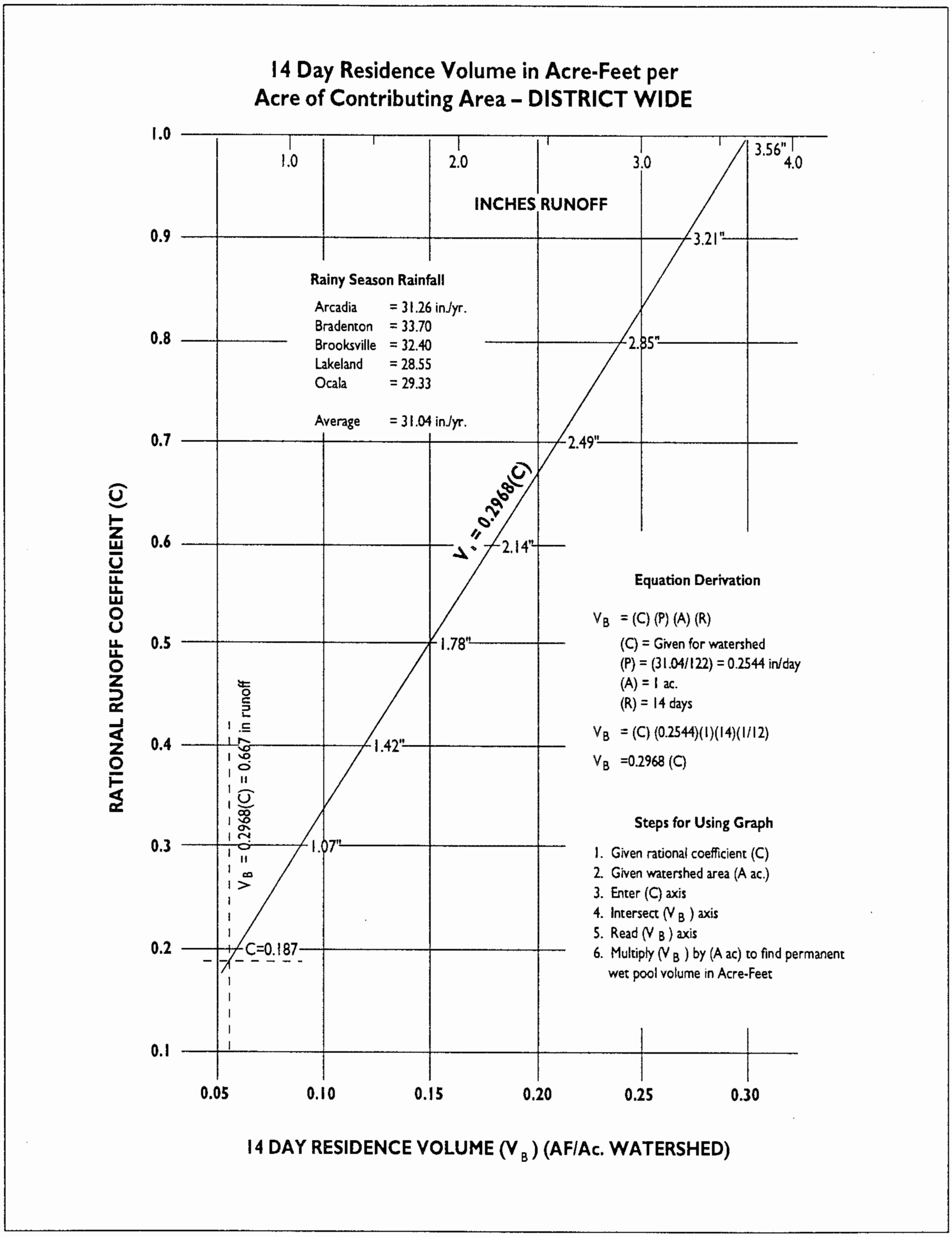
Figure 1

Table A-1

Wet Detention Treatment

CONSERVATION DESIGN POOL BELOW SHWL WITHOUT DISCHARGE

MANMADE WET DETENTION DESIGN AND PERFORMANCE STANDARDS	
Treatment Volume/Depth	1" runoff from on-site; runoff from first 1" of rainfall from offsite
Draw Down Time	Not required for treatment volume
Permanent Design Pool Volume	Rainy season 14 day residence volume plus treatment volume; minimum 1.667 inch runoff
Other Criteria for System Design	• 35% littoral zone @ control elevation; concentrated at outfall. • V-notch weir sized to discharge ½ inch runoff in 24 hours, 10" maximum flux. above SHWL/control elevation. • Littoral zone 2' maximum depth below control elevation. • Design pool, 8' maximum depth; 34% minimum pond bottom below SHWL. • Sediment sump and skimmer usually required. • Mulching or planting required if soils are unsuitable. • Side slopes 4H:1V unless safety fenced. • Inflow/outflow points must maximize circulation. • Control elevation not lower than SHWL and tailwater, nor higher than 2' above SHWL.


14 Day Residence Volume in Acre-Feet per Acre of Contributing Area - DISTRICT WIDE

Rainy Season Rainfall

Arcadia	= 31.26 in./yr.
Bradenton	= 33.70
Brooksville	= 32.40
Lakeland	= 28.55
Ocala	= 29.33
Average	= 31.04 in./yr.

Equation Derivation

V_B = (C) (P) (A) (R)

(C) = Given for watershed
(P) = (31.04/122) = 0.2544 in/day
(A) = 1 ac.
(R) = 14 days

V_B = (C) (0.2544)(1)(14)(1/12)

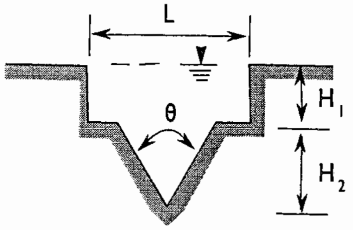
V_B =0.2968 (C)

Steps for Using Graph

1. Given rational coefficient (C)
2. Given watershed area (A ac.)
3. Enter (C) axis
4. Intersect (V_B) axis
5. Read (V_B) axis
6. Multiply (V_B) by (A ac) to find permanent wet pool volume in Acre-Feet

Figure 2

Discharge and Central Angle for a "V" - Notch Weir



The total flow over a rectangular sharp crested weir with a "v" - notch step discharge fluctuation device is approximated by the equation:

$Q_D = 3.13\,(L)(H_1)^{1.5} + 4.8\,[(H_2)^2 \ \mathrm{Tan}\ \theta/2](H_1 + H_2/3)^{0.5}$

Refer to Reference 1., pp. C-48 through C-50; and Reference 5., pp. C-IV-26 through C-IV-28.

Required V-Notch Size, θ

NOTE: V-Notch Size Required to Bleed-Down 0.5 Inch of Detention Volume in 24 Hours

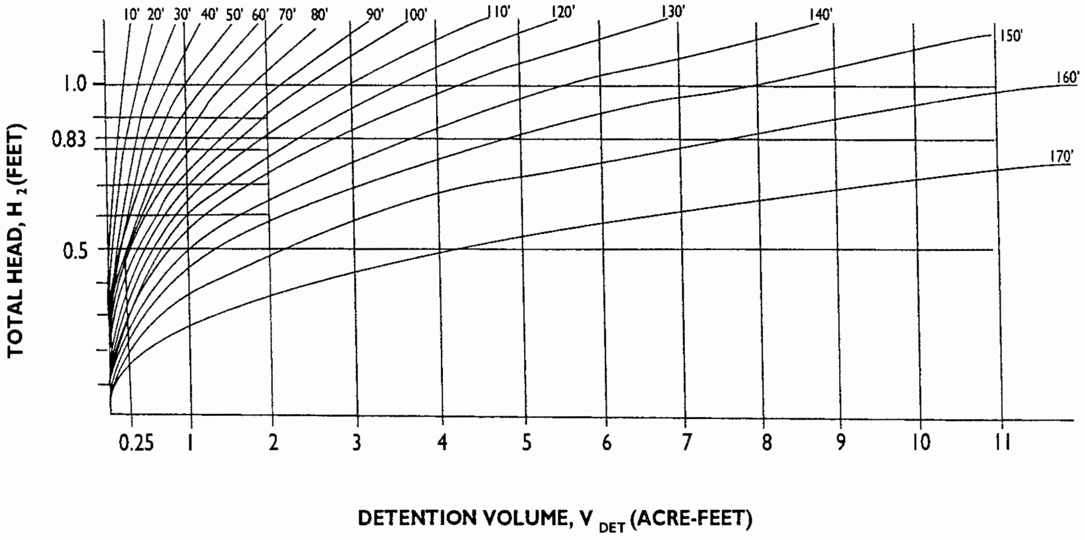


Figure 3

APPENDIX B

Quality Assurance Information for Inflow Calculations

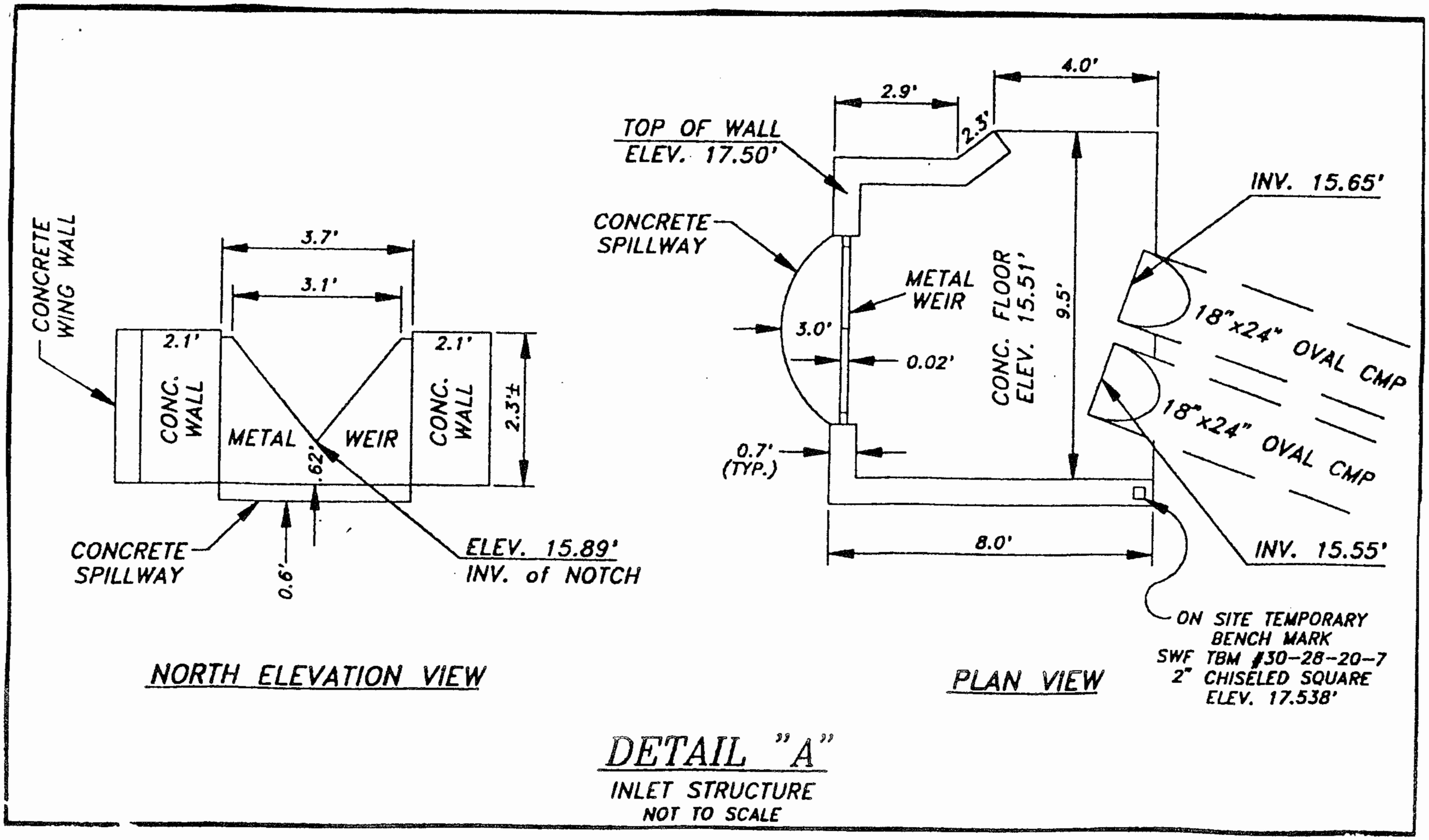


Figure B-1. Design and demensions of inflow weir structure taken from the official survey. This survey was completed late in the study and elevations differ slightly from preliminary measurements used in graphs and tables. The preliminary survey measured the control elevation (INV. of NOTCH) as 16.00 NGVD (ft). The earlier levels are 0.11 feet higher than the official survey. Since head and flow measurements are calculated from differences in water levels, this discrepancy does not affect any of the data.

Table B-1. Water level data for inflow station. For quality checks the sensor readings were compared to actual staff guage using the factory generic conversion factors (LOGGER PRGM). Also a regression equation calculated from field data was compared to the generic equation (REGR CALCS). Accuracy for reading the staff gauge is 0.02 feet.

STAFF GAUGE	**FLOAT**	**DATE**	**LOGGER PRGM** (FLOAT+8.949)	**REGRES CALCS** (calculations)	**ERROR LOGGER**	**ERROR REGRES**	**ISCO HEAD**	**ISCO OFFSET 16.00**
15.90	6.9523	18JUL94	15.901	15.899	-0.001	0.001	-0.094	15.994
15.97	7.0122	2SEP94	15.961	15.960	0.009	0.010	-0.040	16.010
16.03	7.0814	19JUL94	16.030	16.031	-0.000	-0.001	0.030	16.000
16.03	7.0847	20JUL94	16.034	16.034	-0.004	-0.004	0.030	16.000
16.04	7.0821	27JUL94	16.031	16.032	0.009	0.008	0.053	15.987
16.04	7.0885	4AUG94	16.038	16.038	0.002	0.002	0.035	16.005
16.04	7.0891	3AUG94	16.038	16.039	0.002	0.001	•	•
16.04	7.0925	31JUL94	16.042	16.042	-0.002	-0.002	0.040	16.000
16.06	7.1119	22JUL94	16.061	16.062	-0.001	-0.002	0.058	16.002
16.08	7.1126	13JUL94	16.062	16.063	0.018	0.017	0.075	16.005
16.08	7.1327	11JUL94	16.082	16.083	-0.002	-0.003	0.084	15.996
16.08	7.1413	8AUG94	16.090	16.092	-0.010	-0.012	0.089	15.991
16.10	7.1503	16SEP94	16.099	16.101	0.001	-0.001	•	•
16.41	7.5215	29SEP94	16.471	16.480	-0.061	-0.070	0.415	15.995
16.57	7.6013	27SEP94	16.550	16.561	0.020	0.009	0.571	15.999
16.75	7.7480	27SEP94	16.697	16.711	0.053	0.039	0.733	16.017
16.76	7.7641	27SEP94	16.713	17.727	0.047	0.033	0.765	15.995
17.02	8.0460	18SEP94	16.995	17.015	0.025	0.005	•	•
17.20	8.2270	18SEP94	17.176	17.200	0.024	0.000	•	•
17.28	8.3060	18SEP94	17.255	17.280	0.025	-0.000	•	•
AVERAGE					0.008	0.001		
STD.DEV.					0.023	0.020		

Abbreviations:

FLOAT=Float and pulley from data logger (ft)
LOGGER PRGM=Calculations for NGVD from program in data logger.
REGRES CALCS=Calculations using the regression equation of staff gauge and sensor.
ERROR=Difference between calculations and actual staff gauge reading in the field.
ISCO HEAD=Reading from ISCO flowmeter.
ISCO OFFSET=Calculation of NGVD using ISCO HEAD reading. It should be 16.00.
•=Data not available.

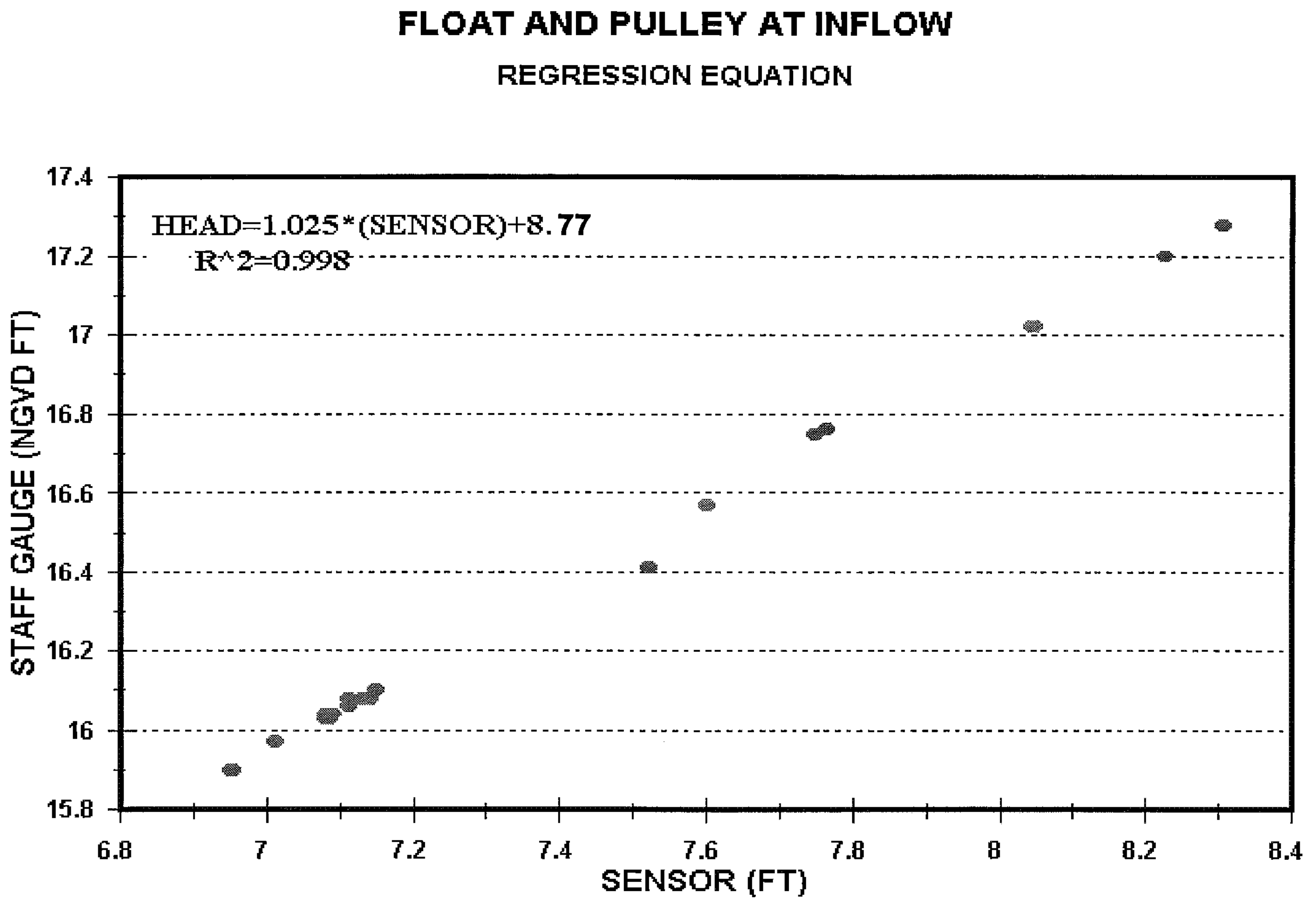


Figure B-2. Regression equation at inflow to determine accuracy of measurements. See Table B-1.

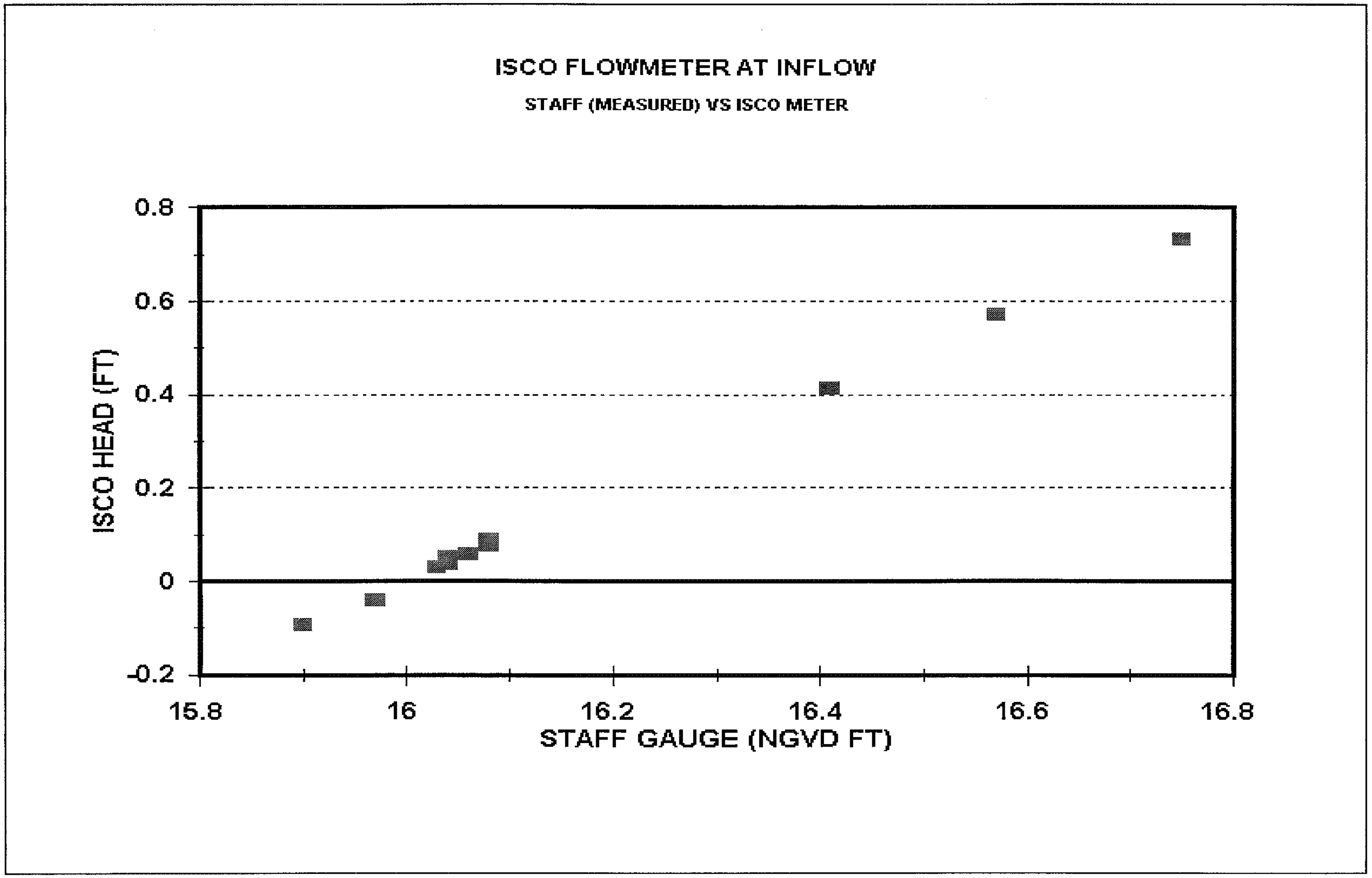


Figure B-3. Comparison of ISCO flowmeter level with the staff gauge at the inflow to determine accuracy. See Table B-1.

APPENDIX C

Quality Assurance Information for Outflow Data

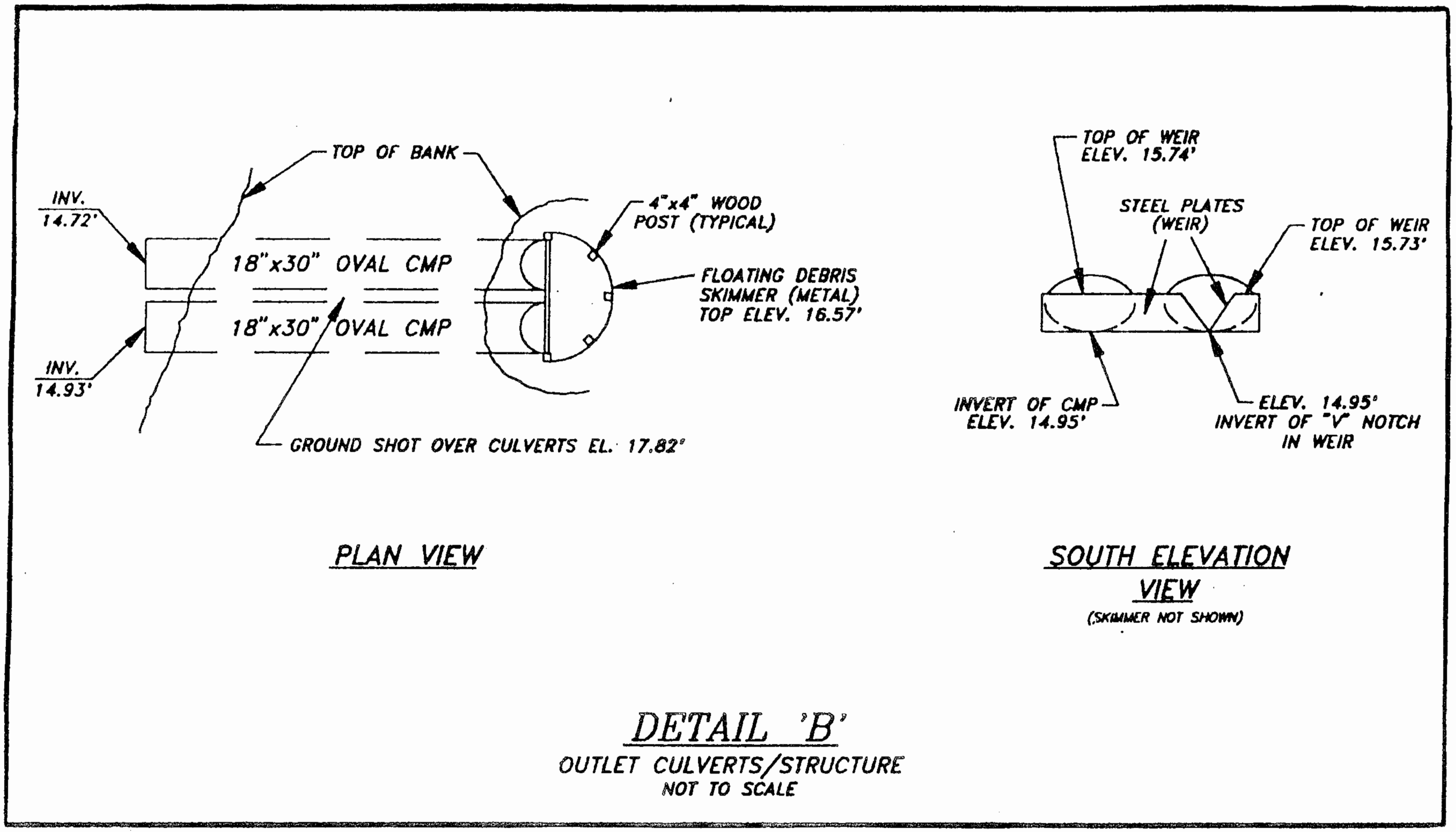


Figure C-1. Design and dimensions of outflow weir structure taken from the official survey. This survey was completed late in the study and elevations differ slightly from the preliminary measurements used in graphs and tables. The preliminary survey measured the control elevation (INVERT OF “V” NOTCH) as 15.064 NGVD (ft). The earlier levels are 0.11 feet higher than the official survey. Since head and flow measurements are calculated from differences in water levels, this discrepancy does not affect any of the data.

Table C-1. To check for accuracy, the sensors at the outflow were compared to actual staff gauge readings. Also the Isco flowmeter levels were compared to the staff gauge. The offset should read 15.035 for the Isco offset.

STAFF GAUGE NGVD(ft)	**FLOAT** (raw data) (feet)	**DATE**	**LOGGER PRGM** (FLOAT+8.949) NGVD(ft)	**REGRES CALCS** (Calculations) NGVD(ft)	**ERROR LOGGER** (feet)	**ERROR CALCS** (feet)	**ISCO** (raw data) (feet)	**ISCO OFFSET 15.035** NGVD(ft)
15.02	5.1100	7JUN94	15.0100	14.9920	0.0100	0.0280	•	•
15.08	5.1100	27JUN94	15.0827	15.0694	-0.0027	0.0106	•	•
15.08	5.1827	18JUL94	15.0911	15.0783	-0.0111	0.0017	0.0500	15.030
15.08	5.1911	27JUN94	15.0829	15.0696	-0.0029	0.0104	0.0410	15.039
15.10	5.1829	11JUN94	15.1140	15.1027	-0.0140	-0.0027	0.0720	15.028
15.14	5.2440	6SEP94	15.1440	15.1346	-0.0040	0.0054	0.1040	15.036
15.16	5.2610	29JUN94	15.1610	15.1527	-0.0010	0.0073	0.1170	15.043
15.19	5.2799	14SEP94	15.1799	15.1728	0.0101	0.0172	0.1400	15.050
15.19	5.2790	30JUN94	15.1790	15.1719	0.0110	0.0181	0.1430	15.047
15.20	5.3027	20JUN94	15.2027	15.1971	-0.0027	0.0029	0.1620	15.038
15.20	5.3016	3AUG94	15.2016	15.1959	-0.0016	0.0041	0.1580	15.042
15.21	5.3032	12SEP94	15.2032	15.1976	0.0068	0.0124	0.1710	15.039
15.22	5.3183	24AUG94	15.2183	15.2137	0.0017	0.0063	0.1800	15.040
15.23	5.3262	28JUN94	15.2262	15.2221	0.0038	0.0079	0.1940	15.036
15.25	5.3580	23JUN94	15.2580	15.2559	-0.0080	-0.0059	0.2190	15.031
15.28	5.3708	11JUL94	15.2708	15.2695	0.0092	0.0105	0.2550	15.025
15.30	5.4001	26AUG94	15.3001	15.3007	-0.0001	-0.0007	0.2590	15.041
15.30	5.4033	5JUL94	15.3033	15.3041	-0.0033	-0.0041	0.2650	15.035
15.30	5.4054	19SEP94	15.3054	15.3063	-0.0054	-0.0063	0.2660	15.034
15.30	5.4104	1AUG94	15.3104	15.3117	-0.0104	-0.0117	0.2710	15.029
15.30	5.3990	21JUN94	15.2990	15.2995	0.0010	0.0005	0.2630	15.037
15.32	5.4153	25JUL94	15.3153	15.3169	0.0047	0.0031	0.2880	15.032
15.34	5.4082	7JUL94	15.3082	15.3093	0.0318	0.0307	0.3030	15.037
15.37	5.4717	4JUL94	15.3717	15.3769	-0.0017	-0.0069	•	•
15.38	5.4870	25AUG94	15.3870	15.3932	-0.0070	-0.0132	0.3430	15.037
15.38	5.4770	22JUN94	15.3770	15.3825	0.0030	-0.0025	0.3370	15.043
15.40	5.5063	18JUN94	15.4063	15.4137	-0.0063	-0.0137	0.3690	15.031
15.46	5.5659	18SEP94	15.4659	15.4771	-0.0059	-0.0171	0.4160	15.044
15.51	5.6130	16JUN94	15.5130	15.5272	-0.0030	-0.0172	•	•
15.53	5.6310	17JUN94	15.5310	15.5464	-0.0010	-0.0164	0.4970	15.033
15.55	5.6522	16SEP94	15.5522	15.5689	-0.0022	-0.0189	0.5070	15.043
15.60	5.7115	11AUG94	15.6115	15.6320	-0.0115	-0.0320	0.5680	15.032
15.87	5.9254	29SEP94	15.8254	15.8596	0.0446	0.0104	0.8270	15.043
15.90	5.9979	27SEP94	15.8979	15.9368	0.0021	-0.0368	0.8565	15.044
15.93	5.9777	27SEP94	15.8777	15.9153	0.0523	0.0147	0.8755	15.055
15.93	5.9777	27SEP94	15.8777	15.9153	0.0523	0.0147	•	•
15.95	6.0010	27SEP94	15.9010	15.9401	0.0490	0.0099	•	•
15.96	6.0001	27SEP94	15.9001	15.9391	0.0599	0.0209	0.8985	15.062
15.97	6.0112	27SEP94	15.9112	15.9509	0.0588	0.0191	0.9120	15.058
15.98	6.0160	27SEP94	15.9160	15.9560	0.0640	0.0240	0.9170	15.063
				mean	0.009	0.002		
				std.dev.	0.022	0.015		

Abbreviations:

STAFF=Actual measurement read from staff gauge NGVD (ft).
FLOAT=Data (ft) read from the data logger without the offset.
LOGGER=Water level (NGVD) recorded from logger using offset of 9.90.
REGRES=Water level (NGVD) calculated from raw data using regression equation.
ERROR=Amount of difference from actual staff gauge readings using the two methods.
ISCO HEAD=Reading from Isco flowmeter.
ISCO OFFSET=Calculation of NGVD using Isco Head reading. It should be 15.035.
•=Data not available.

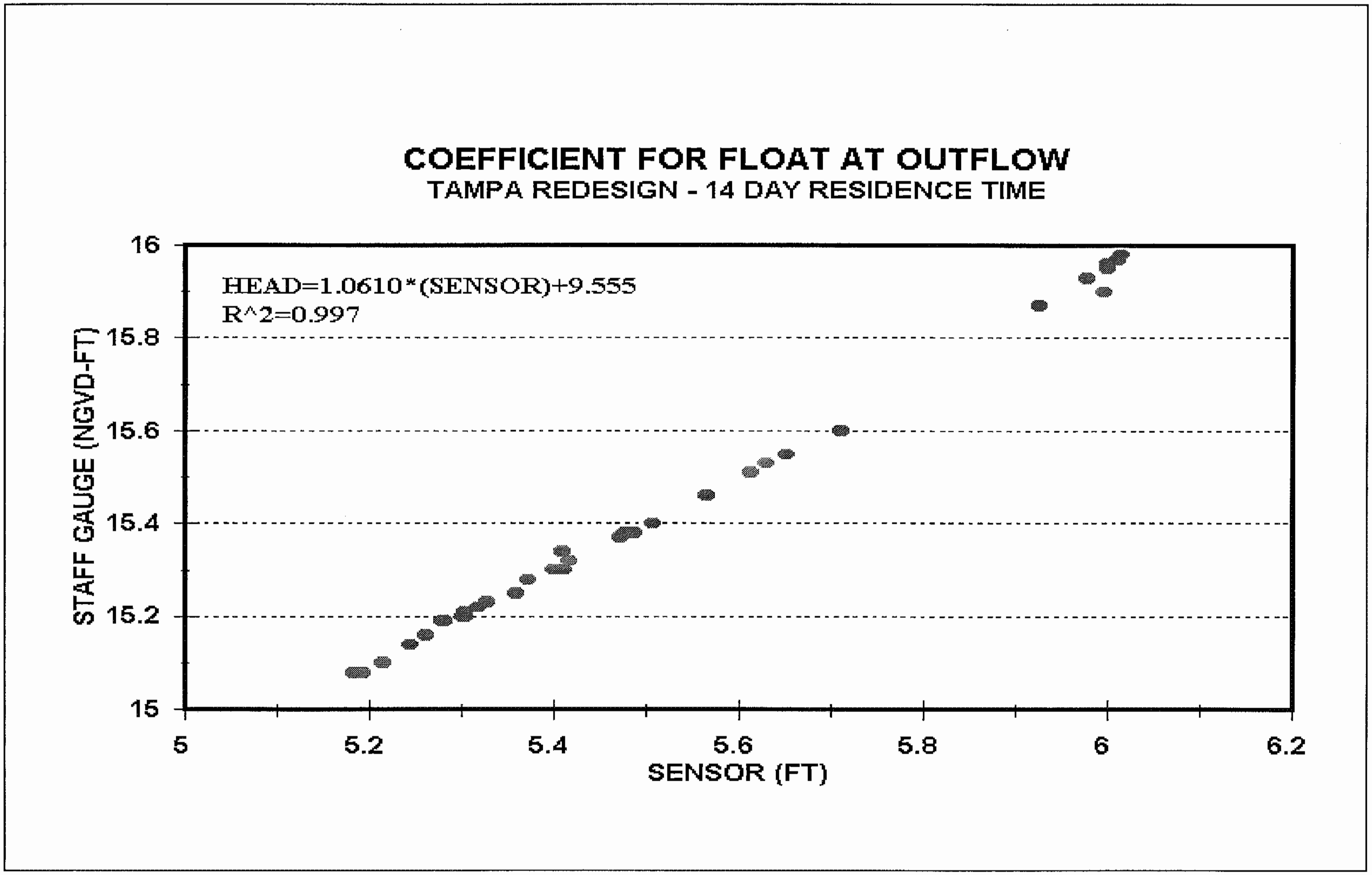


Figure C-2. Regression equation at outflow to determine accuracy of measurements. See Table C-1.

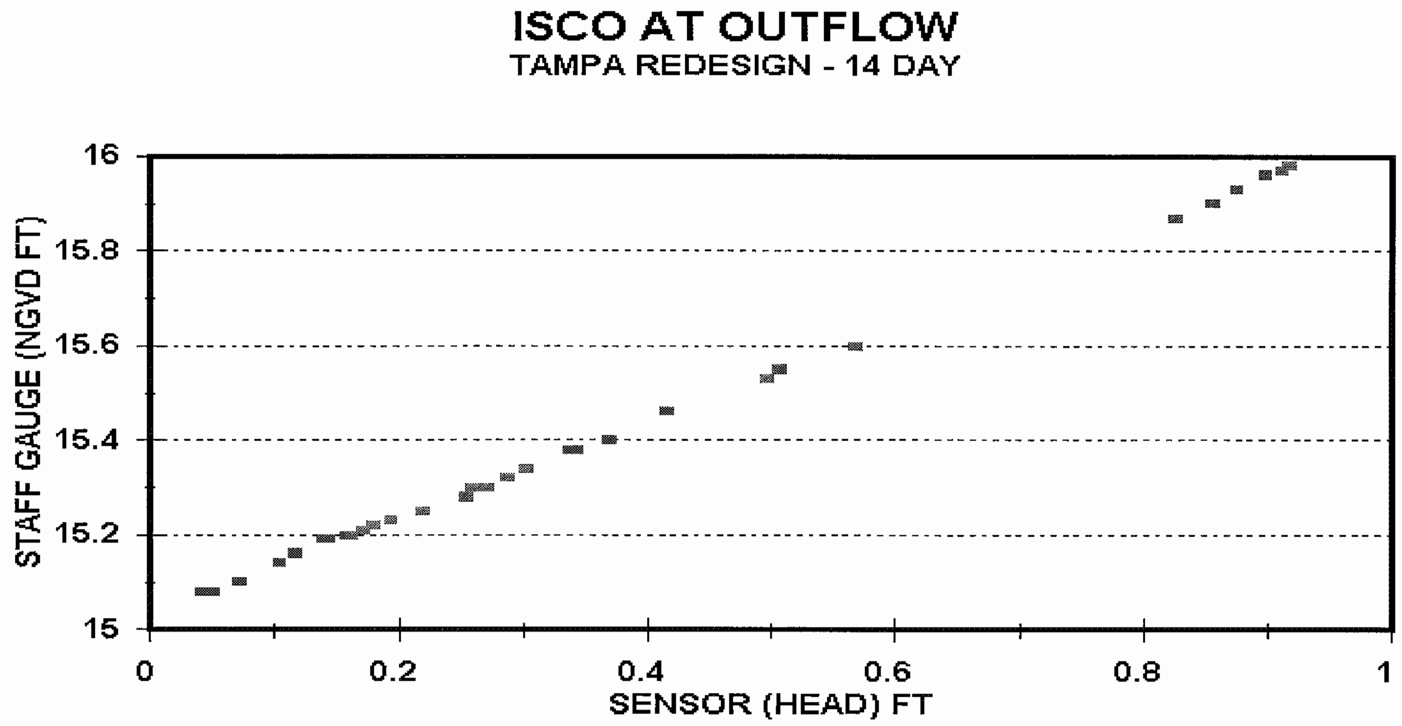


Figure C-3. Comparison of ISCO flowmeter level with the staff gauge at the outflow to determine accuracy. See Table C-1.

Table C-2. Flow measurements through 20° V-notch weir at outfall.

DATE	STAFF NGVD	MEAS CFS	ISCO CFS	FLOAT CFS	ISCO FT	FLOAT FT
1-11-94	15.18	0.0064	0.0047	0.0054	0.14	0.15
9-24-93	15.20	0.0115	0.0103	0.0086	0.19	0.18
10-10-93	15.23	0.0110	0.0124	0.0111	0.21	0.20
9-29-93	15.29	0.0248	0.0240	0.0236	0.27	0.27
1-07-94	15.36	0.0385	0.0432	0.0420	0.34	0.34
9-15-93	15.38	0.0498	0.0501	0.0491	0.37	0.36
9-15-93	15.41	0.0533	0.0573	0.0563	0.39	0.38
1-03-94	15.48	0.0780	0.0786	0.0894	0.44	0.46
9-22-93	15.50	0.1050	0.0984	0.0994	0.48	0.48
1-18-94	15.62	0.1670	0.1638	0.1737	0.59	0.60

Abbreviations:

STAFF=Measurement read directly from staff gauge in feet.
MEAS= Actual amount measured using stop watch and bucket.
ISCO=Flow as read from flow meter using coefficient of 0.623.
FLOAT=Flow as read from data logger using float and pulley with coefficient of 0.623.
ISCO=Water level read from flow meter.
FLOAT=Water level from data logger.

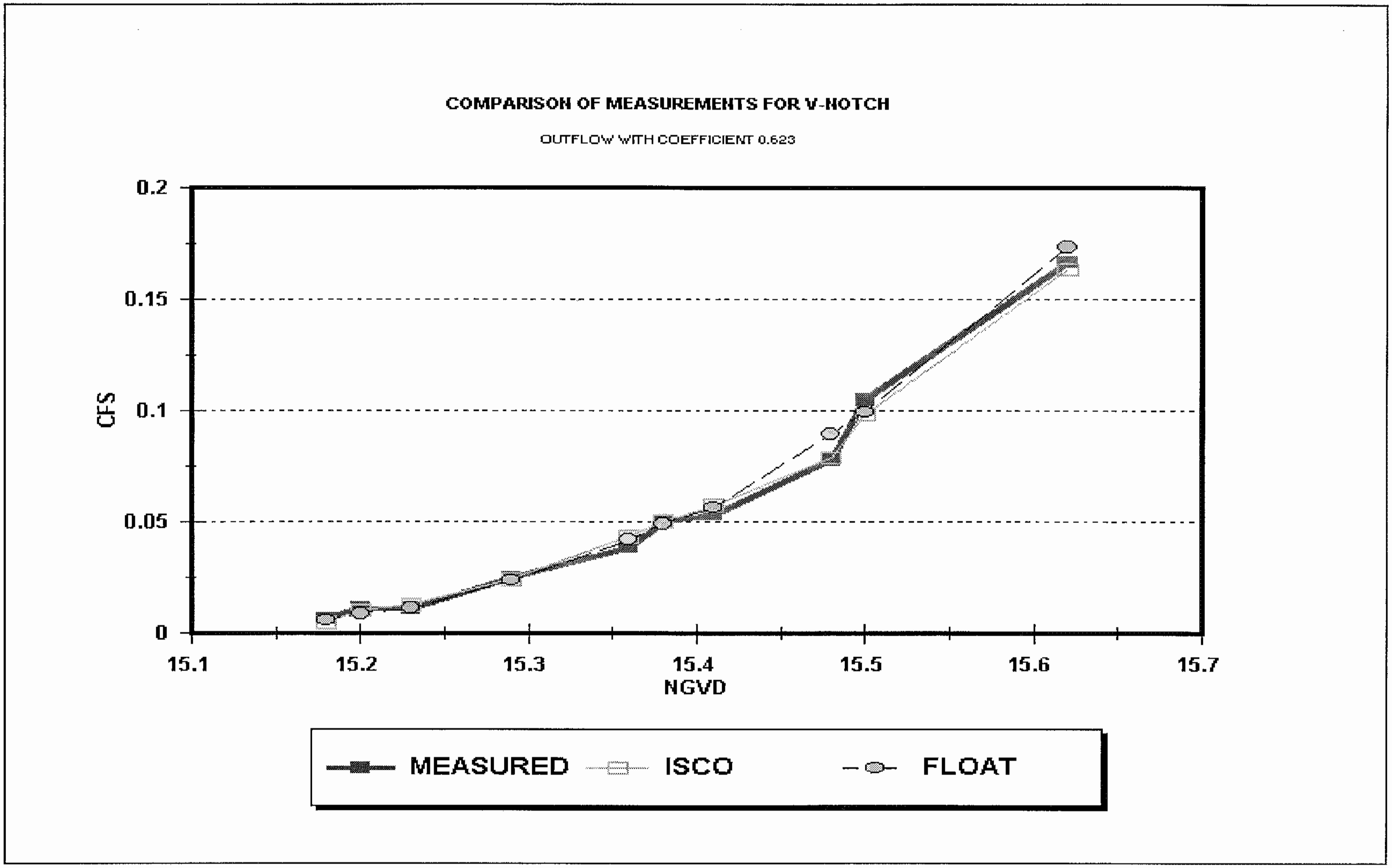


Figure C-4. Comparison of sensors for the V-notch at the outflow with measured values. See Table C-2.

APPENDIX D

Data for Field Blanks for Water Quality Assurance

Table D-1. Samples taken for quality assurance. Samples were taken using deionized water (D.I.) in the same manner (i.e. through the equipment tubing) as the regular samples. Samples were also analyzed using the D.I. water directly from the bottle. In a few cases samples were analyzed using D.I. water both before and after the tubing was changed. BD=Below the detction limit, MDL=Minimum detection limit.

DATE	SAMPLE	NH3	CD	CU	FE	PB	MN	NOX	OP	TP	TKN	ZN
	NUMBER MDL=	0.01	0.003	0.001	0.03	0.002	0.07	0.01	0.01	0.01	0.1	0.03
Equipment samples taken using D.I. water right before the tubing was changed.												
6-08-92	1019	BD	BD	0.002	0.100	BD	BD	BD	BD	BD	BD	BD
3-26-92	0307	0.047	BD	0.006	0.140	BD	BD	0.443	BD	0.017	0.37	BD
7-28-92	0361	BD	BD	BD	0.060	BD	BD	BD	BD	0.012	BD	BD
2-02-93	0467	0.035	BD	BD	0.064	BD	BD	BD	BD	0.016	0.12	BD
4-08-93	0504	BD	BD	0.003	0.045	BD	BD	BD	BD	BD	0.11	BD
3-26-92	0308	BD	BD	BD	0.130	BD	BD	0.013	BD	BD	BD	BD
7-28-92	0364	BD	BD	BD	BD	BD	BD	BD	BD	0.013	BD	BD
2-02-93	0465	BD	BD	BD	0.066	BD	BD	BD	BD	0.022	BD	BD
6-08-93	0505	BD	BD	BD	0.034	BD	BD	BD	BD	BD	BD	BD
3-02-93	0309	BD	BD	BD	BD	BD	BD	0.012	BD	BD	BD	BD
7-28-93	0363	BD	BD	BD	0.060	BD	BD	BD	BD	0.023	BD	0.038
2-02-93	0466	BD	BD	BD	BD	BD	BD	BD	BD	0.021	BD	BD
6-08-93	0506	BD	BD	BD	BD	BD	BD	BD	BD	BD	0.14	BD
6-25-93	3008	BD	BD	BD	BD	BD	BD	0.013	0.012	0.025	0.36	BD
6-30-93	3007	0.020	BD	0.006	BD	BD	BD	0.020	BD	BD	0.16	BD
10-6-94	1137	BD	BD	0.006	0.290	BD	BD	BD	0.017	0.036	0.02	BD
10-6-94	1138	BD	BD	0.003	BD	BD	BD	BD	BD	BD	0.49	BD

continued next page

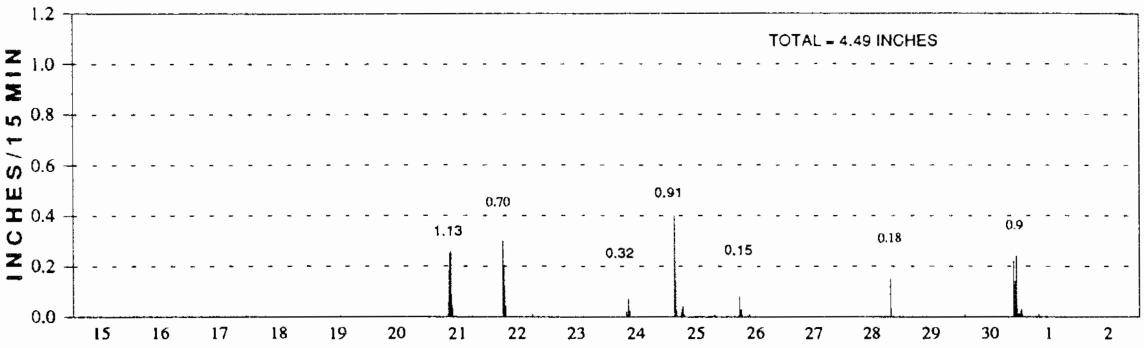
Table D-1. Continued

DATE	SAMPLE NUMBER MDL=	NH3 0.01	CD 0.0003	CU 0.001	FE 0.03	PB 0.002	MN 0.07	NOX 0.01	OP 0.01	TP 0.01	TKN 0.1	ZN 0.03
Samples taken using D.I. water right before tubing changed "A" and right after tubing changed "B'.												
7-05-93	528A	BD	BD	BD	0.035	BD	BD	BD	BD	BD	0.25	BD
7-05-93	528B	BD	BD	BD	0.054	BD	BD	BD	BD	BD	0.10	BD
7-05-93	529A	BD	BD	0.003	BD	BD	BD	BD	BD	BD	0.14	BD
7-05-93	529B	BD	BD	BD	BD	BD	BD	BD	BD	BD	0.19	BD
7-05-93	530A	BD	BD	BD	0.077	BD	BD	BD	BD	BD	0.24	BD
7-05-93	530B	BD	BD	0.004	0.081	BD	BD	0.012	0.028	0.090	0.54	BD
7-05-93	531A	BD	BD	0.002	0.040	BD	BD	0.011	BD	BD	0.31	BD
7-05-93	531B	BD	BD	BD	BD	BD	BD	0.053	BD	BD	0.23	BD
12-17-93	3100 A	BD	BD	BD	BD	BD	BD	BD	BD	0.029	0.50	0.039
12-17-93	3100 B	BD	BD	BD	0.050	BD	BD	BD	BD	BD	BD	BD
12-17-93	3101 A	BD	BD	BD	BD	BD	BD	BD	BD	0.016	0.38	BD
12-17-93	3101 B	BD	BD	BD	0.041	BD	BD	0.015	BD	0.016	0.29	BD
Samples taken through the rain collector using D.I. water.												
6-08-92	0340	BD	BD	0.005	BD	BD	BD	BD	BD	BD	0.21	BD
7-28-92	0362	BD	BD	BD	0.050	BD	BD	BD	BD	BD	BD	BD
2-02-93	0463	BD	BD	BD	0.053	BD	BD	BD	BD	BD	0.26	BD
4-08-93	0503	BD	BD	BD	0.052	BD	BD	BD	BD	BD	0.24	BD
6-30-93	3015	0.018	BD	0.004	BD	BD	BD	0.026	BD	BD	0.21	BD
8-18-93	1141	0.012	BD	BD	0.261	BD	BD	0.020	BD	0.274	0.21	BD
Samples taken directly from the D.I. bottle.												
6-25-93	3009	0.046	BD	BD	BD	BD	BD	BD	BD	BD	0.25	BD
7-05-93	532	BD	BD	BD	BD	BD	BD	BD	BD	BD	0.17	BD
10-6-94	1140	BD	BD	0.006	0.082	BD	BD	BD	BD	BD	0.15	BD
12-22-93	3105	BD	BD	BD	BD	BD	BD	BD	BD	BD	0.62	BD

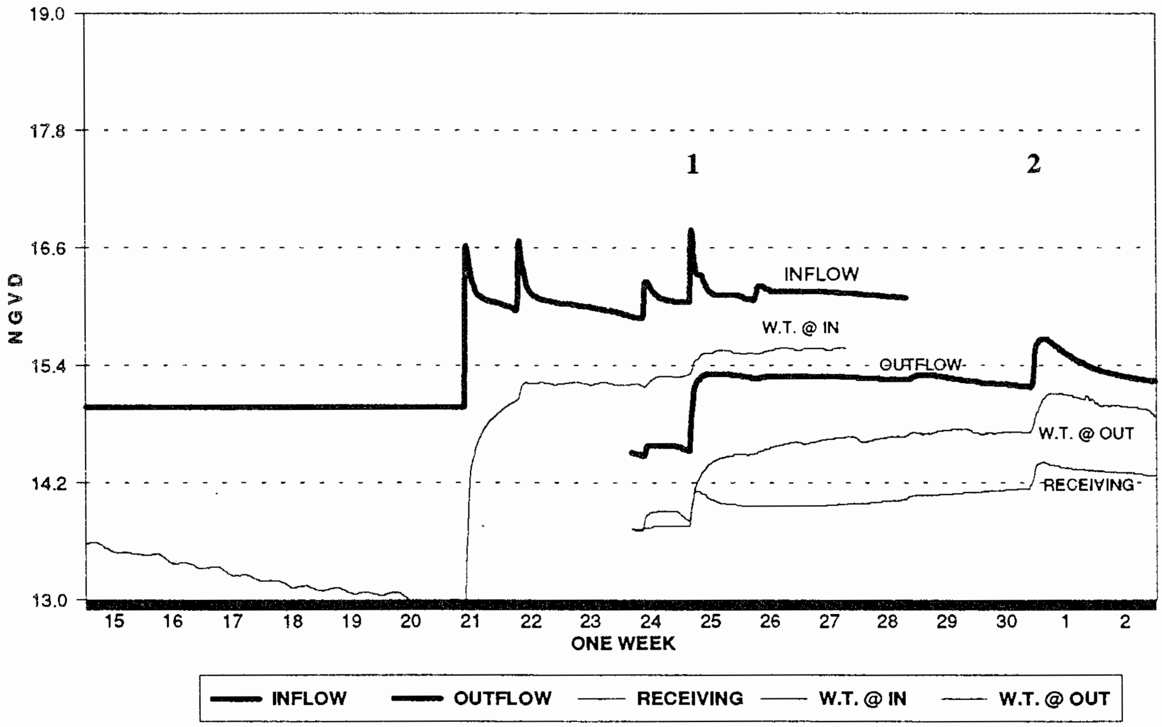
APPENDIX E

Rainfall and Water Level Comparisons for 1993

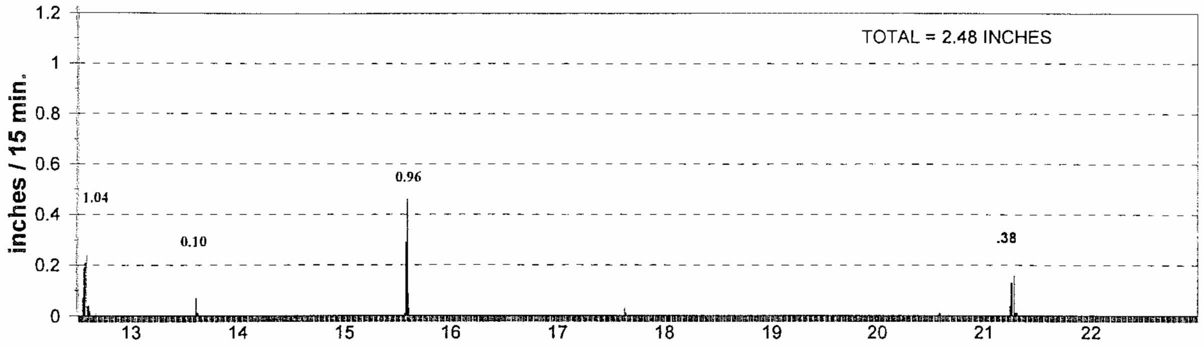
JUNE 14, 1993 TO JULY 1, 1993
RAINFALL



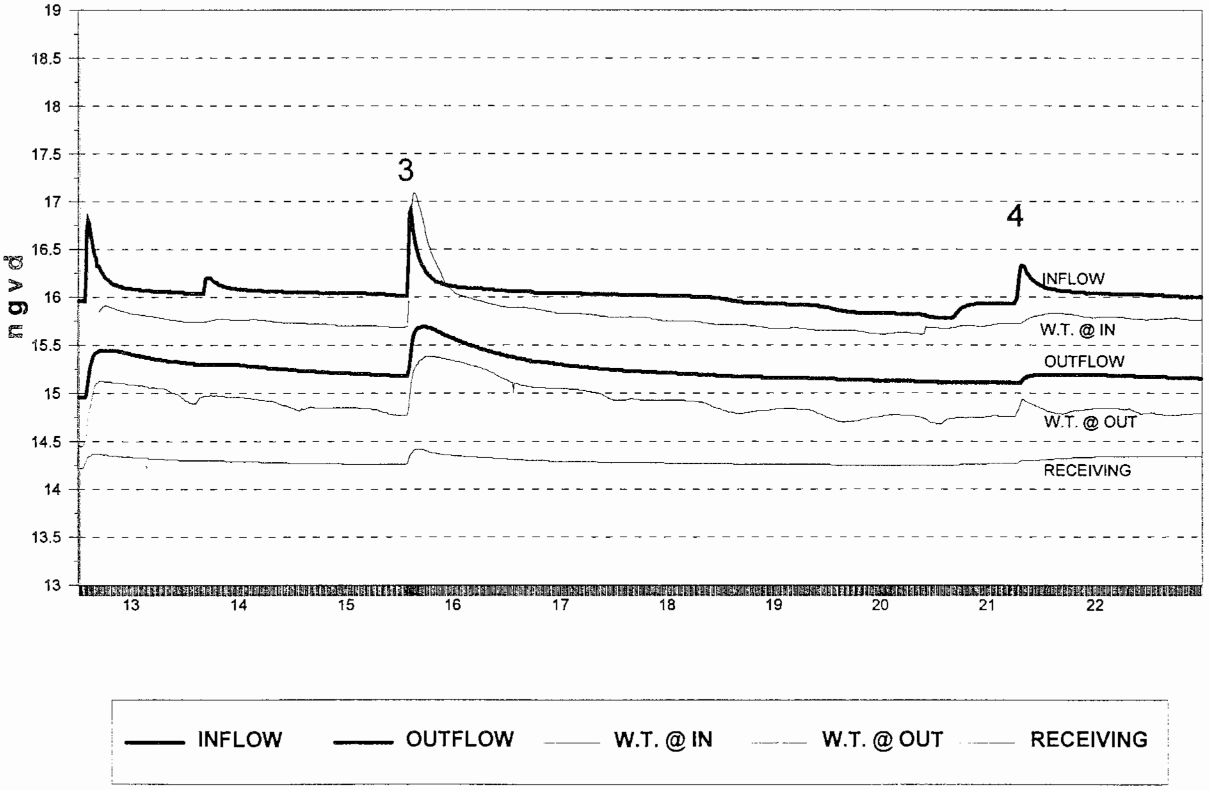
WATER LEVEL COMPARISONS



July 12 to July 23 1993
RAINFALL

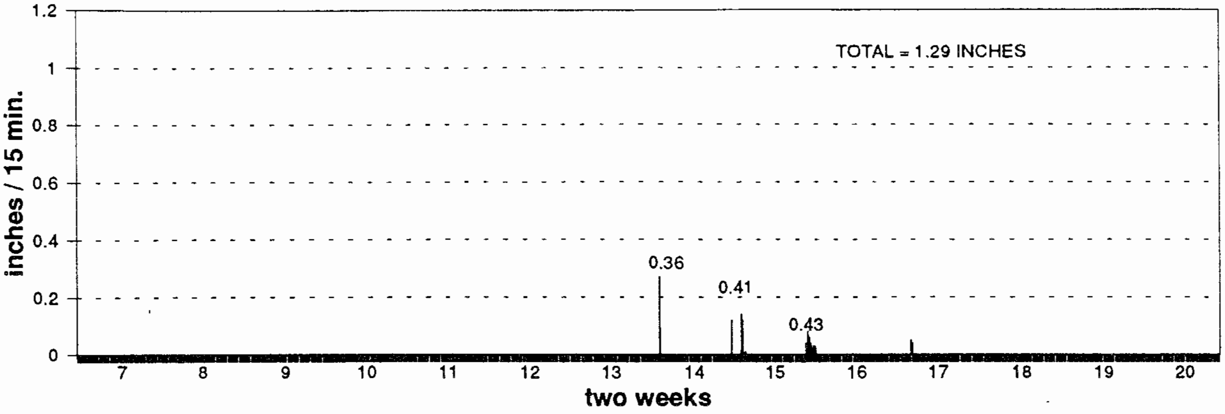


WATER LEVEL COMPARISONS

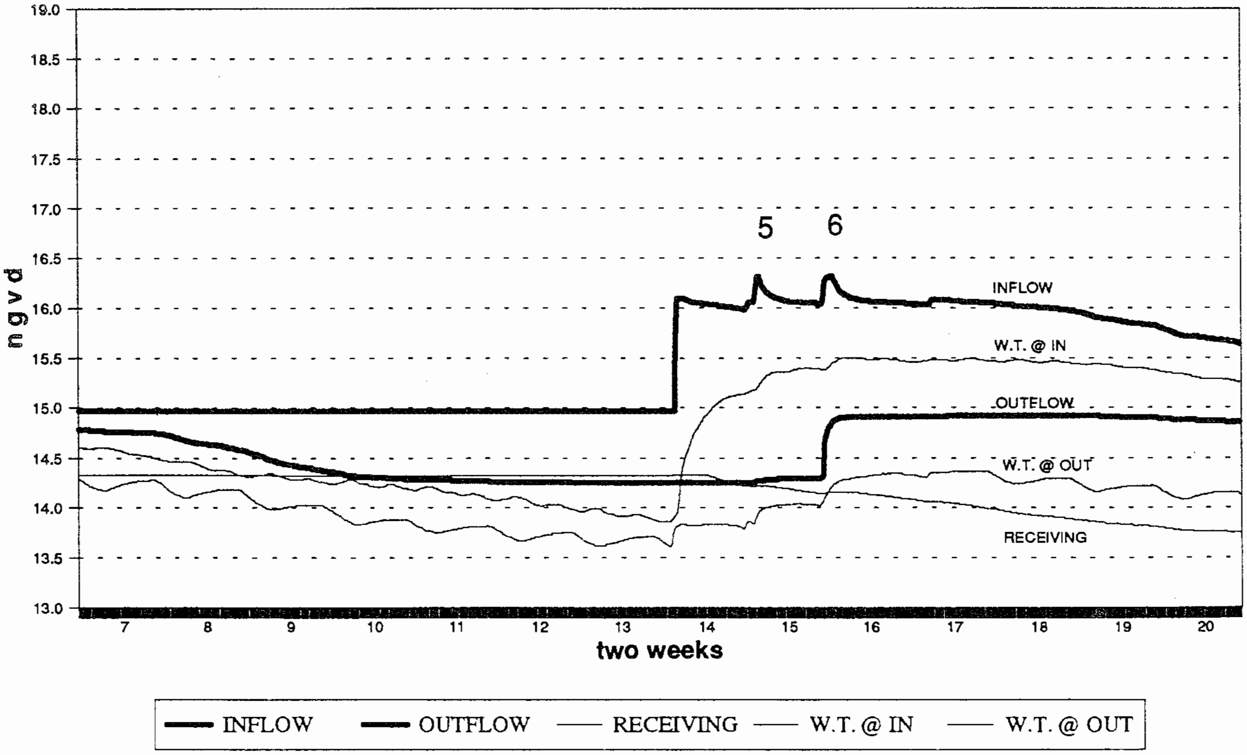


August 6 to August 20, 1993

RAINFALL

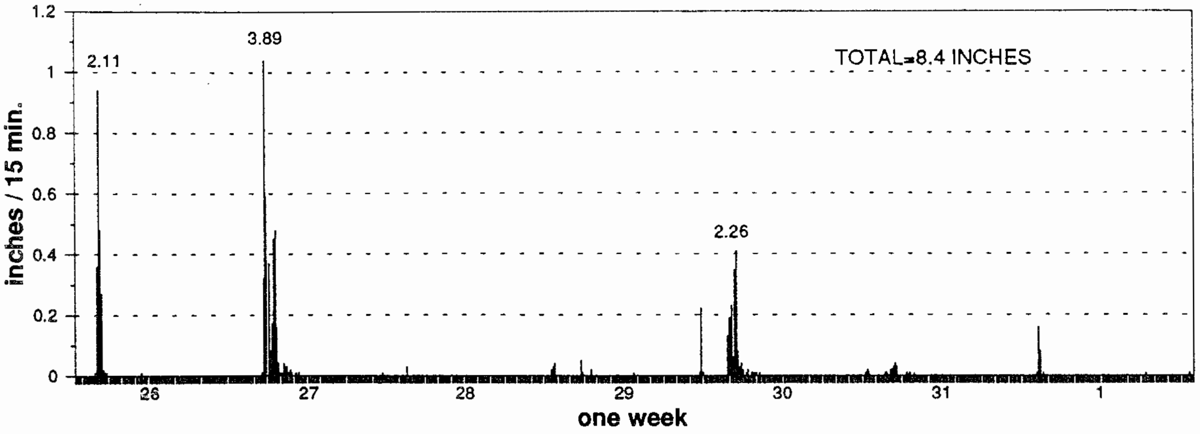


WATER LEVEL COMPARISONS

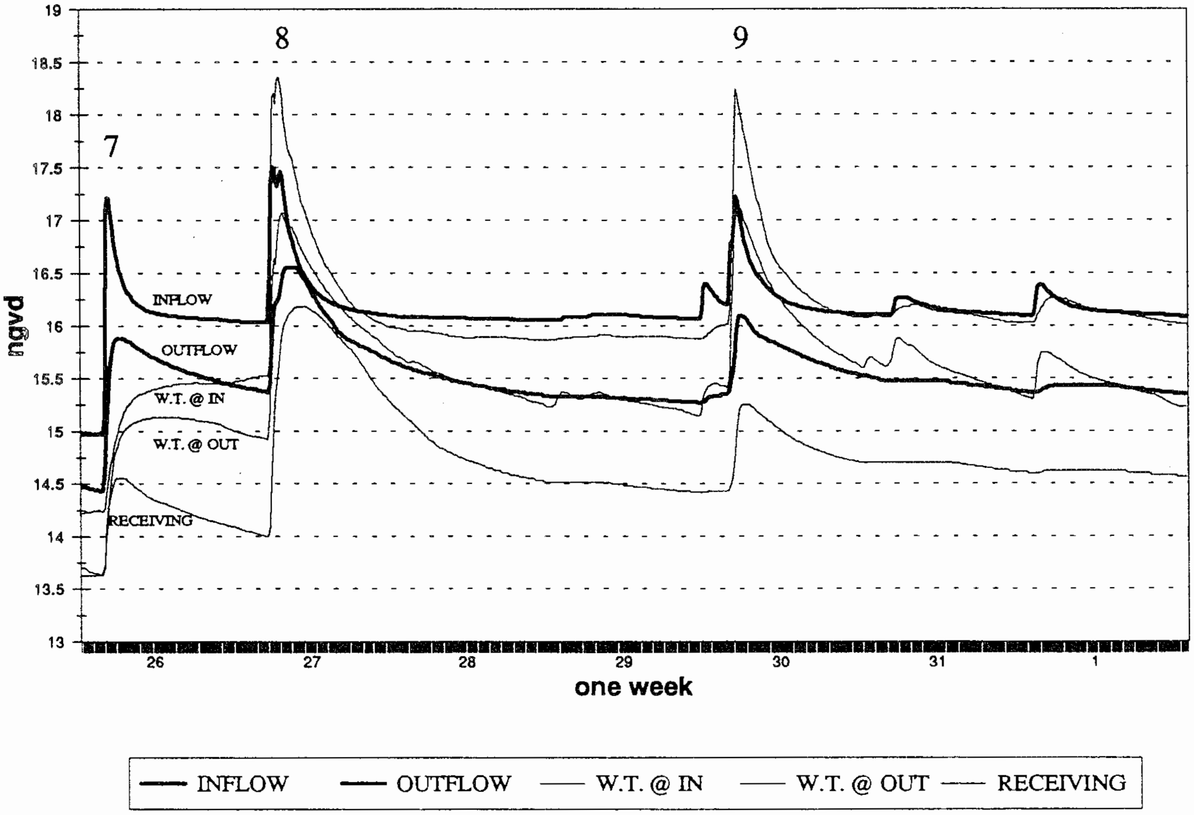


August 25 to September 1, 1993

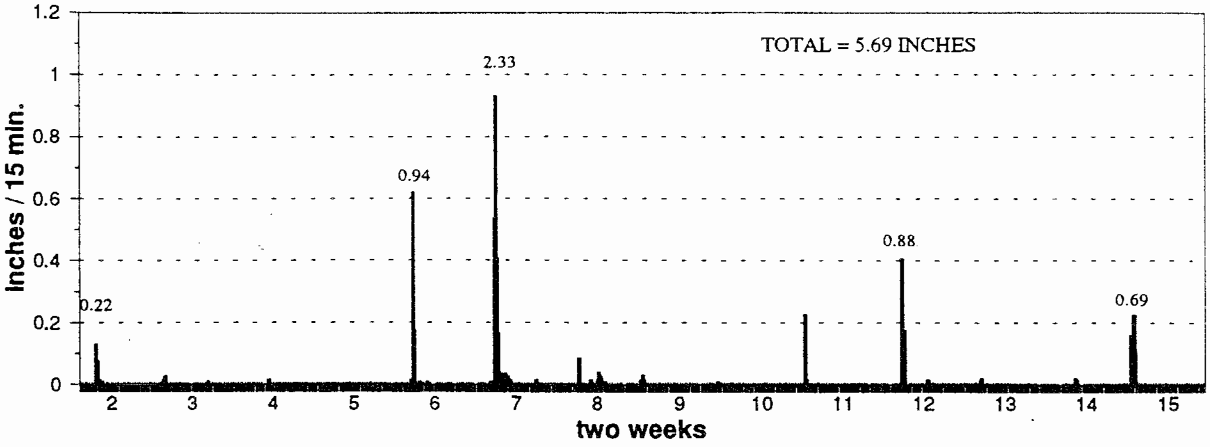
RAINFALL



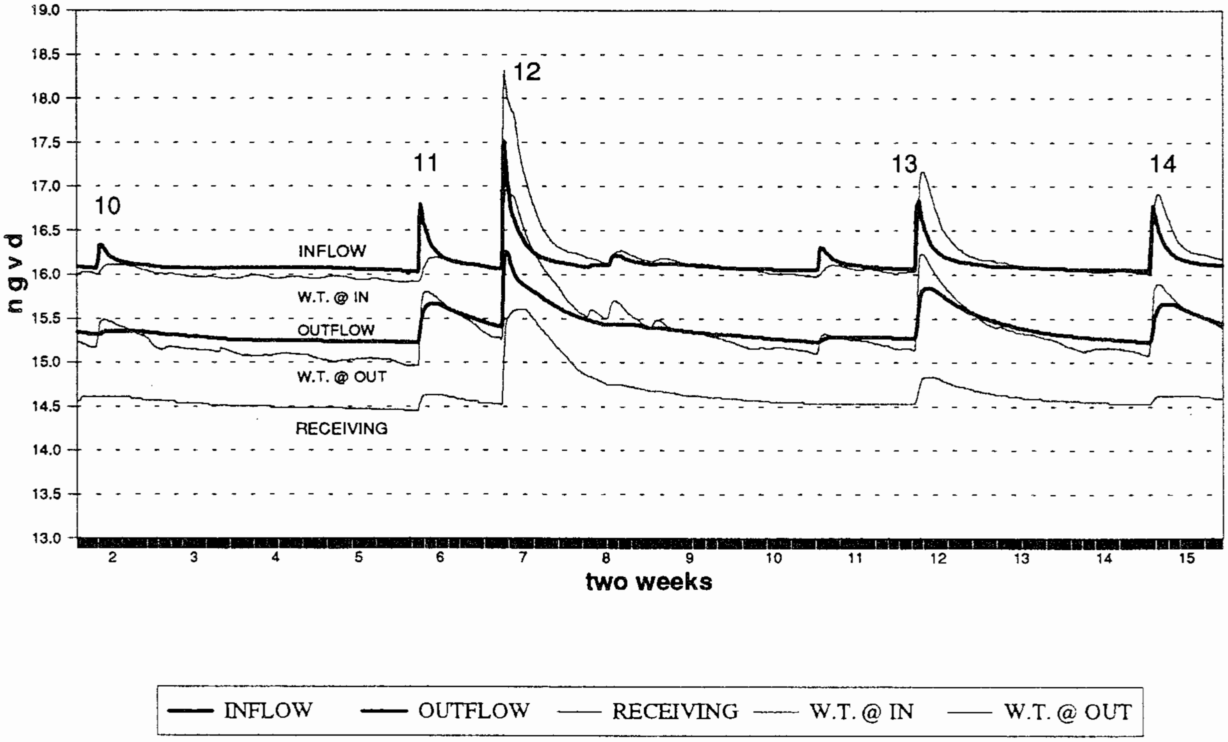
WATER LEVEL COMPARISONS



September 1 to September 15, 1993
RAINFALL

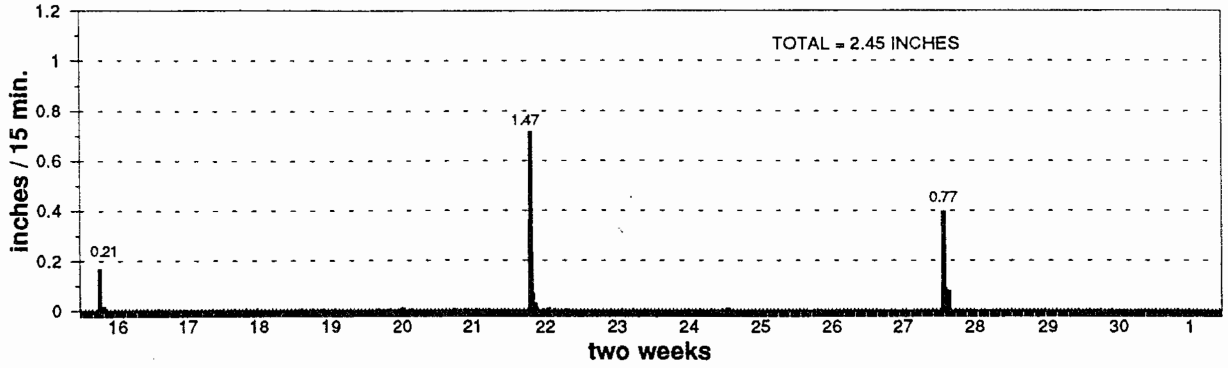


WATER LEVEL COMPARISONS

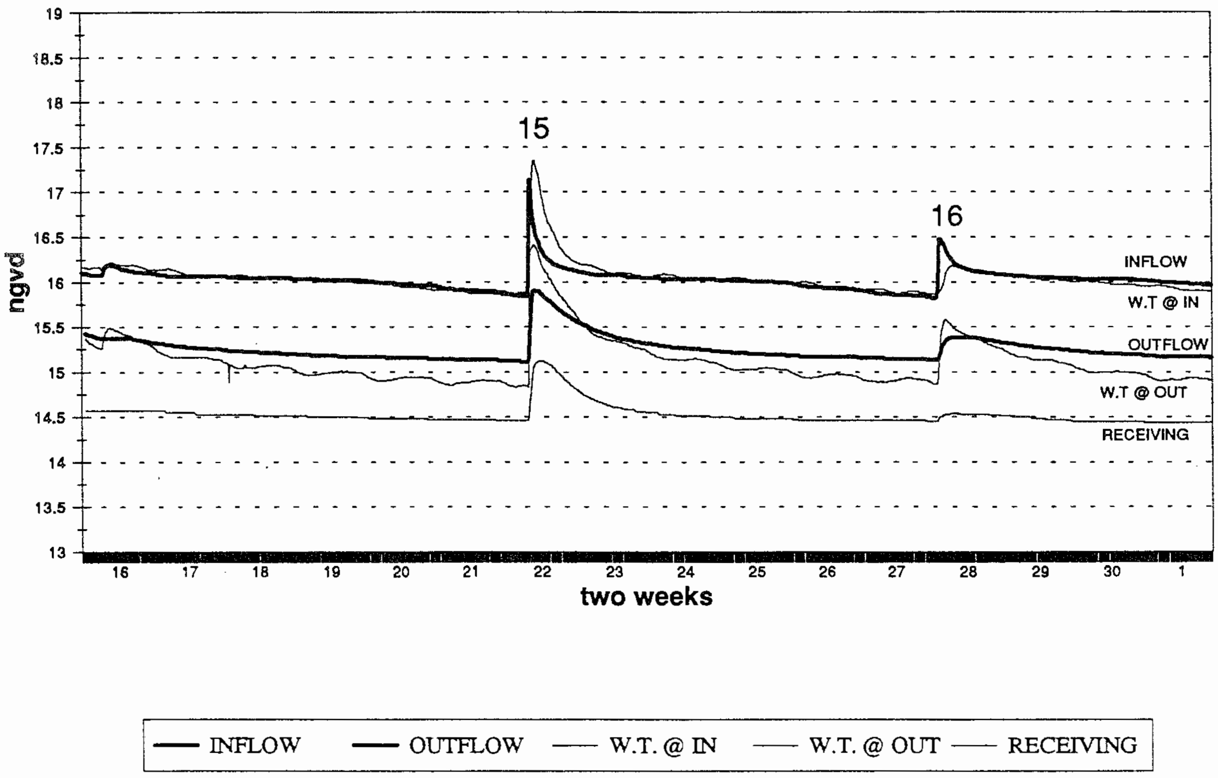


September 15 to October 1, 1993

RAINFALL

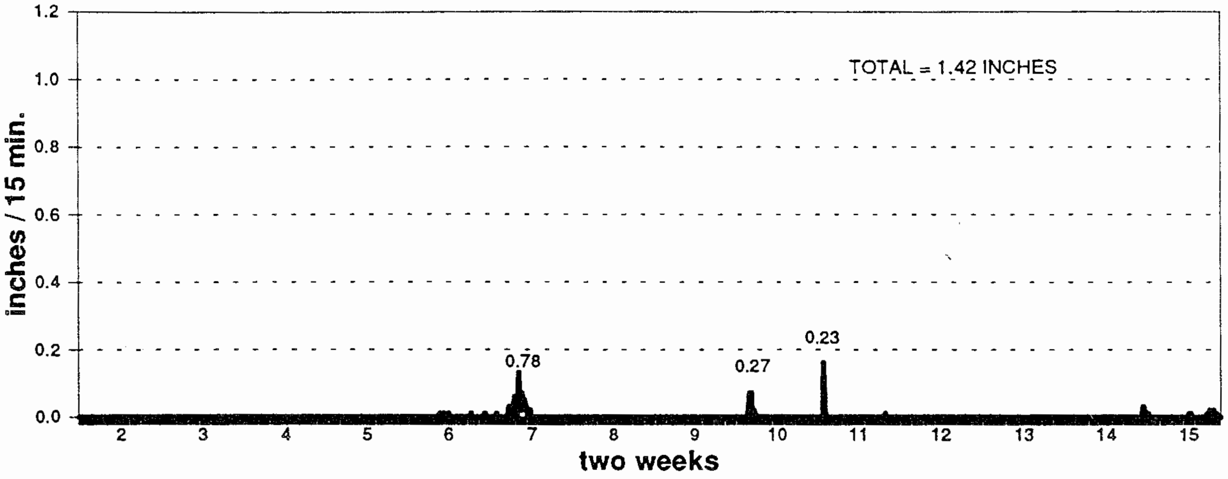


WATER LEVEL COMPARISONS

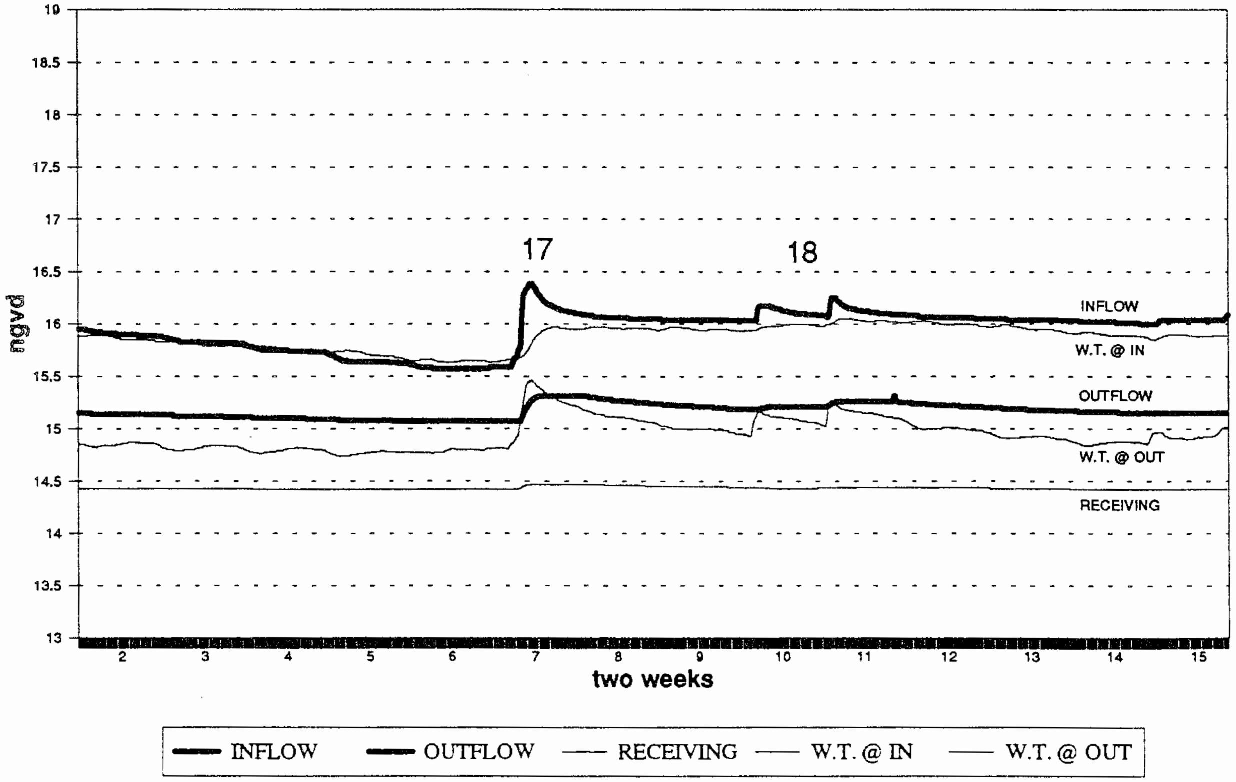


October1 to October 15, 1993

RAINFALL

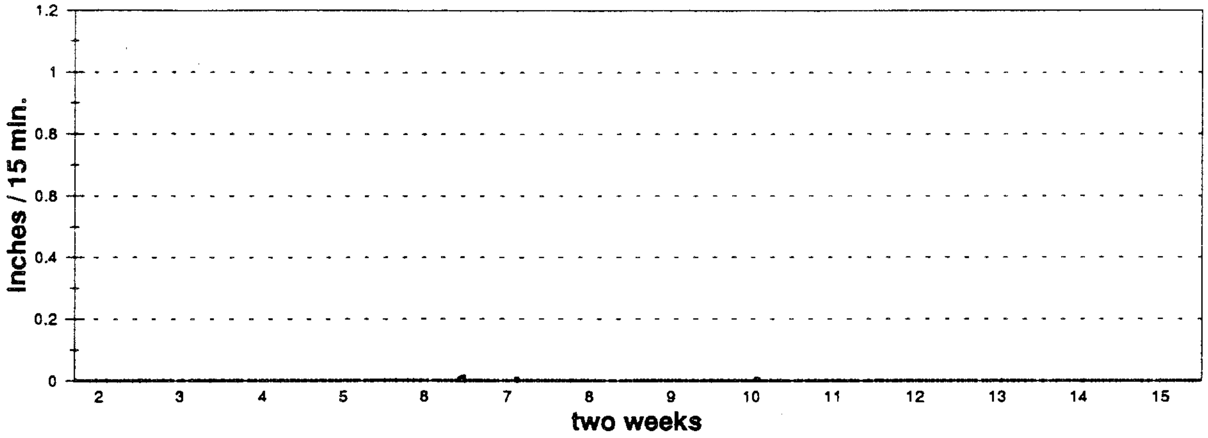


WATER LEVEL COMPARISONS

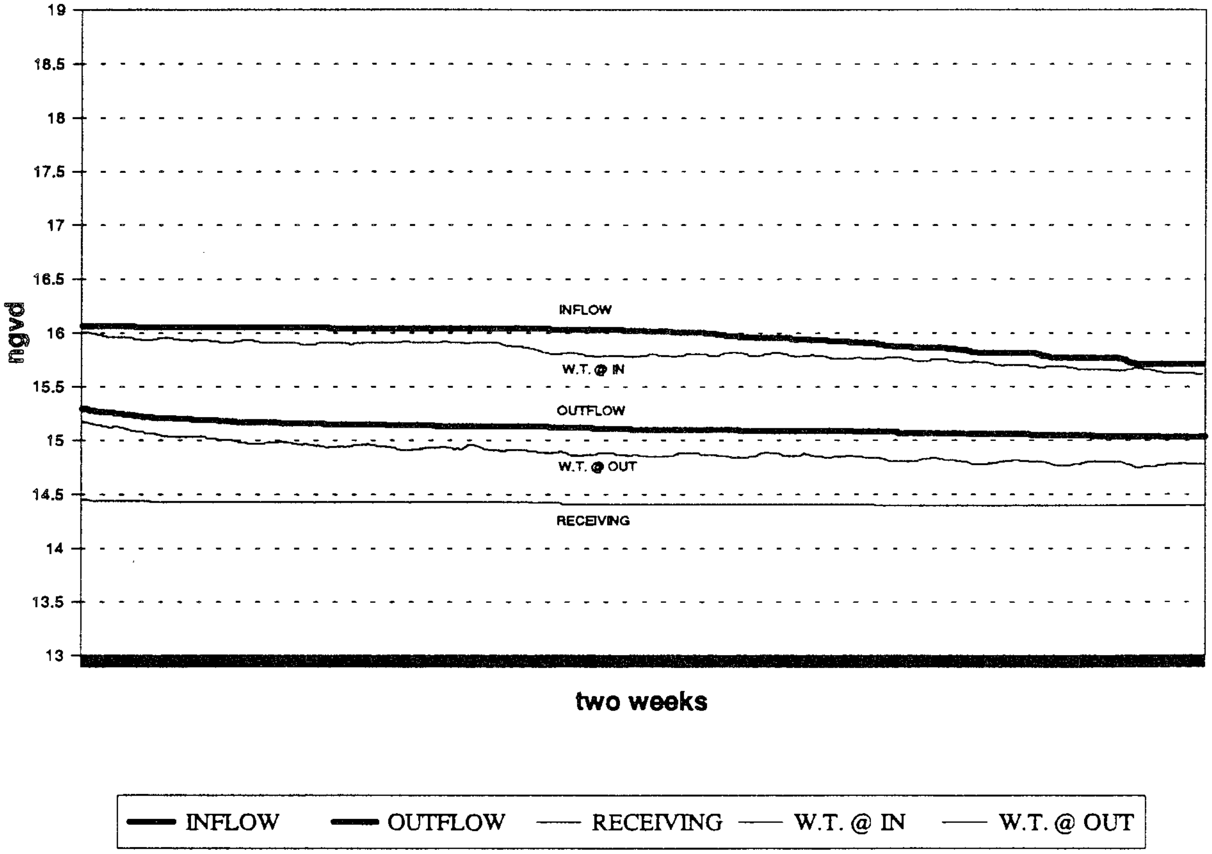


November 1 to November 15, 1993

RAINFALL

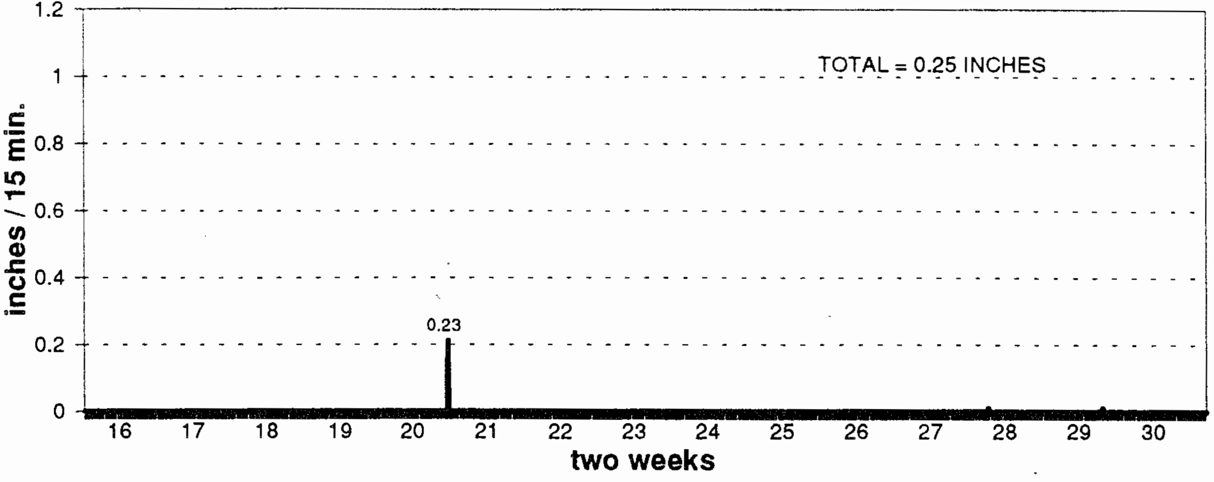


WATER LEVEL COMPARISONS

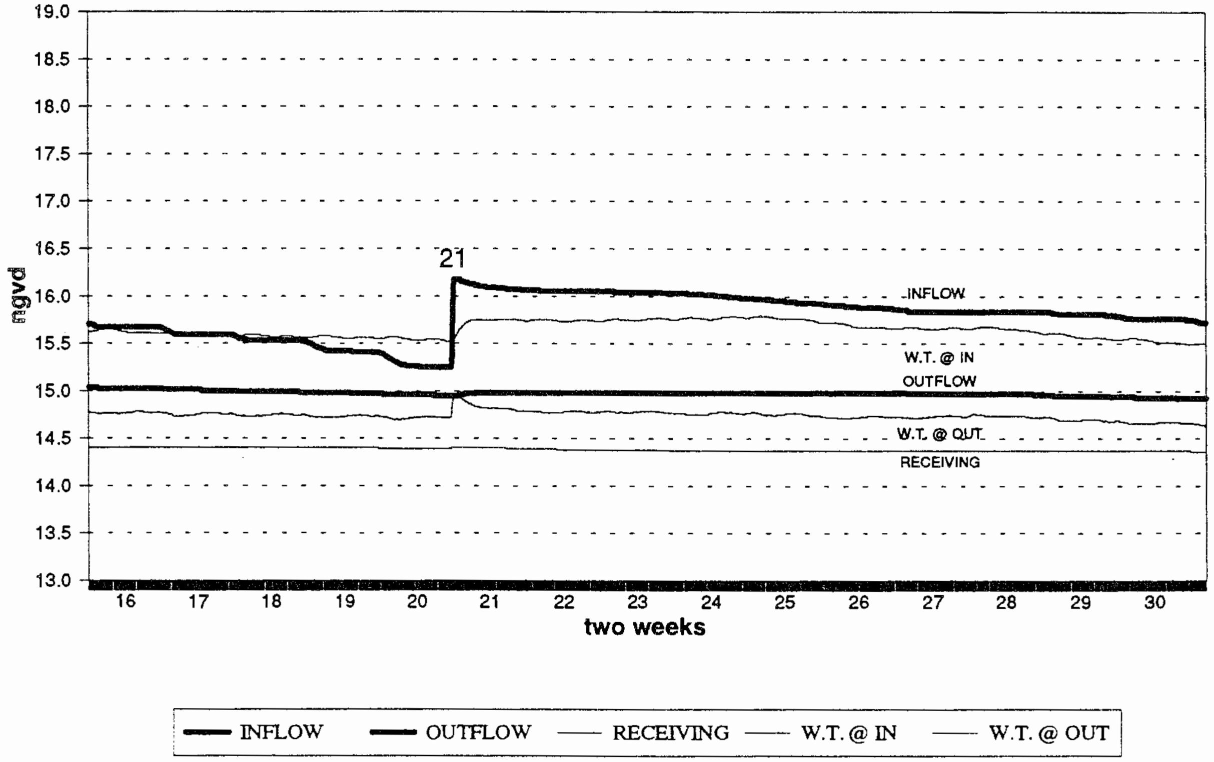


November 15 to November 30, 1993

RAINFALL

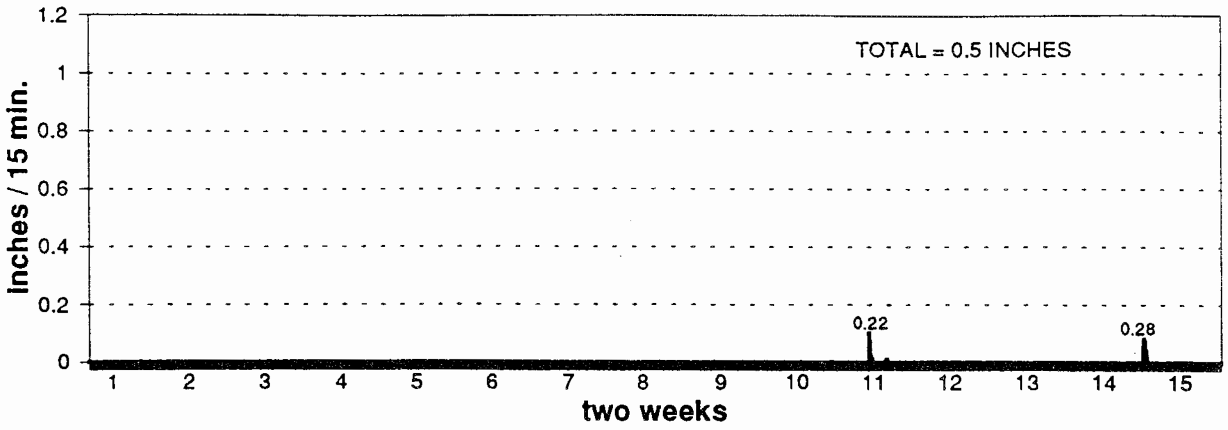


WATER LEVEL COMPARISONS

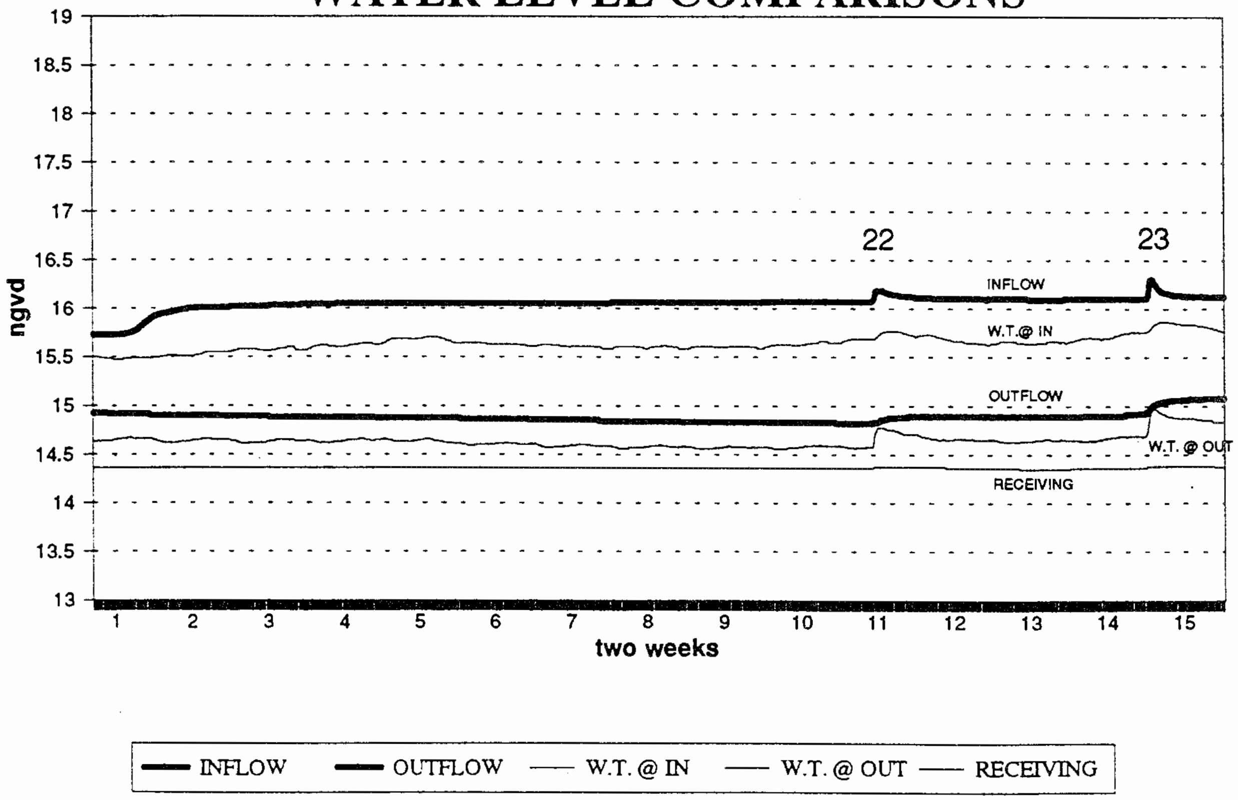


November 30 to December 15, 1993

RAINFALL

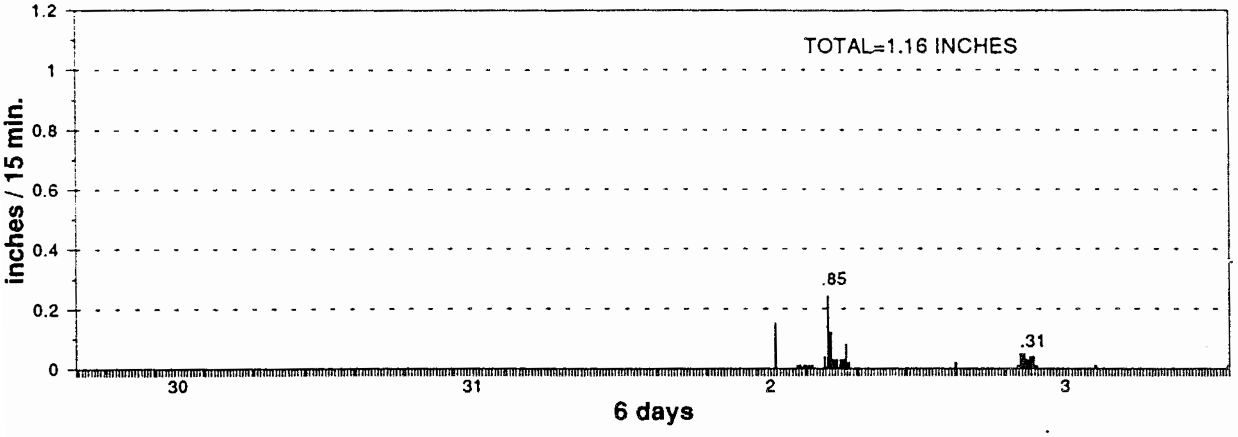


WATER LEVEL COMPARISONS

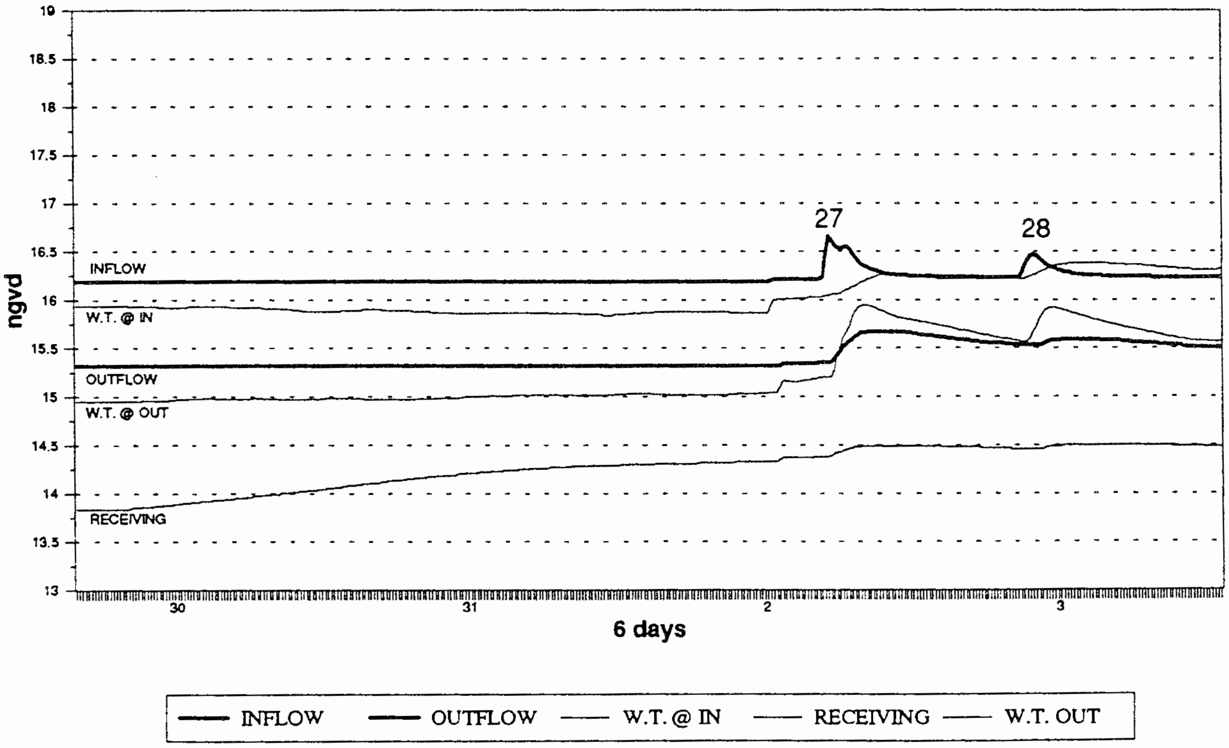


December 29, 1993 to January 3, 1994

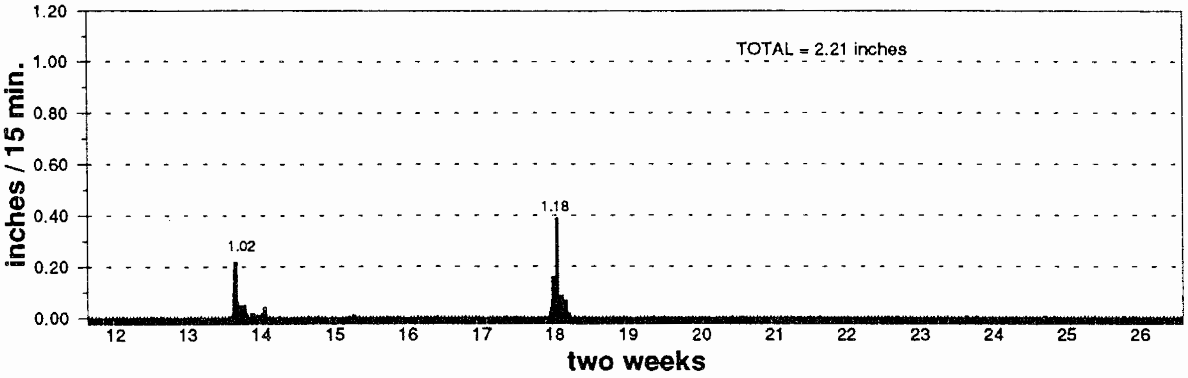
RAINFALL



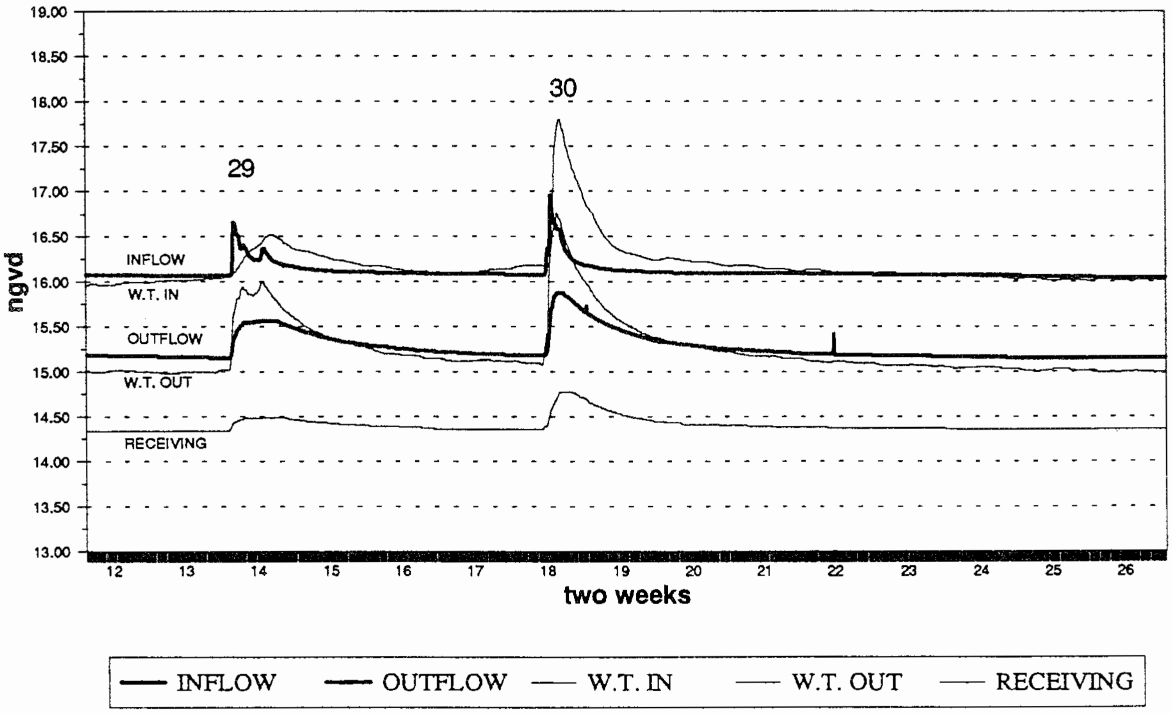
WATER LEVEL COMPARISONS



January 11 to January 26, 1994
RAINFALL



WATER LEVEL COMPARISONS

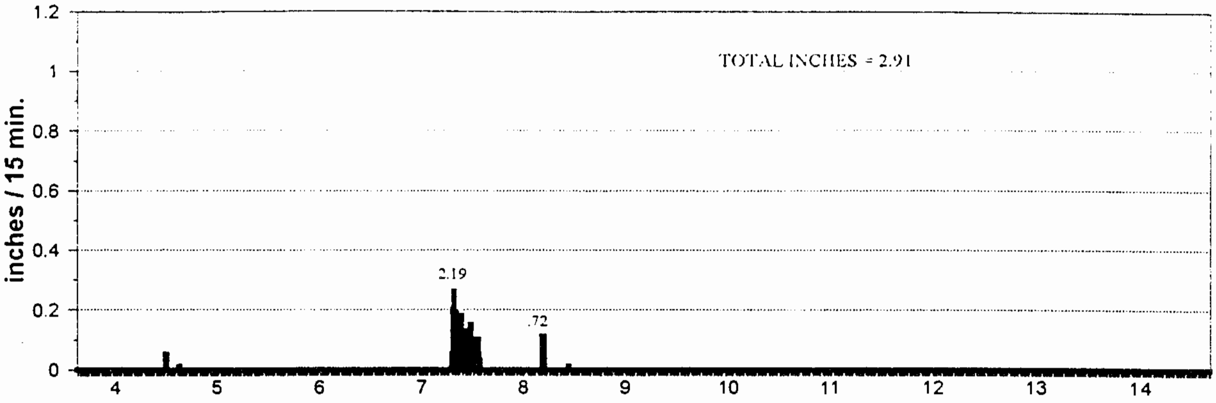


APPENDIX F

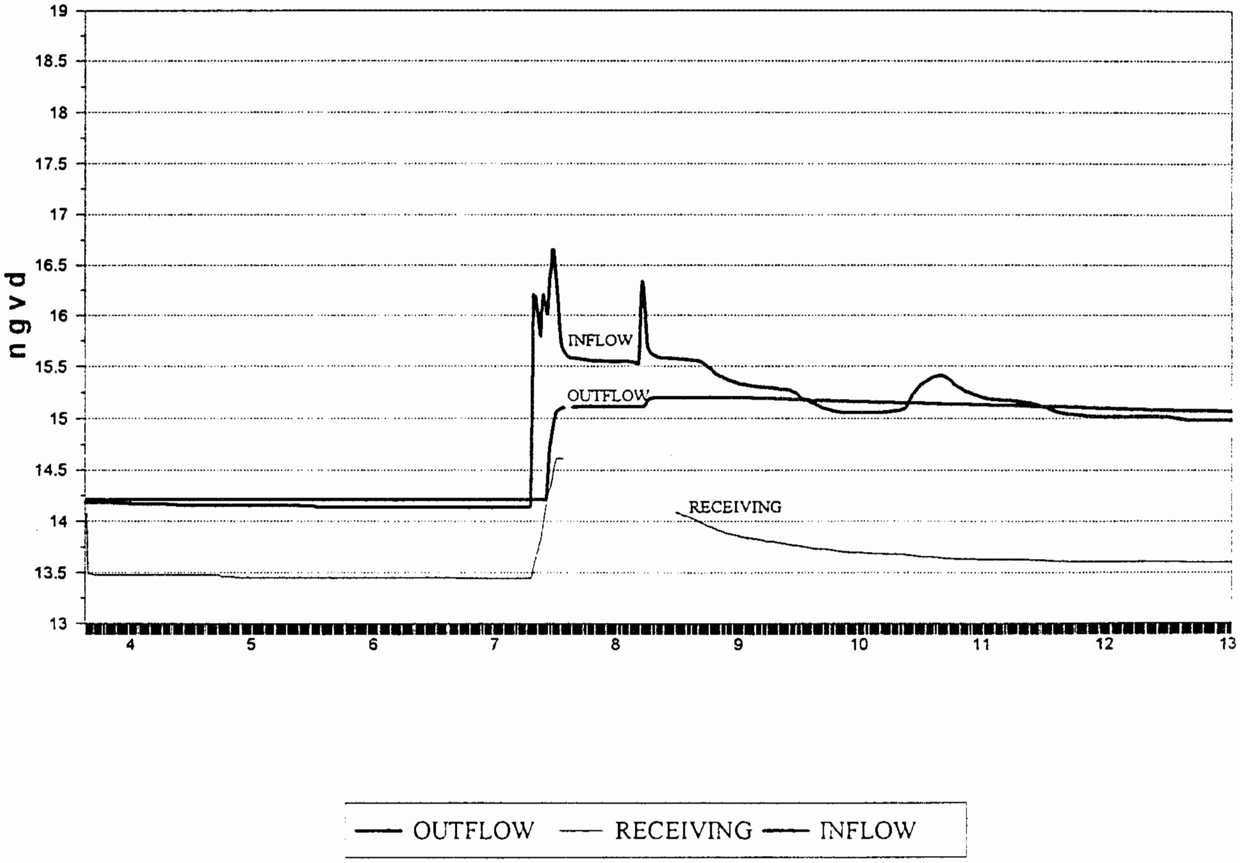
Rainfall and Water Level Comparisons for 1994

June 3 to June 14, 1994

RAINFALL

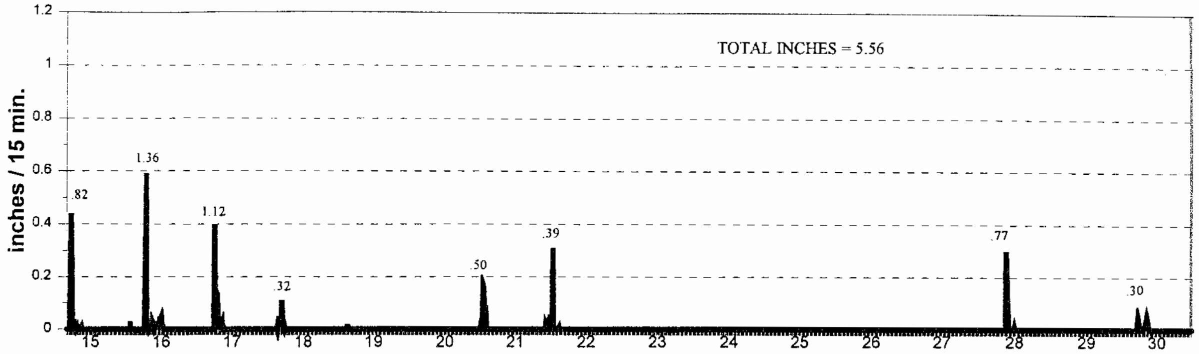


WATER LEVEL COMPARISONS

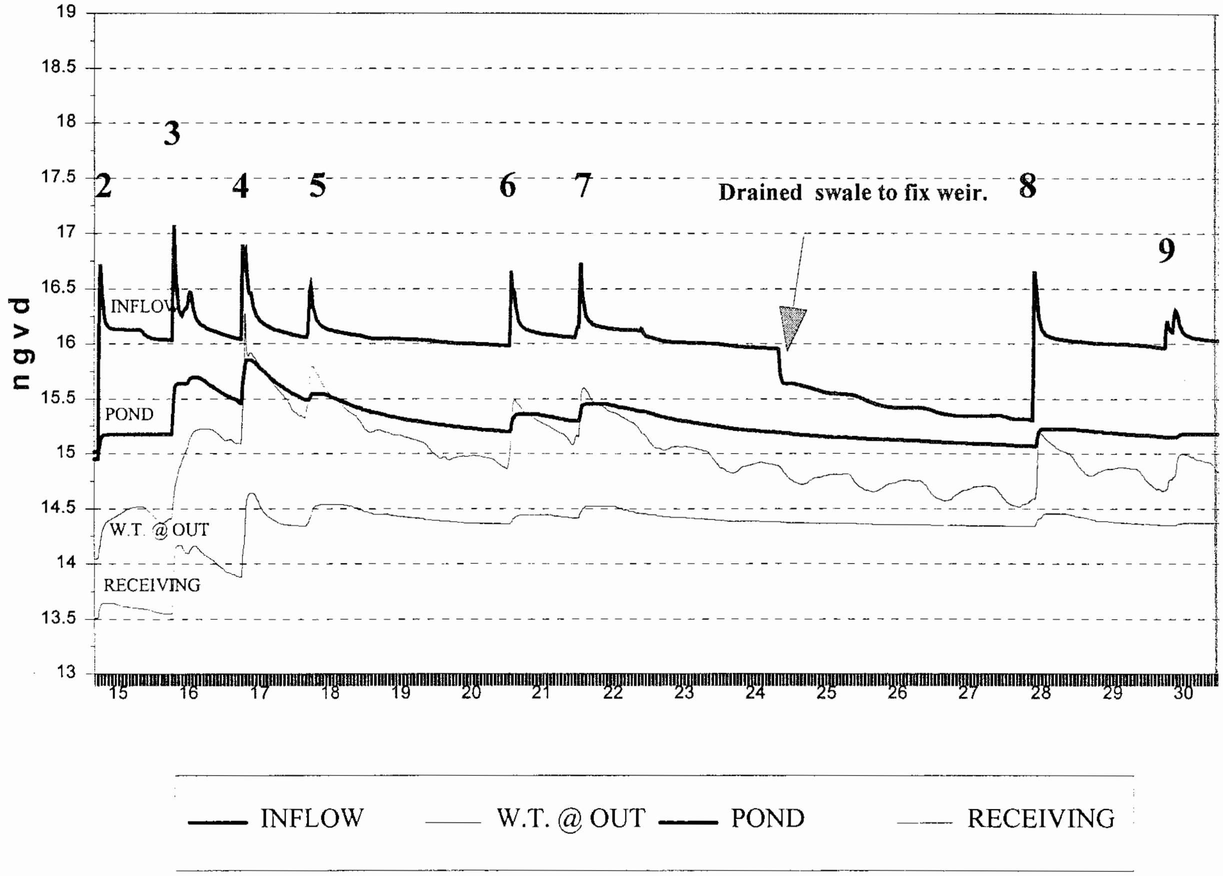


June 14 to June 30, 1994

RAINFALL

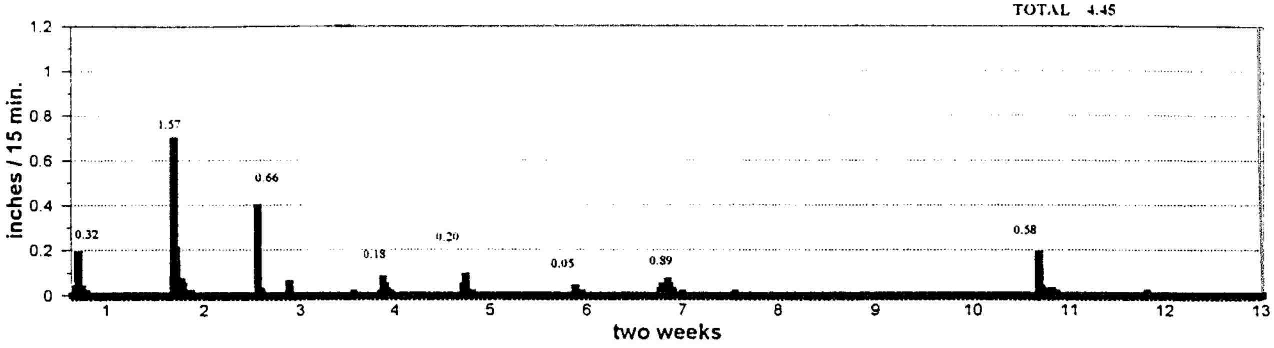


WATER LEVEL COMPARISONS

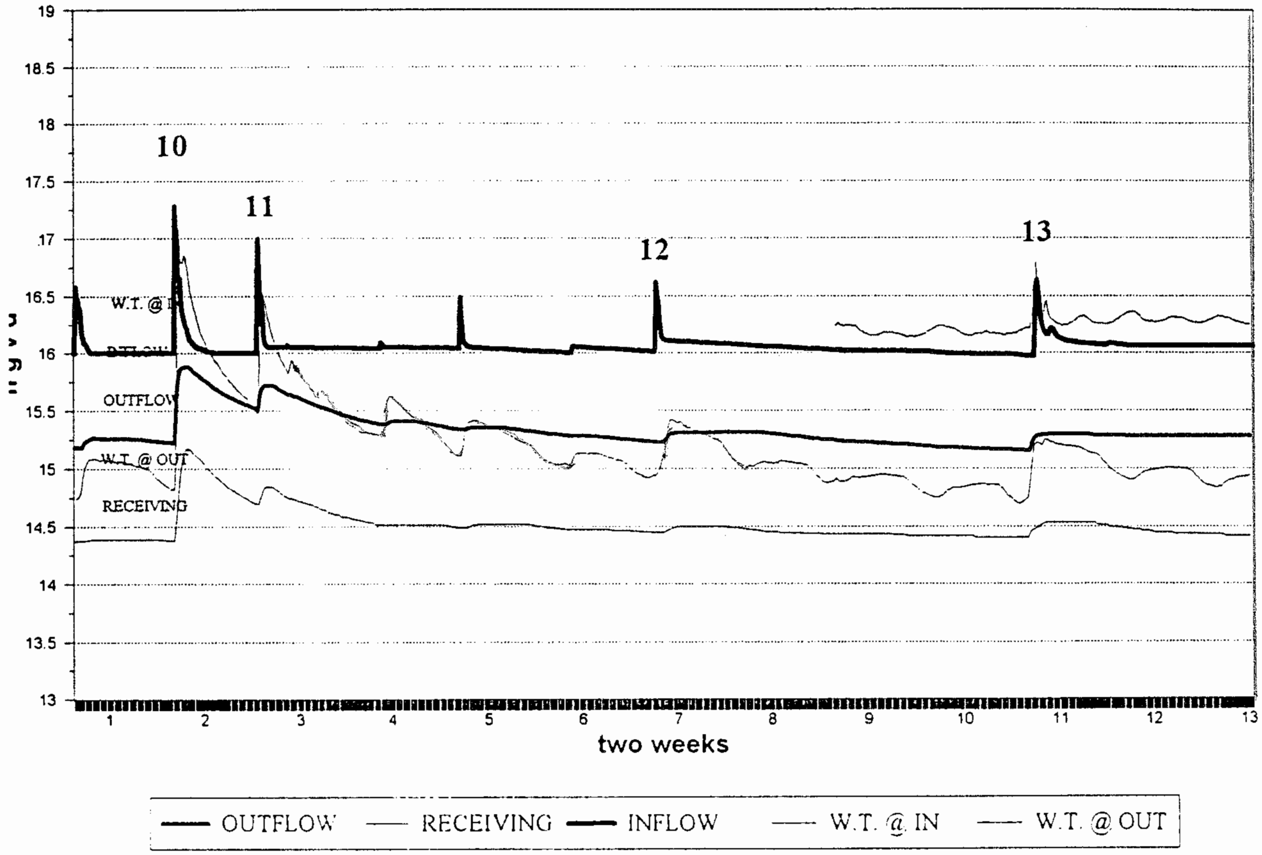


July 1 to July 13, 1994

RAINFALL

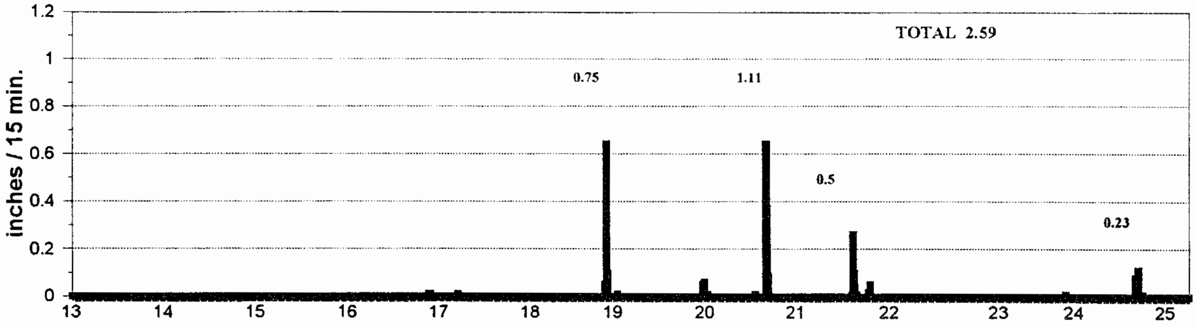


WATER LEVEL COMPARISONS

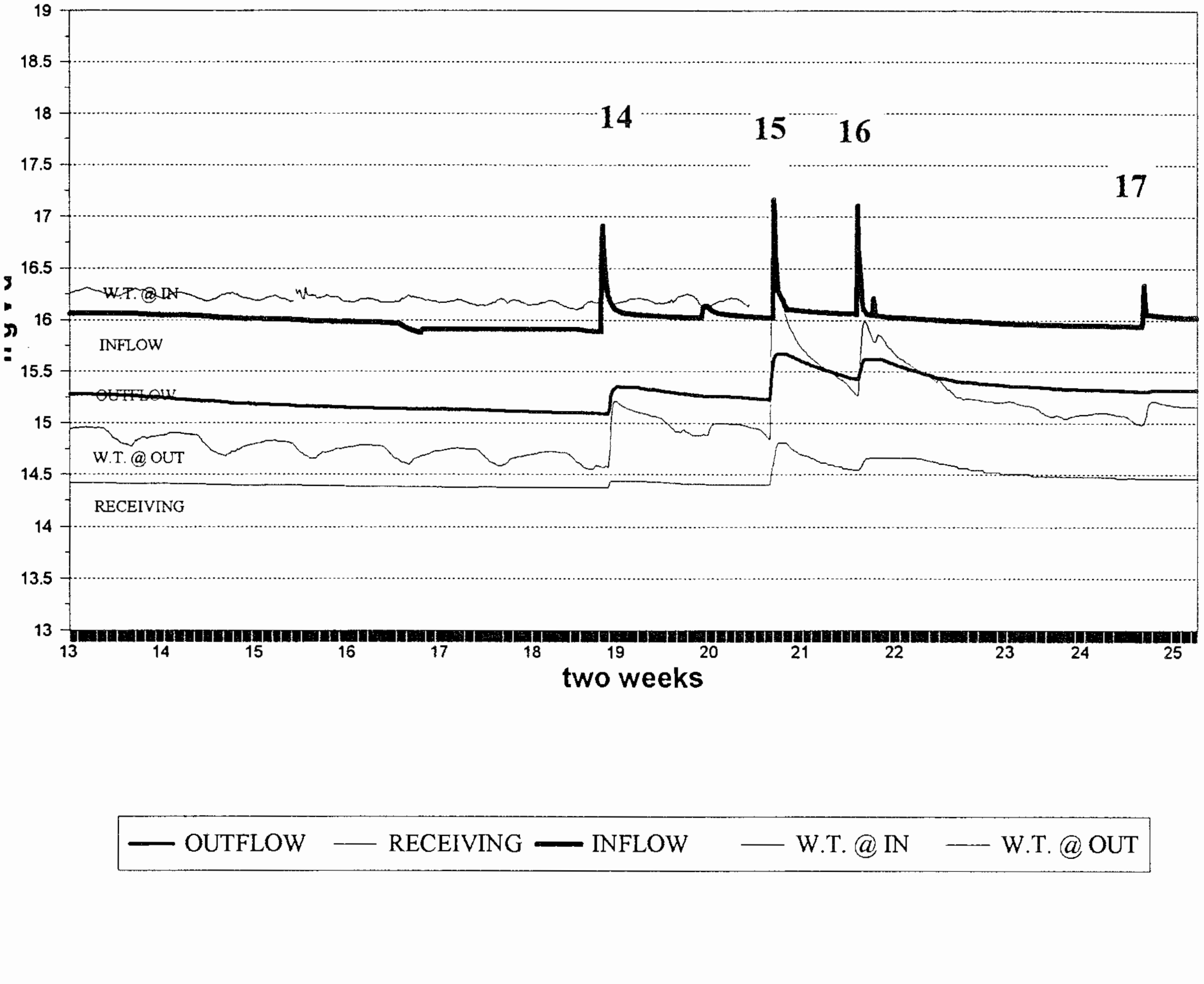


July 13 to July 25, 1994

RAINFALL

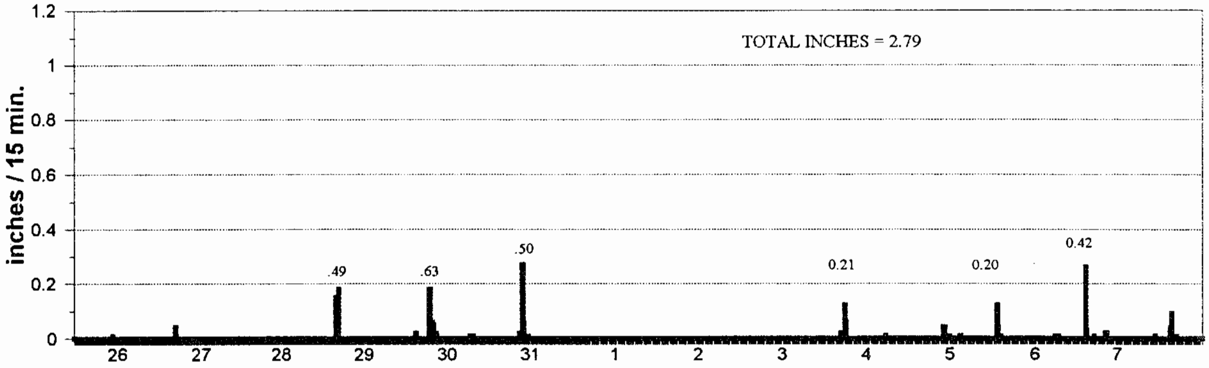


WATER LEVEL COMPARISONS

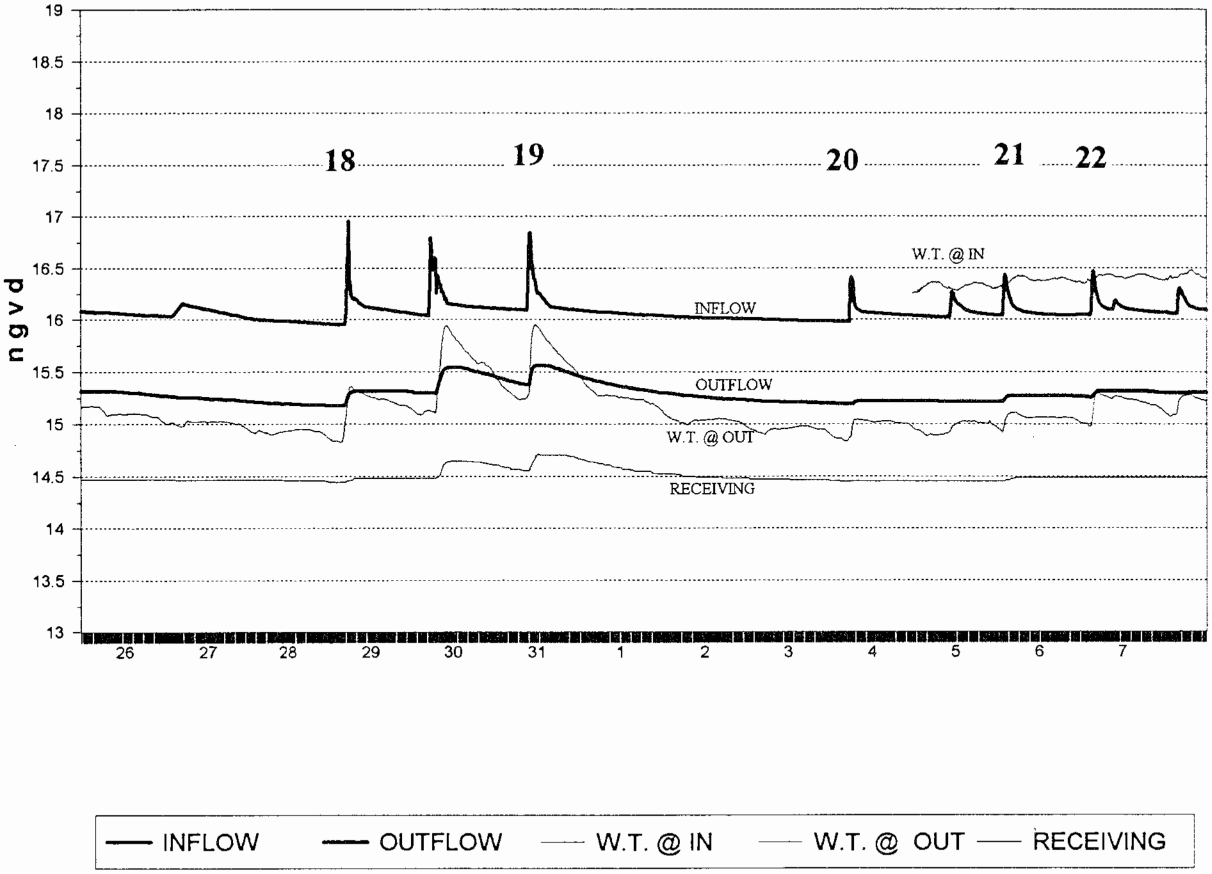


July 25 to August 7, 1994

RAINFALL

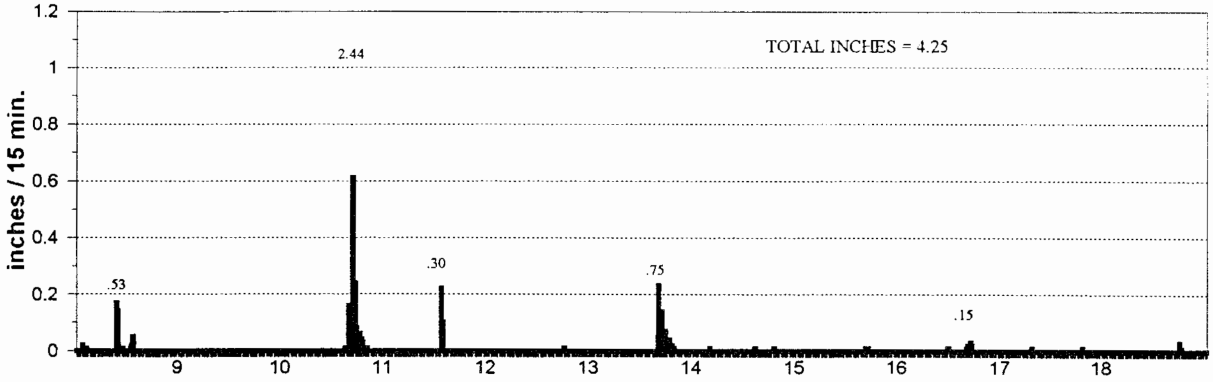


WATER LEVEL COMPARISONS

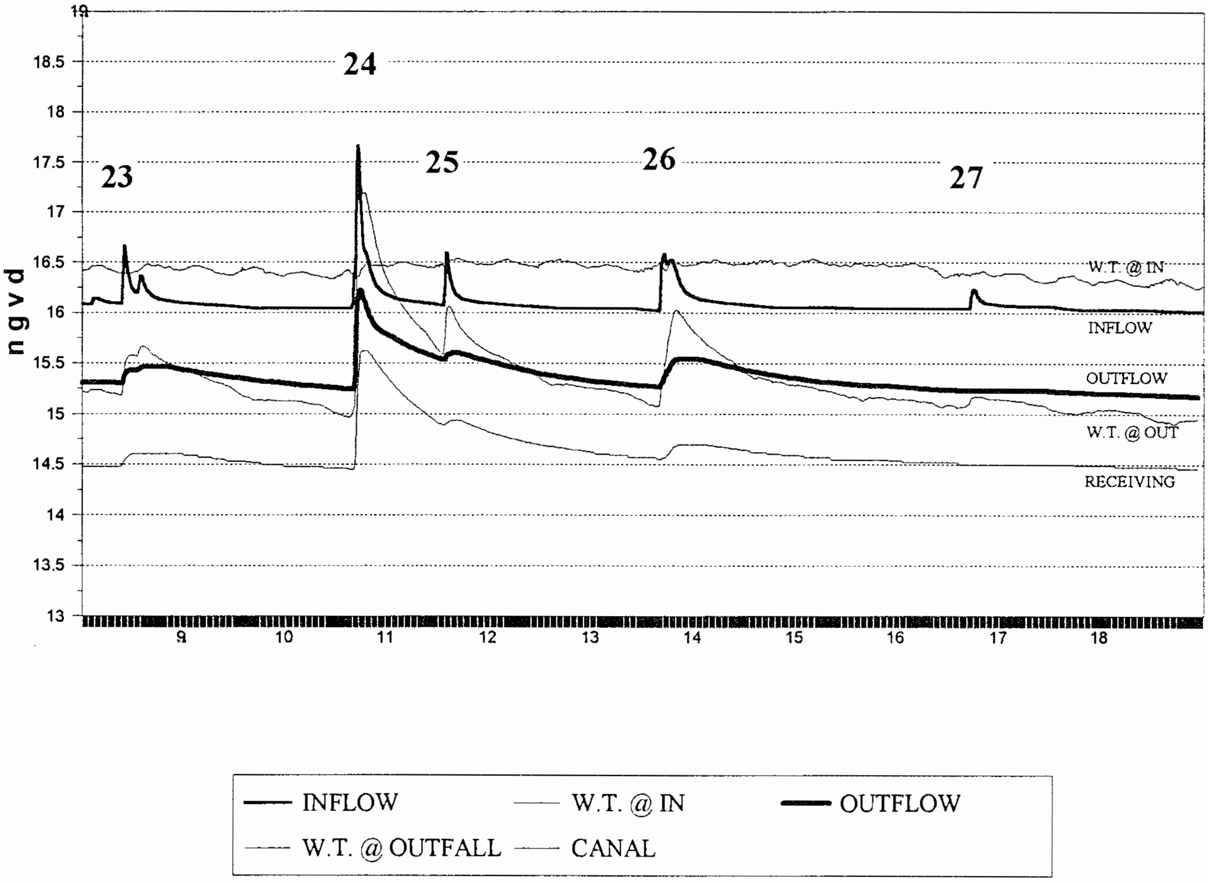


August 8 to August 18, 1994

RAINFALL

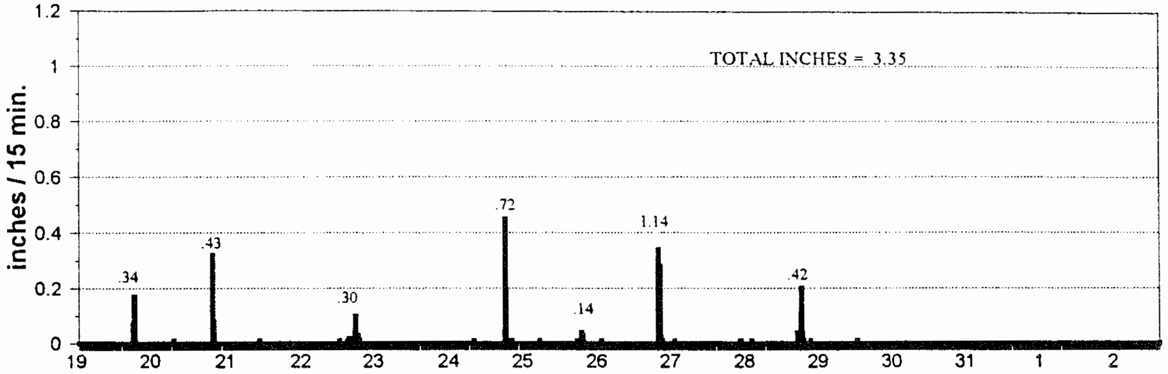


WATER LEVEL COMPARISONS

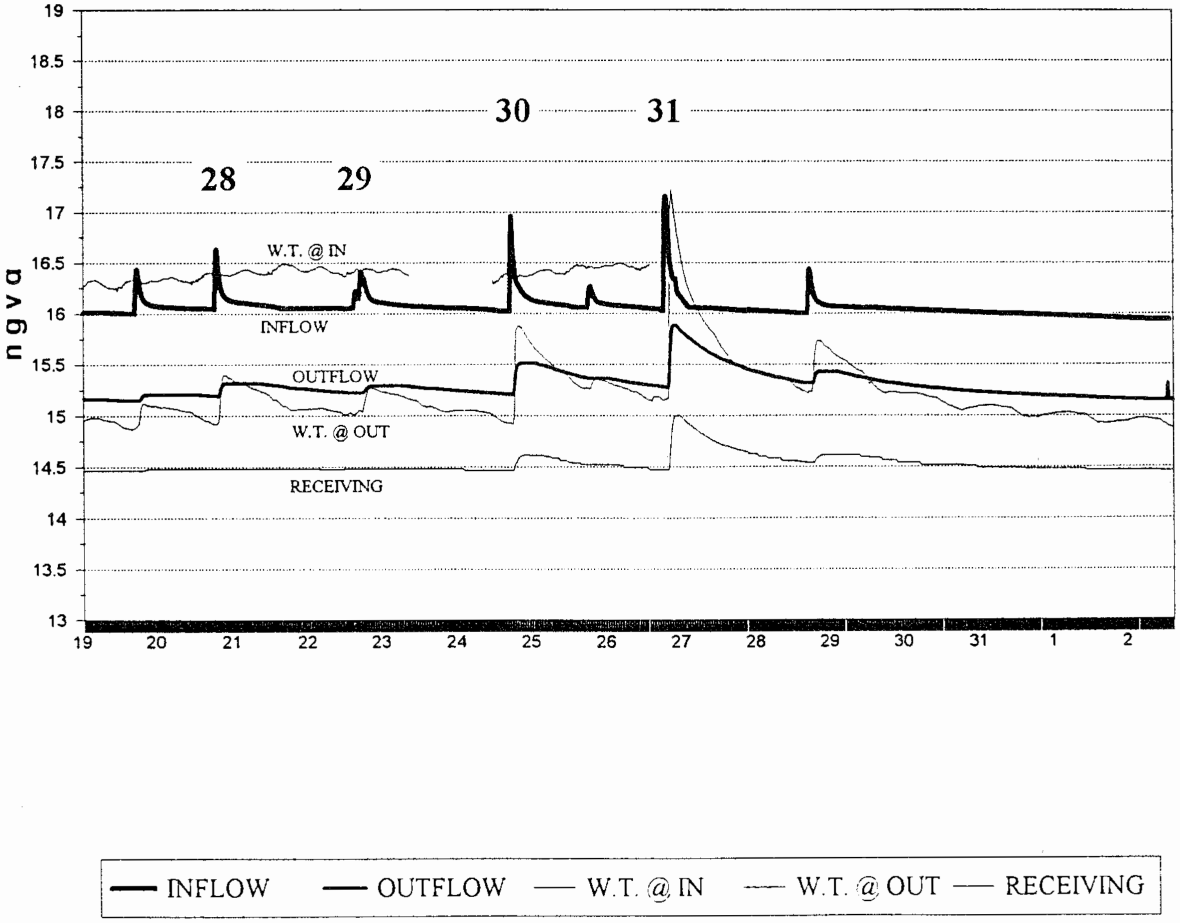


August 19 to September 2, 1994

RAINFALL

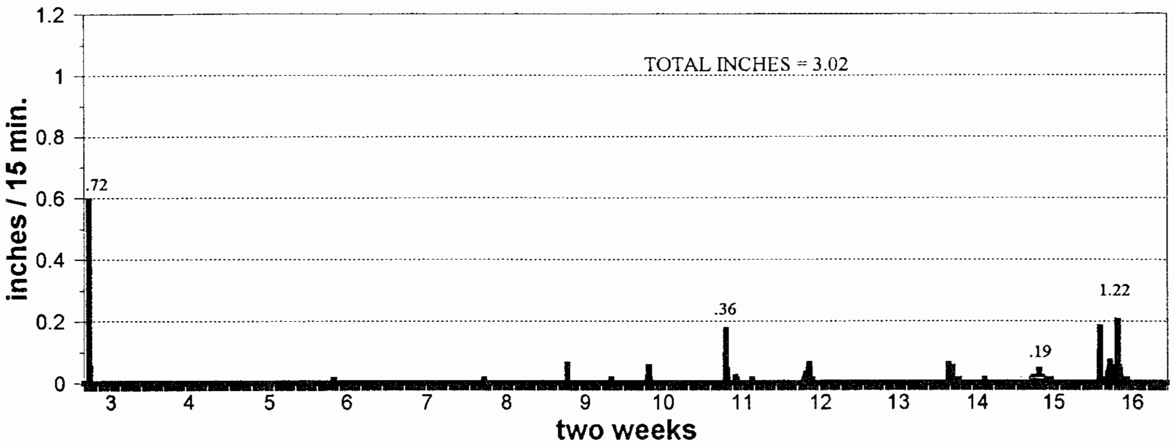


WATER LEVEL COMPARISONS

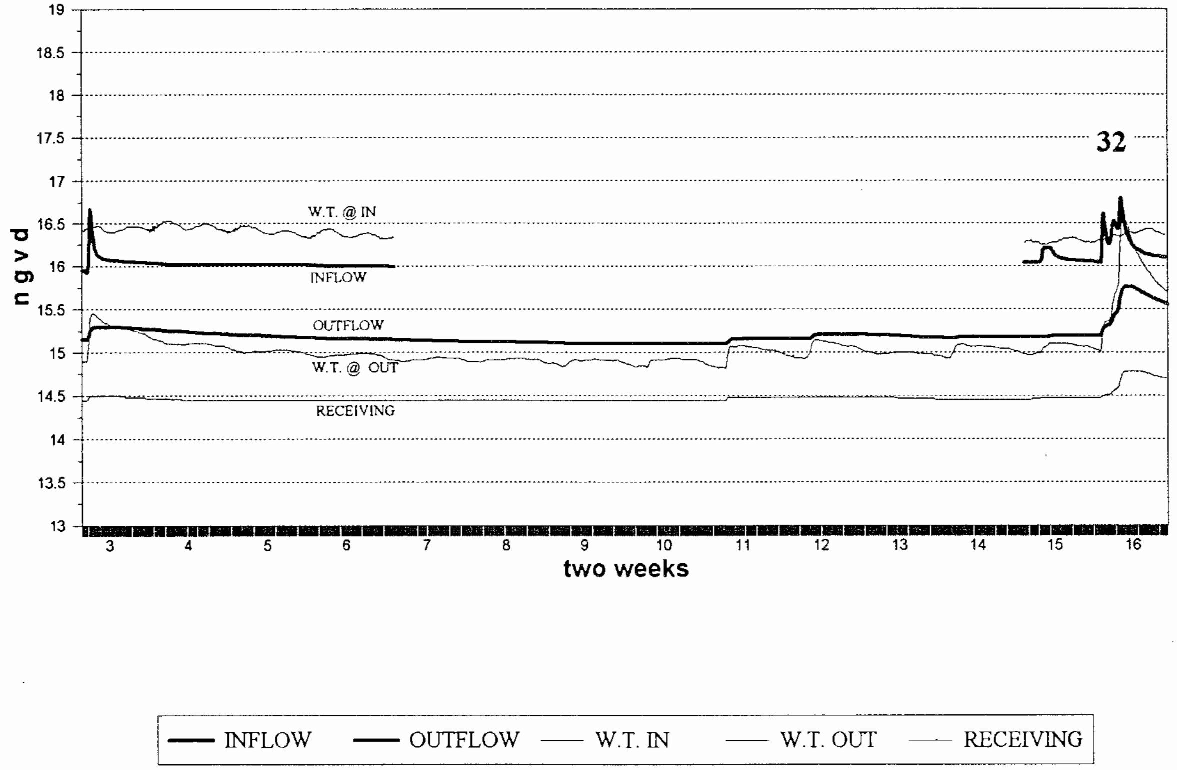


September 2 to September 16, 1994

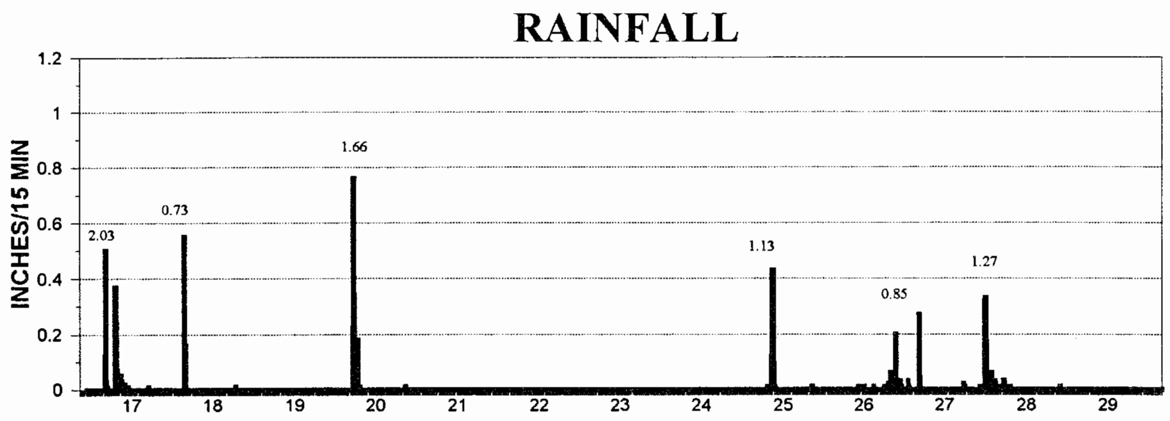
RAINFALL



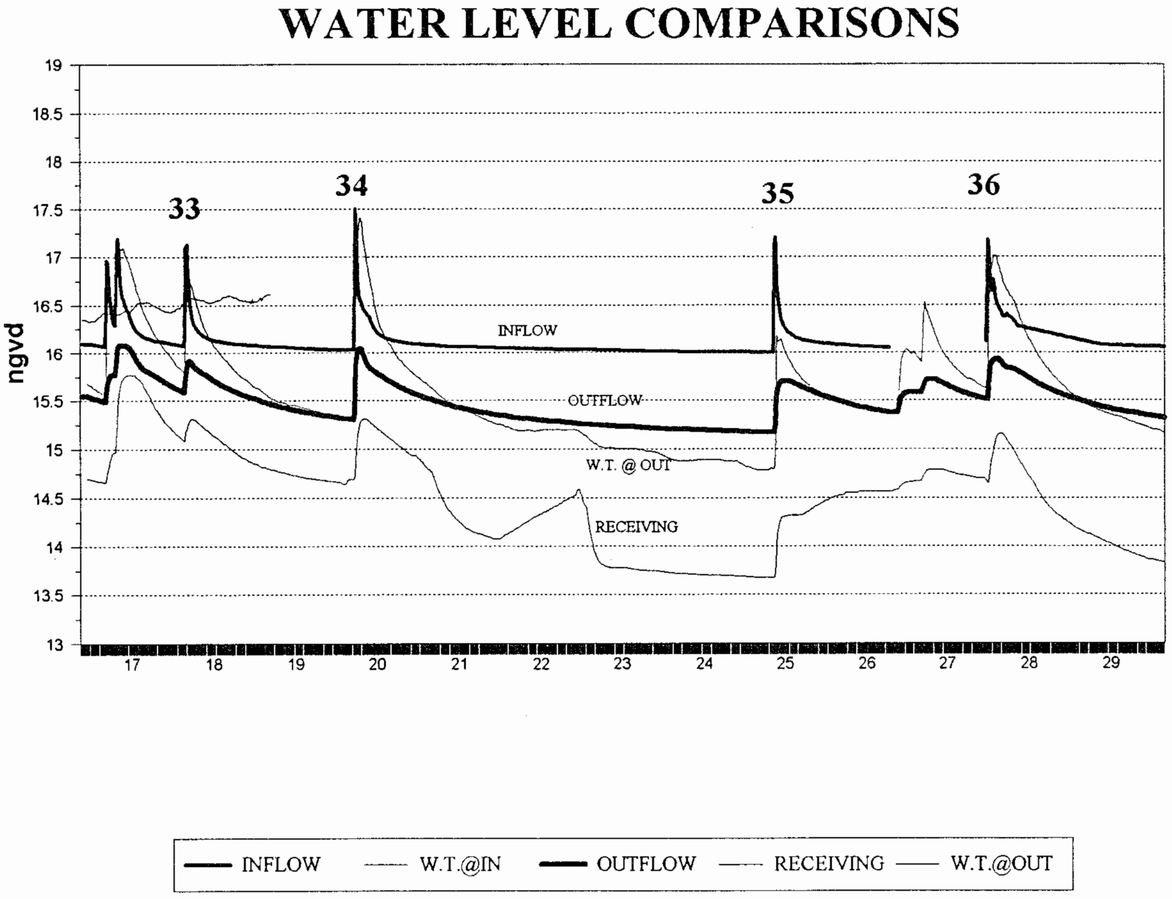
WATER LEVEL COMPARISONS



September 16 to 29, 1994



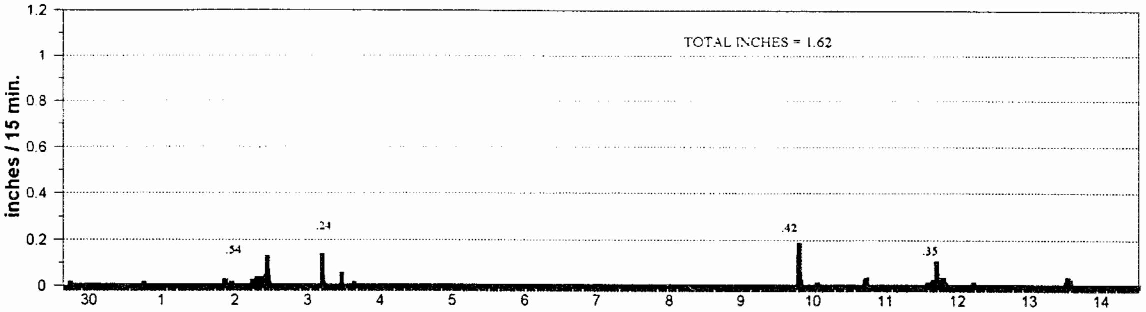
RAINFALL



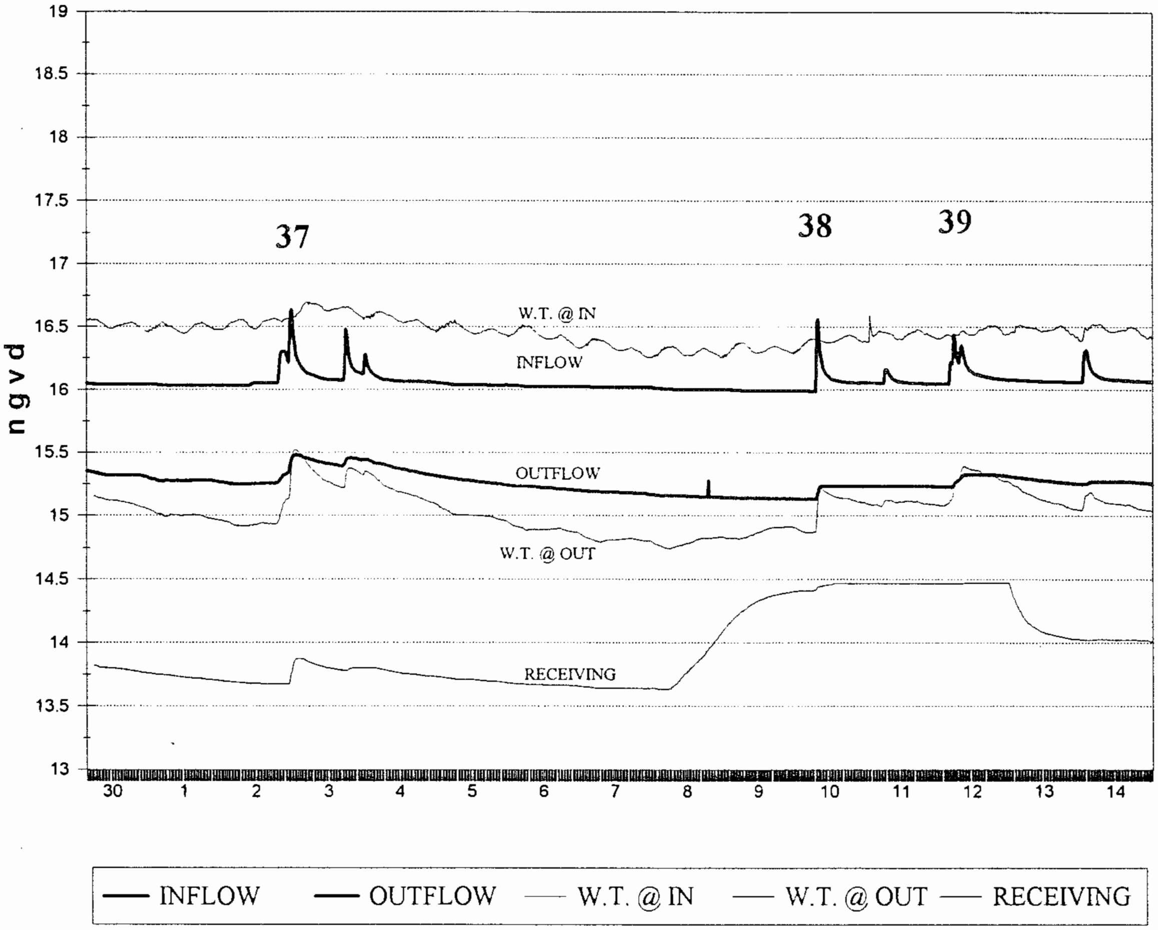
WATER LEVEL COMPARISONS

September 29 to October 14, 1994

RAINFALL

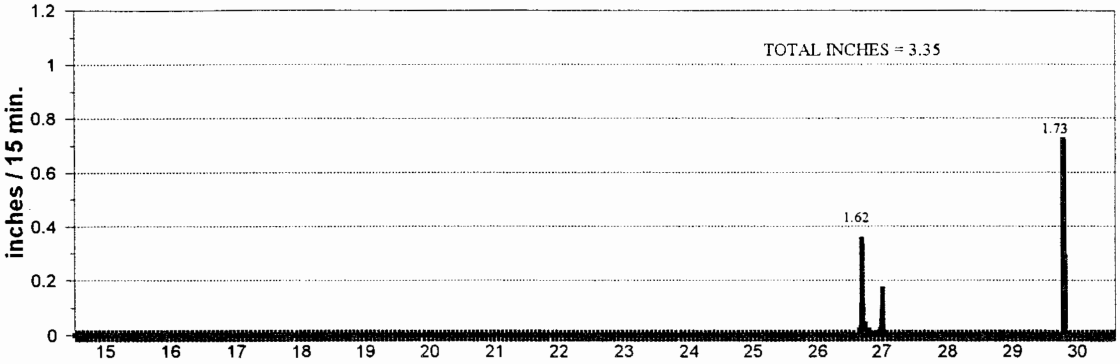


WATER LEVEL COMPARISONS

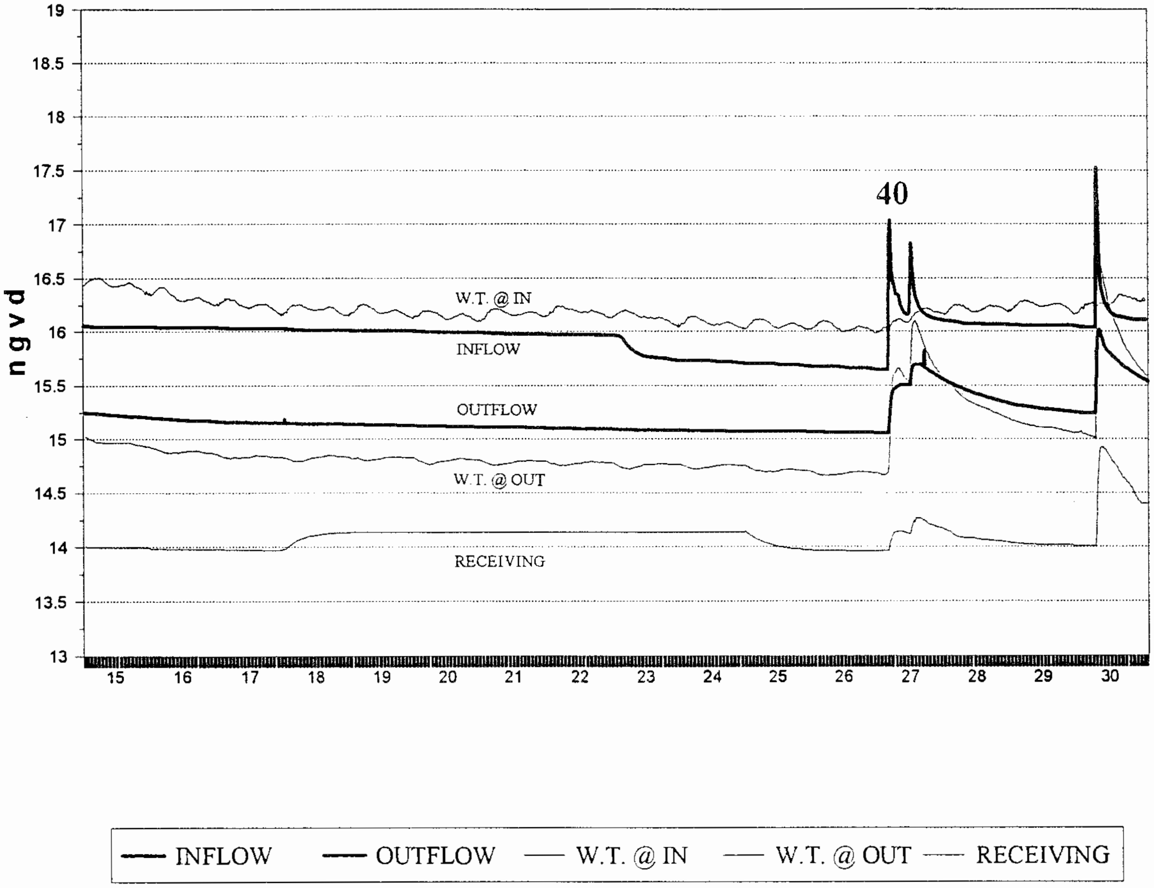


October 14 to October 30, 1994

RAINFALL

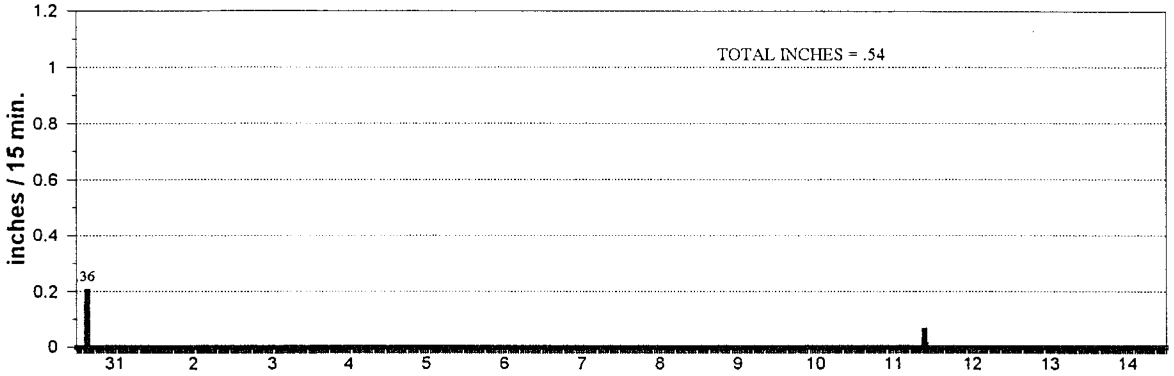


WATER LEVEL COMPARISONS

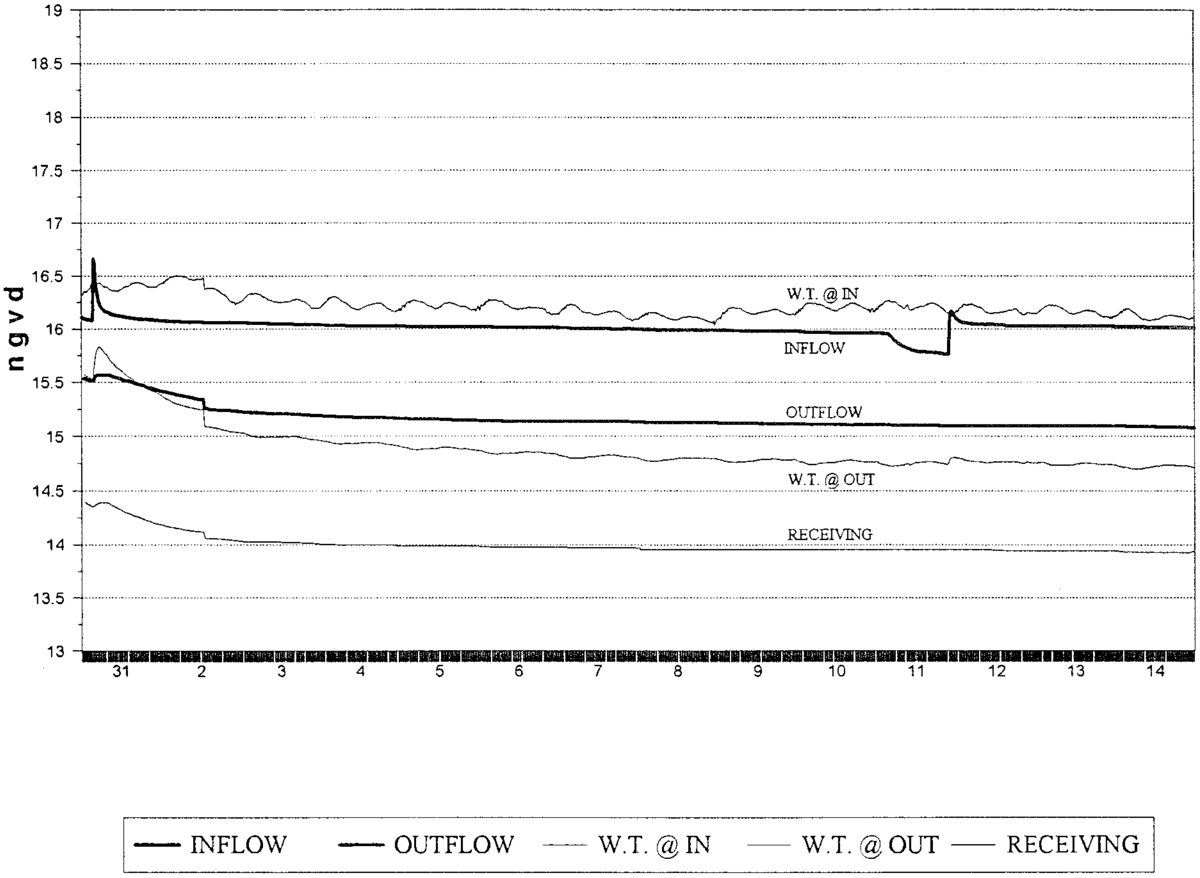


October 30 to November 14, 1994

RAINFALL

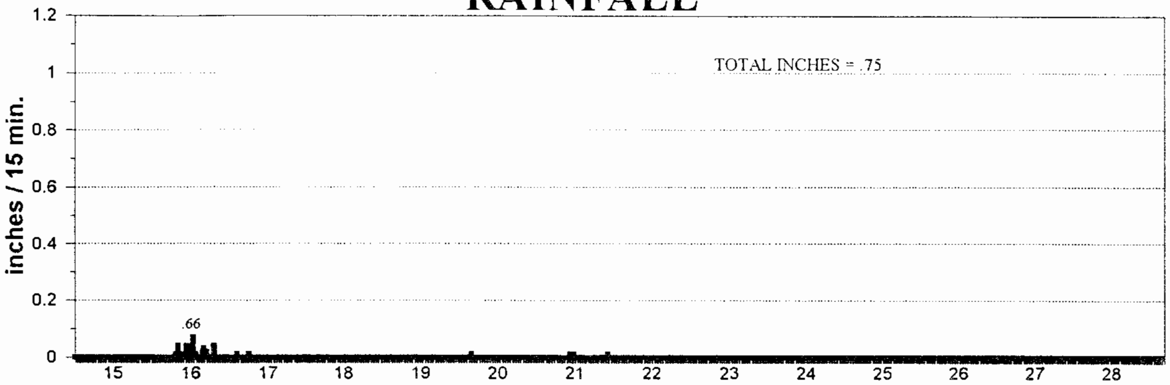


WATER LEVEL COMPARISONS

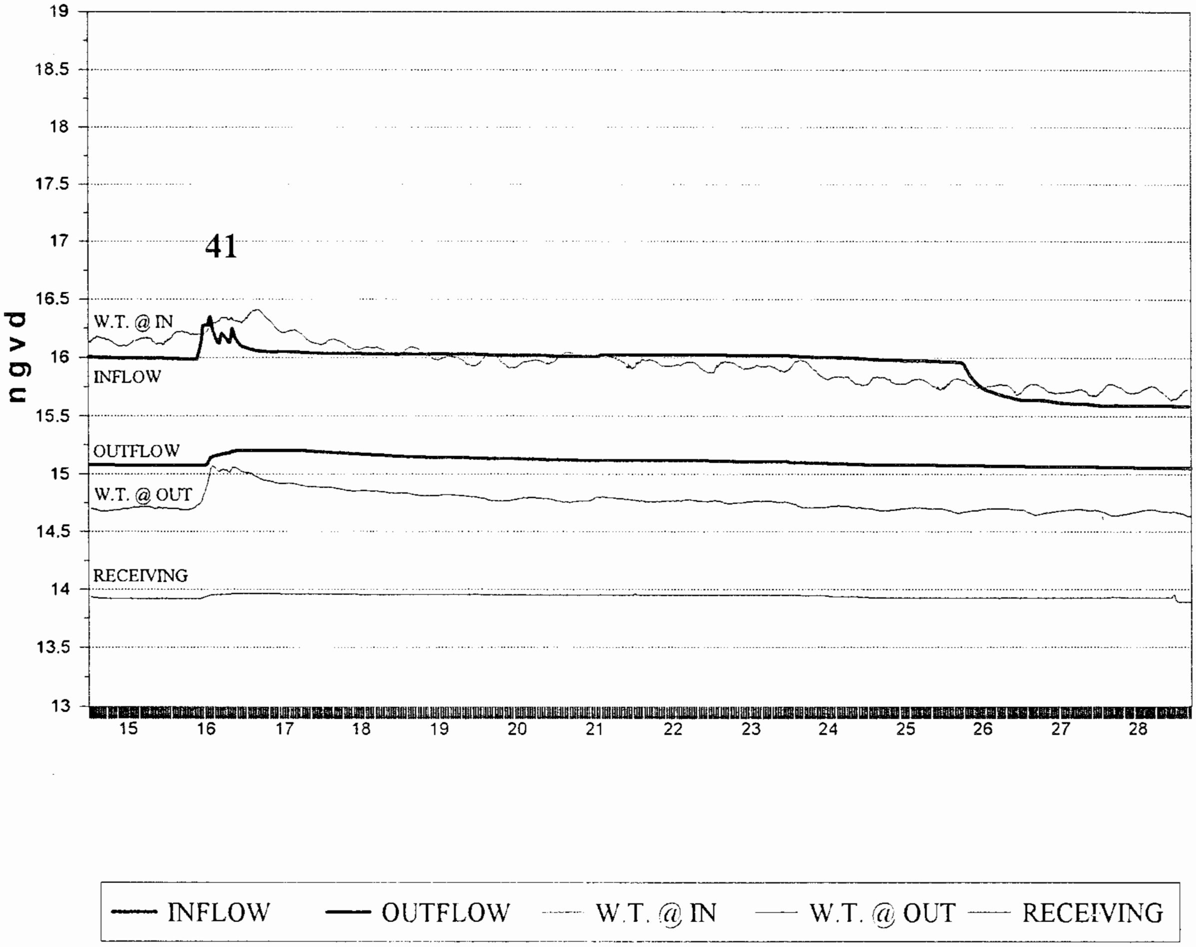


November 14 to November 30, 1994

RAINFALL

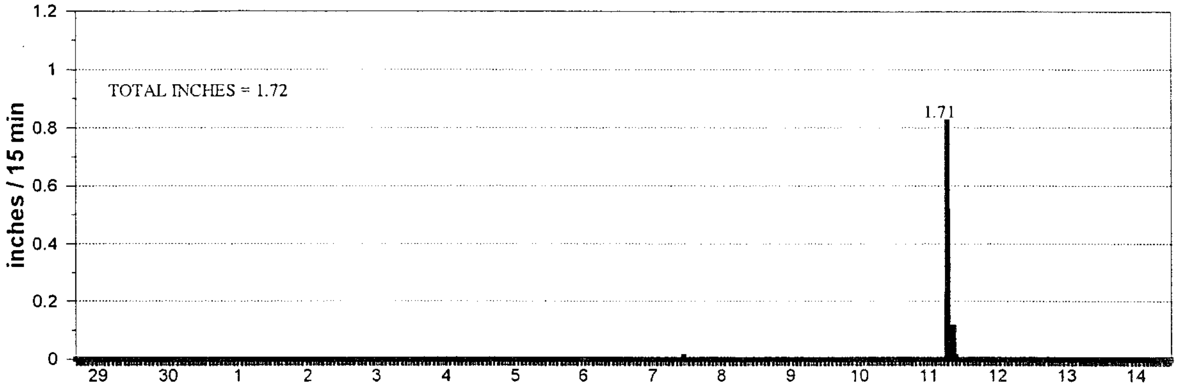


WATER LEVEL COMPARISONS

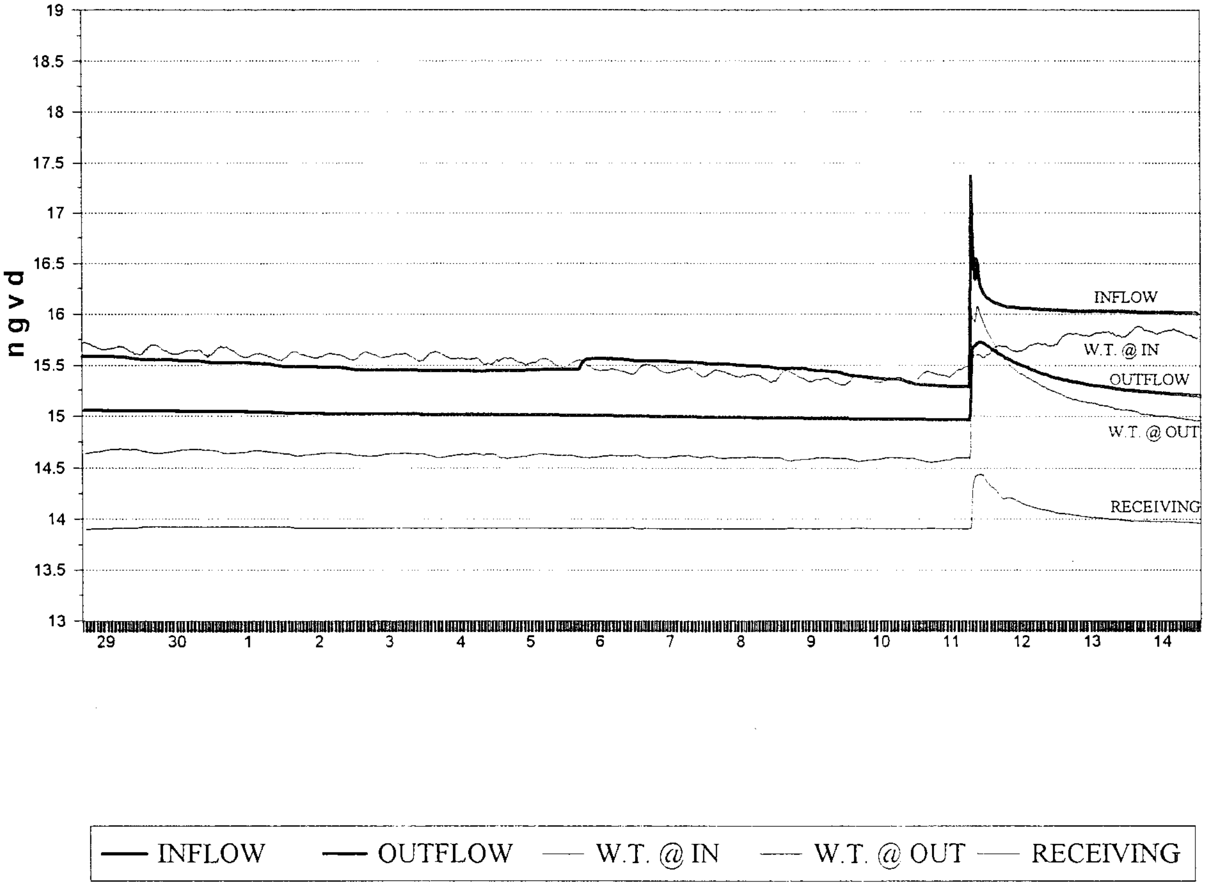


November 28 to December 14, 1994

RAINFALL

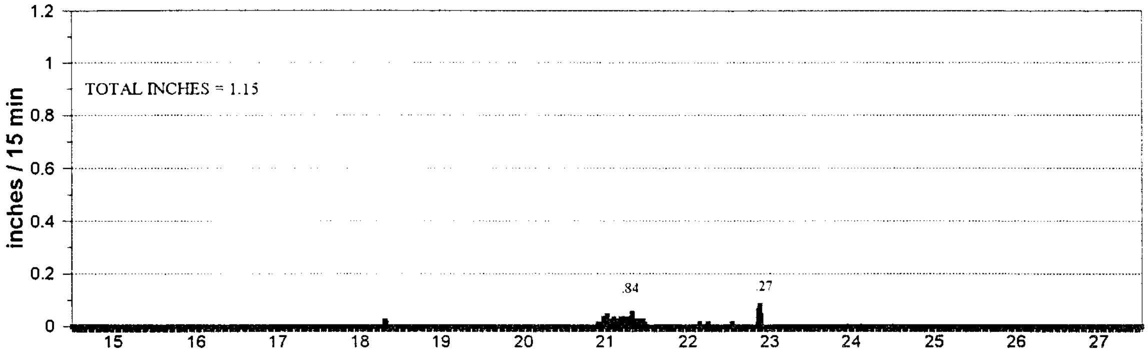


WATER LEVEL COMPARISONS

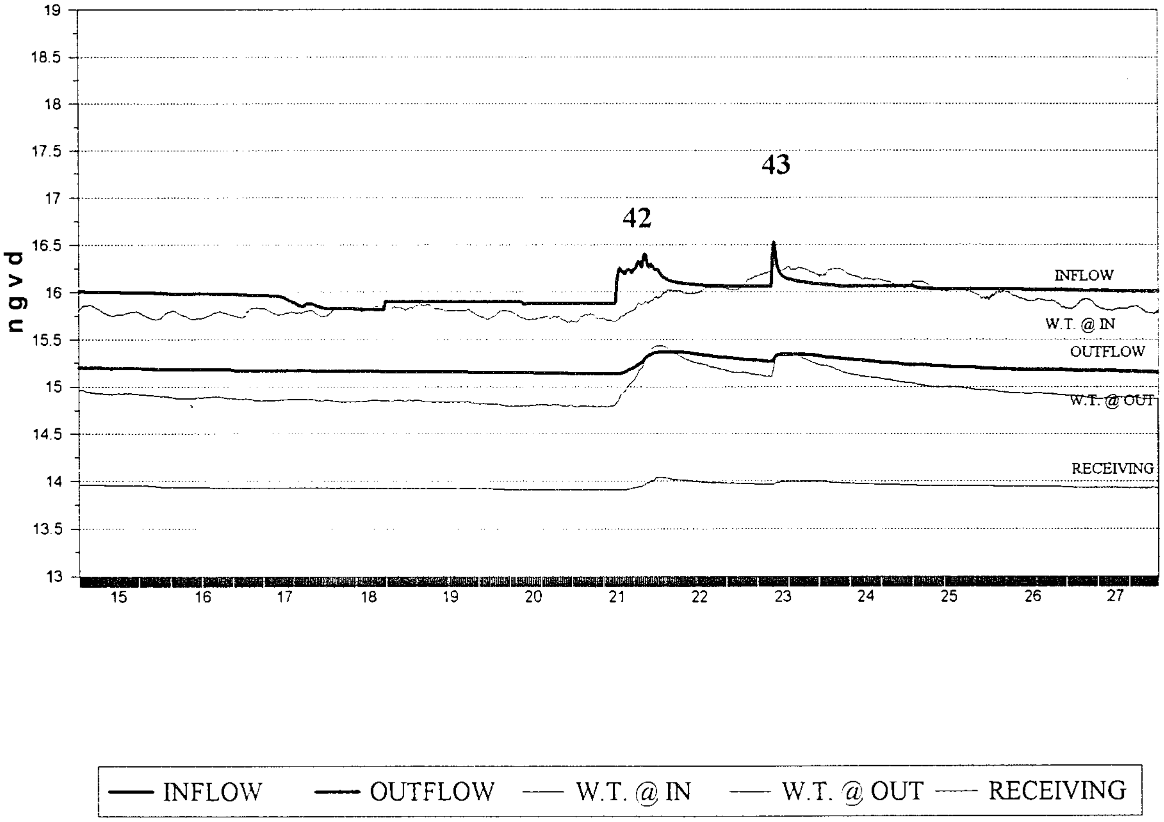


DECEMBER 14 TO 27, 1994

RAINFALL

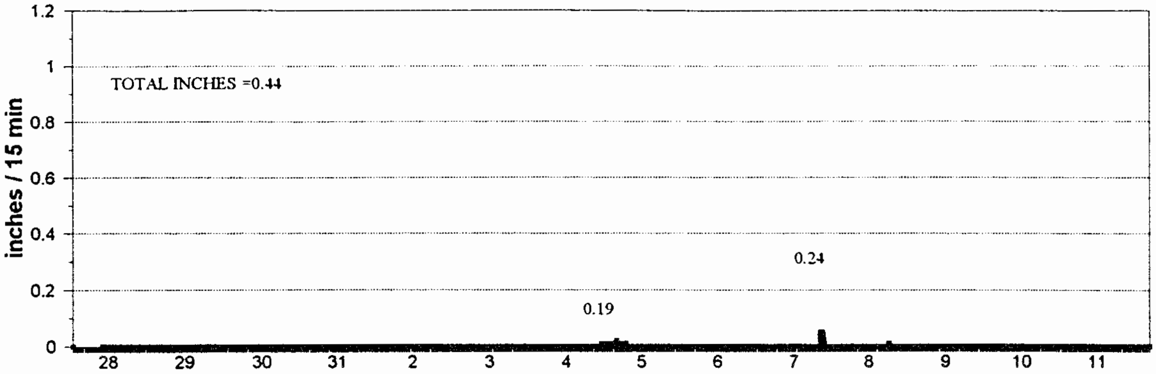


WATER LEVEL COMPARISONS

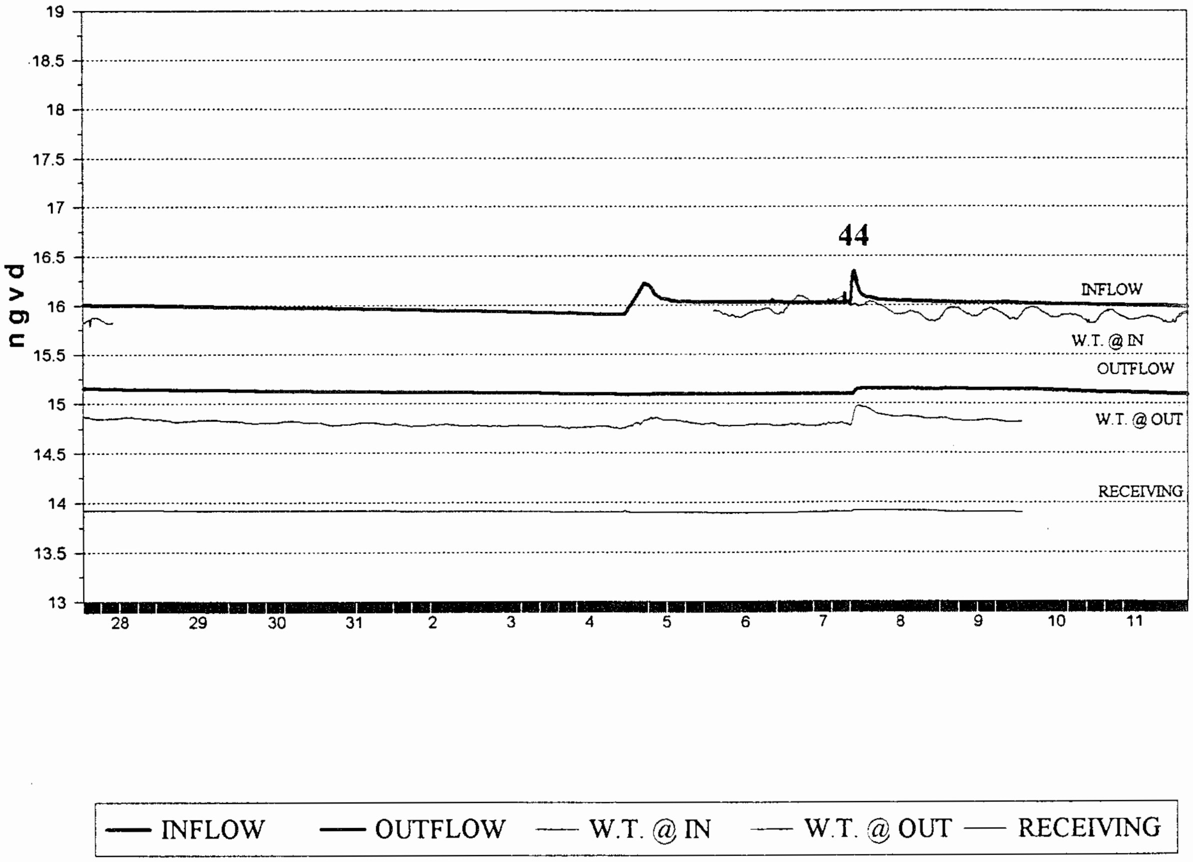


DECEMBER 27 TO JANUARY 11, 1995

RAINFALL

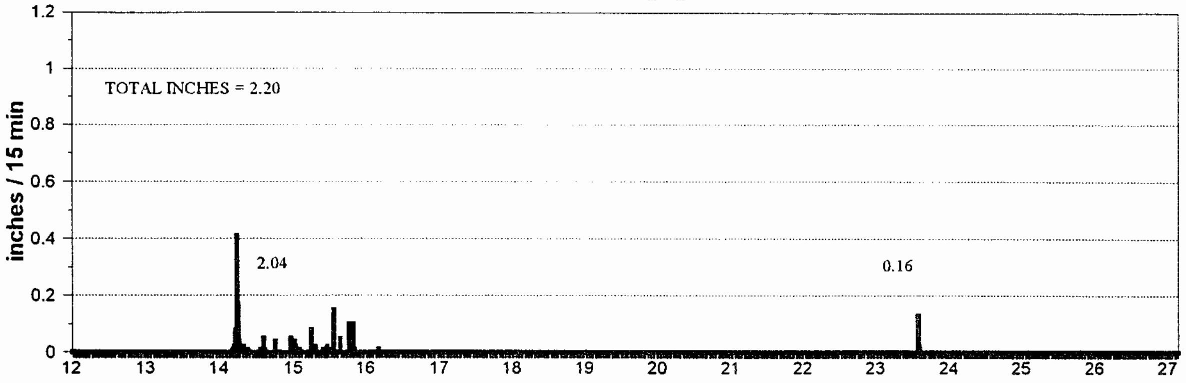


WATER LEVEL COMPARISONS

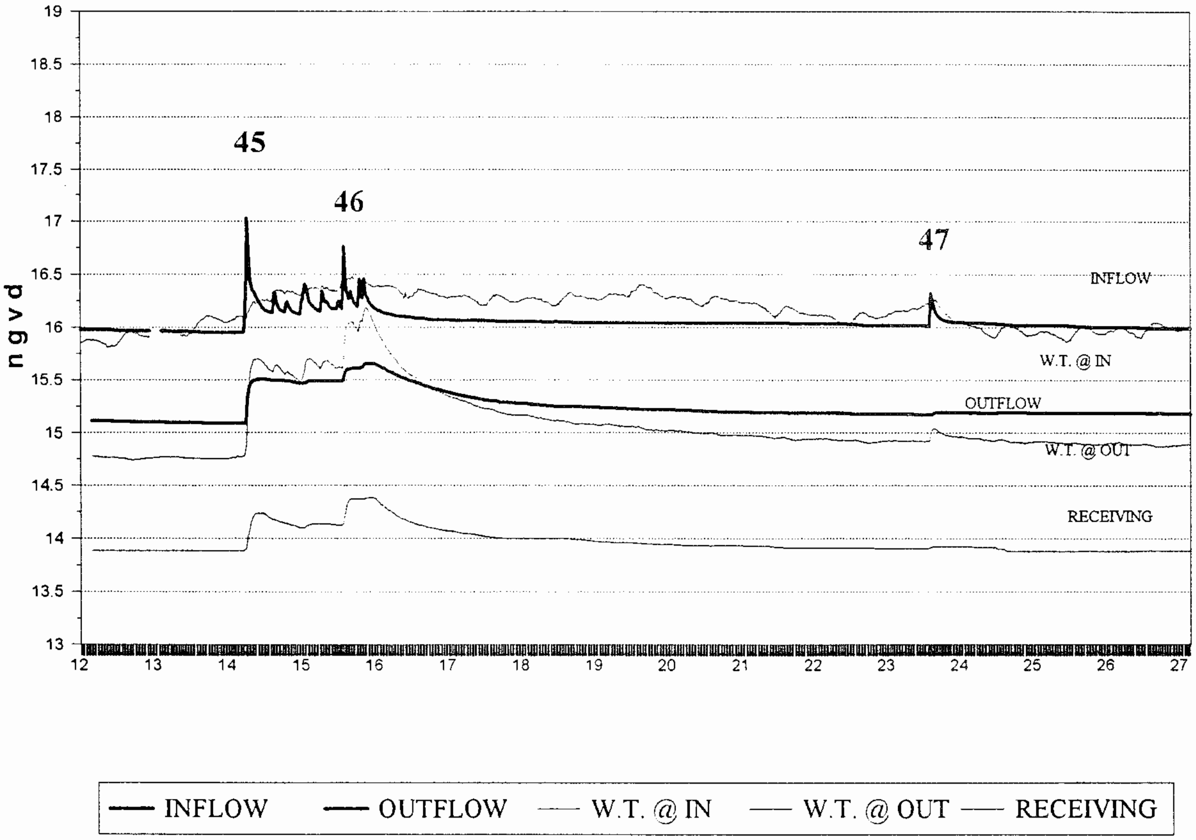


January 12 to January 27, 1995

RAINFALL



WATER LEVEL COMPARISONS



APPENDIX G

Rainfall Characteristics and Runoff Coefficient

Table G-1. Summary table for rainfall characteristics

	INTER-EVENT PERIOD days	RAIN inches	AVERAGE INTENSITY in/hr	MAXIMUM INTENSITY in/hr	DURATION hours	RUNOFF COEFF.
1990 (June 1990 through January 1991)						
# Obs.	53	53	52	52	52	52
Average	4.40	0.53	0.26	0.85	2.67	0.19
Std. Dev.	5.27	0.53	0.22	0.71	2.62	0.22
Maximum	25.77	2.34	0.87	2.72	15.88	0.91
Minimum	0.16	0.05	0.03	0.12	0.38	0.00
Median	2.71	0.35	0.16	0.57	2.06	0.12
CV	1.20	1.00	0.85	0.83	0.98	1.12
Total		28.00				
1993 (June 1993 through January 1994)						
# Obs	59	60	57	57	57	46
Average	3.56	0.57	0.27	0.81	2.61	0.38
Std.Dev.	4.14	0.67	0.23	0.92	2.53	0.24
Maximum	20.45	3.91	0.93	4.16	16.50	0.85
Minimum	0.16	0.05	0.03	0.04	0.25	0.00
Median	1.96	0.27	0.19	0.52	1.75	0.39
CV	1.16	1.18	0.85	1.13	0.97	0.62
Total		34.21				
1994 (June 1994 through January 1995)						
# Obs	83	83	83	83	83	75
Average	2.67	0.53	0.30	0.91	2.72	0.37
Std. Dev.	3.63	0.50	0.35	0.89	2.63	0.18
Maximum	24.89	2.28	2.31	3.88	13.00	0.81
Minimum	0.07	0.05	0.02	0.08	0.07	0.00
Median	1.02	0.36	0.15	0.64	1.75	0.35
CV	1.36	0.94	1.18	0.98	0.97	0.49
Total		44.38				

Table G-2. Hydrologic characteristics of rainfall at a wet-detention pond in Tampa, Fla. during 1990-91.

STORM #	DATE	INTER-EVENT PERIOD days	* INTER-EVENT PERIOD days	RAIN inches	AVERAGE INTENSITY in/hr	MAXIMUM INTENSITY in/hr	DURATION hours	RUNOFF COEFF.	INFLOW VOLUME (CU. FT)
2	5-24-90	14.49	14.49	0.37	0.37	0.78	1.00	0.05	433
	5-27-90	2.71		0.07	0.05	0.16	1.50	0.00	0
	5-27-90	0.24		0.06	0.08	0.14	0.75	0.00	0
	6-01-90	4.92		0.15	0.11	0.16	1.38	0.01	41
	6-02-90	0.96		0.16	0.13	0.26	1.25	0.05	178
3	6-03-90	0.95	9.78	0.69	0.62	1.88	1.13	0.26	4311
	6-06-90	2.91		0.35	0.10	0.62	3.50	0.08	675
4	6-10-90	3.83	6.74	0.46	0.36	0.58	1.25	0.17	1798
	6-20-90	9.67		0.05	0.10	0.12	0.50	0.62	727
	6-21-90	1.07		0.21	0.17	0.42	1.25	0.09	448
5	6-22-90	1.38	12.12	1.05	0.70	1.98	1.50	0.29	7112
6	6-23-90	0.53	0.53	0.83	0.16	1.32	5.38	0.25	4933
7	7-07-90	14.05	14.05	0.86	0.57	1.88	1.50	0.21	4256
8	7-10-90	2.97	2.97	1.10	0.59	1.96	2.00	0.28	7142
9a	7-11-90	0.85	0.85	1.04	0.69	1.42	1.50	0.40	9769
9b	7-11-90	0.22	0.22	0.08	0.25	0.28	0.38	0.51	958
10	7-12-90	0.81	0.81	0.48	0.14	0.94	3.38	0.27	2980
11	7-13-90	0.47	0.47	0.57	0.38	2.64	4.75	0.38	5109
	7-14-90	0.71		1.70	0.31	1.64	3.00	0.91	35449
	7-15-90	1.15		1.78	0.39	2.00	3.50	0.88	35817
12	7-18-90	3.95	5.81	0.29	0.20	0.92	1.50	0.24	1629
13	7-31-90	12.74	12.74	0.40	0.11	0.56	3.75	0.12	1167
	8-09-90	8.99		0.44	0.74	1.30	0.63	0.06	622
	8-13-90	4.08		0.36	0.36	0.30	3.00	0.02	185
14	8-14-90	0.65	13.72	0.32	0.63	1.22	0.50	0.22	1604
15	8-18-90	3.98	3.98	0.40	0.54	1.02	0.75	0.16	1490
	8-20-90	2.21		0.12	0.14	0.23	0.88	0.00	0
	8-22-90	2.16		0.05	0.15	0.18	0.38	0.00	0
	8-23-90	0.63		0.15	0.08	0.20	2.13	0.01	29
	8-24-90	0.89		0.12	0.06	0.24	2.13	0.00	0
16	8-25-90	1.07	6.96	0.62	0.25	0.82	2.50	0.21	3005
17a	8-28-90	2.94	2.94	0.84	0.30	2.28	2.88	0.26	5068
17b	8-28-90	0.16	0.16	0.14	0.28	0.44	0.50	0.22	727
	8-30-90	1.69		0.08	0.16	0.20	0.50	0.00	0
18	8-31-90	1.00	2.69	1.06	•	•	•	•	8441
19	9-17-90	16.83	16.83	1.90	0.58	2.72	3.25	0.31	13403
	9-28-90	11.02		0.26	0.03	0.48	8.50	0.00	•
	9-29-90	0.67		0.26	0.09	0.48	3.00	0.07	419
20	9-30-90	1.92	13.61	0.65	0.87	1.44	0.75	0.36	5312
21	10-3-90	2.97	2.97	0.45	0.60	1.08	0.75	0.17	1854
22a	10-10-90	6.26	6.26	1.40	0.22	1.40	6.50	0.42	13570
22b	10-11-90	1.23	1.23	1.24	0.28	1.08	4.50	0.66	18680
	11-6-90	25.77		0.10	0.06	0.16	1.88	0.00	0
	11-9-90	3.21		0.39	0.05	0.30	7.88	0.05	484
	11-23-90	14.03		0.27	0.10	0.28	2.75	0.01	36
	11-24-90	0.39		0.06	0.11	0.20	0.50	0.02	29
	11-28-90	4.34		0.22	0.06	0.38	3.63	0.11	587
	1-12-90	13.09		0.31	0.11	0.84	3.13	0.06	416
23	1-15-90	3.24	64.07	2.34	0.15	1.24	15.88	0.38	20352
	1-19-90	3.91		0.20	0.08	0.38	2.38	0.08	376
	1-25-90	6.92		0.18	0.04	0.14	4.63	0.01	56
	1-28-90	2.25		0.19	0.04	0.34	4.63	0.06	277
	1-31-90	2.96		0.17	0.09	0.24	2.13	0.06	242

* Storms that produced flow over the inflow weir.

Table G-3. Hydrologic characteristics at a wet detention pond in Tampa, Florida during 1993-1994

STORM #	DATE	INTER-EVENT PERIOD days	INTER-EVENT * days	RAIN inches	AVERAGE INTENSITY in/hr	MAXIMUM INTENSITY in/hr	STORM DURATION hours	RUNOFF COEFFIC
	6-20-93	•		1.13	0.41	1.04	2.75	0.165
	6-21-93	0.80		0.69	0.55	1.20	1.25	0.324
	6-23-93	2.89		0.33	0.19	0.64	1.50	0.118
1	6-24-93	0.74	4.43	0.93	0.24	1.50	4.00	0.386
	6-25-93	0.92		0.15	0.09	0.32	1.25	0.846
	6-28-93	2.49		0.18	0.36	0.60	0.50	0.455
2	6-30-93	2.06	5.47	0.93	0.23	0.96	4.00	0.466
	7-05-93	4.20		0.05	0.05	0.08	1.00	•
	7-08-93	2.82		0.17	0.11	0.56	1.50	•
	7-10-93	2.02		0.12	0.03	0.12	3.75	•
3	7-12-93	1.69	10.73	1.09	0.34	0.96	3.25	0.308
	7-13-93	0.93		0.12	0.24	0.44	0.50	0.252
	7-15-93	1.89		0.89	0.71	1.86	1.25	0.450
4	7-21-93	5.63	8.45	0.36	0.23	0.66	3.00	0.168
	7-24-93	3.26		0.25	0.17	0.40	3.00	0.000
	7-27-93	2.96		0.10	0.20	0.36	0.50	0.000
5	8-13-93	16.92	23.14	0.37	0.74	1.04	0.50	0.001
6	8-14-93	0.85	0.85	0.43	0.74	0.68	2.00	0.021
	8-15-93	0.73		0.43	0.13	0.26	3.25	0.035
	8-16-93	1.17		0.10	0.19	0.28	0.50	0.016
7	8-25-93	8.90	10.80	2.16	0.93	3.90	2.00	0.384
8	8-26-93	0.97	0.97	3.91	0.67	4.16	5.75	0.704
	8-28-93	1.60		0.23	0.17	0.54	1.50	0.024
	8-28-93	0.16		0.08	0.05	0.18	1.75	0.157
9	8-29-93	0.68	2.44	1.79	0.27	1.76	5.00	0.729
	8-30-93	0.66		0.22	0.04	0.18	4.75	0.509
	8-31-93	0.75		0.27	0.18	0.64	1.25	0.523
	9-01-93	1.15		0.22	0.14	0.60	2.00	0.496
11	9-02-93	3.82	6.38	0.91	0.91	2.08	1.00	0.752
12	9-05-93	0.94	0.94	2.32	0.41	3.70	5.75	0.430
	9-06-93	0.84		0.08	0.32	0.32	0.25	0.773
	9-07-93	0.22		0.14	0.06	0.16	2.25	0.361
	9-08-93	0.43		0.07	0.06	0.12	1.25	0.515
	9-10-93	1.96		0.23	0.39	0.86	0.50	0.383
13	9-11-93	1.17	4.62	0.85	0.52	1.12	1.25	0.715
14	9-14-93	2.77	2.77	0.66	0.48	0.94	1.50	0.695
	9-15-93	1.13		0.22	0.12	0.60	1.75	0.405
15	9-21-93	5.98	7.11	1.46	0.59	2.84	2.25	0.570
16	9-27-93	5.67	5.67	0.77	0.46	1.62	1.25	0.279
17	10-6-93	9.04	9.04	0.75	0.12	0.50	6.25	0.187
18	10-9-93	2.67	2.67	0.27	0.14	0.30	2.00	0.238
	10-10-93	0.83		0.22	0.44	0.58	0.50	•
	10-14-93	3.82		0.11	0.04	0.12	1.75	0.013
19	10-15-93	0.70	5.35	0.12	0.03	0.08	3.25	0.574
	10-15-93	0.29		0.32	0.09	0.44	3.75	•
	10-16-93	0.18		0.05	0.03	0.04	1.50	•
	10-16-93	6.80		0.28	0.04	0.16	6.25	•
	10-26-93	9.73		0.20	0.10	0.20	2.00	0.256
20	10-30-93	4.07	21.07	1.34	0.08	1.00	16.50	0.437
	11-07-93	5.90		0.05	0.04	0.08	1.50	0.054
21	11-20-93	14.03	19.93	0.24	0.39	0.84	0.50	0.211
22	12-11-93	20.45	20.45	0.20	0.18	0.40	1.00	0.337
23	12-15-93	3.53	3.53	0.28	0.15	0.30	1.50	0.602
24	12-22-93	7.20	7.20	0.27	•	•	•	•
25	12-23-93	1.21	1.21	0.20	•	•	•	•
26	12-26-93	1.39	1.39	0.50	•	•	•	•
27	1-02-93	8.50	8.50	0.85	0.12	0.24	7.00	•
28	1-02-93	0.53	0.53	0.31	0.18	0.05	1.75	•
29	1-13-93	10.50	10.50	1.06	0.28	0.24	3.75	0.503
30	1-17-93	4.17	4.17	1.18	0.21	0.46	5.75	0.730

*Storms that produced flow over the inflow weir

Table G-4. Hydrologic characteristics of rainfall at a wet detention pond in Tampa, Fla. during 1994-95.

STORM NUMBER	DATE	TIME	INTER-EVENT days	RAIN inches	AVERAGE INTENSITY in/hr	MAXIMUM INTENSITY in/hr	STORM DURATION hours	RUNOFF COEFFIC.
2	6-14-94	17:15	6.29	0.77	0.39	2.00	2.00	0.203
3	6-15-94	18:45	0.99	1.39	0.22	2.56	6.25	0.377
4	6-16-94	18:15	0.72	1.10	0.34	1.60	3.25	0.488
5	6-17-94	15:45	0.76	0.32	0.16	0.52	2.00	0.345
6	6-20-94	12:30	2.78	0.50	0.25	1.08	2.00	0.334
7	6-21-94	10:45	0.84	0.39	0.14	1.24	2.75	0.547
8	6-27-94	21:00	6.36	0.77	0.77	2.00	1.00	0.151
9	6-29-94	20:45	4.00	0.30	0.08	0.28	4.00	0.132
	6-30-94	15:00	0.62	0.32	0.14	0.72	2.25	0.263
10	7-1-94	15:00	0.90	1.56	0.52	2.76	3.00	0.544
11	7-2-94	12:00	0.75	0.52	1.04	1.56	0.50	0.530
	7-2-94	20:25	0.29	0.08	0.11	0.20	0.75	•
	7-3-94	20:30	0.97	0.18	0.10	0.28	1.75	0.528
	7-4-94	16:30	0.78	0.18	0.18	0.16	1.00	0.392
	7-5-94	19:45	1.09	0.07	0.09	0.12	0.75	0.279
12	7-6-94	17:45	0.85	0.37	0.10	0.24	3.75	0.175
13	7-10-94	14:00	3.77	0.49	0.39	0.72	1.25	0.315
	7-10-94	18:10	0.07	0.06	0.06	0.08	0.07	•
14	7-18-94	19:30	8.23	0.76	1.01	2.56	0.75	0.277
15	7-20-94	10:15	0.66	1.11	1.11	2.56	1.00	0.389
16	7-21-94	13:00	0.90	0.42	0.34	1.04	1.25	0.610
	7-21-94	17:00	0.13	0.08	0.11	0.20	0.75	•
17	7-24-94	10:00	2.86	0.22	0.22	0.32	1.00	0.208
	7-26-94	12:00	2.27	0.05	0.10	0.16	0.50	0.150
18	7-28-94	13:30	1.91	0.49	0.39	0.72	1.25	0.281
	7-29-94	13:45	0.90	0.63	0.09	0.72	6.50	0.332
19	7-30-94	19:00	0.97	0.45	0.26	1.08	1.75	0.571
20	8-3-94	16:00	3.77	0.22	0.15	0.48	1.50	0.154
	8-4-94	19:45	1.14	0.12	0.05	0.16	2.25	0.124
21	8-5-94	11:15	0.55	0.20	0.13	0.60	1.50	0.313
22	8-6-94	4:45	0.98	0.42	0.34	1.04	1.25	0.223
	8-6-94	18:45	0.21	0.06	0.12	0.16	0.50	•
	8-7-94	14:00	0.76	0.17	0.10	0.32	1.75	0.230
23	8-8-94	00:00	0.69	0.42	0.10	0.68	4.25	0.522
24	8-10-94	14:00	2.05	2.28	0.48	3.88	4.75	0.641
25	8-11-94	13:00	0.74	0.30	0.60	1.04	0.50	0.447
27	8-13-94	15:00	2.08	0.71	0.20	1.00	3.50	0.468
27	8-16-94	15:00	2.84	0.11	0.07	0.12	1.50	0.196
	8-19-94	15:00	3.01	0.34	0.32	0.68	1.00	0.187
28	8-20-94	20:00	1.02	0.45	0.60	1.32	0.75	0.324
29	8-22-94	5:00	1.78	0.29	0.07	0.44	4.25	0.336
30	8-24-94	16:00	1.94	0.72	0.26	1.84	2.75	0.455
	8-25-94	16:30	0.88	0.14	0.06	0.16	2.50	0.245
31	8-26-94	19:00	1.00	1.14	0.65	1.36	1.75	0.649
	8-28-94	15:30	1.81	0.42	0.17	0.80	2.50	0.198
	9-2-94	15:00	4.24	0.72	0.96	2.36	0.75	0.163
	9-8-94	17:30	6.06	0.06	0.24	0.24	0.25	0.081
	9-9-94	18:15	1.01	0.09	0.06	0.20	1.50	•
	9-10-94	18:00	0.92	0.31	0.31	0.68	1.00	•
	9-11-94	18:15	0.95	0.26	0.07	0.24	4.00	•
	9-13-94	14:15	1.72	0.21	0.08	0.24	2.50	•
	9-14-94	18:00	0.97	0.18	0.04	0.16	5.00	0.185
32	9-15-94	13:15	0.64	1.22	0.15	0.84	8.00	0.503
	9-16-94	15:00	0.92	2.03	0.29	2.08	7.25	0.553
33	9-17-94	14:15	0.96	0.72	0.96	2.60	0.75	0.683
34	9-19-94	15:00	2.04	1.63	0.72	3.04	2.25	0.807
35	9-24-94	18:15	5.05	1.13	0.90	1.72	1.25	0.507
	9-26-94	5:00	1.39	0.85	0.09	1.08	10.00	0.699
36	9-27-94	9:30	2.18	1.27	0.39	1.32	3.25	0.802
37	10-1-94	19:30	5.78	0.51	0.09	0.48	5.50	0.485
	10-3-94	3:45	0.73	0.24	0.04	0.52	6.50	0.585
38	10-9-94	17:45	6.32	0.42	0.34	0.72	1.25	0.254
	10-10-94	16:00	0.88	0.08	0.11	0.12	0.75	0.151
39	10-11-94	13:15	0.85	0.36	0.06	0.20	6.00	0.400
	10-13-94	6:30	1.67	0.14	0.08	0.12	1.75	0.354
40	10-26-94	14:30	13.00	1.60	0.38	1.40	4.25	0.461
	10-29-94	18:00	3.00	1.73	2.31	2.88	0.75	0.601
	10-30-94	12:15	0.81	0.36	0.70	0.64	0.50	0.448
	11-11-94	8:00	10.72	0.09	0.12	0.24	0.75	0.118

Table G-4. Hydrologic characteristics of rainfall at a wet detention pond in Tampa, Fla. during 1994-95.

STORM NUMBER	DATE	TIME	INTER-EVENT days	RAIN inches	AVERAGE INTENSITY in/hr	MAXIMUM INTENSITY in/hr	STORM DURATION hours	RUNOFF COEFFIC.
(Continued)								
41	11-15-94	18:30	4.35	0.66	0.05	0.28	12.25	0.179
	12-11-94	5:15	24.89	1.70	0.68	3.28	2.50	0.416
	12-18-94	6:45	6.91	0.05	0.10	0.12	0.50	0.000
42	12-20-94	21:45	2.63	0.83	0.06	0.20	13.00	0.274
43	12-22-94	19:45	1.35	0.28	0.22	0.32	1.25	0.480
	1-4-95	10:30	11.53	0.19	0.02	0.08	7.75	0.131
44	1-7-95	7:15	2.55	0.25	0.14	0.20	1.75	0.186
45	1-14-94	4:00	6.75	1.02	0.20	1.64	5.00	0.441
	1-14-95	12:46	0.16	0.07	0.09	0.20	0.75	0.482
	1-14-94	17:30	0.14	0.05	0.05	0.16	0.75	0.468
	1-14-95	22:15	0.17	0.18	0.07	0.20	2.50	0.503
	1-15-95	5:15	0.19	0.11	0.06	0.32	1.75	0.268
46	1-15-95	12:00	0.23	0.53	0.07	0.72	7.50	0.561
47	1-23-94	13:15	7.72	0.16	0.16	0.52	1.00	0.188

APPENDIX H

Surface Water Volumes Including Inflow, Outflow and Rainfall

Table H-1. Surface water inflow and outflow for June through January 1993-4. Rainfall directly on the pond is considered an input. Rainfall measured at the inflow and outflow stations give slightly different readings. LOGGER = DATA LOGGER, METER = ISCO FLOW METER.

			INFLOW			OUTFLOW			AVERAGE		
STORM NUMBER	DATE	TIME	RAIN inches	LOGGER cu ft	METER cu ft	RAIN inches	LOGGER cu ft	METER cu ft	RAIN cu ft	INFLOW cu ft	OUTFLOW cu ft
	20-JUN-93	19:30	1.13	4402	* 4402	1.13	0	0	1435	4402	0
	21-JUN-93	17:45	0.70	5345	* 5345	0.70	0	0	889	5345	0
	23-JUN-93	19:45	0.32	921	* 921	0.34	0	0	419	921	0
1	24-JUN-93	17:15	0.91	8571	* 8571	0.97	1151	1064	1194	8571	1108
	25-JUN-93	16:45	0.15	2995	* 2995	0.15	2492	2152	191	2995	2322
	28-JUN-93	6:45	0.18	1986	* 1986	0.19	1373	1173	235	1986	1273
2	30-JUN-93	9:00	0.94	10940	9732	0.94	9292	8680	1194	10336	8986
TOTALS JUNE			**4.33**	**35160**	**33952**	**4.42**	**14308**	**13069**	**5556**	**34556**	**13689**
	12-JUL-93	13:45	1.08	7640	* 7640	1.02	3120	* 3120	1334	7640	3120
	13-JUL-93	16:00	0.16	713	* 713	0.08	1612	* 1612	152	713	1612
3	15-JUL-93	14:00	0.97	10295	* 10295	0.97	8873	* 8873	1232	10295	8873
4	21-JUL-93	6:00	0.38	1406	* 1406	0.33	480	* 480	451	1406	480
TOTALS JULY			**2.59**	**20054**	***20054**	**2.40**	**14085**	***14085**	**3169**	**20054**	**14085**
	8-AUG-93	13:30	0.36	19	* 19	0.38	0	0	470	10	0
5	14-AUG-93	10:30	0.41	206	* 206	0.42	0	0	527	206	0
6	15-AUG-93	08:30	0.43	353	* 353	0.42	0	0	540	353	0
	16-AUG-93	15:45	0.09	36	* 36	0.10	0	0	121	36	0
7	25-AUG-93	15:15	2.11	19665	* 19665	2.23	12537	9077	2756	19665	10807
8	26-AUG-93	16:45	3.93	65600	* 65600	3.97	82590	87590	5017	65600	85090
	28-AUG-93	12:45	0.09	52	* 52	0.09	348	471	114	52	410
	28-AUG-93	17:15	0.09	333	* 333	0.09	1130	544	114	333	837
	29-AUG-93	11:15	0.24	1684	* 1684	0.25	303	147	311	1684	225
9	29-AUG-93	15:30	1.62	28948	* 28349	1.71	19299	19669	2115	28649	19484
	30-AUG-93	12:15	0.05	85	151	0.07	890	774	76	118	832
	30-AUG-93	15:15	0.19	2039	2521	0.19	4539	2964	241	2280	3752
	31-AUG-93	14:00	0.28	3099	3815	0.28	3663	3096	356	3457	3380
TOTALS AUGUST			**9.53**	**121505**	**122170**	**9.82**	**125299**	**124332**	**12757**	**121838**	**124815.5**
10	1-SEP-93	19:00	0.22	2084	3064	0.22	1119	2510	279	2574	1815
	2-SEP-93	15:00	0.06	671	1457	0.06	3051	1137	76	1064	2094
11	5-SEP-93	16:45	0.95	9540	* 9540	0.93	7157	7157	1194	9540	7157
12	6-SEP-93	17:30	2.42	43866	*43866	2.39	39973	* 39973	3054	43866	39973
	7-SEP-93	23:45	0.14	1192	* 1192	0.14	1659	* 1659	178	1192	1659
	8-SEP-93	12:15	0.07	851	* 851	0.07	2290	* 2290	89	851	2290
	10-SEP-93	12:30	0.23	1843	626	0.23	819	* 819	292	2078	819
13	11-SEP-93	17:00	0.94	14421	16445	0.89	14850	15615	1162	15433	15233
14	14-SEP-93	12:45	0.66	10125	11372	0.65	7788	7896	832	10749	7842
	15-SEP-93	17:15	0.22	1828	2378	0.22	4183	4168	279	2103	4176
15	21-SEP-93	18:30	1.48	19045	21051	1.50	19654	18456	1892	20048	19055
16	27-SEP-93	12:45	0.77	4849	5756	0.84	4011	3052	1022	5303	3532
TOTALS SEPTEMBER			**7.94**	**108231**	**116221**	**7.92**	**105435**	**102222**	**10351**	**112226**	**103829**

(continued)

Table H-1 (continued)

			INFLOW			OUTFLOW			AVERAGE		
STORM NUMBER	DATE	TIME	RAIN inches	LOGGER cu ft	METER cu ft	RAIN inches	LOGGER cu ft	METER cu ft	RAIN cu ft	INFLOW cu ft	OUTFLOW cu ft
17	6-OCT-93	00:00	0.81	4149	3057	0.82	2609	3095	1035	3603	2852
18	9-OCT-93	13:30	0.50	2940	2629	0.49	2340	2775	629	2785	2558
	14-OCT-93	2:45	0.13	42	40	0.13	264	320	165	41	292
19	15-OCT-93	14:30	0.73	* 10028	10028	0.75	8097	9180	940	10028	8639
	26-OCT-93	12:15	0.20	* 1208	1208	0.20	13	25	254	1208	19
20	30-OCT-93	19:00	1.34	* 13828	13828	1.34	8874	11417	1702	13828	10146
TOTALS OCTOBER			**3.71**	**32195**	**30790**	**3.73**	**22197**	**26812**	**4724**	**31493**	**24505**
	7-NOV-93	8:12	0.07	107	72	0.07	36	45	89	90	36
21	20-NOV-93	10:30	0.25	1038	1351	0.23	0	0	305	1195	676
TOTALS NOVEMBER			**0.32**	**1145**	**1423**	**0.30**	**36**	**45**	**394**	**1284**	**712**
22	11-DEC-93	11:45	0.18	* 1432	1432	* 0.18	0	0	229	1432	0
23	15-DEC-93	16:30	0.28	* 3974	3974	* 0.28	0	0	356	3974	0
24	22-DEC-93	00:00	0.27	* 5963	5963	* 0.27	* 3011	3011	343	5963	3011
25	23-DEC-93	5:00	0.20	* 4613	4613	* 0.20	* 2434	2434	254	4613	2434
26	24-DEC-93	12:00	0.50	* 14682	14682	* 0.50	* 9104	9104	635	14682	9104
TOTALS DECEMBER			**1.43**	*** 30664**	**30664**	*** 1.43**	*** 14549**	**14549**	**1816**	**30664**	**14549**
27	2-JAN-94	00:00	0.85	9975	10331	0.87	5521	6503	1092	10153	6012
28	2-JAN-94	20:00	0.31	6512	6038	0.24	4707	4904	349	6275	4806
29	11-JAN-94	15:00	1.03	12705	12434	1.09	11079	9458	1346	12570	10269
30	17-JAN-94	21:45	1.18	20699	19796	1.17	20547	17664	1492	20248	19106
TOTALS JANUARY			**3.37**	**49891**	**48599**	**3.37**	**41854**	**38529**	**4280**	**49245**	**40192**

* Instrument not operational and the alternate measuring device was substituted

Table H-2. Surface water inflow and outflow data for 1994-5. Rainfall directly on the pond is considered an input . Average values are the average of the two instruments used for measuring rainfall, inflow and outflow.

			INFLOW			OUTFLOW			AVERAGE		
STORM NUMBER	DATE	TIME	RAIN inches	LOGGER cu ft	METER cu ft	RAIN inches	LOGGER cu ft	METER cu ft	RAIN cu ft	INFLOW cu ft	OUTFLOW cu ft
2	14-JUN-94	17:15	0.79	3782	3690	0.78	152	470	1727	3736	311
3	15-JUN-94	18:45	1.38	12214	12713	1.42	10946	*10946	3100	12464	10946
4	16-JUN-94	18:15	1.08	13119	12930	1.18	14427	13394	2502	13025	13911
5	17-JUN-94	15:45	0.35	3178	3007	0.41	7663	* 7663	841	3093	7663
6	20-JUN-94	12:30	0.47	3965	3927	0.52	1765	1990	1107	3946	1878
7	21-JUN-94	10:45	0.39	5148	4916	0.39	6130	5970	863	5032	6050
8	27-JUN-94	21:00	0.66	3017	3176	0.87	590	810	1926	3097	700
9	29-JUN-94	20:45	0.30	1036	826	0.30	137	200	664	931	169
	30-JUN-94	15:00	*	* 1986	1986	0.32	715	715	708	1986	715
TOTAL JUNE			**5.74**	**47445**	**47171**	**6.19**	**42525**	**41443**	**13438**	**47308**	**42342**
10	1-JUL-94	15:00	*	*20151	20151	1.57	15202	*15202	3476	20151	15202
11	2-JUL-94	12:00	*	* 8000	8000	0.66	12293	*12293	1416	8000	12293
	3-JUL-94	20:30	*	* 2245	2245	0.18	2574	* 2574	399	2245	2574
	4-JUL-94	16:30	*	* 1853	1853	0.20	2186	2375	443	1853	2281
	5-JUL-94	19:45	*	* 330	330	0.05	783	940	111	330	862
12	6-JUL-94	17:45	*	* 3684	3684	0.89	3145	3333	1970	3684	3239
13	10-JUL-94	14:00	0.56	4738	3879	0.58	4873	5079	1284	4309	4976
14	18-JUL-94	19:30	0.86	4867	5544	0.93	2083	2123	1764	5206	2103
15	20-JUL-94	10:15	*	*10289	10289	1.12	8873	6781	2480	10289	7827
16	21-JUL-94	13:00	*	* 7343	7343	0.51	12965	11493	1129	7343	12229
17	24-JUL-94	10:00	*	* 1126	1126	0.23	2575	3121	509	1126	2848
	26-JUL-94	12:00	*	* 177	177	0.05	1310	949	111	177	1130
18	28-JUL-94	13:30	*	* 3254	3254	0.49	1466	1626	1085	3254	1546
	29-JUL-94	13:45	*	* 5328	5328	0.68	6309	8028	1506	5328	7169
19	30-JUL-94	19:00	*	* 6334	6334	0.47	8961	8129	1041	6334	8545
TOTAL JULY			*	**79719**	**79537**	**8.61**	**85598**	**84046**	**18724**	**79628**	**84822**
20	3-AUG-94	16:00	*	* 762	762	0.21	591	1038	465	762	815
	4-AUG-94	19:45	0.22	447	575	0.13	261	639	387	511	450
21	5-AUG-94	11:15	0.22	1618	1342	0.18	685	1277	443	1480	981
22	6-AUG-94	4:45	0.46	2320	2100	0.38	1942	1980	930	2210	1961
	7-AUG-94	14:00	0.15	921	921	0.19	589	581	376	921	585
23	8-AUG-94	00:00	0.49	5669	5911	0.45	6615	6113	1041	5790	6364
24	10-AUG-94	14:00	2.44	35199	33881	2.13	21923	20325	5059	34540	21124
25	11-AUG-94	13:00	0.33	3079	3248	0.27	10176	14556	664	3164	12366
	13-AUG-94	15:00	0.82	8029	9100	0.73	8980	8130	1716	8565	8555
26	16-AUG-94	15:00	0.17	660	730	0.12	1109	1446	332	695	1278
27	19-AUG-94	15:00	0.37	1441	1645	0.32	410	471	775	1543	441
28	20-AUG-94	20:00	0.46	3323	3716	0.44	2027	2846	1018	3520	2437
29	22-AUG-94	5:00	0.34	2211	2621	0.27	2111	2178	675	2416	2145
30	24-AUG-94	16:00	0.71	7406	8274	0.75	5045	4476	1616	7840	4761
	25-AUG-94	16:30	0.15	726	894	0.12	2280	1950	310	810	2115
31	26-AUG-94	19:00	1.17	17912	17912	1.17	18100	15576	2590	17912	16838
	28-AUG-94	15:30	0.43	2555	1470	0.43	5514	5568	952	2013	5541
TOTAL AUGUST			**9.14**	**94278**	**95102**	**8.29**	**88358**	**89150**	**19349**	**94690**	**88754**

(continued)

Table H-2. Continued

			INFLOW			OUTFLOW			AVERAGE		
STORM NUMBER	**DATE**	**TIME**	**RAIN inches**	**LOGGER cu ft**	**METER cu ft**	**RAIN inches**	**LOGGER cu ft**	**METER cu ft**	**RAIN cu ft**	**INFLOW cu ft**	**OUTFLOW cu ft**
	2-SEP-94	15:00	0.80	2824	* 2824	0.67	2163	2336	1627	2824	2250
	8-SEP-94	17:30	*	1920	* 1920	1.01	1500	1870	2236	1920	1685
	14-SEP-94	14:15	0.19	742	* 742	0.17	387	391	376	742	389
32	15-SEP-94	13:15	1.29	14478	*14478	1.17	12277	8370	2701	14478	10324
	16-SEP-94	15:00	2.11	26428	*26428	1.94	40406	45029	4483	26428	42718
33	17-SEP-94	14:15	0.73	11764	*11764	0.73	19176	18097	1616	11764	18637
34	19-SEP-94	15:00	*	31601	*31601	1.66	27614	27624	3675	31601	27619
35	24-SEP-94	18:15	*	13518	*13518	1.13	11637	9479	2502	13518	10558
	26-SEP-94	5:00	*	14028	*14028	0.85	12809	10710	1882	14028	11760
36	27-SEP-94	9:30	*	24771	23253	1.27	27842	27173	2811	24012	27508
TOTAL SEPTEMBER			**11.04**	**142074**	**140556**	**10.60**	**155811**	**151079**	**23909**	**141315**	**153445**
37	1-OCT-94	19:30	*	5821	6546	0.54	3929	2692	1196	6184	3311
	3-OCT-94	3:45	*	2874	3747	0.24	6338	6161	531	3311	6250
38	9-OCT-94	17:45	0.42	2423	2616	0.41	541	779	930	2520	660
	10-OCT-94	16:00	0.11	288	282	0.08	553	579	177	285	566
39	11-OCT-94	13:15	0.36	3338	3637	0.37	2308	2609	819	3488	2459
	13-OCT-94	6:30	0.16	1508	1492	0.17	2254	2694	398	1500	2474
40	26-OCT-94	14:30	1.60	17339	17432	1.60	14786	12774	3542	17386	13780
	29-OCT-94	18:00	1.73	23794	22400	1.52	16036	17491	3609	23097	16764
	30-OCT-94	12:15	0.36	3680	3935	0.30	9214	10333	797	3808	9774
TOTAL OCTOBER			**5.52**	**61065**	**62087**	**5.23**	**55959**	**56112**	**11999**	**61576**	**56036**
	11-NOV-94	8:00	0.09	258	242	0.08	22	113	199	250	68
41	15-NOV-94	18:30	0.75	2719	3060	0.62	963	1046	1517	2890	1005
TOTAL NOVEMBER			**0.84**	**2977**	**3302**	**0.70**	**985**	**1159**	**1716**	**3140**	**1073**
	11-DEC-94	5:15	1.71	15809	17725	1.55	14484	13821	3786	16767	14153
	18-DEC-94	6:45	0.05	0	0	0.06	305	515	111	0	410
42	20-DEC-94	21:45	0.84	5088	5764	0.83	2990	3090	1860	5426	3040
43	22-DEC-94	19:45	0.27	2964	3154	0.28	3583	4208	598	3059	3896
TOTAL DECEMBER			**2.87**	**23861**	**26643**	**2.72**	**21362**	**21634**	**6355**	**25252**	**21498**
	4-JAN-95	10:30	0.20	587	* 587	0.19	25	179	421	587	102
44	7-JAN-95	7:15	0.26	1017	1182	0.24	246	815	554	1100	531
45	14-JAN-95	4:00	1.14	13693	15421	1.08	7960	7224	2458	14557	7592
46	15-JAN-95	12:00	0.54	8122	9203	0.77	17178	15532	1450	8663	16355
47	23-JAN-95	13:15	0.16	672	750	0.16	1186	1783	354	711	1485
TOTAL JANUARY			**2.30**	**24091**	**27143**	**2.44**	**26595**	**25533**	**5237**	**25617**	**26064**

* Instrument not operational. For calculations the alternate measuring device was substituted.

APPENDIX I

Concentrations for Constituents of Water Quality Concern

Table I-1. Concentration of constituents from June 1990 through January 1991. The suffix RA=concentration of constituent in rainfall, IN=at the inflow, and OU=at the outflow. NO=storm number

NUTRIENTS

			AMMONIA			NITRATE+NITRITE			ORGANIC NITROGEN			ORTHO-PHOSPHATE			TOTAL PHOSPHORUS		
LOD=detection limit			NH3=0.01			NOX=0.01			TON=0.1			OP=0.01			TP=0.01		
NO	YEAR	RAIN in	NH3RA mg/l	NH3IN mg/l	NH3OU mg/l	NOXRA mg/l	NOXIN mg/l	NOXOU mg/l	ONRA mg/l	ONIN mg/l	ONOU mg/l	OPRA mg/l	OPIN mg/l	OPOU mg/l	TPRA mg/l	TPIN mg/l	TPOU mg/l
2	5-24-90	0.37	0.770	0.020	0.040	0.490	0.120	0.010	0.300	0.930	1.230	0.138	0.193	0.037	0.166	0.244	0.083
3	6-04-90	0.69	0.280	0.050	0.040	0.460	0.220	0.020	1.630	0.480	0.870	0.248	0.180	0.037	0.249	0.137	0.079
4	6-11-90	0.46	0.140	0.060	0.060	0.640	0.490	0.030	0.140	1.610	1.570	0.005	0.108	0.064	0.020	0.174	0.128
5	6-23-90	1.05	0.098	0.030	0.015	0.082	0.100	0.036	0.140	0.674	0.519	0.011	0.332	0.106	0.292	0.395	0.167
6	6-24-90	0.83	0.065	0.021	0.233	0.075	0.068	0.032	0.191	0.797	0.561	0.005	0.272	0.049	0.005	0.310	0.092
7	7-08-90	0.86	0.466	0.277	0.089	0.376	0.473	0.457	0.382	0.822	1.327	0.022	0.309	0.080	0.046	0.442	0.156
8	7-11-90	1.10	0.202	0.047	0.099	0.199	0.036	0.135	0.209	1.425	0.909	0.014	0.422	0.101	0.015	0.658	0.193
9	7-12-90	1.12	0.308	0.353	0.043	0.051	0.709	0.043	0.050	0.679	0.597	0.064	0.439	0.123	0.403	0.556	0.229
10	7-13-90	0.48	0.134	0.036	0.150	0.150	0.241	0.032	0.229	0.954	0.657	0.005	0.467	0.104	0.005	0.559	0.184
11	7-14-90	1.78	0.262	0.085	0.053	0.031	0.132	0.177	0.050	0.930	0.886	0.005	0.408	0.129	0.005	0.511	0.236
12	7-19-90	0.29	0.024	0.179	0.024	0.051	0.307	0.222	0.050	1.396	1.015	0.024	0.179	0.093	0.030	0.351	0.157
13	8-01-90	0.40	0.258	0.026	0.073	1.183	0.376	0.018	0.506	2.723	2.456	0.010	0.078	0.018	0.010	0.206	0.188
14	8-15-90	0.32	0.123	0.049	0.096	0.161	0.029	0.096	0.256	1.164	1.225	0.005	0.203	0.102	0.005	0.333	0.194
15	8-19-90	0.40	0.202	0.155	0.084	0.161	0.309	0.085	0.140	0.780	1.167	0.005	0.156	0.100	0.005	0.204	0.166
16	8-26-90	0.62	0.239	0.050	0.076	0.410	0.077	0.005	0.050	0.994	1.014	0.005	0.361	0.082	0.005	0.455	0.119
17	8-29-90	0.94	0.154	0.154	0.037	0.308	0.096	0.005	0.430	0.330	0.877	0.005	0.632	0.100	0.005	0.005	0.120
18	9-01-90	1.06	0.380	0.055	0.047	0.580	0.218	0.031	1.169	1.620	0.716	0.034	0.900	0.148	0.026	1.127	0.182
19	9-17-90	1.90	0.229	0.026	0.098	0.436	0.316	0.161	0.050	0.770	0.663	0.013	0.474	0.142	0.013	0.565	0.202
20	9-30-90	0.65	0.182	0.035	0.023	0.120	0.179	0.032	0.050	0.785	0.911	0.005	0.248	0.080	0.005	0.353	0.147
21	10-03-90	0.45	0.228	0.040	0.023	0.160	0.144	0.005	0.105	0.720	0.749	0.005	0.206	0.070	0.005	0.272	0.096
22	10-10-90	2.64	0.080	0.029	0.013	0.063	0.039	0.005	0.109	0.885	0.905	0.005	0.388	0.358	0.005	0.482	0.427
23	1-15-91	2.34	0.084	0.041	0.078	0.044	0.396	0.266	0.143	1.071	1.210	0.005	0.430	0.258	0.011	0.461	0.332
	Average		**0.223**	**0.083**	**0.068**	**0.283**	**0.231**	**0.087**	**0.290**	**1.025**	**1.002**	**0.029**	**0.336**	**0.108**	**0.061**	**0.400**	**0.176**
	Std.Dev.		**0.158**	**0.086**	**0.049**	**0.270**	**0.173**	**0.110**	**0.379**	**0.492**	**0.413**	**0.056**	**0.184**	**0.073**	**0.109**	**0.225**	**0.079**
	C.V.		**0.708**	**1.045**	**0.724**	**0.954**	**0.748**	**1.269**	**1.308**	**0.481**	**0.413**	**1.935**	**0.548**	**0.671**	**1.803**	**0.561**	**0.448**
	Maximum		**0.770**	**0.353**	**0.233**	**1.183**	**0.709**	**0.457**	**1.630**	**2.723**	**2.456**	**0.248**	**0.900**	**0.358**	**0.403**	**1.127**	**0.427**
	Minimum		**0.024**	**0.020**	**0.013**	**0.031**	**0.029**	**0.005**	**0.050**	**0.330**	**0.519**	**0.005**	**0.078**	**0.018**	**0.005**	**0.005**	**0.079**
	# Obs.		**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**
	%Efficiency				**18**			**63**			**2**			**68**			**56**

Table I-1. Concentrations 1990-91 (Continued).

METALS AND TOTAL SUSPENDED SOLIDS

LOD=detection limit			TOTAL ZINC ZN=0.005			TOTAL IRON FE=0.02			TOTAL CADMIUM CD=0.002			SUSPENDED SOLIDS S=0.05		
NO	YEAR	RAIN in	ZNRA mg/l	ZNIN mg/l	ZNOU mg/l	FERA mg/l	FEIN mg/l	FEOU mg/l	CDRA mg/l	CDIN mg/l	CDOU mg/l	SSRA mg/l	SSIN mg/l	SSOU mg/l
2	5-24-90	0.37	0.030	0.050	0.030	0.110	0.290	0.360	0.001	0.001	0.007	2.10	6.63	5.11
3	6-04-90	0.69	0.050	0.030	0.030	0.070	0.350	0.250	0.001	0.014	0.016	1.09	27.98	7.10
4	6-11-90	0.46	0.060	0.040	0.030	0.060	0.180	0.650	0.005	0.007	0.014	2.10	6.69	5.68
5	6-23-90	1.05	0.041	0.058	0.023	0.091	1.051	0.285	0.003	0.005	0.003	5.94	60.17	15.94
6	6-24-90	0.83	0.035	0.044	0.031	0.001	0.462	0.448	0.001	0.002	0.001	6.40	19.22	20.28
7	7-08-90	0.86	0.043	0.036	0.041	0.060	0.593	0.658	0.001	0.002	0.001	1.87	23.20	9.13
8	7-11-90	1.10	0.011	0.035	0.021	0.043	0.553	0.571	0.001	0.001	0.001	0.16	29.17	10.00
9	7-12-90	1.12	0.019	0.056	0.011	0.133	0.371	0.331	0.001	0.003	0.006	2.96	20.55	16.62
10	7-13-90	0.48	0.041	0.062	0.024	0.039	0.332	0.416	0.005	0.001	0.006	2.10	28.43	7.52
11	7-14-90	1.78	0.024	0.010	0.017	0.001	0.266	0.410	0.001	0.001	0.001	0.61	15.95	9.46
12	7-19-90	0.29	0.003	0.036	0.011	0.001	0.377	0.523	0.009	0.001	0.012	2.10	12.03	16.65
13	8-01-90	0.40	0.108	0.051	0.003	0.051	0.124	0.010	0.001	0.008	0.002	2.10	9.03	27.98
14	8-15-90	0.32	0.051	0.079	0.057	0.001	0.583	0.565	0.006	0.009	0.006	0.85	28.88	16.47
15	8-19-90	0.40	0.045	0.074	0.064	0.005	0.255	0.415	0.003	0.009	0.017	2.10	9.80	13.69
16	8-26-90	0.62	0.056	0.066	0.074	0.045	1.367	0.466	0.001	0.006	0.007	2.08	87.04	12.53
17	8-29-90	0.94	0.050	0.073	0.053	0.001	0.978	0.349	0.015	0.014	0.019	1.55	79.95	12.43
18	9-01-90	1.06	0.201	0.053	0.027	0.001	0.434	0.276	0.004	0.02	0.001	2.10	34.28	9.62
19	9-17-90	1.90	0.020	0.043	0.024	0.130	0.250	0.250	0.001	0.019	0.001	1.16	7.74	7.92
20	9-30-90	0.65	0.009	0.038	0.010	0.020	0.844	0.550	0.001	0.001	0.001	0.47	35.82	7.60
21	10-03-90	0.45	0.016	0.099	0.027	0.110	1.700	0.390	0.001	0.004	0.006	2.10	9.19	7.11
22	10-10-90	2.64	0.032	0.044	0.018	0.100	0.530	0.330	0.006	0.007	0.003	2.10	24.36	7.26
23	1-15-91	2.34	0.040	0.050	0.060	0.005	0.32	0.22	0.001	0.001	0.001	5.98	31.20	0.03
Average			**0.045**	**0.051**	**0.031**	**0.049**	**0.555**	**0.397**	**0.003**	**0.006**	**0.006**	**2.3**	**27.6**	**11.2**
Std.Dev.			**0.041**	**0.019**	**0.019**	**0.045**	**0.392**	**0.151**	**0.003**	**0.006**	**0.006**	**1.7**	**21.6**	**5.9**
C.V.			**0.906**	**0.368**	**0.601**	**0.921**	**0.706**	**0.381**	**1.093**	**0.936**	**0.957**	**0.731**	**0.782**	**0.530**
Maximum			**0.201**	**0.099**	**0.074**	**0.133**	**1.700**	**0.658**	**0.015**	**0.02**	**0.019**	**6.4**	**87.0**	**28.0**
Minimum			**0.003**	**0.010**	**0.003**	**0.001**	**0.124**	**0.010**	**0.001**	**0.001**	**0.001**	**0.2**	**6.6**	**0.0**
#Obs			**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**
%Efficiency					**39**			**29**			**3**			**59**

Table I-2. **Concentrations of constituents from June 1993 through January 1994. Missing values at the outflow indicate no flow conditions. Data for TOC was for grab samples after the rain event.**

Nutrients and Suspended Solids

			AMMONIA-N			NITRATE+NITRITE			ORGANIC-NITROGEN			ORTHO-PHOSPHATE			TOTAL PHOSPHORUS			SUS.SOLIDS		ORG. CARBON	
MDL=Minimum Det. Limit			NH3=0.01 mg/l			NOX=0.01 mg/l			TON=0.1 mg/l			OP=0.01 mg/l			TP=O.01 mg/l			TSS=0.05 mg/l		TOC=0.5	
RAIN in	NO	DATE	NH3RA mg/l	NH3IN mg/l	NH3OU mg/l	NOXRA mg/l	NOXIN mg/l	NOXOU mg/l	TONRA mg/l	TONIN mg/l	TONOU mg/l	OPRA mg/l	OPIN mg/l	OPOU mg/l	TPRA mg/l	TPIN mg/l	TPOU mg/l	SSIN mg/l	SSOU mg/l	TOCIN mg/l	TOCOU mg/l
1.06	1	6-24-93	0.175	0.021	0.020	0.234	0.056	0.020	0.21	1.43	0.14	0.008	0.262	0.005	0.023	0.576	0.006	53	15	•	•
0.94	2	6-30-93	0.305	0.158	0.131	0.434	0.117	0.033	0.05	1.45	1.35	0.012	0.944	0.120	0.014	2.066	0.207	264	29	•	•
1.05	3	7-12-93	0.290	0.133	0.070	0.892	0.439	0.100	0.24	1.06	0.78	0.005	0.446	0.094	0.005	0.891	0.424	147	49	•	•
0.97	4	7-21-93	0.299	0.520	0.038	0.538	0.134	0.013	0.16	1.00	0.67	0.005	0.198	0.049	0.005	0.364	0.121	36	11	•	•
0.77	5	8-13-93	0.236	0.150	•	0.734	0.130	•	0.00	0.00	•	0.010	0.223	•	0.361	0.629	•	9	•	•	•
0.43	6	8-14-93	0.093	0.060	•	0.450	0.090	•	0.00	0.91	•	0.007	0.185	•	0.410	0.315	•	7	•	•	•
2.11	7	8-25-93	0.031	0.159	0.007	0.270	0.510	0.150	2.61	0.22	0.81	0.005	0.007	0.248	0.023	0.411	0.333	77	31	•	•
3.95	8	8-26-93	0.118	0.004	0.297	0.030	0.170	0.107	0.10	1.11	1.71	0.008	0.140	0.250	0.023	0.254	0.340	9	21	•	•
1.62	9	8-29-93	0.224	0.033	0.021	0.410	0.050	0.002	0.25	2.22	1.02	0.008	0.140	0.276	0.023	0.254	0.363	90	11	20.04	11.99
0.94	11	9-05-93	0.203	0.026	0.051	0.574	0.000	0.014	0.33	1.59	0.73	0.007	0.526	0.161	0.013	2.855	0.303	5	10	•	•
2.40	12	9-06-93	0.127	0.035	0.032	0.183	0.000	0.052	0.08	0.99	1.05	0.010	0.259	0.152	0.025	0.373	0.263	4	12	20.78	10.32
0.92	13	9-11-93	0.229	0.007	0.007	0.446	0.073	0.009	0.26	1.15	1.21	0.013	0.405	0.112	0.023	0.797	0.185	104	15	19.24	11.02
0.65	14	9-14-93	0.192	0.072	0.021	0.234	0.002	0.000	0.27	1.11	1.03	0.018	0.430	0.095	0.013	0.686	0.174	55	10	15.23	11.87
1.49	15	9-21-93	0.020	0.044	0.061	0.011	0.030	0.093	0.54	0.65	0.49	0.000	0.140	0.063	0.184	0.456	0.125	50	16	14.09	9.71
0.77	16	9-27-93	0.066	0.030	0.010	0.009	0.042	0.006	0.45	1.13	0.86	0.009	0.148	0.039	0.006	0.373	0.098	12	10	13.14	9.05
0.81	17	10-6-93	0.042	0.014	0.016	0.071	0.052	0.014	0.61	1.05	0.88	0.000	0.012	0.002	0.008	0.287	0.078	9	5	10.95	14.32
0.49	18	10-09-93	0.081	0.015	0.000	0.170	0.037	0.000	0.51	1.28	0.39	0.000	0.033	0.011	0.011	0.228	0.066	8	3	17.06	9.88
0.74	19	10-15-93	0.128	0.022	0.019	0.071	0.003	0.000	0.05	1.00	0.00	0.009	0.131	0.010	0.047	0.279	0.070	9	5	15.71	12.81
1.34	20	10-30-93	0.095	0.076	0.088	0.066	0.040	0.008	0.05	0.84	0.85	0.008	0.204	0.017	0.010	0.290	0.064	12	5	12.04	11.02
0.24	21	11-20-93	0.244	0.020	0.068	0.262	0.119	0.008	0.210	1.37	0.88	0.008	0.036	0.049	0.023	0.049	0.010	4	4	14.40	13.37
0.18	22	12-11-93	0.175	0.004	•	0.975	0.065	•	0.21	0.60	•	0.014	0.046	•	0.054	0.083	•	2	•	•	•
0.28	23	12-15-93	0.206	0.010	•	0.171	0.094	•	0.21	1.37	•	0.016	0.000	•	0.054	0.092	•	2	•	9.37	•
0.27	24	12-20-93	0.382	0.011	0.008	0.496	0.271	0.012	0.38	0.63	0.75	0.102	0.025	0.012	0.130	0.048	0.051	2	5	3.98	7.82
0.20	25	12-23-93	0.329	0.009	0.067	0.362	0.276	0.025	0.33	0.58	0.82	0.027	0.020	0.015	0.051	0.035	0.038	1	3	2.71	8.36
0.50	26	12-24-93	0.162	0.044	0.012	0.188	0.604	0.010	0.16	0.41	0.51	0.009	0.009	0.014	0.023	0.175	0.046	1	5	2.94	6.30
0.86	27	1-02-94	0.178	0.025	0.023	0.104	0.367	0.074	0.18	0.65	0.54	0.008	0.014	0.027	0.020	0.029	0.065	1	8	6.46	6.20
0.28	28	1-03-94	0.175	0.028	0.012	0.234	0.335	0.013	0.21	0.47	0.34	0.008	0.038	0.008	0.023	0.080	0.041	3	8	2.26	7.06
1.05	29	1-13-94	0.175	0.029	0.010	0.068	0.010	0.000	0.18	0.99	0.97	0.008	0.104	0.013	0.015	0.189	0.048	13	3	16.11	7.92
1.17	30	1-17-94	0.081	0.059	0.033	0.030	0.009	0.003	0.08	1.42	0.63	0.000	0.407	0.072	0.004	0.720	0.169	12	11	9.25	8.48
MEAN			**0.174**	**0.063**	**0.039**	**0.303**	**0.142**	**0.026**	**0.311**	**0.989**	**0.669**	**0.012**	**0.191**	**0.066**	**0.057**	**0.479**	**0.127**	**34**	**11**	**7.78**	**6.12**
STD.DEV.			**0.091**	**0.099**	**0.059**	**0.259**	**0.164**	**0.040**	**0.469**	**0.447**	**0.425**	**0.018**	**0.210**	**0.080**	**0.099**	**0.607**	**0.123**	**57**	**11**	**7.34**	**5.09**
MAXIMUM			**0.382**	**0.520**	**0.297**	**0.975**	**0.604**	**0.150**	**2.609**	**2.217**	**1.713**	**0.102**	**0.944**	**0.276**	**0.410**	**2.855**	**0.424**	**264**	**49**	**20.78**	**14.32**
MINIMUM			**0.020**	**0.004**	**0.000**	**0.009**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.004**	**0.029**	**0.000**	**1**	**0**	**0.00**	**0.00**
C.V.			**0.522**	**1.582**	**1.517**	**0.855**	**1.152**	**1.499**	**1.509**	**0.452**	**0.634**	**1.528**	**1.102**	**1.219**	**1.731**	**1.268**	**0.968**	**1.661**	**1.021**	**0.94**	**0.83**
NO. OBS.			**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**
% EFFICIENCY					**38**			**81**			**32**			**65**			**73**		**69**		**21**
Data was removed between December 12 and January 3 because of problems with rain collector which colleceted bulk precipitation during this period and a water main leak into																					
MEAN			**0.156**	**0.077**	**0.050**	**0.283**	**0.096**	**0.032**	**0.34**	**1.09**	**0.82**	**0.007**	**0.245**	**0.092**	**0.059**	**0.606**	**0.172**	**45**	**14**	**15.23**	**10.90**
NO. OBS.			**22**	**22**	**20**	**22**	**22**	**20**	**22**	**22**	**20**	**22**	**22**	**20**	**22**	**22**	**20**	**22**	**20**	**21**	**21**
% EFFICIENCY					**35**			**67**			**24**			**62**			**72**		**69**		**28**

Table I-2. (Continued). Constituent concentrations for 1993-94.

Metals and Hardness

			ZINC			CADMIUM			COPPER			IRON			LEAD			MANGANESE			HARDNESS		
Laboratory Method			FLAME			FURNACE			FURNACE			FLAME			FURNACE			FURNACE			HARD=0.02 mg/l		
LOD=Limit of Detection			ZN=10 ug/l			CD=0.3 ug/l			CU=0.1 ug/l			FE=30 ug/l			PB=2 ug/l			MN=0.6 ug/l					
RAIN in	NO	DATE	ZNRA ug/l	ZNIN ug/l	ZNOU ug/l	CDRA ug/l	CDIN ug/l	CDOU ug/l	CURA ug/l	CUIN ug/l	CUOU ug/l	FERA ug/l	FEIN ug/l	FEOU ug/l	PBRA ug/l	PBIN ug/l	PBOU ug/l	MNRA ug/l	MNIN ug/l	MNOU ug/l	HRA mg/l	HIN mg/l	HOU mg/l
1.06	1	6-24-93	95	24	5	1.0	0.0	0.0	1.9	2.3	6.0	56	1844	15	0.8	0.0	0.0	1.7	59.9	4.0	0	190	144
0.94	2	6-30-93	95	64	29	0.5	0.5	0.2	3.0	9.8	2.6	209	6648	792	0.0	12.6	0.0	8.0	36.1	12.1	3	113	186
1.05	3	7-12-93	125	39	22	0.6	0.0	0.0	2.8	4.0	4.0	56	3082	2834	0.0	0.0	0.0	2.5	23.3	1.6	0	131	167
0.97	4	7-21-93	119	46	21	2.8	0.0	0.3	4.9	5.6	2.0	214	1581	456	0.0	4.6	0.0	6.4	28.9	17.8	4	174	131
0.77	5	8-13-93	213	32	•	1.0	0.1	•	2.0	2.8	•	120	1205	•	1.7	1.0	•	4.6	69.7	•	3	185	•
0.43	6	8-14-93	145	8	•	0.1	0.0	•	1.0	0.7	•	72	533	•	1.0	0.6	•	4.2	28.0	•	0	185	•
2.11	7	8-25-93	35	25	25	0.3	0.6	0.2	3.4	3.0	4.0	129	2569	922	0.8	5.0	1.4	2.8	37.0	10.0	1	124	69
3.95	8	8-26-93	19	2	24	0.3	0.2	0.1	4.4	3.0	4.8	85	1474	415	0.9	0.7	1.1	1.4	11.0	13.7	0	60	114
1.62	9	8-29-93	234	23	26	1.0	0.2	0.2	2.7	3.0	2.3	91	1898	352	1.7	3.6	1.7	3.3	30.9	18.1	0	111	144
0.94	11	9-05-93	91	12	23	0.3	0.3	0.2	0.0	0.0	3.1	21	872	283	0.3	0.0	0.7	2.7	74.8	21.9	0	231	144
2.40	12	9-06-93	39	18	17	0.3	0.2	0.3	0.0	0.0	0.1	25	642	367	0.0	0.0	2.2	0.0	41.4	13.7	0	177	123
0.92	13	9-11-93	79	20	39	0.3	0.1	0.0	1.0	2.0	1.4	45	1823	389	1.0	4.6	0.8	1.0	28.9	14.0	0	121	142
0.65	14	9-14-93	102	34	34	0.2	0.1	0.2	1.4	4.3	4.8	32	2026	352	0.4	3.4	1.4	0.0	26.6	4.8	1	126	143
1.49	15	9-21-93	39	28	15	0.3	0.1	0.1	2.5	2.4	2.9	24	1257	458	0.5	2.2	0.6	0.9	15.8	8.2	1	76	104
0.77	16	9-27-93	141	36	15	0.3	1.0	0.1	0.3	3.5	1.7	30	905	205	0.6	2.4	0.9	1.7	23.1	7.9	1	147	123
0.81	17	10-06-93	12	24	9	0.1	0.1	0.1	0.0	2.2	0.3	54	379	177	0.7	1.9	1.1	0.9	17.2	6.2	1	185	116
0.49	18	10-09-93	65	21	6	0.1	0.0	0.1	0.0	0.0	7.0	29	711	117	0.5	1.2	2.0	1.7	46.1	6.0	0	249	135
0.74	19	10-15-93	7	19	5	0.0	0.0	0.1	0.0	2.0	1.3	54	597	165	1.0	1.4	1.0	1.2	40.5	6.3	0	246	131
1.34	20	10-30-93	14	21	23	0.1	0.1	0.2	1.0	2.1	1.0	35	356	149	0.0	0.0	0.0	0.0	13.4	6.3	0	161	190
0.24	21	11-20-93	244	20	68	0.1	0.1	0.3	2.0	1.0	2.0	62	213	161	1.0	0.0	0.0	2.0	43.0	20.0	0	543	228
0.18	22	12-11-93	697	28	•	2.8	0.0	•	10.8	1.3	•	127	166	•	3.7	0.2	•	7.9	18.1	•	1	285	•
0.28	23	12-15-93	48	14	•	0.4	0.0	•	4.8	2.8	•	75	112	•	1.1	0.2	•	3.3	8.7	•	0	239	•
0.27	24	12-20-93	435	20	10	0.7	0.0	0.0	2.5	0.1	0.0	93	82	101	1.8	0.0	0.0	4.5	5.8	4.2	0	230	171
0.20	25	12-23-93	95	22	20	1.0	0.1	0.0	1.9	0.0	0.0	56	70	95	0.8	0.0	0.2	1.7	4.0	3.0	1	239	175
0.50	26	12-24-93	148	25	17	0.7	0.0	0.0	1.9	0.0	0.0	62	43	93	0.5	0.1	0.2	1.7	2.6	1.4	3	240	183
0.86	27	1-02-94	27	19	15	0.1	0.2	0.0	0.0	0.0	0.0	85	50	134	0.8	0.1	0.3	1.1	4.6	2.9	1	243	183
0.28	28	1-03-94	302	26	16	1.5	0.0	0.1	4.4	0.0	0.0	151	98	97	2.4	0.5	0.0	3.5	5.6	3.5	0	256	201
1.05	29	1-13-94	107	17	4	0.7	0.0	0.0	2.4	1.0	1.0	46	417	140	0.9	0.8	0.2	0.7	19.5	5.0	0	229	185
1.17	30	1-17-94	29	28	14	0.1	0.1	0.1	0.4	2.3	4.4	38	2351	508	0.1	5.5	1.2	0.3	19.7	6.4	0	109	150
MEAN			**134**	**25**	**20**	**0.6**	**0.1**	**0.1**	**2.2**	**2.1**	**2.3**	**76**	**1173**	**391**	**0.87**	**1.82**	**0.68**	**2.5**	**27.0**	**8.8**	**1**	**194**	**152**
STD.DEV.			**148**	**12**	**13**	**0.7**	**0.2**	**0.1**	**2.3**	**2.1**	**2.0**	**52**	**1336**	**543**	**0.82**	**2.67**	**0.68**	**2.2**	**18.7**	**5.9**	**1**	**92**	**36**
MAXIMUM			**697**	**64**	**68**	**2.8**	**1.0**	**0.3**	**10.8**	**9.8**	**7.0**	**214**	**6648**	**2834**	**3.67**	**12.60**	**2.20**	**8.0**	**74.8**	**21.9**	**4**	**543**	**228**
MINIMUM			**7**	**2**	**4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**21**	**43**	**15**	**0.00**	**0.00**	**0.00**	**0.0**	**2.6**	**1.4**	**0**	**60**	**69**
C.V.			**1.11**	**0.47**	**0.66**	**1.27**	**1.50**	**0.84**	**1.04**	**0.99**	**0.88**	**0.67**	**1.14**	**1.39**	**0.95**	**1.47**	**1.00**	**0.87**	**0.69**	**0.67**	**1.47**	**0.47**	**0.24**
NO. OBS			**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**
% EFFICIENCY					**19**			**20**			**-8**			**67**			**63**			**68**			**22**

Data for storms from December 11 through January 3 were removed because of problems. The rainfall sampler collected only bulk samples and a leak into the inflow ditch diluted inflow samples during this period.

MEAN			**93**	**25**	**21**	**0.5**	**0.2**	**0.1**	**1.7**	**2.6**	**2.8**	**69**	**1517**	**463**	**0.87**	**1.82**	**0.68**	**2.2**	**33.4**	**10.2**	**1**	**176**	**143**
NO. OBS			**22**	**22**	**20**	**22**	**22**	**20**	**22**	**22**	**20**	**22**	**22**	**20**	**27**	**29**	**25**	**22**	**22**	**20**	**22**	**22**	**20**
% EFFICIENCY					**17**			**23**			**-9**			**69**			**63**			**69**			**19**

Table I-3. Concentration of constituents from June 1994 through January 1995. The suffix RA=concentration of constituent in rainfall, IN=at the inflow, and OU=at the outflow. NO=storm number.

NUTRIENTS , TOTAL SUSPENDED SOLIDS AND TOTAL ORGANIC CARBON

LOD=Limit of Detection			AMMONIA-N NH3=0.01 mg/l			NITRATE+NITRITE-N NOX=0.01 mg/l			ORGANIC NITROGEN TON=0.1mg/l			ORTHO-PHOSPHORUS OP=0.01 mg/l			TOTAL PHOSPHORUS TP=0.01 mg/l			SUS.SOLIDS TSS=0.05 mg/l		T. ORGANIC CARBON	
RAIN in	NO	DATE	NH3RA mg/l	NH3IN mg/l	NH3OU mg/l	NOXRA mg/l	NOXIN mg/l	NOXOU mg/l	TONRA mg/l	TONIN mg/l	TONOU mg/l	OPRA mg/l	OPIN mg/l	OPOU mg/l	TPRA mg/l	TPIN mg/l	TPOU mg/l	SSIN mg/l	SSOU mg/l	TOCIN mg/l	TOCOU mg/l
0.78	2	6-14-94	0.401	0.047	0.076	0.641	0.643	0.051	0.68	1.43	0.96	0.006	0.224	0.018	0.023	0.322	0.071	131	3	11.18	10.81
1.40	3	6-15-94	0.189	0.103	0.035	0.385	0.397	0.019	0.04	1.00	0.79	0.000	0.478	0.018	0.008	0.739	0.082	279	10	19.32	8.17
1.13	4	6-16-94	0.251	0.052	0.021	0.420	0.051	0.001	0.00	2.30	1.02	0.010	0.217	0.007	0.013	0.325	0.064	32	5	17.81	8.25
0.38	5	6-17-94	0.159	0.089	0.050	0.547	0.167	0.018	0.46	1.10	0.96	0.000	0.215	0.016	0.008	0.355	0.054	56	3	17.51	9.98
0.50	6	6-20-94	0.193	0.057	0.025	0.292	0.158	0.015	0.00	0.75	0.19	0.011	0.273	0.036	0.015	0.557	0.048	170	3	20.47	14.61
0.39	7	6-21-94	0.185	0.115	0.044	0.235	0.160	0.000	0.33	1.37	0.00	0.009	0.427	0.015	0.009	0.940	0.008	415	3	16.04	13.51
0.62	9	6-29-94	0.364	0.062	0.056	0.641	0.084	2.024	0.53	0.85	1.15	0.039	0.089	0.019	0.034	0.179	0.048	6	2	13.99	9.71
0.89	12	7-06-94	0.150	0.085	0.037	0.444	0.094	0.000	0.00	1.04	0.23	0.003	0.136	0.023	0.002	0.302	0.058	40	3	17.58	9.70
0.57	13	7-10-94	0.244	0.147	0.028	0.308	0.580	0.020	0.00	0.99	0.63	0.024	0.182	0.015	0.034	0.310	0.058	69	3	20.15	11.67
0.90	14	7-18-94	0.287	0.252	0.030	0.469	0.472	0.003	0.37	1.27	1.05	0.008	0.283	0.012	0.030	0.610	0.060	185	3	16.13	10.44
1.12	15	7-20-94	0.321	0.218	0.027	0.528	0.549	0.033	0.00	0.99	0.34	0.019	0.292	0.037	0.040	0.550	0.056	132	6	12.53	10.03
0.50	16	7-21-94	0.300	0.103	0.030	0.253	0.459	0.286	0.13	1.64	1.42	0.005	0.367	0.027	0.007	0.760	0.020	218	9	14.78	8.65
0.28	17	7-24-94	0.449	0.045	0.047	0.456	0.400	0.013	0.54	1.10	0.83	0.002	0.070	0.029	0.007	0.060	0.060	131	23	15.54	8.39
0.58	18	7-28-94	0.089	0.126	0.026	1.122	1.312	0.149	0.30	1.59	0.38	0.003	0.212	0.002	0.001	0.621	0.017	10	2	16.68	8.11
0.47	19	7-30-94	0.124	0.070	0.021	0.250	0.073	0.004	0.04	1.20	0.63	0.012	0.275	0.010	0.012	0.543	0.031	319	3	19.31	10.79
0.34	20	8-03-94	0.243	0.077	0.024	0.363	0.576	0.000	0.00	0.67	0.00	0.034	0.111	0.008	0.028	0.274	0.024	131	1	16.24	9.92
0.42	21	8-06-94	0.273	0.071	0.032	0.500	0.300	0.000	0.00	0.29	0.24	0.013	0.099	0.011	0.011	0.196	0.022	72	2	12.58	8.07
0.17	22	8-07-94	0.202	0.125	0.035	0.624	0.116	0.009	0.19	0.11	0.00	0.009	0.096	0.010	0.012	0.164	0.019	131	7	18.37	8.10
0.47	23	8-08-94	0.255	0.038	0.045	0.230	0.163	0.001	0.20	0.78	0.42	0.006	0.321	0.011	0.003	0.465	0.024	171	2	12.13	7.76
2.44	24	8-10-94	0.095	0.431	0.020	0.155	0.120	0.019	0.06	1.55	0.41	0.014	1.550	0.074	0.039	2.136	0.207	248	47	6.26	6.43
0.32	25	8-11-94	0.125	0.047	0.038	0.168	0.088	0.004	0.40	1.00	0.78	0.010	0.243	0.056	0.001	0.422	0.102	196	16	9.60	6.18
0.75	26	8-13-94	0.064	0.062	0.028	0.139	3.000	0.003	0.33	1.03	0.64	0.000	0.212	0.049	0.000	0.338	0.106	78	7	10.33	6.95
0.12	27	8-16-94	0.418	0.042	0.041	0.271	0.014	0.000	0.13	0.84	0.40	0.014	0.046	0.022	0.000	0.099	0.000	22	3	18.60	8.29
0.65	29	8-23-94	0.172	0.042	0.054	0.841	0.651	0.011	0.23	1.01	0.97	0.018	0.161	0.016	0.000	0.000	0.021	13	7	17.27	8.65
0.72	30	8-24-94	0.166	0.214	0.036	0.302	0.258	0.005	0.41	1.71	0.78	0.001	0.451	0.009	0.000	1.126	0.032	12	6	18.24	9.85
1.14	31	8-25-94	0.200	0.115	0.041	0.257	0.262	0.013	0.44	1.36	0.94	0.001	0.297	0.029	0.003	0.663	0.039	204	4	7.70	8.46
1.22	32	9-16-94	0.076	0.015	0.019	0.074	0.003	0.212	0.22	0.92	0.75	0.000	0.087	0.014	0.000	0.120	0.047	22	8	16.06	7.40
1.94	33	9-17-94	0.160	1.102	0.012	0.114	0.015	0.017	0.42	2.37	0.76	0.000	0.049	0.034	0.000	0.287	0.088	131	19	14.72	7.06
1.66	34	9-19-94	0.081	0.129	0.015	0.159	0.160	0.008	0.01	1.17	0.66	0.009	0.365	0.066	0.012	0.531	0.105	163	11	8.10	2.28
1.13	35	9-25-94	0.051	0.014	0.006	0.151	0.028	0.005	0.24	1.09	0.65	0.004	0.321	0.035	0.012	0.397	0.063	105	5	6.85	6.08
1.42	36	9-27-94	0.076	0.304	0.034	0.088	0.170	0.002	0.06	1.31	0.41	0.013	1.178	0.097	0.050	2.027	0.127	592	19	16.46	8.61
0.79	37	10-02-94	0.089	0.024	0.006	0.312	0.119	0.089	0.00	0.96	0.68	0.001	0.385	0.042	0.003	0.446	0.054	97	3	12.43	7.01
0.49	38	10-10-94	0.168	0.093	0.042	0.380	0.213	0.693	0.20	1.41	1.08	0.004	0.418	0.033	0.007	0.227	0.047	129	6	19.64	10.51
0.16	39	10-12-94	0.507	0.080	0.058	0.455	2.844	0.098	0.19	1.26	0.51	0.009	0.385	0.016	0.012	0.443	0.032	53	4	23.11	10.72
1.62	40	10-26-94	0.172	0.133	0.026	0.311	0.467	0.029	0.00	0.38	0.11	0.011	0.548	0.047	0.005	0.591	0.055	180	8	14.52	8.14
0.66	41	11-15-94	0.126	0.017	0.019	0.497	0.040	0.000	0.00	0.43	0.53	0.035	0.096	0.028	0.024	0.140	0.047	10	2	13.14	9.63
0.75	42	12-21-94	0.191	0.070	0.024	0.357	0.577	0.025	0.00	1.23	0.52	0.000	0.217	0.025	0.015	0.365	0.055	17	1	14.78	8.65
0.27	43	12-22-94	0.244	0.087	0.024	0.271	0.169	0.013	0.19	0.77	0.44	0.000	0.203	0.008	0.000	0.215	0.020	120	3	17.04	7.19
0.24	44	1-07-95	0.134	0.046	0.141	0.200	0.160	0.613	0.00	0.61	0.30	0.000	0.000	0.000	0.000	0.000	0.000	22	2	10.84	7.10
1.10	45	1-14-95	0.199	0.154	0.060	0.108	0.196	0.002	0.39	0.95	0.79	0.009	0.738	0.036	0.010	0.790	0.043	250	3	11.81	6.78
0.66	46	1-15-95	0.208	0.021	0.025	0.161	0.177	0.043	0.00	0.90	0.54	0.006	0.151	0.032	0.008	0.169	0.047	46	4	10.58	6.41
0.21	47	1-23-95	0.090	0.059	0.012	0.263	0.127	0.002	0.19	0.97	1.19	0.008	0.341	0.033	0.010	0.329	0.046	112	4	14.48	8.40
Average			**0.202**	**0.123**	**0.035**	**0.351**	**0.396**	**0.108**	**0.188**	**1.09**	**0.62**	**0.009**	**0.305**	**0.027**	**0.012**	**0.479**	**0.053**	**131**	**7**	**14.78**	**8.65**
Std. Dev.			**0.107**	**0.173**	**0.022**	**0.210**	**0.617**	**0.332**	**0.187**	**0.44**	**0.34**	**0.009**	**0.283**	**0.020**	**0.013**	**0.434**	**0.037**	**117**	**8**	**3.91**	**2.08**
C.V.			**0.531**	**1.403**	**0.635**	**0.597**	**1.560**	**3.066**	**0.997**	**0.408**	**0.551**	**1.046**	**0.927**	**0.735**	**1.045**	**0.905**	**0.705**	**0.891**	**1.184**	**0.265**	**0.241**
Maximum			**0.507**	**1.102**	**0.141**	**1.122**	**3.000**	**2.024**	**0.677**	**2.37**	**1.42**	**0.039**	**1.550**	**0.097**	**0.050**	**2.136**	**0.207**	**592**	**47**	**23.11**	**14.61**
Median			**0.187**	**0.079**	**0.030**	**0.305**	**0.170**	**0.013**	**0.188**	**1.018**	**0.637**	**0.008**	**0.234**	**0.023**	**0.009**	**0.360**	**0.048**	**124**	**4**	**15.158**	**8.397**
Minimum			**0.051**	**0.014**	**0.006**	**0.074**	**0.003**	**0.000**	**0.000**	**0.11**	**-0.02**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**6**	**1**	**6.26**	**2.28**
# Observations			**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**
%Efficiency					**72**			**73**			**43**			**91**			**89**		**95**		**41**

Table I-3. (continued). Constituent concentrations 1994-95

METALS AND HARDNESS

Laboratory Method LOD=Limit of Detection			ZINC FLAME ZN=10 ug/l			CADMIUM FURNACE CD=0.3 ug/l			COPPER FURNACE CU=0.1 ug/l			IRON FLAME FE=30 ug/l			LEAD FURNACE PB=2 ug/l			MANGANESE FURNACE MN=0.6 ug/l			HARDNESS HARD=0.02 mg/l		
RAIN in	NO	DATE	ZNRA ug/l	ZNIN ug/l	ZNOU ug/l	CDRA ug/l	CDIN ug/l	CDOU ug/l	CURA ug/l	CUIN ug/l	CUOU ug/l	FERA ug/l	FEIN ug/l	FEOU ug/l	PBRA ug/l	PBIN ug/l	PBOU ug/l	MNRA ug/l	MNIN ug/l	MNOU ug/l	HRA mg/l	HIN mg/l	HOU mg/l
0.78	2	6-14-94	182	25	12	0.50	0.30	0.10	2.8	4.6	1.4	83	723	255	2.2	0.0	0.0	5.1	17.7	2.9	2.5	432	411
1.40	3	6-15-94	103	37	12	0.20	0.30	0.00	1.0	3.8	1.2	61	4616	207	0.0	5.9	0.0	2.5	28.2	1.4	0.7	122	307
1.13	4	6-16-94	93	30	10	0.10	0.10	0.10	1.1	3.4	3.5	69	851	135	0.0	0.1	0.0	2.7	22.0	9.6	0.7	241	284
0.38	5	6-17-94	201	48	32	0.30	0.00	0.00	0.0	3.2	1.2	27	1159	185	0.0	0.6	0.1	1.5	25.0	15.9	0.5	248	301
0.50	6	6-20-94	80	40	13	0.20	0.40	0.10	1.7	3.5	1.9	81	3375	165	0.3	3.9	0.0	3.8	24.1	17.0	1.0	127	290
0.39	7	6-21-94	83	56	17	0.20	0.10	0.10	1.1	5.4	4.4	76	6511	151	0.2	0.0	1.4	2.4	44.6	13.8	1.0	156	279
0.62	9	6-29-94	135	40	15	0.20	0.20	0.10	2.7	7.7	0.5	221	253	268	2.8	2.7	1.3	11.2	16.3	42.4	1.5	144	286
0.89	12	7-06-94	261	39	20	0.30	0.10	0.00	2.7	2.7	3.7	74	820	196	2.8	1.9	1.1	4.0	22.2	10.7	1.0	254	244
0.57	13	7-10-94	104	43	19	0.30	0.20	0.00	3.5	4.0	4.4	61	1091	299	0.0	2.3	0.4	2.2	15.8	9.8	0.0	153	253
0.90	14	7-18-94	84	71	14	0.20	0.40	0.10	1.7	5.4	4.4	376	3176	156	1.1	7.4	0.0	9.0	25.8	8.2	1.5	101	234
1.12	15	7-20-94	66	68	25	0.20	0.30	0.40	8.7	9.1	7.4	52	5707	233	0.2	10.5	0.0	4.7	32.3	8.3	1.0	108	221
0.50	16	7-21-94	192	65	13	0.20	0.40	0.00	9.8	7.4	5.4	231	6358	276	1.4	9.6	0.0	6.2	35.6	9.7	1.0	125	211
0.28	17	7-24-94	115	40	17	1.15	0.20	0.05	8.2	7.3	6.7	120	404	347	0.3	0.9	0.0	3.5	15.7	17.0	0.0	251	220
0.58	18	7-28-94	33	615	15	0.30	0.30	0.00	10.2	10.1	12.6	59	4354	184	0.0	6.0	0.0	1.0	28.7	11.5	0.0	150	214
0.47	19	7-30-94	47	545	12	0.10	0.40	0.00	4.7	6.2	12.5	69	8174	148	0.0	5.2	0.0	2.0	37.5	4.8	0.0	217	199
0.34	20	8-03-94	54	70	11	0.60	0.20	0.00	1.7	11.9	3.1	62	1096	156	0.3	3.6	0.0	1.7	15.2	27.4	1.0	99	219
0.42	21	8-06-94	114	46	10	0.30	0.20	0.00	9.0	5.9	9.4	65	1539	135	0.3	1.7	0.0	0.6	19.8	9.8	1.0	161	211
0.17	22	8-07-94	23	48	6	0.20	0.10	0.00	6.7	16.9	8.1	100	778	101	0.0	0.9	0.0	0.2	27.7	3.3	1.0	265	203
0.47	23	8-08-94	64	7	3	0.30	0.20	0.20	5.9	7.3	2.7	26	3008	69	0.3	4.8	0.0	0.0	32.8	4.2	1.0	187	206
2.44	24	8-10-94	36	111	25	0.30	0.90	0.00	5.0	17.7	8.1	17	16175	987	0.0	23.0	0.3	2.4	87.5	11.6	1.0	82	173
0.32	25	8-11-94	39	50	12	0.50	0.30	0.10	4.6	6.8	3.4	37	4127	500	1.2	8.3	2.5	1.8	31.9	7.2	1.0	178	156
0.75	26	8-13-94	22	29	10	0.10	0.40	0.00	2.9	6.5	2.1	29	2190	258	1.5	4.3	1.0	1.1	20.9	9.2	1.0	154	162
0.12	27	8-16-94	192	41	4	0.70	0.20	0.00	4.1	3.4	1.4	70	718	207	0.0	1.8	0.0	5.7	28.3	12.7	1.0	451	188
0.65	29	8-23-94	83	27	7	0.20	0.10	0.00	4.1	2.9	2.2	75	1265	145	0.4	2.0	0.1	2.0	32.9	10.2	1.0	222	187
0.72	30	8-24-94	17	79	5	0.00	0.50	0.00	2.0	8.7	1.0	46	9084	150	0.0	16.9	0.0	1.8	56.0	8.0	0.0	174	193
1.14	31	8-25-94	20	37	17	0.10	0.40	0.10	2.9	3.4	4.8	51	4722	169	0.0	10.7	0.1	1.4	22.1	11.1	0.7	150	190
1.22	32	9-16-94	15	49	19	0.00	0.60	0.10	2.1	11.5	3.2	26	683	224	0.0	0.4	0.4	1.7	28.2	6.5	0.5	236	186
1.94	33	9-17-94	22	66	15	0.10	0.00	0.00	2.3	7.2	1.7	55	858	466	0.0	0.0	0.0	1.3	37.3	7.2	0.5	291	180
1.66	34	9-19-94	13	202	10	0.00	0.26	0.09	0.5	4.4	2.6	33	3433	29	0.0	5.8	2.1	1.5	37.8	11.3	0.5	143	153
1.13	35	9-25-94	28	29	9	0.10	0.20	0.20	1.9	4.6	3.3	13	2085	137	0.0	4.8	0.6	1.1	16.3	6.4	2.0	149	150
1.42	36	9-27-94	36	88	8	0.20	1.05	0.10	2.9	11.1	3.2	31	11127	511	1.3	18.2	1.7	2.8	112.5	11.4	1.2	137	151
0.79	37	10-02-94	34	41	12	0.10	0.20	0.10	6.2	4.0	4.7	82	1347	152	0.4	2.5	0.8	1.1	26.0	12.4	2.8	192	182
0.49	38	10-10-94	8	7	22	0.40	0.50	0.00	7.5	4.3	3.4	118	11189	245	1.4	4.1	0.5	2.2	75.2	9.7	1.0	232	203
0.16	39	10-12-94	119	74	5	0.70	0.10	0.00	4.0	3.3	1.9	71	1626	132	0.6	3.2	0.3	2.4	75.3	7.3	1.0	252	184
1.62	40	10-26-94	15	59	6	0.00	0.20	0.00	2.1	4.1	0.6	19	2104	192	0.9	5.5	0.7	0.4	27.0	7.2	0.7	132	175
0.66	41	11-15-94	13	32	12	0.20	0.20	0.00	6.2	7.8	2.6	29	229	62	0.0	2.5	0.4	0.0	8.0	12.6	0.0	177	211
0.75	42	12-21-94	60	111	14	0.20	0.00	0.10	6.6	12.5	5.4	33	444	104	1.7	3.3	1.5	0.0	4.1	10.1	0.5	430	217
0.27	43	12-22-94	43	90	31	0.00	0.20	0.10	6.1	1.0	5.2	60	4	97	0.8	3.6	1.0	1.0	26.2	4.4	1.0	270	205
0.24	44	1-07-95	88	87	21	0.20	0.20	0.00	2.6	12.6	4.6	51	336	84	0.4	3.7	0.9	1.3	18.9	12.2	1.0	199	219
1.10	45	1-14-95	31	76	8	0.20	0.34	0.00	5.0	3.5	2.7	30	3578	114	0.9	8.6	0.3	0.8	25.5	5.1	0.7	119	178
0.66	46	1-15-95	31	50	12	0.00	0.30	0.00	1.4	4.3	0.4	34	580	449	0.2	2.8	0.8	0.7	6.7	5.5	1.6	189	162
0.21	47	1-23-95	36	47	29	0.10	0.10	0.10	2.2	2.5	3.6	39	2521	171	0.5	5.6	2.3	0.8	16.2	4.0	1.0	171	184
Average			**72**	**81**	**14**	**0.24**	**0.28**	**0.06**	**4.01**	**6.52**	**3.96**	**71**	**3200**	**220**	**0.6**	**5.0**	**0.5**	**2.4**	**31.1**	**10.3**	**0.9**	**197**	**214**
Std. Dev.			**60**	**116**	**7**	**0.22**	**0.21**	**0.08**	**2.67**	**3.79**	**2.85**	**66**	**3509**	**164**	**0.8**	**4.9**	**0.7**	**2.3**	**21.2**	**6.8**	**0.6**	**85**	**51**
C.V.			**0.83**	**1.43**	**0.50**	**0.91**	**0.75**	**1.41**	**0.67**	**0.58**	**0.72**	**0.93**	**1.1**	**0.74**	**1.31**	**0.98**	**1.28**	**0.99**	**0.68**	**0.66**	**0.65**	**0.43**	**0.24**
Maximum			**261**	**615**	**32**	**1.15**	**1.05**	**0.40**	**10.20**	**17.70**	**12.60**	**376**	**16175**	**987**	**2.8**	**23.0**	**2.5**	**11.2**	**112.5**	**42.4**	**2.8**	**451**	**411**
Minimum			**8**	**7**	**3**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**0.40**	**13**	**4**	**29**	**0.0**	**0.0**	**0.0**	**0.0**	**4.1**	**1.4**	**0.0**	**82**	**150**
Median			**51**	**49**	**12**	**0.20**	**0.20**	**0.00**	**2.90**	**5.40**	**3.35**	**60**	**1856**	**170**	**0.3**	**3.7**	**0.3**	**1.8**	**26.1**	**9.7**	**1.0**	**176**	**204**
# Observations			**42**	**42**	**42**	**42**	**42**	**42**	**41**	**42**	**42**	**41**	**42**	**42**	**41**	**42**	**42**	**40**	**42**	**42**	**42**	**42**	**42**
%Efficiency					**83**			**80**			**39**			**93**			**89**			**67**			**-8**

APPENDIX J

Mass Loading for Constituents of Water Quality Concern

Table J-1. Mass loading 1990-91. NO=storm number, INFLO and OUTFL=water measured over weirs, RAIN (cu ft)=water falling directly on the pond as rainfall. The suffix RA=amount of constituent in rainfall, IN=amount measured at the inflow and OU=amount at outflow.

NUTRIENTS

			WATER VOLUME			AMMONIA			NITRATE+NITRITE			ORGANIC NITROGEN			ORTHO-PHOSPHATE			TOTAL PHOSPHORUS		
NO	YEAR	RAIN in	RAIN cu.ft.	INFLO cu.ft.	OUTFL cu.ft.	NH3RA grams	NH3IN grams	NH3OU grams	NOXRA grams	NOXIN grams	NOXOU grams	ONRA grams	ONIN grams	ONOU grams	OPRA grams	OPIN grams	OPOU grams	TPRA grams	TPIN grams	TPOU grams
2	5-24-90	0.37	424	433	0	9.2	0.2	0.0	5.9	1.5	0.0	3.6	11.4	0.0	1.7	2.4	0.0	2.0	3.0	0.0
3	6-04-90	0.69	801	4311	1858	6.4	6.1	2.1	10.4	26.9	1.1	37.0	58.6	45.8	5.6	22.0	1.9	5.6	16.7	4.2
4	6-11-90	0.46	528	1798	562	2.1	3.1	1.0	9.6	25.0	0.5	2.1	82.0	25.0	0.1	5.5	1.0	0.3	8.9	2.0
5	6-23-90	1.05	1219	7112	836	3.4	6.0	0.4	2.8	20.1	0.9	4.8	135.7	12.3	0.4	66.9	2.5	10.1	79.6	4.0
6	6-24-90	0.83	964	4994	7416	1.8	3.0	48.9	2.0	9.6	6.7	5.2	112.7	117.8	0.1	38.5	10.3	0.1	43.8	19.3
7	7-08-90	0.86	998	3859	3087	13.2	30.3	7.8	10.6	51.7	40.0	10.8	89.8	116.0	0.6	33.8	7.0	1.3	48.3	13.6
8	7-11-90	1.10	1277	8535	3755	7.3	11.4	10.5	7.2	8.7	14.4	7.6	344.5	96.7	0.5	102.0	10.7	0.5	159.1	20.5
9	7-12-90	1.12	1300	12644	15750	11.3	126.4	19.2	1.9	253.9	19.2	1.8	243.1	266.3	2.4	157.2	54.9	14.8	199.1	102.1
10	7-13-90	0.48	551	2980	2181	2.1	3.0	9.3	2.3	20.3	2.0	3.6	80.5	40.6	0.1	39.4	6.4	0.1	47.2	11.4
11	7-14-90	1.78	2067	35817	28908	15.3	86.2	43.4	1.8	133.9	144.9	2.9	943.3	725.3	0.3	413.8	105.6	0.3	518.3	193.2
12	7-19-90	0.29	337	1629	4658	0.2	8.3	3.2	0.5	14.2	29.3	0.5	64.4	133.9	0.2	8.3	12.3	0.3	16.2	20.7
13	8-01-90	0.40	464	1167	1147	3.4	0.9	2.4	15.6	12.4	0.6	6.7	90.0	79.8	0.1	2.6	0.6	0.1	6.8	6.1
14	8-15-90	0.32	366	1604	719	1.3	2.2	2.0	1.7	1.3	2.0	2.7	52.9	24.9	0.1	9.2	2.1	0.1	15.1	3.9
15	8-19-90	0.40	464	1490	1083	2.7	6.5	2.6	2.1	13.0	2.6	1.8	32.9	35.8	0.1	6.6	3.1	0.1	8.6	5.1
16	8-26-90	0.62	720	3005	2404	4.9	4.3	5.2	8.4	6.6	0.3	1.0	84.6	69.0	0.1	30.7	5.6	0.1	38.7	8.1
17	8-29-90	0.94	1091	5795	4636	4.8	25.3	4.9	9.5	15.8	0.7	13.3	54.2	115.1	0.2	103.7	13.1	0.2	0.8	15.8
18	9-01-90	1.06	1231	8441	8011	13.2	13.1	10.7	20.2	52.1	7.0	40.7	387.3	162.4	1.2	215.1	33.6	0.9	269.4	41.3
19	9-17-90	1.90	2206	13247	13081	14.3	9.8	36.3	27.2	118.5	59.6	3.1	288.9	245.6	0.8	177.8	52.6	0.8	212.0	74.8
20	9-30-90	0.65	755	5312	3719	3.9	5.3	2.4	2.6	26.9	3.4	1.1	118.1	95.9	0.1	37.3	8.4	0.1	53.1	15.5
21	10-03-90	0.45	522	1854	3109	3.4	2.1	2.0	2.4	7.6	0.4	1.6	37.8	65.9	0.1	10.8	6.2	0.1	14.3	8.5
22	10-10-90	2.64	3065	32250	20220	6.9	26.5	7.4	5.5	35.6	2.9	9.5	808.3	518.2	0.4	354.4	205.0	0.4	440.2	244.5
23	1-15-91	2.34	2717	20352	13493	6.5	23.6	29.8	3.4	228.2	101.6	11.0	617.3	462.4	0.4	247.8	98.6	0.8	265.7	126.9
TOTALS			24068	178628	140632	138	404	251	154	1084	440	172	4738	3455	15	2086	641	39	2465	941
#OBS			22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
%EFFICIENCY								54			64			30			69			62

Table J-1. Mass loading 1990-91 (continued)

METALS AND TOTAL SUSPENDED SOLIDS

		WATER VOLUME				TOTAL ZINC			TOTAL IRON			TOTAL CADMIUM			SUSPENDED SOLIDS		
NO	YEAR	RAIN in	RAIN cu.ft.	INFLO cu.ft.	OUTFL cu.ft.	ZNRA mg/l	ZNIN mg/l	ZNOU mg/l	FERA mg/l	FEIN mg/l	FEOU mg/l	CDRA mg/l	CDIN mg/l	CDOU mg/l	SSRA mg/l	SSIN mg/l	SSOU mg/l
2	5-24-90	0.37	424	433	0	0.4	0.6	0.0	1.3	3.6	0.0	0.0	0.0	0.0	25	81	0
3	6-04-90	0.69	801	4311	1858	1.1	3.7	1.6	1.6	42.7	13.2	0.0	1.7	0.8	25	3416	374
4	6-11-90	0.46	528	1798	562	0.9	2.0	0.5	0.9	9.2	10.4	0.1	0.4	0.2	31	341	90
5	6-23-90	1.05	1219	7112	836	1.4	11.7	0.5	3.1	211.7	6.7	0.1	1.0	0.1	205	12118	378
6	6-24-90	0.83	964	4994	7416	1.0	6.2	6.5	0.0	65.3	94.1	0.0	0.3	0.2	175	2718	4259
7	7-08-90	0.86	998	3859	3087	1.2	3.9	3.6	1.7	64.8	57.5	0.0	0.2	0.1	53	2535	798
8	7-11-90	1.10	1277	8535	3755	0.4	8.5	2.2	1.6	133.7	60.7	0.0	0.2	0.1	6	7051	1063
9	7-12-90	1.12	1300	12644	15750	0.7	20.1	4.9	4.9	132.8	147.6	0.0	1.1	2.7	109	7359	7413
10	7-13-90	0.48	551	2980	2181	0.6	5.2	1.5	0.6	28.0	25.7	0.1	0.1	0.4	33	2399	464
11	7-14-90	1.78	2067	35817	28908	1.4	10.1	13.9	0.1	269.8	335.7	0.1	1.0	0.8	36	16179	7745
12	7-19-90	0.29	337	1629	4658	0.0	1.7	1.5	0.0	17.4	69.0	0.1	0.0	1.6	20	555	2196
13	8-01-90	0.40	464	1167	1147	1.4	1.7	0.1	0.7	4.1	0.3	0.0	0.3	0.1	28	298	909
14	8-15-90	0.32	366	1604	719	0.5	3.6	1.2	0.0	26.5	11.5	0.1	0.4	0.1	9	1312	335
15	8-19-90	0.40	464	1490	1083	0.6	3.1	2.0	0.1	10.8	12.7	0.0	0.4	0.5	28	413	420
16	8-26-90	0.62	720	3005	2404	1.1	5.6	5.0	0.9	116.3	31.7	0.0	0.5	0.5	42	7407	853
17	8-29-90	0.94	1091	5795	4636	1.5	12.0	7.0	0.0	160.5	45.8	0.5	2.3	2.5	48	13121	1632
18	9-01-90	1.06	1231	8441	8011	7.0	12.7	6.1	0.0	103.7	62.6	0.1	4.8	0.2	73	8195	2183
19	9-17-90	1.90	2206	13247	13081	1.2	16.1	8.9	8.1	93.8	92.6	0.1	7.1	0.4	72	2904	2934
20	9-30-90	0.65	755	5312	3719	0.2	5.7	1.1	0.4	127.0	57.9	0.0	0.2	0.1	10	5389	800
21	10-03-90	0.45	522	1854	3109	0.2	5.2	2.4	1.6	89.3	34.3	0.0	0.2	0.5	31	483	626
22	10-10-90	2.64	3065	32250	20220	2.8	40.2	10.3	8.7	484.1	189.0	0.5	6.4	1.7	182	22248	4157
23	1-15-91	2.34	2717	20352	13493	3.1	28.8	22.9	0.4	184.4	84.1	0.1	0.6	0.4	460	17983	11
	TOTALS		**24068**	**178628**	**140632**	**29**	**208**	**104**	**37**	**2379**	**1443**	**2**	**29**	**14**	**1701**	**134505**	**39641**
	#OBS		**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**
	%EFFICIENCY							**56**			**40**			**55**			**71**

Table J-2. **Calculations for Mass Loadings from June 1993 through January 1994. RAIN is the volume of rain falling directly on the pond, INFLO is the volume measured entering the pond, and OUTFL is the volume discharged from the pond. Abbreviations are in Appendix R.**

NUTRIENTS AND SUSPENDED SOLIDS

			WATER VOLUME			AMMONIA			NITRATE+NITRITE			ORGANIC NITROGEN			ORTHO-PHOSPHATE			TOTAL PHOSPHORUS			SUS. SOLIDS	
RAIN in	NO	DATE	RAIN cu ft	INFLO cu ft	OUTFL cu ft	NH3RA grams	NH3IN grams	NH3OU grams	NOXRA grams	NOXIN grams	NOXOU grams	TONRA grams	TONIN grams	TONOU grams	OPRA grams	OPIN grams	OPOU grams	TPRA grams	TPIN grams	TPOU grams	SSIN grams	SSOU grams
1.06	1	6-24-93	1385	11566	3430	6.9	6.9	1.9	9.2	18.3	1.9	8	468	14	0.3	85.8	0.5	0.9	188.7	0.6	17310	1457
0.94	2	6-30-93	1194	10336	8986	10.3	46.2	33.3	14.7	34.2	8.3	2	425	343	0.4	276.3	30.6	0.5	604.8	52.8	77277	7488
1.05	3	7-12-93	1486	8353	4732	12.2	31.5	9.4	37.5	103.8	13.4	10	251	105	0.2	105.5	12.6	0.2	210.8	56.8	34656	6600
0.97	4	7-21-93	1683	11701	9353	14.3	172.3	10.1	25.6	44.4	3.4	8	331	178	0.2	65.6	13.0	0.2	120.6	32.1	11929	3036
0.77	5	8-13-93	997	216	0	6.7	0.9	0.0	20.7	0.8	0.0	0	0	0	0.3	1.4	0.0	10.2	3.8	0.0	52	0
0.43	6	8-14-93	540	353	0	1.4	0.6	0.0	6.9	0.9	0.0	0	9	0	0.1	1.8	0.0	6.3	3.1	0.0	67	0
2.11	7	8-25-93	2756	19665	10807	2.4	88.5	2.1	21.1	284.0	45.9	204	123	249	0.4	3.9	75.9	1.8	228.9	101.9	42660	9411
3.95	8	8-26-93	5131	65652	86337	17.1	7.4	726.2	4.4	316.1	261.6	15	2056	4188	1.2	260.3	611.3	3.3	472.3	831.3	15841	50613
1.62	9	8-29-93	2432	31047	27448	15.4	29.0	16.3	28.2	44.0	1.6	17	1949	795	0.6	123.1	214.5	1.6	223.3	282.2	79045	8286
0.94	11	9-05-93	1194	9540	7157	6.9	7.0	10.3	19.4	0.0	2.8	11	430	148	0.2	142.1	32.6	0.4	771.3	61.4	1451	2122
2.40	12	9-06-93	3321	45909	44741	11.9	45.2	40.5	17.2	0.0	65.9	8	1289	1325	0.9	336.3	192.6	2.4	484.8	333.2	5656	15331
0.92	13	9-11-93	1162	15433	15233	7.5	3.1	3.0	14.7	31.9	3.9	9	502	523	0.4	177.0	48.3	0.8	348.3	79.8	45455	6471
0.65	14	9-14-93	1111	12852	12018	6.0	26.2	7.1	7.4	0.7	0.0	8	404	350	0.6	156.5	32.3	0.4	249.7	59.2	20146	3356
1.49	15	9-21-93	1892	20048	19055	1.1	25.0	32.8	0.6	17.0	50.3	29	371	263	0.0	79.5	34.0	9.9	258.9	67.5	28308	8634
0.77	16	9-27-93	1022	5303	3532	1.9	4.5	1.0	0.3	6.3	0.6	13	170	86	0.3	22.2	3.9	0.2	56.0	9.8	1874	965
0.81	17	10-6-93	1035	3603	2852	1.2	1.4	1.3	2.1	5.3	1.1	18	107	71	0.0	1.2	0.2	0.2	29.3	6.3	912	424
0.49	18	10-09-93	629	2785	2850	1.4	1.2	0.0	3.0	2.9	0.0	9	101	31	0.0	2.6	0.9	0.2	18.0	5.3	631	242
0.74	19	10-15-93	940	10028	8639	3.4	6.2	4.6	1.9	0.7	0.0	1	283	0	0.2	37.2	2.4	1.3	79.2	17.1	2556	1223
1.34	20	10-30-93	1702	13828	10146	4.6	29.8	25.3	3.2	15.7	2.3	2	329	244	0.4	79.9	4.9	0.5	113.6	18.4	4699	1437
0.24	21	11-20-93	305	1195	676	2.1	0.7	1.3	2.3	4.0	0.2	2	46	17	0.1	1.2	0.9	0.2	1.7	0.2	135	77
0.18	22	12-11-93	229	1432	0	1.1	0.2	0.0	6.3	2.6	0.0	1	24	0	0.1	1.9	0.0	0.4	3.4	0.0	81	0
0.28	23	12-15-93	356	3974	0	2.1	1.1	0.0	1.7	10.6	0.0	2	154	0	0.2	0.0	0.0	0.5	10.4	0.0	225	0
0.27	24	12-20-93	343	5963	3011	3.7	1.9	0.7	4.8	45.8	1.0	4	107	64	1.0	4.2	1.0	1.3	8.1	4.3	338	426
0.20	25	12-23-93	254	4613	2434	2.4	1.2	4.6	2.6	36.1	1.7	2	76	56	0.2	2.6	1.0	0.4	4.6	2.6	131	207
0.50	26	12-24-93	635	14682	9104	2.9	18.3	3.1	3.4	251.1	2.6	3	170	131	0.2	3.7	3.6	0.4	72.8	11.9	416	1289
0.86	27	1-02-94	1092	10153	6012	5.5	7.2	3.9	3.2	105.5	12.6	6	187	92	0.2	4.0	4.6	0.6	8.3	11.1	288	1362
0.28	28	1-03-94	349	6275	4806	1.7	5.0	1.6	2.3	59.5	1.8	2	84	46	0.1	6.8	1.1	0.2	14.2	5.6	533	1089
1.05	29	1-13-94	1346	12570	10269	6.7	10.3	2.9	2.6	3.6	0.0	7	353	282	0.3	37.0	3.8	0.6	67.3	14.0	4628	872
1.17	30	1-17-94	1492	20248	19106	3.4	33.8	17.9	1.3	5.2	1.6	3	815	338	0.0	233.4	39.0	0.2	412.9	91.4	6881	5952
TOTAL			**38013**	**379323**	**332734**	**164**	**613**	**961**	**269**	**1451**	**485**	**404**	**11615**	**9942**	**9**	**2253**	**1366**	**46**	**5069**	**2157**	**404178**	**138372**
NO. OBS.			**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**
% EFFICIENCY								**-24**			**72**			**17**			**40**			**58**		**66**

Data was removed between December 12 and January 3 because of problems with rain collector which sampled bulk precipitation during this period and a water main leak into the inflow ditch.

TOTAL			**34755**	**332231**	**307367**	**145**	**578**	**947**	**244**	**940**	**465**	**384**	**10813**	**9551**	**7**	**2230**	**1354**	**42**	**4947**	**2121**	**402167**	**133999**
NO. OBS.			**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**
%EFFICIENCY								**-31**			**61**			**15**			**39**			**57**		**67**

Table J-2. (Continued) CALCULATIONS FOR MASS LOADING - 1993-94

Metals

1899.00			WATER VOLUME			ZINC			CADMIUM			COPPER			IRON			LEAD			MANGANESE			HARDNESS		
RAIN in	NO	DATE	RAIN cu ft	INFLOW cu ft	OUTFLOW cu ft	ZNRA grams	ZNIN grams	ZNOU grams	CDRA grams	CDIN grams	CDOU grams	CURA grams	CUIN grams	CUOU grams	FERA grams	FEIN grams	FEOU grams	PBRA grams	PBIN grams	PBOU grams	MNRA grams	MNIN grams	MNOU grams	HRA grams	HIN grams	HOU grams
1.06	1	6-24-93	1385	11566	3430	3.73	7.83	0.49	0.04	0.00	0.00	0.07	0.75	0.58	2	604	1	0.03	0.00	0.00	0.07	19.6	0.4	0	62234	13988
0.94	2	6-30-93	1194	10336	8986	3.21	18.76	7.38	0.02	0.13	0.05	0.10	2.87	0.67	7	1946	202	0.00	3.69	0.00	0.27	10.6	3.1	101	33077	47334
1.05	3	7-12-93	1486	8353	4732	5.26	9.18	2.95	0.03	0.00	0.00	0.12	0.95	0.54	2	729	380	0.00	0.00	0.00	0.11	5.5	0.2	0	30989	22380
0.97	4	7-21-93	1683	11701	9353	5.67	15.34	5.56	0.13	0.00	0.08	0.23	1.86	0.53	10	524	121	0.00	1.52	0.00	0.31	9.6	4.7	191	57659	34699
0.77	5	8-13-93	997	216	0	6.01	0.20	0.00	0.03	0.00	0.00	0.06	0.02	0.00	3	7	0	0.05	0.01	0.00	0.13	0.4	0	85	1132	0
0.43	6	8-14-93	540	353	0	2.22	0.08	0.00	0.00	0.00	0.00	0.02	0.01	0.00	1	5	0	0.02	0.01	0.00	0.06	0.3	0	0	1849	0
2.11	7	8-25-93	2756	19665	10807	2.73	13.92	7.65	0.02	0.33	0.06	0.27	1.67	1.22	10	1431	282	0.06	2.78	0.43	0.22	20.6	3.1	109	69057	21118
3.95	8	8-26-93	5131	65652	86337	2.76	2.97	58.68	0.04	0.33	0.34	0.64	5.58	11.74	12	2741	1015	0.13	1.30	2.69	0.20	20.5	33.5	0	111556	3e+05
1.62	9	8-29-93	2432	31047	27448	16.12	20.22	20.21	0.07	0.15	0.14	0.19	2.64	1.79	6	1669	274	0.12	3.17	1.35	0.23	27.2	14	0	97597	1e+05
0.94	11	9-05-93	1194	9540	7157	3.08	3.24	4.66	0.01	0.07	0.04	0.00	0.00	0.63	1	236	57	0.01	0.00	0.14	0.09	20.2	4.4	0	62410	29187
2.40	12	9-06-93	3321	45909	44741	3.67	23.40	21.54	0.02	0.31	0.37	0.00	0.00	0.13	2	835	465	0.00	0.00	2.79	0.00	53.8	17.4	0	230125	155849
0.92	13	9-11-93	1162	15433	15233	2.60	8.74	16.82	0.01	0.04	0.02	0.03	0.87	0.60	1	797	168	0.03	2.01	0.35	0.03	12.6	6	0	52885	61259
0.65	14	9-14-93	1111	12852	12018	3.21	12.37	11.49	0.01	0.04	0.05	0.04	1.57	1.62	1	737	120	0.01	1.24	0.48	0.00	9.7	1.6	38	45860	48670
1.49	15	9-21-93	1892	20048	19055	2.09	15.90	8.27	0.01	0.07	0.04	0.13	1.36	1.56	1	714	247	0.03	1.27	0.30	0.05	9.0	4.4	64	43150	56122
0.77	16	9-27-93	1022	5303	3532	4.08	5.41	1.46	0.01	0.14	0.01	0.01	0.53	0.17	1	136	20	0.02	0.35	0.09	0.05	3.5	0.8	41	22077	12303
0.81	17	10-06-	1035	3603	2852	0.35	2.45	0.73	0.00	0.01	0.01	0.00	0.22	0.02	2	39	14	0.02	0.19	0.09	0.03	1.8	0.5	29	18877	9369
0.49	18	10-09-	629	2785	2850	1.16	1.66	0.48	0.00	0.00	0.01	0.00	0.00	0.56	1	56	9	0.01	0.09	0.16	0.03	3.6	0.5	0	19639	10896
0.74	19	10-15-	940	10028	8639	0.19	5.30	1.15	0.00	0.00	0.02	0.00	0.57	0.32	1	170	40	0.03	0.40	0.24	0.03	11.5	1.5	0	69862	32050
1.34	20	10-30-	1702	13828	10146	0.67	8.07	6.61	0.00	0.04	0.05	0.05	0.81	0.29	2	139	43	0.00	0.00	0.00	0.00	5.2	1.8	0	63049	54594
0.24	21	11-20-	305	1195	676	2.11	0.68	1.30	0.00	0.00	0.01	0.02	0.03	0.04	1	7	3	0.01	0.00	0.00	0.02	1.5	0.4	0	18376	4365
0.18	22	12-11-	229	1432	0	4.52	1.14	0.00	0.02	0.00	0.00	0.07	0.05	0.00	1	7	0	0.02	0.01	0.00	0.05	0.7	0	6	11558	0
0.28	23	12-15-	356	3974	0	0.48	1.58	0.00	0.00	0.00	0.00	0.05	0.32	0.00	1	13	0	0.01	0.02	0.00	0.03	1.0	0	0	26898	0
0.27	24	12-20-	343	5963	3011	4.23	3.38	0.85	0.01	0.00	0.00	0.02	0.02	0.00	1	14	9	0.02	0.00	0.00	0.04	1.0	0.4	0	38841	14581
0.20	25	12-23-	254	4613	2434	0.68	2.87	1.38	0.01	0.01	0.00	0.01	0.00	0.00	0	9	7	0.01	0.00	0.01	0.01	0.5	0.2	7	31223	12063
0.50	26	12-24-	635	14682	9104	2.66	10.38	4.49	0.01	0.00	0.00	0.03	0.00	0.00	1	18	24	0.01	0.05	0.05	0.03	1.1	0.4	54	99791	47182
0.86	27	1-02-94	1092	10153	6012	0.83	5.46	2.55	0.00	0.04	0.00	0.00	0.00	0.00	3	14	23	0.03	0.03	0.06	0.03	1.3	0.5	31	69871	31158
0.28	28	1-03-94	349	6275	4806	2.98	4.62	2.18	0.02	0.00	0.01	0.04	0.00	0.00	1	17	13	0.02	0.09	0.00	0.03	1.0	0.5	0	45493	27357
1.05	29	1-13-94	1346	12570	10269	4.08	6.02	1.02	0.02	0.01	0.01	0.09	0.34	0.29	2	148	41	0.03	0.28	0.05	0.03	7.0	1.5	0	81520	53801
1.17	30	1-17-94	1492	20248	19106	1.23	16.06	7.30	0.00	0.07	0.03	0.02	1.32	2.35	2	1348	275	0.00	3.18	0.65	0.01	11.3	3.4	0	62503	81162
TOTAL			**38013**	**379323**	**332734**	**93**	**227**	**197**	**0.55**	**1.81**	**1.35**	**2.32**	**24.34**	**25.66**	**80**	**15109**	**3852**	**0.72**	**21.70**	**9.93**	**2.20**	**271.4**	**105.2**	**757**	**1579157**	**1272159**
NUMBER OBS			**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**
% EFFICIENCY								**38**						**4**			**75**			**56**			**62**			**19**

Data for storms from December 11 through January 3 were removed because of problems. The rainfall sampler collected only bulk samples and a leak into the inflow ditch diluted inflow samples during this period.

TOTAL			**34755**	**332231**	**307367**	**76**	**198**	**186**	**0.48**	**1.76**	**1.31**	**2.08**	**23.96**	**25.66**	**72**	**15017**	**3777**	**0.61**	**21.49**	**9.81**	**1.95**	**264.8**	**103**	**658**	**1255483**	**1139818**
NUMBER OBS			**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**
% EFFICIENCY								**32**			**42**			**1**			**75**			**56**			**61**			**9**

Table J-3. **Mass loading for 1994-95. NO=storm number, INFLO and OUTFL=water measured over weirs, RAIN=water falling direcly on the pond as rainfall. The suffix RA=amount of constituent in rainfall, IN=amount measured at inflow and OU=amount at outflow**

1994-95			WATER VOLUME			AMMONIA-N			NITRATE+NITRITE-N			ORGANIC NITROGEN			ORTHO-PHOSPHORUS			TOTAL PHOSPHORUS			SUS.SOLIDS	
RAIN in	NO	DATE	RAIN cu ft	INFLO cu ft	OUTFL cu ft	NH3RA grams	NH3IN grams	NH3OU grams	NOXRA grams	NOXIN grams	NOXOU grams	TONRA grams	TONIN grams	TONOU grams	OPRA grams	OPIN grams	OPOU grams	TPRA grams	TPIN grams	TPOU grams	SSIN grams	SSOU grams
0.78	2	6-14-94	1727	3736	311	19.6	5.0	0.7	31.4	68.0	0.4	33	151	8	0.3	23.7	0.2	1.1	34.1	0.6	13860	24
1.40	3	6-15-94	3100	12464	10946	16.6	36.4	10.8	33.8	140.1	5.9	3	354	245	0.0	168.7	5.6	0.7	260.9	25.4	98393	3242
1.13	4	6-16-94	2502	13025	13911	17.8	19.2	8.3	29.8	18.8	0.4	0	847	402	0.7	80.0	2.8	0.9	119.9	25.2	11703	1931
0.38	5	6-17-94	841	3093	7663	3.8	7.8	10.9	13.0	14.6	3.9	11	96	209	0.0	18.8	3.5	0.2	31.1	11.7	4937	593
0.50	6	6-20-94	1107	3946	1878	6.1	6.4	1.3	9.2	17.7	0.8	0	84	10	0.3	30.5	1.9	0.5	62.2	2.6	19026	157
0.39	7	6-21-94	863	5032	6050	4.5	16.4	7.5	5.7	22.8	0.0	8	195	0	0.2	60.9	2.6	0.2	134.0	1.4	59140	514
0.62	9	6-29-94	1372	2917	884	14.1	5.1	1.4	24.9	6.9	50.7	20	70	29	1.5	7.4	0.5	1.3	14.8	1.2	506	40
0.89	12	7-06-94	1970	3684	3239	8.4	8.9	3.4	24.8	9.8	0.0	0	108	21	0.2	14.2	2.1	0.1	31.5	5.3	4173	281
0.57	13	7-10-94	1284	4309	4976	8.9	17.9	3.9	11.2	70.8	2.8	0	121	89	0.9	22.2	2.1	1.2	37.8	8.2	8420	455
0.90	14	7-18-94	1764	5206	2103	14.3	37.2	1.8	23.4	69.6	0.2	18	187	63	0.4	41.7	0.7	1.5	89.9	3.6	27255	188
1.12	15	7-20-94	2480	10289	7827	22.5	63.5	6.0	37.1	160.0	7.3	0	288	76	1.3	85.1	8.2	2.8	160.3	12.4	38390	1308
0.50	16	7-21-94	1129	7343	12229	9.6	21.4	10.4	8.1	95.5	99.0	4	340	493	0.2	76.3	9.4	0.2	158.0	6.9	45334	3006
0.28	17	7-24-94	619	1303	3978	7.9	1.7	5.2	8.0	14.8	1.4	9	41	93	0.0	2.6	3.2	0.1	2.2	6.8	4834	2591
0.58	18	7-28-94	2591	8582	8715	6.5	30.6	6.4	82.3	318.9	36.8	22	387	95	0.2	51.5	0.5	0.1	150.9	4.2	2430	494
0.47	19	7-30-94	1041	6334	8545	3.7	12.6	5.1	7.4	13.1	1.0	1	215	152	0.4	49.3	2.4	0.4	97.4	7.5	57186	814
0.34	20	8-03-94	852	1273	1267	5.9	2.8	0.9	8.8	20.8	0.0	0	24	0	0.8	4.0	0.3	0.7	9.9	0.9	4723	47
0.42	21	8-06-94	930	2210	1961	7.2	4.4	1.8	13.2	18.8	0.0	0	18	13	0.3	6.2	0.6	0.3	12.3	1.2	4495	94
0.17	22	8-07-94	376	921	585	2.2	3.3	0.6	6.6	3.0	0.1	2	3	0	0.1	2.5	0.2	0.1	4.3	0.3	3417	116
0.47	23	8-08-94	1041	5790	6364	7.5	6.2	8.1	6.8	26.7	0.2	6	128	75	0.2	52.6	2.0	0.1	76.2	4.3	28110	360
2.44	24	8-10-94	5059	34540	21124	13.6	421.6	12.0	22.2	117.4	11.4	8	1515	245	2.0	1516.2	44.3	5.6	2089.4	123.8	242391	28079
0.32	25	8-11-94	664	3164	12366	2.4	4.2	13.3	3.2	7.9	1.4	7	90	274	0.2	21.8	19.6	0.0	37.8	35.7	17592	5764
0.75	26	8-13-94	1716	8565	8555	3.1	15.0	6.8	6.8	727.7	0.7	16	249	156	0.0	51.4	11.9	0.0	82.0	25.7	18993	1797
0.12	27	8-16-94	332	695	1278	3.9	0.8	1.5	2.5	0.3	0.0	1	16	14	0.1	0.9	0.8	0.0	1.9	0.0	439	107
0.65	29	8-23-94	1693	5936	4582	8.2	7.1	7.0	40.3	109.4	1.4	11	169	125	0.9	27.1	2.1	0.0	0.0	2.7	2147	908
0.72	30	8-24-94	1616	7840	6876	7.6	47.5	7.0	13.8	57.3	1.0	19	379	153	0.0	100.1	1.8	0.0	250.0	6.2	2624	1083
1.14	31	8-25-94	2590	17912	16838	14.7	58.3	19.6	18.9	132.9	6.2	32	687	448	0.1	150.7	13.8	0.2	336.3	18.6	103381	1907
1.22	32	9-16-94	2701	14478	10324	5.8	6.2	5.6	5.7	1.2	62.0	17	375	220	0.0	35.7	4.1	0.0	49.2	13.7	9119	2459
1.94	33	9-17-94	6099	38192	61355	27.6	1191.9	20.9	19.7	16.2	29.5	73	2561	1317	0.0	53.0	59.1	0.0	310.4	152.9	141689	33014
1.66	34	9-19-94	3675	31601	27619	8.4	115.3	12.0	16.5	143.2	6.2	1	1051	514	0.9	326.5	51.5	1.2	474.9	82.1	145875	8678
1.13	35	9-25-94	2502	13518	10558	3.6	5.4	1.8	10.7	10.7	1.5	17	418	195	0.3	122.9	10.5	0.9	152.0	18.8	40149	1495
1.42	36	9-27-94	4693	38040	39268	10.1	327.0	37.8	11.7	183.1	2.2	8	1407	459	1.7	1269.1	107.9	6.6	2183.7	141.2	637757	21129
0.79	37	10-02-94	1727	9495	9561	4.4	6.5	1.6	15.3	32.0	24.1	0	259	184	0.0	103.5	11.4	0.1	119.9	14.6	26164	888
0.49	38	10-10-94	996	3773	3025	4.7	9.9	3.6	10.7	22.8	59.4	6	151	93	0.1	44.7	2.8	0.2	24.3	4.0	13766	476
0.16	39	10-12-94	398	1500	2474	5.7	3.4	4.1	5.1	120.8	6.9	2	54	36	0.1	16.4	1.1	0.1	18.8	2.2	2263	303
1.62	40	10-26-94	3542	17386	13780	17.3	65.5	10.1	31.2	229.9	11.3	0	186	44	1.1	269.8	18.3	0.5	291.0	21.5	88430	3169
0.66	41	11-15-94	1517	2890	1005	5.4	1.4	0.5	21.4	3.3	0.0	0	35	15	1.5	7.9	0.8	1.0	11.5	1.3	811	56
0.75	42	12-21-94	1860	5426	3040	10.1	10.8	2.1	18.8	88.7	2.2	0	189	44	0.0	33.3	2.2	0.8	56.1	4.7	2612	86
0.27	43	12-22-94	598	3059	3896	4.1	7.5	2.6	4.6	14.6	1.4	3	67	48	0.0	17.6	0.9	0.0	18.6	2.2	10396	331
0.24	44	1-07-95	554	1100	531	2.1	1.4	2.1	3.1	5.0	9.2	0	19	4	0.0	0.0	0.0	0.0	0.0	0.0	685	30
1.10	45	1-14-95	2458	14557	7592	13.9	63.5	12.9	7.5	80.8	0.4	27	392	169	0.6	304.2	7.7	0.7	325.7	9.2	103064	624
0.66	46	1-15-95	1450	8663	16355	8.5	5.2	11.6	6.6	43.4	19.9	0	221	249	0.2	37.0	14.8	0.3	41.5	21.8	11285	1853
0.21	47	1-23-95	354	711	1485	0.9	1.2	0.5	2.6	2.6	0.1	2	20	50	0.1	6.9	1.4	0.1	6.6	1.9	2255	168
Total			**76383**	**384498**	**386919**	**373**	**2683**	**291**	**684**	**3262**	**469**	**389**	**14169**	**7129**	**18**	**5315**	**437**	**31**	**8369**	**835**	**2060220**	**130662**
# Observations			**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**	**42**

Table J-3. (continued).Mass loading 1994-95.

1994-95			WATER VOLUME			ZINC			CADMIUM			COPPER			IRON			LEAD			MANGANESE			HARDNESS		
RAIN in	NO	DATE	RAIN cu ft	INFLO cu ft	OUTFL cu ft	ZNRA grams	ZNIN grams	ZNOU grams	CDRA grams	CDIN grams	CDOU grams	CURA grams	CUIN grams	CUOU grams	FERA grams	FEIN grams	FEOU grams	PBRA grams	PBIN grams	PBOU grams	MNRA grams	MNIN grams	MNOU grams	HRA grams	HIN grams	HOU grams
0.78	2	6-14-94	1727	3736	311	8.90	2.65	0.11	0.02	0.03	0.00	0.14	0.49	0.01	4	76	2	0.11	0.00	0.00	0.25	1.87	0.03	12	4571	362
1.40	3	6-15-94	3100	12464	10946	9.04	13.06	3.72	0.02	0.11	0.00	0.09	1.34	0.37	5	1629	64	0.00	2.08	0.00	0.22	9.95	0.43	6	4306	9517
1.13	4	6-16-94	2502	13025	13911	6.59	11.07	3.94	0.01	0.04	0.04	0.08	1.25	1.38	5	314	53	0.00	0.04	0.00	0.19	8.12	3.78	5	8890	11188
0.38	5	6-17-94	841	3093	7663	4.79	4.20	6.94	0.01	0.00	0.00	0.00	0.28	0.26	1	102	40	0.00	0.05	0.02	0.04	2.19	3.45	1	2172	6532
0.50	6	6-20-94	1107	3946	1878	2.51	4.47	0.69	0.01	0.04	0.01	0.05	0.39	0.10	3	377	9	0.01	0.44	0.00	0.12	2.69	0.90	3	1419	1542
0.39	7	6-21-94	863	5032	6050	2.03	7.98	2.91	0.00	0.01	0.02	0.03	0.77	0.75	2	928	26	0.00	0.00	0.24	0.06	6.36	2.36	2	2223	4780
0.62	9	6-29-94	1372	2917	884	5.25	3.30	0.38	0.01	0.02	0.00	0.10	0.64	0.01	9	21	7	0.11	0.22	0.03	0.44	1.35	1.06	6	1190	716
0.89	12	7-06-94	1970	3684	3239	14.56	4.07	1.83	0.02	0.01	0.00	0.15	0.28	0.34	4	86	18	0.16	0.20	0.10	0.22	2.32	0.98	6	2650	2238
0.57	13	7-10-94	1284	4309	4976	3.78	5.25	2.68	0.01	0.02	0.00	0.13	0.49	0.62	2	133	42	0.00	0.28	0.06	0.08	1.93	1.38	0	1867	3565
0.90	14	7-18-94	1764	5206	2103	4.20	10.47	0.83	0.01	0.06	0.01	0.08	0.80	0.26	19	468	9	0.05	1.09	0.00	0.45	3.80	0.49	7	1489	1394
1.12	15	7-20-94	2480	10289	7827	4.64	19.81	5.54	0.01	0.09	0.09	0.61	2.65	1.64	4	1663	52	0.01	3.06	0.00	0.33	9.41	1.84	7	3147	4899
0.50	16	7-21-94	1129	7343	12229	6.14	13.52	4.50	0.01	0.08	0.00	0.31	1.54	1.87	7	1322	96	0.04	2.00	0.00	0.20	7.40	3.36	3	2599	7307
0.28	17	7-24-94	619	1303	3978	2.02	1.48	1.92	0.02	0.01	0.01	0.14	0.27	0.75	2	15	39	0.01	0.03	0.00	0.06	0.58	1.92	0	926	2478
0.58	18	7-28-94	2591	8582	8715	2.42	149.47	3.70	0.02	0.07	0.00	0.75	2.45	3.11	4	1058	45	0.00	1.46	0.00	0.07	6.98	2.84	0	3646	5282
0.47	19	7-30-94	1041	6334	8545	1.39	97.76	2.90	0.00	0.07	0.00	0.14	1.11	3.02	2	1466	36	0.00	0.93	0.00	0.06	6.73	1.16	0	3893	4816
0.34	20	8-03-94	852	1273	1267	1.30	2.52	0.39	0.01	0.01	0.00	0.04	0.43	0.11	1	40	6	0.01	0.13	0.00	0.04	0.55	0.98	2	357	786
0.42	21	8-06-94	930	2210	1961	3.00	2.88	0.56	0.01	0.01	0.00	0.24	0.37	0.52	2	96	7	0.01	0.11	0.00	0.02	1.24	0.54	3	1008	1172
0.17	22	8-07-94	376	921	585	0.24	1.25	0.10	0.00	0.00	0.00	0.07	0.44	0.13	1	20	2	0.00	0.02	0.00	0.00	0.72	0.05	1	691	336
0.47	23	8-08-94	1041	5790	6364	1.89	1.15	0.54	0.01	0.03	0.04	0.17	1.20	0.49	1	493	12	0.01	0.79	0.00	0.00	5.38	0.76	3	3066	3713
2.44	24	8-10-94	5059	34540	21124	5.16	108.58	14.96	0.04	0.88	0.00	0.72	17.31	4.85	2	15822	590	0.00	22.50	0.18	0.34	85.59	6.94	14	8021	10349
0.32	25	8-11-94	664	3164	12366	0.73	4.48	4.20	0.01	0.03	0.04	0.09	0.61	1.19	1	370	175	0.02	0.74	0.88	0.03	2.86	2.52	2	1595	5463
0.75	26	8-13-94	1716	8565	8555	1.07	7.03	2.42	0.00	0.10	0.00	0.14	1.58	0.51	1	531	63	0.07	1.04	0.24	0.05	5.07	2.23	5	3735	3925
0.12	27	8-16-94	332	695	1278	1.81	0.81	0.14	0.01	0.00	0.00	0.04	0.07	0.05	1	14	7	0.00	0.04	0.00	0.05	0.56	0.46	1	888	680
0.65	29	8-23-94	1693	5936	4582	3.98	4.54	0.91	0.01	0.02	0.00	0.20	0.49	0.29	4	213	19	0.02	0.34	0.01	0.10	5.53	1.32	5	3732	2427
0.72	30	8-24-94	1616	7840	6876	0.78	17.54	0.97	0.00	0.11	0.00	0.09	1.93	0.19	2	2017	29	0.00	3.75	0.00	0.08	12.43	1.56	0	3863	3758
1.14	31	8-25-94	2590	17912	16838	1.47	18.77	8.11	0.01	0.20	0.05	0.21	1.72	2.29	4	2395	81	0.00	5.43	0.05	0.10	11.21	5.29	5	7609	9060
1.22	32	9-16-94	2701	14478	10324	1.15	20.09	5.56	0.00	0.25	0.03	0.16	4.72	0.94	2	280	65	0.00	0.16	0.12	0.13	11.56	1.90	4	9676	5438
1.94	33	9-17-94	6099	38192	61355	3.80	71.39	26.06	0.02	0.00	0.00	0.40	7.79	2.95	9	928	810	0.00	0.00	0.00	0.22	40.34	12.51	9	31474	31276
1.66	34	9-19-94	3675	31601	27619	1.35	180.78	7.82	0.00	0.23	0.07	0.05	3.90	2.02	3	3072	23	0.00	5.17	1.66	0.16	33.85	8.87	5	12798	11967
1.13	35	9-25-94	2502	13518	10558	1.98	11.10	2.69	0.01	0.08	0.06	0.13	1.76	0.99	1	798	41	0.00	1.84	0.18	0.08	6.24	1.91	14	5704	4485
1.42	36	9-27-94	4693	38040	39268	4.78	94.80	8.90	0.03	1.13	0.11	0.39	11.96	3.56	4	11987	568	0.17	19.59	1.86	0.37	121.20	12.64	16	14759	16792
0.79	37	10-02-94	1727	9495	9561	1.66	11.02	3.25	0.00	0.05	0.03	0.30	1.08	1.27	4	362	41	0.02	0.67	0.22	0.05	6.99	3.36	14	5163	4928
0.49	38	10-10-94	996	3773	3025	0.23	0.75	1.88	0.01	0.05	0.00	0.21	0.46	0.29	3	1196	21	0.04	0.44	0.04	0.06	8.04	0.83	3	2479	1739
0.16	39	10-12-94	398	1500	2474	1.34	3.14	0.35	0.01	0.00	0.00	0.05	0.14	0.13	1	69	9	0.01	0.14	0.02	0.03	3.20	0.51	1	1070	1289
1.62	40	10-26-94	3542	17386	13780	1.50	29.05	2.34	0.00	0.10	0.00	0.21	2.02	0.23	2	1036	75	0.09	2.71	0.27	0.04	13.29	2.81	7	6499	6829
0.66	41	11-15-94	1517	2890	1005	0.56	2.62	0.34	0.01	0.02	0.00	0.27	0.64	0.07	1	19	2	0.00	0.20	0.01	0.00	0.65	0.36	0	1449	601
0.75	42	12-21-94	1860	5426	3040	3.16	17.06	1.21	0.01	0.00	0.01	0.35	1.92	0.46	2	68	9	0.09	0.51	0.13	0.00	0.63	0.87	3	6608	1868
0.27	43	12-22-94	598	3059	3896	0.73	7.80	3.42	0.00	0.02	0.01	0.10	0.09	0.57	1	0	11	0.01	0.31	0.11	0.02	2.27	0.49	2	2339	2262
0.24	44	1-07-95	554	1100	531	1.38	2.71	0.32	0.00	0.01	0.00	0.04	0.39	0.07	1	10	1	0.01	0.12	0.01	0.02	0.59	0.18	2	620	329
1.10	45	1-14-95	2458	14557	7592	2.16	31.33	1.72	0.01	0.14	0.00	0.35	1.46	0.58	2	1475	25	0.06	3.55	0.06	0.06	10.51	1.10	5	4906	3827
0.66	46	1-15-95	1450	8663	16355	1.27	12.27	5.56	0.00	0.07	0.00	0.06	1.05	0.19	1	142	208	0.01	0.69	0.37	0.03	1.64	2.55	7	4637	7503
0.21	47	1-23-95	354	711	1485	0.36	0.95	1.22	0.00	0.00	0.00	0.02	0.05	0.15	0	51	7	0.01	0.11	0.10	0.01	0.33	0.17	1	344	774
Total			76383	384498	386919	127.1	1015.0	148.5	0.4	4.2	0.6	7.9	80.3	39.6	131	53164	3445	1.2	83.0	7.0	4.9	464.1	99.7	191	190079	210195
# Observations			42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
% Efficiency								87			87			55			94			92			79			-10

APPENDIX K

Concentrations of Major Ions at the Inflow, Outflow and in Rainfall

Table K1. **Concentrations of major ions measured from June 1993 through January 1994 for the rainfall, the inflow and the outflow. NF=no flow, "."=no data. The suffix RA=in rain, IN=at the inflow and OU=at the outflow.**

1993 MDL=MIN.DETECTION LIMIT			SODIUM NA=0.06 mg/l			SULFATE SO3=0.1 mg/l			MAGNESIUM MG=0.006 mg/l			CALCIUM CA=0.04 mg/l			CHLORIDE CL=1.0 mg/l			POTASSIUM K=0.07 mg/l		
NO	DATE	SAMP NO.	NARA	NAIN	NAOU	SO3R	SO3IN	SO3O	MGRA	MGIN	MGOU	CARA	CAIN	CAOU	CLRA	CLIN	CLOU	KRA	KIN	KOU
1	6-24-93	30XX,07,12	•	6.1	6.8	•	35	73	•	5.8	5.9	•	67	65	•	9.3	11.0	•	4.2	3.1
2	6-30-93	3014,11,16	1.7	3.5	6.0	3.3	19	60	0.0	3.0	5.4	1.3	40	59	1.1	5.5	10.0	0.0	4.6	3.1
3	7-12-93	3025,23,24	0.0	3.5	5.2	5.2	38	•	•	4.1	5.4	0.0	46	58	1.2	4.2	7.5	0.0	2.1	1.9
4	7-21-93	3028,26,27	0.0	3.5	3.0	8.8	65	49	0.0	5.8	4.0	0.9	60	46	1.5	5.9	5.5	0.0	1.0	1.1
5	8-13-93	3029,30,NF	0.0	•	•	4.0	•	•	0.0	•	•	1.2	•	•	2.0	•	•	0.0	•	•
6	8-14-93	3031,32,NF	0.0	•	•	4.0	•	•	0.0	•	•	0.0	•	•	2.5	•	•	•	•	•
7	8-25-93	3035,34,36	0.1	1.9	1.5	1.5	17	23	0.1	2.9	2.2	0.4	45	24	0.0	4.2	2.9	0.2	8.7	2.5
8	8-26-93	3038,37,39	0.0	0.0	4.5	6.0	9	42	0.0	1.9	4.1	0.0	21	39	0.0	2.5	7.8	0.0	6.7	7.7
9	8-29-93	3041,40,XX	0.0	1.6	•	8.0	17	•	0.0	3.2	•	0.0	39	•	2.2	7.8	•	0.0	7.7	•
10	9-01-93	3043,44,42	•	3.6	3.3	•	35	43	•	6.0	4.0	•	68	51	•	6.5	6.0	•	5.1	4.0
11	9-05-93	3046,45,47	0.0	5.2	•	8.0	10	•	0.0	7.1	•	0.0	81	•	1.0	8.5	•	0.0	5.0	•
12	9-06-93	3049,48,52	•	4.8	2.4	•	44	29	•	7.9	3.2	•	79	44		7.5	4.0	•	4.0	2.2
13	9-11-93	3055,53,54	0.1	1.2	2.9	4.2	10	40	0.1	2.8	4.2	0.2	44	50	0.4	2.9	4.7	0.0	3.9	2.1
14	9-14-93	3058,56,57	0.3	2.5	3.0	2.6	11	39	0.1	3.3	4.3	0.3	45	50	0.6	3.5	4.7	0.0	3.3	1.9
15	9-21-93	3062,60,61	0.1	1.0	2.7	0.0	10	36	0.1	1.6	3.5	0.3	28	36	0.0	2.1	3.9	0.2	3.0	1.6
16	9-27-93	3066,64,65	0.2	2.8	2.8	2.0	35	38	0.1	4.2	3.7	0.4	52	43	0.6	4.4	3.9	0.2	2.2	1.4
17	10-06-	3068,69,70	0.7	5.3	3.4	2.9	90	49	0.3	5.5	3.3	0.0	65	42	1.1	8.1	4.4	0.3	3.1	1.5
18	10-09-	3072,71,73	•	•	3.6	•	•	54	•	•	4.3	•	•	47	•	•	4.4	•	•	1.4
19	10-15-	3076,74,75	0.0	4.4	4.0	1.0	40	59	0.0	7.1	5.1	0.0	87	44	0.0	9.3	5.2	0.0	5.0	1.7
20	10-30-	3089,87,88	0.7	4.3	5.4	•	42	65	0.0	4.5	5.8	0.0	53	44	•	8.9	8.6	0.0	5.2	2.4
21	11-20-	3095,93,94	•	15.0	7.2	•	413	52	•	19.0	6.8	•	186	80	•	25.0	13.0	•	4.1	3.9
22	12-11-	3097,96,NF	•	12.0		•	121	•	•	18.1	•	•	96	•	•	23.0		•	2.3	•
23	12-15-	3099,98,NF	•	9.8		•	103	•	•	8.9	•	•	81	•	•	17.0		•	1.7	•
24	12-20-	3102,03,04	•	9.8	9.2	•	96	98	•	8.5	8.1	•	78	55	•	18.0	14.0	•	1.0	2.5
25	12-23-	3108,06,07	•	9.5	9.5	•	102	99	•	8.9	8.5	•	81	56	•	17.0	15.0	•	1.0	2.2
26	12-24-	3111,09,10	0.3	11.0	8.9	2.0	115	97	0.1	9.6	8.4	0.9	80	59	0.0	19.0	15.0	0.0	1.0	1.8
27	1-02-94	3116,14,15	•	9.8	9.1	•	108	99	•	8.7	8.0	•	83	60	•	18.0	16.0	•	1.3	1.5
28	1-03-94	3119,17,18	•	9.6	9.4	•	109	102	•	8.9	8.2	•	88	67	•	17.0	16.0	•	2.7	1.7
29	1-13-94	3124,22,23	1.0	5.0	8.9	2.2	47	109	0.0	4.2	8.9	0.0	53	57	2.7	12.0	17.0	•	4.6	•
30	1-17-94	3129,27,28	0.3	3.1	6.2	1.3	22	64	0.0	2.9	5.5	0.0	39	46	0.8	6.9	11.0	0.0	•	•
MEAN			0.2	5.0	4.6	2.2	59	47	0.0	5.8	4.4	0.2	60	41	0.6	9.1	7.6	0.0	3.2	1.8
STD.DEV			0.4	4.0	3.1	2.7	76	35	0.1	4.4	2.8	0.4	35	23	0.8	6.9	5.3	0.1	2.3	1.6
MAXIMUM			1.7	15.0	9.5	8.8	413	109	0.3	19.0	8.9	1.3	186	80	2.7	25.0	17.0	0.3	8.7	7.7
MINIUM			0.0	0.0	0.0	0.0	0	0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
VARIANCE			0.1	15.8	9.3	7.1	5851	1193	0.0	19.4	7.8	0.1	1248	518	0.7	47.3	27.9	0.0	5.1	2.5
NO.OBS.			30	30	28	30	30	30	30	30	30	30	30	30	29	30	28	30	30	30
Removed storms 21-28 because of water main leak into the inflow swale.																				
MEAN			0.3	3.3	4.1	3.4	31	52	0.0	4.4	4.4	0.3	53	46	0.9	6.3	6.9	0.1	4.4	2.3
STD.DEV			0.4	1.6	1.8	2.7	21	19	0.1	1.8	1.7	0.4	17	9	0.9	2.7	3.4	0.1	1.9	1.6
MAXIMUM			1.7	6.1	8.9	8.8	90	109	0.3	7.9	8.9	1.3	87	65	2.7	12.0	17.0	0.3	8.7	7.7
MINIMUM			0.0	0.0	1.5	0.0	9	23	0.0	1.6	0.0	0.0	21	24	0.0	2.1	2.9	0.0	1.0	0.0
VARIANCE			0.2	2.6	3.2	7.1	432	361	0.0	3.2	3.0	0.2	300	89	0.8	7.1	11.8	0.0	3.5	2.6
NO.OBS.			18.0	19.0	19.0	19.0	19	18	18.0	19.0	19.0	19.0	19	19	19.0	19.0	19.0	18.0	18.0	17.0

Table K2. Concentrations of major cations and anions measured from June 1994 through January 1995. "." = no data. Suffix abbreviations: RA=conc. in rainfall, IN=conc. at the inflow, OU=conc. at outflow.

1994 MDL=MIN.DETECTION LIMIT			SODIUM NA=0.06 mg/l			SULFATE SO3=0.1 mg/l			MAGNESIUM MG=0.006 mg/l			CALCIUM CA=0.04 mg/l			CHLORIDE CL=1.0 mg/l			POTASSIUM K=0.07 mg/l		
NO	DATE	SAMP NO.	NARA	NAIN	NAOU	SO3R	SO3IN	SO3O	MGRA	MGIN	MGOU	CARA	CAIN	CAOU	CLRA	CLIN	CLOU	KRA	KIN	KOU
2	6-14-94	4005,04,06	0.2	12.0	6.0	0.0	325	316	0.0	17.0	10.0	1.0	134	148	0.6	18.0	8.2	0.2	7.7	1.8
3	6-15-94	4007,08,09	0.3	2.0	4.7	4.2	63	253	0.0	3.0	7.9	0.3	44	110	0.3	2.8	6.4	0.0	2.0	1.6
4	6-16-94	4010,11,12	0.1	4.5	4.2	4.0	117	223	0.0	7.7	7.2	0.3	84	102	0.3	5.2	5.7	0.0	4.1	1.6
5	6-17-94	4013,14,15	•	4.7	4.3	•	132	220	0.0	8.1	7.6	0.2	86	108	•	5.1	5.6	0.0	3.1	1.5
6	6-20-94	4017,18,16	•	2.4	4.2	•	61	204	•	2.9	7.3	•	46	104	•	3.3	5.5	•	1.7	1.5
7	6-21-94	4019,20,21	•	3.6	4.2	•	73	199	•	5.2	7.0	•	54	100	•	4.6	5.4	•	1.5	1.7
9	6-29-94	1026,25,27	0.3	3.5	4.4	4.6	111	201	0.0	4.6	7.6	0.6	50	102	1.2	5.7	5.5	0.0	2.1	1.3
12	7-06-94	1043,42,41	•	7.0	3.8	•	99	152	•	8.2	6.4	•	88	87	•	9.5	4.5	•	4.0	1.6
13	7-10-94	1045,46,44	0.3	4.0	4.2	3.6	71	151	0.0	4.5	6.7	0.3	54	89	0.6	5.6	5.0	0.0	2.5	1.6
14	7-18-94	1050,49,48	0.2	2.0	4.7	0.0	53	155	0.0	2.2	6.6	0.6	37	83	0.4	2.8	6.0	0.0	1.7	1.8
15	7-20-94	1053,51,52	0.0	1.4	3.8	6.0	45	148	0.0	2.5	6.4	0.4	39	78	0.4	2.4	5.8	0.0	1.6	1.9
16	7-21-94	1054,55,56	•	2.0	3.9	•	47	143	•	3.1	5.7	•	45	75	•	2.7	4.9		1.6	1.8
17	7-24-94	1057,58,59	•	4.8	4.0	•	109	132	•	7.6	5.9	•	64	79	•	6.6	5.0		1.4	1.7
18	7-28-94	1063,64,65	0.5	2.9	3.2	2.7	73	134	0.0	4.4	5.9	0.2	53	76	1.1	6.0	5.1	0.0	3.0	1.5
19	7-30-94	1068,66,67	0.3	2.6	3.4	1.6	51	129	0.0	4.2	5.8	0.0	80	70	0.9	5.0	5.4	0.0	3.7	1.7
20	8-03-94	1071,70,69	•	3.0	3.9	•	35	118	•	2.7	5.8	•	35	78	•	5.5	5.9	•	1.2	1.8
21	8-06-94	1074,73,72	0.3	3.6	3.9	3.6	65	117	0.0	5.1	5.8	0.6	56	75	1.1	6.3	5.7	0.0	1.2	1.7
22	8-07-94	1077,76,75	•	4.6	3.9	•	96	119	•	8.6	5.7	•	92	72	•	8.1	6.1	•	2.4	1.7
23	8-08-94	1080,78,79	0.0	2.8	3.9	3.0	60	120	0.0	4.8	5.8	0.4	67	73	0.6	5.0	6.2	0.0	2.4	1.7
24	8-10-94	1083,81,82	0.0	1.0	3.5	1.5	29	100	0.0	1.8	5.0	0.3	30	61	0.3	1.9	5.3	0.0	1.7	1.6
25	8-11-94	1085,84,86	•	2.8	2.5	•	51	74	•	4.5	3.9	•	64	56	•	4.0	4.0	•	1.9	1.5
26	8-13-94	1089,87,88	0.0	2.4	2.6	3.1	62	75	0.0	20.9	4.1	0.3	55	58	0.5	4.1	4.1	0.0	2.0	1.5
27	8-16-94	1090,92,91	0.4	8.3	2.9	5.3	198	79	0.0	18.0	4.4	0.9	151	68	1.3	12.0	4.5	0.0	1.5	1.5
29	8-23-94	1096,98,97	0.3	4.1	3.1	11.0	86	85	0.0	6.7	4.9	0.4	78	67	1.1	6.7	5.4	0.0	1.4	1.6
30	8-24-94	1099,00,01	0.0	1.9	3.3	0.0	45	86	0.0	2.9	5.1	0.2	65	69	0.0	1.9	5.3	0.0	1.9	1.6
31	8-25-94	1104,02,03	0.3	1.5	3.4	1.7	31	79	0.0	2.4	5.0	0.3	56	66	0.3	2.5	5.2	0.0	1.8	1.6
32	9-16-94	1108,07,09	0.0	4.0	3.5	0.7	96	88	0.0	7.0	5.2	0.2	83	66	0.5	6.6	6.2	0.0	2.1	1.5
33	9-17-94	1111,12,10	0.0	5.3	3.4	1.6	94	79	0.0	10.0	5.0	0.2	105	64	0.5	6.6	5.7	0.0	2.1	1.6
34	9-19-94	1116,dd,dd	0.0	2.7	2.8	1.1	47	56	0.0	4.6	4.1	0.2	50	54	0.4	3.7	5.0	0.0	1.5	1.5
35	9-25-94	1124,23,25	0.4	1.9	2.8	2.3	35	55	0.0	3.4	3.9	0.8	54	55	0.4	3.3	4.8	0.0	1.8	1.5
36	9-27-94	1129,dd,dd	0.0	1.9	2.9	1.8	41	60	0.0	3.2	4.1	0.5	50	54	0.9	3.3	5.2	0.0	1.7	1.4
37	10-02-94	1136,34,35	1.1	4.6	3.3	4.0	75	64	0.2	6.5	4.7	0.8	66	65	2.0	6.8	5.8	0.0	1.3	1.3
38	10-10-94	1141,42,43	•	7.1	3.9	•	86	115	•	8.4	5.6	•	79	72	•	13.0	7.0	•	5.3	1.7
39	10-12-94	1146,45,44	•	6.6	4.4	•	92	79	•	8.5	5.2	•	87	65	•	13.0	7.4	•	3.9	1.5
40	10-26-94	1148,49,47	0.2	3.3	3.9	2.6	78	91	0.0	3.6	5.6	0.3	47	61	0.5	7.0	8.0	0.0	3.1	1.9
41	11-15-94	1154,52,53	0.5	6.4	4.6	2.7	107	92	0.0	7.2	5.7	0.0	59	75	0.9	8.2	8.0	0.0	1.5	2.5
42	12-21-94	1156,55,57	0.2	15.0	4.9	6.5	304	104	0.0	17.0	6.1	0.2	144	77	0.5	22.0	8.4	0.0	4.6	2.3
43	12-22-94	1160,58,59	•	7.2	5.0	•	143	114	•	9.7	6.2	•	92	71	•	14.0	8.1	•	3.8	1.5
44	1-07-95	1165,63,64	•	6.3	5.8	•	131	127	•	8.9	6.6	•	65	76	•	8.1	9.1	•	1.2	1.8
45	1-14-95	1173,dd,72	0.7	3.4	5.2	7.7	65	122	0.0	3.3	6.2	0.3	42	61	1.5	5.8	8.5	0.0	1.9	1.6
46	1-15-95	1176,75,77	2.1	9.7	5.1	2.5	95	•	0.2	9.0	6.1	0.3	61	55	4.0	16.0	8.4	0.0	2.1	1.4
MEAN			**0.3**	**4.4**	**3.9**	**3.2**	**90**	**126**	**0.0**	**6.7**	**5.8**	**0.4**	**68**	**76**	**0.8**	**6.8**	**6.0**	**0.0**	**2.4**	**1.6**
STD.DEV.			**0.4**	**2.9**	**0.8**	**2.4**	**61**	**57**	**0.1**	**4.5**	**1.2**	**0.2**	**27**	**19**	**0.7**	**4.5**	**1.3**	**0.0**	**1.3**	**0.2**
MAXIMUM			**2.1**	**15.0**	**6.0**	**11.0**	**325**	**316**	**0.2**	**20.9**	**10.0**	**1.0**	**151**	**148**	**4.0**	**22.0**	**9.1**	**0.2**	**7.7**	**2.5**
MINIUM			**0.0**	**1.0**	**2.5**	**0.0**	**29**	**55**	**0.0**	**1.8**	**3.9**	**0.0**	**30**	**54**	**0.0**	**1.9**	**4.0**	**0.0**	**1.2**	**1.3**
VARIANCE			**0.2**	**8.3**	**0.7**	**5.9**	**3771**	**3290**	**0.0**	**20.1**	**1.5**	**0.1**	**755**	**355**	**0.6**	**20.2**	**1.7**	**0.0**	**1.7**	**0.0**
NO.OBS.			**28**	**41**	**41**	**28**	**41**	**40**	**29**	**41**	**41**	**29**	**41**	**41**	**28**	**41**	**41**	**29**	**41**	**41**

APPENDIX L

Mass Loading for Major Ions at the Inflow, Outflow and in Rainfall

Table L-1. Mass loading 1993-94 for major ions. Hydrologic is the amount of water entering or leaving the pond in rainfall, inflow and outflow. No=storm number. The suffix RA=rainfall, IN=inflow and OU=outflow. For % efficiency a positive number indicates % removal and a negative number is an increase at the outflow station.

1993		WATER VOLUME CU.FT.			SODIUM GRAMS			SULFATE GRAMS			MAGNESIUM GRAMS			CALCIUM GRAMS			CHLORIDE GRAMS			POTASSIUM GRAMS		
NO	DATE	RAIN	INFLOW	OUTFLOW	NARA	NAIN	NAOU	SO3R	SO3IN	SO3O	MGRA	MGIN	MGOU	CARA	CAIN	CAOU	CLRA	CLIN	CLOU	KRA	KIN	KOU
1	6-24-93	1385	11566	3430	12	1998	661	133	11464	7091	0	1900	573	12	21946	6314	35	3046	1069	4	1376	301
2	6-30-93	1194	10336	8986	57	1025	1527	112	5562	15269	0	878	1374	44	11709	15015	37	1610	2545	0	1346	789
3	7-12-93	1486	8353	4732	0	828	697	219	8989	6298	0	970	724	0	10882	7773	51	994	1005	0	497	255
4	7-21-93	1683	11701	9353	0	1160	795	419	21539	12979	0	1922	1060	43	19882	12184	71	1955	1457	0	331	291
5	8-13-93	997	216	0	0	20	0	113	190	0	0	27	0	34	324	0	56	39	0	0	27	0
6	8-14-93	540	353	0	0	33	0	61	310	0	0	44	0	0	530	0	38	63	0	2	44	0
7	8-25-93	2756	19665	10807	8	1058	459	117	9468	7039	8	1615	673	31	25061	7345	0	2339	888	16	4845	765
8	8-26-93	5131	65652	86337	0	0	11003	872	16733	1e+05	0	3533	10025	0	39045	95357	0	4648	19071	0	12457	18827
9	8-29-93	2432	31047	27448	0	1407	2954	551	14947	36534	0	2814	3032	0	34291	32648	152	6858	4902	0	6770	1632
11	9-05-93	1194	9540	7157	0	1405	770	271	2567	9526	0	1918	790	0	21884	8513	34	2296	1277	0	1351	426
12	9-06-93	3321	45909	44741	28	6241	3041	320	57206	36745	0	10271	4055	28	1e+05	55751	85	9751	5068	9	5201	2788
13	9-11-93	1162	15433	15233	3	524	1251	138	4371	17256	3	1224	1812	7	19231	21570	13	1267	2028	0	1705	906
14	9-14-93	1111	12852	12018	9	910	1021	82	4004	13274	3	1201	1464	9	16379	17017	19	1274	1600	0	1201	647
15	9-21-93	1892	20048	19055	5	568	1457	0	5678	19427	5	908	1889	16	15897	19427	0	1192	2105	11	1703	863
16	9-27-93	1022	5303	3532	6	421	280	58	5256	3801	3	631	370	12	7809	4301	17	661	390	6	330	140
17	10-06-93	1035	3603	2852	21	541	275	85	9183	3958	9	561	267	0	6632	3392	32	826	355	9	316	121
18	10-09-93	629	2785	2850	5	260	291	61	2445	4358	0	347	347	5	4180	3793	16	497	355	2	347	113
19	10-15-93	940	10028	8639	0	1250	979	27	11360	14435	0	2016	1248	0	24707	10765	0	2641	1272	0	1420	416
20	10-30-93	1702	13828	10146	34	1684	1552	164	16448	18677	0	1762	1667	0	20755	12643	43	3485	2471	0	2036	690
21	11-20-93	305	1195	676	3	508	138	29	13977	996	0	643	130	3	6295	1532	8	846	249	1	139	75
22	12-11-93	229	1432	0	2	487	0	22	4907	0	0	733	0	2	3893	0	6	933	0	1	93	0
23	12-15-93	356	3974	0	3	1103	0	34	11592	0	0	1002	0	3	9116	0	9	1913	0	1	191	0
24	12-20-93	343	5963	3011	3	1655	784	33	16212	8357	0	1435	691	3	13172	4690	9	3040	1194	1	169	213
25	12-23-93	254	4613	2434	2	1241	655	24	13325	6824	0	1163	586	2	10582	3860	6	2221	1034	1	131	152
26	12-24-93	635	14682	9104	5	4574	2295	36	47816	25009	2	3992	2166	16	33264	15212	0	7900	3867	0	416	464
27	1-02-94	1092	10153	6012	9	2818	1549	105	31054	16856	0	2502	1362	9	23865	10216	28	5176	2724	3	374	255
28	1-03-94	349	6275	4806	3	1706	1279	34	19370	13883	0	1582	1116	3	15638	9119	9	3021	2178	1	480	231
29	1-13-94	1346	12570	10269	38	1780	2588	84	16731	31699	0	1495	2588	0	18867	16577	103	4272	4944	4	1638	611
30	1-17-94	1492	20248	19106	13	1778	3355	55	12615	34629	0	1663	2976	0	22364	24890	34	3957	5952	0	2523	1136
TOTALS IN GRAMS					270	38980	41654	4258	4e+05	5e+05	33	50751	42982	282	6e+05	4e+05	912	78721	69999	70	49457	33107
TOTAL INPUT IN GRAMS						39249			4e+05			50784			6e+05			79633			49527	
% Efficiency				20.27			-6.13			-17.03			15.36			25.18			12.10			33.15

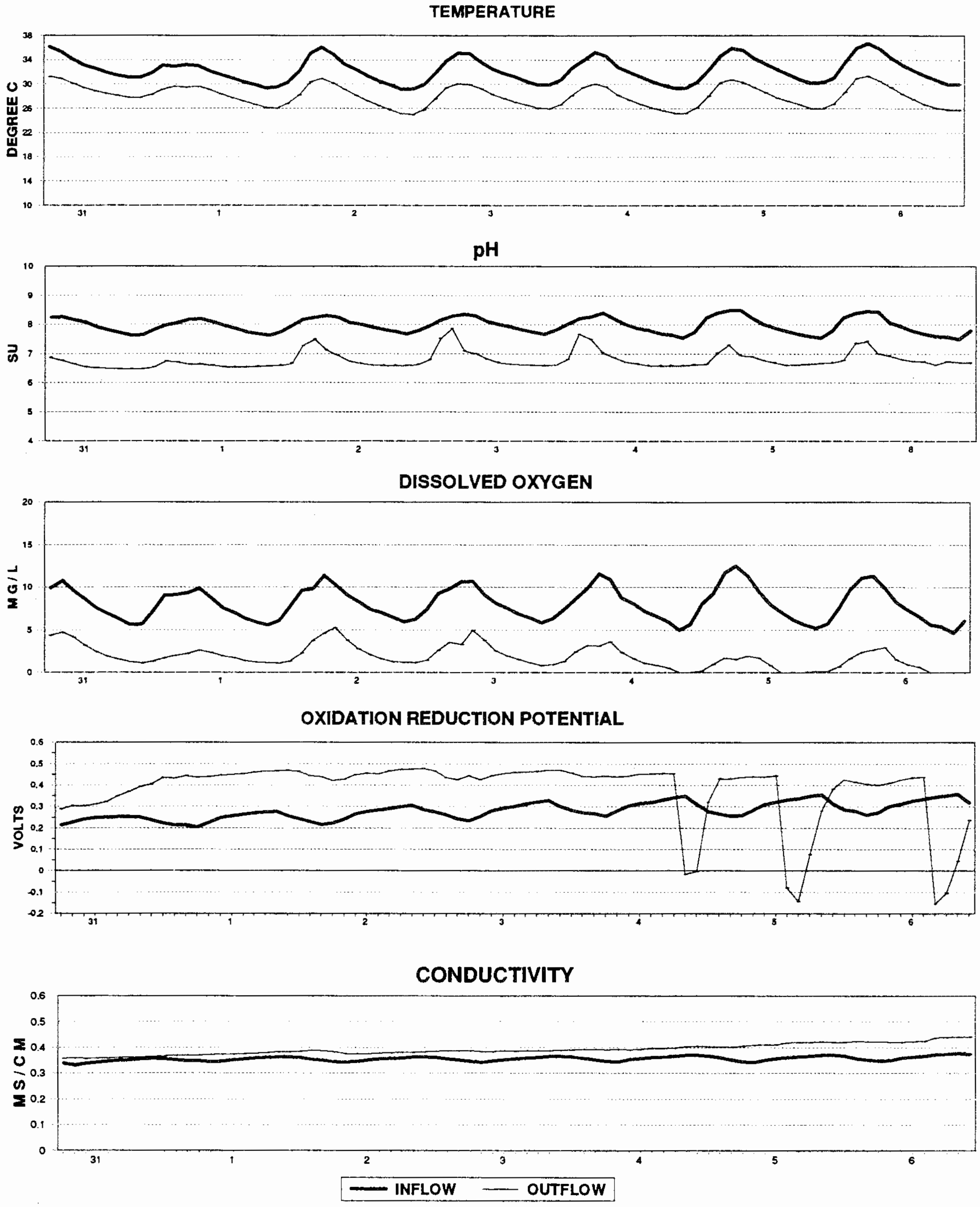
Table L-2. Mass loading 1994-95 for major ions. Hydrologic is the amount of water coming into and out of the system in rainfall, inflow and outflow. No=storm number. The suffix RA=rainfall, IN=inflow and OU=outflow. INFLO and OUTFL=water measured over weirs, RAIN=water falling directly on the pond as rainfall. For % efficiency, a positive number indicates % removal and a negative number indicates an increased amount at the outflow station.

1994		WATER VOLUME CU.FT.			SODIUM GRAMS			SULFATE GRAMS			MAGNESIUM GRAMS			CALCIUM GRAMS			CHLORIDE GRAMS			POTASSIUM GRAMS		
NO	DATE	RAIN	INFLO	OUTFL	NARA	NAIN	NAOU	SO3R	SO3IN	SO3O	MGRA	MGIN	MGOU	CARA	CAIN	CAOU	CLRA	CLIN	CLOU	KRA	KIN	KOU
2	6-14-94	1727	3736	311	10	1270	53	0	34386	2783	0	1799	88	49	14178	1304	29	1904	72	10	815	16
3	6-15-94	3100	12464	10946	26	706	1457	369	22238	78428	0	1059	2449	26	15531	34099	26	988	1984	0	706	496
4	6-16-94	2502	13025	13911	7	1660	1655	283	43158	87853	0	2840	2837	21	30985	40184	21	1918	2246	0	1512	630
5	6-17-94	841	3093	7663	6	412	933	77	11562	47744	0	710	1649	5	7533	23438	0	447	1215	0	272	326
7	6-21-94	863	5032	6050	6	513	720	78	10403	34096	0	741	1199	10	7695	17134	0	656	925	0	214	291
9	6-29-94	1372	2917	884	12	289	110	179	9170	5032	0	380	190	23	4130	2554	47	471	138	0	173	33
12	7-06-94	1970	3684	3239	13	730	349	179	10329	13943	0	856	587	22	9181	7980	0	991	413	0	417	147
13	7-10-94	1284	4309	4976	11	488	592	131	8664	21279	0	549	944	11	6590	12542	22	683	705	0	305	225
14	7-18-94	1764	5206	2103	10	295	280	0	7814	9231	0	324	393	30	5455	4943	20	413	357	0	251	107
15	7-20-94	2480	10289	7824	0	408	842	421	13112	32793	0	728	1418	28	11364	17283	28	699	1285	0	466	421
16	7-21-94	1129	7343	12229	8	416	1351	102	9774	49525	0	645	1974	12	9358	25974	0	561	1697	0	333	623
17	7-24-94	619	1303	3978	4	177	451	56	4022	14871	0	280	665	7	2362	8900	0	244	563	0	52	192
18	7-28-94	2591	8582	8715	37	705	790	198	17742	33072	0	1069	1456	15	12881	18757	81	1458	1259	0	729	370
19	7-30-94	1041	6334	8545	9	466	823	47	9148	31217	0	753	1404	0	14350	16940	27	897	1307	0	664	411
20	8-03-94	852	1273	1267	6	108	140	77	1262	4234	0	97	208	9	1262	2799	0	198	212	0	43	65
21	8-06-94	930	2210	1961	8	225	217	95	4068	6498	0	319	322	16	3505	4165	29	394	317	0	75	94
22	8-07-94	376	921	585	3	120	65	34	2504	1971	0	224	94	4	2400	1193	0	211	101	0	63	28
23	8-08-94	1041	5790	6364	0	459	703	88	9838	21627	0	787	1045	12	10986	13157	18	820	1117	0	394	306
24	8-10-94	5059	34540	21124	0	978	2094	215	28367	59823	0	1761	2991	43	29345	36492	43	1859	3171	0	1663	957
25	8-11-94	664	3164	12366	5	251	876	60	4570	25915	0	403	1366	7	5735	19611	0	358	1401	0	170	525
26	8-13-94	1716	8565	8555	0	582	630	151	15039	18171	0	5070	993	15	13341	14052	24	994	993	0	485	363
27	8-16-94	332	695	1278	4	163	105	50	3897	2859	0	354	159	8	2972	2461	12	236	163	0	30	54
29	8-23-94	1693	5936	4582	14	689	402	527	14457	11030	0	1126	636	19	13112	8694	53	1126	701	0	235	208
30	8-24-94	1616	7840	6876	0	422	643	0	9991	16747	0	644	993	9	14432	13436	0	422	1032	0	422	312
31	8-25-94	2590	17912	16838	22	761	1621	125	15725	37671	0	1217	2384	22	28407	31472	22	1268	2480	0	913	763
32	9-16-94	2701	14478	10324	0	1640	1023	54	39362	25729	0	2870	1520	15	34031	19297	38	2706	1813	0	861	439
33	9-17-94	6099	38192	61355	0	5732	5908	276	101670	137268	0	10816	8688	35	1e+05	1e+05	86	7139	9904	0	2271	2780
34	9-19-94	3675	31601	27619	0	2416	2190	114	42062	43802	0	4117	3207	21	44747	42237	42	3311	3911	0	1342	1173
35	9-25-94	2502	13518	10558	28	727	837	163	13399	16445	0	1302	1166	57	20673	16445	28	1263	1435	0	689	449
36	9-27-94	4693	38040	39268	0	2047	3225	239	44169	66724	0	3447	4559	66	53865	60052	120	3555	5783	0	1831	1557
37	10-02-94	1727	9495	9561	54	1237	894	196	20167	17329	10	1748	1273	39	17747	17600	98	1829	1570	0	350	352
38	10-10-94	996	3773	3025	7	759	334	90	9189	9852	0	898	480	11	8441	6168	0	1389	600	0	566	146
39	10-12-94	398	1500	2474	3	280	308	36	3908	5535	0	361	364	4	3696	4554	0	552	518	0	166	105
40	10-26-94	3542	17386	13780	20	1625	1522	261	38405	35513	0	1773	2185	30	23141	23805	50	3447	3122	0	1526	741
41	11-15-94	1517	2890	1005	21	524	131	116	8757	2618	0	589	162	0	4829	2135	39	671	228	0	123	71
42	12-21-94	1860	5426	3040	11	2305	422	342	46714	8954	0	2612	525	11	22128	6629	26	3381	723	0	707	198
43	12-22-94	598	3059	3896	4	624	552	54	12388	12578	0	840	684	7	7970	7834	0	1213	894	0	329	166
44	1-07-95	554	1100	531	4	196	87	50	4081	1910	0	277	99	6	2025	1143	0	252	137	0	37	27
45	1-14-95	2458	14557	7592	49	1402	1118	536	26797	26231	0	1360	1333	21	17315	13115	104	2391	1828	0	783	344
46	1-15-95	1350	8663	16355	80	2380	2362	96	23307	58360	8	2208	2825	11	14966	25475	153	3925	3891	0	515	648
TOTALS IN GRAMS					500	37188	38811	6166	755617	1137261	17	59955	57518	758	666231	737257	1286	57243	62208	10	2349	17160
TOTAL INPUT IN GRAMS						37688			761783			59973			666989			58529			2350	
% Efficiency				15.64			-2.98			-49.29			4.09			-10.54			-6.29			27.00

APPENDIX M

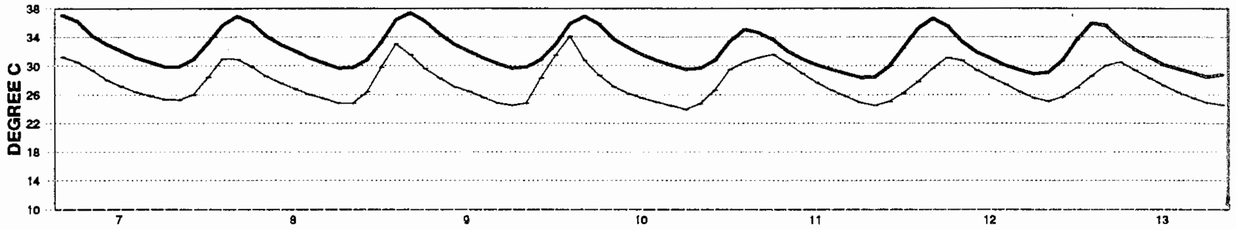
Measurements for Field Parameters Taken at Two Hour Intervals

JULY 30 TO AUGUST 6, 1993

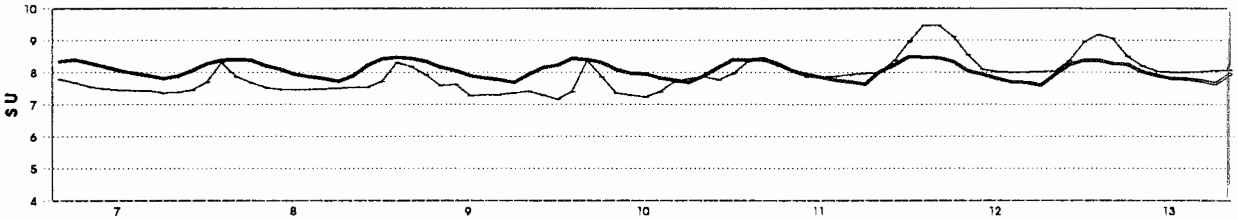


AUGUST 6 TO AUGUST 13, 1993

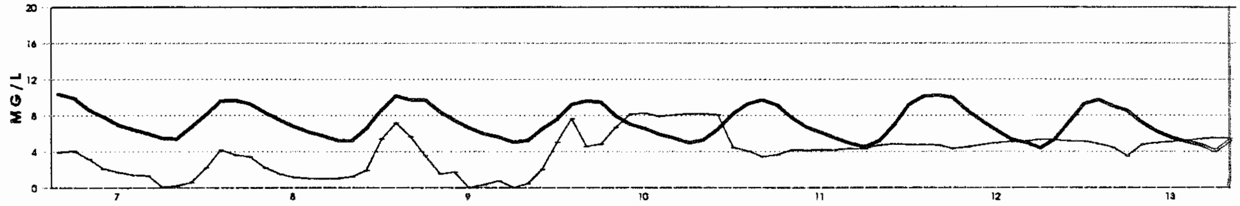
TEMPERATURE



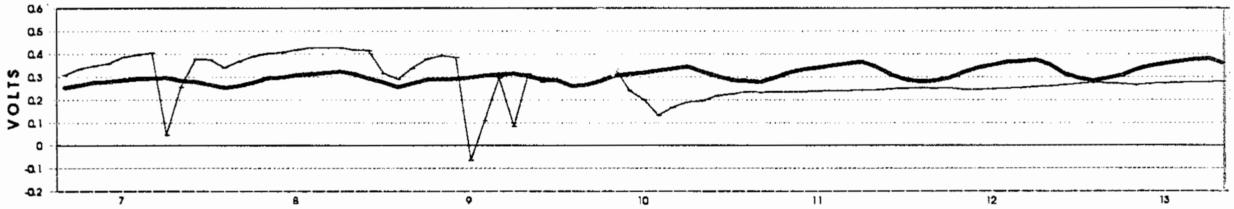
pH



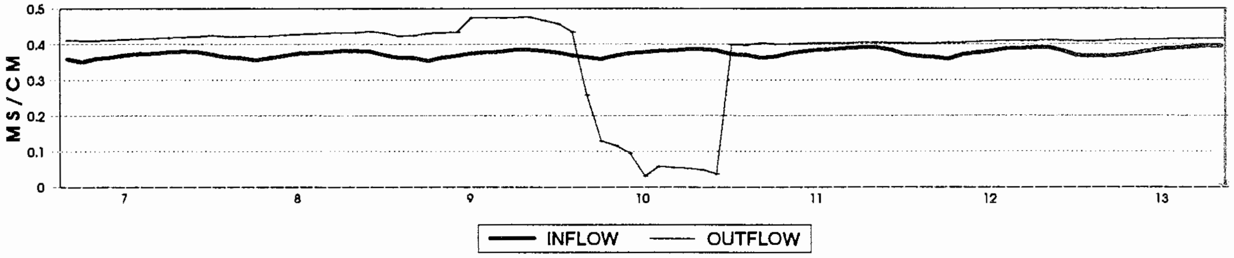
DISSOLVED OXYGEN



OXIDATION REDUCTION POTENTIAL

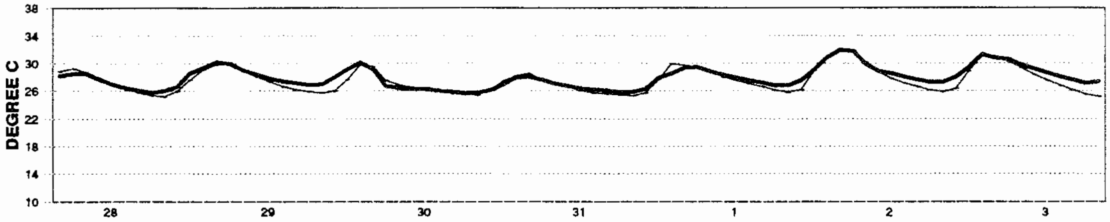


CONDUCTIVITY

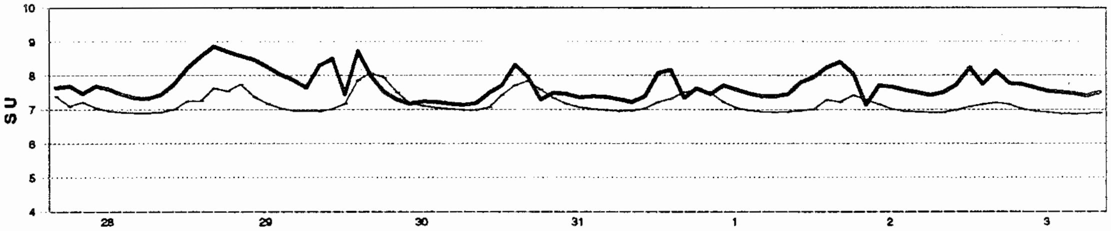


AUGUST 27 TO SEPTEMBER 3, 1993

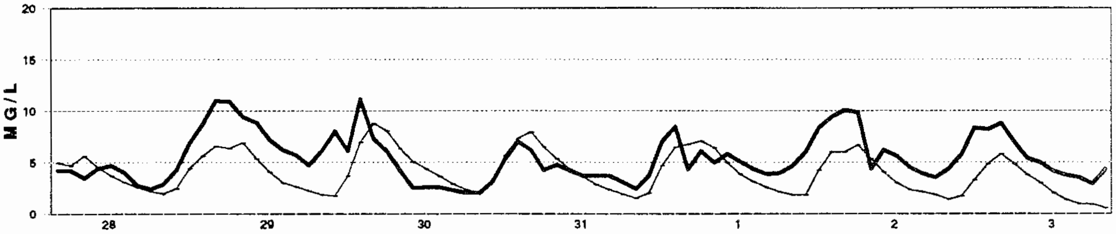
TEMPERATURE



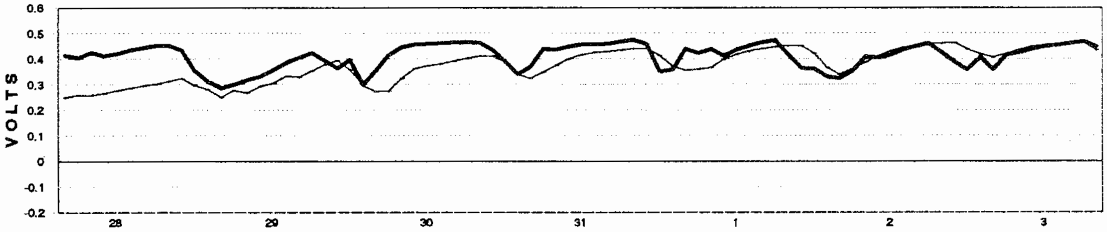
pH



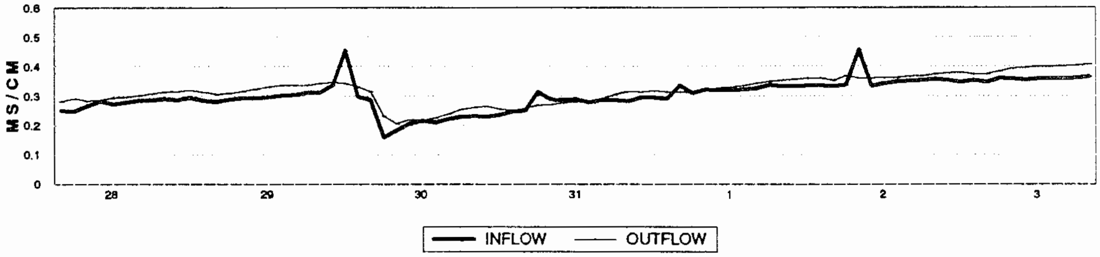
DISSOLVED OXYGEN

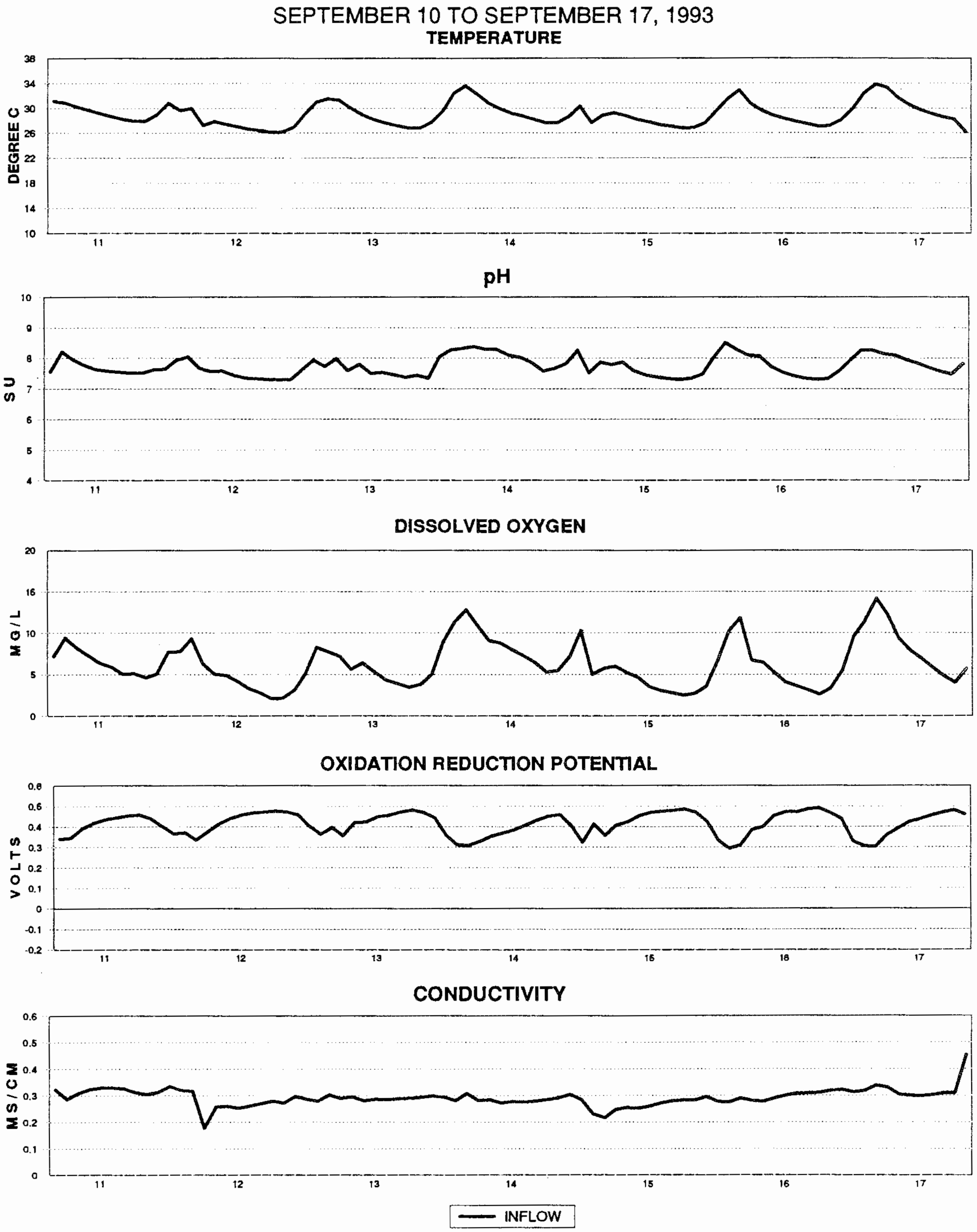


OXIDATION REDUCTION POTENTIAL



CONDUCTIVITY




SEPTEMBER 10 TO SEPTEMBER 17, 1993

TEMPERATURE

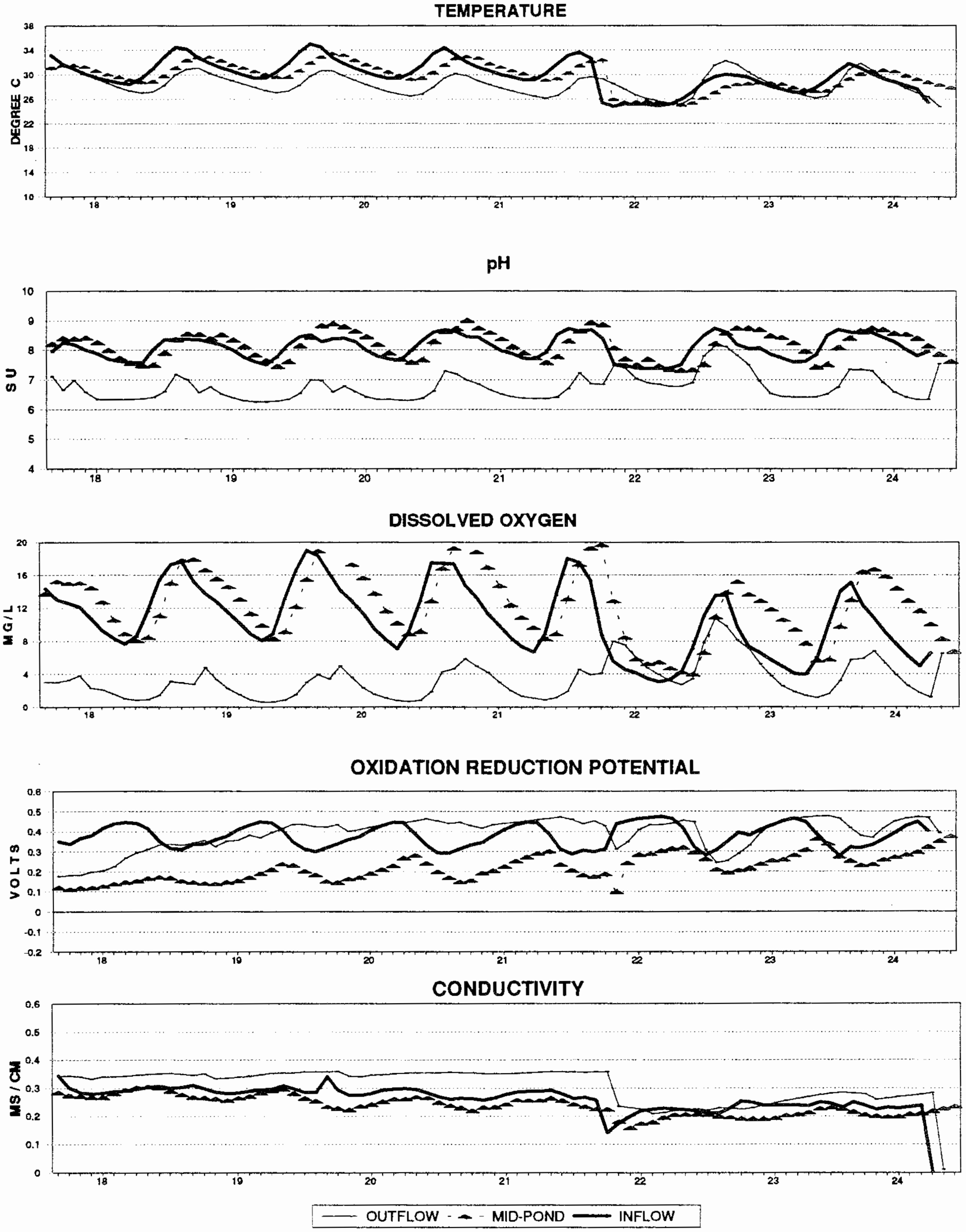
pH

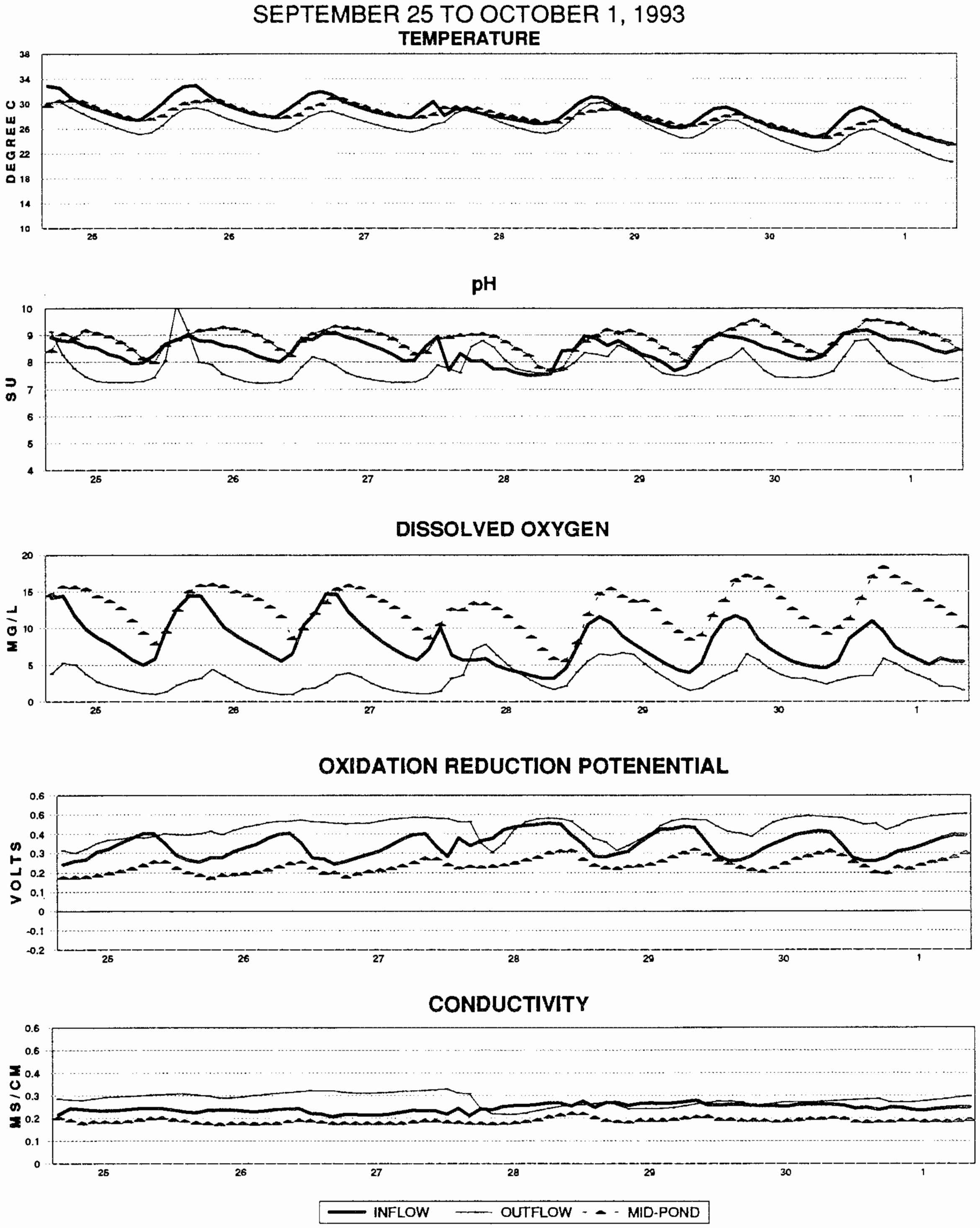
DISSOLVED OXYGEN

OXIDATION REDUCTION POTENTIAL

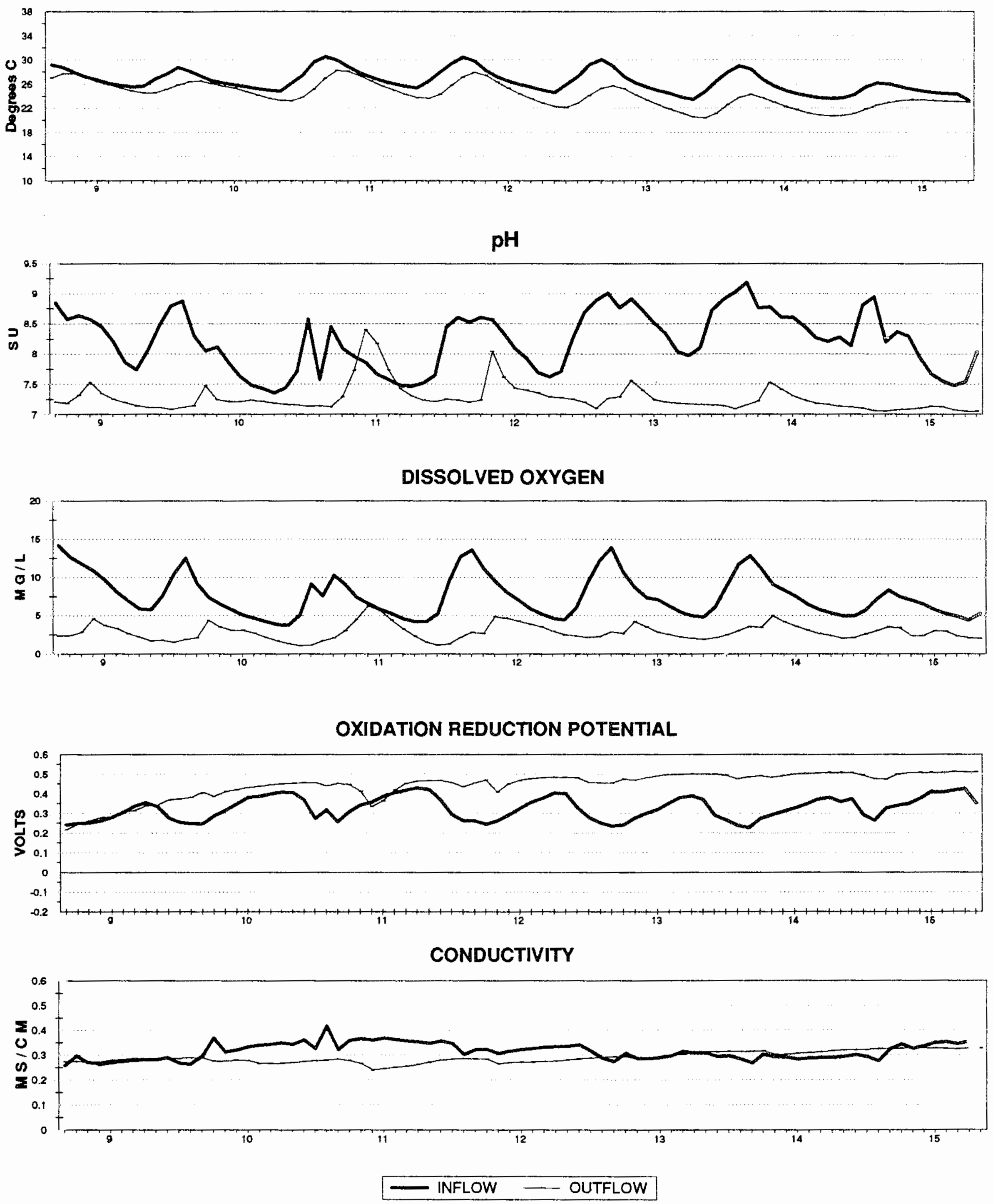
CONDUCTIVITY

SEPTEMBER 17 T0 SEPTEMBER 24, 1993



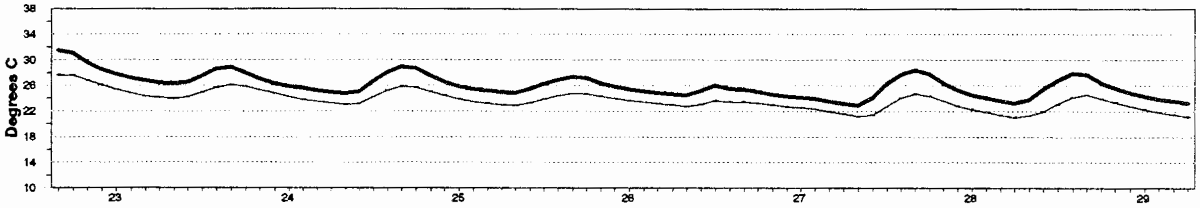

SEPTEMBER 25 TO OCTOBER 1, 1993
TEMPERATURE
DEGREE C
38
34
30
26
22
18
14
10
25
26
27
28
29
30
1
pH
SU
10
9
8
7
6
5
4
25
26
27
28
29
30
1
DISSOLVED OXYGEN
MG/L
20
15
10
5
0
25
26
27
28
29
30
1
OXIDATION REDUCTION POTENENTIAL
VOLTS
0.6
0.6
0.4
0.3
0.2
0.1
0
-0.1
-0.2
25
26
27
28
29
30
1
CONDUCTIVITY
MS/CM
0.6
0.6
0.4
0.3
0.2
0.1
0
25
26
27
28
29
30
1
INFLOW
OUTFLOW
MID-POND

OCTOBER 8 TO OCTOBER 15, 1993

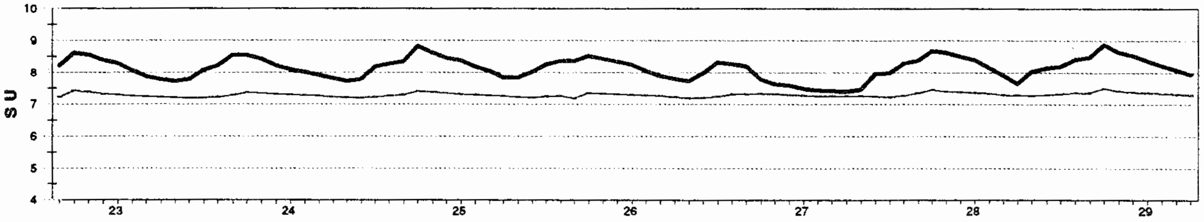


OCTOBER 22 TO OCTOBER 29, 1993

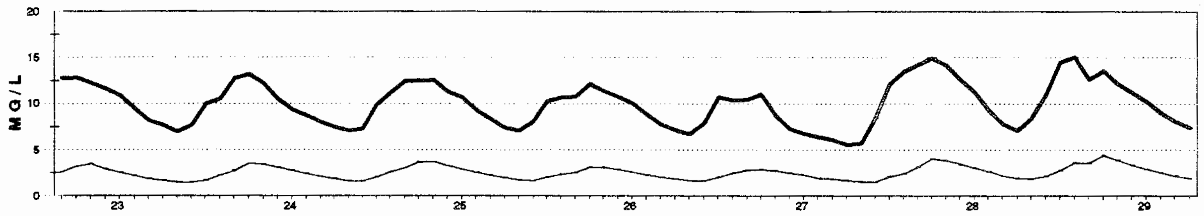
TEMPERATURE



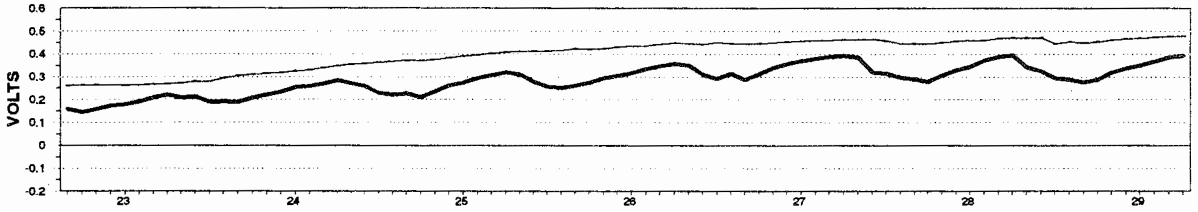
pH



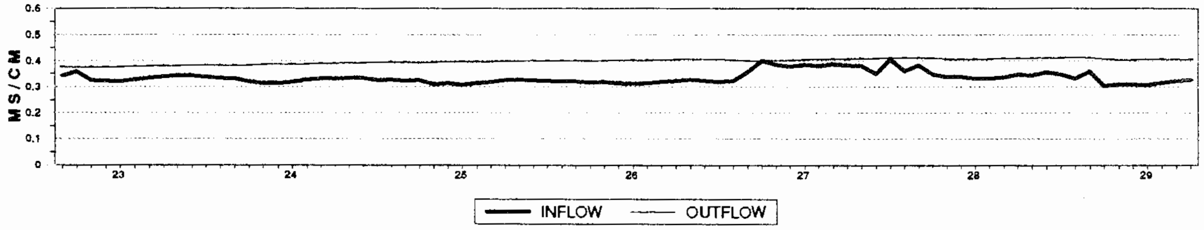
DISSOLVED OXYGEN



OXIDATION REDUCTION POTENTIAL

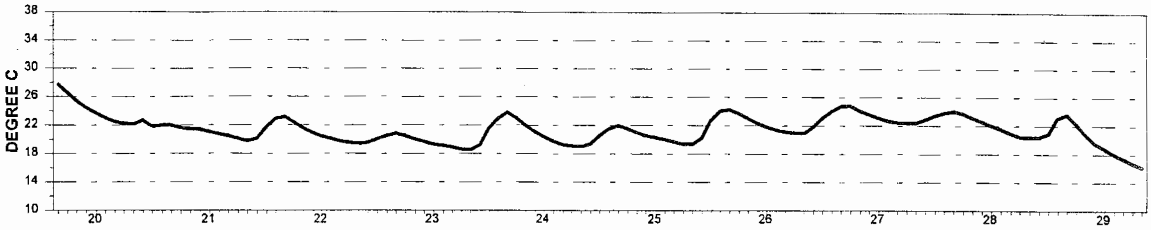


CONDUCTIVITY

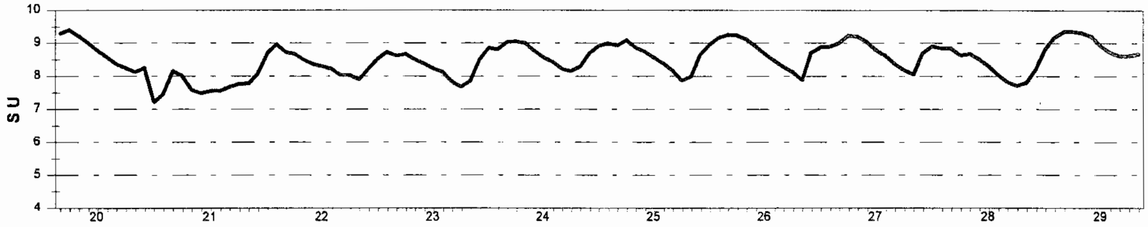


NOVEMBER 19 TO 29, 1993

TEMPERATURE



pH



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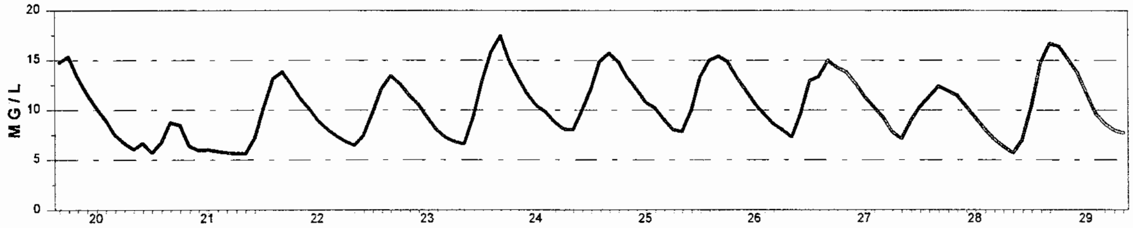
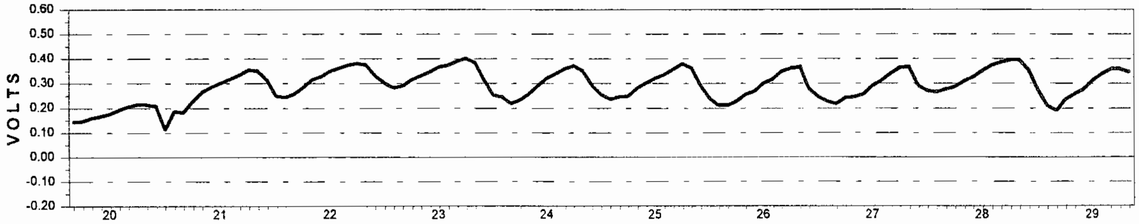
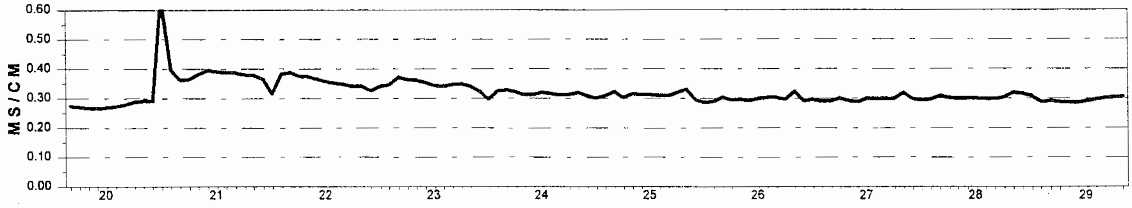


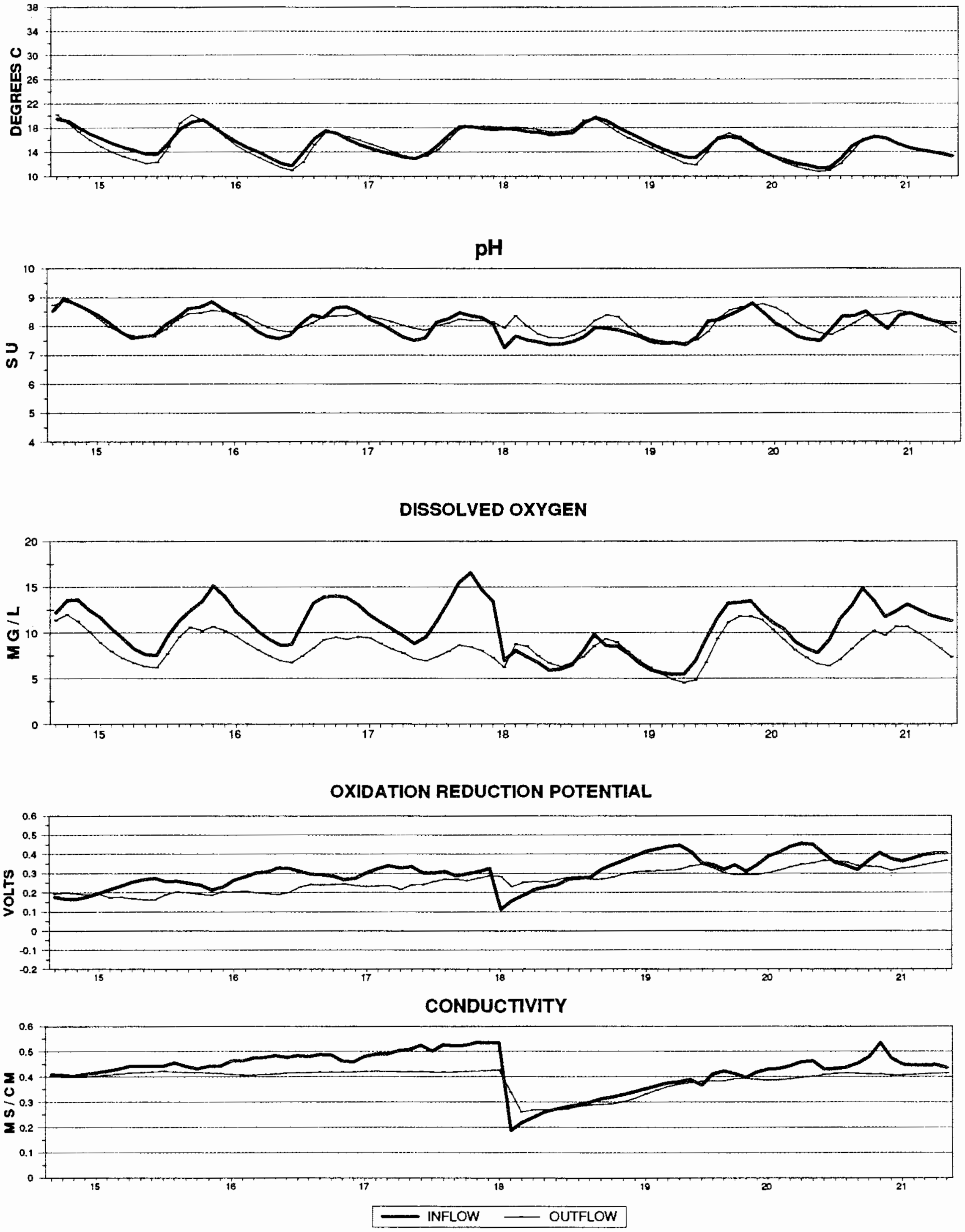
OXIDATION REDUCTION POTENTIAL



CONDUCTIVITY

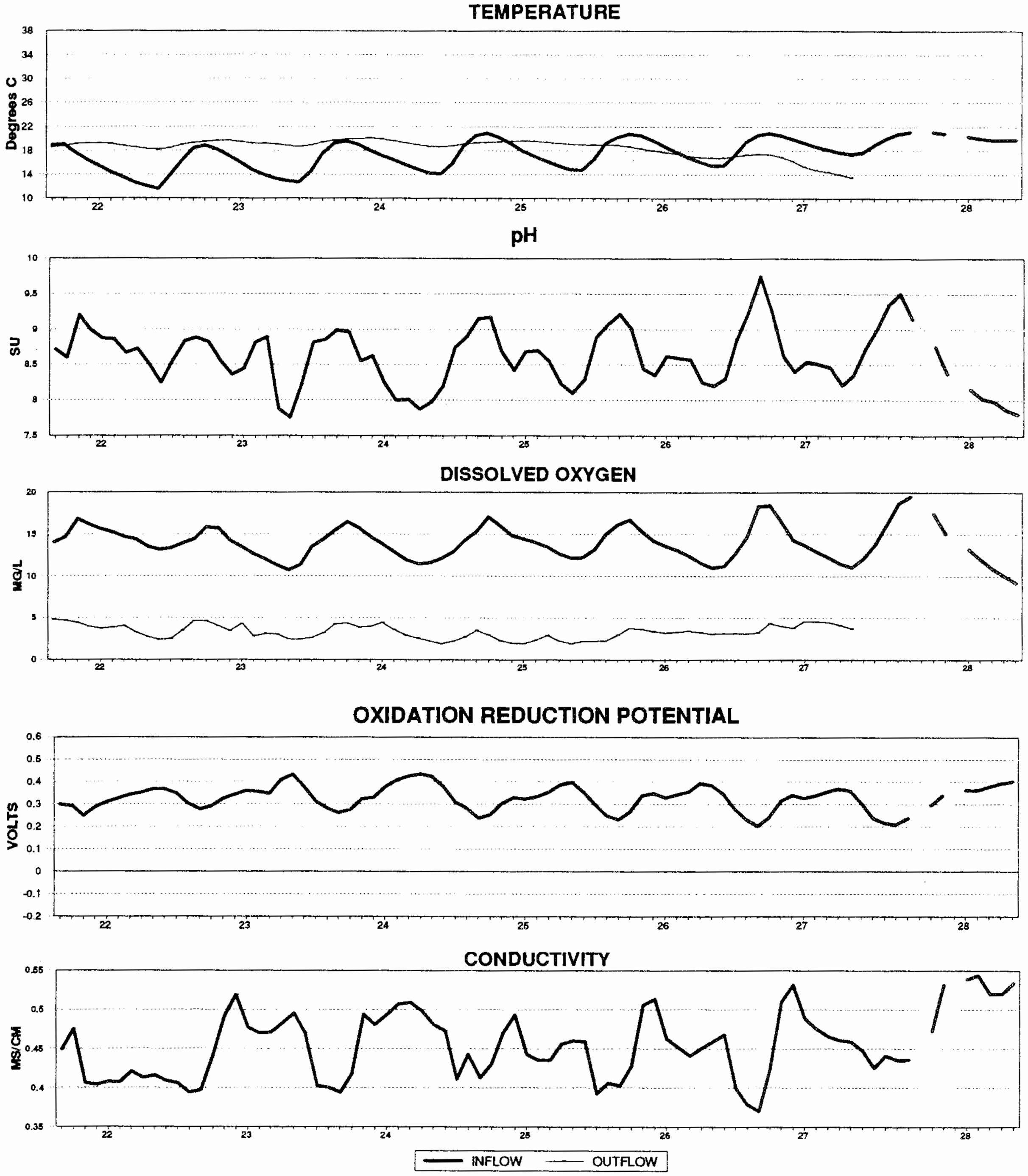


INFLOW



JANUARY 15 TO JANUARY 21, 1994

JANUARY 21 TO JANUARY 28, 1994


TEMPERATURE

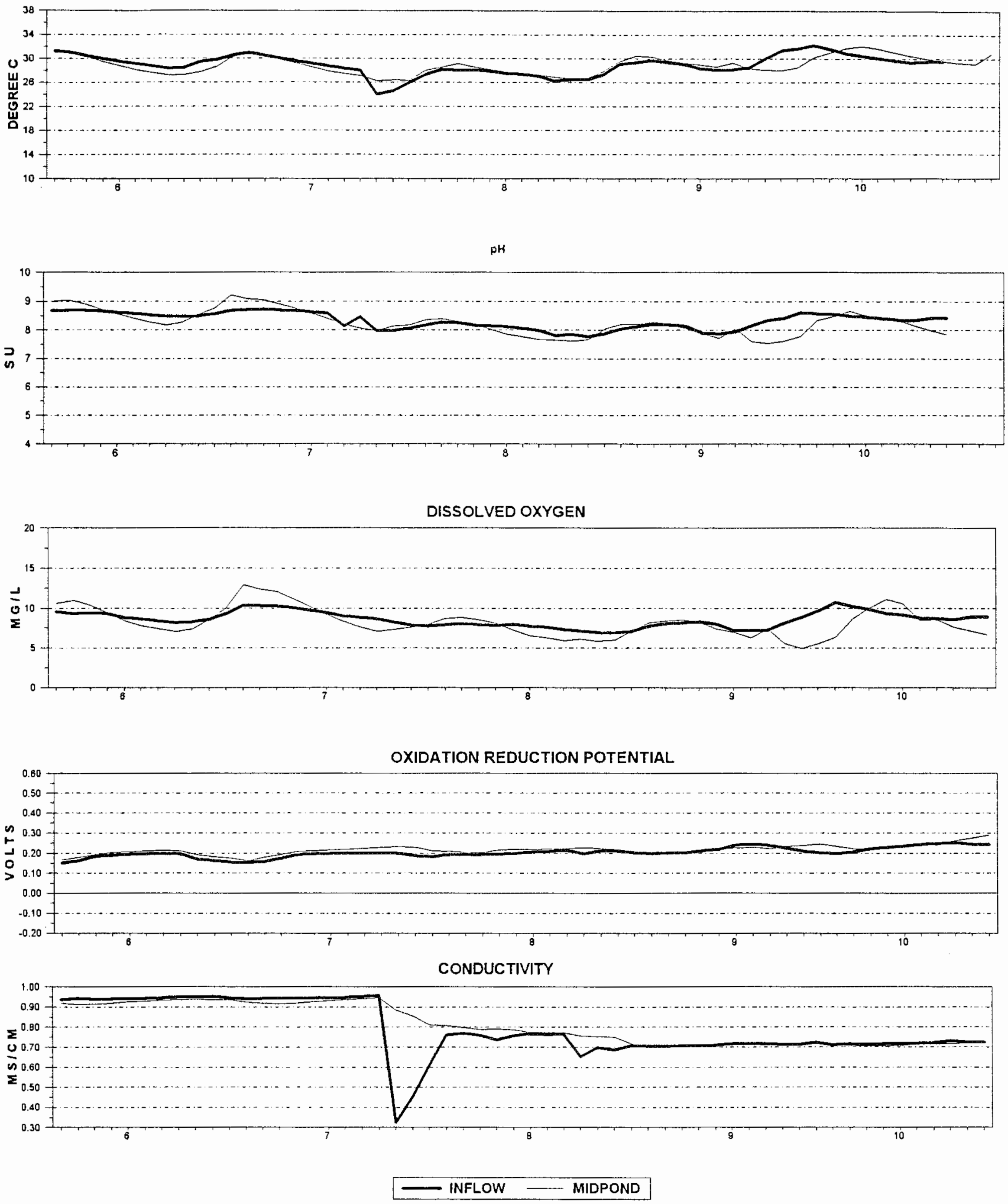
pH

DISSOLVED OXYGEN

OXIDATION REDUCTION POTENTIAL

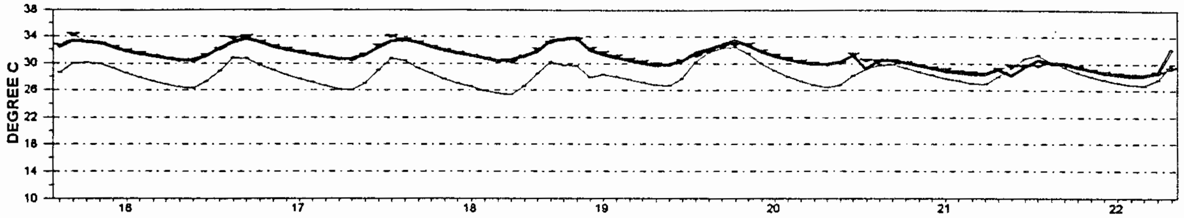
CONDUCTIVITY

JUNE 5 to JUNE 10, 1994

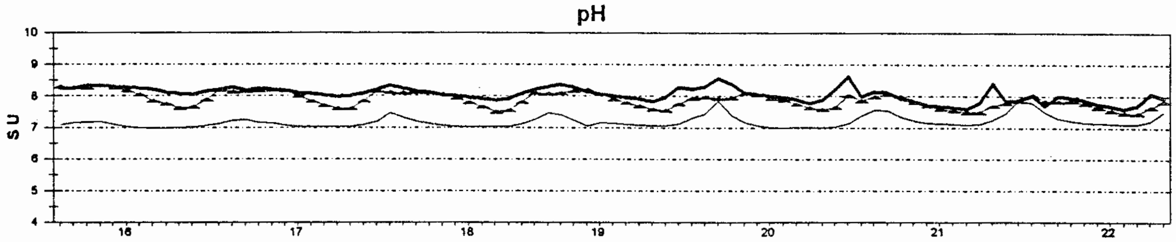


JULY 15 to JULY 22, 1994

TEMPERATURE



pH



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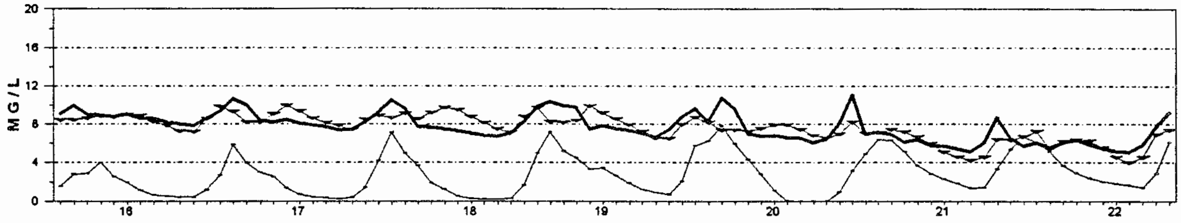

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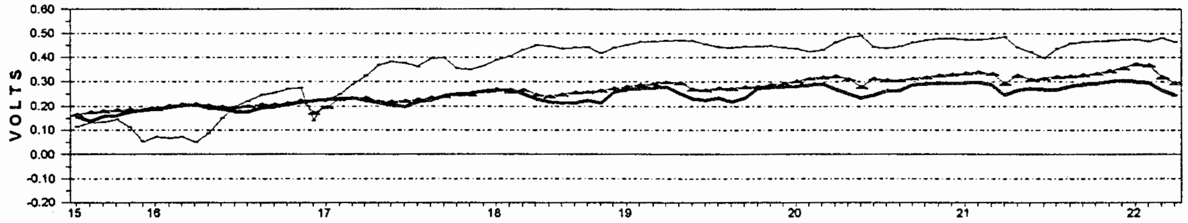
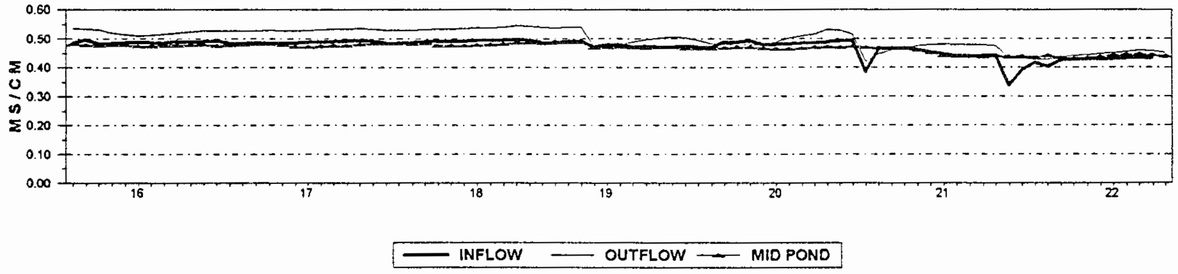
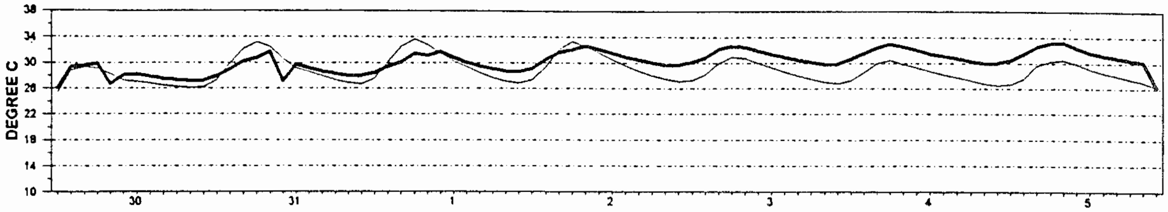


CONDUCTIVITY

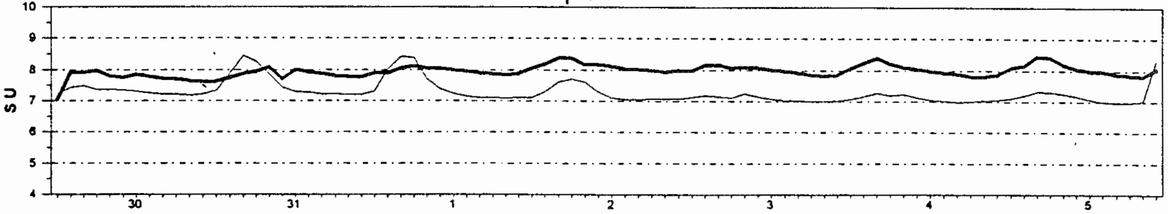


JULY 29 to AUGUST 5, 1994

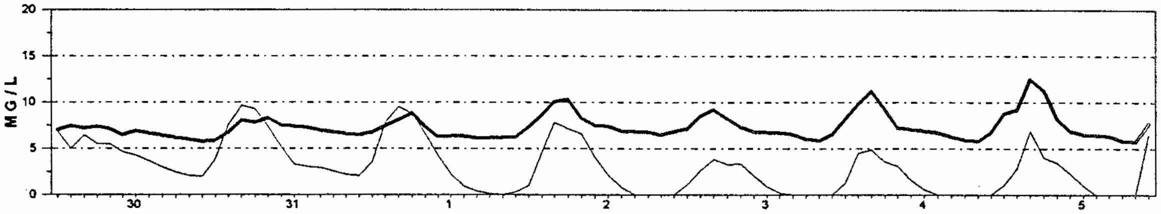
TEMPERATURE



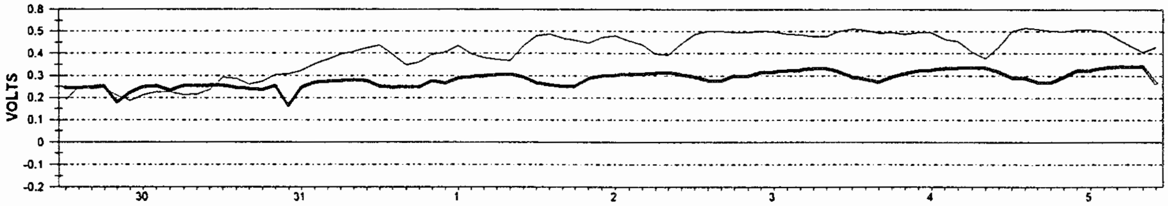
pH



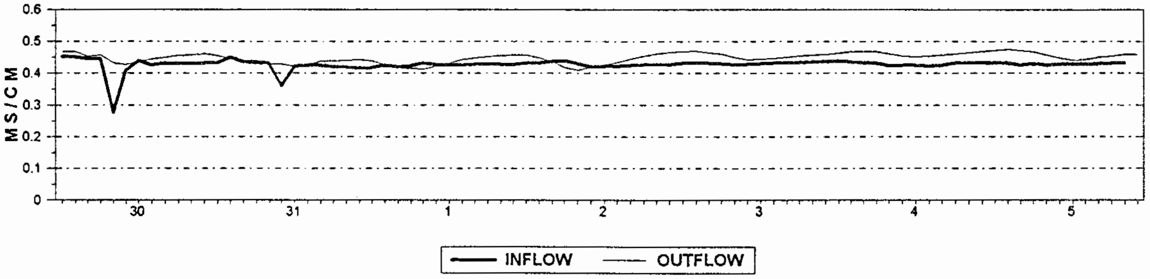
DISSOLVED OXYGEN



OXIDATION REDUCTION POTENTIAL

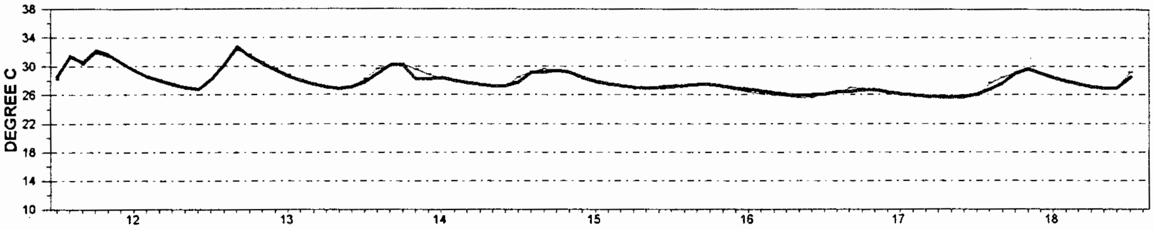


CONDUCTIVITY

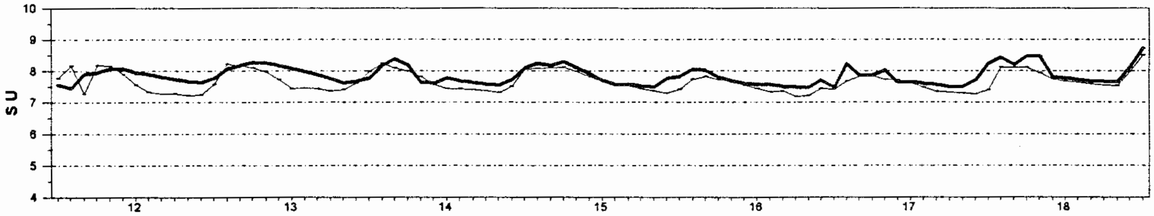


AUGUST 11 to AUGUST 18, 1994

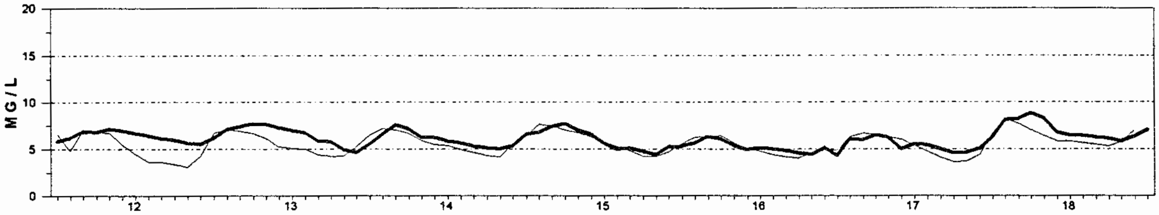
TEMPERATURE



pH



DISSOLVED OXYGEN



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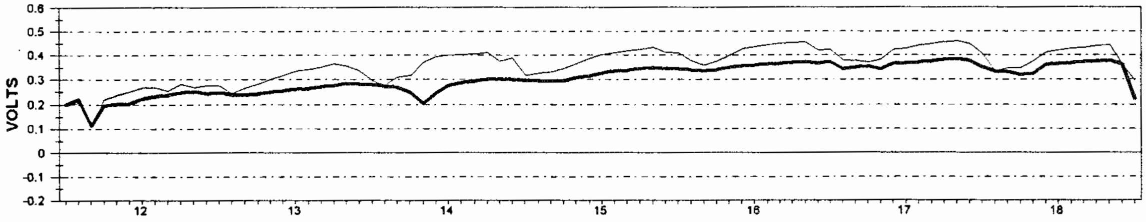
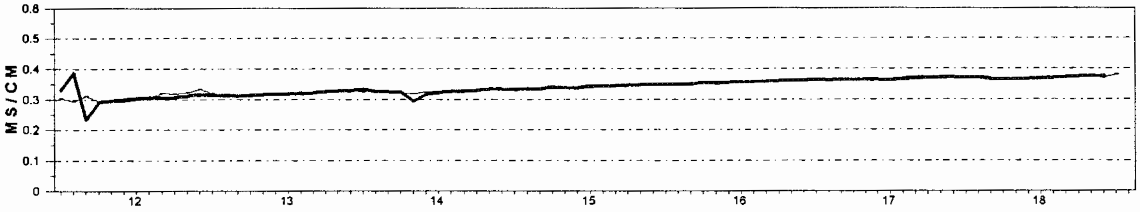


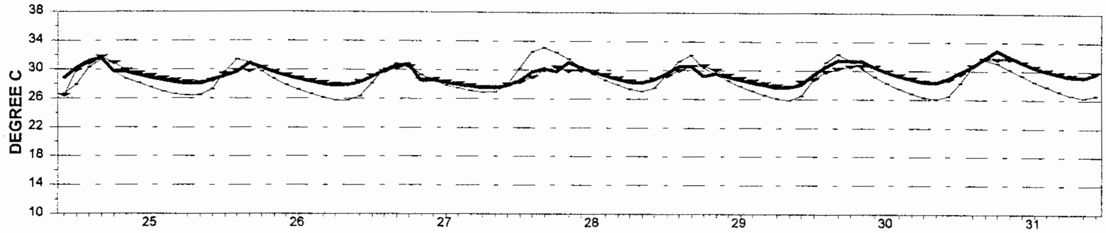
CONDUCTIVITY



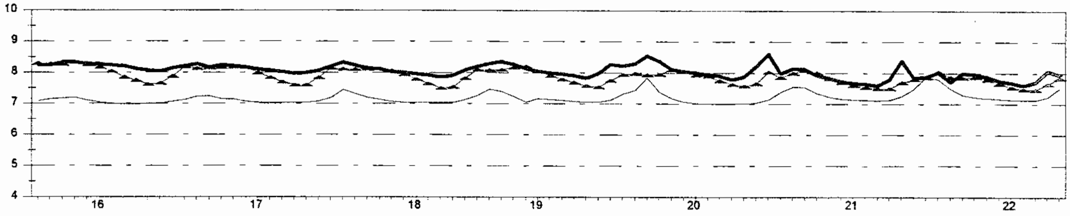
━ INFLOW — MIDPOND

AUGUST 17 TO 31, 1994

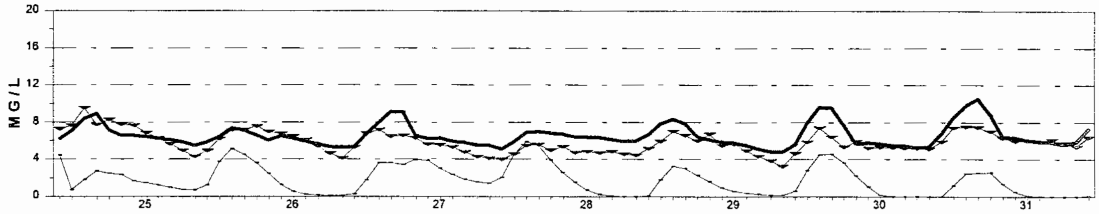
TEMPERATURE



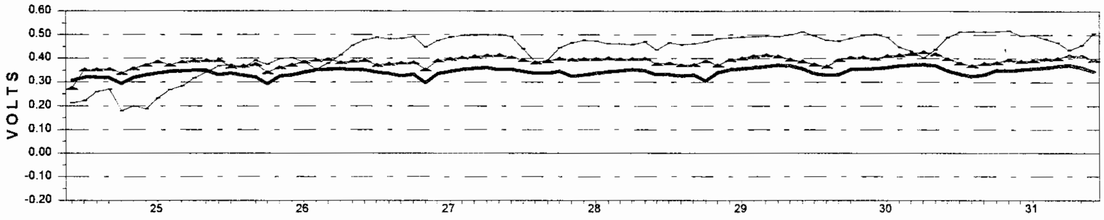
pH



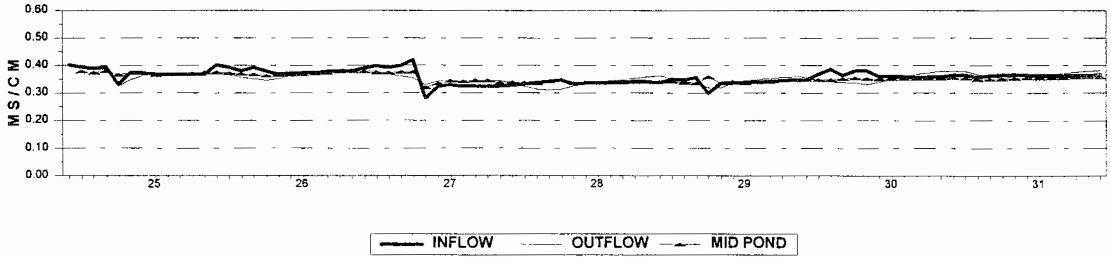
DISSOLVED OXYGEN



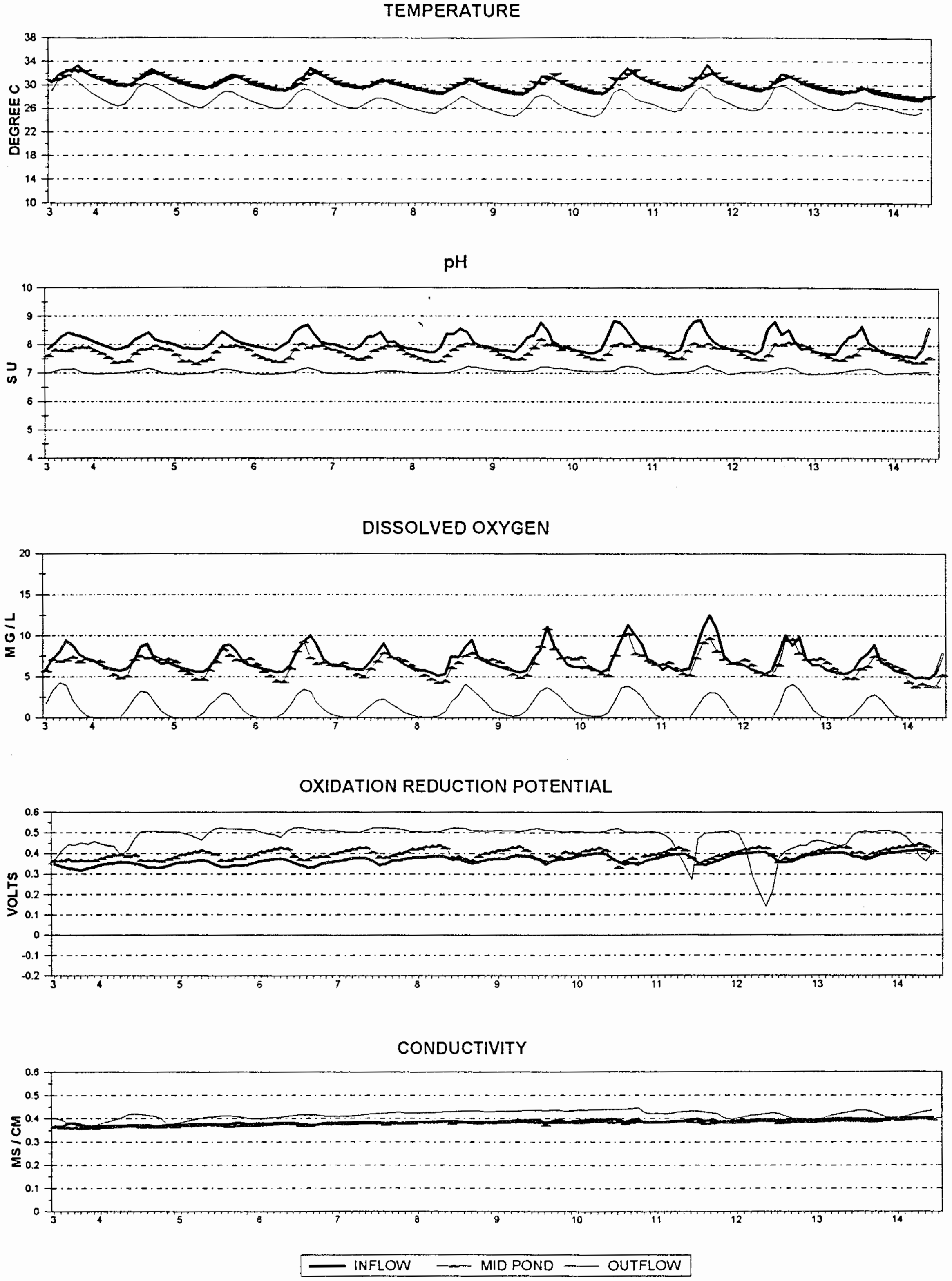
OXIDATION REDUCTION POTENTIAL



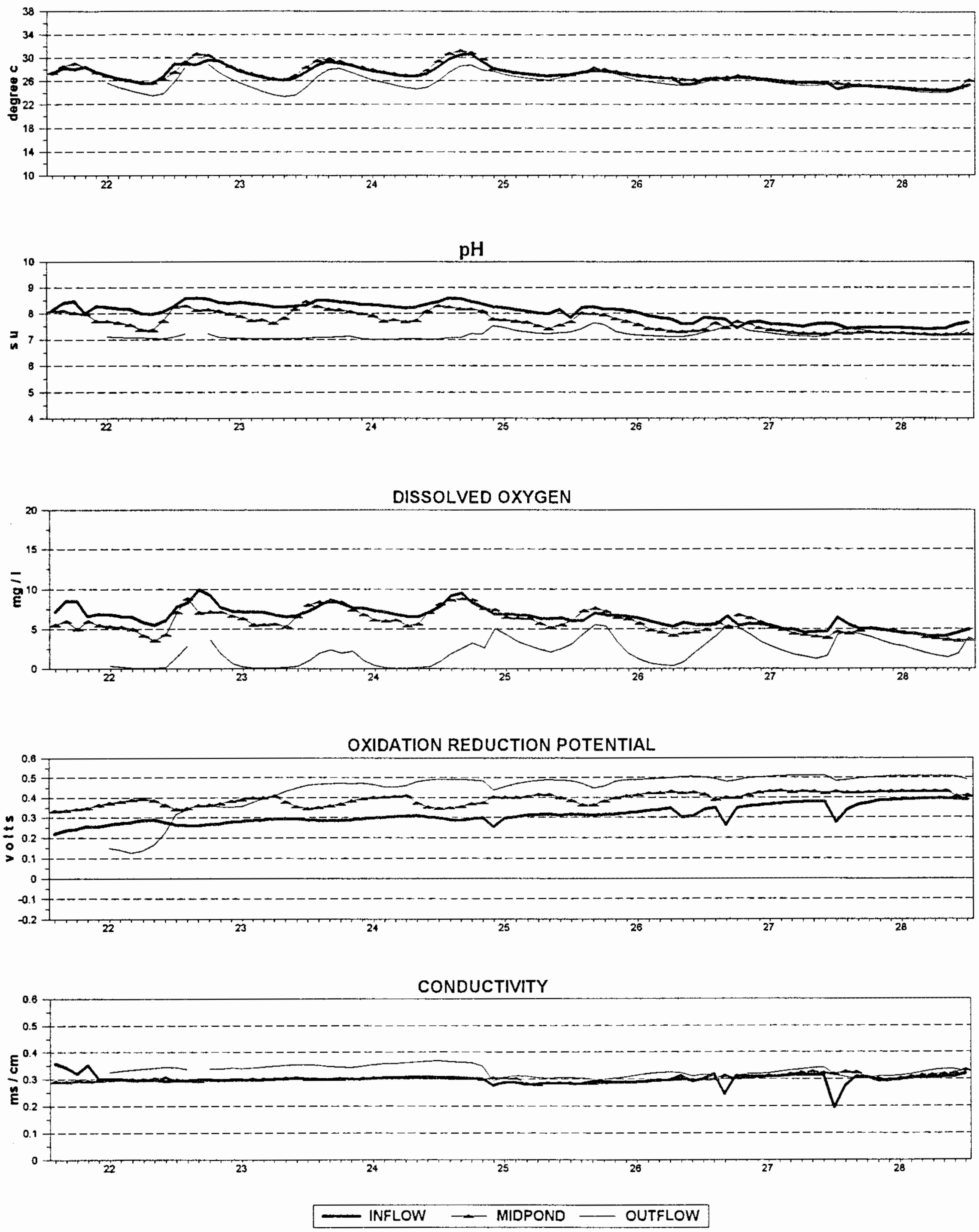
CONDUCTIVITY



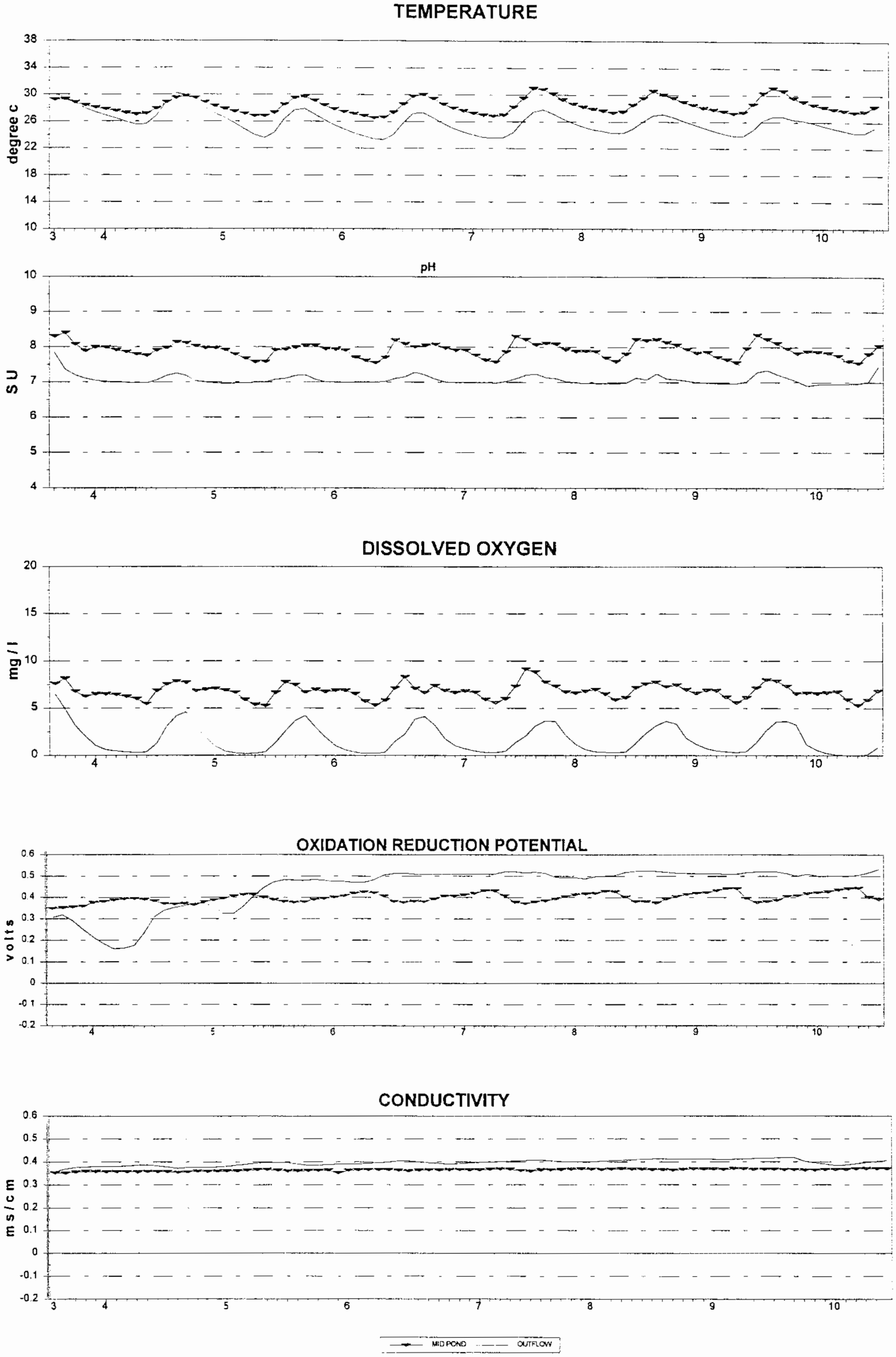
September 3 to September 14, 1994



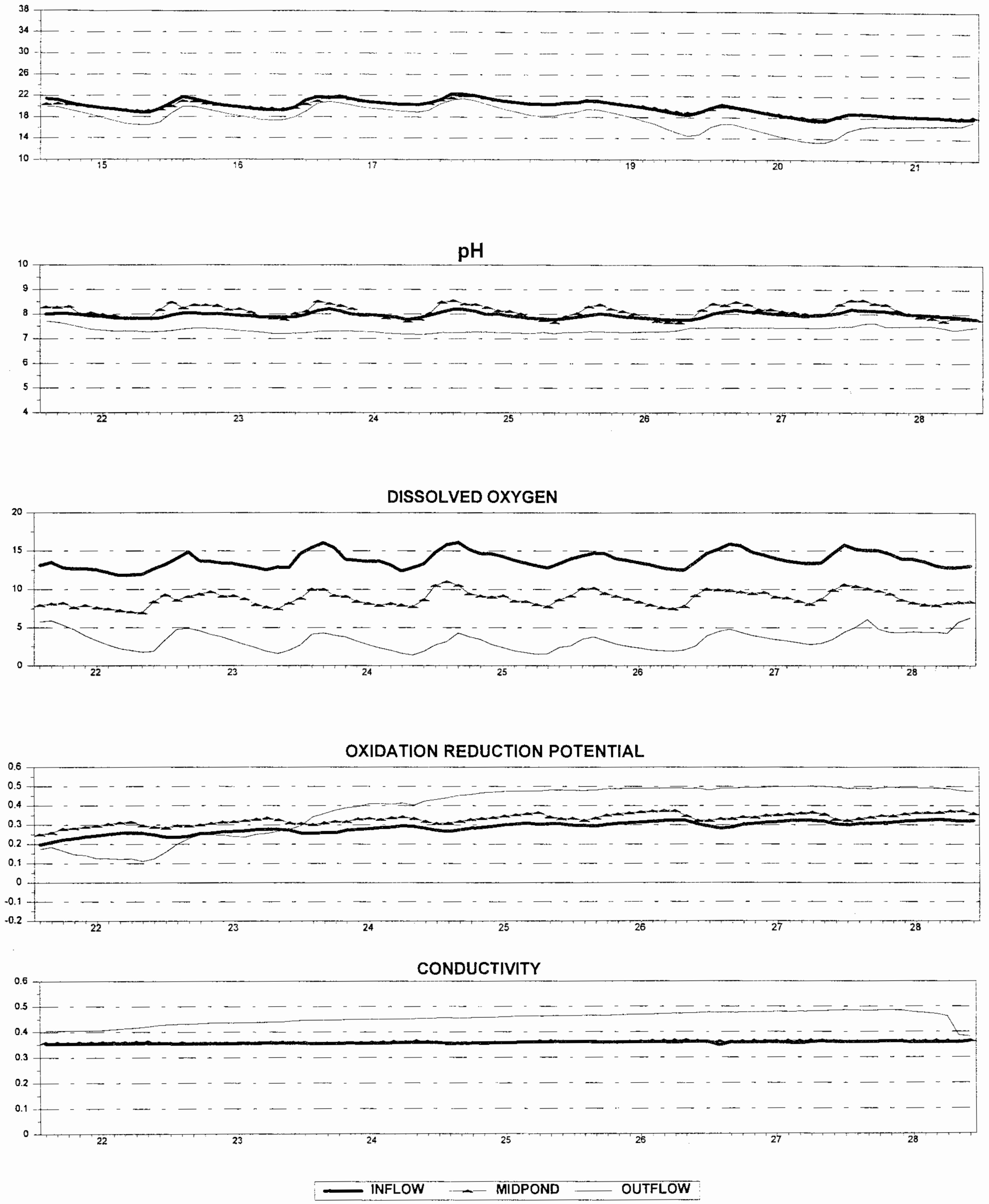
September 21 to September 28



October 3 to October 10, 1994



December 14 to 21, 1994



APPENDIX N

Figures for Sediment Sample Data

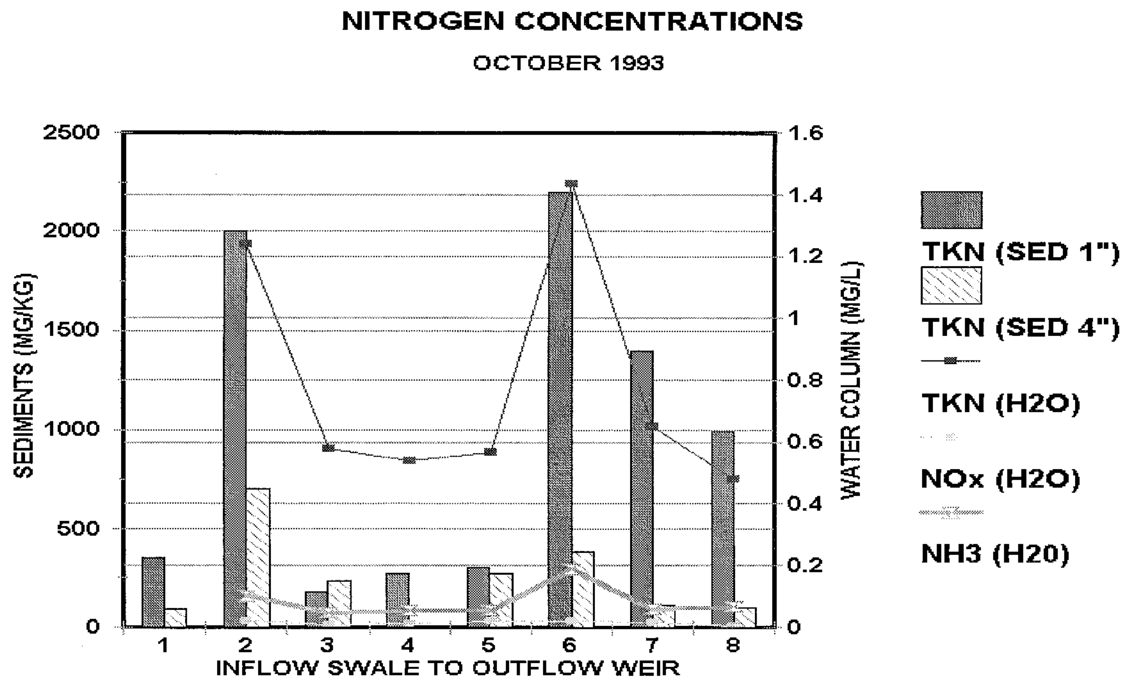


Figure N-1. Elevated concentrations of nitrogen in the water column are related to elevated concentrations in the sediments during the quiescent no-flow conditions in October 1993. See Figure 3 for sampling locations.

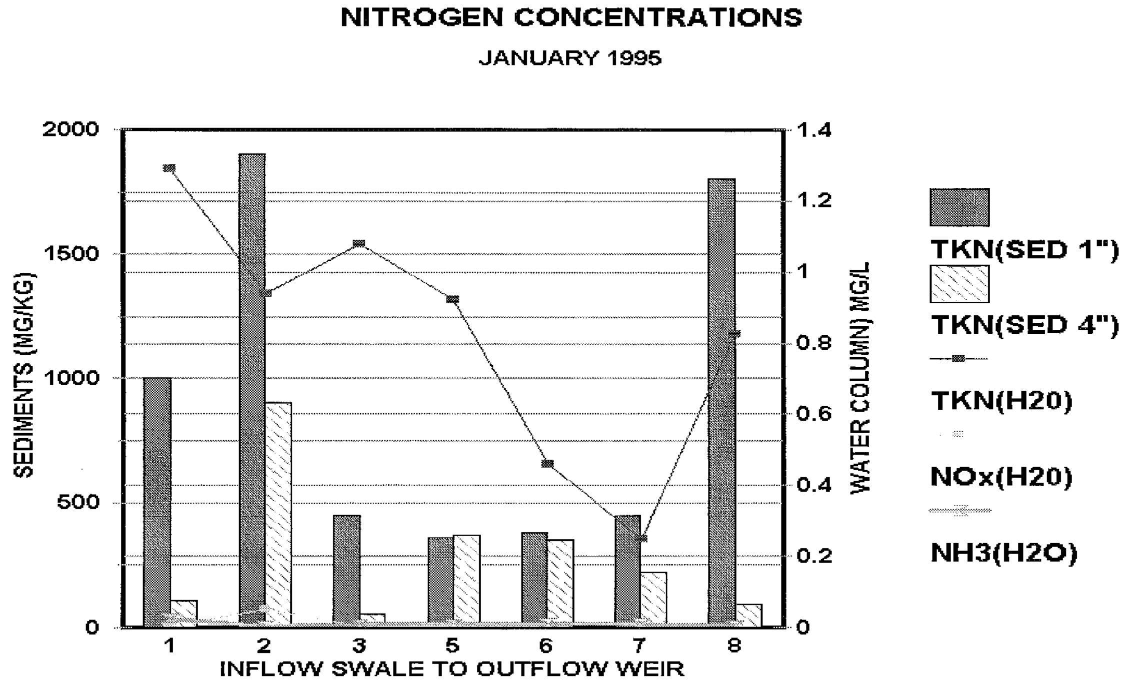


Figure N-2. Elevated nitrogen concentrations in the water column are not necessarily consistent with elevated concentrations in the sediments measured while the pond was discharging in January 1995. See Figure 3 for sampling locations.

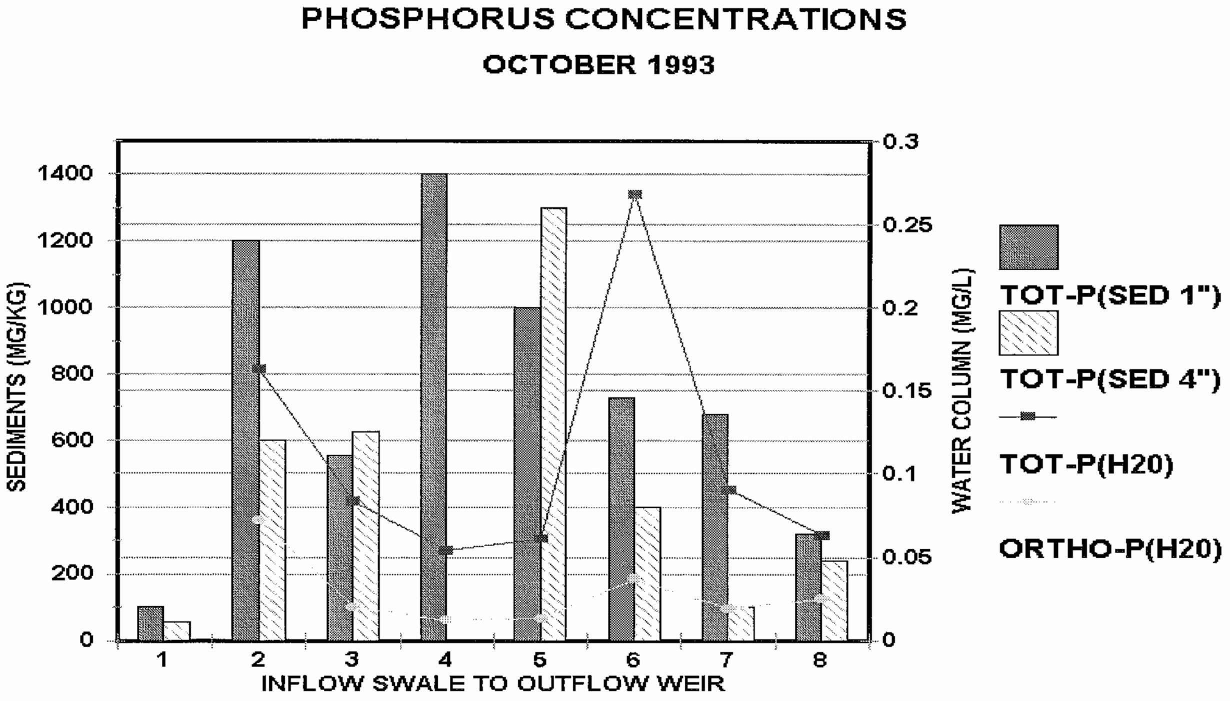


Figure N-3. No consistent relationship exists between phosphorus concentrations in the water column compared to the sediments for either year. October 1993 is shown above. See Figure 3 for sampling locations. Sediments were not analyzed for phosphorus at the four inch depth at site 4.

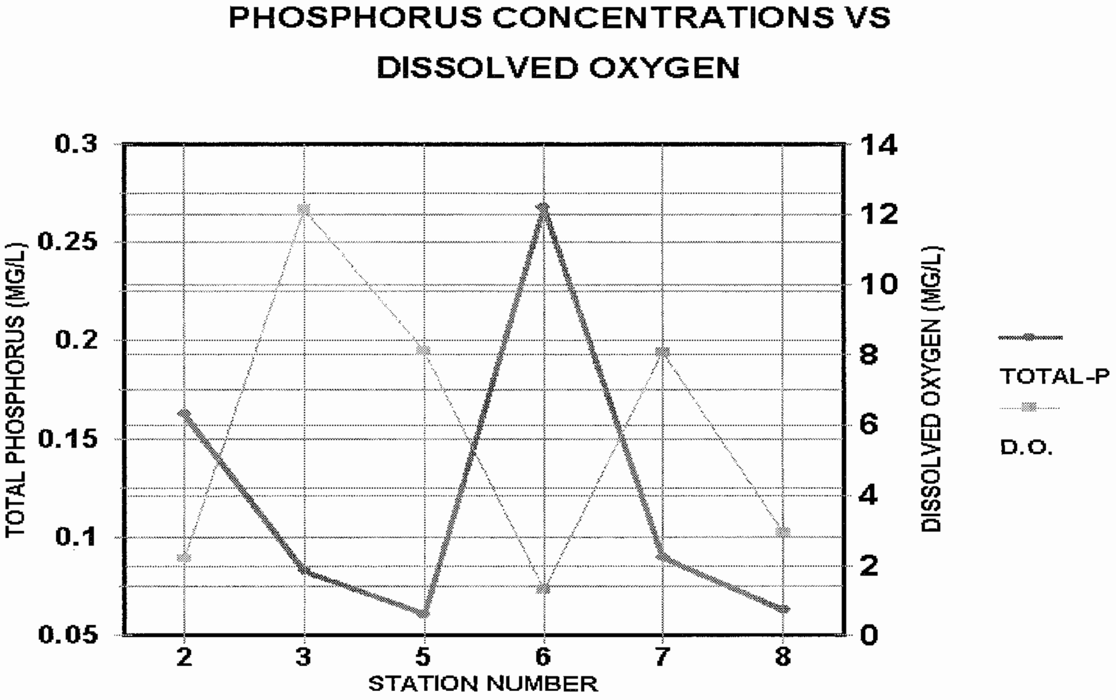


Figure N-4. Phosphorus was measured at higher concentrations in the water column when dissolved oxygen concentrations were below 2 mg/l during the 1993 sampling event.

APPENDIX O

StatisticalAnalyses for Inflow Data

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                     RESIDENCE TIME AND WATER QUALITY IMPROVEMENT
                              TAMPA OFFICE 1990 TO 1995
                                     INFLOW DATA
                              NON-PARMETRIC CORRELATIONS

 26 'VAR' Variables:  ZNIN     CDIN     CUIN     FEIN     PBIN     MNIN     HIN      NHIN
                      NOXIN    ONIN     OPIN     TPIN     SSIN     TOCIN    INTER    TRAIN
                      AVGINT   MAXINT   DURA     RCOEF    NAIN     SO3IN    MGIN     CAIN
                      CLIN     KIN

 Variable             N         Mean        Std Dev        Median       Minimum       Maximum

 ZNIN                84    44.761905      23.674306     40.500000      2.000000    111.000000
 CDIN                87     0.336782       0.388831      0.200000             0      2.000000
 CUIN                65     5.090769       3.853883      4.000000             0     17.700000
 FEIN                87  1951.413793    2627.855017    978.000000      4.000000         16175
 PBIN                64     4.081250       4.533014      3.000000             0     23.000000
 MNIN                65    31.495385      20.184968     27.000000      4.100000    112.500000
 HIN                 63   190.746032      90.602636    174.000000     60.000000    543.000000
 NHIN                87     0.100103       0.141747      0.059000      0.004000      1.102000
 NOXIN               87     0.277782       0.462363      0.158000             0      3.000000
 ONIN                87     1.067115       0.459168      1.002000             0      2.723000
 OPIN                84     0.299619       0.249784      0.245500             0      1.550000
 TPIN                82     0.469268       0.393793      0.369000             0      2.136000
 SSIN                87    81.804598     100.757231     36.000000      1.000000    592.000000
 TOCIN               54    14.737778       4.026542     15.385000      6.260000     23.110000
 INTER               87     4.025632       4.642638      2.180000      0.230000     25.770000
 TRAIN               87     0.811724       0.631908      0.660000      0.100000      3.910000
 AVGINT              86     0.364419       0.262623      0.290000      0.030000      1.110000
 MAXINT              86     1.253256       0.937660      1.030000      0.080000      4.160000
 DURA                85     3.234118       2.911345      2.000000      0.500000     16.500000
 RCOEF               85     0.370447       0.194705      0.336000             0      0.807000
 NAIN                61     4.349180       3.038235      3.500000             0     15.000000
 SO3IN               61    78.016393      73.141300     62.000000      9.000000    413.000000
 MGIN                61     6.219672       4.326539      4.600000      1.600000     20.900000
 CAIN                61    65.639344      30.159041     56.000000     21.000000    186.000000
 CLIN                61     7.167213       4.857630      5.900000      1.900000     25.000000
 KIN                 60     2.978333       1.762807      2.150000      1.000000      8.700000
```

ABBREVIATIONS:

OBS	Observation number.
MO	Month.
DA	Day of the month.
YR	Year
ZNIN	Zinc event mean concentrations (uG/l) at the inflow.
CDIN	Cadmium event mean concentrations (uG/l) at the inflow.
CUIN	Copper event mean concentrations (uG/l) at the inflow.
FEIN	Iron event mean concentrations (uG/l) at the inflow.
PBIN	Lead event mean concentrations (uG/l) at the inflow
MNIN	Magnesium event mean concentrations (uG/l) at the inflow.
HIN	Total hardness as CaCO3 event mean concentrations (mg/l) at the inflow.
NHIN	Ammonia event mean concentrations (mg/l) at the inflow.
NOXIN	Nitrate+nitrite event mean concentrations (mg/l) at the inflow.
ONIN	Organic nitrogen event mean concentrations (mg/l) at the inflow.
OPIN	Ortho-phosphate event mean concentrations (mg/l) at the inflow.
TPIN	Total phosphorus event mean concentrations (mg/l) at the inflow.
SSIN	Total suspended solids event mean concentrations (mg/l) at the inflow.
TOCIN	Total organic carbon grab sample after rain event (mg/l) at the inflow.
RT	Residence time as calculated from pond size (days).
TRAIN	Total rain for event in inches
INTER	Inter-event dry period (days) a.k.a. antecedent conditions for all storms > 0.05 inches
LINTER	Inter-event dry period (days) for all storms > 0.25 inches.
AVGINT	Average rain intensity (in/hr).
MAXINT	Maximum intensity (in/hr) for a 15 minute period.
DURA	Duration of storm (hours).
RCOEF	Runoff coefficient.
NO	Storm number for each year.
NAIN	Sodium event mean concentration (mg/l) at the inflow.
SO3IN	Sulfate event mean concentration (mg/l) at the inflow.
MGIN	Magnesium event mean concentration (mg/l) at the inflow.
CAIN	Calcium event mean concentration (mg/l) at the inflow.
CLIN	Chloride event mean concentration (mg/l) at the inflow.
KIN	Potassium event mean conentration (mg/l) at the inflow.

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                              RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                                6
                                         TAMPA OFFICE 1990 TO 1995
                                                INFLOW DATA

OBS  MO  DA  YR  ZNIN  CDIN  CUIN    FEIN  PBIN  MNIN   HIN   NHIN  NOXIN    ONIN    OPIN     TPIN  SSIN

  1   5  24  90    50   0.1     .     290     .     .     .  0.020  0.120   0.930   0.193    0.244     7
  2   6   4  90    30   1.4     .     350     .     .     .  0.050  0.220   0.480   0.180    0.137    28
  3   6  11  90    40   0.7     .     180     .     .     .  0.060  0.490   1.610   0.108    0.174     7
  4   6  23  90    58   0.5     .    1051     .     .     .  0.030  0.100   0.674   0.332    0.395    60
  5   6  24  90    44   0.2     .     462     .     .     .  0.021  0.068   0.797   0.272    0.310    19
  6   7   8  90    36   0.2     .     593     .     .     .  0.277  0.473   0.822   0.309    0.442    23
  7   7  11  90    35   0.1     .     553     .     .     .  0.047  0.036   1.425   0.422    0.658    29
  8   7  12  90    56   0.3     .     371     .     .     .  0.353  0.709   0.679   0.439    0.556    21
  9   7  13  90    62   0.1     .     332     .     .     .  0.036  0.241   0.954   0.467    0.559    28
 10   7  14  90    10   0.1     .     266     .     .     .  0.085  0.132   0.930   0.408    0.511    16
 11   7  19  90    36   0.1     .     377     .     .     .  0.179  0.307   1.396   0.179    0.351    12
 12   8   1  90    51   0.8     .     124     .     .     .  0.026  0.376   2.723   0.078    0.206     9
 13   8  15  90    79   0.9     .     583     .     .     .  0.049  0.029   1.164   0.203    0.333    29
 14   8  19  90    74   0.9     .     255     .     .     .  0.155  0.309   0.780   0.156    0.204    10
 15   8  26  90    66   0.6     .    1367     .     .     .  0.050  0.077   0.994   0.361    0.455    87
 16   8  29  90    73   1.4     .     978     .     .     .  0.154  0.096   0.330   0.632        .    80
 17   9   1  90    53   2.0     .     434     .     .     .  0.055  0.218   1.620   0.900    1.127    34
 18   9  17  90    43   1.9     .     250     .     .     .  0.026  0.316   0.770   0.474    0.565     8
 19   9  30  90    38   0.1     .     844     .     .     .  0.035  0.179   0.785   0.248    0.353    36
 20  10   3  90    99   0.4     .    1700     .     .     .  0.040  0.144   0.720   0.206    0.272     9
 21  10  10  90    44   0.7     .     530     .     .     .  0.029  0.039   0.885   0.388    0.482    24
 22   1  15  91    50   0.1     .      32     .     .     .  0.041  0.396   1.071   0.430    0.461    31
 23   6  24  93    24   0.0   2.3    1844   0.0  59.9   190  0.021  0.056   1.429   0.262    0.576    53
 24   6  30  93    64   0.5   9.8    6648  12.6  36.1   113  0.158  0.117   1.452   0.944    2.066   264
 25   7  12  93    39   0.0   4.0    3082   0.0  23.3   131  0.133  0.439   1.060   0.446    0.891   147
 26   7  21  93    46   0.0   5.6    1581   4.6  28.9   174  0.520  0.134   1.000   0.198    0.364    36
 27   8  13  93    32   0.1   2.8    1205   1.0  69.7     .  0.150  0.130   0.000   0.223    0.629     9
 28   8  14  93     8   0.0   0.7     533   0.6  28.0     .  0.060  0.090   0.910   0.185    0.315     7
 29   8  25  93    25   0.6   3.0    2569   5.0  37.0   124  0.159  0.510   0.221   0.007    0.411    77
 30   8  26  93     2   0.2   3.0    1474   0.7  11.0    60  0.004  0.170   1.106       .        .     9
 31   8  29  93    23   0.2   3.0    1898   3.6  30.9   111  0.033  0.050   2.217       .        .    90
 32   9   5  93    12   0.3   0.0     872   0.0  74.8   231  0.026  0.000   1.593   0.526 (2.855)*     5
 33   9   6  93    18   0.2   0.0     642   0.0  41.4   177  0.035  0.000   0.991   0.259    0.373     4
 34   9  11  93    20   0.1   2.0    1823   4.6  28.9   121  0.007  0.073   1.149   0.405    0.797   104
 35   9  14  93    34   0.1   4.3    2026   3.4  26.6   126  0.072  0.002   1.111   0.430    0.686    55

OBS  TOCIN  RT  INTER  TRAIN  AVGINT   MAXINT    DURA  RCOEF  NO  NAIN  SO3IN  MGIN  CAIN  CLIN  KIN

  1      .   2  14.49   0.37    0.37     0.78    1.00  0.050   2     .      .     .     .     .    .
  2      .   2   0.95   0.69    0.62     1.88    1.13  0.265   3     .      .     .     .     .    .
  3      .   2   3.83   0.46    0.36     0.58    1.25  0.167   4     .      .     .     .     .    .
  4      .   2   1.38   1.05    0.70     1.98    1.50  0.287   5     .      .     .     .     .    .
  5      .   2   0.53   0.83    0.16     1.32    5.38  0.252   6     .      .     .     .     .    .
  6      .   2  14.05   0.86    0.57     1.88    1.50  0.210   7     .      .     .     .     .    .
  7      .   2   2.97   1.10    0.59     1.96    2.00  0.275   8     .      .     .     .     .    .
  8      .   2   0.85   1.17    0.60     1.42       .  0.450   9     .      .     .     .     .    .
  9      .   2   0.81   0.48    0.14     0.94    3.38  0.266  10     .      .     .     .     .    .
 10      .   2   0.47   0.57    0.38     2.64    4.75  0.380  11     .      .     .     .     .    .
 11      .   2   3.95   0.29    0.20     0.92    1.50  0.238  12     .      .     .     .     .    .
 12      .   2  12.74   0.40    0.11     0.56    3.75  0.124  13     .      .     .     .     .    .
 13      .   2   0.65   0.32    0.63     1.22    0.50  0.216  14     .      .     .     .     .    .
 14      .   2   3.98   0.40    0.54     1.02    0.75  0.158  15     .      .     .     .     .    .
 15      .   2   1.07   0.62    0.25     0.82    2.50  0.205  16     .      .     .     .     .    .
 16      .   2   2.94   0.98    0.30     2.28    2.88  0.250  17     .      .     .     .     .    .
 17      .   2   1.00   1.06       .        .       .      .  18     .      .     .     .     .    .
 18      .   2  16.83   1.90    0.58     2.72    3.25  0.308  19     .      .     .     .     .    .
 19      .   2   1.92   0.65    0.87     1.44    0.75  0.357  20     .      .     .     .     .    .
 20      .   2   2.97   0.45    0.60     1.08    0.75  0.175  21     .      .     .     .     .    .
 21      .   2   6.26   2.64    0.24     1.40   11.00  0.500  22     .      .     .     .     .    .
 22      .   2  25.77   0.10    0.06     0.16    1.88  0.000  23     .      .     .     .     .    .
 23      .   5   0.74   0.93    0.24     1.50    4.00  0.386   1   6.1     35   5.8    67   9.3  4.2
 24      .   5   2.06   0.93    0.23     0.96    4.00  0.466   2   3.5     19   3.0    40   5.5  4.6
 25      .   5   1.69   1.09    0.34     0.96    3.25  0.308   3   3.5     38   4.1    46   4.2  2.1
 26      .   5   5.63   0.36    0.23     0.66    3.00  0.168   4   3.5     65   5.8    60   5.9  1.0
 27      .   5  16.92   0.37    0.74     1.04    0.50  0.001   5     .      .     .     .     .    .
 28      .   5   0.85   0.43    0.74     0.68    2.00  0.021   6     .      .     .     .     .    .
 29      .   5   8.90   2.16    0.93     3.90    2.00  0.384   7   1.9     17   2.9    45   4.2  8.7
 30      .   5   0.97   3.91    0.67     4.16    5.75  0.704   8   0.0      9   1.9    21   2.5  6.7
 31  20.04   5   0.68   1.79    0.27     1.76    5.00  0.729   9   1.6     17   3.2    39   7.8  7.7
 32      .   5   3.82   0.91    0.91     2.08    1.00  0.752  11   5.2     10   7.1    81   8.5  5.0
 33  20.78   5   0.94   2.32    0.41     3.70    5.75  0.430  12   4.8     44   7.9    79   7.5  4.0
 34  19.24   5   1.17   0.85    0.52     1.12    1.25  0.715  13   1.2     10   2.8    44   2.9  3.9
 35  15.23   5   2.77   0.66    0.48     0.94    1.50  0.695  14   2.5     11   3.3    45   3.5  3.3
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                          RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                     7
                                    TAMPA OFFICE 1990 TO 1995
                                           INFLOW DATA

OBS  MO  DA  YR  ZNIN  CDIN  CUIN   FEIN  PBIN   MNIN  HIN   NHIN  NOXIN   ONIN   OPIN   TPIN  SSIN

 36   9  21  93    28   0.1   2.4   1257   2.2   15.8   76  0.044  0.030  0.653    .      .      50
 37   9  27  93    36   1.0   3.5    905   2.4   23.1  147  0.030  0.042  1.131  0.148  0.373   12
 38  10   6  93    24   0.1   2.2    379   1.9   17.2  185  0.014  0.052  1.049  0.012  0.287    9
 39  10   9  93    21   0.0   0.0    711   1.2   46.1  249  0.015  0.037  1.275  0.033  0.228    8
 40  10  15  93    19   0.0   2.0    597   1.4   40.5  246  0.022  0.003  0.998  0.131  0.279    9
 41  10  30  93    21   0.1   2.1    356   0.0   13.4  161  0.076  0.040  0.840  0.204  0.290   12
 42  11  20  93    20   0.1   1.0    213   0.0   43.0  543  0.020  0.119  1.370  0.036  0.049    4
 43   1   2  94    19   0.2   0.0     50   0.1    4.6  243  0.025  0.367  0.650  0.014  0.029    1
 44   1  13  94    17   0.0   1.0    417   0.8   19.5  229  0.029  0.010  0.991  0.104  0.189   13
 45   1  17  94    28   0.1   2.3   2351   5.5   19.7  109  0.059  0.009  1.421  0.407  0.720   12
 46   6  14  94    25   0.3   4.6    723   0.0   17.7  432  0.047  0.643  1.431  0.224  0.322  131
 47   6  15  94    37   0.3   3.8   4616   5.9   28.2  122  0.103  0.397  1.002  0.478  0.739  279
 48   6  16  94    30   0.1   3.4    851   0.1   22.0  241  0.052  0.051  2.296  0.217  0.325   32
 49   6  17  94    48   0.0   3.2   1159   0.6   25.0  248  0.089  0.167  1.098  0.215  0.355   56
 50   6  20  94    40   0.4   3.5   3375   3.9   24.1  127  0.057  0.158  0.753  0.273  0.557  170
 51   6  21  94    56   0.1   5.4   6511    .    44.6  156  0.115  0.160  1.365  0.427  0.940  415
 52   6  29  94    40   0.2   7.7    253   2.7   16.3  144  0.062  0.084  0.848  0.089  0.179    6
 53   7   6  94    39   0.1   2.7    820   1.9   22.2  254  0.085  0.094  1.035  0.136  0.302   40
 54   7  10  94    43   0.2   4.0   1091   2.3   15.8  153  0.147  0.580  0.993  0.182  0.310   69
 55   7  18  94    71   0.4   5.4   3176   7.4   25.8  101  0.252  0.472  1.269  0.283  0.610  185
 56   7  20  94    68   0.3   9.1   5707  10.5   32.3  108  0.218  0.549  0.989  0.292  0.550  132
 57   7  21  94    65   0.4   7.4   6358   9.6   35.6  125  0.103  0.459  1.635  0.367  0.760  218
 58   7  24  94    40   0.2   7.3    404   0.9   15.7  251  0.045  0.400  1.101  0.070  0.060  131
 59   7  28  94 (615)*  0.3  10.1   4354   6.0   28.7  150  0.126  1.312  1.594  0.212  0.621   10
 60   7  30  94 (545)   0.4   6.2   8174   5.2   37.5  217  0.070  0.073  1.200  0.275  0.543  319
 61   8   3  94    70   0.2  11.9   1096   3.6   15.2   99  0.077  0.576  0.671  0.111  0.274  131
 62   8   6  94    46   0.2   5.9   1539   1.7   19.8  161  0.071  0.300  0.290  0.099  0.196   72
 63   8   7  94    48   0.1  16.9    778   0.9   27.7  265  0.125  0.116  0.108  0.096  0.164  131
 64   8   8  94     7   0.2   7.3   3008   4.8   32.8  187  0.038  0.163  0.782  0.321  0.465  171
 65   8  10  94   111   0.9  17.7  16175  23.0   87.5   82  0.431  0.120  1.549  1.550  2.136  248
 66   8  11  94    50   0.3   6.8   4127   8.3   31.9  178  0.047  0.088  1.003  0.243  0.422  196
 67   8  13  94    29   0.4   6.5   2190   4.3   20.9  154  0.062  3.000  1.028  0.212  0.338   78
 68   8  16  94    41   0.2   3.4    718   1.8   28.3  451  0.042  0.014  0.838  0.046  0.099   22
 69   8  23  94    27   0.1   2.9   1265   2.0   32.9  222  0.042  0.651  1.008  0.161  0.000   13
 70   8  24  94    79   0.5   8.7   9084  16.9   56.0  174  0.210  0.258  1.706  0.451  1.126   12

OBS  TOCIN  RT  INTER  TRAIN  AVGINT  MAXINT   DURA  RCOEF  NO  NAIN  SO3IN  MGIN  CAIN  CLIN  KIN

 36  14.09   5   5.98   1.46   0.59    2.84    2.25  0.570  15   1.0     10   1.6    28   2.1  3.0
 37  13.14   5   5.67   0.77   0.46    1.62    1.25  0.279  16   2.8     35   4.2    52   4.4  2.2
 38  10.95   5   9.04   0.75   0.12    0.50    6.25  0.187  17   5.3     90   5.5    65   8.1  3.1
 39  17.06   5   2.67   0.27   0.14    0.30    2.00  0.238  18    .       .     .      .     .    .
 40  15.71   5   0.70   0.12   0.03    0.08    3.25  0.574  19   4.4     40   7.1    87   9.3  5.0
 41  12.04   5   4.07   1.34   0.08    1.00   16.50  0.437  20   4.3     42   4.5    53   8.9  5.2
 42  14.40   5  14.03   0.24   0.39    0.84    0.50  0.211  21  15.0    413  19.0   186  25.0  4.1
 43   6.46   5   8.50   0.85   0.12    0.24    7.00    .    27   9.8    108   8.7    83  18.0  1.3
 44  16.11   5  10.50   1.06   0.28    0.24    3.75  0.503  29   5.0     47   4.2    53  12.0  4.6
 45   9.25   5   4.17   1.18   0.21    0.46    5.75  0.730  30   3.1     22   2.9    39   6.9   .
 46  11.18  14   6.29   0.77   0.39    2.00    2.00  0.203   2  12.0    325  17.0   134  18.0  7.7
 47  19.32  14   0.99   1.39   0.22    2.56    6.25  0.377   3   2.0     63   3.0    44   2.8  2.0
 48  17.81  14   0.72   1.10   0.34    1.60    3.25  0.488   4   4.5    117   7.7    84   5.2  4.1
 49  17.51  14   0.76   0.32   0.16    0.52    2.00  0.345   5   4.7    132   8.1    86   5.1  3.1
 50  20.47  14   2.78   0.50   0.25    1.08    2.00  0.334   6   2.4     61   2.9    46   3.3  1.7
 51  16.04  14   0.84   0.39   0.14    1.24    2.75  0.547   7   3.6     73   5.2    54   4.6  1.5
 52  13.99  14   4.00   0.30   0.08    0.28    4.00  0.132   9   3.5    111   4.6    50   5.7  2.1
 53  17.58  14   0.85   0.37   0.10    0.24    3.75  0.175  12   7.0     99   8.2    88   9.5  4.0
 54  20.15  14   3.77   0.49   0.39    0.72    1.25  0.315  13   4.0     71   4.5    54   5.6  2.5
 55  16.13  14   8.23   0.76   1.01    2.56    0.75  0.277  14   2.0     53   2.2    37   2.8  1.7
 56  12.53  14   0.66   1.11   1.11    2.56    1.00  0.389  15   1.4     45   2.5    39   2.4  1.6
 57    .    14   0.90   0.42   0.34    1.04    1.25  0.610  16   2.0     47   3.1    45   2.7  1.6
 58  15.54  14   2.86   0.22   0.22    0.32    1.00  0.208  17   4.8    109   7.6    64   6.6  1.4
 59  16.68  14   1.91   0.49   0.39    0.72    1.25  0.281  18   2.9     73   4.4    53   6.0  3.0
 60  19.31  14   0.97   0.45   0.26    1.08    1.75  0.571  19   2.6     51   4.2    80   5.0  3.7
 61  16.24  14   3.77   0.22   0.15    0.48    1.50  0.154  20   3.0     35   2.7    35   5.5  1.2
 62  12.58  14   0.55   0.20   0.13    0.60    1.50  0.313  21   3.6     65   5.1    56   6.3  1.2
 63  18.37  14   0.98   0.42   0.34    1.04    1.25  0.223  22   4.6     96   8.6    92   8.1  2.4
 64  12.13  14   0.69   0.42   0.10    0.68    4.25  0.522  23   2.8     60   4.8    67   5.0  2.4
 65   6.26  14   2.05   2.28   0.48    3.88    4.75  0.641  24   1.0     29   1.8    30   1.9  1.7
 66   9.60  14   0.74   0.30   0.60    1.04    0.50  0.447  25   2.8     51   4.5    64   4.0  1.9
 67  10.33  14   2.08   0.71   0.20    1.00    3.50  0.468  26   2.4     62  20.9    55   4.1  2.0
 68  18.60  14   2.84   0.11   0.07    0.12    1.50  0.196  27   8.3    198  18.0   151  12.0  1.5
 69  17.27  14   1.78   0.29   0.07    0.44    4.25  0.336  29   4.1     86   6.7    78   6.7  1.4
 70  18.24  14   1.94   0.72   0.26    1.84    2.75  0.455  30   1.9     45   2.9    65   1.9  1.9
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                          RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                    8
                                  TAMPA OFFICE 1990 TO 1995
                                         INFLOW DATA

OBS  MO  DA  YR  ZNIN  CDIN  CUIN   FEIN  PBIN   MNIN  HIN   NHIN  NOXIN   ONIN   OPIN   TPIN  SSIN

 71   8  25  94    37   0.4   3.4   4722  10.7   22.1  150  0.115  0.262  1.355  0.297  0.663   204
 72   9  16  94    49   0.6  11.5    683   0.4   28.2  236  0.015  0.003  0.915  0.087  0.120    22
 73   9  17  94    66   0.0   7.2    858   0.0   37.3  291  1.102  0.015  2.368  0.049  0.287   131
 74   9  19  94     .   0.3   4.4   3433   5.8   37.8  143  0.129  0.160  1.175  0.365  0.531   163
 75   9  25  94    29   0.2   4.6   2085   4.8   16.3  149  0.014  0.028  1.092  0.321  0.397   105
 76   9  27  94    88   1.1  11.1  11127  18.2  112.5  137  0.304  0.170  1.307  1.178  2.027   592
 77  10   2  94    41   0.2   4.0   1347   2.5   26.0  192  0.024  0.119  0.962  0.385  0.446    97
 78  10  10  94     7   0.5   4.3   1189   4.1   75.2  232  0.093  0.213  1.414  0.418  0.227   129
 79  10  12  94    74   0.1   3.3   1626   3.2   75.3  252  0.080  2.844  1.260  0.385  0.443    53
 80  10  26  94    59   0.2   4.1   2104   5.5   27.0  132  0.133  0.467  0.377  0.548  0.591   180
 81  11  15  94    32   0.2   7.8    229   2.5    8.0  177  0.017  0.040  0.433  0.096  0.140    10
 82  12  21  94   111   0.0  12.5    444   3.3    4.1  430  0.070  0.577  1.230  0.217  0.365    17
 83  12  22  94    90   0.2   1.0      4   3.6   26.2  270  0.087  0.169  0.768  0.203  0.215   120
 84   1   7  95    87   0.2  12.6    336   3.7   18.9  199  0.046  0.160  0.612  0.000  0.000    22
 85   1  14  95    76   0.3   3.5   3578   8.6   25.5  119  0.154  0.196  0.950  0.738  0.790   250
 86   1  15  95    50   0.3   4.3    580   2.8    6.7  189  0.021  0.177  0.902  0.151  0.169    46
 87   1  16  95    47   0.1   2.5   2521   5.6   16.2  171  0.059  0.127  0.971  0.341  0.329   112

OBS  TOCIN  RT  INTER  TRAIN  AVGINT  MAXINT   DURA  RCOEF  NO  NAIN  SO3IN  MGIN  CAIN  CLIN  KIN

 71   7.70  14   1.00   1.14   0.65    1.36    1.75  0.649  31   1.5     31   2.4    56   2.5  1.8
 72  16.06  14   0.64   1.22   0.15    0.84    8.00  0.503  32   4.0     96   7.0    83   6.6  2.1
 73  14.72  14   0.96   0.72   0.96    2.60    0.75  0.683  33   5.3     94  10.0   105   6.6  2.1
 74   8.10  14   2.04   1.63   0.72    3.04    2.25  0.807  34   2.7     47   4.6    50   3.7  1.5
 75   6.85  14   5.05   1.13   0.90    1.72    1.25  0.507  35   1.9     35   3.4    54   3.3  1.8
 76  16.46  14   2.18   1.27   0.39    1.32    3.25  0.802  36   1.9     41   3.2    50   3.3  1.7
 77  12.43  14   5.78   0.51   0.09    0.48    5.50  0.485  37   4.6     75   6.5    66   6.8  1.3
 78  19.64  14   6.32   0.42   0.34    0.72    1.25  0.254  38   7.1     86   8.4    79  13.0  5.3
 79  23.11  14   0.85   0.36   0.06    0.20    6.00  0.400  39   6.6     92   8.5    87  13.0  3.9
 80  14.52  14  13.00   1.60   0.38    1.40    4.25  0.461  40   3.3     78   3.6    47   7.0  3.1
 81  13.14  14   4.35   0.66   0.05    0.28   12.25  0.179  41   6.4    107   7.2    59   8.2  1.5
 82    .    14   2.63   0.83   0.06    0.20   13.00  0.274  42  15.0    304  17.0   144  22.0  4.6
 83  17.04  14   1.35   0.28   0.22    0.32    1.25  0.480  43   7.2    143   9.7    92  14.0  3.8
 84  10.84  14   2.55   0.25   0.14    0.20    1.75  0.186  44   6.3    131   8.9    65   8.1  1.2
 85  11.81  14   6.75   1.02   0.20    1.64    5.00  0.441  45   3.4     65   3.3    42   5.8  1.9
 86  10.58  14   0.23   0.53   0.07    0.72    7.50  0.561  46   9.7     95   9.0    61  16.0  2.1
 87  14.48  14   7.72   0.16   0.16    0.52    1.00  0.188  47    .       .     .     .     .    .

* (#) Numbers in parenthses were considered outliers and were removed for comparison graphs.
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                         RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                        10
                                 TAMPA OFFICE 1990 TO 1995
                                        INFLOW DATA
                                 NON-PARMETRIC CORRELATIONS
         Spearman Correlation Coefficients / Prob > |R| under Ho: Rho=0 / Number of Observations

ZNIN                 ZNIN            CUIN            PBIN             KIN            NHIN
                  1.00000         0.65531         0.48640        -0.47253         0.43219
                      0.0          0.0001          0.0001          0.0002          0.0001
                       84              62              61              57              84

                     SSIN            CDIN           NOXIN           SO3IN            OPIN
                  0.35074         0.34568         0.29727         0.25746         0.21984
                   0.0011          0.0013          0.0060          0.0510          0.0486
                       84              84              84              58              81

CDIN                 CDIN            PBIN            CUIN            NAIN            CLIN
                  1.00000         0.56646         0.43222        -0.40889        -0.39385
                      0.0          0.0001          0.0003          0.0011          0.0017
                       87              64              65              61              61

                   MAXINT             HIN            ZNIN            MGIN            CAIN
                  0.37419        -0.36092         0.34568        -0.32150        -0.29869
                   0.0004          0.0037          0.0013          0.0115          0.0194
                       86              63              84              61              61

CUIN                 CUIN            ZNIN            SSIN            PBIN             KIN
                  1.00000         0.65531         0.48123         0.46241        -0.44421
                      0.0          0.0001          0.0001          0.0001          0.0004
                       65              62              65              64              60

                     CDIN            NHIN            FEIN           NOXIN            CLIN
                  0.43222         0.42359         0.34823         0.34070        -0.31029
                   0.0003          0.0004          0.0045          0.0055          0.0149
                       65              65              65              65              61

 FEIN                FEIN            NAIN            PBIN            CLIN            SSIN
                  1.00000        -0.73978         0.73891        -0.73324         0.67597
                      0.0          0.0001          0.0001          0.0001          0.0001
                       87              61              64              61              87

                     MGIN            TPIN             HIN           SO3IN            CAIN
                 -0.65704         0.62743        -0.60921        -0.53806        -0.53389
                   0.0001          0.0001          0.0001          0.0001          0.0001
                       61              82              63              61              61

PBIN                 PBIN            FEIN            NAIN            TPIN            SSIN
                  1.00000         0.73891        -0.61818         0.60542         0.59011
                      0.0          0.0001          0.0001          0.0001          0.0001
                       64              64              60              60              64

                     CDIN            MGIN            CLIN             HIN            OPIN
                  0.56646        -0.56266        -0.56258        -0.56238         0.52562
                   0.0001          0.0001          0.0001          0.0001          0.0001
                       64              60              60              62              61

 MNIN                MNIN            FEIN            TPIN            ONIN            OPIN
                  1.00000         0.42296         0.40585         0.38756         0.37078
                      0.0          0.0004          0.0012          0.0014          0.0030
                       65              65              61              65              62

                    TOCIN          MAXINT            NHIN          AVGINT           RCOEF
                  0.36801         0.28741         0.28702         0.27077         0.25213
                   0.0062          0.0203          0.0204          0.0291          0.0444
                       54              65              65              65              64

 HIN                  HIN            CAIN            MGIN            NAIN           SO3IN
                  1.00000         0.97275         0.88503         0.83011         0.72693
                      0.0          0.0001          0.0001          0.0001          0.0001
                       63              61              61              61              61
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                        RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                        11
                                 TAMPA OFFICE 1990 TO 1995
                                        INFLOW DATA
                                 NON-PARMETRIC CORRELATIONS

  Spearman Correlation Coefficients / Prob > |R| under Ho: Rho=0 / Number of Observations

HIN                CLIN           TPIN           FEIN           PBIN         MAXINT
                0.72304       -0.66563       -0.60921       -0.56238       -0.50982
                 0.0001         0.0001         0.0001         0.0001         0.0001
                     61             59             63             62             63

NHIN               NHIN           PBIN           SSIN           ZNIN          NOXIN
                1.00000        0.46814        0.44380        0.43219        0.42969
                    0.0         0.0001         0.0001         0.0001         0.0001
                     87             64             87             84             87

                   CUIN           TPIN           FEIN           CLIN           OPIN
                0.42359        0.40096        0.39406       -0.35278        0.29008
                 0.0004         0.0002         0.0002         0.0053         0.0074
                     65             82             87             61             84

 NOXIN            NOXIN           NHIN           CUIN           PBIN           ZNIN
                1.00000        0.42969        0.34070        0.33527        0.29727
                    0.0         0.0001         0.0055         0.0068         0.0060
                     87             87             65             64             84

                    KIN          SO3IN          RCOEF           CDIN           SSIN
               -0.22798        0.22782       -0.21496        0.21480        0.20143
                 0.0798         0.0774         0.0482         0.0457         0.0614
                     60             61             85             87             87

 ONIN              ONIN           MNIN           TPIN          RCOEF            KIN
                1.00000        0.38756        0.33944        0.28756        0.27816
                    0.0         0.0014         0.0018         0.0076         0.0314
                     87             65             82             85             60

                   FEIN           OPIN          SO3IN           CLIN           PBIN
                0.25647        0.21615       -0.19383       -0.14630        0.12286
                 0.0165         0.0483         0.1344         0.2606         0.3335
                     87             84             61             61             64

 OPIN              OPIN           TPIN           PBIN          SO3IN            HIN
                1.00000        0.85226        0.52562       -0.50832       -0.50365
                    0.0         0.0001         0.0001         0.0001         0.0001
                     84             82             61             58             60

                   MGIN           NAIN         MAXINT           CLIN          TRAIN
               -0.50364       -0.48116        0.46857       -0.46144        0.45869
                 0.0001         0.0001         0.0001         0.0003         0.0001
                     58             58             83             58             84

 TPIN              TPIN           OPIN           MGIN           NAIN           CLIN
                1.00000        0.85226       -0.69624       -0.68559       -0.67002
                    0.0         0.0001         0.0001         0.0001         0.0001
                     82             82             57             57             57

                    HIN          SO3IN           FEIN           PBIN           CAIN
               -0.66563       -0.64546        0.62743        0.60542       -0.58732
                 0.0001         0.0001         0.0001         0.0001         0.0001
                     59             57             82             60             57

 SSIN              SSIN           FEIN           PBIN           CUIN           CLIN
                1.00000        0.67597        0.59011        0.48123       -0.47565
                    0.0         0.0001         0.0001         0.0001         0.0001
                     87             87             64             65             61

                   TPIN           NHIN           OPIN           NAIN          RCOEF
                0.46766        0.44380        0.42669       -0.41565        0.38984
                 0.0001         0.0001         0.0001         0.0009         0.0002
                     82             87             84             61             85
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                         RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                           12
                                   TAMPA OFFICE 1990 TO 1995
                                          INFLOW DATA
                                   NON-PARMETRIC CORRELATIONS
 Spearman Correlation Coefficients / Prob > |R| under Ho: Rho=0 / Number of Observations


TOCIN              TOCIN          MNIN           KIN         INTER         TRAIN
                 1.00000       0.36801       0.35484      -0.23371      -0.18773
                     0.0        0.0062        0.0106        0.0890        0.1740
                      54            54            51            54            54

                     HIN          CAIN          PBIN          CUIN         RCOEF
                 0.18284       0.17794      -0.16118      -0.16040      -0.15059
                  0.1857        0.2069        0.2489        0.2466        0.2818
                      54            52            53            54            53

INTER              INTER         RCOEF         TOCIN          MNIN          SSIN
                 1.00000      -0.35293      -0.23371      -0.22851      -0.22584
                     0.0        0.0009        0.0890        0.0671        0.0354
                      87            85            54            65            87

                    FEIN          CUIN          CAIN          CLIN          DURA
                -0.20543      -0.18107      -0.15141       0.14790      -0.11143
                  0.0563        0.1489        0.2441        0.2553        0.3099
                      87            65            61            61            85

TRAIN              TRAIN        MAXINT         RCOEF         SO3IN           HIN
                 1.00000       0.68598       0.53571      -0.53172      -0.50794
                     0.0        0.0001        0.0001        0.0001        0.0001
                      87            86            85            61            63

                    MGIN          TPIN          CAIN          OPIN          NAIN
                -0.48390       0.47979      -0.47628       0.45869      -0.44829
                  0.0001        0.0001        0.0001        0.0001        0.0003
                      61            82            61            84            61

AVGINT            AVGINT        MAXINT          DURA          CLIN          NAIN
                 1.00000       0.73469      -0.57186      -0.52861      -0.52050
                     0.0        0.0001        0.0001        0.0001        0.0001
                      86            86            85            61            61

                   SO3IN          MGIN         TRAIN           HIN          CAIN
                -0.49344      -0.45646       0.42190      -0.40027      -0.35802
                  0.0001        0.0002        0.0001        0.0012        0.0046
                      61            61            86            63            61

MAXINT            MAXINT        AVGINT         TRAIN          NAIN          CLIN
                 1.00000       0.73469       0.68598      -0.59425      -0.58706
                     0.0        0.0001        0.0001        0.0001        0.0001
                      86            86            86            61            61

                   SO3IN           HIN          TPIN          MGIN          OPIN
                -0.52325      -0.50982       0.50794      -0.49299       0.46857
                  0.0001        0.0001        0.0001        0.0001        0.0001
                      61            63            81            61            83

DURA                DURA        AVGINT         TRAIN         RCOEF          CLIN
                 1.00000      -0.57186       0.42220       0.25938       0.23807
                     0.0        0.0001        0.0001        0.0172        0.0647
                      85            85            85            84            61

                    MNIN          NHIN          ZNIN          OPIN          NAIN
                -0.21596      -0.19448      -0.16137       0.14801       0.13487
                  0.0840        0.0745        0.1475        0.1845        0.3000
                      65            85            82            82            61

RCOEF              RCOEF         SO3IN         TRAIN          FEIN          TPIN
                 1.00000      -0.57112       0.53571       0.51593       0.46936
                     0.0        0.0001        0.0001        0.0001        0.0001
                      85            60            85            85            80
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                    RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                 13
                              TAMPA OFFICE 1990 TO 1995
                                     INFLOW DATA
                               NON-PARMETRIC CORRELATIONS
     Spearman Correlation Coefficients / Prob > |R| under Ho: Rho=0 / Number of Observations

RCOEF               NAIN           OPIN           SSIN         MAXINT          INTER
                -0.45852        0.42657        0.38984        0.37969       -0.35293
                  0.0002         0.0001         0.0002         0.0003         0.0009
                      60             82             85             85             85

NAIN
                    NAIN           CLIN           MGIN            HIN           CAIN
                 1.00000        0.90515        0.86310        0.83011        0.77565
                     0.0         0.0001         0.0001         0.0001         0.0001
                      61             61             61             61             61

                    FEIN          SO3IN           TPIN           PBIN         MAXINT
                -0.73978        0.72756       -0.68559       -0.61818       -0.59425
                  0.0001         0.0001         0.0001         0.0001         0.0001
                      61             61             57             60             61

SO3IN
                   SO3IN           MGIN           NAIN            HIN           CAIN
                 1.00000        0.76712        0.72756        0.72693        0.68465
                     0.0         0.0001         0.0001         0.0001         0.0001
                      61             61             61             61             61

                    TPIN          RCOEF           CLIN           FEIN          TRAIN
                -0.64546       -0.57112        0.56926       -0.53806       -0.53172
                  0.0001         0.0001         0.0001         0.0001         0.0001
                      57             60             61             61             61

MGIN
                    MGIN            HIN           CAIN           NAIN          SO3IN
                 1.00000        0.88503        0.86738        0.86310        0.76712
                     0.0         0.0001         0.0001         0.0001         0.0001
                      61             61             61             61             61

                    CLIN           TPIN           FEIN           PBIN           OPIN
                 0.76384       -0.69624       -0.65704       -0.56266       -0.50364
                  0.0001         0.0001         0.0001         0.0001         0.0001
                      61             57             61             60             58

CAIN
                    CAIN            HIN           MGIN           NAIN          SO3IN
                 1.00000        0.97275        0.86738        0.77565        0.68465
                     0.0         0.0001         0.0001         0.0001         0.0001
                      61             61             61             61             61

                    CLIN           TPIN           FEIN           PBIN          TRAIN
                 0.66305       -0.58732       -0.53389       -0.52151       -0.47628
                  0.0001         0.0001         0.0001         0.0001         0.0001
                      61             57             61             60             61

CLIN
                    CLIN           NAIN           MGIN           FEIN            HIN
                 1.00000        0.90515        0.76384       -0.73324        0.72304
                     0.0         0.0001         0.0001         0.0001         0.0001
                      61             61             61             61             61

                    TPIN           CAIN         MAXINT          SO3IN           PBIN
                -0.67002        0.66305       -0.58706        0.56926       -0.56258
                  0.0001         0.0001         0.0001         0.0001         0.0001
                      57             61             61             61             60

KIN
                     KIN           ZNIN           CUIN          TOCIN           PBIN
                 1.00000       -0.47253       -0.44421        0.35484       -0.31514
                     0.0         0.0002         0.0004         0.0106         0.0151
                      60             57             60             51             59
```

APPENDIX P

Statistical Analyses for Outflow Data

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                    RESIDENCE TIME AND WATER QUALITY IMPROVEMENT
                              TAMPA OFFICE 1990 TO 1995
                                     OUTFLOW DATA

                                 Correlation Analysis

  26 'VAR' Variables:  ZNOU      CDOU      FEOU      PBOU      MNOU      HOU       NH3OU     NOXOU
                       ONOU      OPOU      TPOU      SSOU      TOCOU     INTER     TRAIN     AVGINT
                       MAXINT    DURA      RCOEF     NAOU      SO4OU     MGOU      CAOU      CLOU
                       CLIN      KOU

 Variable              N          Mean       Std Dev        Median       Minimum       Maximum

 ZNOU                 85     20.235294     14.695843     17.000000      3.000000     74.000000
 CDOU                 85      0.216471      0.380741      0.100000             0      1.900000
 FEOU                 63      3.488889      2.703171      3.100000             0     12.600000
 PBOU                 85    319.164706    337.728365    250.000000     10.000000   2834.000000
 MNOU                 63      0.622222      0.701023      0.400000             0      2.500000
 HOU                  63     10.028571      6.585331      9.200000      1.400000     42.400000
 NH3OU                61    191.196721     56.066276    186.000000     69.000000    411.000000
 NOXOU                85      0.046800      0.045727      0.035000             0      0.297000
 ONOU                 85      0.084388      0.244381      0.017000             0      2.024000
 OPOU                 85      0.757729      0.406412      0.758000     -0.024000      2.456000
 TPOU                 84      0.060976      0.065526      0.036500             0      0.358000
 SSOU                 84      0.109917      0.095829      0.074500             0      0.427000
 TOCOU                84      9.666667      8.960870      7.500000             0     49.000000
 INTER                85      8.564706      5.388363      5.000000      2.000000     14.000000
 TRAIN                85      3.909059      4.468726      2.180000      0.230000     25.770000
 AVGINT               85      0.812118      0.637781      0.660000      0.100000      3.910000
 MAXINT               84      0.353571      0.259841      0.265000      0.030000      1.110000
 DURA                 84      1.244167      0.954880      1.010000      0.050000      4.160000
 RCOEF                83      3.263855      2.932386      2.000000      0.500000     16.500000
 NAOU                 61      4.349180      3.038235      3.500000             0     15.000000
 SO4OU                61     78.016393     73.141300     62.000000      9.000000    413.000000
 MGOU                 61      6.219672      4.326539      4.600000      1.600000     20.900000
 CAOU                 61     65.639344     30.159041     56.000000     21.000000    186.000000
 CLOU                 61      7.167213      4.857630      5.900000      1.900000     25.000000
 CLIN                 60     67.650000     21.286444     65.500000     24.000000    148.000000
 KOU                  60      2.978333      1.762807      2.150000      1.000000      8.700000
```

ABBREVIATIONS:

OBS	Observation number.
MO	Month.
DA	Day of the month.
YR	Year
ZNOU	Zinc event mean concentrations (uG/l) at the outflow.
CDOU	Cadmium event mean concentrations (uG/l) at the outflow.
CUOU	Copper event mean concentrations (uG/l) at the outflow.
FEOU	Iron event mean concentrations (uG/l) at the outflow.
PBOU	Lead event mean concentrations (uG/l) at the outflow
MNOU	Magnesium event mean concentrations (uG/l) at the outflow.
HOU	Total hardness as CaCO3 event mean concentrations (mg/l) at the outflow.
NHOU	Ammonia event mean concentrations (mg/l) at the outflow.
NOXOU	Nitrate+nitrite event mean concentrations (mg/l) at the outflow.
ONOU	Organic nitrogen event mean concentrations (mg/l) at the outflow.
OPOU	Ortho-phosphate event mean concentrations (mg/l) at the outflow.
TPOU	Total phosphorus event mean concentrations (mg/l) at the outflow.
SSOU	Total suspended solids event mean concentrations (mg/l) at the outflow.
TOCOU	Total organic carbon grab sample after rain event (mg/l) at the outflow.
RT	Residence time as calculated from pond size (days).
TRAIN	Total rain for event in inches.
INTER	Inter-event dry period (days) a.k.a. antecedent conditions for all storms > 0.05 inches
LINTER	Inter-event dry period (days) for all storms > 0.25 inches.
AVGINT	Average rain intensity (in/hr).
MAXINT	Maximum intensity (in/hr) for a 15 minute period.
DURA	Duration of storm (hours).
RCOEF	Runoff coefficient.
NO	Storm number for each year.
NAOU	Sodium event mean concentration (mg/l) at the outflow.
SO3OU	Sulfate event mean concentration (mg/l) at the outflow.
MGOU	Magnesium event mean concentration (mg/l) at the outflow.
CAOU	Calcium event mean concentration (mg/l) at the outflow.
CLOU	Chloride event mean concentration (mg/l) at the outflow.
KOU	Potassium event mean conentration (mg/l) at the outflow.

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                          RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                     8
                                    TAMPA OFFICE 1990 TO 1995
                                          OUTFLOW DATA

OBS ZNOU CDOU  CUOU FEOU PBOU MNOU HOU NH3OU NOXOU  ONOU  OPOU  TPOU  SSOU TOCOU   RT  INTER

  1  30   0.7   .   360   .    .    .  0.040 0.010  1.230 0.037 0.083   5    .      2  14.49
  2  30   1.6   .   250   .    .    .  0.040 0.020  0.870 0.037 0.079   7    .      2   0.95
  3  30   1.4   .   650   .    .    .  0.060 0.030  1.570 0.064 0.128   6    .      2   3.83
  4  23   0.3   .   285   .    .    .  0.015 0.036  0.519 0.106 0.167  16    .      2   1.38
  5  31   0.1   .   448   .    .    .  0.233 0.032  0.561 0.049 0.092  20    .      2   0.53
  6  41   0.1   .   658   .    .    .  0.089 0.457  1.327 0.080 0.156   9    .      2  14.05
  7  21   0.1   .   571   .    .    .  0.099 0.135  0.909 0.101 0.193  10    .      2   2.97
  8  11   0.6   .   331   .    .    .  0.043 0.043  0.597 0.123 0.229  17    .      2   0.85
  9  24   0.6   .   416   .    .    .  0.150 0.032  0.657 0.104 0.184   8    .      2   0.81
 10  17   0.1   .   410   .    .    .  0.053 0.177  0.886 0.129 0.236   9    .      2   0.47
 11  11   1.2   .   523   .    .    .  0.024 0.222  1.015 0.093 0.157  17    .      2   3.95
 12   3   0.2   .    10   .    .    .  0.073 0.018  2.456 0.018 0.188  28    .      2  12.74
 13  57   0.6   .   565   .    .    .  0.096 0.096  1.225 0.102 0.194  16    .      2   0.65
 14  64   1.7   .   415   .    .    .  0.084 0.085  1.167 0.100 0.166  14    .      2   3.98
 15  74   0.7   .   466   .    .    .  0.076 0.005  1.014 0.082 0.119  13    .      2   1.07
 16  53   1.9   .   349   .    .    .  0.037 0.005  0.877 0.100 0.120  12    .      2   2.94
 17  27   0.1   .   276   .    .    .  0.047 0.031  0.716 0.148 0.182  10    .      2   1.00
 18  24   0.1   .   250   .    .    .  0.098 0.161  0.663 0.142 0.202   8    .      2  16.83
 19  10   0.1   .   550   .    .    .  0.023 0.032  0.911 0.080 0.147   8    .      2   1.92
 20  27   0.6   .   390   .    .    .  0.023 0.005  0.749 0.070 0.096   7    .      2   2.97
 21  18   0.3   .   330   .    .    .  0.013 0.005  0.905 0.358 0.427   7    .      2   6.26
 22  60   0.1   .    22   .    .    .  0.078 0.266  1.210 0.258 0.332   0    .      2  25.77
 23   5   0.0  6.0   15  0.0  4.0   .  0.020 0.020  0.140 0.005 0.006  15    .      5   0.74
 24  29   0.2  2.6  792  0.0 12.1 186  0.131 0.033  1.346 0.120 0.207  29    .      5   2.06
 25  22   0.0  4.0 2834  0.0  1.6 167  0.070 0.100  0.784 0.094 0.424  49    .      5   1.69
 26  21   0.3  2.0  456  0.0 17.8 131  0.038 0.013  0.672 0.049 0.121  11    .      5   5.63
 27  25   0.2  4.0  922  1.4 10.0  69  0.007 0.150  0.813 0.248 0.333  31    .      5   8.90
 28  24   0.1  4.8  415  1.1 13.7 114  0.297 0.107  1.713   .     .    21    .      5   0.97
 29  26   0.2  2.3  352  1.7 18.1 144  0.021 0.002  1.023 0.276 0.363  11  11.99    5   0.68
 30  23   0.2  3.1  283  0.7 21.9   .  0.051 0.014  0.728 0.161 0.303  10    .      5   3.82
 31  17   0.3  0.1  367  2.2 13.7 123  0.032 0.052  1.046 0.152 0.263  12  10.32    5   0.94
 32  39   0.0  1.4  389  0.8 14.0 142  0.007 0.009  1.213 0.112 0.185  15  11.02    5   1.17
 33  34   0.2  4.8  352  1.4  4.8 143  0.021 0.000  1.029 0.095 0.174  10  11.87    5   2.77
 34  15   0.1  2.9  458  0.6  8.2 104  0.061 0.093  0.488 0.063 0.125  16   9.71    5   5.98
 35  15   0.1  1.7  205  0.9  7.9 123  0.010 0.006  0.861 0.039 0.098  10   9.05    5   5.67

OBS TRAIN AVGINT MAXINT DURA RCOEF  NAIN NAOU SO4IN SO4OU MGIN MGOU CAIN CAOU CLIN CLOU KIN KOU MO DA

  1  0.37   0.37  0.78  1.00 0.050   .    .      .     .    .    .    .    .    .    .    .   .   5 24
  2  0.69   0.62  1.88  1.13 0.260   .    .      .     .    .    .    .    .    .    .    .   .   6  4
  3  0.46   0.36  0.58  1.25 0.170   .    .      .     .    .    .    .    .    .    .    .   .   6 11
  4  1.05   0.70  1.98  1.50 0.290   .    .      .     .    .    .    .    .    .    .    .   .   6 23
  5  0.83   0.16  1.32  5.38 0.250   .    .      .     .    .    .    .    .    .    .    .   .   6 24
  6  0.86   0.57  1.88  1.50 0.210   .    .      .     .    .    .    .    .    .    .    .   .   7  8
  7  1.10   0.59  1.96  2.00 0.280   .    .      .     .    .    .    .    .    .    .    .   .   7 11
  8  1.17   0.60  1.42   .   0.450   .    .      .     .    .    .    .    .    .    .    .   .   7 12
  9  0.48   0.14  0.94  3.38 0.270   .    .      .     .    .    .    .    .    .    .    .   .   7 13
 10  0.57   0.38  2.64  4.75 0.380   .    .      .     .    .    .    .    .    .    .    .   .   7 14
 11  0.29   0.20  0.92  1.50 0.240   .    .      .     .    .    .    .    .    .    .    .   .   7 19
 12  0.40   0.11  0.56  3.75 0.120   .    .      .     .    .    .    .    .    .    .    .   .   8  1
 13  0.32   0.63  1.22  0.50 0.220   .    .      .     .    .    .    .    .    .    .    .   .   8 15
 14  0.40   0.54  1.02  0.75 0.160   .    .      .     .    .    .    .    .    .    .    .   .   8 19
 15  0.62   0.25  0.82  2.50 0.210   .    .      .     .    .    .    .    .    .    .    .   .   8 26
 16  0.98   0.30  2.28  2.88 0.250   .    .      .     .    .    .    .    .    .    .    .   .   8 29
 17  1.06    .     .     .     .     .    .      .     .    .    .    .    .    .    .    .   .   9  1
 18  1.90   0.58  2.72  3.25 0.310   .    .      .     .    .    .    .    .    .    .    .   .   9 17
 19  0.65   0.87  1.44  0.75 0.360   .    .      .     .    .    .    .    .    .    .    .   .   9 30
 20  0.45   0.60  1.08  0.75 0.170   .    .      .     .    .    .    .    .    .    .    .   .  10  3
 21  2.64   0.24  1.40 11.00 0.500   .    .      .     .    .    .    .    .    .    .    .   .  10 10
 22  0.10   0.06  0.16  1.88 0.000   .    .      .     .    .    .    .    .    .    .    .   .   1 15
 23  0.93   0.24  1.50  4.00 0.386  6.1  6.8    35    73  5.8  5.9   67   65  9.3 11.0 4.2 3.1  6 24
 24  0.93   0.23  0.96  4.00 0.466  3.5  6.0    19    60  3.0  5.4   40   59  5.5 10.0 4.6 3.1  6 30
 25  1.09   0.34  0.96  3.25 0.308  3.5  5.2    38     .  4.1  5.4   46   58  4.2  7.5 2.1 1.9  7 12
 26  0.36   0.23  0.66  3.00 0.168  3.5  3.0    65    49  5.8  4.0   60   46  5.9  5.5 1.0 1.1  7 21
 27  2.16   0.93  3.90  2.00 0.384  1.9  1.5    17    23  2.9  2.2   45   24  4.2  2.9 8.7 2.5  8 25
 28  3.91   0.67  4.16  5.75 0.704  0.0  4.5     9    42  1.9  4.1   21   39  2.5  7.8 6.7 7.7  8 26
 29  1.79   0.27  1.76  5.00 0.729  1.6   .     17     .  3.2   .    39    .  7.8   .  7.7  .   8 29
 30  0.91   0.91  2.08  1.00 0.752  5.2   .     10     .  7.1   .    81    .  8.5   .  5.0  .   9  5
 31  2.32   0.41  3.70  5.75 0.430  4.8  2.4    44    29  7.9  3.2   79   44  7.5  4.0 4.0 2.2  9  6
 32  0.85   0.52  1.12  1.25 0.715  1.2  2.9    10    40  2.8  4.2   44   50  2.9  4.7 3.9 2.1  9 11
 33  0.66   0.48  0.94  1.50 0.695  2.5  3.0    11    39  3.3  4.3   45   50  3.5  4.7 3.3 1.9  9 14
 34  1.46   0.59  2.84  2.25 0.570  1.0  2.7    10    36  1.6  3.5   28   36  2.1  3.9 3.0 1.6  9 21
 35  0.77   0.46  1.62  1.25 0.279  2.8  2.8    35    38  4.2  3.7   52   43  4.4  3.9 2.2 1.4  9 27
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                         RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                         9
                                   TAMPA OFFICE 1990 TO 1995
                                          OUTFLOW DATA

OBS ZNOU CDOU CU0U  FEOU PBOU MNOU HOU  NH3OU NOXOU  ONOU  OPOU   TPOU   SSOU TOCOU   RT  INTER


 36   9   0.1  0.3  177  1.1  6.2  116  0.016 0.014  0.882 0.002 0.078   5  14.32    5   9.04
 37   6   0.1  7.0  117  2.0  6.0  135  0.000 0.000  0.390 0.011 0.066   3   9.88    5   2.67
 38   5   0.1  1.3  165  1.0  6.3  131  0.019 0.000  0.000 0.010 0.070   5  12.81    5   0.70
 39  23   0.2  1.0  149  0.0  6.3  190  0.088 0.008  0.850 0.017 0.064   5  11.02    5   4.07
 40  68   0.3  2.0  161  0.0 20.0  228  0.068 0.008  0.882 0.049 0.010   4  13.37    5  14.03
 41  15   0.0  0.0  134  0.3  2.9  183  0.023 0.074  0.541 0.027 0.065   8   6.20    5   8.50
 42  16   0.1  0.0   97  0.0  3.5  201  0.012 0.013  0.338 0.008 0.041   8   7.06    5   0.53
 43   4   0.0  1.0  140  0.2  5.0  185  0.010 0.000  0.970 0.013 0.048   3   7.92    5  10.50
 44  14   0.1  4.4  508  1.2  6.4  150  0.033 0.003  0.625 0.072 0.169  11   8.48    5   4.17
 45  12   0.1  1.4  255  0.0  2.9  411  0.076 0.051  0.963 0.018 0.071   3  10.81   14   6.29
 46  12   0.0  1.2  207  0.0  1.4  307  0.035 0.019  0.790 0.018 0.082  10   8.17   14   0.99
 47  32   0.0  1.2  185  0.1 15.9  301  0.050 0.018  0.964 0.016 0.054   3   9.98   14   0.76
 48  13   0.1  1.9  165  0.0 17.0  290  0.025 0.015  0.185 0.036 0.048   3  14.61   14   2.78
 49  17   0.1  4.4  151  1.4 13.8  279  0.044 0.000  0.000 0.015 0.008   3  13.51   14   0.84
 50  15   0.1  0.5  268  1.3 42.4  286  0.056 2.024  1.154 0.019 0.048   2   9.71   14   4.00
 51  20   0.0  3.7  196  1.1 10.7  244  0.037 0.000  0.233 0.023 0.058   3   9.70   14   0.85
 52  19   0.0  4.4  299  0.4  9.8  253  0.028 0.020  0.632 0.015 0.058   3  11.67   14   3.77
 53  14   0.1  4.4  156  0.0  8.2  234  0.030 0.003  1.051 0.012 0.060   3  10.44   14   8.23
 54  25   0.4  7.4  233  0.0  8.3  221  0.027 0.033  0.341 0.037 0.056   6  10.03   14   0.66
 55  13   0.0  5.4  276  0.0  9.7  211  0.030 0.286  1.423 0.027 0.020   9     .    14   0.90
 56  17   0.1  6.7  347  0.0 17.0  220  0.047 0.013  0.830 0.029 0.060  23   8.39   14   2.86
 57  15   0.0 12.6  184  0.0 11.5  214  0.026 0.149  0.384 0.002 0.017   2   8.11   14   1.91
 58  12   0.0 12.5  148  0.0  4.8  199  0.021 0.004  0.629 0.010 0.031   3  10.79   14   0.97
 59  11   0.0  3.1  156  0.0 27.4  219  0.024 0.000 -0.024 0.008 0.024   1   9.92   14   3.77
 60  10   0.0  9.4  135  0.0  9.8  211  0.032 0.000  0.235 0.011 0.022   2   8.07   14   0.55
 61   6   0.0  8.1  101  0.0  3.3  203  0.035 0.009  0.001 0.010 0.019   .   8.10   14   0.98
 62   3   0.2  2.7   69  0.0  4.2  206  0.045 0.001  0.415 0.011 0.024   2   7.76   14   0.69
 63  25   0.0  8.1  987  0.3 11.6  173  0.020 0.019  0.410 0.074 0.207  47   6.43   14   2.05
 64  12   0.1  3.4  500  2.5  7.2  156  0.038 0.004  0.782 0.056 0.102  16   6.18   14   0.74
 65  10   0.0  2.1  258  1.0  9.2  162  0.028 0.003  0.642 0.049 0.106   7   6.95   14   2.08
 66   4   0.0  1.4  207  0.0 12.7  188  0.041 0.000  0.399 0.022 0.000   3   8.29   14   2.84
 67   7   0.0  2.2  145  0.1 10.2  187  0.054 0.011  0.966 0.016 0.021   7     .    14   1.78
 68   5   0.0  1.0  150  0.0  8.0  193  0.036 0.005  0.784 0.009 0.032   6   9.85   14   1.94
 69  17   0.1  4.8  169  0.1 11.1  190  0.041 0.013  0.939 0.029 0.039   4   8.46   14   1.00
 70  19   0.1  3.2  224  0.4  6.5  186  0.019 0.212  0.751 0.014 0.047   8   7.40   14   0.64

OBS TRAIN AVGINT MAXINT DURA RCOEF  NAIN NAOU SO4IN SO4OU MGIN MGOU CAIN CAOU CLIN CLOU KIN KOU MO DA

 36  0.75   0.12  0.50  6.25 0.187  5.3  3.4    90    49  5.5  3.3   65   42  8.1  4.4 3.1 1.5 10  6
 37  0.27   0.14  0.30  2.00 0.238   .   3.6     .    54   .   4.3    .   47   .   4.4  .  1.4 10  9
 38  0.12   0.03  0.08  3.25 0.574  4.4  4.0    40    59  7.1  5.1   87   44  9.3  5.2 5.0 1.7 10 15
 39  1.34   0.08  1.00 16.50 0.437  4.3  5.4    42    65  4.5  5.8   53   44  8.9  8.6 5.2 2.4 10 30
 40  0.24   0.39  0.84  0.50 0.211 15.0  7.2   413    52 19.0  6.8  186   80 25.0 13.0 4.1 3.9 11 20
 41  0.85   0.12  0.24  7.00   .    9.8  9.1   108    99  8.7  8.0   83   60 18.0 16.0 1.3 1.5  1  2
 42  0.31   0.18  0.05  1.75   .    5.0  8.9    47   109  4.2  8.9   53   57 12.0 17.0 4.6  .   1 13
 43  1.06   0.28  0.24  3.75 0.503  3.1  6.2    22    64  2.9  5.5   39   46  6.9 11.0  .   .   1 17
 44  1.18   0.21  0.46  5.75 0.730 12.0  6.0   325   316 17.0 10.0  134  148 18.0  8.2 7.7 1.8  6 14
 45  0.77   0.39  2.00  2.00 0.203  2.0  4.7    63   253  3.0  7.9   44  110  2.8  6.4 2.0 1.6  6 15
 46  1.39   0.22  2.56  6.25 0.377  4.5  4.2   117   223  7.7  7.2   84  102  5.2  5.7 4.1 1.6  6 16
 47  0.32   0.16  0.52  2.00 0.345  4.7  4.3   132   220  8.1  7.6   86  108  5.1  5.6 3.1 1.5  6 17
 48  0.50   0.25  1.08  2.00 0.334  2.4  4.2    61   204  2.9  7.3   46  104  3.3  5.5 1.7 1.5  6 20
 49  0.39   0.14  1.24  2.75 0.547  3.6  4.2    73   199  5.2  7.0   54  100  4.6  5.4 1.5 1.7  6 21
 50  0.30   0.08  0.28  4.00 0.132  3.5  4.4   111   201  4.6  7.6   50  102  5.7  5.5 2.1 1.3  6 29
 51  0.37   0.10  0.24  3.75 0.175  7.0  3.8    99   152  8.2  6.4   88   87  9.5  4.5 4.0 1.6  7  6
 52  0.49   0.39  0.72  1.25 0.315  4.0  4.2    71   151  4.5  6.7   54   89  5.6  5.0 2.5 1.6  7 10
 53  0.76   1.01  2.56  0.75 0.277  2.0  4.7    53   155  2.2  6.6   37   83  2.8  6.0 1.7 1.8  7 18
 54  1.11   1.11  2.56  1.00 0.389  1.4  3.8    45   148  2.5  6.4   39   78  2.4  5.8 1.6 1.9  7 20
 55  0.42   0.34  1.04  1.25 0.610  2.0  3.9    47   143  3.1  5.7   45   75  2.7  4.9 1.6 1.8  7 21
 56  0.22   0.22  0.32  1.00 0.208  4.8  4.0   109   132  7.6  5.9   64   79  6.6  5.0 1.4 1.7  7 24
 57  0.49   0.39  0.72  1.25 0.281  2.9  3.2    73   134  4.4  5.9   53   76  6.0  5.1 3.0 1.5  7 28
 58  0.45   0.26  1.08  1.75 0.571  2.6  3.4    51   129  4.2  5.8   80   70  5.0  5.4 3.7 1.7  7 30
 59  0.22   0.15  0.48  1.50 0.154  3.0  3.9    35   118  2.7  5.8   35   78  5.5  5.9 1.2 1.8  8  3
 60  0.20   0.13  0.60  1.50 0.313  3.6  3.9    65   117  5.1  5.8   56   75  6.3  5.7 1.2 1.7  8  6
 61  0.42   0.34  1.04  1.25 0.223  4.6  3.9    96   119  8.6  5.7   92   72  8.1  6.1 2.4 1.7  8  7
 62  0.42   0.10  0.68  4.25 0.522  2.8  3.9    60   120  4.8  5.8   67   73  5.0  6.2 2.4 1.7  8  8
 63  2.28   0.48  3.88  4.75 0.641  1.0  3.5    29   100  1.8  5.0   30   61  1.9  5.3 1.7 1.6  8 10
 64  0.30   0.60  1.04  0.50 0.447  2.8  2.5    51    74  4.5  3.9   64   56  4.0  4.0 1.9 1.5  8 11
 65  0.71   0.20  1.00  3.50 0.468  2.4  2.6    62    75 20.9  4.1   55   58  4.1  4.1 2.0 1.5  8 13
 66  0.11   0.07  0.12  1.50 0.196  8.3  2.9   198    79 18.0  4.4  151   68 12.0  4.5 1.5 1.5  8 16
 67  0.29   0.07  0.44  4.25 0.336  4.1  3.1    86    85  6.7  4.9   78   67  6.7  5.4 1.4 1.6  8 23
 68  0.72   0.26  1.84  2.75 0.455  1.9  3.3    45    86  2.9  5.1   65   69  1.9  5.3 1.9 1.6  8 24
 69  1.14   0.65  1.36  1.75 0.649  1.5  3.4    31    79  2.4  5.0   56   66  2.5  5.2 1.8 1.6  8 25
 70  1.22   0.15  0.84  8.00 0.503  4.0  3.5    96    88  7.0  5.2   83   66  6.6  6.2 2.1 1.5  9 16
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                         RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                          10
                                  TAMPA OFFICE 1990 TO 1995
                                        OUTFLOW DATA

OBS ZNOU CDOU   CUOU   FEOU PBOU MNOU HOU NH3OU NOXOU  ONOU  OPOU    TPOU  SSOU TOCOU   RT  INTER

 71  15   0.0  1.7  466  0.0  7.2  180  0.012 0.017  0.758 0.034 0.088   19   7.06   14   0.96
 72  10   0.1  2.6   29  2.1 11.3  153  0.015 0.008  0.657 0.066 0.105   11   2.28   14   2.04
 73   9   0.2  3.3  137  0.6  6.4  150  0.006 0.005  0.651 0.035 0.063    5   6.08   14   5.05
 74   8   0.1  3.2  511  1.7 11.4  151  0.034 0.002  0.413 0.097 0.127   19   8.61   14   2.18
 75  12   0.1  4.7  152  0.8 12.4  182  0.006 0.089  0.681 0.042 0.054    3   7.01   14   5.78
 76  22   0.0  3.4  245  0.5  9.7  203  0.042 0.693  1.081 0.033 0.047    6  10.51   14   6.32
 77   5   0.0  1.9  132  0.3  7.3  184  0.058 0.098  0.512 0.016 0.032    4  10.72   14   0.85
 78   6   0.0  0.6  192  0.7  7.2  175  0.026 0.029  0.114 0.047 0.055    8   8.14   14  13.00
 79  12   0.0  2.6   62  0.4 12.6  211  0.019 0.000  0.531 0.028 0.047    2   9.63   14   4.35
 80  14   0.1  5.4  104  1.5 10.1  217  0.024 0.025  0.515 0.025 0.055    1    .     14   2.63
 81  31   0.1  5.2   97  1.0  4.4  205  0.024 0.013  0.436 0.008 0.020    3   7.19   14   1.35
 82  21   0.0  4.6   84  0.9 12.2  219  0.141 0.613  0.298 0.000 0.000    2   7.10   14   2.55
 83   8   0.0  2.7  114  0.3  5.1  178  0.060 0.002  0.785 0.036 0.043    3   6.78   14   6.75
 84  12   0.0  0.4  449  0.8  5.5  162  0.025 0.043  0.537 0.032 0.047    4   6.41   14   0.23
 85  29   0.1  3.6  171  2.3  4.0  184  0.012 0.002  1.191 0.033 0.046    4   8.40   14   7.72

OBS TRAIN AVGINT MAXINT DURA RCOEF  NAIN NAOU SO4IN SO4OU MGIN MGOU CAIN CAOU CLIN CLOU KIN KOU MO DA

 71  0.72    0.96   2.60  0.75 0.683  5.3  3.4    94    79 10.0  5.0  105   64  6.6  5.7 2.1 1.6  9 17
 72  1.63    0.72   3.04  2.25 0.807  2.7  2.8    47    56  4.6  4.1   50   54  3.7  5.0 1.5 1.5  9 19
 73  1.13    0.90   1.72  1.25 0.507  1.9  2.8    35    55  3.4  3.9   54   55  3.3  4.8 1.8 1.5  9 25
 74  1.27    0.39   1.32  3.25 0.802  1.9  2.9    41    60  3.2  4.1   50   54  3.3  5.2 1.7 1.4  9 27
 75  0.51    0.09   0.48  5.50 0.485  4.6  3.3    75    64  6.5  4.7   66   65  6.8  5.8 1.3 1.3 10  2
 76  0.42    0.34   0.72  1.25 0.254  7.1  3.9    86   115  8.4  5.6   79   72 13.0  7.0 5.3 1.7 10 10
 77  0.36    0.06   0.20  6.00 0.400  6.6  4.4    92    79  8.5  5.2   87   65 13.0  7.4 3.9 1.5 10 12
 78  1.60    0.38   1.40  4.25 0.461  3.3  3.9    78    91  3.6  5.6   47   61  7.0  8.0 3.1 1.9 10 26
 79  0.66    0.05   0.28 12.25 0.179  6.4  4.6   107    92  7.2  5.7   59   75  8.2  8.0 1.5 2.5 11 15
 80  0.83    0.06   0.20 13.00 0.274 15.0  4.9   304   104 17.0  6.1  144   77 22.0  8.4 4.6 2.3 12 21
 81  0.28    0.22   0.32  1.25 0.480  7.2  5.0   143   114  9.7  6.2   92   71 14.0  8.1 3.8 1.5 12 22
 82  0.25    0.14   0.20  1.75 0.186  6.3  5.8   131   127  8.9  6.6   65   76  8.1  9.1 1.2 1.8  1  7
 83  1.02    0.20   1.64  5.00 0.441  3.4  5.2    65   122  3.3  6.2   42   61  5.8  8.5 1.9 1.6  1 14
 84  0.53    0.07   0.72  7.50 0.561  9.7  5.1    95     .  9.0  6.1   61   55 16.0  8.4 2.1 1.4  1 15
 85  0.16    0.16   0.52  1.00 0.188   .    .      .     .    .    .     .    .    .    .   .   .   1 16
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                            RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                       12
                                      TAMPA OFFICE 1990 TO 1995
                                            OUTFLOW DATA

                                        Correlation Analysis

   Spearman Correlation Coefficients / Prob > |R| under Ho: Rho=0 / Number of Observations

ZNOU
                      ZNOU             TPOU             PBOU             CDOU            INTER
                   1.00000          0.50370          0.45215          0.45012         -0.44495
                       0.0           0.0001           0.0001           0.0001           0.0001
                        85               84               85               85               85

                      OPOU             SSOU              HOU            NOXOU              KOU
                   0.41387          0.39492          0.31901          0.30606          0.29848
                    0.0001           0.0002           0.0108           0.0044           0.0205
                        85               84               63               85               60

CDOU
                      CDOU            INTER             TPOU             SSOU             ZNOU
                   1.00000         -0.63501          0.51922          0.49980          0.45012
                       0.0           0.0001           0.0001           0.0001           0.0001
                        85               85               84               84               85

                      OPOU             PBOU            TOCOU           MAXINT            SO4OU
                   0.34772          0.34002          0.30866          0.29865         -0.28476
                    0.0011           0.0015           0.0043           0.0058           0.0261
                        85               85               84               84               61

FEOU
                      FEOU            RCOEF            INTER             CLIN           MAXINT
                   1.00000         -0.33493          0.24273          0.23595          0.22735
                       0.0           0.0073           0.0553           0.0695           0.0731
                        63               63               63               60               63

                      CLOU             OPOU             SSOU             NAOU            TRAIN
                  -0.21499         -0.21116         -0.19128         -0.18195         -0.16053
                    0.0961           0.0967           0.1364           0.1605           0.2088
                        61               63               62               61               63

PBOU
                      PBOU             TPOU             SSOU            TOCOU           MAXINT
                   1.00000          0.66346          0.64926          0.64822          0.46034
                       0.0           0.0001           0.0001           0.0001           0.0001
                        85               84               84               84               84

                      ZNOU            INTER             DURA             OPOU             CDOU
                   0.45215         -0.42156          0.39700          0.35984          0.34002
                    0.0001           0.0001           0.0002           0.0007           0.0015
                        85               85               84               85               85

MNOU
                      MNOU            NH3OU             SSOU             CLIN             TPOU
                   1.00000         -0.49253          0.36859         -0.35042          0.33883
                       0.0           0.0001           0.0032           0.0061           0.0071
                        63               61               62               60               62

                     NOXOU             CDOU              KOU            RCOEF           AVGINT
                  -0.26296          0.24667          0.22950          0.18779          0.15514
                    0.0373           0.0513           0.0777           0.1405           0.2247
                        63               63               60               63               63

HOU
                       HOU             ZNOU             TPOU             PBOU            NOXOU
                   1.00000          0.31901          0.30365          0.24734          0.20589
                       0.0           0.0108           0.0164           0.0507           0.1055
                        63               63               62               63               63

                      CLIN              KOU             CDOU             CAOU            NH3OU
                   0.19770         -0.18786          0.17157         -0.13284          0.13074
                    0.1300           0.1506           0.1788           0.3074           0.3152
                        60               60               63               61               61

NH3OU
                     NH3OU             CLIN            TOCOU            INTER             SSOU
                   1.00000          0.89295         -0.59886          0.59215         -0.58861
                       0.0           0.0001           0.0001           0.0001           0.0001
                        61               59               60               61               60
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                      RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                         13
                               TAMPA OFFICE 1990 TO 1995
                                     OUTFLOW DATA

                                 Correlation Analysis

   Spearman Correlation Coefficients / Prob > |R| under Ho: Rho=0 / Number of Observations

NH3OU
                         SO4OU            MNOU            TPOU          AVGINT            PBOU
                       0.50632        -0.49253        -0.49123        -0.40104        -0.33768
                        0.0001          0.0001          0.0001          0.0014          0.0078
                            59              61              60              61              61

NOXOU
                         NOXOU            ONOU           NH3OU            ZNOU            CLIN
                       1.00000         0.35677         0.33622         0.30606         0.30219
                           0.0          0.0008          0.0081          0.0044          0.0189
                            85              85              61              85              60

                          OPOU            MNOU           INTER            PBOU             HOU
                       0.27202        -0.26296        -0.25077         0.21704         0.20589
                        0.0118          0.0373          0.0206          0.0460          0.1055
                            85              63              85              85              63

ONOU
                          ONOU           NOXOU            PBOU            ZNOU            OPOU
                       1.00000         0.35677         0.30524         0.27489         0.27057
                           0.0          0.0008          0.0045          0.0109          0.0123
                            85              85              85              85              85

                          TPOU           TOCOU           INTER            SSOU            DURA
                       0.25695         0.24650        -0.24300         0.23977         0.18569
                        0.0183          0.0238          0.0250          0.0280          0.0908
                            84              84              85              84              84

OPOU
                          OPOU            ZNOU            SSOU            TPOU           INTER
                       1.00000         0.41387         0.41381         0.39734        -0.39392
                           0.0          0.0001          0.0001          0.0002          0.0002
                            85              85              84              84              85

                          PBOU            CDOU           TRAIN           NOXOU            ONOU
                       0.35984         0.34772         0.29110         0.27202         0.27057
                        0.0007          0.0011          0.0069          0.0118          0.0123
                            85              85              85              85              85

TPOU
                          TPOU            SSOU            PBOU           INTER           TOCOU
                       1.00000         0.84557         0.66346        -0.59700         0.59179
                           0.0          0.0001          0.0001          0.0001          0.0001
                            84              84              84              84              83

                          CDOU            ZNOU           NH3OU            DURA          MAXINT
                       0.51922         0.50370        -0.49123         0.47698         0.45329
                        0.0001          0.0001          0.0001          0.0001          0.0001
                            84              84              60              83              83

SSOU
                          SSOU            TPOU           INTER           TOCOU            PBOU
                       1.00000         0.84557        -0.67647         0.65568         0.64926
                           0.0          0.0001          0.0001          0.0001          0.0001
                            84              84              84              83              84

                         NH3OU            CDOU            CLIN          AVGINT           SO4OU
                      -0.58861         0.49980        -0.47730         0.45857        -0.45762
                        0.0001          0.0001          0.0001          0.0001          0.0002
                            60              84              59              84              60

TOCOU
                         TOCOU            SSOU            PBOU           NH3OU            TPOU
                       1.00000         0.65568         0.64822        -0.59886         0.59179
                           0.0          0.0001          0.0001          0.0001          0.0001
                            84              83              84              60              83

                          CLIN            DURA          MAXINT           SO4OU           INTER
                      -0.51556         0.50528         0.46648        -0.45447        -0.45368
                        0.0001          0.0001          0.0001          0.0003          0.0001
                            59              83              83              60              84
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                     RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                  14
                               TAMPA OFFICE 1990 TO 1995
                                     OUTFLOW DATA

                                 Correlation Analysis

   Spearman Correlation Coefficients / Prob > |R| under Ho: Rho=0 / Number of Observations

INTER
                 INTER           SSOU           CDOU           CLIN           TPOU
               1.00000       -0.67647       -0.63501        0.60349       -0.59700
                   0.0         0.0001         0.0001         0.0001         0.0001
                    85             84             85             60             84

                 NH3OU            KOU          SO4OU          TOCOU           ZNOU
               0.59215       -0.51597        0.45873       -0.45368       -0.44495
                0.0001         0.0001         0.0002         0.0001         0.0001
                    61             60             61             84             85

TRAIN
                 TRAIN           OPOU           CAOU           FEOU           SSOU
               1.00000        0.29110       -0.17694       -0.16053        0.13658
                   0.0         0.0069         0.1725         0.2088         0.2154
                    85             85             61             63             84

                 INTER          TOCOU           TPOU          NH3OU           MGOU
              -0.13650       -0.12994        0.12280       -0.10169       -0.09468
                0.2129         0.2388         0.2658         0.4355         0.4679
                    85             84             84             61             61

AVGINT
                AVGINT           DURA          SO4OU         MAXINT           SSOU
               1.00000        0.69251       -0.48118        0.46779        0.45857
                   0.0         0.0001         0.0001         0.0001         0.0001
                    85             84             61             84             84

                 TOCOU           TPOU           NAOU           MGOU          RCOEF
               0.44474        0.42748       -0.42334       -0.42011        0.41309
                0.0001         0.0001         0.0007         0.0007         0.0001
                    84             84             61             61             83

MAXINT
                MAXINT           DURA           NAOU           CLOU          RCOEF
               1.00000        0.76592       -0.58574       -0.58481       -0.55909
                   0.0         0.0001         0.0001         0.0001         0.0001
                    84             84             61             61             83

                 SO4OU           MGOU         AVGINT          TOCOU           PBOU
              -0.54543       -0.51651        0.46779        0.46648        0.46034
                0.0001         0.0001         0.0001         0.0001         0.0001
                    61             61             84             83             84

DURA
                  DURA         MAXINT         AVGINT           CLOU           NAOU
               1.00000        0.76592        0.69251       -0.63861       -0.63270
                   0.0         0.0001         0.0001         0.0001         0.0001
                    84             84             84             61             61

                 SO4OU           MGOU          TOCOU           TPOU           CAOU
              -0.54691       -0.51439        0.50528        0.47698       -0.44346
                0.0001         0.0001         0.0001         0.0001         0.0003
                    61             61             83             83             61

RCOEF
                 RCOEF         MAXINT         AVGINT           FEOU           ZNOU
               1.00000       -0.55909        0.41309       -0.33493       -0.28282
                   0.0         0.0001         0.0001         0.0073         0.0096
                    83             83             83             63             83

                  CLOU          NH3OU           CDOU           NAOU           CLIN
               0.27138       -0.20736       -0.19849        0.19445       -0.18799
                0.0344         0.1088         0.0720         0.1332         0.1503
                    61             61             83             61             60

NAOU
                  NAOU           CLOU           MGOU           CAOU          SO4OU
               1.00000        0.90515        0.86310        0.77565        0.72756
                   0.0         0.0001         0.0001         0.0001         0.0001
                    61             61             61             61             61
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                      RESIDENCE TIME AND WATER QUALITY IMPROVEMENT                     15
                               TAMPA OFFICE 1990 TO 1995
                                      OUTFLOW DATA

                                  Correlation Analysis

   Spearman Correlation Coefficients / Prob > |R| under Ho: Rho=0 / Number of Observations

NAOU
                      DURA           MAXINT           AVGINT             SSOU             PBOU
                  -0.63270         -0.58574         -0.42334         -0.31048         -0.29978
                    0.0001           0.0001           0.0007           0.0158           0.0189
                        61               61               61               60               61

SO4OU
                     SO4OU             MGOU             NAOU             CAOU             CLIN
                   1.00000          0.76712          0.72756          0.68465          0.60211
                       0.0           0.0001           0.0001           0.0001           0.0001
                        61               61               61               61               59

                      CLOU             DURA           MAXINT            NH3OU           AVGINT
                   0.56926         -0.54691         -0.54543          0.50632         -0.48118
                    0.0001           0.0001           0.0001           0.0001           0.0001
                        61               61               61               59               61

MGOU
                      MGOU             CAOU             NAOU            SO4OU             CLOU
                   1.00000          0.86738          0.86310          0.76712          0.76384
                       0.0           0.0001           0.0001           0.0001           0.0001
                        61               61               61               61               61

                    MAXINT             DURA           AVGINT             SSOU             CLIN
                  -0.51651         -0.51439         -0.42011         -0.23593          0.23335
                    0.0001           0.0001           0.0007           0.0696           0.0753
                        61               61               61               60               59

CAOU
                      CAOU             MGOU             NAOU            SO4OU             CLOU
                   1.00000          0.86738          0.77565          0.68465          0.66305
                       0.0           0.0001           0.0001           0.0001           0.0001
                        61               61               61               61               61

                      DURA           MAXINT           AVGINT             SSOU             PBOU
                  -0.44346         -0.42609         -0.40753         -0.31163         -0.28318
                    0.0003           0.0006           0.0011           0.0154           0.0270
                        61               61               61               60               61

CLOU
                      CLOU             NAOU             MGOU             CAOU             DURA
                   1.00000          0.90515          0.76384          0.66305         -0.63861
                       0.0           0.0001           0.0001           0.0001           0.0001
                        61               61               61               61               61

                    MAXINT            SO4OU             PBOU           AVGINT              KOU
                  -0.58481          0.56926         -0.32694         -0.32364          0.30063
                    0.0001           0.0001           0.0101           0.0109           0.0196
                        61               61               61               61               60

CLIN
                      CLIN            NH3OU            INTER            SO4OU            TOCOU
                   1.00000          0.89295          0.60349          0.60211         -0.51556
                       0.0           0.0001           0.0001           0.0001           0.0001
                        60               59               60               59               59

                      SSOU           AVGINT             MNOU             TPOU            NOXOU
                  -0.47730         -0.37028         -0.35042         -0.31729          0.30219
                    0.0001           0.0036           0.0061           0.0143           0.0189
                        59               60               60               59               60

KOU
                       KOU            INTER           AVGINT             CLOU             ZNOU
                   1.00000         -0.51597          0.30412          0.30063          0.29848
                       0.0           0.0001           0.0182           0.0196           0.0205
                        60               60               60               60               60

                      SSOU            TOCOU             MNOU             CDOU             OPOU
                   0.28024          0.25007          0.22950          0.22498          0.22288
                    0.0316           0.0561           0.0777           0.0839           0.0870
                        59               59               60               60               60
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APPENDIX Q

Vegetation Percent Cover for Individual Quadrats
Divided into Sections of the Pond (see Figure 4)

Table Q-1. Vegetation analysis of the littoral zone using percent cover conducted June 1994 (shaded columns) and June 1996. Dead end extension - West Side. See Figure 4 for sampling locations.

Quadrat number		1a		1b		2a		2b		3a		3b		4a		4b		5a		5b		6a		6b		7a		7b		Avg94	Avg96
Open Water		0.90	0.11	0.95	0.75	0.40	0.26	0.80	0.15	0.15	0.16	0.40	0.07	0.80	0.33	0.94	0.55	0.30	0.31	0.90	0.52	0.60	0.46	0.65	0.70	0.70	0.67	0.75	0.64	0.66	0.41
SCIENTIFIC NAME	COMMON NAME																														
Alternanthera phloxeroides	Alligator weed								0.01		0.02			0.04	0.30		0.09				0.08	0.10	0.10		0.01	0.10	0.15		0.05	0.02	0.06
Acer rubrum	Red maple		0.01							0.01																				0.00	0.00
Ampelopsis arborea	Pepper vine						0.02																			0.02				0.00	0.00
Bacopa monnieri	Water-hyssops		0.10				0.01				0.10								0.50				0.10							0.00	0.06
Centrella asiatica	Coinwort																		0.03			0.05	0.01				0.01			0.00	0.00
Commelina sp.	Dayflower																													0.00	0.00
Cyperus distinctus																														0.00	0.00
Cyperus haspens																														0.00	0.00
Cyperus oderatus							0.01																							0.00	0.00
Cyperus polystachyos																														0.00	0.00
Dichromina colorata	White top sedge		0.05			0.02	0.15							0.15	0.05			0.15	0.01			0.08	0.03							0.03	0.02
Echinochloa crusgalli	Barnyard grass																													0.00	0.00
Eupatorium capillifolium	Dog fennel																													0.00	0.00
Galium sp.	Bed straw																													0.00	0.00
Glabrous Grass																		0.02												0.00	0.00
Grass (red head)																														0.00	0.00
Grass	St. Augustine																													0.00	0.00
Hydrocotyle umbellata	Pennywort										0.03				0.05		0.02		0.08		0.03		0.05		0.01	0.05	0.02	0.05	0.01	0.01	0.02
Juncus effusus																														0.00	0.00
Juncus megacephalus																														0.00	0.00
Lippia nodiflora	Carpet weed																	0.05				0.05								0.01	0.00
Lolium spp ?																														0.00	0.00
Ludwigia leptocarpa																														0.00	0.00
Ludwigia microcarpa							0.02																							0.00	0.00
Ludwigia peruviana	Primrose Willow	0.05	0.01							0.15																				0.01	0.00
Ludwigia repens			0.02			0.08	0.10		0.02		0.01							0.35												0.03	0.01
Lythrum alatum	Loosestrife						0.01																0.02			0.05				0.00	0.00
Mitreola petiolata																														0.00	0.00
Mikania scandens	Hemp vine						0.01								0.02			0.10	0.01				0.01	0.05						0.01	0.00
Panicum repens	Torpedo grass		0.70	0.05	0.03	0.50	0.35	0.20	0.72	0.69	0.65	0.56	0.85	0.01	0.25	0.04	0.26	0.03	0.06	0.10	0.25	0.02	0.15	0.30	0.08	0.02	0.15	0.20	0.15	0.20	0.33
Paspalum distichum	Knot grass	0.05																												0.00	0.00
Pluchea purpurascens	Marsh-fleabane															0.01														0.00	0.00
Polygonium punctatum	Knot weed																													0.00	0.00
Pontederia cordata	Pickerel weed								0.03																					0.00	0.00
Ptilimnium capillaceum	Bishop's weed																				0.02									0.00	0.00
Rhynchospora corniculata	Horned-rush																													0.00	0.00
Sagittaria lancifolia	Arrowhead						0.02															0.10								0.01	0.00
Sagittaria sp.																														0.00	0.00
Salix caroliniana	Willow																						0.02							0.00	0.00
Sesbania Vesicaria	Bag-pod																													0.00	0.00
Spartina bakeri	Cord grass																													0.00	0.00
Typha sp.	Cat-tail																													0.00	0.00
Ulmus americana var	Elm seedling																													0.00	0.00
Floating filamentous algae				0.22	0.22		0.02		0.07		0.03	0.04	0.08	0.01			0.08				0.10				0.20				0.15	0.02	0.07
Unknown alternate leaf							0.02																							0.00	0.00
Unknown opposite leaf																														0.00	0.00
Unknown red node																							0.05							0.00	0.00
Number of species		3	7	3	3	4	13	2	6	4	7	3	3	6	6	4	5	7	7	2	6	6	11	3	5	7	5	3	5	4.21	6.36
Minimum water depth (ft)		0.11	0.00	1.11	1.38	0.13	0.00	1.50	1.29	0.10	0.17	1.87	1.25	0.20	0.00	1.52	0.75	0.20	0.08	1.09	0.50	0.00	0.13	1.89	1.25	0.10	0.17	1.74	0.92	0.83	0.56
Maximum water depth (ft)		1.09	0.58	1.88	1.92	1.38	0.54	2.58	1.75	0.78	1.25	2.32	na	1.32	0.67	2.55	1.25	0.25	0.42	2.32	1.50	1.65	1.08	4.30	3.83	1.00	0.75	2.35	1.50	1.84	1.22

Table Q-2. Vegetation analysis of the littoral zone using percent cover conducted June 1994 (shaded columns) and June 1996. West Side. See Figure 4 for sampling locations.

Quadrat number		8a		8b		9a		9b		10a		10b		11a		11b		12a		12b		13a		13b		Avg94	Avg96
Open Water		0.55	0.05	0.80	0.18	0.65	0.25	0.65	0.20	0.40	0.53	0.85	0.65	0.80	0.41	0.70	0.20	0.50	0.09	0.50	0.08	0.05	0.00	0.90	0.20	0.61	0.24
SCIENTIFIC NAME	COMMON NAME																										
Alternanthera phloxeroides	Alligator weed	0.03	0.01		0.05	0.15	0.07	0.05	0.10	0.10	0.08		0.05	0.10	0.08				0.04		0.01					0.04	0.04
Acer rubrum	Red maple seedling																						0.05			0.00	0.00
Ampelopsis arborea	Pepper vine						0.01																			0.00	0.00
Bacopa monnieri	Water-hyssops		0.46		0.01		0.07												0.01							0.00	0.05
Centrella asiatica	Coinwort					0.02	0.05				0.01			0.03												0.00	0.01
Commelina sp.	Dayflower																		0.01							0.00	0.00
Cyperus distinctus																										0.00	0.00
Cyperus haspens																		0.05								0.00	0.00
Cyperus oderatus																		0.05		0.05						0.01	0.00
Cyperus polystachyos																										0.00	0.00
Dichromina colorata	White top sedge	0.01					0.01								0.01				0.01							0.00	0.00
Echinochloa crusgalli	Barnyard grass							0.20		0.05		0.10				0.10		0.15		0.10	0.10	0.25	0.90	0.02	0.60	0.08	0.13
Eupatorium capillifolium	Dog fennel																			0.02						0.00	0.00
Galium sp.	Bed straw																									0.00	0.00
Glabrous Grass															0.10											0.00	0.01
Grass (red head)																										0.00	0.00
Grass	St. Augustine																									0.00	0.00
Hydrocotyle umbellata	Pennywort	0.01	0.08		0.01						0.05		0.02						0.08	0.05	0.04					0.01	0.02
Juncus effusus																										0.00	0.00
Juncus megacephalus																										0.00	0.00
Lippia nodiflora	Carpet weed		0.02																				0.03			0.00	0.00
Lolium spp ?																										0.00	0.00
Ludwigia leptocarpa						0.10				0.10																0.02	0.00
Ludwigia microcarpa																										0.00	0.00
Ludwigia peruviana	Primrose Willow						0.01																			0.00	0.00
Ludwigia repens																										0.00	0.00
Lythrum alatum	Loosestrife					0.03	0.08											0.03								0.01	0.01
Mitreola petiolata																										0.00	0.00
Mikania scandens	Hemp vine							0.03			0.02									0.01			0.02			0.00	0.00
Panicum repens	Torpedo grass	0.40	0.35	0.20	0.25		0.10	0.05	0.05			0.05		0.02	0.05	0.10	0.40			0.25	0.15	0.70		0.08		0.15	0.11
Paspalum distichum	Knot grass																									0.00	0.00
Pluchea purpurascens	Marsh-fleabane							0.02								0.03		0.01		0.02						0.01	0.00
Polygonium punctatum	Knot weed		0.03							0.10	0.01			0.05		0.05	0.08									0.02	0.01
Pontederia cordata	Pickerel weed						0.25		0.15						0.25		0.07	0.21	0.06		0.50					0.02	0.11
Ptilimnium capillaceum	Bishop's weed																									0.00	0.00
Rhynchospora corniculata	Horned-rush																		0.70							0.00	0.06
Sagittaria lancifolia	Arrowhead																									0.00	0.00
Sagittaria sp.																										0.00	0.00
Salix caroliniana	Willow																				0.02					0.00	0.00
Sesbania Vesicaria	Bag-pod					0.05																				0.00	0.00
Spartina bakeri	Cord grass									0.25																0.02	0.00
Typha sp.	Cat-tail																									0.00	0.00
Ulmus americana var floridana	Elm seedling																									0.00	0.00
Floating filamentous algae					0.50		0.10		0.50		0.30		0.28		0.10		0.25				0.10				0.20	0.00	0.19
Unknown alternate leaf																										0.00	0.00
Unknown opposite leaf																										0.00	0.00
Unknown red node			0.01																							0.00	0.00
Number of species		6	8	2	6	7	11	7	5	7	7	3	4	6	7	5	5	7	8	8	8	3	5	3	3	5.33	6.42
Minimum water depth (ft)		0.19	0.00	2.09	0.83	0.00	0.00	1.68	na	0.10	0.25	1.98	1.75	0.25	0.00	0.85	0.67	0.38	0.00	0.55	0.33	0.20	0.00	1.00	0.33	0.76	0.36
Maximum water depth (ft)		1.15	0.83	4.20	2.67	1.85	0.67	3.20	na	1.10	1.50	4.20	3.16	0.87	0.67	2.85	1.59	0.55	0.33	1.75	0.50	0.65	0.25	3.90	2.08	2.19	1.19

Table Q-3. Vegetation analysis of the littoral zone using percent cover conducted June 1994 (shaded columns) and 1996. East side of original pond - see Figure 4 for locations.

Quadrat number		14a		14b		16a		16b		17b		18a		18b		19a		19b		20a		20b		Avg94	Avg96
Open Water		0.20	0.10	0.69	0.56	0.29	0.04	0.70	0.55	0.70	0.24	0.30	0.10	0.79	0.56	0.83	0.52	0.87	0.71	0.19	0.19	0.46	0.40	0.51	0.32
SCIENTIFIC NAME	COMMON NAME																								
Alternanthera phloxeroides	Alligator weed	0.05	0.03		0.02		0.03		0.07	0.02		0.07	0.15	0.01	0.06		0.10		0.04		0.02			0.01	0.00
Acer rubrum	Red maple seedling					0.05	0.03																	0.00	0.00
Ampelopsis arborea	Pepper vine						0.01																	0.00	0.00
Bacopa monnieri	Water-hyssops								0.03		0.08		0.35											0.00	0.04
Centrella asiatica	Coinwort										0.03	0.10												0.01	0.00
Commelina sp.	Dayflower					0.20	0.01	0.01																0.02	0.00
Cyperus distinctus																								0.00	0.00
Cyperus haspens								0.04																0.00	0.00
Cyperus oderatus																								0.00	0.00
Cyperus polystachyos																								0.00	0.00
Dichromina colorata	White top sedge		0.01				0.04		0.02												0.01			0.00	0.01
Echinochloa crusgalli	Barnyard grass	0.10	0.10	0.20	0.30					0.08			0.02		0.30	0.10	0.35	0.05	0.10					0.05	0.11
Eupatorium capillifolium	Dog fennel																							0.00	0.00
Galium sp.	Bed straw						0.01																	0.00	0.00
Glabrous Grass							0.05																	0.00	0.01
Grass (red head)																						0.20		0.00	0.00
Grass	St. Augustine						0.50		0.04															0.00	0.05
Hydrocotyle umbellata	Pennywort		0.30	0.01		0.01	0.04		0.10		0.10		0.15											0.00	0.06
Juncus effusus																								0.00	0.00
Juncus megacephalus																								0.00	0.00
Lippia nodiflora	Carpet weed	0.04									0.03						0.01							0.00	0.00
Lolium spp ?				0.10				0.20		0.15								0.05						0.05	0.00
Ludwigia leptocarpa																								0.00	0.00
Ludwigia microcarpa																								0.00	0.00
Ludwigia peruviana	Primrose Willow															0.07		0.03		0.01	0.15			0.01	0.01
Ludwigia repens		0.05				0.40				0.05														0.05	0.00
Lythrum alatum	Loosestrife						0.03					0.03												0.00	0.00
Mitreola petiolata																								0.00	0.00
Mikania scandens	Hemp vine	0.01	0.38				0.20		0.05				0.05											0.00	0.06
Panicum repens	Torpedo grass	0.60	0.02		0.05	0.05		0.05	0.10		0.45	0.50	0.15	0.20	0.05					0.80	0.20	0.35	0.50	0.20	0.09
Paspalum distichum	Knot grass																							0.00	0.00
Pluchea purpurascens	Marsh-fleabane												0.03											0.00	0.00
Polygonium punctatum	Knot weed																				0.08		0.10	0.00	0.01
Pontederia cordata	Pickerel weed								0.04								0.02				0.35			0.00	0.04
Ptilimnium capillaceum	Bishop's weed																							0.00	0.00
Rhynchospora corniculata	Horned-rush		0.03																					0.00	0.00
Sagittaria lancifolia	Arrowhead																							0.00	0.00
Sagittaria sp.			0.03		0.05						0.07													0.00	0.01
Salix caroliniana	Willow																							0.00	0.00
Sesbania Vesicaria	Bag-pod																							0.00	0.00
Spartina bakeri	Cord grass																							0.00	0.00
Typha sp.	Cat-tail																							0.00	0.00
Ulmus americana var floridana	Elm seedling						0.01																	0.00	0.00
Floating filamentous algae					0.02										0.03				0.15					0.00	0.02
Unknown alternate leaf																								0.00	0.00
Unknown opposite leaf																								0.00	0.00
Unknown red node																								0.00	0.00
Number of species		7	9	4	6	5	13	5	9	5	7	6	8	4	5	3	5	4	4	3	7	3	3	4.27	6.64
Minimum water depth (ft)		0.29	0.29	1.10	1.08	0.10	0.00	0.32	0.63	1.05	0.75	0.10	0.75	1.50	1.62	0.36	0.83	1.30	1.88	0.15	0.67	0.85	1.00	0.57	0.77
Maximum water depth (ft)		0.72	0.88	1.25	1.63	0.24	0.17	2.05	2.13	2.75	2.91	0.88	1.33	3.00	2.50	1.30	1.67	3.80	2.91	0.90	0.71	2.60	1.83	1.51	1.53

Table Q-4. Vegetation analysis of the littoral zone using percent cover conducted June 1994 (shaded columns) and June 1996. New construction 1994 - See Figure 4 for sampling locations.

		21a		22a		23a		24a		25a		26a		27a		28a		29a		30a		Avg94	Avg96
Open Water		1.00	0.34	0.83	0.15	1.00	0.08	1.00	0.38	0.80	0.38	0.88	0.61	1.00	0.21	1.00	0.07	0.92	0.19	0.95	0.12	0.751	0.222
SCIENTIFIC NAME	COMMON NAME																						
Alternanthera phloxeroides	Alligator weed														0.04							0.000	0.004
Acer rubrum	Red maple seedling																					0.000	0.000
Ampelopsis arborea	Pepper vine																					0.000	0.000
Bacopa monnieri	Water-hyssops																					0.000	0.000
Centella asiatica	Coinwort																					0.000	0.000
Commelina sp.	Dayflower																					0.000	0.000
Cyperus distinctus																						0.000	0.000
Cyperus haspens																						0.000	0.000
Cyperus oderatus										0.01		0.02										0.003	0.000
Cyperus polystachyos			0.10																0.02			0.000	0.010
Dichromina colorata	White top sedge		0.05																			0.000	0.005
Echinochloa crusgalli	Barnyard grass										0.08											0.000	0.008
Eupatorium capillifolium	Dog fennel										0.01											0.000	0.001
Galium sp.	Bed straw																		0.01			0.000	0.000
Glabrous Grass			0.02																			0.000	0.002
Grass (red head)				0.02			0.07															0.002	0.007
Grass (St. Augustine)	St. Augustine																					0.000	0.000
Hydrocotyle umbellata	Pennywort												0.01		0.02		0.01					0.000	0.004
Juncus effusus							0.05															0.000	0.005
Juncus megacephalus			0.03																			0.000	0.003
Lippia nodiflora	Carpet weed																					0.000	0.000
Lolium spp ?																						0.000	0.000
Ludwigia leptocarpa			0.03														0.01					0.000	0.004
Ludwigia microcarpa																						0.000	0.000
Ludwigia peruviana	Primrose Willow																					0.000	0.000
Ludwigia repens			0.03								0.03				0.01							0.000	0.007
Lythrum alatum	Loosestrife										0.04								0.03			0.000	0.004
Mitreola petiolata			0.01																			0.000	0.001
Mikania scandens	Hemp vine						0.15															0.000	0.015
Panicum repens	Torpedo grass		0.25	0.15	0.45		0.45		0.20	0.09	0.23		0.10		0.70		0.90	0.06	0.70	0.05	0.80	0.024	0.328
Paspalum distichum	Knot grass									0.10		0.10										0.020	0.000
Pluchea purpurascens	Marsh-fleabane																					0.000	0.000
Polygonium punctatum	Knot weed																					0.000	0.000
Pontederia cordata	Pickerel weed		0.10		0.40		0.05		0.25		0.18		0.10				0.01				0.05	0.000	0.109
Ptilimnium capillaceum	Bishop's weed		0.02																0.01			0.000	0.002
Rhynchospora corniculata	Horned-rush		0.02																			0.000	0.002
Sagittaria lancifolia	Arrowhead																					0.000	0.000
Sagittaria sp.													0.08									0.000	0.008
Salix caroliniana	Willow																					0.000	0.000
Sesbania Vesicaria	Bag-pod																					0.000	0.000
Spartina bakeri	Cord grass																					0.000	0.000
Typha sp.	Cat-tail						0.15		0.15													0.000	0.030
Ulmus americana var floridana	Elm seedling																					0.000	0.000
Floating filamentous algae					0.02						0.05		0.10		0.02				0.04		0.03	0.000	0.019
Unknown alternate leaf																						0.000	0.000
Unknown									0.02													0.000	0.002
Unknown red node																						0.000	0.000
Number of species		1	12	3	4	1	7	1	5	4	8	3	6	1	6	1	5	2	7	2	4	1.50	5.30
Minimum water depth (ft)		na	0.50	na	0.83	na	0.33	na	0.50	0.35	0.46	0.15	0.38	na	0.79	na	0.67	0.15	0.50	0.19	0.83	>0.21	0.45
Maximum water depth (ft)		na	1.42	na	2.50	na	1.33	na	1.71	2.40	2.50	2.55	2.58	na	1.63	na	1.58	1.35	1.25	1.15	1.75	>1.06	1.53

Table Q-5. Vegetation analysis of the littoral zone using percent cover conducted June 1994 (shaded columns) and 1996. Littoral shelf concentrated at outflow - See Figure 4 for locations.

		31		32		33		34		35		15a		15b		Avg94	Avg96
Open Water		0.10	0.25	0.20	0.08	0.45	0.33	0.00	0.05	0.10	0.00	0.15	0.13	0.55	0.18	0.221	0.146
SCIENTIFIC NAME	COMMON NAME																
Alternanthera phloxeroides	Alligator weed	0.10	0.08	0.05	0.03	0.20	0.01		0.05		0.04	0.15	0.15	0.08	0.15	0.083	0.073
Acer rubrum	Red maple seedling										0.01					0.000	0.001
Ampelopsis arborea	Pepper vine															0.000	0.000
Bacopa monnieri	Water-hyssops															0.000	0.000
Centella asiatica	Coinwort										0.01					0.000	0.001
Commelina sp.	Dayflower								0.02							0.000	0.003
Cyperus distinctus									0.03							0.000	0.004
Cyperus haspens						0.10										0.014	0.000
Cyperus oderatus			0.05						0.02							0.000	0.010
Cyperus polystachyos																0.000	0.000
Dichromena colorata	White top sedge													0.09		0.013	0.000
Echinochloa crusgalli	Barnyard grass	0.25		0.10	0.04	0.05		0.96							0.04	0.194	0.011
Eupatorium capillifolium	Dog fennel															0.000	0.000
Galium sp.	Bed straw															0.000	0.000
Glabrous Grass																0.000	0.000
Grass (red head)																0.000	0.000
Grass (St. Augustine)	St. Augustine															0.000	0.000
Hydrocotyle umbellata	Pennywort		0.20		0.30		0.01		0.15		0.03		0.30	0.05	0.31	0.007	0.186
Juncus effusus																0.000	0.000
Juncus megacephalus																0.000	0.000
Lippia nodiflora	Carpet weed		0.01								0.01				0.01	0.000	0.004
Lolium spp ?														0.15		0.021	0.000
Ludwigia leptocarpa													0.01			0.000	0.001
Ludwigia microcarpa																0.000	0.000
Ludwigia peruviana	Primrose Willow								0.01							0.000	0.001
Ludwigia repens														0.02	0.02	0.003	0.003
Lythrum alatum	Loosestrife										0.04			0.01		0.001	0.006
Mitreola petiolata																0.000	0.000
Mikania scandens	Hemp vine		0.04								0.02		0.15	0.05	0.11	0.007	0.046
Panicum repens	Torpedo grass	0.50	0.05	0.65	0.02	0.20	0.05		0.10			0.70	0.03		0.02	0.293	0.039
Paspalum distichum	Knot grass															0.000	0.000
Pluchea purpurascens	Marsh-fleabane															0.000	0.000
Polygonum punctatum	Knot weed															0.000	0.000
Pontederia cordata	Pickerel weed		0.12		0.50		0.45		0.23	0.05			0.07		0.10	0.007	0.210
Ptilimnium capillaceum	Bishop's weed		0.03		0.01				0.10				0.01		0.02	0.000	0.024
Rhynchospora corniculata	Horned-rush	0.05								0.80	0.80					0.121	0.114
Sagittaria lancifolia	Arrowhead									0.05	0.04					0.007	0.006
Sagittaria latifolia	Common arrowhead		0.17		0.02		0.15		0.20				0.15		0.04	0.000	0.104
Salix caroliniana	Willow															0.000	0.000
Sesbania Vesicaria	Bag-pod															0.000	0.000
Spartina bakeri	Cord grass															0.000	0.000
Typha sp.	Cat-tail							0.04	0.04							0.006	0.006
Ulmus americana var floridana	Elm seedling															0.000	0.000
Floating filamentous algae																0.000	0.000
Unknown alternate leaf																0.000	0.000
Unknown																0.000	0.000
Unknown red node																0.000	0.000
Number of species		6	10	5	8	6	6	3	12	4	10	4	9	8	11	5.143	9.429
Minimum water depth (ft)		0.62	0.63	0.62	0.88	0.75	1.08	0	0.71	na	0.54	0.1	0.5	0.25	0.42	0.390	0.680
Maximum water depth (ft)		0.55	0.83	0.73	0.92	0.9	1.17	0.15	0.71	na	0.67	0.36	0.5	1.95	0.71	0.660	0.787

APPENDIX R

Some Abbreviations Used in the Report

Appendix R. Abbreviation and detection limits. Most of the abbreviations are defined in the Tables and Figures.

ABBREVIATIONS	DEFINITION	UNITS	DETECTION LIMIT
NH3	AMMONIA-N	MG/L	0.01
NOX	NITRATE+NITRITE-N	MG/L	0.01
OPH or OP	ORTHO-PHOSPHORUS	MG/L	0.01
TPH or TP	TOTAL PHOSPHORUS	MG/L	0.01
TON	TOTAL ORGANIC NITROGEN	MG/L	0.10
TN	TOTAL NITROGEN (SUM OF NH3,NOX,TON)		
TSS	TOTAL SUSPENDED SOLIDS	MG/L	0.05
ZN	TOTAL ZINC	uG/L	30
FE	TOTAL IRON	uG/L	30
CD	TOTAL CADMIUM	uG/L	0.3
CU	TOTAL COPPER	uG/L	0.1
PB	TOTAL LEAD	uG/L	2
MN	TOTAL MANGANESE	uG/L	0.6
TOC	TOTAL ORGANIC CARBON	MG/L	0.5
HARD	HARDNESS	MG/L	0.02
TKN	TOTAL KJELDAHL NITROGEN (TON + NH3)		
BOD	BIOLOGICAL OXYGEN DEMAND		
RAIN	RAINFALL DIRECTLY ON POND		
INFLOW	DATA COLLECTED AT INFLOW STATION		
OUTFLOW	DATA COLLECTED AT OUTFLOW STATION		
ND, NA or "."	DATA NOT AVAILABLE		
D.L. or L.O.D.	LABORATORY DETECTION LIMIT		
COEFFICIENT	RUNOFF COEFFICIENT (EXCEPT FOR "r" VALUES)		
BE	BERYLLUIM		
NI	NICKEL		
CR	CHROMIUM		
BD	BELOW LABORATORY DETECTION LIMIT		
ngvd	National Geodetic Vertical Datum of 1929 and Approximates the Elevation above Mean Sea Level. In this Report it Is Measured in Feet.		