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Phosphorus Cycling in the Ellison Park Wetland at the Mouth of Irondequoit Creek, Rochester, NY: A Case Study Evaluating the Movement of Phosphorus as it Transits a Coastal Wetland of Lake Ontario

Elizabeth McGuire
The College at Brockport, bethamcguire@gmail.com

Phosphorus cycling in the Ellison Park Wetland at the mouth of Irondequoit Creek, Rochester, NY: A case study evaluating the movement of phosphorus as it transits a coastal wetland of Lake Ontario

By

Elizabeth Ann McGuire

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Department of Environmental Science and Biology
Thesis Defense by

Elizabeth A. McGuire

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Abstract

The Ellison Park wetland complex lies at the head of Irondequoit Bay, a large embayment on the south shore of Lake Ontario near Rochester, NY. It receives water from the Irondequoit Creek watershed, which drains an area of 391 km^2 of mixed land use. This is a mature, marsh wetland with some locations encompassing riparian wetland characteristics. This project was developed to answer three objectives: 1) what role hydrology plays in phosphorus (P) removal efficiency of the Ellison Park Wetland complex; 2) what role sediments play in the retention or release of P; and 3) the possibility of predicting P discharge from the Ellison Park Wetland into Irondequoit Bay.

The results for soluble reactive phosphorus (SRP) and total phosphorus (TP) show values in stream and wetland water samples during baseflow event periods ranging from 5.01 to 10.87 $\mu g\ L^{-1}$ for SRP and 22.73 to 88.67 $\mu g\ L^{-1}$ for TP. Stormflow event water samples are typically at higher concentrations ranging from 6.24 to 93.00 $\mu g\ L^{-1}$ for SRP and 46.65 to 428.33 $\mu g\ L^{-1}$ for TP. TP and SRP values give evidence that hydrologic event type plays a significant role in the quantity of P in Irondequoit Creek and its removal efficiency by Ellison Park. In addition, data suggests the direction of P flux in Ellison Park moves from the wetland sediments to the depleted water column; a result of historical nutrient loading. Modeling of TP data produced prediction errors of less than 5%, suggesting that Ellison Park tends to

react in a predictable manner when regarding TP data in relation to hydrologic event type.

Introduction

Phosphorus

Interest in phosphorus (P) stems from its high importance in biological metabolism but its disproportionate occurrence naturally in water; this often leads to P being the limiting nutrient in plant growth within an aquatic ecosystem (Wetzel 2001). Phosphorus, a naturally occurring element, can be found in fresh water in many organic and inorganic forms and fractions, such as orthophosphate and organically bound P. Organic forms, associated with plant or animal tissue, are the most abundant (APHA 1998, Wetzel 2001). Orthophosphate (PO_4^{-3}) is the most commonly found form of inorganic P; these are phosphates not associated with organic materials and are a useable form for plants (Bostrom et al. 1982, Wetzel 2001).

Sources of P from the environment include point sources such as wastewater discharges; and non-point sources including surface and subsurface runoff from urban, agricultural, and natural landscapes (House 2003). Surface and subsurface runoff acquires P from such things within its watershed as applications of inorganic and organic fertilizers, animal manure, and septic systems (Sparks 2003). The use of inorganic P fertilizers, for example, began in the early 1940s in the United States (Sparks 2003). By the early 1980s their use had spread to farmers and homeowners alike, causing a four-fold increase from 1940 levels, resulting in elevated water quality issues related to P (Sparks 2003). Sources of P can also come from within the aquatic system. In-system sources include the waste of animals, the decay of plant and organic matter, and desorption from sediments (Wetzel 2001).

Understanding P in aquatic ecosystems is complicated by the fact that its movements are influenced by both biotic and abiotic mechanisms (Lottig and Stanley 2007). Examples of biotic mechanisms that influence levels of P include uptake and use by primary producers and decomposers, and the mineralization of organic P (Lottig and Stanley 2007). Simultaneously, abiotic mechanisms influence the sorbtion and release of P from the surfaces of suspended sediments and benthic particles, directly changing P levels in aquatic environments through a collection of geochemical reactions (Lottig and Stanley 2007).

The importance of studying and monitoring phosphorus lies in its role as a major nutrient for plants and microorganisms, strongly influencing their growth (vanLoon and Duffy 2000). In high concentrations, phosphorus fuels the growth of microorganisms, such as algae, to nuisance levels (vanLoon and Duffy 2000). Initially, the increase of algae does also increase the dissolved oxygen concentration in the water column as a product of photosynthesis. But as the algae dies, the decomposition of the material consumes available oxygen, resulting in an anoxic environment (vanLoon and Duffy 2000).

Some forms of P found in the environment are more bioavailable and mobile than others. Analysis for P can separate forms for a more accurate assessment of what is present in the environment. Total P (TP) analysis, the analysis of an acid digested unfiltered sample, is analyzing for all forms of particulate and dissolved constituents (Wetzel 2001, House 2003). Total dissolved P (TDP) analysis, the analysis of an acid digested filtered sample, is reporting the combined presence of orthophosphates, polyphosphates, P colloids, and phosphate esters (Wetzel 2001). A subfraction of TDP that is often analyzed for is soluble reactive P (SRP). This fraction is the immediately biological available P, found as orthophosphate, in a filtered sample (Wetzel 2001, House 2003). The difference between TP and TDP of a sample will provide the amount of P associated with particulate matter. Particulate P (PP) includes P associated with plant and animal tissues, P absorbed to minerals, and any P absorbed to dead particulates or macroorganic aggregations (Wetzel 2001).

Phosphorus in Water

In water, under natural conditions, P is a trace element. In developed countries, the most harmful human impacts to freshwater lakes and rivers are being caused by high nutrient loadings of P and nitrogen (N) (Hilton *et al.* 2006). Increased P input can stimulate lake eutrophication, resulting in a decrease in a lake's overall value to society (Hilton *et al.* 2006). This makes P and N important and essential elements to regulate in regards to aquatic ecosystem health. The New York State Water Quality Standards for P provided by the NYSDEC state that none should be added in "amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (NYSDEC 2008). The U.S. EPA has established that a stream entering a lake or reservoir should not contain more than

0.05 mg L^{-1} of TP; and in streams where discharge is not directly into lakes or reservoirs TP should not exceed 0.1 mg L^{-1} (Sparks 2003).

Phosphorus in Sediment

Research has shown sediments to be an important and integral part of long-term phosphorus storage in aquatic systems (Bostrom *et al.* 1982, Dunne *et al.* 2007). This is especially true when phosphate is chemically adsorbed; which, is not as easily released back into the water column as physically held phosphate (Nichols 1983). Chemosorption, or the chemical fixation of compounds, is not altered due to changes in solute concentration when pH and redox-potentials are stable (Bostrom *et al.* 1982). On the other hand, the physical adsorption of compounds to substrate is a reversible process sensitive to fluctuations of solute concentration (Bostrom *et al.* 1982). Soil type is an important determining factor in this process; soils that tend to have a low adsorption rate for P tend to also release P quickly (Nichols 1983). For these reasons, specific knowledge of sediment type and the associated affinity for phosphorus sorption or release will aid in the prediction of P loading impacts to aquatic habitats (Bostrom *et al.* 1982).

Phosphorus interactions with mineral and organic materials are very different. Clay sediment, an example of mineral material, has an especially high attraction to P due to their high surface-to-mass ratio, which provides more binding opportunities on their surfaces. Their binding mechanisms include a chemical attraction to positively charged aluminum and the placement of phosphate, rather than silicate, in clay structures (Bostrom *et al.* 1982). This process is favored by low pH levels, but is associated with both inorganic and organic P fractions (Bostrom *et al.* 1982). In contrast, the P sorbed onto humic material is indirect and associated with humic-iron-phosphate complexes (Bostrom *et al.* 1982). The organic material itself has a very low ability to fix P, but relies on the direct relationship between the iron, aluminum, and calcium content and the levels of P sorbed (Bostrom *et al.* 1982, Nichols 1983). Under alkaline conditions, P likely reacts with calcium; while under acid or neutral conditions reactions occur mainly with aluminum and iron in sediments (Nichols 1983).

Interactions between Phosphorus contained in water and sediments

Surface sediments in an aquatic environment are not simply a passive component in a dynamic system. They collect settling material, but also are involved in active exchange reactions with the water column (Bostrom *et al.* 1982, Dunne *et al.* 2010). The type of sediment present can influence the nutrient content and productivity of the water column above the sediment layer (Bostrom *et al.* 1982). Higher levels of phosphorus-binding ions, such as iron, aluminum, and calcium, can increase P removal efficiency (Fisher *et al.* 2009). Movement of P between the sediment-water interfaces occurs in both directions at the same time (Bostrom *et al.* 1982). Phosphorus can be released from the sediment compartment and transported to the water column, and vice versa (Bostrom *et al.* 1982, Dunne *et al.* 2010). A contingency of parameters act together to influence P concentrations in bed sediments, the water column, and suspended sediments (Reddy *et al.* 1995, Evans 2004).

In many aquatic environments, the direction of the P flux from bottom sediments to the water interface can exceed the retention of P in sediments for weeks or months in a year, resulting in an internal loading of P (Bostrom *et al.* 1982). Internal loading results when a history of heavy loading exists from a source that has been reduced or eliminated (Bostrom *et al.* 1982). Over time the sediment becomes saturated with P; and with the contaminant source eliminated the flux of P moves in the direction of lower concentration, which is now in the direction of the water column. Internal loading can be the result of a P concentration gradient between surface sediments and a water column with a lower P concentration (Nichols 1983, Dunne *et al.* 2010). It can also occur from bioturbation, which is caused by the disturbance of sediments and soil pore water by invertebrate movements and feeding (Reddy *et al.* 1995, Dunne *et al.* 2010). Not only can internal loading increase primary productivity, but it can also hinder and retard the recovery of environments impacted by heavy P loading (Bostrom *et al.* 1982).

Sediments do tend to have a large storing capacity for phosphorus and are considered efficient P traps (Dunne *et al.* 2007). On the other hand, it can be viewed that the P stored by sediments has a potential of being released from the particulate fraction within the sediment layer and transferred to the overlying water column (Bostrom *et al.* 1982, Dunne *et al.* 2010). The phosphorus trapped and stored in the sediment encompasses an extensive potential nutrient source for the aquatic system.

This implicates the importance of knowing the tendencies sediments have for releasing P; such as, the configuration of the particulate P in the sediment, its extent of P saturation, and its sensitivity to environmental changes (Bostrom *et al.* 1982).

Phosphorus, Biology, and Vegetation

Living organisms and plants depend on P, in the form of phosphates, for healthy cellular function. Biological assimilation and the incorporation into cellular structure of living organisms bind and associate P to organic compounds (Bostrom *et al.* 1982). During its biological cycle, P is taken up by an organism or plant and used by its cells as phosphate. It is also released as phosphate by excretion or through the mineralization of dead organic matter (Bostrom *et al.* 1982). Bacteria can directly use organic phosphates and benefit from their release within the biological cycle (Bostrom *et al.* 1982).

Seasonal growth cycles and vegetation type shape nutrient availability in the water column of an aquatic ecosystem. For instance, the growth and accumulation of peat in a wetland system contributes to the long-term storage of P; while, the growth of emergent vegetation acts as a temporary P sink (Nichols 1983). Although, the growing season for emergent vegetation tends to be the period of greatest overall P retention for a wetland; their death and decay during the non-growing season can release 35 to 75% of the P associated with plant tissue (Nichols 1983, Fisher *et al.* 2009).

Vegetation can also influence the rate of sedimentation in a system through growth density, stem diameter, and species variety (Fisher *et al*. 2009). Decomposer microorganisms benefit from the surface plants provide, enabling them to contribute to the filtering and decomposing of nutrients (Nichols 1983). Greater plant diversity can increase nutrient removal efficiency from the combined collection of varying nutrient removal abilities by many species (Fisher *et al.* 2009).

Wetlands and Phosphorus

Wetlands are defined as having three main characteristics: hydric soils, hydrophytic vegetation, and the presence of water at the land surface or within the root zone (Mitsch and Gosselink 2000). The definition used by the U.S. Fish and Wildlife Service, developed in 1979, expands on these three components:

> "Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water...Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year" (Mitsch and Gosselink 2000).

Definitions vary depending on region and agency, but the basic elements of water, substrate, and vegetation are typically included.

The fraction of any watershed categorized as wetland space is generally small, but their placement within the watershed often requires a large portion of the area runoff, and subsequently its nutrient load, to pass through them (Devito *et al.* 1989). Nutrient transformation, removal, and storage that occur as waters pass through wetlands have biological impacts and repercussions on downstream ecosystems that warrant their protection (Devito *et al.* 1989, Morrice *et al.* 2004).

Wetlands are often intermediate ecosystems connecting uplands to aquatic systems, such as streams and lakes. They are regularly found to trap sediments and nutrients, making their protection and restoration an important water quality management tool (Zhou *et al.* 2010). The nutrient filtering efficiency of a wetland is dependent on multiple factors; such as, wetland type, hydraulic loading, soil type, vegetation, residency time, flow rate, and sedimentation (Fink and Mitsch 2004, Fisher *et al.* 2009). Specifically, the removal of P within a wetland is often done through its adsorption to iron, aluminum and calcium minerals, the development of peat, and consumption by plants (Adler *et al.* 1996, Fu *et al.* 2006).

Today, wetlands are often characterized as important ecosystems that act as filters and sinks for nutrients. Some research has found that this blanket characterization of wetlands may not be adequate for some nutrients, such as P (Devito *et al.* 1989, Reddy *et al.* 1995, Fisher and Acreman 2004). The ability of a wetland to sequester or release P has been linked to the physico-chemical properties of the water column and sediment (Reddy *et al.* 1995). A deeper understanding of how wetlands process P can ultimately aid in the protection of wetlands and downstream waters.

Phosphorus movement is controlled by its geochemical cycle; wetland characteristics, loading rate of P, and season impact a wetland's ability to act as a nutrient sink for P (Richardson and Craft 1993). The adsorption and retention of P in freshwater wetland soil is influenced by factors such as: redox potential, pH, iron, aluminum, and calcium minerals, and native soil P levels (Nichols 1983, Richardson and Craft 1993).

Hydrology also plays an important role in a wetland's ability to retain or release P through its delivery of energy, nutrients, and sediments (Trebitz *et al.* 2002). Hydrologic inputs interact directly with wetland morphology impacting water residence times, flow patterns, and nutrient retention (Nichols 1983, Trebitz *et al.* 2002). An increase in water depth does increase retention time, but decreases the chance of surface water nutrients interacting with bottom sediments (Nichols 1983). Flooding and drawdown cycles can impact the dynamic relationship between soil, water, and P; often reducing P loss (Dunne *et al.* 2010).

A wetland's ability to reduce nutrient loads from the water column may decline with the age of the wetland and with an increase of hydraulic loading (Fisher *et al.* 2009). Researchers have found mature wetlands to not be effective in retaining phosphorus below 1.0 mg L^{-1} (Alder *et al.* 1996). Previous research by Dunne *et al.* (2007) has also shown that areas permanently inundated have less storage capacity for phosphorus than areas that are seasonally or periodically flooded.

Understanding of the most effective route for P to move from the water column to a permanent sink has the potential to increase natural freshwater wetland capabilities (Richardson and Craft 1993). Previous research has found that permanently bound P levels in wetlands correlated with higher sediment and peat accumulation levels (Howard-Williams 1985, Richardson and Craft 1993, Kadlec

2009). Although peat soils have an affinity for P, their storage capacity can saturate with elevated loading (Kadlec 2009). Wetland soil properties and their biogeochemical processes are keys in understanding the P cycle in a wetland (Zhou *et al.* 2010).

Retention of Phosphorus in Wetlands

When P enters an aquatic system it is part of the short-term P storage compartment (Figure 1); which is defined as having a quick recycle time and limited storage capacity (Richardson and Craft 1993). It is either taken up by microbes, algae, and plants or is absorbed by sediments and removed from the water column (Richardson and Craft 1993). Desorption of reactive P from sediment back into the water column often occurs in top sediments and is termed internal P loading (Howard-Williams 1985, Richardson and Craft 1993, White *et al.* 2008). Until other sediment or peat material cover surface sediments they continue to be part of the wetland's short-term P storage compartment (Howard-Williams 1985, Richardson and Craft 1993). Most of the P in surface sediments can be found in accumulated organic matter (Dunne *et al.* 2007). Surface sediments have a limited capacity for P storage; and once capacity has been reached, the removal of P from the water column stops (Lai and Lam 2009). The long-term P storage compartment is considered a permanent removal of P from the aquatic environment. The input rate of P to the long-term P storage compartment is dependent on the accumulation of peat and the rate of sedimentation (Richardson and Craft 1993). One of the major mechanisms in the long-term storage is the adsorption of P to sediments (Lai and Lam 2009).

Management

The increase of urban areas and impervious surfaces places pressure on local watersheds to absorb and transport greater volumes of surface runoff. They also increase the levels of nutrients and pollutants entering the system. Management practices have been developed to mitigate and reduce harm to aquatic systems; one example being the use of wetlands as a means of filtering stormwater runoff and attenuating peak discharges (Coon 2004). Increases to hydraulic loading are often the result of anthropogenic activities occurring in the watershed, in particular, urbanization. Urbanization can impede on a wetland's ability to remove nutrients through increasing the volume, rate, and nutrient load of water entering the system (Ryan *et al.* 2007). In addition, the quantity of sediments, especially fine sediments, entering the system increases (Ryan *et al.* 2007). The increase of fine sediments can fill-in and diminish pore spaces in the sediment bed and reduce the size of the hyporheic zone (Ryan *et al.* 2007). Secondary changes to an aquatic system that can result from changes in hydrology and hydraulic loading include light infiltration, water temperature, and dissolved oxygen (Ryan *et al.* 2007).

Management strategies that are used to reduce the input of P and nutrients to aquatic systems include a combination of methods; including, reducing the use of fertilizers, reducing soil loss from erosion, reducing water runoff, and including buffer areas surrounding streams, lakes, and wetlands (Dunne *et al.* 2010). Even with management strategies in place to aid in the reduction of external loading, sites with a history of P loading and accumulation in sediments can impact downstream systems through internal loading (Dunne *et al.* 2010).

Site History

The Great Lakes contain the largest collection of freshwater in the world and have been described as inland seas (Grady 2007). The regulation and protection of this valuable freshwater resource, particularly as a source for drinking water, is unquestionable. Much of northwestern New York State borders Lake Ontario, creating over 225 km of coastline from the Niagara River to the St. Lawrence River (Makarewicz 2000). This long stretch of coastline is comprised of many embayments, wetlands, river mouths, and ponds (Makarewicz 2000). Embayments, even though connected to Lake Ontario, are unique in biological composition, ecology, and anthropogenic values (Makarewicz 2000). While, the open waters of Lake Ontario have shown great improvement in their water quality, coastal embayments have not shown a similar progression of progress (Makarewicz 2000). Cultural eutrophication in combination with a lack of funding for the restoration of Lake Ontario coastal embayments has caused the degradation of water quality in these unique transitional habitats (Makarewicz 2000).

Monroe County is one of seven New York State counties that border Lake Ontario (Figure 2). Within its boundaries it contains the state's third largest metropolitan area, Rochester, which has a population exceeding one million people (Makarewicz 2000). Monroe County also houses the fourth largest embayment on

Lake Ontario's coast, Irondequoit Bay encompassing 1,720 acres (NYSDEC 2011). Irondequoit Bay ecosystem functions are similar to a large lake system, being 6.7 km long and 1.0 km wide; it is separated from Lake Ontario by a narrow barrier beach (Makarewicz 2000).

Research of Irondequoit Bay sedimentary microfossil assemblages indicates a mesotrophic aquatic system in 1850, prior to heavy influences from human activity (Verna 1995). Microfossil species composition changes were found to be consistent with rapid population growth within the watershed and the eutrophication of Irondequoit Bay (Verna 1995). Degraded Bay water quality was first reported in the 1900s (White *et al.* 2008). Elevated P input to the watershed was believed to be the catalyst for the degradation of water quality and organism habitat (White *et al.* 2008). Irondequoit Creek has a history of discharging elevated levels of nutrients, dissolved chloride, and sediment into Irondequoit Bay that resulted in severe algal blooms, interference with the natural thermal and chemical stratification, and an increase of heavy metals and organic compound concentrations (Coon 2004).

Efforts to restore Irondequoit Bay have focused on reducing internal and external P loadings (White *et al.* 2008). The constituents that were discharged into Irondequoit Bay until 1978 were the result of 14 wastewater treatment facilities and the city of Rochester's combined sewer overflows (CSO) that were all directly discharging to the creek (Coon 2004). Since, wastewater treatment facilities and CSOs have diverted their discharge to a tertiary-treatment facility that directs its outflow directly to Lake Ontario (Coon 2004). In an effort to reduce the amount of internal P loading, an application of alum was placed over sediments located at depths greater than 6 m (Coon 2004, White *et al.* 2008). This management procedure succeeded in reducing levels of P in the water column by 60% to 75% (White *et al.* 2008). While conditions have improved, this embayment is still considered eutrophic (Makarewicz 2000). No effort was put into researching the effects elevated P loading had on the Ellison Park Wetland.

Previous Studies

An 11-year study (1990-2001) was conducted by USGS in partnership with the Monroe County Department of Health to determine if the addition of a control structure in a naturally narrow section of the Ellison Park Wetland could increase the wetland's ability to sequester nutrients being transported in by Irondequoit Creek, as a means of improving conditions in Irondequoit Bay (Coon *et al.* 2000, Coon 2004). The control structure was constructed to aid in the dispersal of water throughout the upper wetland area. Initial investigations by Coon found that Irondequoit Creek flows lower than bankfull height; retaining the flow of water in the main channel and not allowing for the wetland to filter nutrients (Coon 2004). Storm events producing enough precipitation to disperse water beyond Irondequoit Creek's main channel only occur on average twice a year (Coon 2004). High Lake Ontario levels could also cause dispersal of water beyond the creek's main channel (Coon 2004). The water residency time during low flow was found to be less than 3.5 hours, and water that was able to reach backwater areas of the wetland could reach a residency time of 15 hours or more (Coon 2004). Work by Coon (2004) also found the Ellison Park Wetland to have removal efficiency for TP and total suspended solids (TSS) of 28% and 47%, respectively, during preliminary work from 1990 to 1996 (Coon 2004). After the introduction of a control structure, the removal efficiency increased for TP to 45% and TSS to 52% (Coon 2004). During both periods the wetland continued to be a source of orthophosphate to Irondequoit Bay (Coon 2004).

Previous research has estimated sedimentation rates for the Ellison Park Wetland area. Pre-European-settlement (12,000 to 2,000 years before present) radiocarbon-dating done by Young found sedimentation rates at the mouth of Irondequoit Creek to be 3 mm $year^{-1}$ (Coon 2004). Sedimentation rates from the past 100 to 1,200 years were also determined. During this period, but prior to European settlement of the Irondequoit Creek basin, the sedimentation rates were found to be 3.7 mm $year^{-1}$ (Coon 2004). This rate closely agrees with historic rates determined. Samples processed for post-European-settlement sedimentation rates indicated rates nearly tripled to 11.0 mm $year^{-1}$ during the early 1800s to 1950s (Coon 2004). The increased rate of sedimentation is attributed both to isostatic rebound of Lake Ontario and a rise of deforestation and land-use changed in the Irondequoit Creek basin (Coon 2004). A more recent investigation of current sedimentation reveals rates of 2.8 to 3.7 mm $year^{-1}$ in Irondequoit Bay and 1.8 to 4.9 mm $year^{-1}$ within the Ellison Park Wetland (Coon 2004).

Objective

This project was developed to answer three objectives: 1) what role hydrology plays in P retention efficiency of the Ellison Park Wetland complex; 2) what role sediments play in the retention or release of P; and 3) the possibility of predicting P discharge from the Ellison Park Wetland into Irondequoit Bay. To evaluate the first objective, water samples were collected and analyzed during varying hydrologic conditions. The second objective was assessed using the analysis of sediment samples collected to represent varying hydrologic regimes throughout Ellison Park. The third and final objective was accomplished through the development of three mathematical models representing three predetermined hydrologic event types.

Methods

Study Area

The Ellison Park wetland complex lies at the head of Irondequoit Bay. Water levels in the lower wetland section are controlled by Lake Ontario, in addition to receiving water from Irondequoit Creek, which flows in a northern direction and drains an area of 391 km^2 of mixed land use from Monroe and Ontario Counties (Coon 2004). This is a mature marsh wetland with some locations encompassing riparian wetland characteristics and has been classified by the U.S. Fish and Wildlife Service as a "palustrine persistent emergent" wetland (Coon 2004). The Ellison Park wetland encompasses an area of 1.7 km^2. The wetland vegetation is dominated by dense cattail (*Typha glauca*) growth covering 63% of the area; large floating cattail mats persist in the lower wetland area (northern section) (Coon 2004). This is a very productive wetland, with an estimated total biomass reaching 5,230 g m^{-2} (Coon 2004).

Irondequoit Creek is the main tributary that flows into the Ellison Park Wetland complex (Figure 3), and ultimately into Irondequoit Bay (Bubeck 1972). Irondequoit Creek is 59.5 km long and receives discharge from approximately 40 tributaries (Bubeck 1972). Its headwaters begin at the northern tip of Ontario County where it flows in a northeastern direction towards the village of Fishers in Ontario County. At this point Irondequoit Creek is receiving discharge from tributaries flowing in both northern and southern directions. Once past the Fishers area, Irondequoit Creek travels a more northern route passing under the New York State Barge Canal through a pair of culverts. Near the village of East Rochester, Thomas Creek joins Irondequoit Creek. Thomas Creek is its main eastern tributary draining an area of about 69.9 km^2 (Bubeck 1972). Continuing north near the village of Penfield Irondequoit Creek meets with its main western tributary, Allen Creek (Bubeck 1972). Allen Creek, comparable in size to Thomas Creek, drains an area of about 64.8 km^2 (Bubeck 1972). Just north of this confluence Irondequoit Creek enters the Ellison Park area. There are two channels that enter the Ellison Park Wetland. The larger of the two is the main channel of Irondequoit Creek. The main branch meanders as steep slopes on its western side and the landscape allow until crossing under Browncroft Boulevard. The smaller branch, The Millrace, was created to power an old flourmill located on the south side of Blossom Road (Coon 1997).

Today, the man-made branch is connected to Irondequoit Creek by a culvert designed to direct excess flow from Irondequoit Creek to the eastern reaches of the upper wetlands of Ellison Park during periods of high flow (Coon 1997). The Millrace travels a more direct route to Browncroft Boulevard, is smaller and discharges less than the main branch (Coon 1997). During its journey, Irondequoit Creek drops in elevation from its headwater elevation of 234.8 m to 75.0 m in Irondequoit Bay (Bubeck 1972). Basin soils are a combination of glacial deposits, lacustrine sediments, and alluvium deposits; most commonly found are mixtures of sands, silts, and clays (Bubeck 1972).

Sampling

<u>*Study Site description*</u>

Water

Six locations were chosen for water sampling to determine changes in P concentration as water flows north through the Ellison Park Wetland ecosystem (Figure 4). The locations chosen are described hereafter in the order in which water moves through the system. The first, and most southern, site is located near Blossom Road at the USGS gauging station for Irondequoit Creek (Figure 5). This site was chosen not only for the convenience of USGS's gauging station, but also because it is located before Irondequoit Creek enters into the Ellison Park Wetland system. This location has many trees lining its banks and shading the creek. Water flows quickly at this site, with the average discharge being 2.4 cms, but reaching as high as 16.2 cms during a major storm event (USGS 2011).

Irondequoit Creek separates into two branches prior to entering the wetland complex, the main branch of Irondequoit Creek to the west and the Millrace to the east. At bankfull height, Irondequoit Creek is about 21 m wide and about 3.0 – 3.5 m deep (Coon 2004). Millrace, the second and smaller man-made branch empties into the southeastern portion of Ellison Park and is approximately 6.0 to 7.6 m wide and 1.5 to 1.8 m deep (Coon 2004). Water sample locations for both branches are located at bridges on Browncroft Boulevard (Figure 6 and Figure 7). Once passing under Browncroft Boulevard each enters into the upper wetland area of Ellison Park.

Site four was located approximately halfway through the wetland complex in a section of the wetland called the Narrows (Figure 8). The wetland area constricts at this location separating the wetland into two distinctive halves, the upper wetland (to the south) and the lower wetland (to the north). This is also where the Millrace merges once again with Irondequoit Creek to form a single channel. The banks of this section of wetland are dominated by *Typha glauca* and *Phragmites australis*. There is little shade relief for the stream in this section. A grab sample from the creek bank was collected at this site.

From the Narrows, Irondequoit Creek meanders northward mainly on the eastern edge of the lower wetland area (Coon 1997). There are a few small channels that branch off from Irondequoit Creek and weave through the lower wetland. Large floating mats of *Typha glauca* dominate the lower wetland area. This section is also, generally, deeper than the upper wetland area. Site five was located at the mouth of Irondequoit Creek; where it empties into Irondequoit Bay (Figure 9). This sample was collected from the center of a bridge located on Empire Boulevard.

Lastly, samples were collected from a site located on the western bank of Irondequoit Bay (Figure 10). This site was included for two reasons. First, lake levels of Lake Ontario can directly and indirectly impact conditions in Ellison Park (Coon 1997). Second, Irondequoit Bay has a long history of problems concerning high P loading. This extra location was added to compare Irondequoit Creek P concentration at its mouth to the Bay.

Sediment

Sediment samples were collected throughout the Ellison Park wetland complex to represent various hydraulic regimes. Riparian wetlands are not homogenous in their phosphorus sorption potential (Fu *et al.* 2006); to evaluate this complexity eleven locations were selected with varying hydrologic connections (Figure 11).

Three sites were chosen between Blossom Road and Browncroft Boulevard to represent the upland stream soils in the watershed. These three sites: A, B, and C were collected in the center of the stream. Site A was located south of Blossom Road near the USGS gauging station. The sediment from Site B was collected from the Millrace near Browncroft Boulevard. Site C was located in the main branch of Irondequoit Creek near Browncroft Boulevard.

Within Ellison Park, three sites were chosen within the upper wetland (Sites 1, 2, and 7) and five locations in the lower wetland area (Sites 3, 4, 5, 5, and 8). All sediment samples were collected in areas dominated by cattail growth, except Sites 7 and 8.

Sites 1 and 2 were collected off of a narrow, elevated section of land. To the west is the main branch of Irondequoit Creek and to the east is a shallow inlet flowing from a large open pool area of the wetland. During the time of our sample collection the inlet was being used as a nursery for turtles. Site 1 was located approximately one meter from the eastern edge of the land strip. Site 2 was located only a few meters from the first site, but was collected from an area slightly higher in elevation. This site was drier than the first and contained earthworms. The Site 7 sample was collected on the same strip of land, but on a northern facing edge that is adjacent to the open pool and just west of the turtle inhabited inlet. This site was an exposed mud flat, and did not contain evidence of previous year cattail growth.

Sites 3 and 4 were collected from a floating cattail mat located just past the bend in Irondequoit Creek north of the Narrows. Site 3 was located near the edge of the cattail mat and Site 4 was located several meters north of Site 3 towards the center of the mat.

Sites 5 and 6 were collected in a similar way as Sites 3 and 4. They were, again, collected on a large floating cattail mat. These sites were located on the west site of the wetland before Irondequoit Creek begins to travel in a northern direction towards Irondequoit Bay. Site 5 was located near the edge of the cattail mat and Site 6 was located several meters west of Site 5 towards the center of the mat.

The last site that was chosen, Site 8, was located at a sharp bend in Irondequoit Creek on an exposed mud flat. This site did not contain cattail growth, but some small ground cover vegetation.

Sample Collection Description

Water

Sampling occurred weekly beginning May 2010 and continuing to September 2010. In a previous study conducted by O'Brien and Gere, it was found that 50% to 75% of annual P loads entering Irondequoit Bay occurred during a three month period that included seasonal snowmelt and spring runoff (Coon 2004). The seasonal snowmelt for 2010 occurred in mid-April and was excluded from this study. Since the main focus of the water sample analysis is the comparison between storm events and non-storm events, the exclusion of this component was done purposefully to prevent bias in the samples that were collected.

Water sampling occurred during three stream stages: stormflow, other flow, and baseflow events (Table 1). Rainfall amounts were determined by using data collected from a Weatherbug weather station located at Our Lady of Mercy High School (43.1483, -77.5378). This weather station is located within the Irondequoit Creek watershed, approximately one mile from the location Blossom Road crosses Irondequoit Creek. Stormflow event sampling occurred during a rain event, with an attempt of gathering samples during peak stream flow. For stormflow events, at least 6.35 mm of rain fell during the rain event and the hydrograph for the sampling day was on an increasing trend. Other flow events occurred when less than 6.35 mm of rain fell on the sample date and/or rain fell 72 hours prior to a sampling event. In the case of the sample collected on 6/2/10 that was categorized as an other flow event, more than 6.35 mm of rain fell that day, but the hydrograph for the day shows a declining trend due to the high amount of rain that fell the previous day. No rain fell on the sample date and the prior 72 hours for all baseflow events.

Water samples collected from bridges were gathered using a bailer and bank samples were collected with the aid of a pole sampler. In either instance, collection equipment was given a thorough river rinse before a sample was collected. Samples were collected in 500 mL acid-washed plastic bottles and stored in a cooler with ice during transportation. Included in most sampling rounds was a single randomly selected field replicate sample. Replicate samples were collected in separate sample containers in identical fashion as their counterpart. Conductivity measurements were taken with each sample collected using a Quanta G Hydrolab, which was calibrated before use on each sampling date. Additional information on sample collection is outlined in Appendix 1.

The U.S. Geological Survey (USGS) maintains a gauging station (0423205010) of Irondequoit Creek at Blossom Road (43.1450, -77.5122); four miles upstream of the creek mouth (USGS 2011). Data collected at this site by USGS includes discharge, stream temperature, and gauge height (USGS 2011). Previous

USGS work created a discharge relationship between the gauging station at Blossom Road and a gauging station no longer in operation at Empire Boulevard (0423205025) using daily discharges from February 1997 through September 2001. Equation 1 shows that the insertion of the total instantaneous discharge value at Blossom Road (cfs) will provide the corresponding instantaneous discharge value (cfs) at the mouth of Irondequoit Creek at Empire Boulevard (personal communication, Brett A. Hayhurst and William F. Coon, USGS).

Equation 1: $\text{Empire Q} = e^{(0.0170+0.9902(\text{LN}(\text{Blossom Q}*1.06)))}$

Sediment

Samples were collected on 20 May 2010, prior to the new season growth of cattails. Samples were collected at each location by combining at least six scoops of soil within a 1 m radius of a central location. The sample was thoroughly mixed and transferred into a small plastic bag. Equipment was thoroughly cleaned between sites with a water rinse prior to sample collection. Samples were transported within a cooler to the laboratory for analysis (Appendix 1).

Laboratory Preparation

Water

Five hundred mL samples were transported from collection sites to the laboratory located on The College at Brockport, The State University of New York campus within a cooler packed with ice (Appendix 1). Once in the laboratory, 250 mL of each collected water sample was filtered with a Fisherbrand 0.45 μm pore size membrane nylon filter. Each filter was weighed before filtration with a Toledo A6104 balance to the ten thousandths decimal place. The filters were dried in a Cenco drying oven at 60° Celsius until a constant weight was measured. The recorded weight of the filter before filtration and after drying were applied to the volume filtered, and then doubled to determine the total suspended solids (TSS) content of the grab sample.

Measured from the filtered water used to determine TSS were two subsamples. The first was measured for immediate soluble reactive phosphorus (SRP) analysis using the Ascorbic Acid Method, Method 4500-P E, (APHA 1998). The second was analyzed for total dissolved phosphorus (TDP). TDP samples were digested prior to analysis using the persulfate digestion method, Method 4500-P B5, (APHA 1998). For this method, sulfuric acid and potassium persulfate were added to filtered sample and then digested for three hours using a digi-Prep Jr. by SCP Science, or until about half of sample volume remained. A drop of phenolphthalein indicator aqueous solution was added to each digested sample. The sample was then neutralized with a NaOH solution to a faint pink color. The volume was brought back up to the initial level with deionized water.

The remaining unfiltered portion of sample was used to create two additional sub-samples. The first sub-sample was measured for total phosphorus (TP) analysis. The TP samples were digested using the persulfate digestion method, Method 4500-P

B5, (APHA 1998) the same preservation method used for TDP samples. The second sub-sample was prepared for metal and ion analysis using an inductively coupled plasma atomic emission spectrophotometer (ICP). This sample was digested for two hours using 5 mL of nitric acid, Method SW846 3005A, (USEPA 1996).

Sediment

Sediment samples were brought in from the field inside plastic bags (Appendix 1). Prior to any analysis, the wet-weight equivalent of dry-weight was determined for each sample. This was done by weighing approximately 5 g of each sediment sample into a pre-weighted crucible and then placing crucibles into a 60° Celsius oven to dry to constant weight. The ratio between the initial weight and final sample weight were used to determine the amount of sample needed to represent a desired volume of dry sample.

Laboratory Experiments

Sediment

To determine the distribution between the various physico-chemical phases and potential mobility of P a fractionation scheme modified by Rydin (Figure 12) was used on surface sediments of Ellison Park among various soil physico-chemical phases (Psenner 1988, Rydin 2000). This method is comprised of a series of chemical extractions, with each step removing particular forms of P. The major forms of P identified were loosely adsorbed-P, Fe-P, Ca-P, Al-P, and Organic-P

(Rydin 2000). Any P that was not extracted during this process is considered to be tightly adsorbed and part of the long-term P storage compartment.

A few modifications to Rydin's fractionation scheme were made (Appendix 1). During the first fractionation, a 1-M sodium chloride solution was used instead of an ammonium chloride solution. This was done to prevent the salting out of ammonium salts during ICP analysis, which can clog the injection nozzle. Between extractions, a 0.1-M sodium chloride wash was used to remove any remaining entrained extraction fluids and any loosely re-sorbed phosphorus that could skew remaining extractions.

Once the fractionation scheme was complete, all of the extracts were analyzed for P using the ascorbic acid method, Method 4500-P E, (APHA 1998). The sodium hydroxide extract was first digested using the pursulfate digestion, Method 4500-P B5, (APHA 1998) prior to P analysis. Organic P associated with the sodium hydroxide extraction was calculated by subtracting the Al-sorbed P concentration from its NaOH-TP concentration.

Sample Preparation

Water

Laboratory analyses using the ascorbic acid method, Method 4500-PE, (APHA 1998) were used to determine SRP, TDP, and TP content with a Beckman DU 640 Spectrophotometer (Appendix 1). For this analysis, a combined reagent of sulfuric acid, potassium antimonyl tartrate, ammonium molybdate, and ascorbic acid were added to each sample. Samples were allowed to react for a minimum of 10 minutes before analysis. As previously mentioned, TP and TDP samples were first digested using the persulfate digestion method, Method 4500-P B5, (APHA 1998).

Water samples were digested and analyzed for aluminum, calcium, iron, magnesium, manganese, sodium, phosphorus, and potassium using a Thermo Elemental, IRIS 1000, inductively coupled plasma atomic emission spectrophotometer (ICP) using SW846 Method 3005A and 6010C, respectively (USEPA 1996). As previously mentioned, prior to ICP analysis samples were digested with nitric acid.

Analytical Methods

Sediment

Characteristics of the sediment samples collected were determined by visual inspection and by touch using a Munsell color chart and AGI Data Sheets 28.1 and 29.1 (Dutro *et al.* 1989). Kinds of organic soil materials are described based on the degree of decomposition using definitions from the U.S. Department of Agriculture in Appendix 2 (USDA 2010).

The moisture content of each sediment sample was determined by drying to a constant weight, approximately 5 g of sample at 60° Celsius in a pre-weighed crucible (Appendix 1). The difference in weight before and after drying represents the moisture content of the sample. The organic content of each sample was determined through loss-on-ignition (LOI) by using the dried samples that were created to measure moisture content, and igniting them in a muffle furnace at 350° Celsius for 16 hours (Sparks 1996). Samples were then weighed again and compared to their original weight in order to approximate organic material content. The moisture content and organic content are expressed as a percentage of the original sample.

Total metal analysis was performed on each sediment sample. Into digestion tubes, approximately 0.5 g dry weight of each sample was measured. Acid digestion, SW846 Method 3050B, (USEPA 1996) was used and modified to use only nitric acid. To each sample, 50 mL of concentrated nitric acid was added. Samples were digested using a digi-Prep Jr. (SCP Science) until about 15 mL of volume remained. Samples were filtered using a Fisherbrand 0.45 μm pore size membrane nylon filter, and then sample volume was brought back up to the initial volume with distilled water. Samples were analyzed using a Thermo Elemental, IRIS 1000, ICP atomic emission spectrophotometer, SW846 Method 6010C (USEPA 1996).

Model

A series of exponential correlation equations were created as a means to model and predict P discharge at Empire Boulevard. Three equations were developed with the aid of MATLAB software, one for each event type: Stormflow, other flow, and baseflow. All equations incorporate flow and TP values at each sample location in the following form:

Equation 2: $E = K \cdot A^p \cdot B^q \cdot C^r \cdot D^s$

Where, E = TP at Empire Boulevard ($\mu g\ L^{-1}$) multiplied by outflow (cms); K, p, q, r, and s are constants determined by MATLAB software; A = TP at Blossom Road ($\mu g\ L^{-1}$) multiplied by inflow (cms); B = TP at Millrace ($\mu g\ L^{-1}$) multiplied by inflow (cms) and %TP at Millrace (Equation 3); C = TP at Irondequoit Creek near Browncroft Boulevard ($\mu g\ L^{-1}$) multiplied by inflow (cms) and %TP at Irondequoit Creek near Browncroft Boulevard (Equation 3); D = TP at the Narrows ($\mu g\ L^{-1}$) multiplied by outflow (cms).

Inflow was measured by USGS at the Blossom Road sample location and this value was used to represent 'inflow' as described above. Equation 1 was used to determine outflow values and these calculated values were used to represent 'outflow' as described above. Percent flow was estimated for the sample sites located on the two branches of Irondequoit Creek by using Equation 3 and then multiplying the calculated %TP by inflow.

Equation 3: $\%TP_{MR} = TP_{MR} / T$

$$\%TP_{IC} = TP_{IC} / T$$

Where, TP_{MR} = TP at Millrace ($\mu g\ L^{-1}$); TP_{IC} = TP at Irondequoit Creek near Browncroft Boulevard ($\mu g\ L^{-1}$); and T = TP_{MR} plus TP_{IC} ($\mu g\ L^{-1}$).

The model for baseflow events is represented by Equation 4 (df = 3), other flow events by Equation 5 (df = 6), and stormflow events by Equation 6 (df = 5). The model for stormflow events does not include variable D, TP from the Narrows site, because of a lack of data for this site in the dataset. This does not seem to impact the predictability of the model.

Equation 4: $E = 0.0980 \cdot A^{8.7704} \cdot B^{-6.6483} \cdot C^{-2.2870} \cdot D^{0.0958}$

Equation 5: $E = 1.7616 \cdot A^{0.6524} \cdot B^{0.0356} \cdot C^{-0.1189} \cdot D^{0.3231}$

Equation 6: $E = 0.0127 \cdot A^{0.1675} \cdot B^{1.0705} \cdot C^{0.6823}$

Statistics

Water

Results were analyzed using the SPSS statistical program PASW Statistics 18. Two adjustments were made to raw water sample data, shown in Appendix 3, and ICP data, shown in Appendix 4, prior to statistical analysis. First, duplicate sample results were averaged with their corresponding samples to avoid repeating data. Second, phosphorus sample results that were found to be below their method detection limit of 2.5 μg L^{-1} were assigned a value of 2.0 μg L^{-1} for statistical analysis.

When assumptions were met, analysis of variance (ANOVA) and the Tukey *post hoc* test were used to compare means of SRP, TDP, PP, TP, TSS, conductivity, Al, Ca, Fe, K, Mg, Mn, and Na among locations for each event type and among event types for each location. Data that was not normally distributed was transformed using a log10 transformation. If data still failed to meet the requirements of ANOVA, the nonparametric alternative, Kruskal-Wallis, was used to compare means among sites along with the Tamhane *post hoc* test. An alpha value of 0.05 was used to determine significance for all tests.

Results

Water

<u>Precipitation and Discharge</u>

Monthly mean precipitation during the study period fluctuated from above the historic monthly mean for Rochester, NY during June and July, dipped below the historic mean during May and August, and was nearly average in September (Table 2). May was the driest month of the study period with a monthly total of 43.3 mm of rain, including the lowest daily precipitation maximum of 11.7 mm. Alternatively, the greatest amount of rain fell in June with a precipitation total of 130.1 mm, including the highest daily quantity of 41.2 mm of rain. The maximum daily rainfall that occurred in July was 22.9 mm and the monthly total was 85.6 mm. According to historic monthly mean trends, August is often the wettest month of the year in Rochester (World Climate 2008). This was not the case in 2010. The maximum daily rainfall that occurred in August was 17.0 mm, and the total precipitation for the month was 57.4 mm. Total monthly precipitation for September was 73.4 mm and the daily maximum was 27.4 mm, nearly a third of the total for the month.

Discharge data retrieved from the USGS gauging station 0423205010 of Irondequoit Creek at Blossom Road during the study period mirrors the monthly fluctuations to historic monthly means found with local precipitation data (Figure 13). In regards to discharge, months May, August, and September were below the historical monthly discharge mean, June was above, and July was slightly above average (Table 3). Discharge in May ranged from 1.27 - 6.93 cms with a mean of 2.81 cms. June, the wettest month of the study period also recorded the highest minimum, maximum, and mean discharge levels of 1.73 cms, 16.77 cms, and 3.66 cms respectively. The range for July was 1.22 - 7.87 cms with a monthly mean of 2.47 cms. Discharge for August contained the lowest maximum discharge for the study period with a range from 1.25 - 4.19 cms and a mean of 1.77 cms. September included the lowest minimum and mean discharge values for the study period. The discharge range that occurred in September was 1.19 - 6.26 cms and the mean 1.61 cms.

Discharge data for each sampling date, separated by event type, are shown in Table 4. Discharge range and mean decline as you move from stormflow, to other flow, and then to baseflow events. The discharge range at Blossom Road on the sample collection date for stormflow events was 2.27 - 16.77 cms with an average value of 6.65 cms. For other flow events the range was 1.64 - 8.95 cms and the average value equaling 3.23 cms. During baseflow events the range was 1.25 - 1.73 cms with an average value of 1.45 cms. Hydrographs displaying daily discharge values from USGS station 0423205010 highlighting sample collection dates and their event types are shown in Figures 14 - 17.

Phosphorus, TSS, and Conductivity

Event Type

ANOVA for baseflow events (Table 5) revealed that SRP, TDP, PP, TP, and conductivity were not significantly different among sampling sites. TSS was the only parameter that showed statistically significant differences (ANOVA, df = 5, F = 17.232, $p < 0.00$); the Irondequoit Bay site was significantly higher (Tukeys *post hoc*, $p < 0.05$) than the other sites.

No significant differences were detected during other flow (Table 6) and stormflow events (Table 7) among sample locations for all measured parameters.

Site

Blossom Road (Table 8) showed no significant differences among event types for TDP, PP, and TSS. During baseflow events, SRP was significantly lower (Kruskal-Wallis, df = 2, Chi-square = 7.784, $p = 0.020$) than other flow (Tamhane *post hoc*, $p = 0.017$) and stormflow events (Tamhane *post hoc*, $p = 0.009$). Total phosphorus was significantly higher during stormflow events (ANOVA, df = 2, F = 7.767, $p = 0.005$) than during other flow (Tukey *post hoc*, $p = 0.029$) and baseflow (Tukey *post hoc*, $p = 0.007$) events. Lastly, conductivity was statistically higher during baseflow events (Kruskal-Wallis, df = 2, Chi-square = 8.284, $p = 0.016$) when compared to stormflow events (Tamhane *post hoc*, $p = 0.031$).

The Millrace site showed no significant statistical differences among event types for TDP, PP, TP, TSS, and conductivity (Table 9). Soluble reactive phosphorus during baseflow conditions, however, was significantly lower (ANOVA, df = 2, F = 9.112, p = 0.003) when compared to other flow (Tukey *post hoc*, p = 0.023) and stormflow events (Tukey *post hoc*, p = 0.002).

The Irondequoit Creek near Browncroft Boulevard site had no significant differences among event types for TDP, PP, and conductivity (Table 10). Baseflow SRP was significantly lower (ANOVA, df = 2, F = 8.924, p = 0.003) than both other flow (Tamhane *post hoc*, p = 0.008) and stormflow event (Tamhane *post hoc*, p = 0.002) types. Total phosphorus (ANOVA, df = 2, F = 6.026, p = 0.012) and log10 transformed TSS (ANOVA, df = 2, F = 4.211, p = 0.044), showed significantly lower values during baseflow events (Tukey *post hoc*, p = 0.015) than stormflow events (Tukey *post hoc*, p = 0.037).

Baseflow SRP at the Narrows location was significantly lower (Kruskal-Wallis, df = 2, Chi-square = 6.302, p = 0.043) when compared to other flow (Tamhane *post hoc*, p = 0.00). Stormflow data for this site was not included in analysis from a lack of enough available data (Table 11). The remaining parameters were observed to be statistically similar.

Soluble reactive phosphorus and TDP showed statistical differences among event types at the Empire Boulevard site (Table 12). SRP in baseflow samples were significantly lower (ANOVA, df = 2, F = 7.926, p = 0.004) than those from other flow (Tamhane *post hoc*, p = 0.011) and stormflow events (Tamhane *post hoc*, p =

0.002). Total dissolved phosphorus during baseflow conditions was significantly lower (Kruskal-Wallis, df = 2, Chi-square = 6.359, p = 0.042) from stormflow samples (Mann-Whitney, p = 0.017). No statistical differences were observed for PP, TP, TSS, and conductivity.

Irondequoit Bay showed significant differences (ANOVA, df = 2, F = 6.868, p = 0.008) among event type for log10 transformed SRP (Table 13). Baseflow log10 transformed SRP was significantly lower when compared with stormflow SRP (Tukey *post hoc*, p = 0.006) but was similar to other flow SRP (Tukey *post hoc*, p = 0.067). The remaining parameters were determined to be statistically similar among event types for this site.

<u>*ICP Data*</u>

Event Type

During baseflow (Table 14), significant differences were found for Ca (ANOVA, df = 5, F = 5.752, p = 0.006), Mg (ANOVA, df = 5, F = 4.137, p = 0.020), and Mn (ANOVA, df = 5, F = 5.700, p = 0.006). For Ca, Blossom Road, Millrace, and Irondequoit Creek at Browncroft Boulevard were significantly higher than the Irondequoit Bay site (Tukey *post hoc*, $p < 0.05$). For Mg, only Blossom Road and Irondequoit Creek at Browncroft Boulevard were found to be significantly higher than the Irondequoit Bay site (Tukey *post hoc*, $p < 0.05$). The Narrows site showed significantly higher values than Blossom Road, Millrace, and Irondequoit Bay (Tukey *post hoc*, $p < 0.05$). Significant differences were not found for Al, Fe, K, and Na parameters.

There were no parameters that showed significant differences among site locations during other flow (Table 15) and storm flow (Table 16) event types.

Site

Blossom, Millrace, Narrows, Empire, and Irondequoit Bay sites did not display significant differences among varying event types (Tables 17-21).

Observations of a single parameter (log10 transformed Fe) at the Irondequoit Creek site near Browncroft Boulevard showed significant differences (Table 22). Iron was significantly higher during stormflow events (ANOVA, df = 2, F = 5.726, $p = 0.014$) than other flow (Tukey *post hoc*, $p = 0.034$) and baseflow (Tukey *post hoc*, $p = 0.030$) events.

Sediment

Composition

The color, texture, and composition of sediment were evaluated for each sample (Table 23). Three sediment samples were collected upstream of the Ellison Park Wetlands at Sites A, B, and C. The sediment sample retrieved from Site A had a wet color of 10YR 3/1. It was composed of medium sized sand with some gravel-sized particles and shell fragments. The sediment from Site B had a wet color of 10YR 2/1 and was a silty sediment with some clay, hemic material, and a trace of very fine sand. Site C sediment sample had a wet color of 10YR 3/1 and it was composed of fine sand with some gravel-sized particles and shell fragments.

All other samples collected were located within the Ellison Park Wetland, and are described as they appear when traveling in a northern direction. The sediment from Site 1 had a wet color of 10YR 2/1; it was a silty sediment with an abundance of fibrous material, mostly hemic. The wet color of sediment collected at Site 2 was 10YR 3/2; it was mostly a silty sediment with some clay and hemic fibric material. The collected sample from Site 7 was characterized as having a wet color of 10YR 3/1. It was sediment dominated by silt with some hemic fibers and traces of very fine sand and clay.

Site 3 had a wet color of 10YR 2/2 and Site 4 a wet color of 10YR 2/1. Both samples were characterized as being silty sediments with high amounts of fibric material, dominantly sapric, with a trace of very fine sand and clay.

Both Sites 5 and 6 were determined to have a wet color of 10YR 2/1. The Site 5 sample was composed of silt with a trace amount of very fine sand, there was an abundance of fibers, dominantly hemic and sapric. Site 6 was dominated by organic fibers, both fibric and hemic, with some silt material.

Lastly, Site 8, had a wet color of 10YR 2/1 and was composed of very fine silt and some clay.

Sequential Extraction

Sequential extraction analysis on sediment collected throughout the Ellison Park Wetland complex provides detailed information on the association of P within each sample. Loosely sorbed-P, Fe-P, Al-P, organic-P, and Ca-P were extracted from each sample and are examined as a percentage of TP extracted (Table 24).

Highest levels of extracted loosely sorbed-P were associated with samples highest in organic matter content, such as the highly organic Site 6 with 51.4% of loosely sorbed-P. For many sites, this P association is the second highest fraction and content ranged from 8.1 - 51.4%. Most notable is that the lowest value is found prior to Irondequoit Creek entering Ellison Park Wetland, and the two highest values are from the two most northern wetland sample sites.

Fe-P, measuring P association with oxyhydroxide phases of Fe, ranged from 8.6 - 60.1% in samples. For two sites, 1 and 2 containing 60.1% and 42.5% respectively, this fraction was their highest component of the whole. For others, such as Sites 6 and 8 containing 10.4% and 12.6% respectively, Fe-P was the smallest component of extracted P.

For Sites A, B, C, 3, and 7, Al-P was the smallest P contributing fraction. The range for this fraction, associated with aluminous silicate clays, varied from 2.2% to 23.7% among samples.

Extracted organic P ranged from 1.5%, found at Site 5, to 24.5%, found at site B. This fraction identifies P exhumed directly from organic matter.

Generally, the results show that most P in Ellison Park Wetland sediments is associated with calcite. Ca-P is the highest percent of extracted P in seven of the eleven samples analyzed, sites that did not follow this trend contained only trace amounts or less of sand and gravel. The percent of Ca-P ranged from 7.1 - 78.1% among samples.

Moisture Content and Organic Content

The moisture content and organic content are expressed as a percentage of the original sample in Table 25. Moisture content ranged from 19.59% to 90.69%. Organic content ranged from 0.51% to 64.15%. A positive relationship was found between moisture content and the organic content among samples; as shown in Figure 18 an R^2 value of 0.7823 was determined.

ICP

Total metal and element analysis using ICP was performed on sediment samples to evaluate the content of Al, Ca, Fe, and P. For all samples, levels of Ca were found to be the greatest, followed by Fe, Al and then by P (Table 26). Scatter plots were created to determine any correlations among Al, Ca, Fe, and P (Figures 19-24). The most highly correlated pair of components found was Al and Fe (R^2 = 0.9565). Al and P (R^2 = 0.6676) and Fe and P (R^2 = 0.5839) contained slight positive correlation trends. Ca showed very little association with any other parameter.

Model

Baseflow

The equation developed to model baseflow events (Equation 4) predicted TP concentration at Empire Boulevard with little error. Results produced percent errors less than 0.25% for all baseflow sample events (Table 27).

Other flow

The other flow model (Equation 5), created to predict TP concentrations, produced errors in the range of 0.12% - 3.87%, with two outliers on 6/2/10 and 8/2/10 producing errors of 67.17% and 55.53%, respectively (Table 28). Errors were calculated by subtracting the calculated TP from the model by the measured TP, then dividing by the measured TP and multiplying by 100. These two events have the lowest flow values in this dataset, 1.95 cms on 6/2/10 and 1.64 cms on 8/2/10, which may play a role in the error of the model calculation. The event on 6/2/10 was also the only other flow event that did not include a sample from the Narrows site.

Stormflow

The stormflow event model (Equation 6) was able to predict TP concentrations at Empire Boulevard with errors ranging from 0.06% - 2.96% (Table 29). Again, errors were calculated by subtracting the calculated TP from the model by the measured TP, then dividing by the measured TP and multiplying by 100. As with the other flow model, TP for two events could not be predicted with as much accuracy. Percent error for the second round on 6/6/10 was 42.84% and percent error for sample event 7/9/10 was 86.10%.

There is some discord in the two sample rounds collected on 6/6/10. The stormflow model did a reasonable job of predicting the first sample round with a percent error of 1.07%, but the model was not as good of a fit for the second round. The biggest difference between the two sites was the TP values measured at Blossom Road. The second round had a smaller change in TP concentration from Blossom Road to the two sites near Browncroft Boulevard. This, and the other flow measurement for the event, may impact the model's prediction of TP at Empire Boulevard.

The most noticeable difference in the sample event on 7/9/10 to all the other stormflow events was that TP at the Irondequoit Creek near Browncroft Boulevard sample site was similar to the Empire Boulevard site. Total P at the Irondequoit Creek site near Browncroft Boulevard measured 155.07 $\mu g\ L^{-1}$, while the Empire Boulevard site TP value measured a very similar value of 154.63 $\mu g\ L^{-1}$. The lack of variation between the two sites could influence the ability of the model to predict TP concentration.

Discussion

Hydrology and Phosphorus

Precipitation and Discharge

The Irondequoit Creek basin is large, encompassing 391 km^2 of mixed land use. Variability throughout the watershed, including, rainfall, land use, runoff rates, and nutrient loading amounts are inevitable when researching a large watershed. In addition, the inconsistent intensity and spread of storm events during summer months in Rochester, NY can cause variability in water quality data. To reduce the amount of impact precipitation has on data analysis for this study, samples were categorized and analyzed by event type (Table 1).

Sample collection and mean data analysis show a positive correlation between precipitation and discharge levels in Ellison Park and P concentrations. Mean levels of P input into Ellison Park, and subsequently into Irondequoit Bay, were greatest during stormflow events and lowest during baseflow events; these results are similar to those found in a simulation study by Shigaki *et al*. (2007). Heightened P transport during stormflow events is ascribed to the influence of surface runoff, storm intensity, and precipitation volume; which are not contributing factors during periods of baseflow (Shigaki *et al*. 2007).

Phosphorus

Statistical analysis of water chemistry data from this study found no significant differences in TP and SRP inflow and outflow data (Tables 5, 6, and 7). Keeping this in mind, TP data suggests that Ellison Park does not act as a sink for TP, regardless of hydrologic event type (Tables 31 and 32). The Ellison Park Wetland complex is not unusual in this aspect; similar reports in wetland systems have been found by others, such as Devito *et al.* (1989), Reddy *et al.* (1995), and Fisher and Acreman (2004).

The general trend found amongst baseflow and other flow events, is that Ellison Park does retain SRP, approximately 45% and 12%, respectively (Table 32). During baseflow and other flow events there is a greater mix of low SRP concentrated groundwater causing dilution of SRP at the output. SRP is also the most readily usable form for plants. Uptake of SRP by plants increases during slower water velocities when there is more time for plants to remove nutrients from the water column. During stormflow event periods Ellison Park discharges SRP into Irondequoit Bay with a removal efficiency of -20% (Table 32). The negative retention efficiency during stormflow events is likely related to the increase of water discharge velocity of Irondequoit Creek.

USGS Data Comparison

The United States Geological Survey conducted an 11-year study at Ellison Park to evaluate the effectiveness a control structure at The Narrows may have in reducing P discharge into Irondequoit Bay (Coon *et al.* 2000, Coon 2004). Analysis of water inflow (at Blossom Road) and outflow (at Empire Boulevard) TP and SRP data collected from 1991 through 2001 determined that the removal efficiency of Ellison Park is variable. The range of average monthly total TP and SRP during the months of May through September were -50.90 to 71.00 and -75.00 to -3.23, respectively (Table 30). Despite the large TP removal efficiency range, they did find that Ellison Park tended to sequester a small mean percentage of TP (5%) from May through September. In contrast, Coon *et al.* (2000, Coon 2004) found Ellison Park to discharge SRP into Irondequoit Bay with a mean removal efficiency of -41% found (Table 31). Weighted monthly totals of TP and SRP were developed from 2010 data; making comparisons possible to these historical datasets. Comparisons are made between USGS's past study and this study, but there are differences in the two studies. The first being their quantity of data spans ten years, while this is a study of five months. This study also collected data during wet summer which may cause variability in results. Lastly, a portion of Coon *et al.*'s (2000, Coon 2004) results were collected during the period of time a control structure was in place at The Narrows.

The first step in estimating TP and SRP monthly totals was calculating mean values at Blossom Road (inflow) and Empire Boulevard (outflow) based on event type. Then, using event type criteria outlined in the Methods section, an event type of baseflow, other flow, or stormflow was assigned for each day from May through September 2010. Based on the assigned event type for each day, the corresponding mean TP and SRP values (Table 32) were used to estimate a weighted total for each sample month (Tables 33 and 34, respectively). Monthly totals from USGS's 11-year study period were averaged for data comparison (Tables 30 and 31). Weighted monthly totals, created from current study data, fall within range of data collected by USGS; corroborating the results of this study.

Total P data from this study has lower input loads, but similar output loads compared to USGS data (Tables 30 and 33). Lower TP loads at Blossom Road could indicate that local environmental efforts, such as, stormwater management of erosion and impervious surfaces to reduce TP input to Irondequoit Creek, have been successful. Another explanation for the variation in results may be that the removal of the control structure at the Narrows has reduced the removal efficiency of Ellison Park. Data from this study does indicate that Ellison Park is discharging similar TP loads as USGS found nearly 10-years prior, even with less TP load input. Reddy *et al.* (1995) found similar results with work conducted in South Florida and attributed these findings to diluted P concentrations in the water column causing the direction of P flux to move from P concentrated surface sediments into the overlying water column. In a controlled environment, a P flux has been found from concentrated sediment to a depleted water column following the removal of a P source (Corstanje *et al.* 2007).

Research by USGS found Ellison Park to be a consistent source of SRP, their monthly total average retention efficiency for May through September being -41% (Table 31). Soluble reactive phosphorus monthly totals found by USGS are also lower than SRP monthly totals from this project's data. Exact reasons for this are unknown, but could be related to population and urbanization increases within the watershed as seen in other studies (Pagliosa *et al.* 2005); which, increase SRP through the production of more waste within the watershed.

Sediment and Phosphorus

Sediments were analyzed in addition to water samples to evaluate the direction of the P flux in the Ellison Park Wetland system. Sedimentation is an important long-term storage compartment for P, but historical loading can impede a wetland's ability to absorb and store P by depleting available P sorption space (Dunne *et al.* 2007). The two most northern sediment sample sites closest to the wetland outlet (Sites 5 and 6) contained the greatest amount of P out of all samples, in addition to also containing the greatest percentage of loosely-sorbed P. Loosely-sorbed P is the most readily desorbed form of P in sediments, followed by Fe-P and organic-P (Rydin 2000). Data from this study suggests that the most easily desorbed form of P from sediments is located near the wetland outlet; it is unknown, however, how often these locations are flooded with water from the main channel.

Phosphorus, Biology, and Vegetation

While this study did not focus on the impact flora and fauna have on P concentrations, their influence should not be ignored; P uptake and release by plants, algae, bacteria, and animals do occur. A past USGS study (Coon *et al.* 2000) did examine biomass and its impact on nutrient loads within Ellison Park. Cattails (*Typha glauca*) dominate the biomass in Ellison Park, with biomass totaling 5,230 g m^{-2} (Coon 2004). Even with high quantities of biomass produced during the growing season, data did not suggest their growth influenced the seasonal nutrient removal efficiency (Coon *et al.* 2000). Influencing this conclusion are several factors; including, the internal loading of nutrients, the increase of microbial activity during the growing season, and the confinement of Irondequoit Creek flows within its banks (Coon *et al.* 2000).

Model

Watershed modeling has become a popular and cost effective tool for environmentalists to assess long-term nutrient loading. The three exponential correlation models were developed to see if P loading into Irondequoit Bay could be predicted. The prediction capabilities of these equations were determined to be strong, generally within five percent, although a few outliers did exist. While these equations are specific to the Ellison Park Wetland complex and cannot be used in other wetland systems, the exponential correlation modeling method may be a simple and predictive model of P loading.

Supplementary data is needed to test these equations and to lessen their sensitivities. The inclusion of additional data could lead to the development of a smaller exponential correlation equation that would require less sample collection to predict P output. The inclusion of additional data could lead to the ultimate goal of collecting and analyzing a single sample at Blossom Road and being able to insert this value into an equation to predict P discharge into Irondequoit Bay.

Conclusion

Results from this study suggest that hydrologic event type plays a significant role in the quantity of P in Irondequoit Creek and the retention efficiency of P by Ellison Park. In addition to suggesting that the direction of P flux in Ellison Park is from the sediment to the depleted water column. The results of modeling data do suggest that Ellison Park does react in a relatively predictable manner during baseflow, other flow, and stormflow events.

Ellison Park has a history of high P loading. While, it is not clear to scientists how the natural restoration process for P works (Corstanje *et al.* 2007), some conclusions can be drawn from this case study. Legacy P in Ellison Park will continue to impact Irondequoit Creek water quality until a new P equilibrium is reached between the water column and sediments. Time needed for a new equilibrium to be reached in a natural environment is not completely understood (Corstanje *et al.* 2007). It is not known if simply removing the source of elevated nutrient loading will be enough to enable a wetland to restore itself to its original condition (Corstanje *et al.* 2007). Time, continued monitoring, modeling, and watershed management are going to be key components in the continued effort to understand and restore the Ellison Park Wetland.

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Tables

Event Type	Date	Rainfall total on sample date (mm)	Rainfall total for previous 24 hours (mm)	Rainfall total for previous 48 hours (mm)	Rainfall total for previous 72 hours (mm)
Stormflow	6/5/2010	9.91	0.25	0.76	8.89
	6/6/2010	41.15	9.91	10.16	10.67
	7/9/2010	11.68	0.00	0.00	0.00
	7/13/2010	22.86	0.00	0.00	0.00
	7/21/2010	12.19	0.00	0.00	0.00
	7/23/2010	17.78	0.00	12.19	12.19
Other Flow	5/10/2010	0.00	1.02	7.62	9.14
	5/19/2010	0.00	0.33	0.33	0.33
	6/2/2010	8.13	17.78	17.78	17.78
	6/3/2010	0.51	8.13	25.91	25.91
	6/7/2010	0.00	41.15	51.05	51.31
	6/30/2010	0.00	0.00	9.14	14.48
	8/2/2010	1.02	0.25	0.25	0.25
	8/16/2010	2.79	2.54	2.54	2.54
Baseflow	5/25/2010	0.00	0.00	0.00	0.00
	7/6/2010	0.00	0.00	0.00	0.00
	9/1/2010	0.00	0.00	0.00	0.00

Table 1. Event type categorization.

Event types were determined based on rainfall amounts on the sample date and previous 72 hours. This table shows the rainfall on the sample date, and then subsequent columns are displayed as an accumulated amount for 72 hours prior to the sample date. For example, on 6/5/10 9.91 mm of rain fell. The previous day, 6/4/10, 0.25 mm of rain fell. On 6/3/10, 0.51 mm (0.76 – 0.25) fell; and on 6/2/10, 8.13 mm (8.89 – 0.76).

Rochester, NY	May	June	July	August	September
Mean of Historic Monthly Precipitation (mm)	67.2	70.1	71.7	74.3	69.8
Total Monthly Precipitation 2010 (mm)	43.3	130.1	85.6	57.4	73.4

Table 2. Historic monthly mean precipitation (mm) compared to total monthly precipitation (mm) in 2010. The historic dataset represents 74 years of data collected between 1920 and 1995 at the Rochester International Airport (World Climate 2008). Current 2010 data was retrieved from the Weatherbug station located at Our Lady of Mercy High School (43.1483, -77.5378).

USGS 0423205010	May	June	July	August	September
Mean of Historic Monthly Discharge (cms)	4.13	2.75	2.27	2.21	2.29
Mean of 2010 Monthly Discharge (cms)	2.81	3.66	2.47	1.77	1.61

Table 3. Means of historic monthly discharges (cms) compared to means of 2010 monthly discharges (cms) (USGS 2011).

Event Type	Date	Discharge on sample date (cms)	Discharge for previous day (cms)	Discharge for 2 days prior (cms)	Discharge for 3 days prior (cms)
Stormflow	6/5/2010	5.78	1.84	2.63	1.95
	6/6/2010	16.77	5.78	1.84	2.63
	7/9/2010	2.58	1.30	1.36	1.39
	7/13/2010	2.27	1.47	1.64	2.69
	7/21/2010	4.70	1.22	1.27	1.27
	7/23/2010	7.79	3.31	4.70	1.22
Other Flow	5/10/2010	3.20	3.99	5.81	3.71
	5/19/2010	2.97	2.55	2.55	3.03
	6/2/2010	1.95	3.06	1.36	1.27
	6/3/2010	2.63	1.95	3.06	1.36
	6/7/2010	8.95	16.77	5.78	1.84
	6/30/2010	2.18	3.06	4.76	2.15
	8/2/2010	1.64	1.47	1.47	1.56
	8/16/2010	2.29	1.39	1.33	1.39
Baseflow	5/25/2010	1.73	1.87	1.95	2.15
	7/6/2010	1.39	1.39	1.44	1.53
	9/1/2010	1.25	1.25	1.25	1.27

Table 4. Highest daily discharge recorded for each sample date, separated by event type. Discharge data retrieved from USGS gauging station 0423205010 (USGS 2011).

Baseflow water sample P, TSS, and conductivity data							
Site		SRP	TDP	PP	TP	TSS	Conductivity
		μg/L	μg/L	μg/L	μg/L	mg/L	μS/cm
Blossom Rd	Mean ± Std. Deviation	5.77 ± 3.94	25.88 ± 14.87	25.70 ± 13.88	51.57 ± 12.14	1.47 ± 1.07[b]	1244.33 ± 106.24
	Minimum	2.00	9.29	9.73	41.81	0.30	1182
	Maximum	9.87	38.01	34.84	65.17	2.40	1367
Millrace	Mean ± Std. Deviation	7.50 ± 4.80	25.04 ± 11.95	21.32 ± 8.27	46.36 ± 7.80	1.23 ± 0.50[b]	1240.33 ± 117.93
	Minimum	2.00	11.28	12.59	40.32	0.70	1151
	Maximum	10.87	32.83	29.04	55.17	1.70	1374
IC at Browncroft	Mean ± Std. Deviation	6.76 ± 4.21	26.90 ± 8.51	13.09 ± 6.59	39.99 ± 14.97	1.33 ± 0.50[b]	1234.00 ± 118.53
	Minimum	2.00	17.09	5.64	22.73	0.80	1147
	Maximum	10.01	32.29	18.17	49.50	1.80	1369
Narrows	Mean ± Std. Deviation	4.05 ± 3.55	22.85 ± 5.85	42.93 ± 15.35	65.78 ± 20.70	3.03 ± 1.03[b]	1245.67 ± 117.12
	Minimum	2.00	16.09	27.38	43.47	1.90	1165
	Maximum	8.15	26.28	58.08	84.36	3.90	1380
Empire Blvd	Mean ± Std. Deviation	6.30 ± 5.07	18.70 ± 16.05	50.62 ± 32.01	69.31 ± 16.76	2.43 ± 0.75[b]	1217.67 ± 73.90
	Minimum	2.00	2.00	25.53	59.54	2.00	1175
	Maximum	11.89	34.01	86.67	88.67	3.30	1303
Bay	Mean ± Std. Deviation	2.00 ± 0.00	15.62 ± 6.08	104.07 ± 118.73	119.69 ± 123.01	8.20 ± 2.04[a]	1047.33 ± 106.00
	Minimum	2.00	8.63	18.75	27.38	5.90	926
	Maximum	2.00	19.67	239.66	259.33	9.80	1122

Table 5. Baseflow sample mean and standard deviation, minimum, and maximum values for each parameter separated by sample site location. Lowercase superscript letters identify significant differences ($p < 0.05$) between sites.

Other flow water sample P, TSS, and conductivity data							
Site		SRP	TDP	PP	TP	TSS	Conductivity
		μg/L	μg/L	μg/L	μg/L	mg/L	μS/cm
Blossom Rd	Mean ± Std. Deviation	28.24 ± 16.24	49.02 ± 32.04	32.51 ± 16.03	81.53 ± 33.55	7.38 ± 8.33	1050.38 ± 194.76
	Minimum	2.00	23.00	15.76	39.67	0.90	621
	Maximum	57.82	104.37	59.94	141.04	25.00	1250
Millrace	Mean ± Std. Deviation	26.73 ± 11.99	45.07 ± 28.31	36.95 ± 15.70	82.02 ± 37.68	4.94 ± 4.80	1058.75 ± 173.45
	Minimum	5.17	22.17	17.00	43.83	0.80	683
	Maximum	43.32	101.55	58.08	159.63	12.60	1235
IC at Browncroft	Mean ± Std. Deviation	26.30 ± 11.57	42.03 ± 22.30	45.69 ± 24.37	87.72 ± 34.90	7.67 ± 10.94	1064.63 ± 175.78
	Minimum	5.83	20.83	23.23	48.33	0.85	676
	Maximum	41.11	90.68	94.70	146.70	31.40	1242
Narrows	Mean ± Std. Deviation	30.85 ± 7.02	40.24 ± 12.20	59.07 ± 44.17	99.32 ± 54.63	6.49 ± 9.39	1061.00 ± 188.75
	Minimum	21.17	25.42	15.91	41.33	0.75	678
	Maximum	40.33	61.83	151.99	213.82	27.40	1253
Empire Blvd	Mean ± Std. Deviation	25.55 ± 10.54	47.60 ± 32.86	50.76 ± 18.70	98.36 ± 40.54	6.71 ± 7.74	1057.13 ± 181.20
	Minimum	15.17	22.50	14.00	41.67	0.60	645
	Maximum	46.47	122.79	77.98	173.56	23.40	1203
Bay	Mean ± Std. Deviation	13.88 ± 13.18	37.41 ± 21.74	76.36 ± 28.93	113.77 ± 35.93	5.27 ± 1.82	1010.57 ± 209.90
	Minimum	2.00	12.40	34.91	47.31	3.50	604
	Maximum	40.64	76.83	120.80	149.01	7.60	1253

Table 6. Other flow sample mean and standard deviation, minimum, and maximum values for each parameter separated by sample site location. Lowercase superscript letters identify significant differences ($p < 0.05$) between sites.

Stormflow water sample P, TSS, and conductivity data							
Site		SRP µg/L	TDP µg/L	PP µg/L	TP µg/L	TSS mg/L	Conductivity µS/cm
Blossom Rd	Mean ± Std. Deviation	44.22 ± 21.96	60.51 ± 29.40	87.21 ± 66.63	147.73 ± 58.30	10.13 ± 10.29	842.86 ± 275.02
	Minimum	30.71	40.01	14.06	73.67	1.30	378
	Maximum	93.00	124.23	189.83	234.00	24.70	1155
Millrace	Mean ± Std. Deviation	35.47 ± 7.08	50.42 ± 19.46	36.88 ± 30.15	87.30 ± 44.74	3.41 ± 1.34	927.71 ± 205.55
	Minimum	26.78	31.72	3.24	46.65	1.70	599
	Maximum	46.63	85.94	77.19	163.13	4.50	1150
IC at Browncroft	Mean ± Std. Deviation	45.34 ± 17.62	65.83 ± 42.67	86.96 ± 68.12	152.79 ± 70.33	14.24 ± 10.12	893.29 ± 175.09
	Minimum	24.53	17.27	.48	55.00	6.00	633
	Maximum	75.16	144.03	192.33	239.33	29.00	1163
Narrows	Mean ± Std. Deviation	33.77 ± 2.65	56.15 ± 20.19	85.65 ± 6.51	141.80 ± 26.70	4.68 ± 1.87	1021.50 ± 163.34
	Minimum	31.89	41.87	81.05	122.92	3.35	906
	Maximum	35.64	70.43	90.25	160.68	6.00	1137
Empire Blvd	Mean ± Std. Deviation	36.36 ± 12.78	56.19 ± 15.33	117.09 ± 74.98	173.28 ± 85.61	5.28 ± 2.89	954.71 ± 183.76
	Minimum	15.99	39.00	11.89	50.89	3.30	781
	Maximum	57.19	74.46	251.46	325.92	9.50	1205
Bay	Mean ± Std. Deviation	23.70 ± 17.77	56.52 ± 27.83	121.09 ± 99.91	177.61 ± 116.09	6.65 ± 0.54	961.00 ± 103.00
	Minimum	6.24	28.02	45.68	101.86	6.00	838
	Maximum	60.00	95.84	335.50	428.33	7.30	1093

Table 7. Stormflow event sample mean and standard deviation, minimum, and maximum values for each parameter separated by sample site location. Lowercase superscript letters identify significant differences (p < 0.05) between sites.

Blossom Road water sample P, TSS, and Conductivity data							
Event type		SRP	TDP	PP	TP	TSS	Conductivity
		µg/L	µg/L	µg/L	µg/L	mg/L	µS/cm
Baseflow	Mean ± Std. Deviation	5.77 ± 3.94^{b}	25.88 ± 14.87	25.70 ± 13.88	51.57 ± 12.14^{b}	1.47 ± 1.07	1244 ± 106^{a}
	Minimum	2.00	9.29	9.73	41.81	0.30	1182
	Maximum	9.87	38.01	34.84	65.17	2.40	1367
Other flow	Mean ± Std. Deviation	28.24 ± 16.24^{a}	49.02 ± 32.04	32.51 ± 16.03	81.53 ± 33.55^{b}	7.38 ± 8.33	1050 ± 195^{ab}
	Minimum	2.00	23.00	15.76	39.67	0.90	621
	Maximum	57.82	104.37	59.94	141.04	25.00	1250
Stormevent	Mean ± Std. Deviation	44.22 ± 21.96^{a}	60.51 ± 29.40	87.21 ± 66.63	147.73 ± 58.30^{a}	10.13 ± 10.29	843 ± 275^{b}
	Minimum	30.71	40.01	14.06	73.67	1.30	378
	Maximum	93.00	124.23	189.83	234.00	24.70	1155

Table 8. Blossom Road sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences ($p < 0.05$) between event types.

Millrace water sample P, TSS, and Conductivity data							
Event type		SRP	TDP	PP	TP	TSS	Conductivity
		µg/L	µg/L	µg/L	µg/L	mg/L	µS/cm
Baseflow	Mean ± Std. Deviation	7.50 ± 4.80^{b}	25.04 ± 11.95	21.32 ± 8.27	46.36 ± 7.80	1.23 ± 0.50	1240 ± 118
	Minimum	2.00	11.28	12.59	40.32	0.70	1151
	Maximum	10.87	32.83	29.04	55.17	1.70	1374
Other flow	Mean ± Std. Deviation	26.73 ± 11.99^{a}	45.07 ± 25.70	36.95 ± 15.70	82.02 ± 37.68	4.94 ± 4.80	1059 ± 173
	Minimum	5.17	22.17	17.00	43.83	0.80	683
	Maximum	43.32	101.55	58.08	159.63	12.60	1235
Stormevent	Mean ± Std. Deviation	35.47 ± 7.08^{a}	50.42 ± 19.46	36.88 ± 30.15	87.30 ± 44.74	3.41 ± 1.34	928 ± 206
	Minimum	26.78	31.72	3.24	46.65	1.70	599
	Maximum	46.63	85.94	77.19	163.13	4.50	1150

Table 9. Millrace sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences ($p < 0.05$) between event types.

Irondequoit Creek at Browncroft Boulevard water sample P, TSS, and Conductivity data							
Event type		SRP	TDP	PP	TP	TSS	Conductivity
		µg/L	µg/L	µg/L	µg/L	mg/L	µS/cm
Baseflow	Mean ± Std. Deviation	6.76 ± 4.21^{b}	26.90 ± 8.51	13.09 ± 6.59	39.99 ± 14.97^{b}	1.33 ± 0.50^{b}	1234 ± 119
	Minimum	2.00	17.09	5.64	22.73	0.80	1147
	Maximum	10.01	32.29	18.17	49.50	1.80	1369
Other flow	Mean ± Std. Deviation	26.30 ± 11.57^{a}	42.03 ± 22.30	45.69 ± 24.37	87.72 ± 34.90^{ab}	7.67 ± 10.94^{ab}	1065 ± 176
	Minimum	5.83	20.83	23.23	48.33	0.85	676
	Maximum	41.11	90.68	94.70	146.70	31.40	1242
Stormevent	Mean ± Std. Deviation	45.34 ± 17.62^{a}	65.83 ± 42.67	86.96 ± 68.12	152.79 ± 70.33^{a}	14.24 ± 10.12^{a}	893 ± 175
	Minimum	24.53	17.27	.48	55.00	6.00	633
	Maximum	75.16	144.03	192.33	239.33	29.00	1163

Table 10. Irondequoit Creek at Browncroft Boulevard sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences ($p < 0.05$) between event types.

The Narrows water sample P, TSS, and Conductivity data							
Event type		SRP	TDP	PP	TP	TSS	Conductivity
		µg/L	µg/L	µg/L	µg/L	mg/L	µS/cm
Baseflow	Mean ± Std. Deviation	4.05 ± 3.55[b]	22.85 ± 5.85	42.93 ± 15.35	65.78 ± 20.70	3.03 ± 1.03	1246 ± 117
	Minimum	2.00	16.09	27.38	43.47	1.90	1165
	Maximum	8.15	26.28	58.08	84.36	3.90	1380
Other flow	Mean ± Std. Deviation	30.85 ± 7.02[a]	40.24 ± 12.20	59.07 ± 44.17	99.32 ± 54.63	6.49 ± 9.39	1061 ± 189
	Minimum	21.17	25.42	15.91	41.33	0.75	678
	Maximum	40.33	61.83	151.99	213.82	27.40	1253
Stormevent	Mean ± Std. Deviation	33.77 ± 2.65[a]	56.15 ± 20.19	85.65 ± 6.51	141.80 ± 26.70	4.68 ± 1.87	1022 ± 163
	Minimum	31.89	41.87	81.05	122.92	3.35	906
	Maximum	35.64	70.43	90.25	160.68	6.00	1137

Table 11. Narrows sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences (*p* < 0.05) between event types.

Empire Boulevard water sample P, TSS, and Conductivity data							
Event type		SRP	TDP	PP	TP	TSS	Conductivity
		µg/L	µg/L	µg/L	µg/L	mg/L	µS/cm
Baseflow	Mean ± Std. Deviation	6.30 ± 5.07[b]	18.70 ± 16.05[b]	50.62 ± 32.01	69.31 ± 16.76	2.43 ± 0.75	1218 ± 74
	Minimum	2.00	2.00	25.53	59.54	2.00	1175
	Maximum	11.89	34.01	86.67	88.67	3.30	1303
Other flow	Mean ± Std. Deviation	25.55 ± 10.54[a]	47.60 ± 32.86[ab]	50.76 ± 18.70	98.36 ± 40.54	6.71 ± 7.74	1057 ± 181
	Minimum	15.17	22.50	14.00	41.67	0.60	645
	Maximum	46.47	122.79	77.98	173.56	23.40	1203
Stormevent	Mean ± Std. Deviation	36.36 ± 12.78[a]	56.19 ± 15.33[a]	117.09 ± 74.98	173.28 ± 85.61	5.28 ± 2.89	955 ± 184
	Minimum	15.99	39.00	11.89	50.89	3.30	781
	Maximum	57.19	74.46	251.46	325.92	9.50	1205

Table 12. Empire Boulevard sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences (*p* < 0.05) between event types.

Irondequoit Bay water sample P, TSS, and Conductivity data							
Event type		SRP	TDP	PP	TP	TSS	Conductivity
		µg/L	µg/L	µg/L	µg/L	mg/L	µS/cm
Baseflow	Mean ± Std. Deviation	2.00 ± 0.00[b]	15.62 ± 6.08	104.07 ± 118.73	119.69 ± 123.01	8.20 ± 2.04	1047 ± 106
	Minimum	2.00	8.63	18.75	27.38	5.90	926
	Maximum	2.00	19.67	239.66	259.33	9.80	1122
Other flow	Mean ± Std. Deviation	13.88 ± 12.18[ab]	37.41 ± 21.74	76.36 ± 28.93	113.77 ± 35.93	5.27 ± 1.82	1011 ± 210
	Minimum	2.00	12.40	34.91	47.31	3.50	604
	Maximum	40.64	76.83	120.80	149.01	7.60	1253
Stormevent	Mean ± Std. Deviation	23.70 ± 17.77[a]	56.52 ± 27.83	121.09 ± 99.91	177.61 ± 116.09	6.65 ± 0.54	961 ± 103
	Minimum	6.24	28.02	45.68	101.86	6.00	838
	Maximum	60.00	95.84	335.50	428.33	7.30	1093

Table 13. Irondequoit Bay sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences (*p* < 0.05) between event types.

Baseflow water sample metal and ion data shown in ppm								
Site		Al	Ca	Fe	K	Mg	Mn	Na
Blossom Rd	Mean ± Std. Deviation	1.73 ± 2.08	98.03 ± 4.67^{a}	0.47 ± 0.23	3.31 ± 0.31	29.41 ± 0.95^{a}	0.10 ± 0.02^{b}	74.09 ± 9.11
	Minimum	0.33	94.90	0.26	3.11	28.40	0.09	68.08
	Maximum	4.12	103.40	0.71	3.66	30.29	0.12	84.57
Millrace	Mean ± Std. Deviation	1.59 ± 2.04	90.79 ± 11.89^{a}	0.40 ± 0.24	2.86 ± 0.53	26.84 ± 1.75^{ab}	0.10 ± 0.01^{b}	67.09 ± 1.64
	Minimum	0.37	78.11	0.22	2.29	24.85	0.09	65.67
	Maximum	3.94	101.70	0.67	3.35	28.15	0.11	68.88
IC at Browncroft	Mean ± Std. Deviation	1.59 ± 2.00	97.31 ± 1.80^{a}	0.42 ± 0.24	3.20 ± 0.21	28.46 ± 1.57^{a}	0.11 ± 0.02^{ab}	73.12 ± 9.74
	Minimum	0.32	95.90	0.23	3.05	27.13	0.09	64.78
	Maximum	3.90	99.34	0.69	3.44	30.19	0.13	83.83
Narrows	Mean ± Std. Deviation	1.68 ± 1.91	88.81 ± 11.22^{ab}	0.71 ± 0.27	3.03 ± 0.42	27.23 ± 2.30^{ab}	0.16 ± 0.03^{a}	68.85 ± 0.84
	Minimum	0.54	76.23	0.52	2.56	24.58	0.14	67.98
	Maximum	3.89	97.78	1.02	3.37	28.79	0.19	69.65
Empire Blvd	Mean ± Std. Deviation	1.72 ± 2.01	88.12 ± 8.78^{ab}	0.76 ± 0.37	2.96 ± 0.35	27.20 ± 1.70^{ab}	0.15 ± 0.01^{ab}	70.30 ± 1.78
	Minimum	0.41	78.17	0.36	2.62	25.35	0.14	68.68
	Maximum	4.03	94.78	1.10	3.31	28.69	0.16	72.20
Bay	Mean ± Std. Deviation	1.99 ± 2.26	67.13 ± 5.02^{b}	0.76 ± 0.25	2.89 ± 0.25	23.38 ± 1.93^{b}	0.10 ± 0.02^{b}	69.93 ± 2.24
	Minimum	0.45	63.01	0.50	2.65	21.71	0.08	67.62
	Maximum	4.58	72.72	0.99	3.15	25.50	0.12	72.10

Table 14. Baseflow sample mean and standard deviation, minimum, and maximum values for each parameter separated by sample site location. Lowercase superscript letters identify significant differences ($p < 0.05$) between sites.

Other Flow water sample metal and ion data shown in ppm								
Site		Al	Ca	Fe	K	Mg	Mn	Na
Blossom Rd	Mean ± Std. Deviation	1.91 ± 1.49	83.53 ± 20.02	1.02 ± 1.24	3.20 ± 0.30	25.12 ± 5.56	0.11 ± 0.06	67.54 ± 13.48
	Minimum	0.60	54.30	0.08	2.71	16.57	0.02	47.75
	Maximum	4.38	105.00	4.01	3.67	32.84	0.24	86.38
Millrace	Mean ± Std. Deviation	1.73 ± 1.53	79.75 ± 16.01	0.89 ± 1.14	3.16 ± 0.39	24.15 ± 4.51	0.11 ± 0.06	66.10 ± 9.59
	Minimum	0.58	55.06	0.27	2.50	16.20	0.05	49.94
	Maximum	4.18	103.50	3.68	3.67	29.25	0.23	81.52
IC at Browncroft	Mean ± Std. Deviation	1.97 ± 1.44	81.35 ± 23.93	1.03 ± 1.34	3.38 ± 0.34	25.91 ± 5.78	0.11 ± 0.07	69.00 ± 13.43
	Minimum	0.67	45.88	0.13	3.07	16.28	0.03	48.35
	Maximum	4.58	116.10	4.24	3.99	34.81	0.26	92.95
Narrows	Mean ± Std. Deviation	2.00 ± 1.52	79.48 ± 14.55	1.11 ± 1.24	3.30 ± 0.43	24.24 ± 4.63	0.13 ± 0.06	66.97 ± 9.72
	Minimum	0.55	54.01	0.19	2.74	15.95	0.04	48.67
	Maximum	4.26	97.46	3.87	3.87	29.86	0.23	77.47
Empire Blvd	Mean ± Std. Deviation	1.82 ± 1.33	81.07 ± 20.07	0.85 ± 0.83	3.25 ± 0.40	24.53 ± 5.88	0.13 ± 0.07	68.22 ± 14.06
	Minimum	0.67	52.38	0.11	2.48	14.75	0.02	47.48
	Maximum	3.97	112.20	2.76	3.79	33.97	0.19	95.85
Bay	Mean ± Std. Deviation	1.71 ± 1.22	66.39 ± 10.89	0.70 ± 0.35	2.89 ± 0.40	20.78 ± 4.12	0.11 ± 0.05	59.25 ± 11.79
	Minimum	0.66	45.60	0.27	2.34	12.52	0.04	38.75
	Maximum	4.03	77.01	1.16	3.44	24.60	0.17	71.90

Table 15. Other flow sample mean and standard deviation, minimum, and maximum values for each parameter separated by sample site location. Lowercase superscript letters identify significant differences ($p < 0.05$) between sites.

Stormflow water sample metal and ion data shown in ppm								
Site		Al	Ca	Fe	K	Mg	Mn	Na
Blossom Rd	Mean ± Std. Deviation	3.43 ± 2.83	69.78 ± 20.53	3.33 ± 3.03	3.34 ± 0.30	20.13 ± 6.22	0.29 ± 0.21	52.87 ± 13.73
	Minimum	0.44	40.41	0.37	3.06	11.03	0.10	26.96
	Maximum	7.51	93.89	8.72	3.94	27.60	0.64	67.91
Millrace	Mean ± Std. Deviation	2.66 ± 2.24	74.19 ± 18.87	2.29 ± 2.42	3.22 ± 0.17	21.29 ± 5.49	0.20 ± 0.16	56.32 ± 9.79
	Minimum	0.31	48.55	0.21	3.00	13.81	0.06	44.07
	Maximum	5.48	95.45	6.54	3.43	28.28	0.50	66.79
IC at Browncroft	Mean ± Std. Deviation	3.39 ± 2.15	72.98 ± 14.39	3.06 ± 2.05	3.42 ± 0.21	21.05 ± 4.51	0.25 ± 0.13	54.92 ± 8.12
	Minimum	0.45	54.15	0.47	3.12	15.02	0.10	43.37
	Maximum	6.81	93.54	6.60	3.70	27.99	0.50	66.39
Narrows	Mean ± Std. Deviation	2.11 ± 2.15	86.94 ± 18.18	0.95 ± 0.72	4.00 ± 1.10	24.38 ± 4.78	0.17 ± 0.01	65.67 ± 7.57
	Minimum	0.59	74.08	0.44	3.22	21.00	0.16	60.31
	Maximum	3.63	99.79	1.46	4.78	27.76	0.17	71.02
Empire Blvd	Mean ± Std. Deviation	1.92 ± 1.40	72.14 ± 15.40	1.25 ± 0.84	3.13 ± 0.29	20.99 ± 5.09	0.17 ± 0.03	57.18 ± 8.56
	Minimum	0.37	54.46	0.37	2.65	15.25	0.12	45.16
	Maximum	3.39	97.22	2.69	3.55	27.98	0.20	67.78
Bay	Mean ± Std. Deviation	1.86 ± 1.31	68.56 ± 5.90	1.02 ± 0.40	3.09 ± 0.17	21.61 ± 2.32	0.13 ± 0.02	61.63 ± 5.93
	Minimum	0.38	61.52	0.45	2.92	18.08	0.10	51.97
	Maximum	3.43	78.10	1.52	3.42	25.16	0.16	68.49

Table 16. Stormflow event sample mean and standard deviation, minimum, and maximum values for each parameter separated by sample site location. Lowercase superscript letters identify significant differences ($p < 0.05$) between sites.

Blossom Road water sample metal and ion data shown in ppm								
EventType		Al	Ca	Fe	K	Mg	Mn	Na
Baseflow	Mean ± Std. Deviation	1.73 ± 2.08	98.03 ± 4.67	0.47 ± 0.23	3.31 ± 0.31	29.41 ± 0.95	0.10 ± 0.02	74.09 ± 9.11
	Minimum	0.33	94.90	0.26	3.11	28.40	0.09	68.08
	Maximum	4.12	103.40	0.71	3.66	30.29	0.12	84.57
Other flow	Mean ± Std. Deviation	1.91 ± 1.49	83.53 ± 20.02	1.02 ± 1.24	3.20 ± 0.30	25.12 ± 5.56	0.11 ± 0.06	67.54 ± 13.48
	Minimum	0.60	54.30	0.08	2.71	16.57	0.02	47.75
	Maximum	4.38	105.00	4.01	3.67	32.84	0.24	86.38
Stormevent	Mean ± Std. Deviation	3.43 ± 2.83	69.78 ± 20.53	3.33 ± 3.03	3.34 ± 0.30	20.13 ± 6.22	0.29 ± 0.21	52.87 ± 13.73
	Minimum	0.44	40.41	0.37	3.06	11.03	0.10	26.96
	Maximum	7.51	93.89	8.72	3.94	27.60	0.64	67.91

Table 17. Blossom sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences ($p < 0.05$) between event types.

Millrace water sample metal and ion data shown in ppm								
EventType		Al	Ca	Fe	K	Mg	Mn	Na
Baseflow	Mean ± Std. Deviation	1.59 ± 2.04	90.79 ± 11.89	0.40 ± 0.24	2.86 ± 0.53	26.84 ± 1.75	0.10 ± 0.01	67.09 ± 1.64
	Minimum	0.37	78.11	0.22	2.29	24.85	0.09	65.67
	Maximum	3.94	101.70	0.67	3.35	28.15	0.11	68.88
Other flow	Mean ± Std. Deviation	1.73 ± 1.53	79.75 ± 16.01	0.89 ± 1.14	3.16 ± 0.39	24.15 ± 4.51	0.11 ± 0.06	66.10 ± 9.59
	Minimum	0.58	55.06	0.27	2.50	16.20	0.05	49.94
	Maximum	4.18	103.50	3.68	3.67	29.25	0.23	81.52
Stormevent	Mean ± Std. Deviation	2.66 ± 2.24	74.19 ± 18.87	2.29 ± 2.42	3.22 ± 0.17	21.29 ± 5.49	0.20 ± 0.16	56.32 ± 9.79
	Minimum	0.31	48.55	0.21	3.00	13.81	0.06	44.07
	Maximum	5.48	95.45	6.54	3.43	28.28	0.50	66.79

Table 18. Millrace sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences ($p < 0.05$) between event types.

The Narrows water sample metal and ion data shown in ppm								
EventType		Al	Ca	Fe	K	Mg	Mn	Na
Baseflow	Mean ± Std. Deviation	1.68 ± 1.91	88.81 ± 11.22	0.71 ± 0.27	3.03 ± 0.42	27.23 ± 2.30	0.16 ± 0.03	68.85 ± 0.84
	Minimum	0.54	76.23	0.52	2.56	24.58	0.14	67.98
	Maximum	3.89	97.78	1.02	3.37	28.79	0.19	69.65
Other flow	Mean ± Std. Deviation	2.00 ± 1.52	79.48 ± 14.55	1.11 ± 1.24	3.30 ± 0.43	24.24 ± 4.63	0.13 ± 0.06	66.97 ± 9.72
	Minimum	0.55	54.01	0.19	2.74	15.95	0.04	48.67
	Maximum	4.26	97.46	3.87	3.87	29.86	0.23	77.47
Stormevent	Mean ± Std. Deviation	2.11 ± 2.15	86.94 ± 18.18	0.95 ± 0.72	4.00 ± 1.10	24.38 ± 4.78	0.17 ± 0.01	65.67 ± 7.57
	Minimum	0.59	74.08	0.44	3.22	21.00	0.16	60.31
	Maximum	3.63	99.79	1.46	4.78	27.76	0.17	71.02

Table 19. Narrows sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences ($p < 0.05$) between event types.

Empire Boulevard water sample metal and ion data shown in ppm								
EventType		Al	Ca	Fe	K	Mg	Mn	Na
Baseflow	Mean ± Std. Deviation	1.72 ± 2.01	88.12 ± 8.78	0.76 ± 0.37	2.96 ± 0.35	27.20 ± 1.70	0.15 ± 0.01	70.30 ± 1.78
	Minimum	0.41	78.17	0.36	2.62	25.35	0.14	68.68
	Maximum	4.03	94.78	1.10	3.31	28.69	0.16	72.20
Other flow	Mean ± Std. Deviation	1.82 ± 1.33	81.07 ± 20.07	0.85 ± 0.83	3.25 ± 0.40	24.53 ± 5.88	0.13 ± 0.07	68.22 ± 14.06
	Minimum	0.67	52.38	0.11	2.48	14.75	0.02	47.48
	Maximum	3.97	112.20	2.76	3.79	33.97	0.19	95.85
Stormevent	Mean ± Std. Deviation	1.92 ± 1.40	72.14 ± 15.40	1.25 ± 0.84	3.13 ± 0.29	20.99 ± 5.09	0.17 0.03	57.18 ± 8.56
	Minimum	0.37	54.46	0.37	2.65	15.25	0.12	45.16
	Maximum	3.39	97.22	2.69	3.55	27.98	0.20	67.78

Table 20. Empire sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences ($p < 0.05$) between event types.

Irondequoit Bay water sample metal and ion data shown in ppm								
EventType		Al	Ca	Fe	K	Mg	Mn	Na
Baseflow	Mean ± Std. Deviation	1.99 ± 2.26	67.13 ± 5.02	0.76 ± 0.25	2.89 ± 0.25	23.38 ± 1.93	0.10 ± 0.02	69.93 ± 2.24
	Minimum	0.45	63.01	0.50	2.65	21.71	0.08	67.62
	Maximum	4.58	72.72	0.99	3.15	25.50	0.12	72.10
Other flow	Mean ± Std. Deviation	1.71 ± 1.22	66.39 ± 10.89	0.70 ± 0.35	2.89 ± 0.40	20.78 ± 4.12	0.11 ± 0.05	59.25 ± 11.79
	Minimum	0.66	45.60	0.27	2.34	12.52	0.04	38.75
	Maximum	4.03	77.01	1.16	3.44	24.60	0.17	71.90
Stormevent	Mean ± Std. Deviation	1.86 ± 1.31	68.56 ± 5.90	1.02 ± 0.40	3.09 ± 0.17	21.61 ± 2.32	0.13 ± 0.02	61.63 ± 5.93
	Minimum	0.38	61.52	0.45	2.92	18.08	0.10	51.97
	Maximum	3.43	78.10	1.52	3.42	25.16	0.16	68.49

Table 21. Irondequoit Bay sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences ($p < 0.05$) between event types.

Irondequoit Creek at Browncroft Boulevard water sample metal and ion data shown in ppm								
EventType		Al	Ca	Fe	K	Mg	Mn	Na
Baseflow	Mean ± Std. Deviation	1.59 ± 2.00	97.31 ± 1.80	0.42 ± 0.24^{b}	3.20 ± 0.21	28.46 ± 1.57	0.11 ± 0.02	73.12 ± 9.74
	Minimum	0.32	95.90	0.23	3.05	27.13	0.09	64.78
	Maximum	3.90	99.34	0.69	3.44	30.19	0.13	83.83
Other flow	Mean ± Std. Deviation	1.97 ± 1.44	81.35 ± 23.93	1.03 ± 1.34^{ab}	3.38 ± 0.34	25.91 ± 5.78	0.11 ± 0.07	69.00 ± 13.43
	Minimum	0.67	45.88	0.13	3.07	16.28	0.03	48.35
	Maximum	4.58	116.10	4.24	3.99	34.81	0.26	92.95
Stormevent	Mean ± Std. Deviation	3.39 ± 2.15	72.98 ± 14.39	3.06 ± 2.05^{a}	3.42 ± 0.21	21.05 ± 4.51	0.25 ± 0.13	54.92 ± 8.12
	Minimum	0.45	54.15	0.47	3.12	15.02	0.10	43.37
	Maximum	6.81	93.54	6.60	3.70	27.99	0.50	66.39

Table 22. Irondequoit Creek at Browncroft Boulevard sample site mean and standard deviation, minimum, and maximum values for each parameter separated by event type. Lowercase superscript letters identify significant differences ($p < 0.05$) between event types.

Site	Wet color	Composition
A	10YR 3/1	Medium sized sand with some gravel-sized particles and shell fragments.
B	10YR 2/1	Silty with some clay, hemic material, and a trace of very fine sand.
C	10YR 3/1	Fine sand with some gravel-sized particles and shell fragments.
1	10YR 2/1	Silty with an abundance of fibrous material, mostly hemic.
2	10YR 3/2	Silty with some clay and hemic material.
3	10YR 2/2	Silty with high amounts of sapric material, and traces of very fine sand and clay.
4	10YR 2/1	Silty with high amounts of sapric material, and traces of very fine sand and clay.
5	10YR 2/1	Silty with an abundance of hemic and sapric material and trace amounts of very fine sand.
6	10YR 2/1	Dominated by fibric and hemic fibers with trace amounts of silt.
7	10YR 3/1	Silty with some hemic material and trace amounts of very fine sand and clay.
8	10YR 2/1	Very fine silt and some clay.

Table 23. Sediment sample characterizations determined using a Munsell color chart and AGI Data sheets 28.1 and 29.1.

Sample site	Loosely sorbed-P	Fe-P	Al-P	Organic P	Ca-P
	% of TP	% of TP	% of TP	% of TP	% of TP
A	8.1	8.6	2.2	3.0	78.1
B	25.9	16.5	14.1	24.5	18.9
C	13.0	19.6	5.4	9.4	52.5
1	10.6	60.1	7.3	4.4	17.6
2	29.3	42.5	9.4	11.7	7.1
3	11.6	20.8	9.4	10.2	48.0
4	5.1	14.2	18.8	17.9	44.0
5	31.2	11.7	23.7	1.5	31.8
6	51.4	10.4	11.3	12.5	14.4
7	23.2	11.0	7.6	8.5	49.6
8	17.7	12.6	15.1	15.0	39.6

Table 24. Sediment sample sequential extraction results using Rydin's modified fractionation scheme (2000).

Site	Moisture Content (g)	Percent Moisture (%)	Organic Content (g)	Percent Organic Content (%)
A	1.478	19.59	0.031	0.51
B	2.763	47.25	0.11	3.57
C	1.376	22.99	0.026	0.56
1	3.64	71.97	0.248	17.49
2	2.78	50.05	0.26	9.37
3	3.128	51.65	0.221	7.55
4	4.463	67.34	0.284	13.12
5	5.257	83.60	0.289	28.03
6	5.679	90.69	0.374	64.15
7	2.907	38.32	0.222	4.74
8	3.275	65.33	0.123	7.08

Table 25. Results of moisture and organic content of each sediment sample listed in grams and percent of total sample.

Site	Al	Ca	Fe	TP
	mg/kg	mg/kg	mg/kg	mg/kg
Site A	3,122	21,882	6,087	311
Site B	3,337	14,486	6,539	613
Site C	1,885	14,955	4,754	367
Site 1	3,167	9,458	6,189	503
Site 2	5,687	16,382	9,324	863
Site 3	3,747	12,957	6,759	695
Site 4	6,022	13,473	9,099	901
Site 5	6,663	16,816	10,199	2,032
Site 6	4,841	10,542	8,031	1,216
Site 7	1,401	6,852	2,844	281
Site 8	5,516	36,477	9,892	852

Table 26. Results of ICP analysis on sediment samples, reported in mg/kg.

Sample	Date Collected	Time Collected	*SF/OF/BF	TP	Flow	%TP	Calculated TP at Empire	Error
Units				µg/L	cms	%	µg/L	%
Blossom	05/25/10	930	BF	65.17	1.73			
Millrace	05/25/10	940	BF	55.17	0.91	0.53		
IC at Bwn	05/25/10	950	BF	49.50	0.82	0.47		
Narrows	05/25/10	1015	BF	69.50	1.79			
Empire	05/25/10	1030	BF	88.67	1.79		88.65	0.02
Blossom	07/06/10	1305	BF	47.74	1.39			
Millrace	07/06/10	1240	BF	43.59	0.66	0.48		
IC at Bwn	07/06/10	1250	BF	47.74	0.73	0.52		
Narrows	07/06/10	1220	BF	84.36	1.44			
Empire	07/06/10	1200	BF	59.54	1.44		59.46	0.13
Blossom	09/01/10	1000	BF	41.81	1.25			
Millrace	09/01/10	1010	BF	40.32	0.80	0.64		
IC at Bwn	09/01/10	1020	BF	22.73	0.45	0.36		
Narrows	09/01/10	1030	BF	43.47	1.30			
Empire	09/01/10	1045	BF	59.74	1.30		59.87	0.22

Table 27. Baseflow model results including TP calculated by the model (Equation 4) and the percent error of the calculated results to the measured value. Percent error was calculated by subtracting Empire TP from the calculated Empire TP, then dividing by Empire TP and multiplying by 100.

Sample	Date Collected	Time Collected	*SF/OF/BF	TP	Flow	%TP	Calculated TP at Empire	Error
Units				µg/L	cms	%	µg/L	%
Blossom	05/10/10	920	OF	39.67	3.20			
Millrace	05/10/10	940	OF	43.83	1.52	0.48		
IC at Bwn	05/10/10	1015	OF	48.33	1.68	0.52		
Narrows	05/10/10	1045	OF	41.33	3.29			
Empire	05/10/10	1110	OF	41.67	3.29		42.49	1.97
Blossom	05/19/10	830	OF	58.33	2.97			
Millrace	05/19/10	845	OF	54.17	1.43	0.48		
IC at Bwn	05/19/10	900	OF	58.00	1.54	0.52		
Narrows	05/19/10	930	OF	71.83	3.06			
Empire	05/19/10	945	OF	65.33	3.06		65.04	0.45
Blossom	06/02/10	1600	OF	57.47	1.95			
Millrace	06/02/10	1610	OF	57.90	0.89	0.46		
IC at Bwn	06/02/10	1625	OF	68.77	1.06	0.54		
Empire	06/02/10	1645	OF	81.22	2.02		26.67	67.17
Blossom	06/03/10	900	OF	93.52	2.63			
Millrace	06/03/10	920	OF	102.25	1.32	0.50		
IC at Bwn	06/03/10	935	OF	101.67	1.31	0.50		
Narrows	06/03/10	950	OF	88.94	2.71			
Empire	06/03/10	1005	OF	96.09	2.71		92.37	3.87
Blossom	06/07/10	905	OF	111.00	8.95			
Millrace	06/07/10	915	OF	100.53	3.64	0.41		
IC at Bwn	06/07/10	925	OF	146.70	5.31	0.59		
Narrows	06/07/10	940	OF	213.82	9.12			
Empire	06/07/10	1000	OF	112.12	9.12		112.72	0.53
Blossom	06/30/10	945	OF	89.51	2.18			
Millrace	06/30/10	1000	OF	70.49	1.01	0.46		
IC at Bwn	06/30/10	1015	OF	81.79	1.17	0.54		
Narrows	06/30/10	1030	OF	78.35	2.25			
Empire	06/30/10	1040	OF	87.80	2.25		87.90	0.12
Blossom	08/02/10	955	OF	61.73	1.64			
Millrace	08/02/10	1005	OF	67.37	0.81	0.50		
IC at Bwn	08/02/10	1020	OF	68.20	0.83	0.50		
Narrows	08/02/10	1030	OF	92.42	1.70			
Empire	08/02/10	1045	OF	173.56	1.70		77.18	55.53
Blossom	08/16/10	930	OF	141.04	2.29			
Millrace	08/16/10	940	OF	159.63	1.27	0.55		
IC at Bwn	08/16/10	950	OF	128.26	1.02	0.45		
Narrows	08/16/10	1000	OF	108.52	2.36			
Empire	08/16/10	1020	OF	129.09	2.36		131.28	1.69

Table 28. Other flow model results including TP calculated by the model (Equation 5) and the percent error of the calculated results to the measured value. Percent error was calculated by subtracting Empire TP from the calculated Empire TP, then dividing by Empire TP and multiplying by 100.

Sample	Date Collected	Time Collected	*SF/OF/BF	TP	Flow	%TP	Calculated TP at Empire	Error
Units				μg/L	cms	%	μg/L	%
Blossom	06/05/10	1940	SF	234.00	5.78			
Millrace	06/05/10	1950	SF	46.67	0.94	0.16		
IC at Bwn	06/05/10	2000	SF	239.33	4.84	0.84		
Empire	06/05/10	2010	SF	50.89	5.91		50.85	0.06
Blossom	06/06/10	740	SF	193.49	16.77			
Millrace	06/06/10	650	SF	64.91	9.08	0.54		
IC at Bwn	06/06/10	700	SF	55.00	7.69	0.46		
Empire	06/06/10	710	SF	164.09	16.97		165.84	1.07
Blossom	06/06/10	930	SF	73.67	16.77			
Millrace	06/06/10	830	SF	59.17	8.28	0.49		
IC at Bwn	06/06/10	840	SF	60.67	8.49	0.51		
Empire	06/06/10	855	SF	231.67	16.97		132.43	42.84
Blossom	07/09/10	1800	SF	107.68	2.58			
Millrace	07/09/10	1820	SF	46.65	0.60	0.23		
IC at Bwn	07/09/10	1830	SF	155.07	1.98	0.77		
Empire	07/09/10	1840	SF	154.63	2.66		21.49	86.10
Blossom	07/13/10	1530	SF	169.79	2.27			
Millrace	07/13/10	1540	SF	163.13	1.11	0.49		
IC at Bwn	07/13/10	1600	SF	170.12	1.16	0.51		
Empire	07/13/10	1615	SF	144.03	2.34		141.41	1.82
Blossom	07/21/10	1350	SF	92.51	4.70			
Millrace	07/21/10	1400	SF	108.28	1.75	0.37		
IC at Bwn	07/21/10	1410	SF	181.87	2.95	0.63		
Empire	07/21/10	1440	SF	141.75	4.82		145.95	2.96
Blossom	07/23/10	825	SF	162.96	7.79			
Millrace	07/23/10	745	SF	122.30	2.89	0.37		
IC at Bwn	07/23/10	755	SF	207.46	4.90	0.63		
Empire	07/23/10	835	SF	325.92	7.94		318.62	2.24

Table 29. Stormflow model results including TP calculated by the model (Equation 6) and the percent error of the calculated results to the measured value. Percent error was calculated by subtracting Empire TP from the calculated Empire TP, then dividing by Empire TP and multiplying by 100.

Month	Inflow TP Load Kg/month		Outflow TP Load Kg/month		Removal Efficiency	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
May	435.45	17,091.36	408.23	4962.30	-42.10	71.00
June	417.30	4,127.69	390.09	3238.65	-50.90	45.97
July	353.80	11,875.05	408.23	4835.29	-49.20	59.30
August	471.74	10,668.49	453.59	7148.62	-33.60	32.99
September	335.66	2,113.74	254.01	1805.30	-32.90	49.80
Avgerage of all months	335.66	17,091.36	254.01	7148.62	-50.90	71.00

Table 30. USGS monthly total TP minimum and maximum values from 1991 – 2001 (Coon *et al.* 2000 and Coon 2004). Positive removal efficiencies indicate net retention in Ellison Park and negative removal efficiencies indicate export from Ellison Park. Removal efficiency is calculated by subtracting outflow TP load from inflow TP load, then dividing by inflow TP load and multiplying by 100.

Month	Inflow SRP Load Kg/month		Outflow SRP Load Kg/month		Removal Efficiency	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
May	36.29	344.73	54.43	399.16	-60.00	-3.23
June	45.36	344.73	63.50	435.45	-66.67	-12.50
July	63.50	526.17	99.79	771.11	-75.00	-11.76
August	63.50	526.17	99.79	889.04	-68.97	-15.38
September	45.36	154.22	54.43	254.01	-64.71	-13.33
Avgerage of all months	36.29	526.17	54.43	889.04	-75.00	-3.23

Table 31. USGS monthly total SRP minimum and maximum values from 1991 – 2001 (Coon *et al.* 2000 and Coon 2004). Positive removal efficiencies indicate net retention in Ellison Park and negative removal efficiencies indicate export from Ellison Park. Removal efficiency is calculated by subtracting outflow TP load from inflow TP load, then dividing by inflow TP load and multiplying by 100.

	TP Load Inflow	TP Load Outflow	SRP Load Inflow	SRP Load Outflow
Event Type	Kg/day	Kg/day	Kg/day	Kg/day
Baseflow	6.66	9.28	0.78	0.42
Other flow	24.53	27.87	9.96	8.67
Stormflow	101.22	136.26	20.91	25.02

Table 32. 2010 TP and SRP average event loading (Kg/day).

Date	Inflow TP Load Kg/month	Outflow TP Load Kg/month	Removal Efficiency
May	906.31	1,130.23	-24.71
June	1,160.21	1,449.30	-24.92
July	983.00	1,238.62	-26.00
August	954.67	1,152.00	-20.67
September	912.28	1,105.53	-21.18
Avgerage total of all months	983.29	1,215.14	-23.58

Table 33. TP monthly totals and removal efficiencies for 2010. Positive removal efficiencies indicate net retention in Ellison Park and negative removal efficiencies indicate export from Ellison Park. Removal efficiency is calculated by subtracting outflow TP load from inflow TP load, then dividing by inflow TP load and multiplying by 100.

Date	Inflow SRP Load Kg/month	Outflow SRP Load Kg/month	Removal Efficiency
May	269.91	259.84	3.73
June	346.09	341.63	1.29
July	280.87	276.18	1.67
August	323.18	301.25	6.78
September	304.04	284.33	6.48
Avgerage total of all months	304.82	292.65	3.99

Table 34. SRP monthly totals and removal efficiencies for 2010. Positive removal efficiencies indicate net retention in Ellison Park and negative removal efficiencies indicate export from Ellison Park. Removal efficiency is calculated by subtracting outflow TP load from inflow TP load, then dividing by inflow TP load and multiplying by 100.

Figures

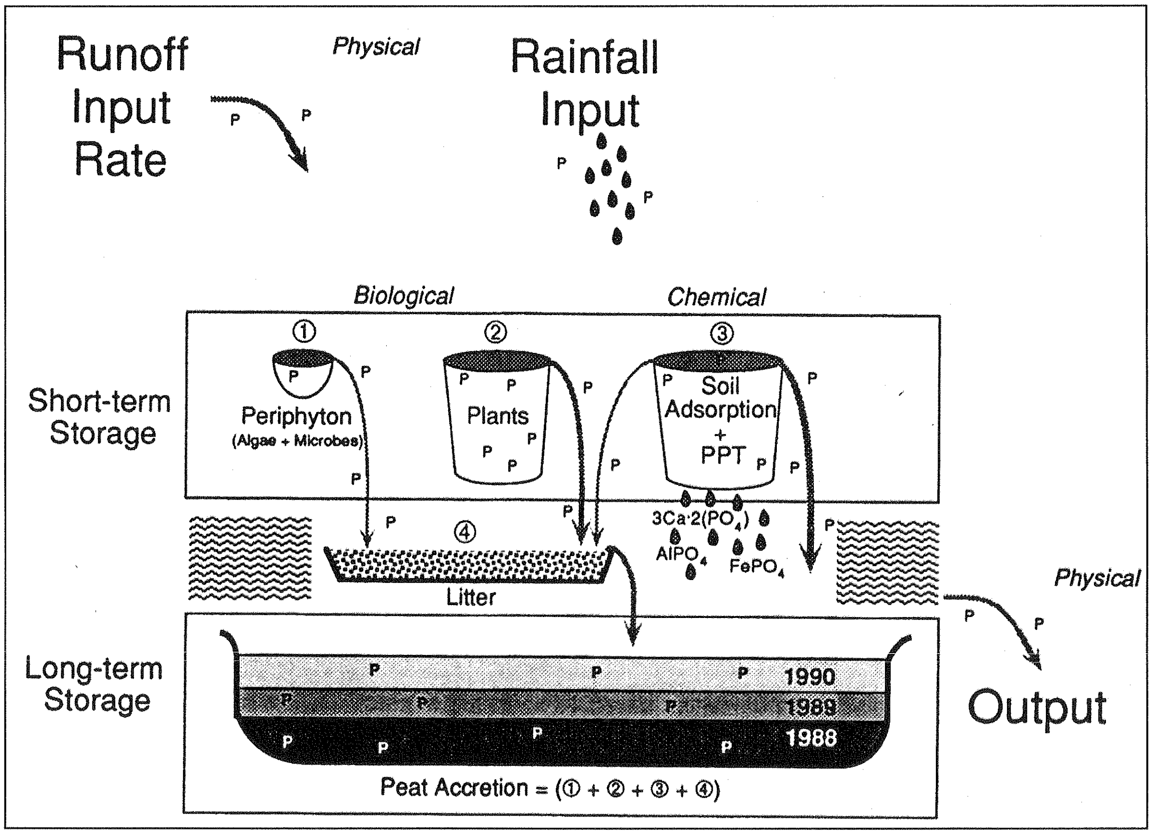

Figure 1. Conceptual model of the P retention in wetlands by Richardson and Craft (1993). This diagram shows the components for both the short-term and long-term P storage compartments.

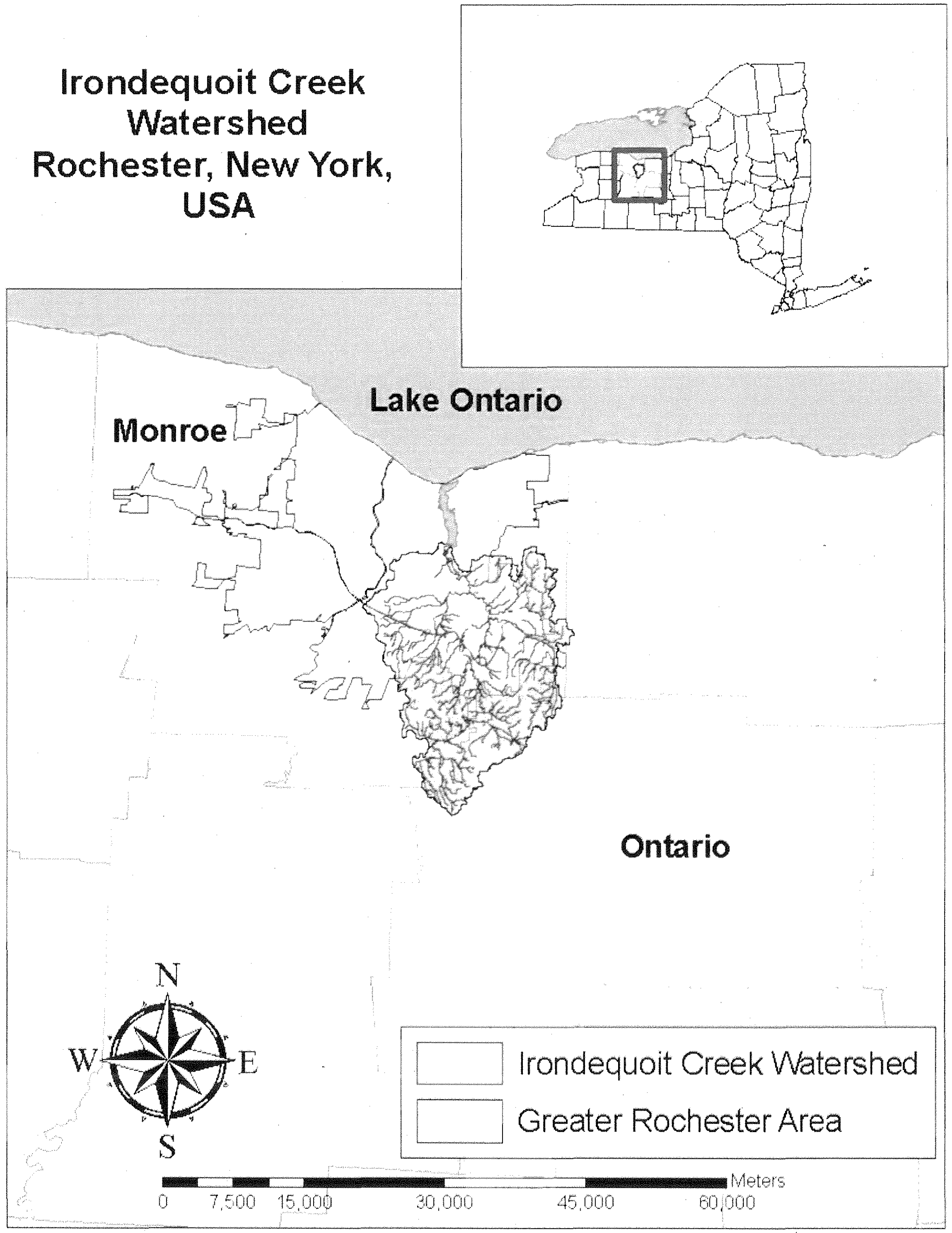

Figure 2. General map of study area; including Lake Ontario, New York State, Monroe County, Rochester, and Irondequoit Creek Watershed.

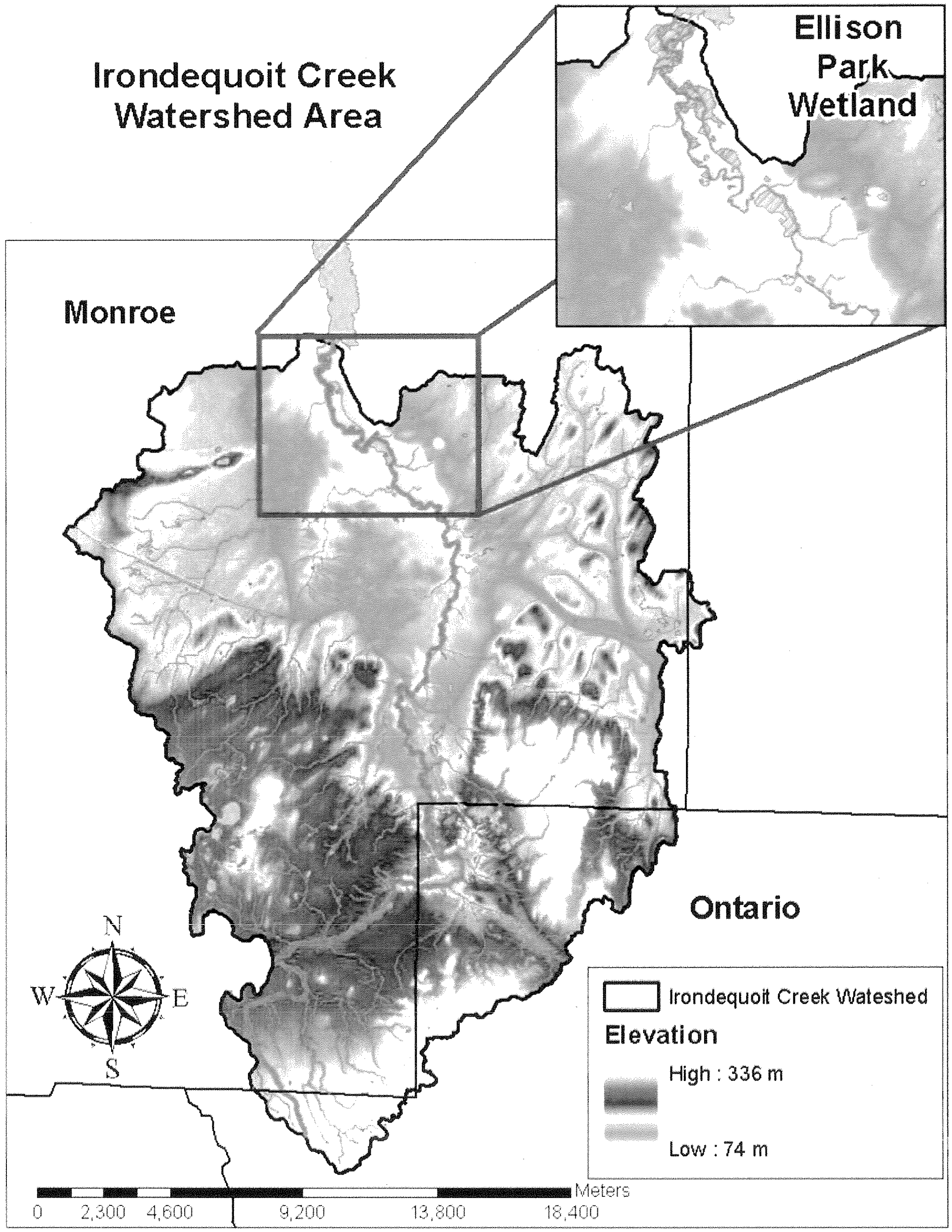

Figure 3. Map of Irondequoit Creek Watershed, highlighting the steep elevations in the headwaters and low elevation areas containing Ellison Park Wetland.

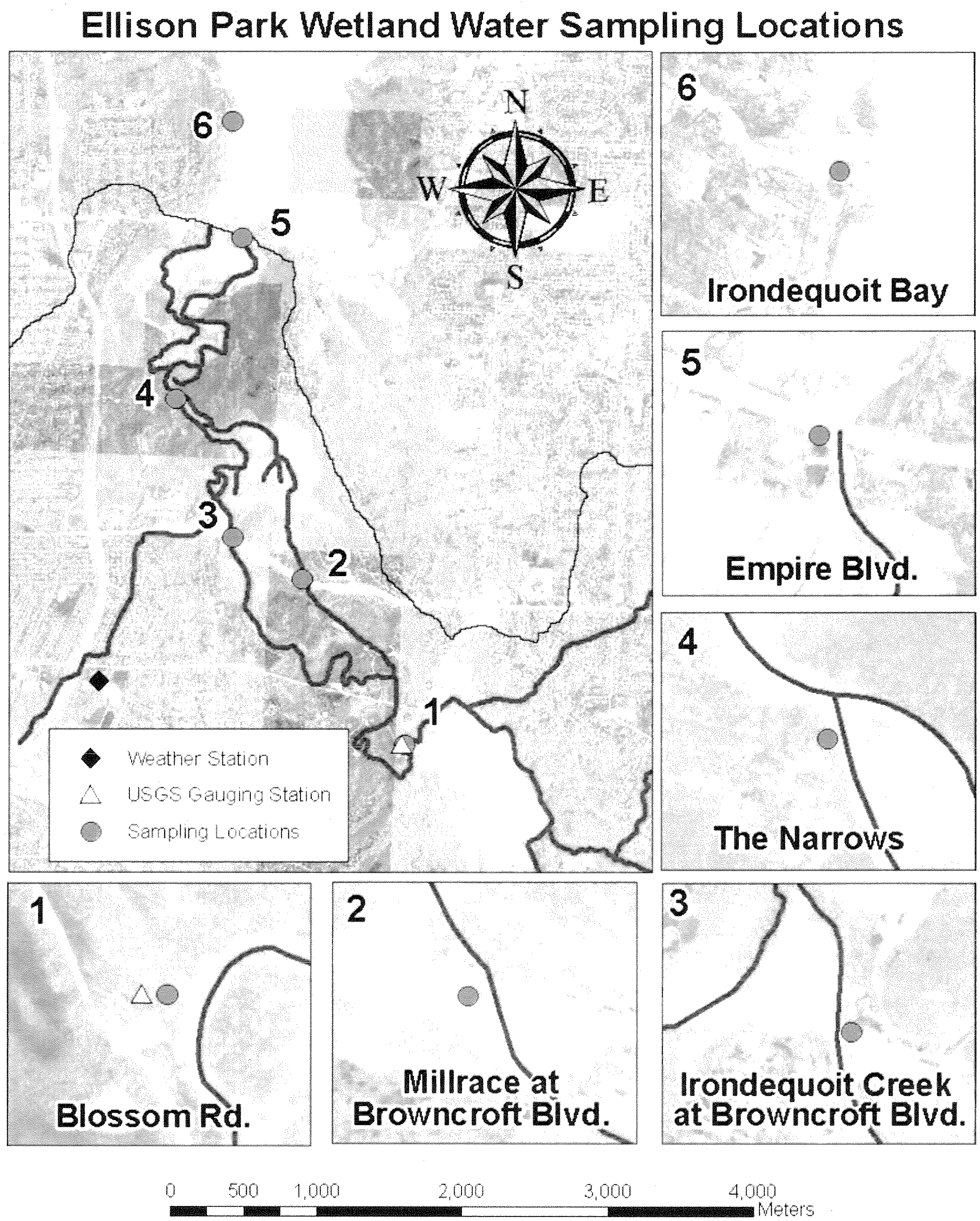

Figure 4. Map of the six water sample locations chosen on Irondequoit Creek to examine water quality as it passes through Ellison Park Wetland.

Figure 5. Blossom Road sample location. Picture facing upstream at sample location.

Figure 6. Irondequoit Creek branch sample location near Browncroft Boulevard. Picture facing upstream at sample location.

Figure 7. Millrace branch sample location near Browncroft Boulevard. Picture facing upstream at sample location.

Figure 8. Narrows sample location. Picture facing downstream at sample location.

Figure 9. View from the Empire Boulevard bridge sample location. Picture facing upstream from sample location.

Figure 10. Irondequoit Bay sample location. Picture facing downstream of sample location.

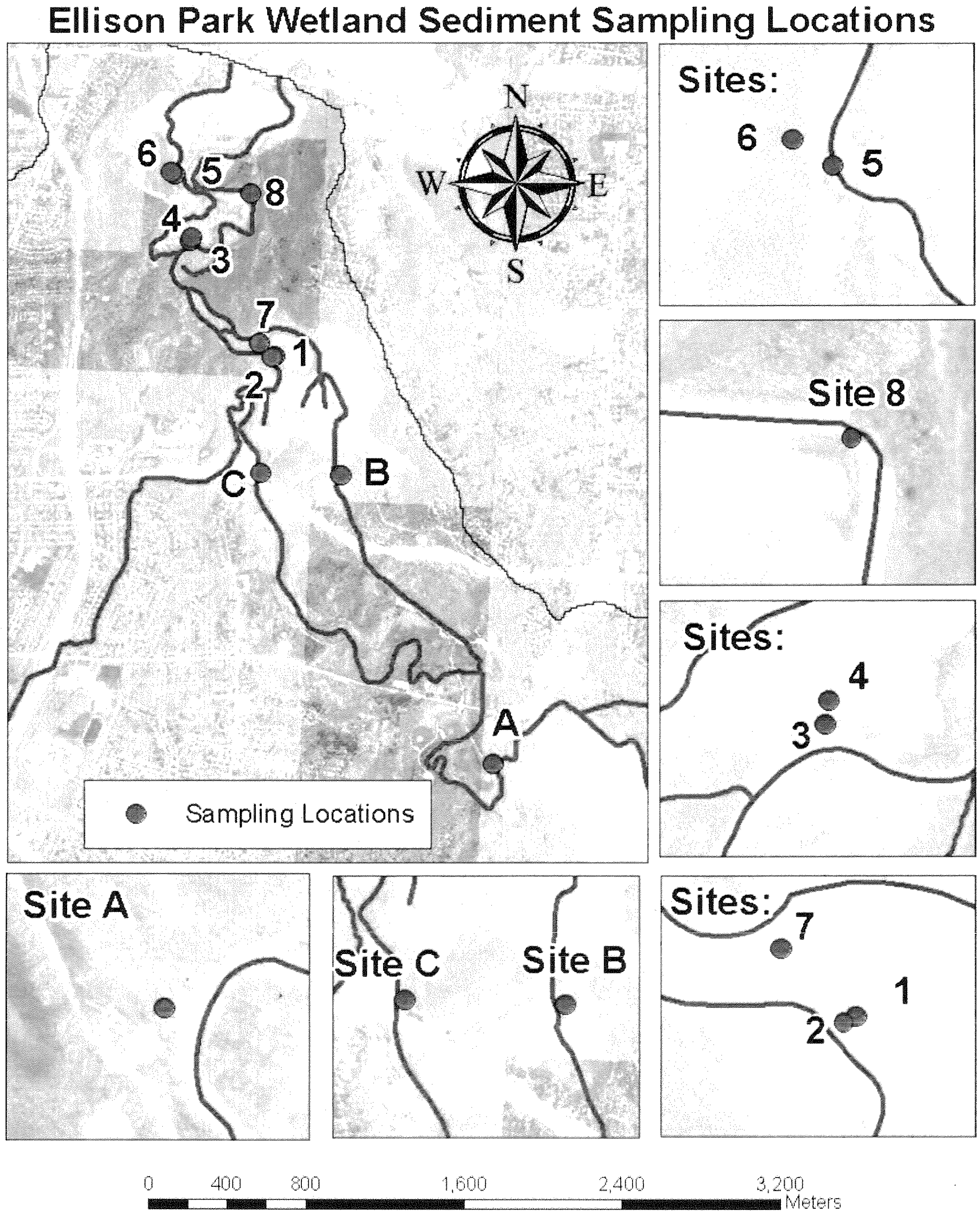

Figure 11. Map of the eleven sediment sampling locations chosen to represent various hydrologic connections within and near Ellison Park Wetland.

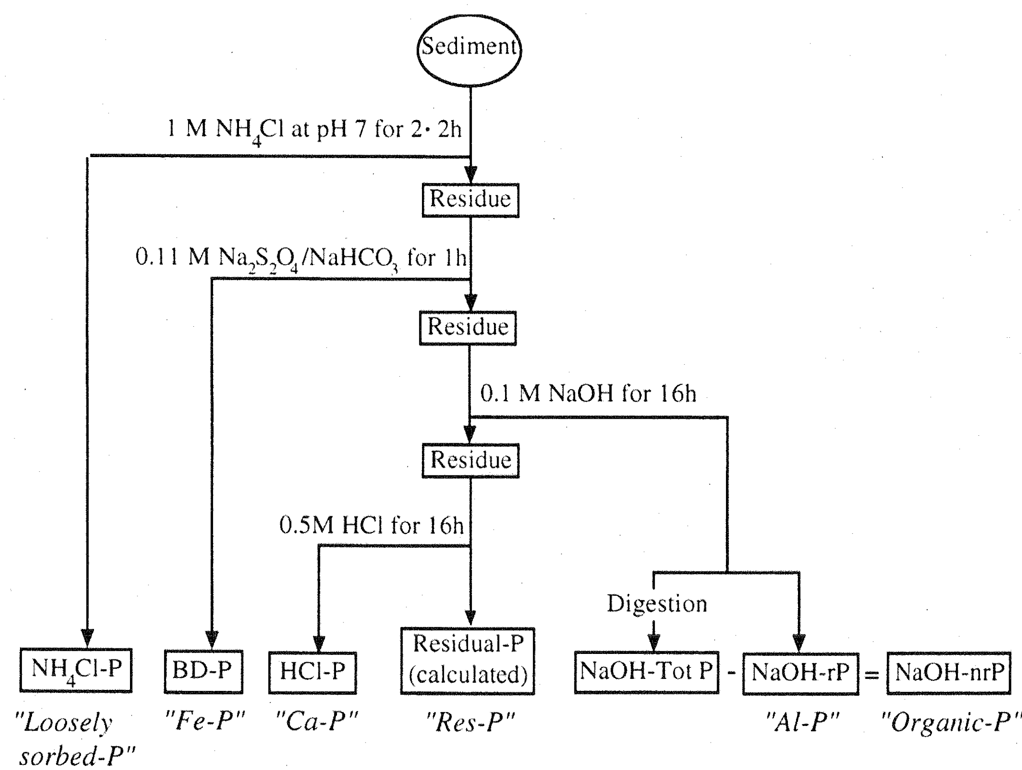

Figure 12. Phosphorus sequential extraction method used to identify P fraction associations in sediment; modified by Rydin (2000).

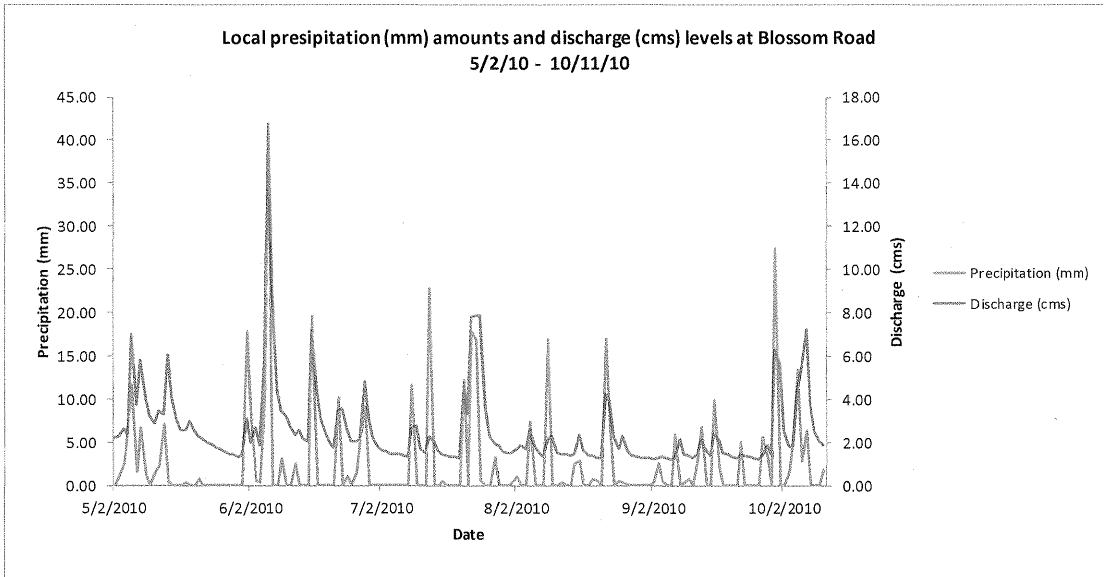

Figure 13. This figure shows the relationship and influence precipitation has on discharge levels. Precipitation data from local Weatherbug weather station located at Our Lady of Mercy High School and discharge data retreived from USGS gauging station 0423205010 located on Irondequoit Creek near Blossom Road.

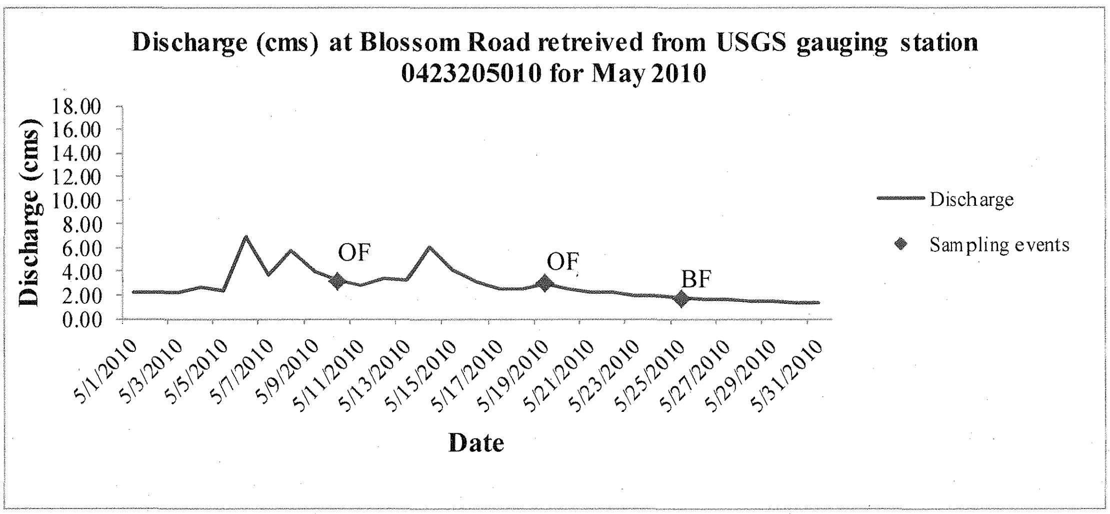

Figure 14. Discharge (cms) at Blossom Road and sampling events for May 2010. Event type is labeled above each sample event (SF = stormflow, OF = other flow, BF = baseflow).

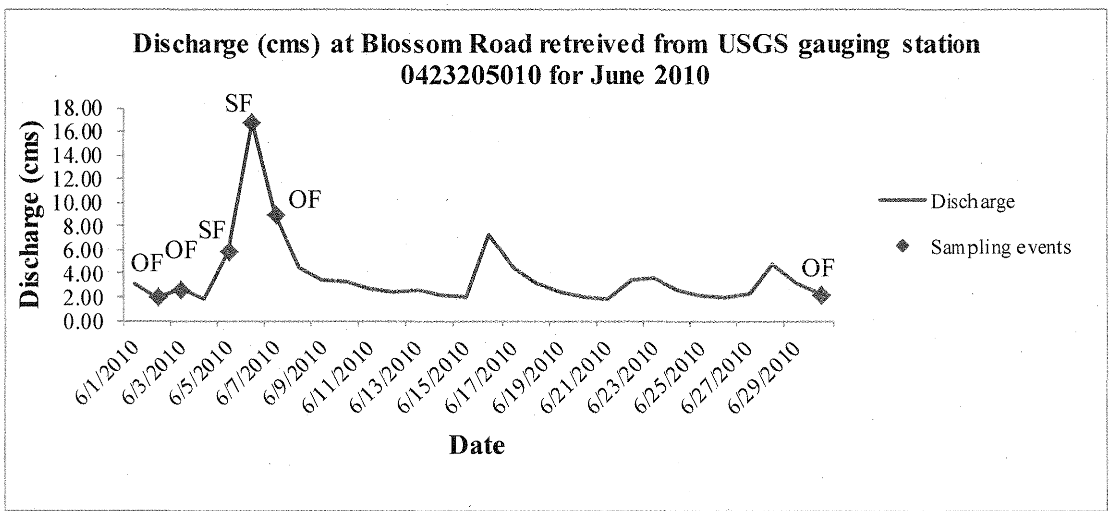

Figure 15. Discharge (cms) at Blossom Road and sampling events for June 2010. Event type is labeled above each sample event (SF = stormflow, OF = other flow, BF = baseflow).

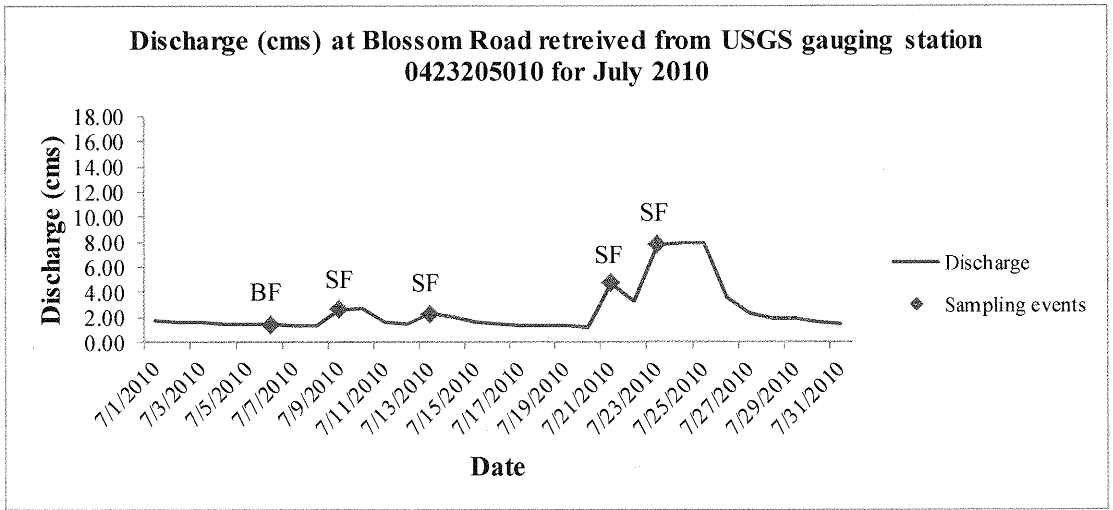

Figure 16. Discharge (cms) at Blossom Road and sampling events for July 2010. Event type is labeled above each sample event (SF = stormflow, OF = other flow, BF = baseflow).

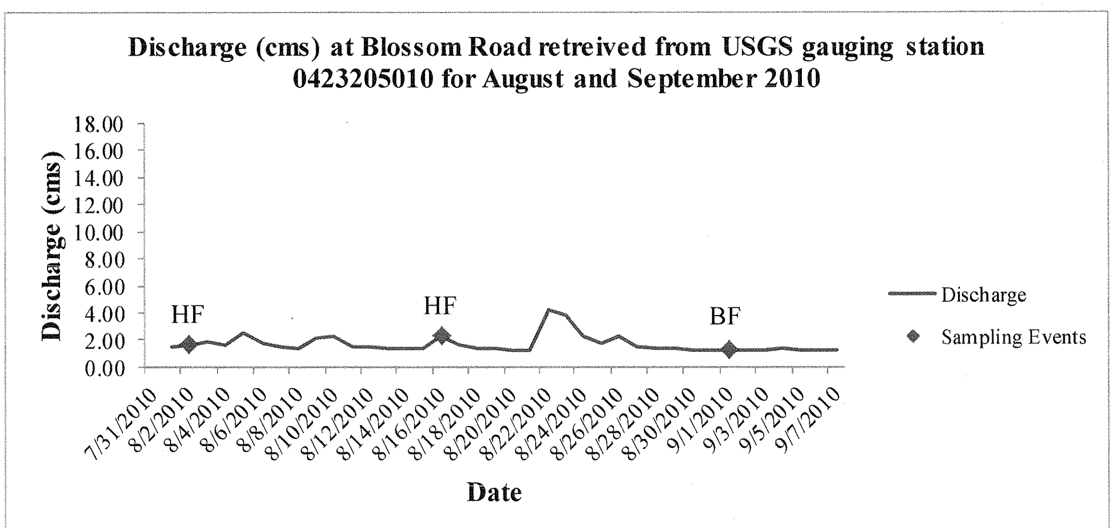

Figure 17. Discharge (cms) at Blossom Road and sampling events for August and September 2010. Event type is labeled above each sample event (SF = stormflow, OF = other flow, BF = baseflow).

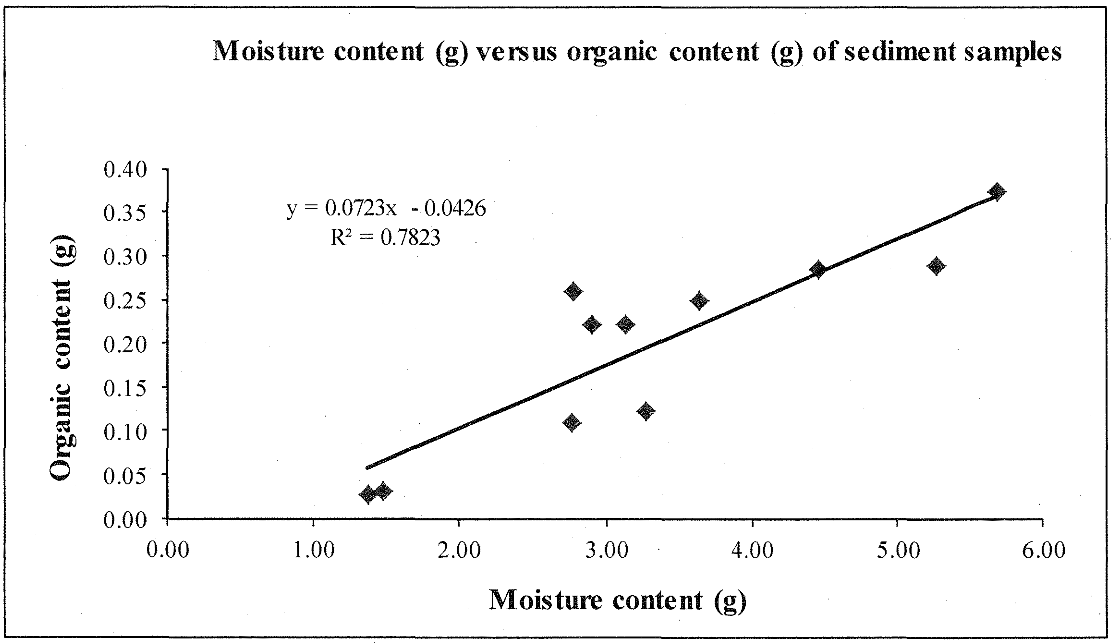

Figure 18. Moisture content versus organic content of sediment samples determined through drying and LOI methods.

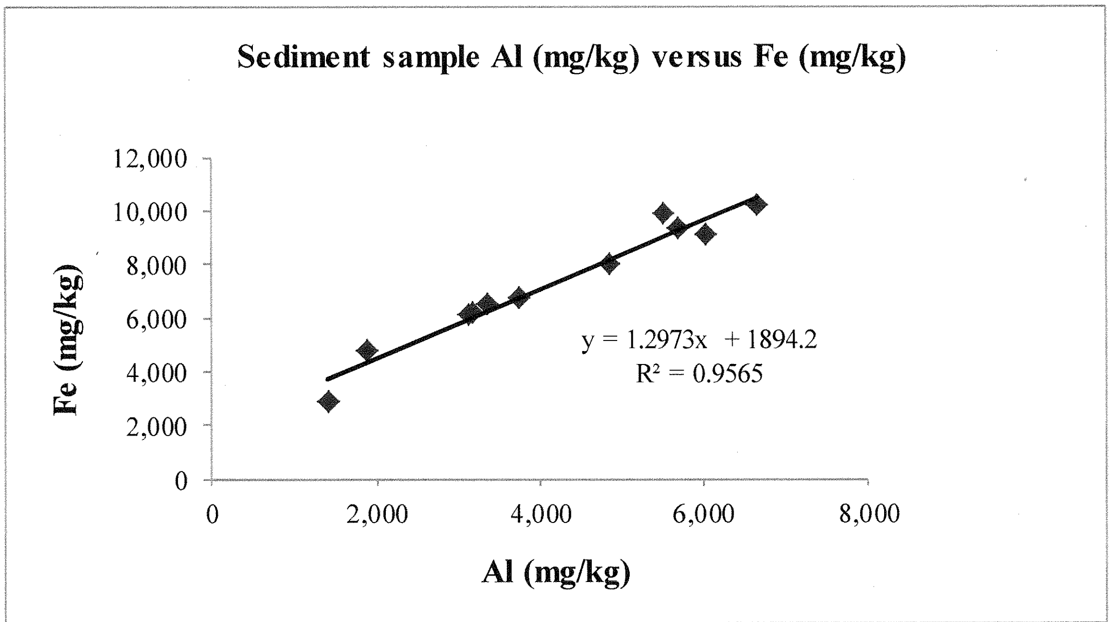

Figure 19. Sediment sample results from ICP analysis show a high correlation (R^2 = 0.9565) between Al (mg/kg) and Fe (mg/kg).

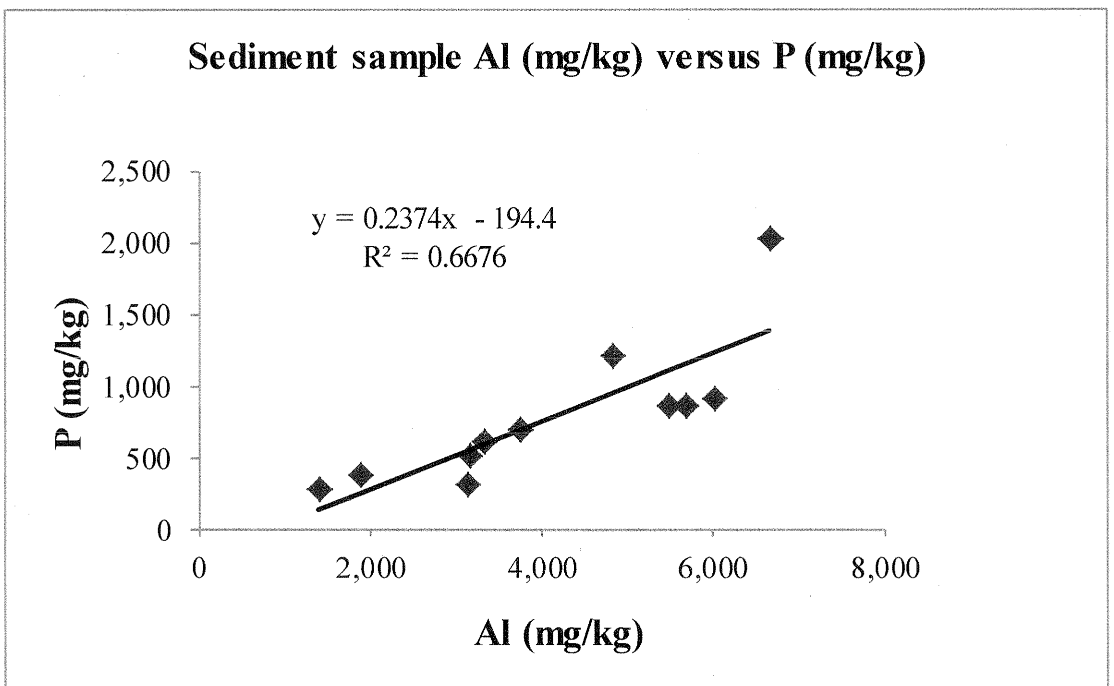

Figure 20. Sediment sample results from ICP analysis show a moderate correlation (R^2 = 0.6676) between Al (mg/kg) and P (mg/kg).

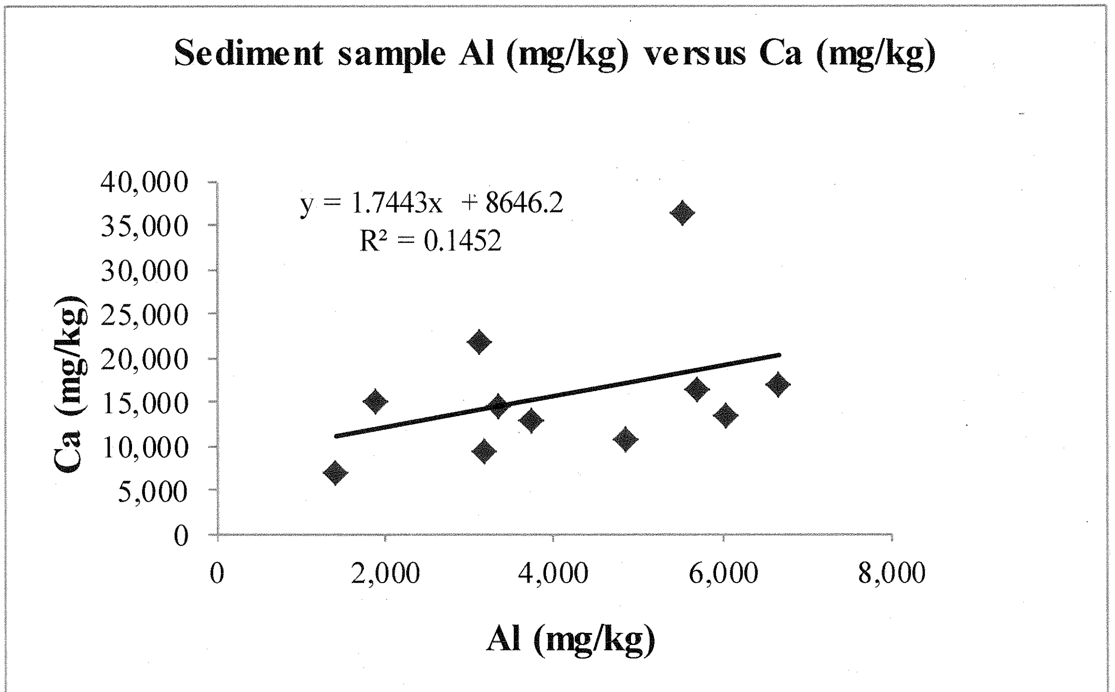

Figure 21. Sediment sample results from ICP analysis show very little correlation ($R^2 = 0.1452$) between Al (mg/kg) and Ca (mg/kg).

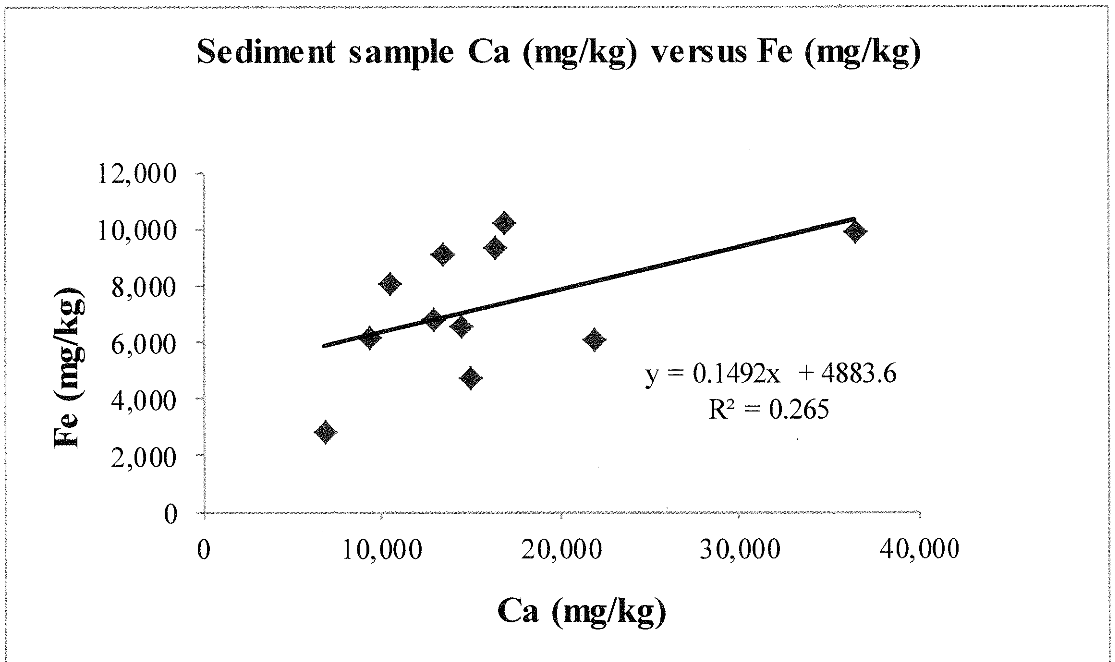

Figure 22. Sediment sample results from ICP analysis show very little correlation (R^2 = 0.2650) between Ca (mg/kg) and Fe (mg/kg).

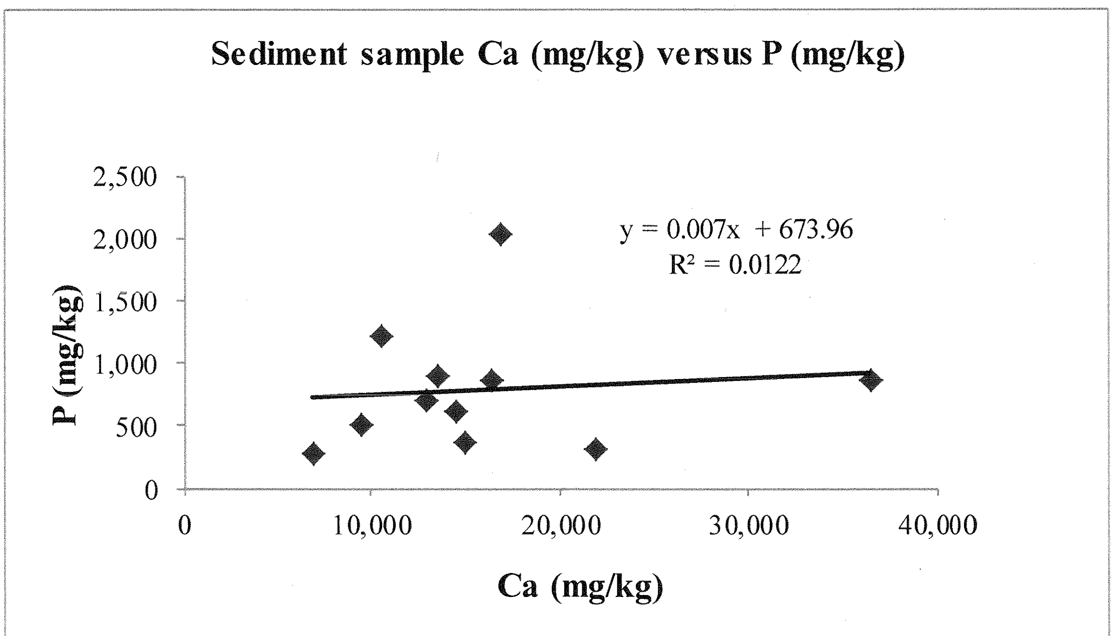

Figure 23. Sediment sample results from ICP analysis show very little correlation (R^2 = 0.0122) between Ca (mg/kg) and P (mg/kg).

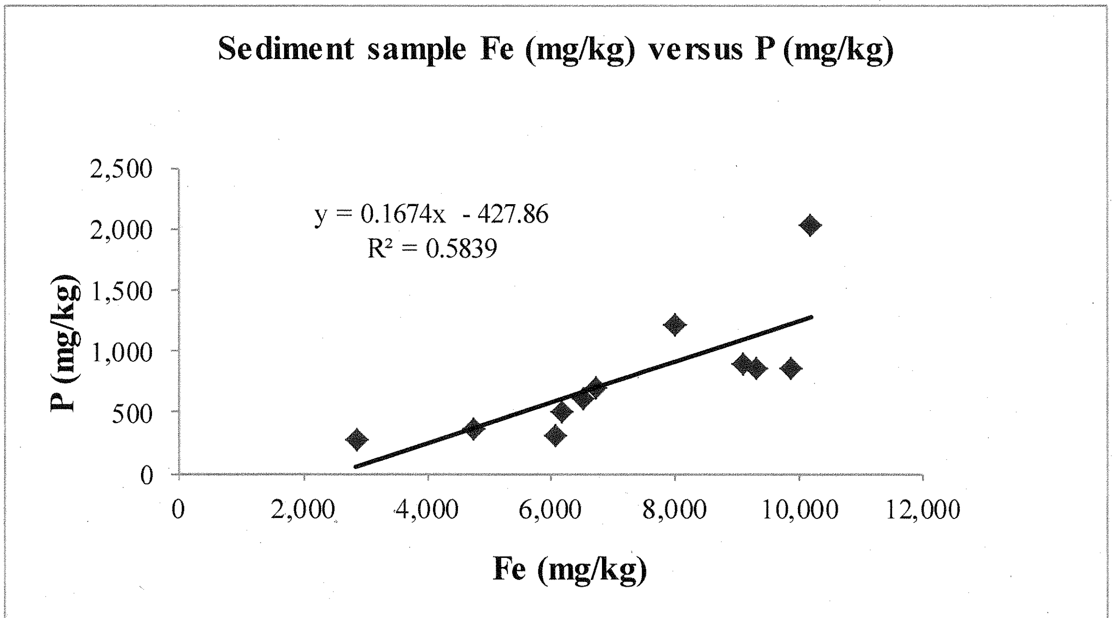

Figure 24. Sediment sample results from ICP analysis show a moderate correlation ($R^2 = 0.5839$) between Fe (mg/kg) and P (mg/kg).

Appendix

Appendix 1. Standard operating procedures for sample collection and analysis.

Sample type	Parameter	Procedures
Water	Collection and Transport	Water was collected in 500 mL acid-washed polyethelyne bottles. Sample collection equipment were given a river rinse prior to sample collection. Samples were transported within a cooler of ice.
	Field Replicate	One field replicate sample was collected on most sample rounds representing 8% of all data collected. A duplicate sample was collected in the same manner as all other samples and stored in its own bottle.
	Conductivity	Quanta G Hydrolab was calibrated within 24 hours of use prior to sampling.
	TSS	250 mL of water was filtered with a Fisherbrand 0.45 μm pore size membrane nylon filter. Filters were weighed to the ten thousandths decimal place prior to filteration and sample was dried to constant weight at 60° Celsius.
	SRP	Samples were filtered immediately once back in the laboratory and were analyzed within 24 hours of collection. The ascorbic acid method was used, Method 4500-PE (APHA 1998). A control chart was created and standards were checked to be within three standard deviations of the mean.
	TDP	Samples were filtered immediately once back in the laboratory and digested within 24 hours of collection. The persulfate digestion, Method 4500-P B5 (APHA 1998) and ascorbic acid analytical method, Method 4500-PE (APHA 1998) were used. Samples were refrigerated until analyzed, analysis taking place within one month of collection.
	TP	Samples were digested within 24 hours of collection. The persulfate digestion, Method 4500-P B5 (APHA 1998) and ascorbic acid analytical method, Method 4500-PE (APHA 1998) were used. Samples were refrigerated until analyzed, analysis taking place within one month of collection.
	Metal and ion	Samples were digested within 24 hours of collection. The nitric acid digestion method, Method SW846 3005A, (USEPA 1996) and analysis method, Method SW846 6010C (USEPA 1996).
Sediment	Collection and Transport	Samples were collected by combining at least six scoops of soil within a one meter radius of a central location. Samples were stored in a plastic bag. Samples were transported within a cooler of ice and then frozen until further analysis.
	Moisture Content	Approximately 5 g of sample were dried in a 60° Celsius oven to a constant weight.
	Organic Content	Dried samples used to determine moisture content were placed in a 350° Celsius muffle furnace for 16 hours.
	Phosphorus	Sequential extraction method modified by Rydin (2000). Modifications include using a 1-M sodium chloride solution was used instead of ammonium chloride solution during the first extraction, and using a 0.1-M sodium chloride wash between extractions.
	Metal and ion	Approximately 0.5 g of samples were digested using method SW846 3050B (USEPA 1996), modified to use only nitric acid. Samples were filtered using with a Fisherbrand 0.45 μm pore size membrane nylon filter. Samples were analyzed using SW846 6010C (USEPA 1996).

Appendix 2. U.S. Department of Agriculture definitions of organic soil material (USDA 2010).

Kinds of Organic Soil Materials

Three different kinds of organic soil materials are distinguished in this taxonomy, based on the degree of decomposition of the plant materials from which the organic materials are derived. The three kinds are (1) fibric, (2) hemic, and (3) sapric. Because of the importance of fiber content in the definitions of these materials, fibers are defined before the kinds of organic soil materials.

Fibers

Fibers are pieces of plant tissue in organic soil materials (excluding live roots) that:
1. Are large enough to be retained on a 100-mesh sieve (openings 0.15 mm across) when the materials are screened; *and*
2. Show evidence of the cellular structure of the plants from which they are derived; *and*
3. Either are 2 cm or less in their smallest dimension or are decomposed enough to be crushed and shredded with the fingers.

Pieces of wood that are larger than 2 cm in cross section and are so undecomposed that they cannot be crushed and shredded with the fingers, such as large branches, logs, and stumps, are not considered fibers but are considered coarse fragments (comparable to gravel, stones, and boulders in mineral soils).

Fibric Soil Materials

Fibric soil materials are organic soil materials that *either*:
1. Contain three-fourths or more (by volume) fibers after rubbing, excluding coarse fragments; *or*
2. Contain two-fifths or more (by volume) fibers after rubbing, excluding coarse fragments, and yield color values and chromas of 7/1, 7/2, 8/1, 8/2, or 8/3 (fig. 2) on white chromatographic or filter paper that is inserted into a paste made of the soil materials in a saturated sodium-pyrophosphate solution.

Hemic Soil Materials

Hemic soil materials (Gr. *hemi*, half; implying intermediate decomposition) are intermediate in their degree of decomposition between the less decomposed fibric and more decomposed sapric materials. Their morphological features give intermediate values for fiber content, bulk density, and water content. Hemic soil materials are partly altered both physically and biochemically.

Sapric Soil Materials

Sapric soil materials (Gr. *sapros*, rotten) are the most highly decomposed of the three kinds of organic soil materials. They have the smallest amount of plant fiber, the highest bulk density, and the lowest water content on a dry-weight basis at saturation. Sapric soil materials are commonly very dark gray to black.

They are relatively stable; i.e., they change very little physically and chemically with time in comparison to other organic soil materials. Sapric materials have the following characteristics:
1. The fiber content, after rubbing, is less than one-sixth (by volume), excluding coarse fragments; *and*
2. The color of the sodium-pyrophosphate extract on white chromatographic or filter paper is below or to the right of a line drawn to exclude blocks 5/1, 6/2, and 7/3 (fig. 2). If few or no fibers can be detected and the color of the pyrophosphate extract is to the left of or above this line, the possibility that the material is limnic must be considered.

Appendix 3. Water sample SRP, TDP, TP, TSS, and conductivity results.

Sample	Date Collected	Time Collected	*SE/HF/BF	Water Temp	SRP	TDP	PP	TP	TSS	Conductivity
Units				C	µg/L	µg/L	µg/L	µg/L	mg/L	µS/cm
Blossom	05/10/10	920	HF	8.63	23.95	23.00	16.67	39.67	0.90	1013
Millrace	05/10/10	940	HF	10.21	21.57	26.83	17.00	43.83	1.25	990
IC at Bwn	05/10/10	1015	HF	9.07	39.53	20.83	27.50	48.33	0.85	1010
Narrows	05/10/10	1045	HF	10.03	23.65	25.50	19.33	44.83	0.80	1009
Empire	05/10/10	1110	HF	11.28	22.76	27.67	14.00	41.67	0.60	988
Narrows dup	05/10/10	1045	HF	10.03	24.54	25.33	12.50	37.83	0.70	1009
Blossom	05/19/10	830	HF	13.16	17.49	21.83	38.33	60.17	3.60	981
Millrace	05/19/10	845	HF	13.79	18.08	22.17	32.00	54.17	2.15	1009
IC at Bwn	05/19/10	900	HF	13.37	21.17	26.00	32.00	58.00	1.95	1014
Narrows	05/19/10	930	HF	14.13	21.17	30.50	41.33	71.83	2.05	1028
Empire	05/19/10	945	HF	15.24	15.28	22.50	42.83	65.33	3.85	1048
Bay	05/19/10	1000	HF	17.37	11.89	23.17	80.83	104.00	7.50	1030
blossom dup	05/19/10	830	HF	13.16	17.19	26.83	29.67	56.50	1.85	981
Blossom	05/25/10	930	BF	19.24	9.87	30.33	34.83	65.17	2.40	1184
Millrace	05/25/10	940	BF	19.46	10.87	32.83	22.33	55.17	1.70	1196
IC at Bwn	05/25/10	950	BF	19.42	10.01	31.33	18.17	49.50	1.80	1186
Narrows	05/25/10	1015	BF	20.71	8.15	26.17	43.33	69.50	3.90	1192
Empire	05/25/10	1030	BF	22.23	5.01	BDL	86.67	88.67	3.30	1175
Bay	05/25/10	1040	BF	26.82	BDL	19.67	239.67	259.33	9.80	1094
Blossom	06/02/10	1600	HF	21.74	BDL	32.01	25.45	57.47	Not Measured	1168
Millrace	06/02/10	1610	HF	21.85	5.17	22.27	35.62	57.90	Not Measured	1149
IC at Bwn	06/02/10	1625	HF	21.59	5.83	28.31	40.46	68.77	Not Measured	1149
Empire	06/02/10	1645	HF	24.48	18.17	24.42	56.80	81.22	Not Measured	1090
Bay	06/02/10	1700	HF	27.38	13.83	32.29	102.10	134.39	Not Measured	1253
Blossom	06/03/10	900	HF	19.66	32.33	33.29	52.07	85.36	9.50	1065
Millrace	06/03/10	920	HF	19.62	34.00	48.00	54.25	102.25	10.80	1073
IC at Bwn	06/03/10	935	HF	19.54	17.83	31.43	70.24	101.67	10.10	1096
Narrows	06/03/10	950	HF	20.02	40.33	33.43	55.51	88.94	6.20	1127
Empire	06/03/10	1005	HF	20.75	15.17	32.00	64.09	96.09	8.20	1147
Bay	06/03/10	1015	HF	24.23	17.83	33.50	56.30	89.80	3.50	1143
Blossom dup	06/03/10	900	HF	19.66	31.33	33.86	67.81	101.67	9.00	1065
Blossom	06/05/10	1940	SE	21.20	30.71	44.17	189.83	234.00	Not Measured	849
Millrace	06/05/10	1950	SE	21.38	32.91	31.72	14.95	46.67	Not Measured	790
IC at Bwn	06/05/10	2000	SE	21.36	31.34	47.00	192.33	239.33	Not Measured	783
Empire	06/05/10	2010	SE	22.26	28.18	39.00	11.89	50.89	Not Measured	784
Bay	06/05/10	2020	SE	26.08	28.18	48.00	142.33	190.33	Not Measured	1091
Blossom	06/06/10	740	SE	18.67	93.00	40.01	153.48	193.49	Not Measured	630
Millrace	06/06/10	650	SE	19.06	33.00	61.67	3.24	64.91	Not Measured	823
IC at Bwn	06/06/10	700	SE	19.17	41.11	17.27	37.73	55.00	Not Measured	825
Empire	06/06/10	710	SE	19.36	35.67	45.67	124.67	170.33	Not Measured	866
Bay	06/06/10	720	SE	20.81	60.00	92.83	335.50	428.33	Not Measured	838
Empire dup	06/06/10	710	SE	19.36	44.33	64.33	93.52	157.85	Not Measured	866
Blossom	06/06/10	930	SE	18.19	34.83	59.61	14.06	73.67	Not Measured	378
Millrace	06/06/10	830	SE	18.51	51.52	40.87	Unknown	Missing	Not Measured	599
IC at Bwn	06/06/10	840	SE	18.59	58.33	60.19	0.48	60.67	Not Measured	633
Empire	06/06/10	855	SE	18.95	57.19	68.17	163.51	231.67	Not Measured	781
Bay	06/06/10	900	SE	21.38	23.17	46.45	58.66	105.11	Not Measured	967
Millrace dup	06/06/10	830	SE	18.51	41.74	36.29	22.88	59.17	Not Measured	599
Blossom	06/07/10	905	HF	16.75	57.82	95.24	15.76	111.00	25.00	621
Millrace	06/07/10	915	HF	16.79	43.32	50.17	50.36	100.53	12.60	683
IC at Bwn	06/07/10	925	HF	17.01	41.11	52.00	94.70	146.70	31.40	676
Narrows	06/07/10	940	HF	17.21	44.26	55.33	229.33	284.67	26.40	678
Empire	06/07/10	1000	HF	17.53	46.47	56.17	55.95	112.12	23.40	645
Bay	06/07/10	1005	HF	19.21	40.64	55.50	78.67	134.17	3.90	604
Narrows dup	06/07/10	940	HF	17.21	28.67	68.33	74.64	142.98	28.40	678
Blossom	06/30/10	945	HF	17.68	22.63	39.16	50.35	89.51	6.30	1250
Millrace	06/30/10	1000	HF	17.65	23.86	41.44	29.04	70.49	4.60	1235
IC at Bwn	06/30/10	1015	HF	17.84	25.26	42.02	39.77	81.79	5.10	1242
Narrows	06/30/10	1030	HF	18.81	28.25	43.59	33.91	77.50	4.60	1253
Empire	06/30/10	1040	HF	19.31	29.66	44.16	43.63	87.80	5.40	1203
Bay	06/30/10	1050	HF	24.56	BDL	12.40	34.91	47.31	4.40	1128
Narrows dup	06/30/10	1030	HF	18.81	27.38	42.88	36.34	79.21	4.30	1253

Appendix 3 continued.

Sample	Date Collected	Time Collected	*SE/HF/BF	Water Temp	SRP	TDP	PP	TP	TSS	Conductivity
Units				C	µg/L	µg/L	µg/L	µg/L	mg/L	µS/cm
Blossom	07/06/10	1305	BF	22.93	5.45	38.01	9.73	47.74	1.70	1367
Millrace	07/06/10	1240	BF	24.61	9.62	31.00	12.59	43.59	1.30	1374
IC at Bwn	07/06/10	1250	BF	23.69	8.28	32.29	15.45	47.74	1.40	1369
Narrows	07/06/10	1220	BF	26.57	BDL	26.28	58.08	84.36	3.30	1380
Empire	07/06/10	1200	BF	27.17	BDL	40.87	19.60	60.47	1.60	1303
Bay	07/06/10	1210	BF	30.86	BDL	18.56	53.79	72.35	5.90	1122
Empire dup	07/06/10	1200	BF	27.17	BDL	27.14	31.47	58.61	2.40	1303
Blossom	07/09/10	1800	SE	24.17	36.29	40.13	67.55	107.68	9.60	958
Millrace	07/09/10	1820	SE	23.83	26.78	32.01	14.64	46.65	3.00	1150
IC at Bwn	07/09/10	1830	SE	23.67	24.53	30.83	124.24	155.07	6.00	1163
Empire	07/09/10	1840	SE	26.15	17.60	54.66*	121.62	176.28	8.30	1205
Bay	07/09/10	1850	SE	28.93	21.79	28.31	76.73	105.04	6.80	1093
Empire dup	07/09/10	1840	SE	26.15	14.38	28.20	104.79	132.99	10.70	1205
Blossom	07/13/10	1530	SE	22.92	36.28	56.06	113.73	169.79	4.90	1155
Millrace	07/13/10	1540	SE	23.21	42.87	108.46	36.45	144.91	5.10	1086
IC at Bwn	07/13/10	1600	SE	23.04	75.16	94.81	75.32	170.12	29.00	931
Empire	07/13/10	1615	SE	24.96	42.54	72.01	72.02	144.03	3.50	1099
Bay	07/13/10	1620	SE	26.84	17.17	56.18	45.68	101.86	7.30	964
Millrace dup	07/13/10	1540	SE	23.21	44.85	63.42	117.94	181.36	3.80	1086
Blossom	07/21/10	1350	SE	21.92	33.37	59.39	33.12	92.51	1.30	1126
Millrace	07/21/10	1400	SE	22.26	33.04	46.42	61.86	108.28	1.70	1130
IC at Bwn	07/21/10	1410	SE	22.14	52.13	144.03	37.84	181.87	11.10	1050
Narrows	07/21/10	1420	SE	23.82	32.38	41.87	77.98	119.85	3.30	1137
Empire	07/21/10	1440	SE	24.69	33.04	43.27	98.48	141.75	3.30	1134
Bay	07/21/10	1445	SE	27.33	9.34	28.02	110.05	138.07	6.00	927
Narrows dup	07/21/10	1420	SE	23.82	31.39	41.87	84.11	125.98	3.40	1137
Blossom	07/23/10	825	SE	21.15	45.03	124.23	38.73	162.96	24.70	804
Millrace	07/23/10	745	SE	21.16	32.05	56.59	65.71	122.30	4.50	916
IC at Bwn	07/23/10	755	SE	21.12	35.23	67.63	157.00	224.63	11.00	868
Narrows	07/23/10	810	SE	21.41	35.64	70.43	90.25	160.68	6.00	906
Empire	07/23/10	835	SE	22.17	37.58	74.46	251.45	325.92	4.80	814
Bay	07/23/10	845	SE	24.76	6.24	95.84	78.68	174.52	6.50	847
IC at Bwn dup	07/23/10	755	SE	21.12	34.40	65.70	124.58	190.28	10.70	868
Blossom	08/02/10	955	HF	20.21	31.00	40.32	22.57	62.89	1.30	1162
Millrace	08/02/10	1005	HF	21.66	34.10	48.12	19.25	67.37	0.80	1167
IC at Bwn	08/02/10	1020	HF	21.17	29.60	44.97	23.23	68.20	1.00	1165
Narrows	08/02/10	1030	HF	22.56	30.22	47.79	44.64	92.42	2.30	1168
Empire	08/02/10	1045	HF	23.47	32.39	122.79	50.77	173.56	2.50	1161
Bay	08/02/10	1050	HF	26.94	8.99	28.21	120.80	149.01	7.60	919
Blossom dup	08/02/10	955	HF	20.21	35.96	40.65	19.91	60.56	1.50	1162
Blossom	08/16/10	930	HF	20.74	36.87	104.37	36.67	141.04	6.10	1143
Millrace	08/16/10	940	HF	21.16	33.73	101.55	58.08	159.63	2.40	1164
IC at Bwn	08/16/10	950	HF	21.17	30.58	91.59	42.98	134.57	3.50	1165
Narrows	08/16/10	1000	HF	22.09	35.87	39.49	69.03	108.52	2.30	1164
Empire	08/16/10	1020	HF	22.75	24.47	51.11	77.99	129.09	3.00	1175
Bay	08/16/10	1030	HF	26.71	BDL	76.83	60.90	137.72	4.70	997
IC at Bwn dup	08/16/10	950	HF	21.17	29.59	89.77	32.19	121.96	3.10	1165
Blossom	09/01/10	1000	BF	20.48	BDL	9.29	32.52	41.81	0.30	1182
Millrace	09/01/10	1010	BF	21.67	BDL	11.28	29.04	40.32	0.70	1151
IC at Bwn	09/01/10	1020	BF	21.55	BDL	17.09	5.64	22.73	0.80	1147
Narrows	09/01/10	1030	BF	22.86	BDL	16.09	27.38	43.47	1.90	1165
Empire	09/01/10	1045	BF	23.89	BDL	23.40	38.00	61.39	2.00	1175
Bay	09/01/10	1055	BF	26.26	BDL	8.63	18.75	27.38	8.90	926
Empire dup	09/01/10	1045	BF	23.89	BDL	16.76	41.32	58.08	2.00	1175

Appendix 4. Water sample Al, Ca, Fe, K, Mg, Mn, and Na from ICP analysis; *TP presented from Beckman spectrophotometer analysis.

Sample	Date	Time	Al	Ca	Fe	K	Mg	Mn	Na	TP*
			ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Blossom	5/10/2010	920	0.845	105.00	0.078	3.317	32.84	0.018	86.15	0.0397
Millrace	5/10/2010	940	0.750	79.17	0.295	2.499	24.44	0.061	70.74	0.0438
IC at BWN	5/10/2010	1015	1.140	96.74	0.129	3.069	30.16	0.026	81.61	0.0483
Narrows	5/10/2010	1045	0.975	88.96	0.211	2.878	27.60	0.048	76.72	0.0448
Empire	5/10/2010	1110	0.817	74.30	0.131	2.483	23.50	0.028	71.93	0.0417
Narrows dup	5/10/2010	1045	0.906	83.18	0.160	2.859	26.51	0.040	78.22	0.0378
Blossom	5/19/2010	830	1.047	110.40	0.756	3.609	33.45	0.134	94.56	0.0602
Millrace	5/19/2010	845	0.674	90.47	0.266	3.140	28.06	0.051	81.52	0.0542
IC at BWN	5/19/2010	900	1.093	116.10	0.293	3.993	34.81	0.052	92.95	0.0580
Narrows	5/19/2010	930	0.553	79.09	0.629	2.736	24.30	0.123	75.61	0.0718
Empire	5/19/2010	945	0.980	112.20	0.107	3.794	33.97	0.017	95.85	0.0653
Bay	5/19/2010	1000	0.989	77.01	0.428	2.602	24.60	0.064	71.90	0.1040
Blossom dup	5/19/2010	830	0.762	86.25	0.677	2.898	26.74	0.114	78.20	0.0565
Blossom	5/25/2010	930	0.736	95.79	0.454	3.145	30.29	0.116	84.57	0.0652
Millrace	5/25/2010	940	0.459	78.11	0.300	2.291	24.85	0.110	68.88	0.0552
IC at BWN	5/25/2010	950	0.563	95.90	0.329	3.097	30.19	0.127	83.83	0.0495
Narrows	5/25/2010	1015	0.621	76.23	0.518	2.559	24.58	0.140	67.98	0.0695
Empire	5/25/2010	1030	0.712	78.17	0.806	2.622	25.35	0.157	72.20	0.0887
Bay	5/25/2010	1040	0.943	65.66	0.793	2.650	25.50	0.111	72.10	0.2593
Blossom	6/2/2010	1600	0.603	69.81	0.340	2.979	22.38	0.095	60.95	0.0575
Millrace	6/2/2010	1610	0.641	70.51	0.337	2.962	22.50	0.107	60.23	0.0579
IC at BWN	6/2/2010	1625	0.667	74.87	0.319	3.079	22.96	0.121	62.09	0.0688
Empire	6/2/2010	1645	0.666	64.63	0.504	3.092	21.08	0.134	58.02	0.0812
Bay	6/2/2010	1700	0.891	65.69	0.945	2.342	18.47	0.135	47.52	0.1344
Blossom	6/3/2010	900	0.876	60.64	0.695	2.579	18.88	0.106	55.08	0.0854
Millrace	6/3/2010	920	0.892	66.23	0.780	2.954	20.42	0.112	60.02	0.1022
IC at BWN	6/3/2010	935	1.082	70.96	1.142	3.177	21.96	0.161	62.55	0.1017
Narrows	6/3/2010	950	1.034	70.62	0.824	3.161	21.32	0.134	61.80	0.0889
Empire	6/3/2010	1005	0.895	71.74	0.951	3.106	22.63	0.187	63.95	0.0961
Bay	6/3/2010	1015	0.656	66.71	0.625	3.442	22.83	0.167	60.40	0.0898
Blossom dup	6/3/2010	900	1.018	63.93	0.947	2.833	20.17	0.131	58.84	0.1017
Blossom	6/5/2010	1940	3.601	62.50	2.982	3.079	18.27	0.217	49.49	0.2340
Millrace	6/5/2010	1950	3.603	58.52	2.992	2.997	16.89	0.205	44.57	0.0467
IC at BWN	6/5/2010	2000	4.012	62.42	3.515	3.117	17.91	0.258	45.92	0.2393
Empire	6/5/2010	2010	2.715	58.72	1.653	2.646	16.32	0.120	45.16	0.0509
Bay	6/5/2010	2020	2.622	71.53	1.246	3.418	23.21	0.130	65.80	0.1903

Appendix 4 continued.

Sample	Date	Time	Al	Ca	Fe	K	Mg	Mn	Na	TP*
			ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Blossom	6/6/2010	740	6.236	50.97	5.908	3.317	14.37	0.516	48.45	0.1935
Millrace	6/6/2010	650	4.945	59.80	4.288	3.362	17.26	0.302	50.40	0.0649
IC at BWN	6/6/2010	700	4.476	62.35	3.917	3.646	18.31	0.289	55.48	0.0550
Empire	6/6/2010	710	3.938	65.42	1.834	3.059	18.88	0.189	53.27	0.1703
Bay	6/6/2010	720	3.431	61.52	1.524	3.092	18.08	0.161	51.97	0.4283
Empire dup	6/6/2010	710	1.577	61.19	1.695	2.924	17.93	0.184	50.97	0.1579
Blossom	6/6/2010	930	7.509	40.41	8.723	3.448	11.03	0.636	26.96	0.0737
Millrace	6/6/2010	830	6.427	50.19	6.646	3.460	14.21	0.503	45.48	Missing
IC at BWN	6/6/2010	840	6.808	54.15	6.598	3.483	15.02	0.495	43.37	0.0607
Empire	6/6/2010	855	3.220	54.46	2.693	3.158	15.25	0.201	51.09	0.2317
Bay	6/6/2010	900	2.116	69.14	1.267	3.143	20.81	0.164	58.92	0.1051
Millrace dup	6/6/2010	830	4.525	46.91	6.442	3.238	13.41	0.490	42.66	0.0592
Blossom	6/7/2010	905	4.375	54.30	4.005	3.667	16.57	0.236	47.75	0.1110
Millrace	6/7/2010	915	4.181	55.06	3.682	3.669	16.20	0.225	49.94	0.1005
IC at BWN	6/7/2010	925	4.579	54.33	4.241	3.747	16.28	0.255	48.35	0.1467
Narrows	6/7/2010	940	3.955	52.81	3.723	3.717	15.46	0.223	46.96	0.2847
Empire	6/7/2010	1000	3.554	52.38	2.758	3.479	14.75	0.160	47.48	0.1121
Bay	6/7/2010	1005	2.224	45.60	1.164	2.664	12.52	0.171	38.75	0.1342
Narrows dup	6/7/2010	940	4.566	55.20	4.018	4.028	16.43	0.246	50.38	0.1430
Blossom	6/30/2010	945	1.233	77.09	0.800	2.989	23.73	0.110	66.56	0.0895
Millrace	6/30/2010	1000	0.584	78.00	0.688	3.035	23.58	0.121	66.17	0.0705
IC at BWN	6/30/2010	1015	1.181	45.88	0.869	3.091	23.80	0.104	67.74	0.0818
Narrows	6/30/2010	1030	1.174	80.78	0.727	3.243	24.44	0.116	68.24	0.0775
Empire	6/30/2010	1040	1.151	76.58	0.773	3.108	22.88	0.138	63.80	0.0878
Bay	6/30/2010	1050	0.891	61.14	0.271	2.847	21.17	0.043	66.27	0.0473
Narrows dup	6/30/2010	1030	1.012	72.51	0.673	3.031	22.70	0.105	64.51	0.0792
Blossom	7/6/2010	1305	0.328	94.90	0.262	3.108	28.40	0.101	68.08	0.0477
Millrace	7/6/2010	1240	0.372	92.57	0.221	2.928	27.53	0.088	66.73	0.0436
IC at BWN	7/6/2010	1250	0.322	99.34	0.231	3.054	27.13	0.098	70.76	0.0477
Narrows	7/6/2010	1220	0.539	92.41	0.576	3.159	28.31	0.190	69.65	0.0844
Empire	7/6/2010	1200	0.405	95.79	0.339	2.882	27.20	0.141	70.83	0.0605
Bay	7/6/2010	1210	0.449	63.01	0.499	2.883	21.71	0.076	67.62	0.0723
Empire dup	7/6/2010	1200	0.420	87.00	0.381	2.992	27.94	0.139	69.18	0.0586
Blossom	7/9/2010	1800	1.079	80.51	1.494	3.251	22.65	0.149	56.09	0.1077
Millrace	7/9/2010	1820	0.311	95.45	0.237	3.001	26.42	0.064	66.79	0.0467
IC at BWN	7/9/2010	1830	0.451	93.54	0.471	3.322	27.99	0.104	66.39	0.1551
Empire	7/9/2010	1840	0.396	91.60	0.334	3.047	26.96	0.159	68.69	0.1763
Bay	7/9/2010	1850	0.384	78.10	0.498	3.066	25.16	0.124	66.76	0.1050
Empire dup	7/9/2010	1840	0.338	80.08	0.399	2.975	26.32	0.159	66.87	0.1330

Appendix 4 continued.

Sample	Date	Time	Al	Ca	Fe	K	Mg	Mn	Na	TP*
			ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Blossom	7/13/2010	1530	0.607	93.33	0.649	3.250	27.22	0.110	67.91	0.1698
Millrace	7/13/2010	1540	0.489	83.50	0.606	3.044	24.26	0.096	60.65	0.1449
IC at BWN	7/13/2010	1600	2.847	76.04	3.806	3.704	22.41	0.254	53.93	0.1701
Empire	7/13/2010	1615	0.519	76.85	0.639	3.178	23.74	0.178	61.89	0.1440
Bay	7/13/2010	1620	0.822	72.11	1.079	3.083	22.39	0.133	62.21	0.1019
Millrace dup	7/13/2010	1540	0.601	89.30	0.709	3.375	25.76	0.112	61.83	0.1814
Blossom	7/21/2010	1350	0.438	93.89	0.372	3.056	27.60	0.097	66.60	0.0925
Millrace	7/21/2010	1400	0.340	94.77	0.208	3.191	28.28	0.104	66.11	0.1083
IC at BWN	7/21/2010	1410	1.101	88.15	1.518	3.256	25.27	0.176	61.02	0.1819
Narrows	7/21/2010	1420	0.760	99.37	0.485	3.240	27.82	0.157	70.22	0.1198
Empire	7/21/2010	1440	0.447	97.22	0.505	3.336	27.98	0.163	66.90	0.1418
Bay	7/21/2010	1445	0.427	63.35	0.451	2.933	21.90	0.096	68.49	0.1381
Narrows dup	7/21/2010	1420	0.423	100.20	0.387	3.194	27.69	0.156	71.81	0.1260
Blossom	7/23/2010	825	4.540	66.82	3.184	3.938	19.79	0.265	54.59	0.1630
Millrace	7/23/2010	745	3.380	75.87	1.125	3.425	21.39	0.119	61.08	0.1223
IC at BWN	7/23/2010	755	4.060	74.17	1.338	3.291	19.91	0.150	59.13	0.2246
Narrows	7/23/2010	810	3.631	74.08	1.462	4.783	21.00	0.174	60.31	0.1607
Empire	7/23/2010	835	3.387	68.57	1.146	3.549	18.62	0.164	55.32	0.3259
Bay	7/23/2010	845	3.253	64.19	1.036	2.919	19.75	0.108	57.25	0.1745
IC at BWN dup	7/23/2010	755	3.961	74.28	1.824	3.550	20.95	0.156	57.46	0.1903
Blossom	8/2/2010	955	3.835	98.00	0.668	3.618	29.45	0.087	70.94	0.0629
Millrace	8/2/2010	1005	3.964	103.50	0.578	3.453	29.25	0.098	73.23	0.0674
IC at BWN	8/2/2010	1020	3.718	95.48	0.606	3.465	29.01	0.080	70.81	0.0682
Narrows	8/2/2010	1030	3.905	97.46	0.906	3.682	29.86	0.170	71.38	0.0924
Empire	8/2/2010	1045	3.968	100.20	0.731	3.344	27.47	0.170	72.99	0.1736
Bay	8/2/2010	1050	4.033	71.70	1.046	3.308	22.95	0.141	64.53	0.1490
Blossom dup	8/2/2010	1020	3.923	104.40	0.519	3.342	28.69	0.086	71.36	0.0606
Blossom	8/16/2010	930	2.474	100.20	0.781	3.204	26.74	0.114	64.43	0.1410
Millrace	8/16/2010	940	2.139	95.06	0.515	3.570	28.73	0.084	66.94	0.1596
IC at BWN	8/16/2010	950	2.416	95.18	0.637	3.433	28.57	0.103	67.01	0.1346
Narrows	8/16/2010	1000	2.196	92.43	0.623	3.617	27.61	0.132	67.48	0.1085
Empire	8/16/2010	1020	2.500	96.51	0.814	3.601	29.95	0.180	71.75	0.1291
Bay	8/16/2010	1030	2.275	76.86	0.447	3.054	22.95	0.081	65.41	0.1377
IC at BWN dup	8/16/2010	950	2.178	97.69	0.639	3.436	27.95	0.101	64.75	0.1220
Blossom	9/1/2010	1000	4.124	103.40	0.709	3.659	29.55	0.090	69.61	0.0418
Millrace	9/1/2010	1010	3.940	101.70	0.667	3.350	28.15	0.103	65.67	0.0403
IC at BWN	9/1/2010	1020	3.901	96.70	0.693	3.442	28.06	0.091	64.78	0.0227
Narrows	9/1/2010	1030	3.889	97.78	1.017	3.370	28.79	0.142	68.93	0.0435
Empire	9/1/2010	1045	3.785	89.56	1.126	3.170	27.47	0.147	66.94	0.0614
Bay	9/1/2010	1055	4.578	72.72	0.986	3.154	22.93	0.121	70.07	0.0274
Empire dup	9/1/2010	1045	4.268	100.00	1.068	3.449	29.91	0.160	70.42	0.0581