Water Quality in the Cranberry Run Wetland

by

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Abstract

The Cranberry Run Wetland is a ten-hectare (24.6 acres) palustrine wetland located within the Mill Creek watershed in Boardman Township, Mahoning County, Ohio. The wetland is situated between Tanglewood Drive and Southern Boulevard, near the intersection of State Route 224. The uplands and area adjacent to the wetland, along the State Route 224 corridor, have seen an increase in the construction of retail stores, restaurants, and parking lots. With this loss of green space, Cranberry Run has become an even more important component to the community by altering water flow after seasonal rain events and filtering non-point water sources and direct sources of water input.

The objective of this research was to independently conduct analysis on the water quality of the Cranberry Run Wetland in order to establish trends. The analysis will assist with future research by providing a record of changes that occur because of weather (seasonal flooding or drought) and in identifying the potential impacts of non-point and point sources on the wetland.

Surface and subsurface (well) water samples were taken over several months from 2006 – 2007 and analyzed by on-site and laboratory methods for various water quality parameters. The parameters for on site analysis included pH, dissolved oxygen (DO), temperature, and conductivity, while laboratory analysis incorporated tests for ammonia-nitrogen (NH_3-N), biochemical oxygen demand (BOD), chemical oxygen demand (COD), fecal coliform, soluble reactive phosphorus, and souble trace metals.

The results determined for the surface and well sampling sites show that the water quality of the wetland is directly influenced by location. These influences include the sources of input that the wetland receives from runoff and drainage systems, types of property that surround the wetland, and weather of Northeast Ohio. The water sources

and surrounding properties govern what the wetland receives in terms of pollution, while weather affects the amount of precipation received, water flow, and water level.

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CHAPTER 1 Introduction and Literature Review

Federal and state government began to provide some protection to wetlands by developing definitions that placed emphasis on certain aspects of what was being protected during the 1960's and 1970's (Tiner 1997). States created definitions to protect particular types of wetlands from becoming exploited, but these definitions were more general and did not contain an inclusive list of plant species. Therefore, using vegetation as factor for identification became difficult. The United States Environmental Protection Agency (USEPA), United States Army Corps of Engineers (USACE), and the United States Soil Conservation Service (SCS) consider only wet soils vegetated with hydrophytes to be wetlands (Tiner 1997).

The United States Fish and Wildlife Service (USFWS) provides a more general definition that uses natural, non-vegetated areas and aquatic beds in shallow waters placing emphasis on three essential aspects of wetlands: hydrology, vegetation, and soils. Hydrology refers to the amount of soil saturation or flooding that occurs. Vegetation describes the types of plants, known as hydrophytes, that have adapted to grow in soil or water that is often oxygen deficient due to saturation. Soils, called hydric soils, signify those that have produced oxygen deficient conditions in the upper portion near the root zone of plants due to extended saturation (Tiner 1997). The Code of Federal Regulations for the United States Army Corps of Engineers (33 CFR 328.3) and Environmental Protection Agency (40 CFR 230.3) include the same definition for wetlands: "Wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." (Tiner 1997).

The United States Soil Conservation Service (SCS), now called the Natural Resources Conservation Service (NRCS), shows that “Wetlands are defined as areas that have a predominance of hydric soils and that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions, except lands in Alaska identified as having potential for agricultural development and a predominance of permafrost soils.” (Tiner 1997).

The United States Fish & Wildlife Service (USFWS) states that “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. For the purposes of this classification 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.” (Tiner 1997).

The characteristics and functions of wetlands are determined by climate, hydrology, location and size, and substrate. Wetlands also share certain structural (biota, substrate, and water) or functional (nutrient cycling, organic production, and water balance) characteristics (National Research Council 1995). Table 1.1 depicts the various wetland functions and their associated, effects, and values.

Table 1.1 Various wetland functions and their associated, effects, and values (National Research Council 1995).

Function	Effects	Societal Value	Indicator
Hydrologic			
Short-term surface water storage	Reduced downstream flood peaks	Reduced damage from floodwaters	Presence of floodplain along river corridor
Long-term surface water storage	Maintenance of base flows, seasonal flow distribution	Maintenance of fish habitat during dry periods	Topographic relief on floodplain
Maintenance of high water table	Maintenance of hydrophytic community	Maintenance of biodiversity	Presence of hydrophytes
Biogeochemical			
Transformation, cycling of elements	Maintenance of nutrient stocks within wetland	Wood production	Tree growth
Retention, removal of dissolved substances	Reduced transport of nutrients downstream	Maintenance of water quality	Nutrient outflow lower than inflow
Accumulation of peat	Retention of nutrients, metals, other substances	Maintenance of water quality	Increase in depth of peat
Accumulation of inorganic sediments	Retention of sediments, some nutrients	Maintenance of water quality	Increase in depth of sediment
Habitat and Food Web Support			
Maintenance of characteristic plant communities	Food, nesting, cover for animals	Support for furbearers, waterfowl	Mature wetland vegetation
Maintenance of characteristic energy flow	Support for populations of vertebrates	Maintenance of biodiversity	High diversity of vertebrates

Mitsch (1995) stated that wetlands are often the transition zones between deepwater aquatic systems and uplands. This location provides a high diversity of species between aquatic and terrestrial systems, while functioning as an inorganic nutrient sink or organic exporter. Location can also create a highly productive ecosystem (Mitsch 1995). The connection between aquatic ecosystems, terrestrial systems, and wetlands is critical to the support of organisms. Maintenance of biodiversity, natural hydrologic flow regimes, and water quality depends in part on the total wetland area and types of wetland within the region. Functions like water quality maintenance and wildlife habitat decline as the acreage

of a wetland within a watershed declines (National Research Council 1995). The significance of wetlands within the landscape become magnified as the remaining wetlands become the sole refuge for displaced wildlife and the main source for flood mitigation, ground water recharge, and water quality improvement (National Research Council 1995). These connections are depicted in Figure 1.1 and Figure 1.2.

Many factors such as; landscape position, topographic postion, vegeatation, soil, water flow, source of ground and surface water, and climate control the hydrologic and water quality functions of a wetland (Figure 1.3) (Carter 1997). These functions include flood control by storing surface water, ground water recharge to replenish water supplies, maintenance of aquatic habitats by maintaining stream flows, and water quality protection through nutrient cycling and sediment removal (Novitski et al. 1997).

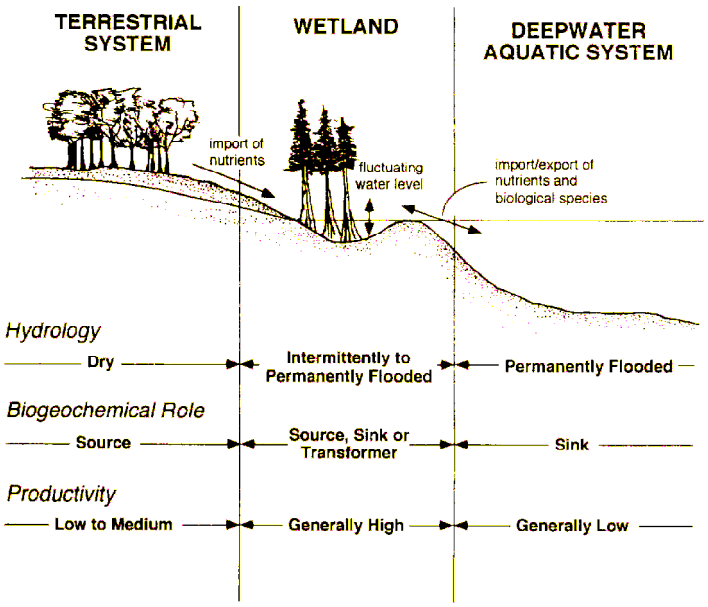

Figure 1.1 Interaction between the terrestrial, wetland, and deepwater aquatic systems. Wetland is maintained by groundwater, precipitation, and deepwater system (Mitsch 1995).

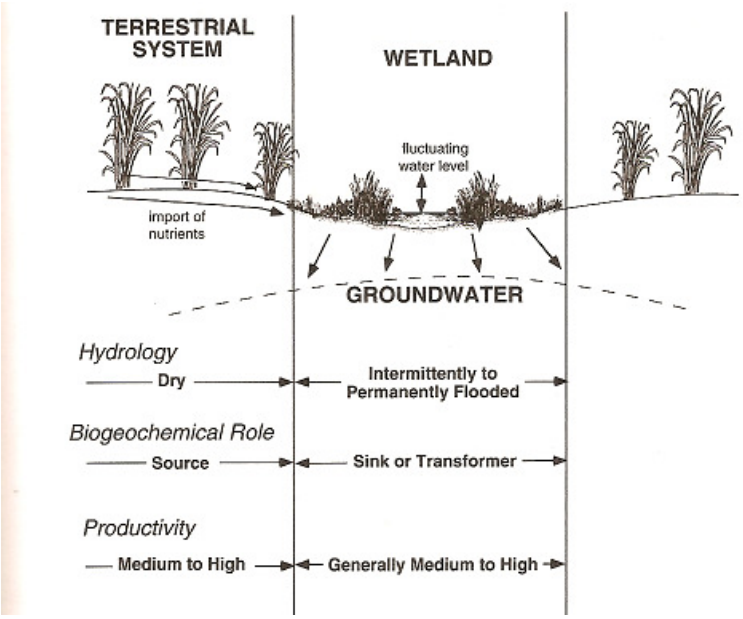

Figure 1.2 Interaction between terrestrial systems and wetland. Wetland is isolated from deepwater habitats and maintained by groundwater and precipitation (National Research Council 1995).

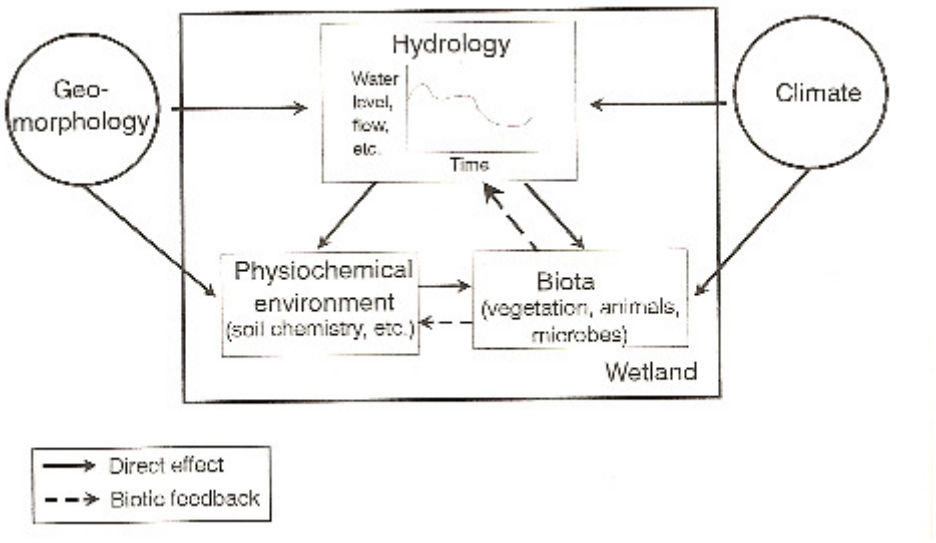

Figure 1.3 Relationship between hydrology, physiochemical environment (abiotic), and biotic components (National Research Council 1995).

Hydrology within a wetland controls the abiotic and biotic characteristics of a wetland, but biota can also control hydrology. Vegetation (biota) provides feedback to the hydrology of a wetland through an increase in flow resistance and evapotranspiration. It also provides feedback to the physiochemical environment of a wetland by affecting soil properties like dissolved oxygen and organic content or soil elevation as organic matter is accumulated or sediment is trapped (National Research Council 1995).

Wetlands have a disproportionately strong influence on water quality because the dissolved and suspend solids that are processed are from an area much greater than their own (National Research Council 1995). It has been observed that water quality is improved in different ways by wetlands that may be in different locations within a watershed. As an example, nitrogen processing and the retention of large sediment particles may be a more important function of wetlands that border uplands, where large particles are abundant, and phosphorus retention and the trapping of fine particles may be a more important function of floodplain wetlands (National Research Council 1995). This water quality maintenance is

affected by season and weather. Wetlands with unregulated inflows are impacted by changes in water flow that directly relate to the retention time of nutrients, and sediment (Jordan et al. 2003). The removal capacities may become overwhelmed which reduces the ability of wetlands to remove nutrients and sediments in some instances of high water flow events (Jordan et al. 2003). Reinelt and Horner (1995) determined that for urbanized wetlands, zinc removal occurred almost always during storms events or increased water flow, while fecal coliform was removed during either base water flow or increased water flow for each season.

Healy and Cawley (2002) state that nitrogen removal depends upon residence time and temperature. This is evidenced from research performed in 2000 where denitrification rates were affected by organic carbon availability and temperature and longer retention times that increased the settlement of particulate organic nitrogen (Healy and Cawley 2002). An upward trend was recorded in the amount of effluent ammonia and total oxidized nitrogen in constructed wetlands during storm events and periods of increased hydraulic loading (Healy and Cawley 2002). As a result, treatment by the wetland may be affected because of the decrease in retention time due to water flow (Healy and Cawley 2002).

Precipitation in summer tends to dilute stream conductivity. In contrast, precipitation in winter increasingly elevates levels because of the large volumes of road salt used (Seilheimer et al. 2007). Research on the Nine Mile Run stream near Pittsburgh, Pennsylvania found an increase in conductivity of 20- to 30- fold during winter thaws(Seilheimer et al. 2007). These seasonal changes in conductivity suggest that even small increases in impervious surface area within a watershed can lead to conductivity increases (Seilheimer et al. 2007).

Wetlands are defined by hydrology, vegetation, and soils. There are many different types of wetlands located within different geographic areas that serve different functions.

These differences allow wetlands to be grouped together in classifications systems, as devised by the USFWS (Tiner 1997).

The USFWS developed a standard for the identification and classification of wetlands, which has been used nationally and internationally. Wetland scientists and mapping experts worked directly with USFWS to identify and establish four key objectives for their standard: "(1) Identify ecologically similar habitat units; (2) Classify these units systematically to facilitate resource management decisions; (3) Identify units for inventory and mapping purposes; and (4) Provide uniformity in concept and terminology throughout the country." (Tiner 1997).

Wetlands are separated into five systems, which represent wetlands and deepwater habitats that have similar biological, chemical, geomorphologic and hydrologic influences. These systems (Table 1.2) are as follows: (1) Marine – Open ocean and associated coastline; (2) Estuarine – Tidal waters of embayments and coastal rivers, mangroves, tidal marshes, and tidal flats; (3) Riverine – Rivers and steams; (4) Lacustrine – Large ponds, lakes, and reservoirs; and (5) Palustrine – Bogs, marshes, potholes, swamps, and wet meadows. A large majority of the wetlands in the United States are Palustrine (Tiner 1997).

Table 1.2 Classes and characteristics of wetlands within the United States (National Research Council 1995).

Common Term	Distribution and Hydrology	Biota
Freshwater marsh	Widespread; seasonal to permanent flooding	Grasses, sedges, frogs
Tidal salt and brackish marsh	Intertidal zones; semidiurnal to fortnightly flooding	Salt-tolerant grasses and rushes, killifish, crabs, clams, snails
Prairie pothole	Northern plains states; temporary to permanent flooding; fluctuating water levels	Grasses, sedges, herbs
Fen	Associated with mineral-rich water; permanently saturated by flowing water	Sedges, grasses, shrubs, trees
Bog	Abundant in recently glaciated regions; precipitation principal source of water	Sphagnum moss, shrubs, trees, desmids
Swamp	Prolonged saturation and flooding	Cypress, gum, red maple
Bottomland	Seasonal flooding; annual dry periods	Oaks, sweetgum, other hardwoods
Mangrove	Subtropical, tropical regions; intermittent flooding by seawater through tidal action	Red, black, white mangroves

Palustrine System

"The Palustrine system includes all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5%. (Cowardin et al. 1979). This system combines the group of vegetated wetlands known as bogs, fens, marshes, prairies, and swamps as well as ponds of small, shallow, intermittent or permanent bodies of water (Cowardin et al. 1979). These systems are found throughout the United States and may be located near estuaries, lake shores, river channels or river floodplains, and slopes or they may be isolated (Cowardin et al. 1979).

Environmental Stressors

The ecology of wetlands in urban areas can be influenced by such stressors as the nutrients and sediments from effluents of storm sewers and culverts that drain major transportation corridors and increased input of runoff due to an increase in the amount of impervious surfaces constructed within the watershed (Seilheimer et al. 2007). According to Reinelt and Horner (1995), bacteria, heavy metals, nutrients, and sediments that enter wetlands through non-point sources have an adverse effect on water quality. Chemical usage, increased amounts of runoff, poor management practices, and vegetation removal all result in wetlands receiving excess quantities of these substances (Reinelt and Horner 1995). While agricultural sources have been determined to be the most extensive non-point source, urban runoff has been identified as the next most common non-point source problem in surface water pollution (Reinelt and Horner 1995).

Through various processes, wetlands can improve the degraded water quality that results from this input. The bacteria that is found in the surface waters and studied as fecal coliform, tends to be a part of the suspended sediments within the water (Reinelt and Horner 1995). This type of bacteria, which is often an indicator of pathogens, can enter through direct input of waste or from animals that inhabit the wetland (Reinelt and Horner 1995). In most instances, the concentrations of fecal coliforms are reduced as the particles settle out or removed as the water temperature decreases (Reinelt and Horner 1995).

Heavy metals are often found in either particulate form or soluble form in urban runoff (Reinelt and Horner 1995). The removal of metals can occur through groundwater infiltration, ion exchange, plant uptake, and precipitation of soluble metals like zinc, which is more mobile in the ionic state (Reinelt and Horner 1995). Metals like lead can be transported in the water column with other solids because they adsorb to sediments and other particles (Reinelt and Horner 1995). Particulates are removed as the velocity of the

water column slows and the solids within the water become deposited on the bottom of the wetland (Reinelt and Horner 1995). The metals that have been adsorbed to these sediments, if at high enough concentrations, can create toxic conditions for aquatic life and animals that ingest plants growing in metal rich soil (Reinelt and Horner 1995).

Wetlands also tend to continually recycle nutrients and become sinks, sources, or transformers of nutrients (Figure 1.4). As a sink, wetlands will show a net retention of a specific nutrient, but as a source, the wetland will show a net loss as it is removed (National Research Council 1995). As a transformer, a substance can be changed from dissolved to particulate form or from one oxidation state to another (National Research Council 1995). Wetlands can also maintain a steady state, as the nutrients that flow in into a wetland are equal to those that flow out (National Research Council 1995).

Poe et al. (2003) found that non-point source pollution on a national basis comprises more than 65% of the total nutrient load that surface waters receive. Non-point sources create variations in the biogeochemical and hydrologic process because of the change in hydrologic, nutrient, and organic matter loading. Runoff, specifically from agricultural fields, controls the nitrogen and phosphorus loading to aquatic ecosystems.

Nitrogen is removed by two different biological pathways in wetlands. The first is a is a temporary immobilization of nitrogen through primary production by benthic microalgae and macrophytes. The second is a permanent removal via denitrification by anaerobic heterotrophic bacteria, which lessens the impact of nitrogen loading by reducing inorganic oxides (NO_3^- and NO_2^-) to gaseous end products (N_2O and N_2) (Poe et al. 2003).

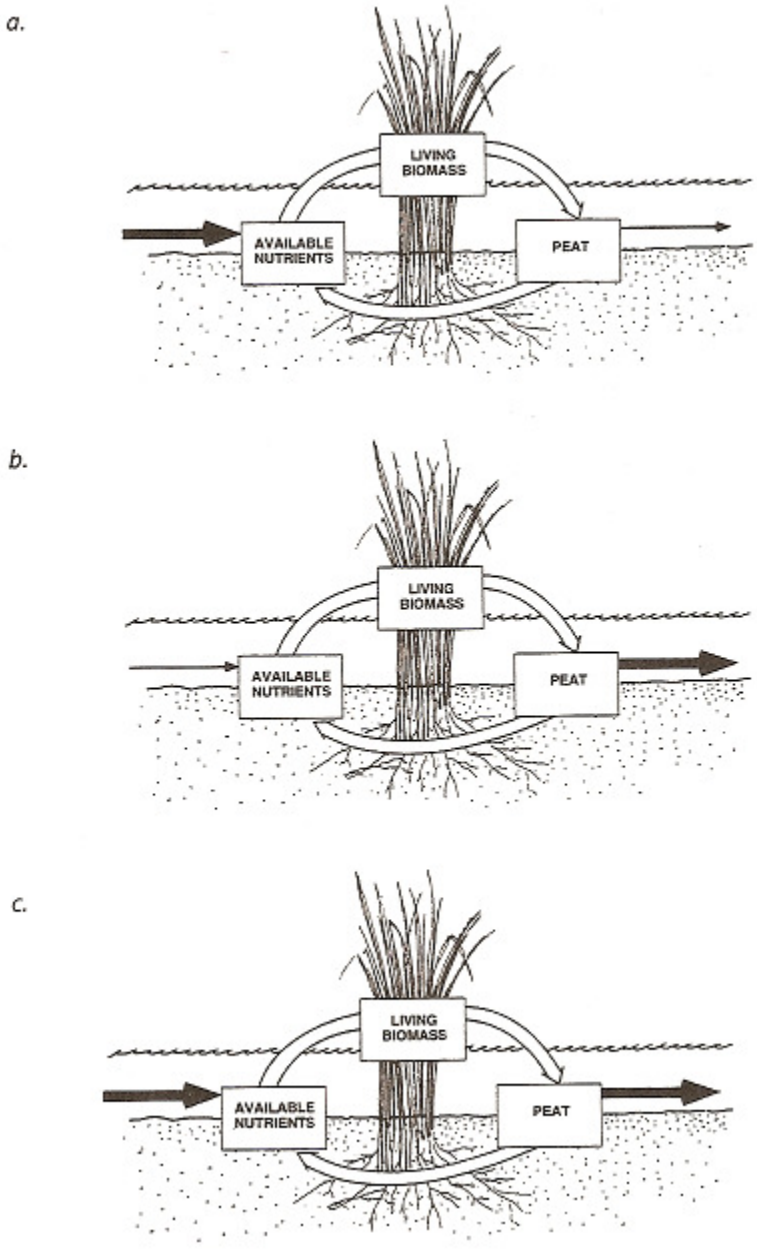

Figure 1.4 Wetland alterations of flow of nutrients becoming (a) a sink, (b) a source, or (c) steady state (National Research Council 1995).

There is no gaseous lost related to the removal of phosphorus. Healy and Cawley (2002) state that the only removal will be through the length in time for storage. Short-term storage or initial removal is accomplished by the uptake by biota, like algae, bacteria, duckweed, and macrophytes. Phosphorus is eventually released into the water when the biota (algae and microbes) die. Long-term storage is accomplished through peat accumulation, which depnds upon the amount of aluminum, calcium, iron, and organic matter contained in the substrate as well as the loading rate (Healy and Cawley 2002).

Sedimentation is one of the primary means of pollutant removal (Reinelt and Horner 1995). The amount of vegetation and soil can decrease the velocity of water entering and flowing through a wetland, increasing the deposition and settling of suspended solids (Reinelt and Horner 1995). The retention of these suspended solids within a wetland is dependent upon several factors that include flow velocity, hydraulic regime, particle size, residence time, storm surges, and wetland morphometry (Reinelt and Horner 1995). Some of the same factors that cause sedimentation can also cause solids to be released. Flow velocity and storm events erode the soil and release solids back into the water column (Reinelt and Horner 1995).

Cranberry Run Wetland

The Cranberry Run Wetland was purchased by the Mahoning River Consortium through a grant from the Ohio Public Works Commission as part of the Clean Ohio Fund (Schroeder 2004). The wetland is situated between Tanglewood Drive and Southern Boulevard, near the intersection of State Route 224 in Boardman Township, Mahoning County, Ohio (Figure 1.5). Information taken from a survey conducted by Western Reserve Land Consultants, Inc. states that the size of the wetland is ten-hectares (24.6 acres).

Figure 1.5 Map of the Cranberry Run Wetland in Boardman, Ohio (Google Earth 2009).

Cranberry Run is part of the Mill Creek Watershed, one of six watersheds in Mahoning County, Ohio (Figure 1.6). The Mill Creek Watershed encompasses approximately 47, 000 acres, of which 4,000 acres are comprised of wetlands (A.W.A.R.E [Internet]. [cited 2009]). The land within the watershed is used for commercial, residential and recreational purposes, with the Mill Creek Watershed being the commercial center for the county (A.W.A.R.E [Internet]. [cited 2009]).

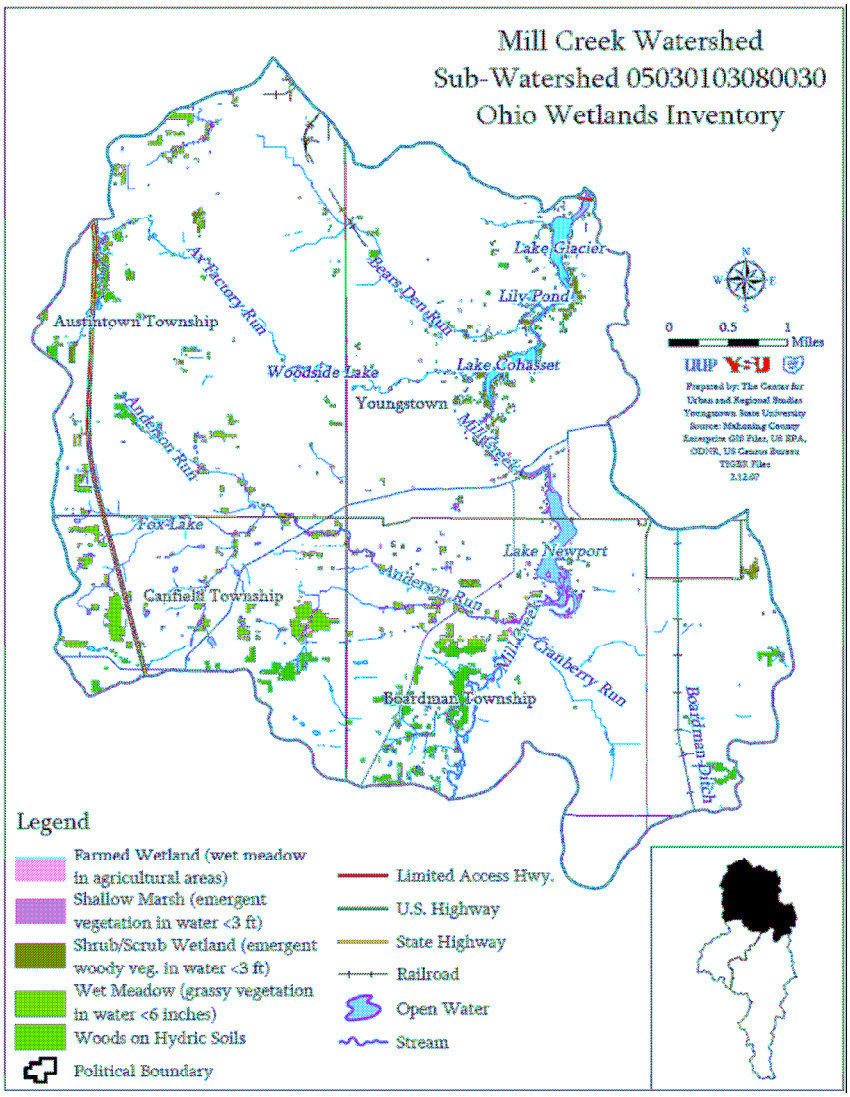

Figure 1.6 Northern portion of the Mill Creek Watershed (Youngstown State University 2007).

The United States Fish & Wildlife Service National Wetlands Inventory (2006) classifies Cranberry Run as a palustrine wetland, which is a nontidal wetland dominated by trees, shrubs, persistent emergents, and emergent mosses or lichens. Figure 1.7 provides information on the classifcation of Cranberry Run and other wetands that surround this location.

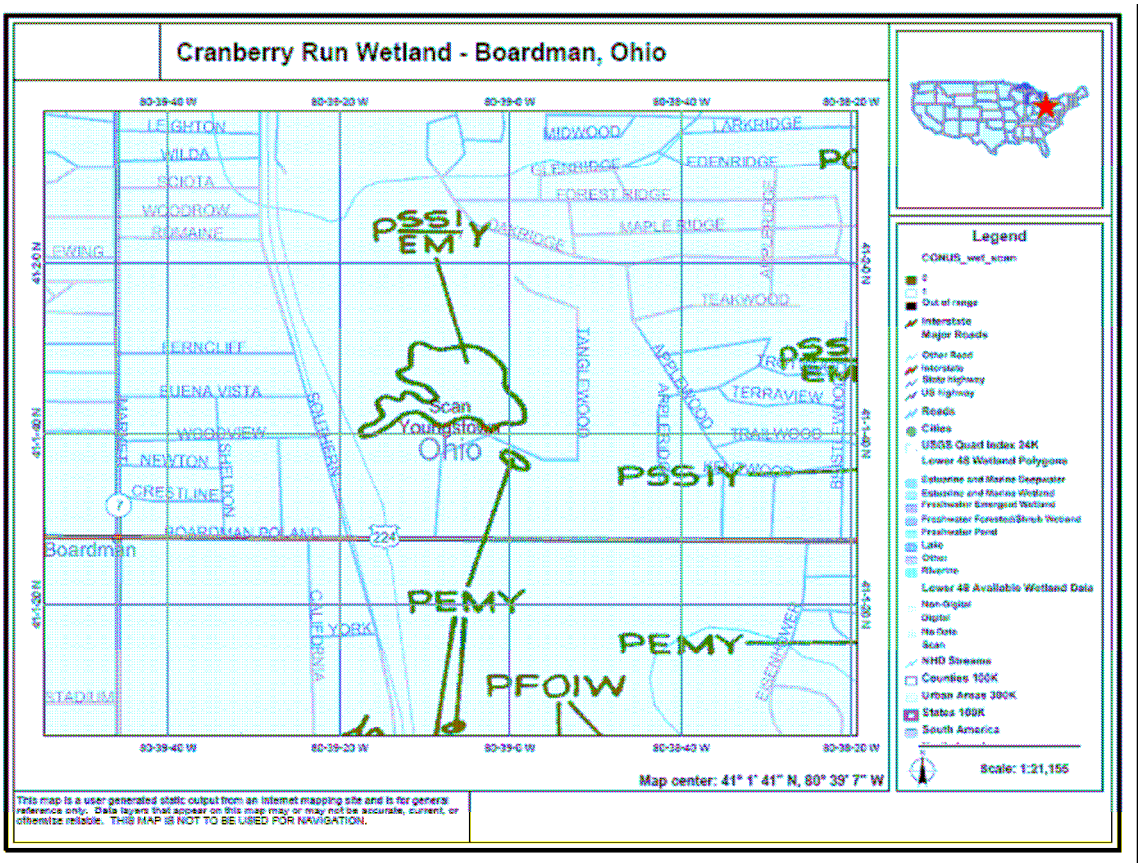

Figure 1.7 Map of Cranberry Run and surrounding wetlands (National Wetlands Inventory 2006).

The Cranberry Run Wetland is comprised mainly of herbaceous trees, grasses, shrubs, and aquatic vegetation. As the seasons progress from spring to early winter, the vegetation, such as duckweed, reeds, and skunk cabbge increase in abundance and size.

The water levels; however, will vary depending on the amount of precipitation, season, and source of input. Areas near the northern border and center of the wetland hold water and have realtively stable levels, both suface and subsurface. Areas near the southern and southwestern portion of the wetland have varing levels of water, mainly from direct inputs by drainage systems. The northwestern portion also varies because this location is the outflow for the wetland as water moves in a direction southeast to northwest and amount of water being discharged from the wetland is dependent upon what is received.

Objective of Study

The objective of this research was to independently conduct analysis on the water quality of the Cranberry Run Wetland in order to establish trends. The analysis will assist with future research by providing a record of changes that occur because of weather (seasonal flooding or drought) and in identifying the potential impacts of non-point and point sources on the wetland.

The uplands and area adjacent to the wetland, along the State Route 224 corridor, have seen an increase in the construction of retail stores, restaurants, and parking lots. The function of Cranberry Run as a filter from non-point water sources as well as direct sources of water input may have become an even more important attribute with this loss of green space.

CHAPTER 2 Materials and Methods

Cranberry Run Sampling Sites

Surface water and groundwater flow through the wetland in a northwest direction. In order to obtain a range of locations that would best represent the wetland water, ten surface sample sites and five subsurface (well) sample sites were chosen in various areas. The position of each site within the wetland was taken in May of 2006 by a Garmin eTrex series GPS unit and listed as either “S” for surface or “W” for subsurface or well sample sites.

The well sampling device was made using a 4-inch diameter PVC pipe, 8 feet in length. Four holes of ¼ inch in diameter were drilled every 4 inches from the bottom of the pipe to 16 inches from the bottom edge. The process and number and locations of holes was repeated for each pipe to be installed. The pipes were installed at each location to a depth of 5 feet and the top of the pipe was capped to prevent debris and rain water from entering. Once installed, the caps were labeled for future identification and contact information. Figure 2.1 depicts each sampling site location and Table 2.1 lists the coordinates and location description of each sampling site.

Figure 2.1 Location of each surface and subsurface (well) site within the Cranberry Run Wetland and direction of water flow (Google Earth 2009).

Table 2.1 Location of sampling sites in the Cranberry Run Wetland.

Sampling Sites	Latitude (N)	Longitude (W)	Location
S1	41° 01' 41.8"	80° 39' 5.9"	Tanglewood Drive - NW of W1
S2	41° 01' 50.5"	80° 39' 11.7"	East of Inglis Greenhouse
S3	41° 01' 45.4"	80° 39' 12.8"	Effluent from retention pond - NW of W3
S4	41° 01' 45.9"	80° 39' 4.7"	SE of gas well
S5	41° 01' 45.4"	80° 39' 9.3"	Middle of deer path
S6	41° 01' 48.6"	80° 39' 11.3"	Concrete area past W2 - South of Inglis Greenhouse, North of Home Depot
S7	41° 01' 42.0"	80° 39' 4.9"	NE of W1
S8	41° 01' 41.2"	80° 39' 2.4"	Stream off Tanglewood Drive - Effluent downstream from road
W1	41° 01' 42.0"	80° 39' 5.4"	Tanglewood Drive
W2	41° 01' 50.5"	80° 39' 11.7"	East of Inglis Greenhouse
W3	41° 01' 45.4"	80° 39' 12.8"	Effluent from retention pond - SE of S3
W4	41° 01' 46.3"	80° 39' 6.2"	End of deer path near gas well
W5	41° 01' 45.4"	80° 39' 9.3"	Middle of deer path
Creek	N/A	N/A	South of Inglis Greenhouse
Pond	N/A	N/A	North of Home Depot

Sample Collection and Analysis

Monthly surface and subsurface (well) water samples were collected mid-morning to mid-afternoon from the Cranberry Run Wetland during the summer and fall of 2006 and during the spring and summer of 2007. A dipper or subsurface water sampler (Sludge Judge) was used to collect the water samples into 1L Nalgene bottles. Field measurements were conducted using the YSI Model 85/50 FT Combination Meter as soon as the samples were taken and included tests for conductivity, dissolved oxygen (DO), and temperature. An Accumet Portable APID pH/mV meter was used to measure the pH. All water samples were then placed in coolers with ice packs until they could be taken to Youngstown State University to be filtered and preserved for lab analysis.

Samples collected from the wetland were filtered within 24 hours. Each 1L Nalgene bottle was filtered into two separate 500mL Nalgene bottles. One sample bottle was used for fecal colifom analysis or biological oxygen demand (BOD) and the second bottle was preserved with H_2SO_4 to a pH of 2.0 or less. Analysis for fecal coliform was conducted according to Standard Methods for the Examination of Water and Wastewater – 9222-B – Standard Total Coliform Membrane Filter Procedure (APHA 1998). Analysis for BOD was conducted according to Standard Methods for the Examination of Water and Wastewater – 5210 A – Biochemical Oxygen Demand (BOD) (APHA 1998). The Accumet Portable APID pH/mV meter was used to measure the pH for the sample to be preserved and a YSI Model 50B Dissolved Oxygen meter was used to analyze samples during the test for BOD.

Equipment for the analysis included Whatman 42 Ashless (2.5 µm) paper filters to filter water samples collected from the field and a Market Forge Sterilmatic autoclave to prepare all glassware and plastic filters for fecal coliform tests. Sterlie Gelman membrane filters were used during the fecal colifom tests. A Metller Toledo A6245 balance was used to weigh chemicals for laboratory analysis. A Bausch & Lomb Spectronic 1001 Split-Beam

spectrophotometer was used to analyze ammonia-nitrogen (NH3-N) and Soluble Reactive Phosphorus samples and a Precision Gravity convection incubator was used for all fecal coliform samples

The preserved samples were used for the COD, ammonia-nitrogen (NH_3-N), soluble reactive phosphorus, and soluble trace metals tests. Each of these tests, with the exception of the analysis for soluble trace metals, was conducted according to the Standard Methods for the Examination of Water and Wastewater. Analysis for COD was conducted according to Standard Methods for the Examination of Water and Wastewater – 5220 A – Chemical Oxygen Demand (COD) (APHA 1998). Analysis for ammonia-nitrogen (NH_3-N) was conducted according to Standard Methods for the Examination of Water and Wastewater – 4500- NH3 – Ammonia (Phenate Method) (APHA 1998). Analysis for soluble reactive phosphorus was conducted according to Standard Methods for the Examination of Water and Wastewater – 4500-P – Phosphorus (Dissolved – Ascorbic Acid Method) (APHA 1998). Analysis for soluble trace metals was conducted by the Youngstown Wastewater Laboratory using Inductively Coupled Plasma Spectrophotometery (ICP). Water samples from July, September, and October of 2006 were analyzed for the presence of As, Be, Cd, Cr, Cu, Fe, Ni, Pb, Se, and Zn.

Air temperatures and precipitation was also monitored throughout the study by accessing the Monthly Weather Summary for Youngstown, Ohio, through the National Weather Service website in Cleveland, OH.

CHAPTER 3 Results and Discussion

Water Acidity and Alkalinity

Natural water has a typical pH range between 6.5 and 8.5 and most aquatic life has adapted to waters within that pH range (pH [Internet]. [updated 2008]). These ranges can be changed by such factors as acid rain or contact with certain minerals in rocks or soil. The changes alter the pH and create more acidic or alkaline waters that cannot support certain species of aquatic life when the pH drops below 5. As the pH continues to drop, metals bound to sediment and organic matter are released (pH [Internet]. [updated 2008]). The pH range established by the state of Ohio for the protection of aquatic life is 6.5-9.0 (Ohio EPA 2008).

The average pH reading for surface sites was 7.40 and the average pH reading for well sites was 6.94 for all samples taken over each season. While all of the readings are within the normal range for natural waters, the elevated readings for S3 (pH 7.80) and Pond (8.15) can be attributed to the input that is received from the parking lots and impervious surfaces adjacent to the retention pond which drains into the wetland near the S3 sampling site (Table 3.1, Figure 3.1). The lowest recorded average pH reading of all sites was taken at W3, also along the southwestern border. W3 had an average pH reading of 6.56. Although W3 is located near S3 and the pond, the water contained at the well site does not seem to mix with waters from other surface sites based on pH readings.

Table 3.1 Average pH readings taken during sampling period of 2006 – 2007.

Sampling Sites	pH		
	Sample Mean	Standard Error (+/-)	Sample Size
S1	7.35	0.085	5
S2	6.97	0.100	5
S3	7.80	0.149	5
S4	7.06	0.159	5
S5	7.28	0.060	5
S6	7.16	0.070	5
S7	7.30	0.187	4
S8	7.48	0.137	6
W1	7.16	0.205	3
W2	7.10	0.127	7
W3	6.56	0.069	6
W4	6.88	0.102	7
W5	6.98	0.097	6
Creek	7.47	0.082	7
Pond	8.15	0.261	7

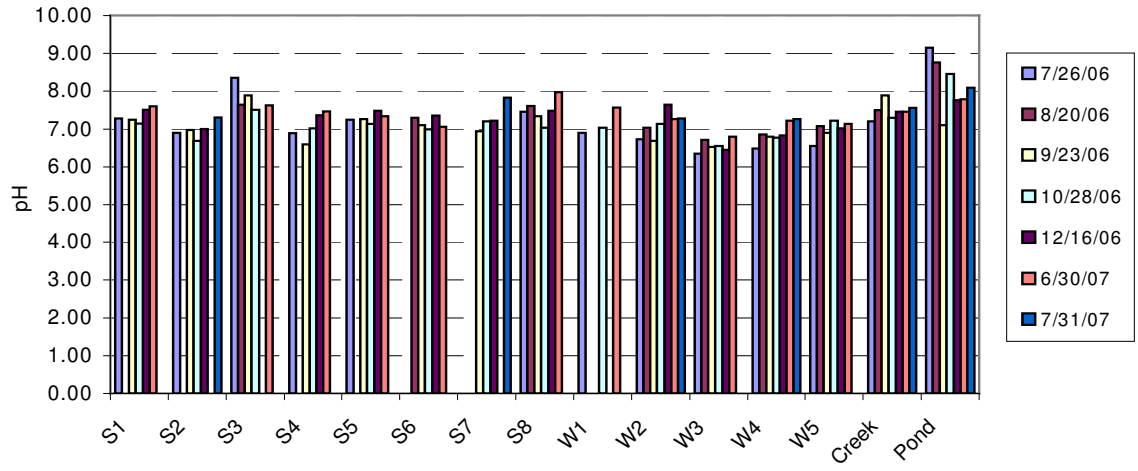

Figure 3.1 pH readings taken during the sampling period of 2006 – 2007.

Dissolved Oxygen (DO) – (mg/L)

Dissolved Oxygen (DO) is the amount of oxygen that has been dissolved in a body of water. It is also an essential indicator for the ability of a body of water to support aquatic life. Oxygen enters water through the atmosphere and by algae and plants through photosynthesis. Oxygen is removed from water with respiration of plants and aquatic life or decomposing organic matter (Murphy 1997).

Several factors can affect the amount of DO that is present, such as the volume and velocity of water that flows into a body of water, climate and season, temperature, and the amount of nutrients (Murphy 1997). A high volume of faster moving water will aerate water that it enters and increase the DO concentration (Murphy 1997). DO concentrations can increase in the winter because colder water can dissolve more oxygen than warmer waters of summer (Murphy 1997). DO concentrations can also decrease in dry seasons because of low water levels and flow rates, but increase during rainy seasons because of rain mixing with air and increased flow rates (Murphy 1997). Eutrophication can occur when water with

an excess amount of nutrients causes an increase in plant or algae growth (Murphy 1997). This increase in plants or algae material causes a decrease in DO when the plants and algae die and are decomposed by microorganisms. The decrease in DO can leads to fish kills, reduction of biodiversity, and lower primary productivity (Murphy 1997).

A decrease in dissolved oxygen, typically below 5 mg/L, will begin to stress species that cannot tolerate low concentrations (MIDEQ 2008). If levels continue to drop, certain species will die and be replaced with those that can tolerate such conditions (MIDEQ 2008). DO levels below 2 mg/L will result in fish kills and anaerobic bacteria will replace aerobic bacteria at levels below 1 mg/L (MIDEQ 2008). This change in bacteria will create an odor of hydrogen sulfide (H_2S) as organic matter is broken down (MIDEQ 2008).

DO is measured in milligrams per liter (mg/L) or as a "percent saturation." The milligrams/liter measurement is the amount of oxygen in a liter of water, while the percent saturation measurement is the amount of oxygen in a liter of water relative to the total amount of oxygen the water can hold at a given temperature (Ohio EPA 2008).

Dissolved Oxygen (DO) readings were highest along the southwestern border of the wetland and lowest along the northern and southern borders. Sampling site S3 and the Pond, along the southwestern border had average DO concentrations of 4.13 mg/L and 6.86 mg/L, respectively. Sample site W2, along the northern border, had an average DO concentration of 0.31 mg/L and W1, along the southern border, had an average DO concentration of 0.59 mg/L. The average readings for surface sites was 2.97 mg/L and 1.06 mg/L for well sites (Table 3.2).

Table 3.2 Average dissolved oxygen levels recorded over the sampling period of 2006 – 2007.

Sampling Sites	Dissolved Oxygen (mg/L)		
	Sample Mean	Standard Error (+/-)	Sample Size
S1	2.37	0.87	5
S2	1.73	0.78	5
S3	4.13	1.00	5
S4	2.08	0.86	5
S5	2.16	0.85	5
S6	2.80	1.12	5
S7	3.37	0.72	4
S8	1.92	0.70	6
W1	0.59	0.44	3
W2	0.31	0.08	7
W3	1.81	0.60	6
W4	1.29	0.49	7
W5	1.29	0.60	6
Creek	2.26	0.97	7
Pond	6.86	1.23	7

The results determined that location, season, and weather influence DO readings. As a result of the rain events that occurred and colder temperatures experienced in the months of September, October, and December, an increase in DO was specifically noticed for these sampling dates. In comparison, the readings taken during the summer were consistently lower each month and did not appear to be more than 2.00 mg/L. The Pond site had the highest DO readings for all sampling sites, regardless of season.

The changes in DO concentrations, with respect to the locations of the sampling sites, is attributed to the constant flowing water from the retention pond that enters the

wetland along the southwestern border, compared with stagnant, nutrient filled water near S2 and the relatively dry area of W1. Figure 3.2 shows the range of DO levels recorded over the entire sampling period of 2006 – 2007.

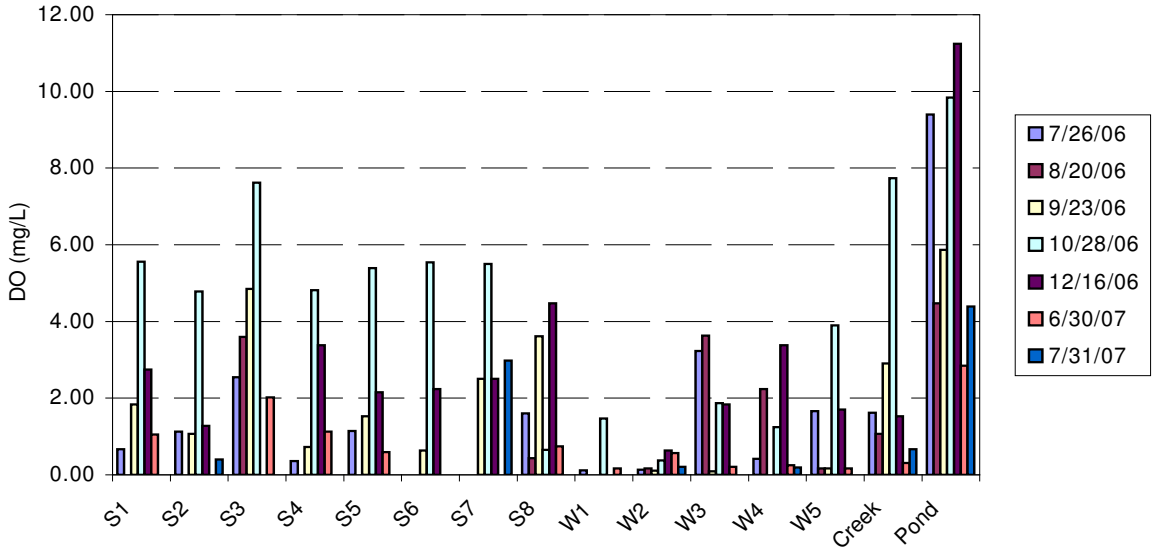

Figure 3.2 Dissolved oxygen levels recorded during the sampling period of 2006 – 2007.

Temperature (℃)

Temperature has an effect on the oxygen content of water as well as aquatic organisms and plants (Ohio EPA 2008). As the temperature of water increases, the oxygen level decreases. This change will also affect the sensitivity of aquatic organisms (microbes to fish) to diseases, parasites, and toxic waste and alter their metabolic rates (Ohio EPA 2008).

Changes in temperature are caused by several factors such as weather, ground water inflows, cooling water discharges, storm water inputs, and the removal of vegetation (Ohio EPA 2008). The average temperature range listed by the state of Ohio for the

protection of aquatic life using data collected for the Mahoning River is between 8.3℃ and 31.7℃ (47℉ and 89℉) (Ohio EPA 2008).

Table 3.3 shows the highest average water temperatures for the sampling period were reported at sites along the southwestern border of the wetland during the summer months of June, July, and August , where water from the pond directly enters the wetland. Water temperatures for S3, Creek, and Pond were consistently warmer during each sampling date, with average temperatures for the research of 20.8℃, 17.0℃, and 19.0℃ respectively. The lowest average water temperatures for the research were reported at sites along the southern border near Tanglewood Drive. S1 had a temperature of 13.8℃ and S7 had a temperature of 13.0℃. The average water temperature taken for all surface sites was 15.8℃, while the average water temperature taken for all well sites was 15.0℃. In contrast, well sample temperatures did not have large variations of temperature. These variations were related more to season and temperatures and were within a smaller, consistent range.

The location of the sampling is the primary reason for the differences in temperature. The sites along the southwestern border receive direct sunlight and input from the parking lots as water flows from the parking lot into the retention pond and then into the wetland. The sites along the southern border are heavily shaded and do not directly receive the runoff or input from Tanglewood Drive. Figure 3.3 depicts the range of temperatures recorded over the entire sampling period.

With respect to weather, Table 3.4 shows the highest, lowest, and average temperatures for the months sampling was conducted. Table 3.5 lists the amount of precipitation that occurred during these months. These factors will influence water temperature, which influences the water quality parameters.

Table 3.3 Average temperature readings taken during sampling period of 2006 – 2007.

Sampling Sites	Temperature (℃)		
	Sample Mean	Standard Error (+/-)	Sample Size
S1	13.8	3.38	5
S2	15.1	4.47	5
S3	20.8	3.24	5
S4	14.0	3.78	5
S5	14.5	3.81	5
S6	14.6	3.83	5
S7	13.0	3.75	4
S8	16.1	2.66	6
W1	14.3	1.27	3
W2	15.8	1.32	7
W3	14.8	1.96	6
W4	15.7	2.14	7
W5	14.6	2.58	6
Creek	17.0	2.92	7
Pond	19.0	3.59	7

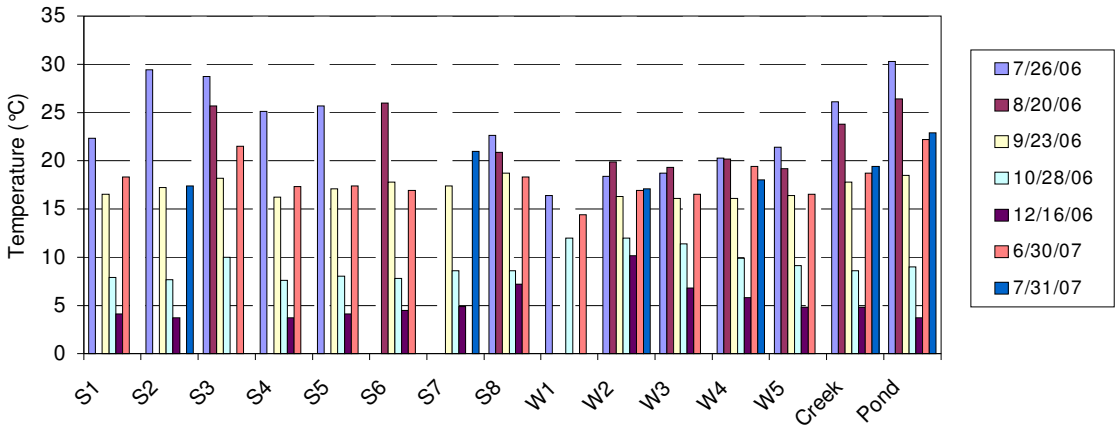

Figure 3.3 Temperature readings taken during sampling period of 2006 – 2007.

Table 3.4 Air temperature readings reported during sampling period of 2006 – 2007 (NWS 2006, 2007).

Month	Highest Temp. (°F)	Highest Temp. (°C)	Lowest Temp. (°F)	Lowest Temp. (°C)	Mean Temp. (°F)	Mean Temp. (°C)
May 2006	89	31.7	28	-2.2	57.2	14.0
May 2007	88	31.1	33	0.5	61.3	16.3
June 2006	88	31.1	40	4.4	64.4	18.0
June 2007	89	31.7	40	4.4	67.4	19.7
July 2006	91	32.8	50	10	72.4	22.4
July 2007	92	3.3	44	6.7	68.9	20.5
August 2006	92	33.3	46	7.8	70.2	21.2
August 2007	93	33.8	48	8.9	71.4	21.8
September 2006	82	27.8	38	3.3	60.3	15.7
October 2006	77	25.0	30	-1.1	48.7	9.3
November 2006	66	18.9	23	-5	43.9	6.7
December 2006	54	12.2	34	1.1	44	6.7

Table 3.5 Precipitation recorded during sampling period 2006 – 2007 (NWS 2006, 2007).

Month	Total Precipitation (Inches)	Total Snowfall (Inches)	Greatest Amount of Precipitaion (Inches) – (24 Hour Total)	Date(s)
May 2006	5.69	0	1.69	5/14-5/15
May 2007	3.45	0	0.88	5/15/-5/16
June 2006	5.97	0	1.93	6/21-6/22
June 2007	3.67	0	1.56	6/2-6/3
July 2006	7.06	0	1.53	7/09-7/10
July 2007	1.61	0	0.85	7/18-7/19
August 2006	2.75	0	1.48	8/28-8/29
August 2007	5.56	0	2.18	8/19-8/20
September 2006	6.73	0	2.09	9/18-9/19
October 2006	5.85	0.6	1.86 (0.4 snow)	10/16-10/17 (snow - not reported)
November 2006	2.46	0.6	0.94 (0.4 snow)	11/15-11/16 (snow - not reported)
December 2006	2.93	9.2	Not Reported	Not Reported

Conductivity (µS/cm)

Electrical Conductivity (EC) is a measure of the amount of dissolved solids or ions in water (NSF 2004]). Waters that contain sodium, magnesium, calcium, iron, and aluminum cations as well as inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions will have higher conductivities than waters that contain organic compounds like alcohol, oil, and sugar because the organic compounds do not conduct as much electrical current as the inorganic compounds. Warmer waters (25℃ or more) will have higher conductivities than waters that have a temperature less than 25℃ (Ohio EPA

2008). Natural surface waters have a range of 50 µS/cm – 1,500 µS/cm (Pennsylvania Lake Management Society 2006).

Average readings for conductivity (Table 3.6) were highest near the center and southern border of the wetland, but lowest was along the northern border. Sites S5 and W5, near the middle of the wetland, had average conductivity readings during the research of 748 µS/cm for S5 and 1362 µS/cm for W5. Sites S7 and W1, along the southern border, had average conductivity readings during the research of 748 µS/cm for S7 and 937 µS/cm for W1. Along the southwestern border, W3 had a conductivity reading of 1557 µS/cm and Pond had a conductivity reading of 847 µS/cm. S2, along the northern border, had a conductivity reading of 259 µS/cm. Overall, a trend was noticed that well samples had conductivities that were relatively equal to or greater than the respective surface samples. Months that had higher levels of precipitation also showed higher levels of conductivity. Although, one of the months, December, did not report warmer water temperatures. Average readings for the surface sites were 572 µS/cm and 1002 µS/cm for well sites.

The high conductivity that was found throughout a large portion of the wetland is likely caused by faster flowing, higher level waters flushing areas where the solids or ions have been able to dissolve in the wetland waters near S5 and W5. The runoff from Tanglewood Drive or nutrient content of the vegetated area near S7 and W1, or the direct input from the retention pond near W3. Precitpitation, with a low pH, that has dissolved more minerals from contact with soil may also account for an increase in conductivity in certain areas. The low conductivity of S2 can be possibly be explained by the soil, with potentially high organic content, that is near the former Inglis Greenhouse (Figure 3.4).

Table 3.6 Average conductivity readings recorded during sampling period of 2006 – 2007.

Sampling Sites	Conductivity (µs/cm)		
	Sample Mean	Standard Error (+/-)	Sample Size
S1	469	120	5
S2	259	103	5
S3	564	103	5
S4	401	47.8	5
S5	748	231	5
S6	460	87.5	5
S7	748	372	3
S8	675	107	6
W1	937	83.3	3
W2	744	144	7
W3	1557	284	6
W4	408	84.1	7
W5	1362	95.6	6
Creek	550	91.9	7
Pond	847	210	7

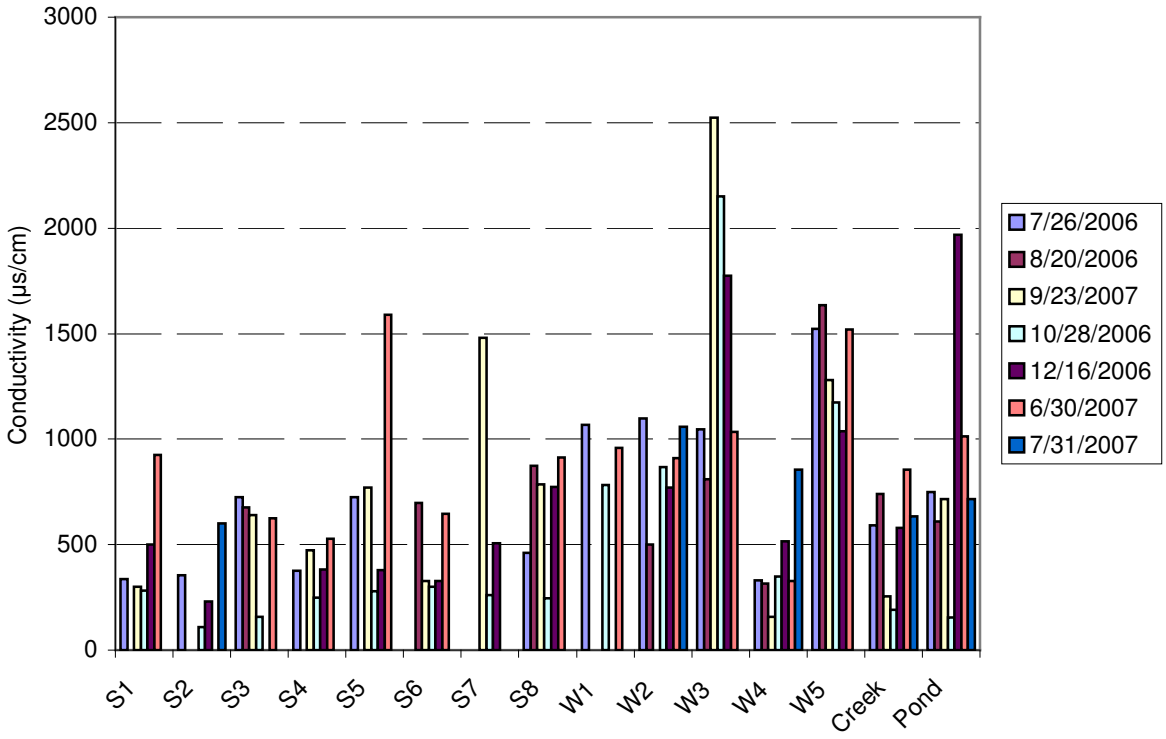

Figure 3.4 Conductivity readings recorded during sampling period of 2006 – 2007.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is a measure of the amount of oxygen consumed by mircoorganisms as organic matter is decomposed. BOD is inversely proportional to the amount of dissolved oxygen present in a body of water. As the concentration of BOD increases the concentration of DO in water will decrease. This can cause detrimental effects to the water itself and the aquatic life (MIDEQ 2008).

The Biochemical Oxygen Demand (BOD) test was conducted on four surface sites (S1, S2, S3, and S8) and three well sites (W1, W2, and W3) taken from the October 28, 2006 water samples. Due to problems with instrumentation and seeding, results of the analysis proved to be inconclusive. The results; however, appear to be of levels at or less

than those used for treated sewage. Results of analysis from test conducted on 10/28/06 are included in Appendix A.

Chemical Oxygen Demand (COD) (mg/L)

Chemical Oxygen Demand (COD) is a test used to measure the organic strength of wastes, both domestic and industrial (Sawyer et al. 2003). The basis for this test is the fact that under acidic conditions, strong oxidizing agents will oxidize organic compounds (Sawyer et al. 2003). When used in conjunction with the BOD test, the COD test can be an indicator of biologically resistant organic substances as well as toxic conditions by measuring the total quantity of oxygen that is necessary for oxidation to carbon dioxide and water (Sawyer et al. 2003).

The advantage to the COD test is that it can be completed in a relatively short amount of time and and estimate results of a BOD test, but there are a few limitations (Sawyer et al. 2003). For example, the test does not offer an indication for “the rate at which the biologically active material would be stabilized under conditions that exist in nature”. (Sawyer et al. 2003). The difference between the biologically oxidizable organic matter and the biologically inert organic matter is also difficult to determine (Sawyer et al. 2003).

A COD test was conducted on all surface and well sites. The results, listed in Appendix B, show that a relatively large number of sites, both surface and well, have the highest concentrations occur during the months of May and June in 2007 and the lowest concentrations occur during the months of September and October in 2006.

The highest concentrations were found during June at S2 (172.5 mg/L), May at W1 (193.0 mg/L), and June at W2 (246.0 mg/L). The lowest concentrations were found during July at S7 (20.8 mg/L), October at Creek (17.0 mg/L), and September/July at Pond (22.0 mg/L). Given the fact that COD is used to measure the organic strength of wastes

(pollution), the high concentrations during late spring and early summer may indicate that the water flowing into the wetland contains a higher organic content, potentially from landscaping and construction activities in the areas surrounding the wetland. The amount of precipitation during those months may also be a factor by increasing the amount and velocity of water that enters and flows through the wetland, possibly releasing organics that have settled into the soil. Location; however, must also be included in this rationale. Depending on the source of water and area near the sampling site, locations like S2 and W2 will have a higher COD concentration because of the soil from Inglis Greenhouse than W3 near the boundary of the wetland. Locations like S1, S7, S8, and W1 along Tanglewood Drive will also have higher level of COD because of the potentially polluted water from the drain or abundance of grasses, skunk cabbage, trees, and other vegetation. Table 3.7 lists the high and low concentrations of COD that were found through analysis.

Table 3.7 High and low chemical oxygen demand (COD) concentrations determined for the sampling period of 2006 – 2007.

Sample Sites	Date	Average COD Concentration (mg/L)
S1	7/26/2006	46.0
	6/30/2007	124
S2	9/23/2006	49.0
	5/30/2007	114
S3	9/23/2006	24.0
	5/30/2007	61.7
S4	9/23/2006	32.0
	5/30/2007	168
S5	10/28/2006	56.0
	6/30/2007	172
S6	8/20/2006	76.0
	10/28/2006	23.0
S7	5/30/2007	146
	7/31/2007	20.8
S8	9/23/2006	28.0
	10/28/2006	156
W1	10/28/2006	30.0
	5/30/2007	193
W2	5/30/2007	48.0
	6/30/2007	246
W3	8/20/2006	29.0
	9/23/2006	34.0
W4	10/28/2006	63.0
	7/31/2007	90.8
W5	9/23/2006	114
	5/30/2007	170
Creek	10/28/2006	17.0
	5/30/2007	70.0
Pond	9/23/2006	22.0
	5/30/2007	58.3

Ammonia-Nitrogen (NH_3-N) – (mg/L)

Nitrogen is found in organic and inorganic forms throughout the environment. Organic nitrogen is found in the cells of all living organisms and is constituent of amino acids, peptides, and proteins. The inorganic forms of nitrogen include ammonia (NH_3), nitrate (NO_3), nitrite (NO_2), and nitrogen gas (N_2). The least stable form of nitrogen in water is ammonia, which is found in two forms, the unionized ammonia gas (NH_3) and ammonium ion (NH_4^+). The pH of the water determines which form will be dominant (Murphy 1997). According to the Quality Criteria for Water 1986 guide published by the USEPA (1986), acute toxicity of ammonia is modified by several factors that include dissolved oxygen, temperature, and pH. Of these factors, pH has been studied the most, showing that the toxicity of NH_3 increases as pH decreases.

The average ammonia-nitrogen (NH_3-N) range listed by the state of Ohio for the protection of aquatic life with a pH range of 6.5-9.0 and 16°C average temperature is 2.2 mg/L-0.2mg/L during the months of March to November (Ohio EPAQ 2008). Tests for ammonia-nitrogen (NH_3-N) showed the highest average concentrations at S8 (1.30 mg/L), W1 (1.24 mg/L), W2 (1.63 mg/L), W4 (0.98 mg/L), and W5 (1.30 mg/L), while the lowest average concentrations were determined to be at sites S1 (0.34 mg/L), S3 (0.21 mg/L), S5 (0.18 mg/L), Creek (0.17 mg/L), and Pond (0.07 mg/L). The average results from the analysis for all sampling sites is listed in Table 3.8.

Table 3.8 Average ammonia-nitrogen (NH_3-N) concentrations determined for the sampling period of 2006 – 2007.

Sampling Sites	Ammonia-Nitrogen (NH_3-N) (mg/L)		
	Sample Mean	Standard Error	Sample Size
S1	0.34	0.19	4
S2	0.53	0.20	4
S3	0.21	0.09	4
S4	0.62	0.33	4
S5	0.18	0.07	4
S6	0.38	0.27	4
S7	0.36	0.26	3
S8	1.30	0.38	5
W1	1.24	0.79	2
W2	1.63	0.55	5
W3	0.54	0.25	5
W4	0.98	0.49	5
W5	1.30	0.26	5
Creek	0.17	0.08	5
Pond	0.07	0.03	5

The areas found to contain high concentrations of ammonia-nitrogen (NH_3-N), near the middle and along the southern and northern borders, are also the areas of abundant vegetation and slow moving waters. The sources for these sites are from Tanglewood Drive and the large amount of fertilized plant soil found behind the former Inglis Greenhouse. The vegetation in these areas of S8, W1, W2, W4, and W5 can account for the low concentrations in the slow flowing surface waters leading to the other sampling sites because the nutrients have been filtered into the soil and taken-up by the plants.

The areas found to contain lowest concentrations can possibly be the result of three factors; vegetation, flow of water, and water source. The Creek and Pond have a low concentration because of the amount and velocity of water that flows into the Pond from the parking lot. Throughout the season, each location was also impacted by rainfall and seasonal flooding events. The monthly concentrations of ammonia-nitrogen are shown in Figure 3.5.

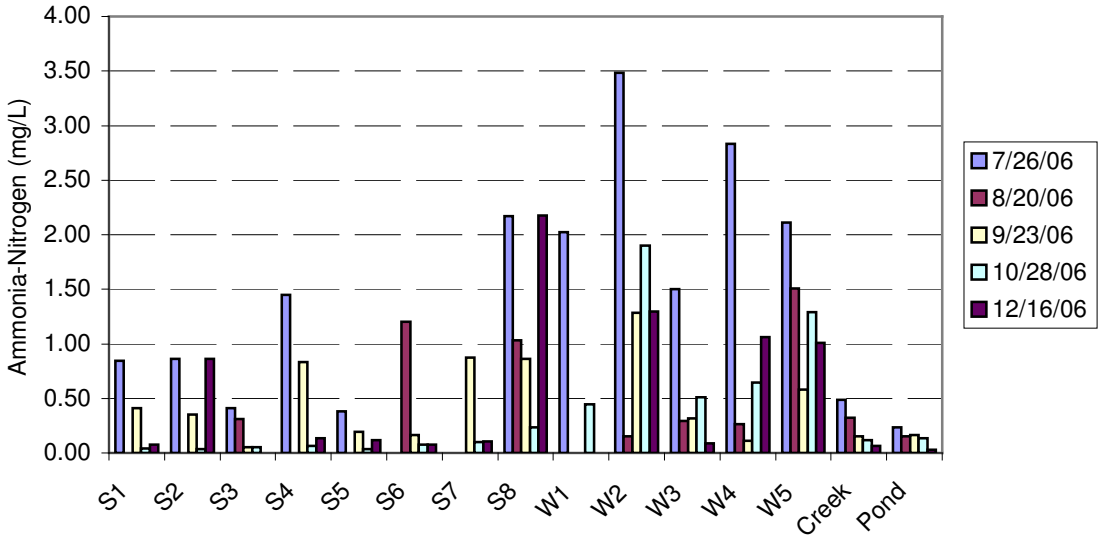

Figure 3.5 Ammonia-nitrogen (NH_3-N) concentrations determined for the sampling period of 2006 – 2007.

Fecal Coliform

Fecal coliform bacteria are a group of bacteria that belong to the family enterobacteriaceae (Murphy 1997). They are rod-shaped, non-spore forming, and can grow with or without oxygen (Murphy 1997). This type of bacteria, which live in the intestinal tracts of humans and other animals, soil, and water, enters a body of water through waste from human and animals that can be released directly by faulty sanitary sewer connections

or septic systems and wastewater treatment plant effluent (Murphy 1997). Fecal colifom is not usually pathogenic; however, the presence of these bacteria could be an indication that other pathogenic bacteria are present (Murphy 1997).

The average fecal coliform content (determined by the most probable number method (MPN) or membrane filter method (MF) that is listed by the state of Ohio for the primary contact shall not exceed 1,000 colonies/100 mL in no less than five percent of samples taken within a thirty-day period and shall not exceed 2,000 colonies/100 mL in ten percent of samples taken within any thirty-day timeframe. For secondary contact, the average fecal coliform content, determined under the same methods, shall not exceed 5,000 colonies/100 mL in more than ten percent of the sample obtained within any thirty-day period (Ohio EPA 2008). Primary contact refers to those waters during recreation season (May 1 – October 15) that are suitable for activities such as swimming or canoeing with a minimal threat to public health. Secondary contact refers to waters during recreation season that are suitable for wading with a minimal threat to public health (Ohio EPA 2008). While the wetland waters will not be used for activities like swimming (primary contact) or fishing (secondary contact), the EPA standards were used as a reference for sampling site results and measurement.

Both higher temperatures and higher levels of nutrients increase the growth rate of bacteria. Diseases, illnesses, and infections like typhoid fever, hepatitis, dysentery, and ear infections can be contracted through contact with waters that contain high fecal coliform counts (Murphy 1997). Certain strains of Escherichia coli, a type of fecal coliform found in the intestinal tracts of animals, can cause intestinal illness (Murphy 1997).

Results of the fecal coliform tests conducted on all samples showed that coliforms were present in each location. Coliform counts exceeded 5,000 colonies/100 mL during the summer for W1, W3, W4, and W5, the summer and fall for S1, S3, S5, S7, S8, and W2, and

the fall for S2, S4, and S6. Coliform counts for Creek and Pond remained consistent throughout the season, with the higher levels in the summer months and lower levels in the fall and winter months. Given this information and knowing that coliforms will be found in areas with high levels of nutrients, it was difficult to establish a trend since all sites had high counts at various times of the year. The presence of coliform bacteria in each location may simply depend upon what animal is inhabiting a specific area at a certain time or the amount of nutrients and water available to sustain colifom growth. Appendix C lists the results of the tests.

Soluble Reactive Phosphorus (SRP) – (µg/L)

Phosphorus is a natural element found in organic material, rocks, or soil and is also a necessary nutrient used by organisms for the basic process of life (Murphy 1997). Phosphorus in water can exist in several different forms; the main form is in a dissolved phase of phosphorus or phosphate (PO_4^{3-}) (Murphy 1997). Phosphates can either be organic, bound to animal or plant tissue formed mostly by biological processes, or inorganic phosphates that include orthophosphates or polyphosphates (Murphy 1997). Orthophosphate is often referred to as “reactive phosphorus” because it is the filterable, inorganic, soluble portion of phosphorus that is readily used by plant cells (Murphy 1997).

In water, phosphorus is considered to a growth-limiting nutrient because the concentration is less than the requirements of plants (Murphy 1997). Increases in nutrients from septic systems and wastewater effluents or agricultural runoff that can contain high concentrations of phosphorus (and nitrate) result in increased growth of algae and other aquatic plants and eventually eutrophic conditions (Murphy 1997).

According to the Ohio EPA Division of Surface Water (2008), waters must be free from nutrients that, as a result of human activity, create nuisance growths of algae and

weeds. Waters with concentrations of above 0.1 mg/L (100 µg/L) may begin to produce slime and algal growths (Cuyahoga Valley National Park Service 2002). The analysis conducted for Soluble Reactive Phosphorus (SRP) produced results that showed high concentrations in three locations; W1 (620.8 µg/L), W2 (687.4 µg/L), and S2 (732.3 µg/L) and lower concentrations in remaining areas of the wetland that ranged from 148.8 µg/L to 406.4 µg/L. The average results from the analysis for all sampling sites is listed in Table 3.9.

Table 3.9 Average soluble reactive phosphorus concentrations determined for the sampling period of 2006 – 2007.

Sampling Sites	Soluble Reactive Phosphorus (µg/L)		
	Sample Mean	Standard Error (+/-)	Sample Size
S1	274.5	71.9	5
S2	732.3	21.4	6
S3	200.3	42.6	6
S4	405.4	86.6	6
S5	406.4	109.5	5
S6	223.5	75.9	4
S7	275.4	67.2	5
S8	290.1	71.2	5
W1	620.8	313.2	4
W2	687.4	229.7	7
W3	193.2	28.7	6
W4	270.1	73.9	7
W5	333.9	68.6	7
Creek	257.7	44.7	7
Pond	148.8	35.3	7

Potential reasons for the higher concentrations along the northern and southern borders is the source of input, low velocity of water that flows in the areas, and vegetation. Site W1 located near Tanglewood Drive, was placed in an area of less vegetation, as compared with the other locations within the wetland, and a low water table. The vegetation in this part of the wetland is comprised of trees and spring herbaceous plants, skunk cabbage, and some grasses. The well W1 had higher levels of SRP compared to the surface sample from the same area (S1, S7, and S8). This may indicate that the soil is holding the phosphorus and only becomes available when conditions alter deep soil below the surface and release the phosphorus into the water.

The SRP levels from S2 and W2 could be due to the input from debris and waste from the former Inglis Greenhouse. There were piles of potting soil and waste that could slowly be eroding, providing higher SRP to this area as compared to other areas in the wetland. The remaining sites had relatively lower concentrations of SRP, although the concentrations were at levels that would produce algal growth. These levels also varied by season and type of location, with surface and well sampling sites having higher concentrations during different seasons. This was mainly noticed in samples taken at S4 and W4, near the center of the wetland. The results from testing S4 showed the highest concentration of SRP in May, compared with the highest concentration of SRP at W4 in October. The monthly concentrations for soluble reactive phosphorus are shown in Figure 3.6.

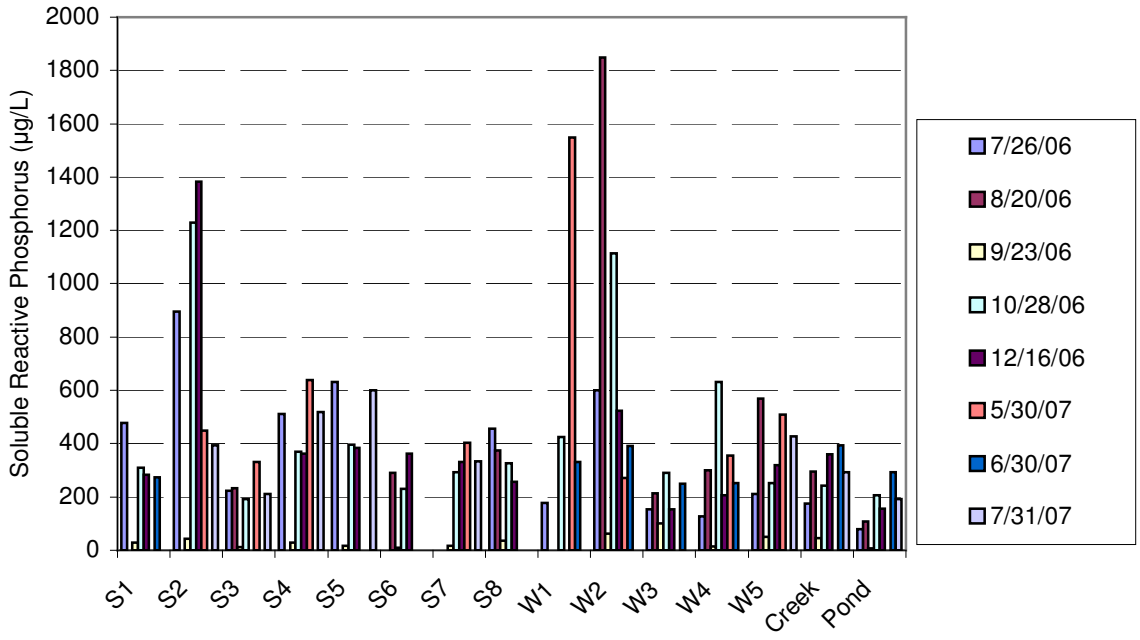

Figure 3.6 Soluble reactive phosphorus concentrations determined for the sampling period of 2006 – 2007.

Soluble Trace Metals

As ground water and surface water contacts rocks and soils that contain metals (usually found as metal salts) like aluminum, barium, calcium, cadmium, iron, and zinc, ions of the metals become dissolved. These metals occur naturally within the soil or enter water through point and non-point sources such as industrial and sewage treatment plants or runoff (Kentucky Water Watch [Internet]. [cited June 2006]).

The migration of metals in soil is influenced by chemical and physical chracteristics that are specific to a metal as well as by different environmental factors that include soil type, total organic content , and pH (Murray et al. 2004). The pH of the water can increase or decrease the toxicity of metals. As pH increases, the cationic metal salts precipitate out of solution and are not available for absorption by aquatic life. As pH decreases, the same

concentrations of metals in the water may become more toxic as they are dissolved in acidic waters (Kentucky Water Watch [Internet]. [cited June 2006]). Appendix D includes the results of the analysis and information on the water quality criteria of certain metals.

Samples taken from all 15 sites for the months of July, September, and October of 2006 were analyzed for various soluble trace metals. No detectable levels of Beryllium (Be) were reported during these dates; however, various sampling sites (both surface and well) reported levels of Arsenic (As), Cadmium (Cd), and Chromium (Cr). All sampling sites recorded concentrations of Copper (Cu), Iron (Fe), Lead (Pb), Nickel (Ni), and Zinc (Zn). Cadmium (Cd) and Iron (Fe) were both found at certain sites in concentrations that exceed Ohio State water quality criteria for the protection of agricultural uses.

The high concentrations of Cadmium were found in the July 26, 2006 sample for W1, which showed a concentration of 94.3 µg/L. Low concentrations of the same metal were reported as 1.81 µg/L for the Creek site on the same date. The average concentrations for sampling sites Creek (7/26/06), Creek (10/28/06), W1 (7/26/06), and W2 (7/26/06), were 1.99 µg/L for the surface samples and 49.3 µg/L for the well samples.

High concentrations for Iron (Fe) on the same sampling date were also found. Site S5 (7/26/06) and W5 (7/26/06) returned concentrations of 12,190 µg/L and 13,4325 µg/L respectively. The lowest concentration was 125.9 µg/L found at S3 (7/26/06). The average concentrations of all sites analyzed were 2171.9 µg/L for the surface samples and 8831.2 µg/L for the well samples.

From this analysis, it has been determined that the well sample sites have higher concentrations of soluble trace metals than surface sample sites. This can be explained by soluble trace metals entering the wetland with the sources of input or water from the surface filtering through the soils, while at the same time adsorbing to soil particles and dissolving minerals. This could also partially explain the low concentrations of metals in the surface

water, where the water has filtered into the soil and had minimal contact with the surface. The other explanation for low metal concentrations in surface water is the higher velocity of water flow during flooding events that flushes the water through various areas of the wetland, not allowing time for mineral dissolution.

Statistical Analysis

Using analysis of variance (ANOVA), statistical analysis was conducted on the surface sample sites of S1 – S5 and well sample sites of WI – W5 to determine statistical significance of means for surface and corresponding well sample sites. With regard to pH, little or low statistical significance was found ($p = 0.08$). All samples were consistent with the 7.40 average for surface samples and 6.94 for well samples. The same determination was made for water temperature ($p = 0.66$). There were no extremes to the 15.8 ℃ average surface temperature or 15.0 ℃ well temperature. For DO, conductivity and ammonia-nitrogen, differences between the surface and well samples were prevalent. Concentrations were higher in surface samples for DO ($p = 0.02$), while concentrations were higher in the well samples for conductivity and ammonia-nitrogen ($p = 0.05$ and 0.005 respectively). There was also no difference found with Soluble Reactive Phosphorus (SRP) ($p = 0.90$); however, the average SRP concentration for W1 (620.8 µg/L) was marginally greater than the average concentration for S1 (274.5 µg/L).

CHAPTER 4 Conclusion and Recommendations

The analysis that was conducted both on-site and in the laboratory has provided the baseline needed to further study the Cranberry Run Wetland. The results determined for the surface and well sampling sites show that the water quality of the wetland is directly influenced by location. These influences include the sources of input that the wetland receives from runoff and drainage systems, types of property that surround the wetland, and weather of Northeast Ohio. The water sources and surrounding properties govern what the wetland receives in terms of pollution, while weather affects the amount of precipitation received, water flow, and water level.

The results of the analysis also show that the wetland is serving in the functional capacity as a filter. The average results for each water quality parameter of the surface sample sites were used to create a comparison between the surface waters of Cranberry Run Wetland as complete system and the water that flows Northeast into the Creek sampling site. Table 4.1 provides the results of the analysis.

Table 4.1 Comparison of analysis for the Creek site to the other surface sampling sites

Parameter	Creek	Average Results (Surface)
Temperature (℃)	17.0 +/- 2.92	15.8
DO (mg/L)	2.26 +/- 0.97	2.97
pH	7.47 +/- 0.082	7.40
Conductivity (µs/cm)	550 +/- 92.0	572
Ammonia-Nitrogen (mg/L)	0.173 +/- 0.077	0.416
Soluble Reactive Phosphorus (µg/L)	257.7 +/- 44.7	321.4

Not represented in the table are the fecal coliform and COD parameters. For fecal colifom counts, the Creek only exceeded 5,000 colonies/100 mL during August, September, and October of 2006. With regard to COD, a higher concentration was determined in the month of May and a lower concentration in the month of October. These results coincide with the other surface sampling site locations.

Recommendations

The sampling and analysis for this project would not have been possible without the assistance that was received from faculty, family, and fellow students. A team approach is needed in order to accomplish the tasks that are required for analyzing water samples for each parameter that was selected.

Should changes need to be made to the methods and procedures that were followed for the project, it is recommended that sample sizes be increased by selecting other sampling locations and additional wells be installed. Also, the time of day when samples are collected should be altered and the frequency of sampling events should be increased so that any trends that have been noticed (natural or man-made through pollution) can be further defined. The sampling period should also be increased to include early spring and early to mid winter, if possible. Additional sources of input should also be collected and analyzed. This should include water from various areas in or around the wetland and from areas near State Route 224. By increasing the sample size, sampling time, frequency, period, and selecting additional sources of input, a greater representation of the wetland will be realized and a better understanding of the wetland's functions will be gained.

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Appendix A – Biological Oxygen Demand (BOD)

Sampling Sites	Temperature Initial (°C)	DO Concentration - Initial		Temperature Final (°C)
		%	mg/L	
Dilution Water - No Seed	20	96.7	8.76	12.1
Dilution Water - 1 mL of Seed	22	98.5	8.62	12.1
Glucose-Glutamic Acid 1 mL of Seed	22.1	95.9	8.45	12.3
S1 - 5 mL	20.3	103.7	9.51	12.2
S1 - 50 mL	20.3	113.8	10.50	12.1
S1 - 100 mL	19.7	100.8	9.28	12.2
S2 - 5 mL	20.2	120.0	11.02	12.4
S2 - 50 mL	20.1	115.3	10.48	12.6
S2 - 100 mL	20.3	122.4	10.97	12.6
S3 - 5 mL	20.3	113.6	10.20	12.6
S3 - 50 mL	20.3	130.4	11.98	12.5
S3 - 100 mL	20.4	127.7	11.47	12.3
S8 - 5 mL	20.4	126.6	11.35	12.6
S8 - 50 mL	20.5	125.4	11.27	12.4
S8 - 100 mL	20.2	126.8	11.53	12.2
W1 - 5 mL	20.5	126.4	11.35	12.5
W1 - 50 mL	20.5	133.0	11.94	12.3
W1 - 100 mL	20.4	123.9	11.09	12.3
W2 - 5 mL	20.8	122.2	11.10	12.4
W2 - 50 mL	20.9	113.8	10.20	12.2
W2 - 100 mL	21.1	113.7	10.10	12.4
W3 - 5 mL	21.1	105.7	9.40	12.5
W3 - 50 mL	21.5	102.5	9.06	12.6
W3 - 100 mL	21.6	102.1	8.98	12.5

S=Surface

W=Well

Biological Oxygen Demand (BOD) Continued

Sampling Sites	Temperature Final (°C)	DO Concentration - Final	
		%	mg/L
Dilution Water - No Seed	12.1	77.7	7.84
Dilution Water - 1 mL of Seed	12.1	77.0	7.77
Glucose-Glutamic Acid 1 mL of Seed	12.3	77.0	0.73
S1 - 5 mL	12.2	35.2	3.53
S1 - 50 mL	12.1	63.7	6.42
S1 - 100 mL	12.2	49.9	4.97
S2 - 5 mL	12.4	78.7	8.01
S2 - 50 mL	12.6	45.2	4.37
S2 - 100 mL	12.6	15.3	1.49
S3 - 5 mL	12.6	82.4	8.26
S3 - 50 mL	12.5	75.4	7.58
S3 - 100 mL	12.3	73.2	7.29
S8 - 5 mL	12.6	80.6	7.91
S8 - 50 mL	12.4	78.0	7.66
S8 - 100 mL	12.2	68.8	6.71
W1 - 5 mL	12.5	76.6	8.19
W1 - 50 mL	12.3	84.9	9.07
W1 - 100 mL	12.3	72.5	7.73
W2 - 5 mL	12.4	80.4	8.56
W2 - 50 mL	12.2	59.4	6.37
W2 - 100 mL	12.4	29.2	2.91
W3 - 5 mL	12.5	72.3	7.58
W3 - 50 mL	12.6	76.5	8.20
W3 - 100 mL	12.5	72.9	7.67

S=Surface
W=Well

Biological Oxygen Demand (BOD) Continued

Sampling Sites			BOD seed		
Dilution Water - No Seed					
Dilution Water - 1 mL of Seed					
Glucose-Glutamic Acid 1 mL of Seed	I - F (%)	I - F (mg/L)	consumed	P- vol. fraction	BOD mg/L
S1 - 5 mL	68.5	5.98	0.85	0.017	307.8
S1 - 50 mL	50.1	4.08	0.85	0.167	19.38
S1 - 100 mL	50.9	4.31	0.85	0.333	10.38
S2 - 5 mL	41.3	3.01	0.85	0.017	129.6
S2 - 50 mL	70.1	6.11	0.85	0.167	31.56
S2 - 100 mL	107.1	9.48	0.85	0.333	25.89
S3 - 5 mL	31.2	1.94	0.85	0.017	65.4
S3 - 50 mL	55	4.40	0.85	0.167	21.3
S3 - 100 mL	54.5	4.18	0.85	0.333	9.99
S8 - 5 mL	46	3.44	0.85	0.017	155.4
S8 - 50 mL	47.4	3.61	0.85	0.167	16.56
S8 - 100 mL	58	4.82	0.85	0.333	11.91
W1 - 5 mL	49.8	3.16	0.85	0.017	138.6
W1 - 50 mL	48.1	2.87	0.85	0.167	12.12
W1 - 100 mL	51.4	3.36	0.85	0.333	7.53
W2 - 5 mL	41.8	2.54	0.85	0.017	101.4
W2 - 50 mL	54.4	3.83	0.85	0.167	17.88
W2 - 100 mL	84.5	7.19	0.85	0.333	19.02
W3 - 5 mL	33.4	1.82	0.85	0.017	58.2
W3 - 50 mL	26	0.86	0.85	0.167	0.06
W3 - 100 mL	29.2	1.31	0.85	0.333	1.38

S=Surface
W=Well

Appendix B – Chemical Oxygen Demand (COD)

Sample Sites	Date	Absorbance @ 620 nm	COD Concentration (mg/L)	Absorbance @ 620 nm	COD Concentration (mg/L)	Average Concentration (mg/L)
S1	7/26/2006	0.021	47	0.02	45	46
S1	9/23/2006	0.021	47	0.02	45	46
S1	10/28/2006	0.024	53	0.018	41	47
S1	6/30/2007	0.035	121.0	0.037	127.7	124.3
S2	7/26/2006	0.051	107	0.043	91	99
S2	9/23/2006	0.023	51	0.021	47	49
S2	10/28/2006	0.054	113	0.045	95	104
S2	5/30/2007	0.046	111.8	0.048	116.8	114.3
S2	5/30/2007	0.026	93.3	0.026	93.3	93.3
S2	6/30/2007	0.026	91.0	0.026	91.0	91.0
S2	7/31/2007	0.019	52.0	0.019	52.0	52.0
S3	8/20/2006	0.016	37	0.016	37	37
S3	9/23/2006	0.011	27	0.008	21	24
S3	10/28/2006	0.009	23	0.013	31	27
S3	5/30/2007	0.021	49.3	0.022	51.8	50.5
S3	5/30/2007	0.015	56.7	0.018	66.7	61.7
S3	6/30/2007	0.014	51.0	0.014	51.0	51.0
S4	9/23/2006	0.013	31	0.014	33	32
S4	10/28/2006	0.021	47	0.022	49	48
S4	5/30/2007	0.053	129.3	0.051	124.3	126.8
S4	5/30/2007	0.049	170.0	0.048	166.7	168.3
S4	6/30/2007	0.034	117.7	0.034	117.7	117.7
S5	7/26/2006	0.053	111	0.054	113	112
S5	9/23/2006	0.038	81	0.037	79	80
S5	10/28/2006	0.025	55	0.026	57	56
S5	6/30/2007	0.067	172.5	0.067	172.5	172.5
S6	8/20/2006	0.035	75	0.036	77	76
S6	9/23/2006	0.018	41	0.018	41	41
S6	10/28/2006	0.009	23	0.009	23	23
S7	9/23/2006	0.015	35	0.016	37	36
S7	10/28/2006	0.017	39	0.021	47	43
S7	5/30/2007	0.035	84.3	0.036	86.8	85.5
S7	5/30/2007	0.042	146.7	0.042	146.7	146.7
S7	6/30/2007	0.013	37.5	0.014	40.0	38.8
S7	7/31/2007	0.008	24.5	0.005	17.0	20.8
S8	8/20/2006	0.014	33	0.016	37	35
S8	9/23/2006	0.011	27	0.012	29	28
S8	10/28/2006	0.023	51	0.128	261	156

Chemical Oxygen Demand (COD) Continued

Sample Sites	Date	Absorbance @ 620 nm	COD Concentration (mg/L)	Absorbance @ 620 nm	COD Concentration (mg/L)	Average Concentration (mg/L)
W1	10/28/2006	0.012	29	0.013	31	30
W1	5/30/2007	0.079	194.3	0.078	191.8	193.0
W1	5/30/2007	0.015	56.7	0.018	66.7	61.7
W1	6/30/2007	0.018	64.3	0.018	64.3	64.3
W2	8/20/2006	0.096	197	0.09	185	191
W2	10/28/2006	0.079	163	0.085	175	169
W2	5/30/2007	0.021	49.3	0.020	46.8	48.0
W2	5/30/2007	0.013	50.0	0.013	50.0	50.0
W2	6/30/2007	0.073	247.7	0.072	244.3	246.0
W2	7/31/2007	0.073	187.0	0.069	177.0	182.0
W3	8/20/2006	0.01	25	0.014	33	29
W3	9/23/2006	0.015	35	0.014	33	34
W3	10/28/2006	0.013	31	0.01	25	28
W3	6/30/2007	0.006	24.3	0.009	34.3	29.3
W4	8/20/2006	0.033	71	0.031	67	69
W4	9/23/2006	0.038	81	0.038	81	81
W4	10/28/2006	0.033	71	0.025	55	63
W4	5/30/2007	0.027	64.3	0.033	79.3	71.8
W4	5/30/2007	0.020	73.3	0.020	73.3	73.3
W4	6/30/2007	0.021	74.3	0.020	71.0	72.7
W4	7/31/2007	0.034	89.5	0.035	92.0	90.8
W5	9/23/2006	0.055	115	0.054	113	114
W5	10/28/2006	0.067	139	0.075	155	147
W5	5/30/2007	0.058	141.8	0.059	144.3	143.0
W5	5/30/2007	0.049	170.0	0.049	170.0	170.0
W5	6/30/2007	0.065	167.5	0.067	172.5	170.0
Creek	8/20/2006	0.015	35	0.016	37	36
Creek	9/23/2006	0.01	25	0.01	25	25
Creek	10/28/2006	0.007	19	0.005	15	17
Creek	5/30/2007	0.026	61.8	0.026	61.8	61.8
Creek	5/30/2007	0.018	66.7	0.020	73.3	70.0
Creek	6/30/2007	0.013	37.5	0.015	42.5	40.0
Creek	7/31/2007	0.008	24.5	0.007	22.0	23.3
Pond	8/20/2006	0.017	39	0.017	39	39
Pond	9/23/2006	0.009	23	0.008	21	22
Pond	5/30/2007	0.019	44.3	0.021	49.3	46.8
Pond	5/30/2007	0.014	53.3	0.017	63.3	58.3
Pond	6/30/2007	0.013	37.5	0.012	35.0	36.3
Pond	7/31/2007	0.006	19.5	0.008	24.5	22.0

Appendix C – Fecal Coliform Analysis from Cranberry Run Wetland Water Samples
Coliforms/100 mL (Ideal range 20 -80 coliforms; not more than 200 coliforms)

Sampling Sites	7/25/2006	8/20/2006	9/23/2006	10/28/2006	12/16/2006	6/30/2007	7/31/2007	8/31/2007
S1	583 coliforms/100 mL	Sample not taken	TNTC	TNTC	TNTC	≥160 coliforms/ 100 mL	Sample not taken	TNTC
S2	No analysis	Sample not taken	TNTC	TNTC	TNTC	Sample not taken	TNTC	≥200 coliforms/ 100 mL
S3	TNTC	TNTC	TNTC	TNTC	Sample not taken	TNTC	Sample not taken	TNTC
S4	No analysis	Sample not taken	TNTC	TNTC	≥100 coliforms/ 100 mL	TNTC	Sample not taken	No analysis
S5	No analysis	Sample not taken	≥160 coliforms/ 100 mL	TNTC	TNTC	TNTC	Sample not taken	TNTC
S6	No analysis	TNTC	TNTC	TNTC	≥150 coliforms/ 100 mL	Sample not taken	Sample not taken	No analysis
S7	No analysis	Sample not taken	TNTC	TNTC	TNTC	Sample not taken	TNTC	TNTC
S8	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	Sample not taken	No analysis
W1	TNTC	Sample not taken	Sample not taken	TNTC	Sample not taken	TNTC	Sample not taken	TNTC
W2	≥2500 coliforms/ 100 mL	≥1000 coliforms/ 100 mL	TNTC	TNTC	250 coliforms/ 100 mL	TNTC	TNTC	TNTC
W3	650 coliforms/ 100 mL	≥200 coliforms/ 100 mL	≥1800 coliforms/ 100 mL	≥100 coliforms/ 100 mL	0	TNTC	Sample not taken	≥533 coliforms/ 100 mL
W4	TNTC	TNTC	TNTC	≥160 coliforms/100 mL	0	TNTC	≥100 coliforms/ 100 mL	TNTC
W5	TNTC	≥100 coliforms/ 100 mL	≥100 coliforms/ 100 mL	800 coliforms/ 100 mL	0	TNTC	Sample not taken	≥1200 coliforms/ 100 mL
Creek	695 coliforms/ 100 mL	TNTC	TNTC	TNTC	≥200 coliforms/ 100 mL	TNTC	TNTC	TNTC
Pond	No analysis	Error with analysis	TNTC	TNTC	TNTC	TNTC	Error with Analysis	TNTC

TNCT - too numerous to count

Appendix D – Soluble Metals

STATE OF OHIO WATER QUALITY STANDARDS
Chapter 3745-1 of the ADMINISTRATIVE CODE 3745-1-07 22
Table 7-12. Statewide water quality criteria for the protection of agricultural uses.

Chemical	Form1	Units2	OMZA3	Units2
Arsenic (As)	TR	µg/l	100	ppb
Beryllium (Be)	TR	µg/l	100	ppb
Cadmium (Cd)	TR	µg/l	50	ppb
Total chromium (Cr)	TR	µg/l	100	ppb
Copper (Cu)	TR	µg/l	500	ppb
Iron (Fe)	TR	µg/l	5,000	ppb
Lead (Pb)	TR	µg/l	100	ppb
Nickel	TR	µg/l	200	ppb
Zinc (Zn)	TR	µg/l	25,000	ppb

1 T = total; TR = total recoverable.
2 mg/l = milligrams per liter (parts per million); µg/l = micrograms per liter (parts per billion).
3 OMZA = outside mixing zone average.

Soluble Arsenic (As) from Cranberry Run Wetland Water Samples

Sample ID	Reporting ppb	Element
YSU CREEK 7-26-06	10.11	As 188.980
YSU S1 7-26-06	8.46	As 188.980
YSU S3 10-28-06	4.80	As 188.980
YSU S5 7-26-06	8.18	As 188.980
YSU S7 9-23-06	5.98	As 188.980
YSU W3 9-23-06	4.49	As 188.980
YSU W4 7-26-06	7.43	As 188.980
YSU W5 7-26-06	16.24	As 188.980
YSU W5 9-23-06	9.70	As 188.980
YSU W1 7-26-06	8.21	As 193.696
YSU W2 7-26-06	18.66	As 193.696

Soluble Beryllium (Be) from Cranberry Run Wetland Water Samples
All samples analyzed were below detectable levels

Soluble Cadmium (Cd) from Cranberry Run Wetland Water Samples

Sample ID	Reporting ppb	Element
YSU CREEK 7-26-06	1.81	Cd 214.439
YSU CREEK 10/28/06	2.16	Cd 214.439
YSU W2 7-26-06	4.29	Cd 214.439
YSU W1 7-26-06	94.27	Cd 214.439
YSU S2 10/28/06	3.08	Cd 226.502
YSU S8 9-23-06	1.77	Cd 228.802

Soluble Chromium (Cr) from Cranberry Run Wetland Water Samples

Sample ID	Reporting ppb	Element
YSU CREEK 10/28/06	6.04	Cr 205.560
YSU CREEK 7-26-06	2.59	Cr 205.560
YSU POND 10/28/06	6.40	Cr 205.560
YSU POND 7-26-06	3.28	Cr 205.560
YSU S3 10-28-06	6.07	Cr 205.560
YSU S3 7-26-06	3.22	Cr 205.560
YSU S4 7-26-06	1.27	Cr 205.560
YSU S5 7-26-06	1.22	Cr 205.560
YSU S8 10/28/07	1.59	Cr 205.560
YSU S8 9-23-06	1.68	Cr 205.560
YSU W1 7-26-06	6.39	Cr 205.560
YSU W5 9-23-06	2.71	Cr 206.158
YSU S2 10/28/06	2.74	Cr 206.158
YSU W5 7-26-06	2.95	Cr 206.158
YSU S3 9-23-06	3.15	Cr 206.158
YSU CREEK 9-23-06	4.27	Cr 267.716
YSU S5 9-23-06	1.57	Cr 267.716
YSU S6 10/28/06	3.44	Cr 267.716
YSU W2 7-26-06	4.93	Cr 267.716
YSU W4 7-26-06	1.66	Cr 267.716

Soluble Copper (Cu) from Cranberry Run Wetland Water Samples

Sample ID	Reporting ppb	Element
YSU S1 7-26-06	12.91	Cu 219.959
YSU S3 10-28-06	15.17	Cu 219.959
YSU S5 7-26-06	10.63	Cu 219.959
YSU W5 9-23-06	16.88	Cu 219.959
YSU POND 7-26-06	15.09	Cu 324.754
YSU S1 9-22-06	10.46	Cu 324.754
YSU S2 10/28/06	25.12	Cu 324.754
YSU S3 7-26-06	14.25	Cu 324.754
YSU S4 10/28/06	9.75	Cu 324.754
YSU S6 10/28/06	14.91	Cu 324.754
YSU S7 10/28/06	11.67	Cu 324.754
YSU W1 7-26-06	27.76	Cu 324.754
YSU W4 7-26-06	23.71	Cu 324.754
YSU CREEK 10/28/06	14.37	Cu 327.395
YSU CREEK 7-26-06	11.11	Cu 327.395
YSU CREEK 9-23-06	14.09	Cu 327.395
YSU POND 10/28/06	15.51	Cu 327.395
YSU S1 10/28/06	11.25	Cu 327.395
YSU S2 7-26-06	10.38	Cu 327.395
YSU S2 9-23-06	9.27	Cu 327.395
YSU S3 9-23-06	11.71	Cu 327.395
YSU S4 7-26-06	11.41	Cu 327.395
YSU S4 9-23-06	15.40	Cu 327.395
YSU S5 10/28/06	10.94	Cu 327.395
YSU S5 9-23-06	13.26	Cu 327.395
YSU S7 9-23-06	9.92	Cu 327.395
YSU S8 10-28-06	17.14	Cu 327.395
YSU S8 9-23-06	14.20	Cu 327.395
YSU W1 10-28-06	10.13	Cu 327.395
YSU W2 7-26-06	20.04	Cu 327.395
YSU W3 9-23-06	12.47	Cu 327.395
YSU W3 7-26-06	8.50	Cu 327.395
YSU W4 10/28/06	10.80	Cu 327.395
YSU W4 9-23-06	9.92	Cu 327.395
YSU W5 7-26-06	13.28	Cu 327.395

Soluble Iron (Fe) from Cranberry Run Wetland Water Samples

Sample ID	Reporting ppb	Element
YSU CREEK 7-26-06	2490	Fe 238.204
YSU CREEK 9-23-06	156	Fe 238.204
YSU POND 10/28/06	151	Fe 238.204
YSU POND 7-26-06	163	Fe 238.204
YSU S2 10/28/06	1568	Fe 238.204
YSU S2 9-23-06	2151	Fe 238.204
YSU S3 9-23-06	126	Fe 238.204
YSU S4 10/28/06	1939	Fe 238.204
YSU S4 9-23-06	1826	Fe 238.204
YSU S5 10/28/06	1624	Fe 238.204
YSU S5 7-26-06	12191	Fe 238.204
YSU S5 9-23-06	4773	Fe 238.204
YSU S6 10/28/06	528	Fe 238.204
YSU S8 10/28/06	722	Fe 238.204
YSU W1 7-26-06	8475	Fe 238.204
YSU W2 7-26-06	10770	Fe 238.204
YSU W3 9-23-06	6856	Fe 238.204
YSU W4 9-23-06	4629	Fe 238.204
YSU W5 7-26-06	13425	Fe 238.204
YSU CREEK 10/28/06	227	Fe 239.563
YSU S1 10/28/06	1060	Fe 239.563
YSU S1 9-22-06	4755	Fe 239.563
YSU S2 7-26-06	5018	Fe 239.563
YSU S3 10-28-06	228	Fe 239.563
YSU S3 7-26-06	124	Fe 239.563
YSU W1 10-28-06	911	Fe 239.563
YSU W3 7-26-06	11996	Fe 239.563
YSU W4 10/28/06	935	Fe 239.563
YSU W4 7-26-06	2514	Fe 239.563
YSU S1 7-26-06	6185	Fe 259.940
YSU S4 7-26-06	8717	Fe 259.940
YSU S7 10/28/06	1005	Fe 259.940
YSU S7 9-23-06	1487	Fe 259.940
YSU S8 9-23-06	1647	Fe 259.940
YSU W5 9-23-06	6424	Fe 259.940

Soluble Lead (Pb) from Cranberry Run Wetland Water Samples

Sample ID	Reporting ppb	Element
YSU CREEK 10/28/06	4.30	Pb 220.353
YSU POND 10/28/06	5.41	Pb 220.353
YSU S1 10/28/06	3.97	Pb 220.353
YSU S1 7-26-06	6.33	Pb 220.353
YSU S2 10/28/06	12.62	Pb 220.353
YSU S3 10-28-06	23.42	Pb 220.353
YSU S3 9-23-06	5.59	Pb 220.353
YSU S4 7-26-06	6.76	Pb 220.353
YSU S4 9-23-06	6.75	Pb 220.353
YSU S5 10/28/06	5.36	Pb 220.353
YSU S5 9-23-06	6.44	Pb 220.353
YSU S6 10/28/06	7.58	Pb 220.353
YSU S7 10/28/06	5.28	Pb 220.353
YSU S8 10/28/06	7.67	Pb 220.353
YSU S8 9-23-06	7.02	Pb 220.353
YSU W1 10-28-06	2.92	Pb 220.353
YSU W1 7-26-06	71.40	Pb 220.353
YSU W2 7-26-06	12.44	Pb 220.353
YSU W3 9-23-06	7.32	Pb 220.353
YSU W3 7-26-06	4.73	Pb 220.353
YSU W4 7-26-06	7.25	Pb 220.353
YSU W5 7-26-06	11.31	Pb 220.353
YSU W5 9-23-06	21.78	Pb 220.353

Soluble Nickel (Ni) from Cranberry Run Wetland Water Samples

Sample ID	Reporting ppb	Element
YSU CREEK 10/28/06	4.56	Ni 221.648
YSU CREEK 7-26-06	6.10	Ni 221.648
YSU CREEK 9-23-06	7.86	Ni 221.648
YSU POND 7-26-06	4.57	Ni 221.648
YSU S1 10/28/06	29.71	Ni 221.648
YSU S1 7-26-06	8.11	Ni 221.648
YSU S1 9-22-06	5.31	Ni 221.648
YSU S2 10/28/06	14.41	Ni 221.648
YSU S2 7-26-06	9.98	Ni 221.648
YSU S2 9-23-06	5.44	Ni 221.648
YSU S3 10-28-06	3.81	Ni 221.648
YSU S3 7-26-06	13.99	Ni 221.648
YSU S3 9-23-06	5.45	Ni 221.648
YSU S4 10/28/06	7.70	Ni 221.648
YSU S4 7-26-06	6.45	Ni 221.648
YSU S4 9-23-06	14.58	Ni 221.648
YSU S5 10/28/06	6.65	Ni 221.648
YSU S5 7-26-06	9.44	Ni 221.648
YSU S5 9-23-06	11.44	Ni 221.648
YSU S6 10/28/06	8.53	Ni 221.648
YSU S7 10/28/06	9.07	Ni 221.648
YSU S7 9-23-06	8.84	Ni 221.648
YSU S8 10-28-06	36.71	Ni 221.648
YSU S8 9-23-06	14.56	Ni 221.648
YSU W1 10-28-06	7.56	Ni 221.648
YSU W1 7-26-06	30.83	Ni 221.648
YSU W2 7-26-06	51.18	Ni 221.648
YSU W3 9-23-06	23.60	Ni 221.648
YSU W3 7-26-06	13.54	Ni 221.648
YSU W4 10/28/06	11.13	Ni 221.648
YSU W4 7-26-06	24.62	Ni 221.648
YSU W4 9-23-06	7.63	Ni 221.648
YSU W5 7-26-06	28.50	Ni 221.648
YSU W5 9-23-06	31.23	Ni 221.648
YSU POND 10/28/06	73.39	Ni 231.604

Soluble Zinc (Zn) from Cranberry Run Wetland Water Samples

Sample ID	Reporting ppb	Element
YSU CREEK 7-26-06	43.39	Zn 206.200
YSU CREEK 9-23-06	44.64	Zn 206.200
YSU POND 7-26-06	34.73	Zn 206.200
YSU S1 7-26-06	50.64	Zn 206.200
YSU S2 10/28/06	155.64	Zn 206.200
YSU S2 7-26-06	37.36	Zn 206.200
YSU S2 9-23-06	35.10	Zn 206.200
YSU S3 9-23-06	36.85	Zn 206.200
YSU S4 10/28/06	42.62	Zn 206.200
YSU S4 7-26-06	39.88	Zn 206.200
YSU S4 9-23-06	55.66	Zn 206.200
YSU S5 7-26-06	35.08	Zn 206.200
YSU S5 9-23-06	54.98	Zn 206.200
YSU S7 10/28/06	45.70	Zn 206.200
YSU S7 9-23-06	32.42	Zn 206.200
YSU W1 7-26-06	212.22	Zn 206.200
YSU W2 7-26-06	147.47	Zn 206.200
YSU W3 9-23-06	39.44	Zn 206.200
YSU W3 7-26-06	27.72	Zn 206.200
YSU W4 7-26-06	105.08	Zn 206.200
YSU W4 9-23-06	32.26	Zn 206.200
YSU W5 7-26-06	167.68	Zn 206.200
YSU W5 9-23-06	199.33	Zn 206.200
YSU CREEK 10/28/06	64.04	Zn 213.857
YSU POND 10/28/06	65.57	Zn 213.857
YSU S1 10/28/06	70.92	Zn 213.857
YSU S1 9-22-06	53.21	Zn 213.857
YSU S3 10-28-06	46.40	Zn 213.857
YSU S3 7-26-06	31.54	Zn 213.857
YSU S5 10/28/06	40.45	Zn 213.857
YSU S6 10/28/06	51.32	Zn 213.857
YSU S8 10/28/06	312.14	Zn 213.857
YSU S8 9-23-06	95.55	Zn 213.857
YSU W1 10-28-06	35.52	Zn 213.857
YSU W4 10/28/06	46.52	Zn 213.857