Physical, Chemical, and Biological Characteristics of Congress Lake Outlet,

Stark and Portage Counties, Ohio

by

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Abstract

A study was performed in the Congress Lake Outlet watershed, Stark and Portage counties, Ohio, examining sediment, general water quality characteristics, nutrients, fecal coliform bacteria, macro-invertebrates, and applying a Qualitative Habitat Evaluation Index to determine the attainment status of Warmwater Habitat Aquatic Life Use designation.

Sediment analysis was performed once utilizing EPA trap and purge method #524 for volatile organic compounds and EPA #3550 Sonication Extraction method for high concentrations of pesticides. Pesticide extractions were analyzed on a Hewlett Packard Gas Chromatograph Mass Spectrometer. General water quality variables, taken four times, included pH, temperature, turbidity, and conductivity were recorded using a YSI model #6600-M probe and data logger. Data was combined into two data sets, winter and spring. Nutrients analyzed included ammonia, nitrate, total phosphorus, and soluble reactive phosphorus. Absorbency was determined on a Bausch & Lomb Spectronic #1001. Fecal coliform bacteria was analyzed twice and macro-invertebrate collection completed the biological sampling. Physical attributes were applied to the Ohio EPA Qualitative Habitat Evaluation Index. A primary components analysis was performed.

The Congress Lake Outlet is in non-attainment of Warmwater Habitat criteria for the Aquatic Life use designation. Primary causes of non-attainment are chemical and physical. Chemical impairment is due to elevated nutrients levels resulting in eutrophic conditions. Physical impairments are due to hydro-modifications primary for agricultural purposes.

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I would like to dedicate this thesis to my husband Robert C. Guyette who has been a source of encouragement and support during both the undergraduate and masters programs.

I would like to offer a special thanks to Dr. Joan Sturtevant for her encouragement and field assistance. She remained a constant source of support during even the harshest conditions.

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Dr. Daryl Mincey - Chairman

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

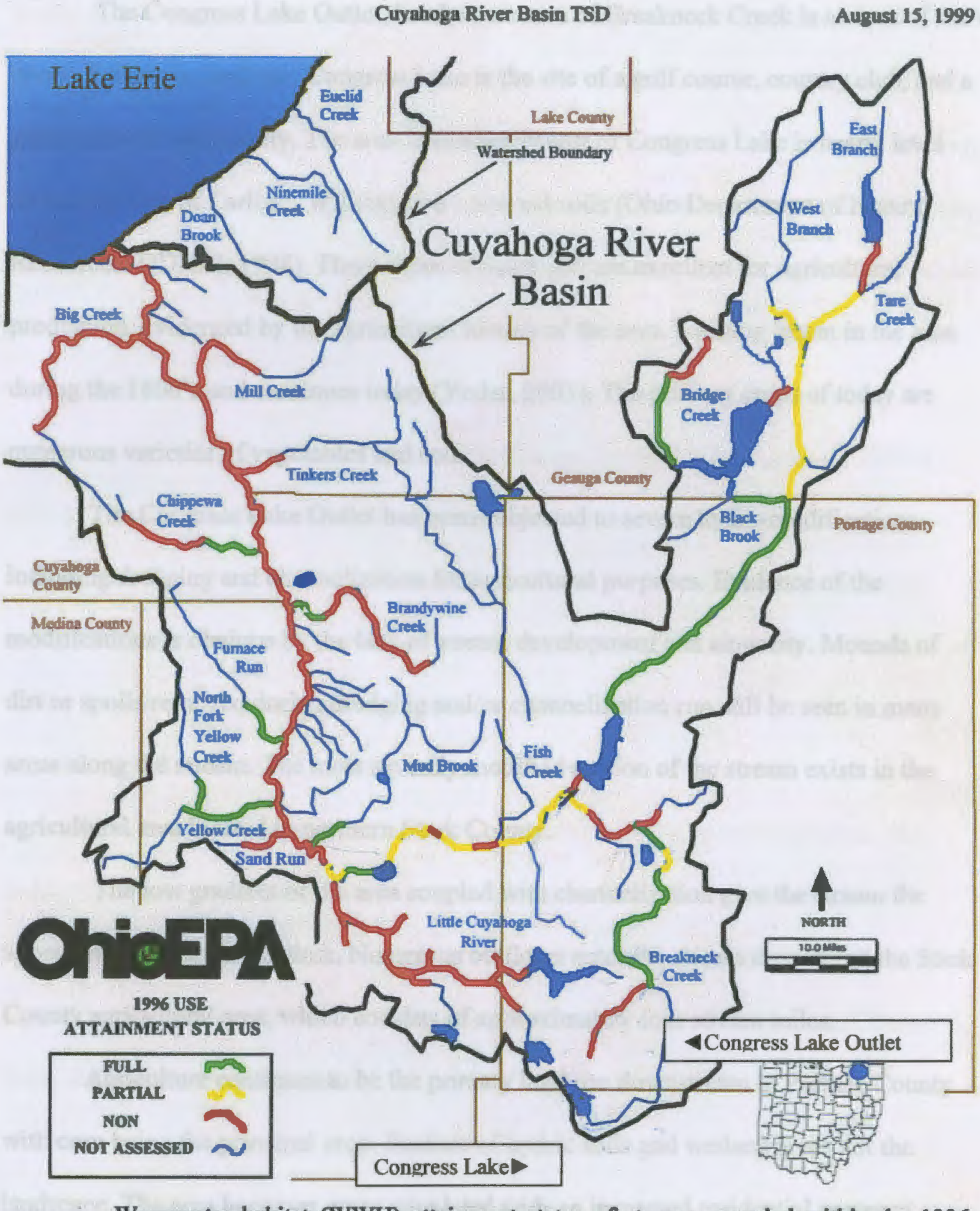
The Clean Water Act (CWA), of 1972 was a direct response to the ongoing assault on America's waterways. The infamous burning Cuyahoga River and streams covered in a sudsy residue of phosphates are but two examples of water quality problems that plagued the streams of America during the decades of the 1960's and 1970's. Industrialization and prosperity came with a heavy environmental cost. For years after its inception the CWA was employed primarily to restore the chemical integrity of waterways and included a focus on point sources or known discharges. Recently, however, an interdisciplinary approach, including both point and non-point sources, has been utilized to restore and maintain the chemical, biological and physical integrity of waterways (Ohio Watershed Academy [OWA], 2003). This approach seeks to maintain water quality that will support the "protection and propagation of fish, shellfish, and wildlife" in addition to human "recreation in and on the water" (OWA, 2003). The Clean Water Act has undergone many revisions and continues to evolve as needs change. Today the Act seeks to protect healthy waters in addition to restoring impaired or degraded streams.

The study site begins at Congress Lake, a privately owned lake located north of the village of Hartville, in Lake Township, Stark County, Ohio. A spillway located at the southeast end of the lake allows discharge creating the Congress Lake Outlet, the focus of this study. The lake is located entirely in northern Stark County; the stream begins at the outlet of the lake and shortly thereafter enters southern Portage County, Ohio. Several miles downstream the Congress Lake Outlet joins Potter Creek to form Breakneck Creek, one of the largest tributaries of the Cuyahoga River. Breakneck Creek then meanders east and west taking a more northerly direction for approximately 27 miles before entering the middle Cuyahoga River south of the Lake Rockwell dam at river mile 56.82 (Ohio Environmental Protection Agency, (OEPA) 1999). Refer to Chapter 1, Figure 3 for land use within the Middle Cuyahoga River.

Water quality is directly affected by the local topography, land uses and various other anthropocentric activities. The Congress Lake Outlet sub-watershed encompasses very diverse land uses. Land uses include residential communities, a golf course, a seven hundred acre state park, one residential housing development under construction, and vast areas of agriculture. The area historically has been primarily agricultural and remains so today.

The Congress Lake Outlet travels primarily north approximately eight miles before joining Potter Creek to form Breakneck Creek. Biological surveys have been performed, by the OEPA, on both Potter Creek and Breakneck Creek to establish the attainment level of water quality standards. The Congress Lake Outlet, located in the southernmost section of the Breakneck Creek watershed, has not been assessed as indicated on the Warmwater habitat attainment status map of the 1996 Cuyahoga River Basin study. Congress Lake Outlet is considered the headwaters of Breakneck Creek. Refer to Chapter 1, Figure 1 for site map and appendix B for additional Breakneck Creek watershed maps.

Figure 1. Cuyahoga River Basin Attainment Status Map 1996



Warmwater habitat (WWH) attainment status of streams sampled within the 1996 Cuyahoga River basin study area.

1.1 PROBLEM STATEMENT

The Congress Lake Outlet, headwaters area of Breakneck Creek is an area of stark contradictions in land use. Congress Lake is the site of a golf course, country club, and a gated, private community. The area immediately east of Congress Lake is nearly level and comprised of Carlisle, Willette, and Linwood soils (Ohio Department of Natural Resources (ODNR), 1998). These types of muck soil are excellent for agricultural production, evidenced by the agricultural history of the area. Farming began in the area during the 1800's and continues today (Yoder, 2003). The primary crops of today are numerous varieties of vegetables and sod.

The Congress Lake Outlet has been subjected to severe hydro-modifications including dredging and channelization for agricultural purposes. Evidence of the modifications is obvious by the lack of stream development and sinuosity. Mounds of dirt or spoils removed during dredging and/or channelization can still be seen in many areas along the stream. The most severely modified section of the stream exists in the agricultural area located in northern Stark County.

The low gradient of the area coupled with channelization give the stream the appearance of a drainage ditch. Numerous outflows enter the stream throughout the Stark County agricultural area, which consists of approximately four stream miles.

Agriculture continues to be the primary land use downstream in Portage County with corn being the principal crop. Pockets of hydric soils and wetland areas dot the landscape. The area becomes more populated with an increased residential presence downstream. A manufacturing firm and two mobile home parks are located in the sub-watershed, both utilizing on site sewage disposal and discharging into the stream. All homes and businesses throughout the watershed utilize on-site sewage treatment.

Non-point pollution may be occurring in the watershed as a result of runoff from residential, commercial (golf course), and agricultural operations. Residential runoff may include inadequately treated sewage and lawn chemicals and/or fertilizer. The golf course may contribute runoff including fertilizers, pesticides, and herbicides. Agricultural runoff may contribute fertilizers, pesticides, herbicides, bacteria, and additional nutrients from the application of manure. Agricultural runoff is the primary source of non-point pollution. According to the United States Environmental Protection Agency (USEPA), 60% of all stream impairment is linked to agricultural practices (Cunningham, Cunningham, and Saigo, (2005). The causes are sediment from the erosion of fields, overgrazing of pasturelands, fertilizers, pesticides, and myriad nutrients including animal wastes from feedlot operations (Montgomery, 1997). Atmospheric deposition also contributes pollutants to a lesser degree.

Based on the land use, propensity to generate non-point source pollution, and hydro-modifications within the non-assessed Congress Lake Outlet sub-watershed, I hypothesize the steam is in non-attainment status of the Environmental Protection Agency's Warm Water Habitat (WWH), aquatic life use designation. Refer to Chapter 2, Table 4 for attainment definitions.

1.2 STUDY GOALS

I propose to assess the Congress Lake Outlet watershed and determine the beneficial use designation, as it applies to aquatic life usage. The beneficial use designations are set forth by the OEPA as part of Ohio's Water Quality Standards (WQS), (OEPA, 2005). I will do this by examining the chemical, biological and physical characteristics of the stream and riparian zone at seven sites. Three previously sampled sites will be used for comparison.

1.2.1 Chemical Assessment

Sediment samples will be collected according to the EPA *Sediment Sampling Guide and Methodologies, 2nd Edition* and analyzed for Volatile Organic Compounds (VOC's) and for select pesticides. The Water Quality Laboratory at Heidelberg College, located in Tiffin, Ohio will analyze the sediment for volatile organic chemicals. I will analyze sediment for select agricultural pesticides. Pesticide analysis will be performed at Youngstown State University, under the direction of Dr. Roland Riesen, Research Scientist, using a Gas Chromatograph Mass Spectrometer. Sediment analyses will be performed once.

I will collect general water quality data at least two times, once during the winter season and again the following spring. The data will include: water temperature, pH, dissolved oxygen, conductivity, and turbidity.

Nutrient testing will be performed twice and will include: total phosphorous, soluble reactive phosphorous, nitrate, and ammonia.

1.2.2 Biological Assessment

Water samples will be taken, at two different times, and tested for fecal coliform bacteria. Samples will be collected during winter and spring. Macro-invertebrate sampling will be performed once as part of the biological assessment. Not all streams are conducive to the collection of macro-invertebrates by kick seining method or use of a filter bag. Core sampling may also be utilized.

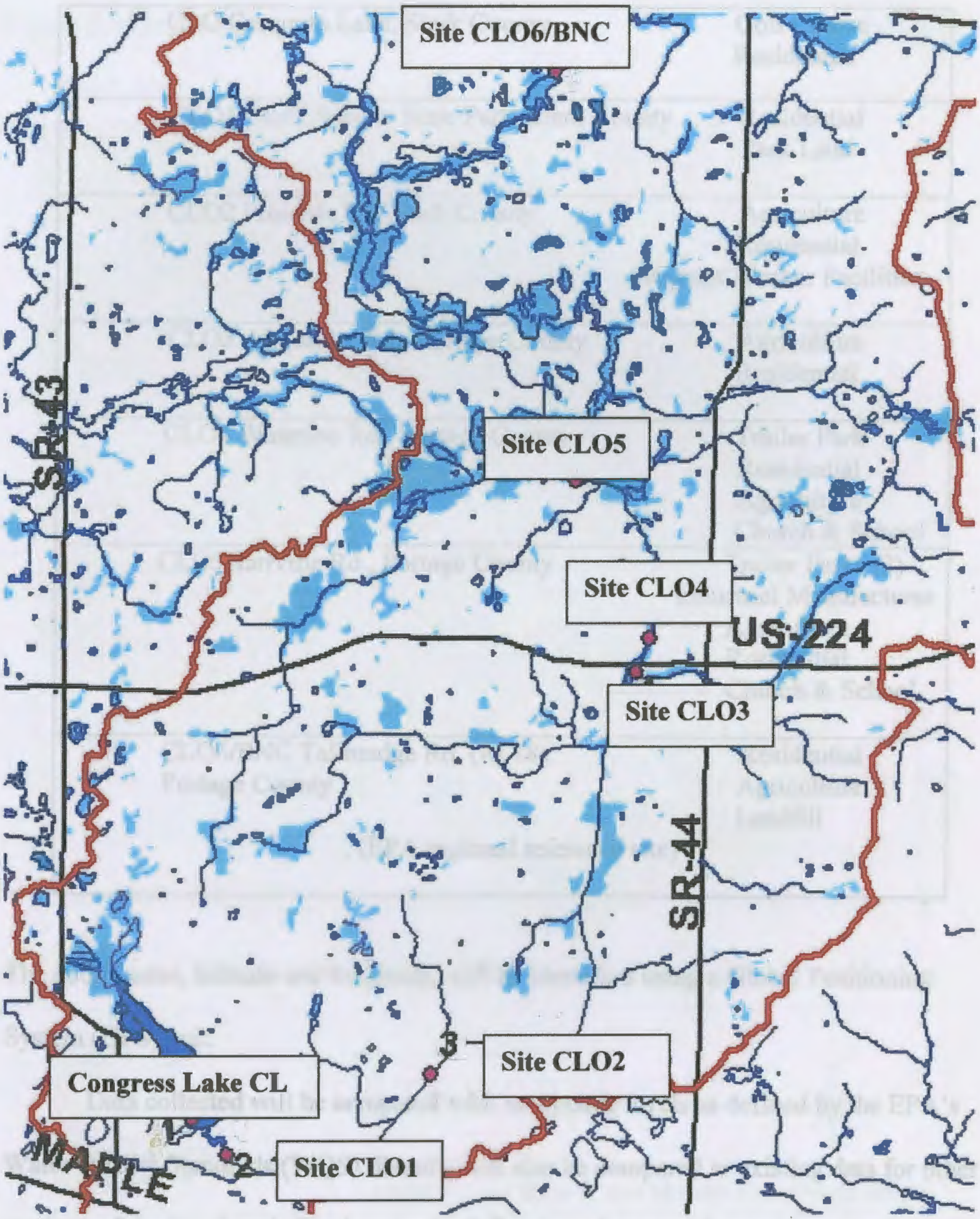
1.2.3 Physical Assessment

I will complete an EPA Qualitative Habitat Evaluation Index (QHEI) at each site to record and assess the physical characteristics of the stream. Visual observations will be recorded. Stream velocity and depth will be recorded.

Seven sampling sites have been selected based on various types of land use adjacent to the stream. Sampling sites will be located on the road or railroad right-of – way, usually near bridges. Sampling sites are depicted in Figure 2 immediately following map.

Figure 2. Site Location Map

North



South

Table 1. Sampling Sites and Land Use(s)

Site	Land Use(s)
CLO Congress Lake, Stark County	Golf Course Residential
CLO1 Quail Hollow State Park, Stark County	Residential Park Land
CLO2 Pinedale Rd, Stark County	Agriculture Residential Migrant Worker Facilities
CLO3 Alexander Rd., Portage County	Agriculture Residential
CLO4 Waterloo Rd., Portage County	Trailer Park Residential Agriculture Church & School
CLO5Hartville Rd., Portage County	Trailer Parks (2) Industrial Manufacturer Agriculture Residential Church & School
CLO6/BNC Tallmadge Rd. (Rt 18). Portage County . (EPA regional reference site)	Residential Agriculture Landfill

The coordinates, latitude and longitude, will be identified using a Global Positioning System (GPS) unit.

Data collected will be compared with acceptable levels as defined by the EPA's Water Quality Standards (WQS). Results will also be compared to existing data for other sections of the Breakneck Creek watershed. Previous data used for comparison will be derived from the Ohio EPA *Biological and Water Quality Study of the Cuyahoga River and Selected Tributaries* of August 15, 1999 and an OEPA study from 1996.

Figure 3. Watershed Land Use

2.0 BACKGROUND INFORMATION

2.1 What is a Watershed?

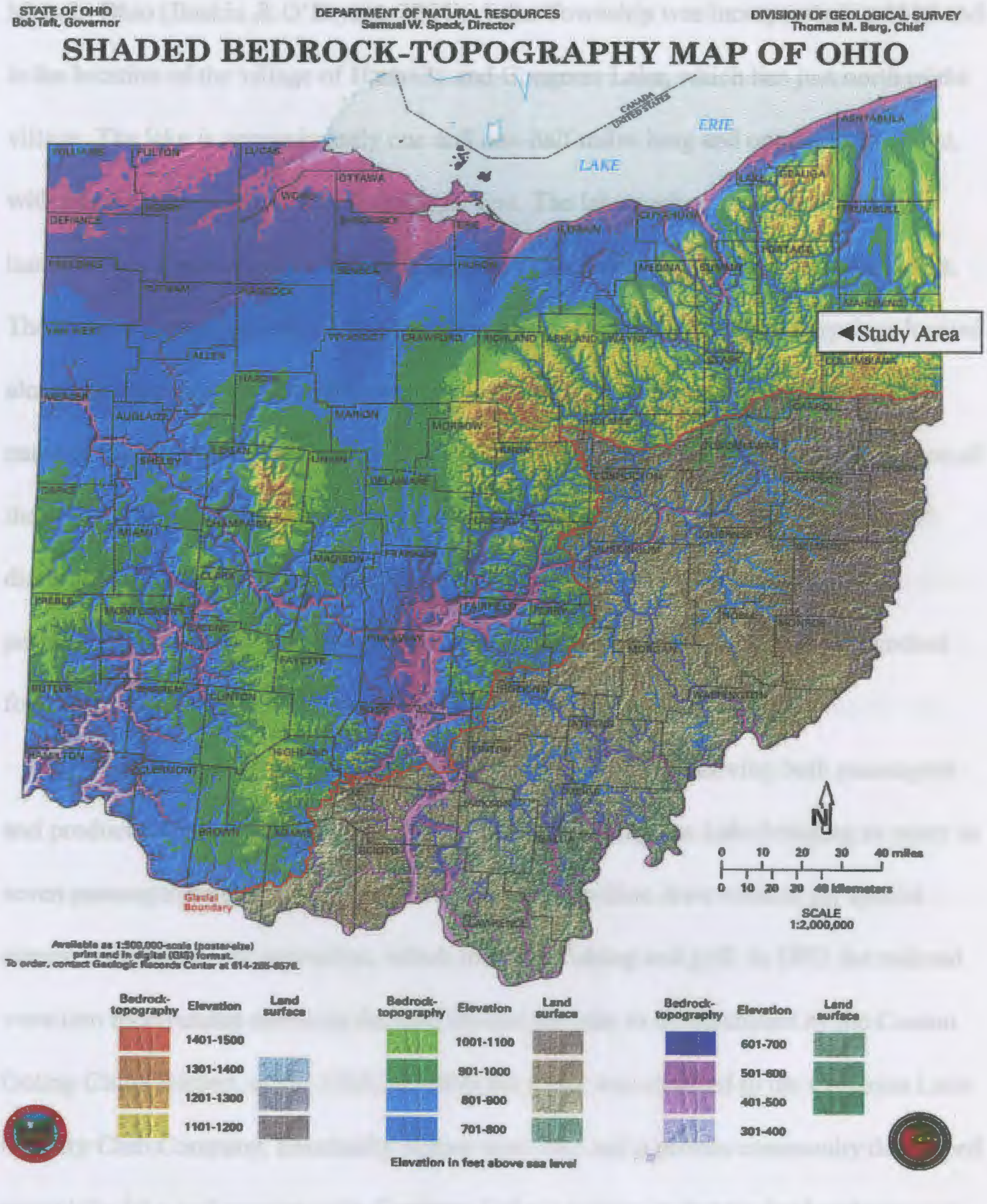
A watershed is described as a land area or drainage basin whereby all water drains into a central location or specific water body. The water body can be a stream, river, lake, wetland or groundwater body. The term water, in this case, refers to all surface and groundwater.

2.2 Watershed Geology

The Congress Lake Outlet and Breakneck Creek watershed are located in northeast Ohio. The area covers part of two counties with the headwaters area located in northern Stark County. An area of approximately 4-1/2 square miles of Stark County drains to Lake Erie through the Congress Lake Outlet and Breakneck Creek (Clements, 1988). The watershed traverses Portage County in its entirety from south to north.

The fairly level topography is a result of glaciation. The study area lies slightly north of the southern terminus of the glaciated area, which cuts through Stark County, east to west, (Ohio Department of Natural Resources, 1968). Elevation within the study area ranges from a high of 1143 feet at Congress Lake to a low of 1077 feet at the Tallmadge Rd sampling site. According to the Stark County and Portage County Soil Surveys the underlying substrate of the area consists of sand, gravel, and clay; bedrock consists of shale and limestone see Chapter 1, Figure 4.

Figure 4. Geology of Ohio



2.3 History of Congress Lake

Congress Lake, located in Lake Township, Stark County is one of the few natural lakes in Ohio (Baskin & O'Bryant, 2004). Lake Township was incorporated in 1816 and is the location of the village of Hartville and Congress Lake, which lies just north of the village. The lake is approximately one and one-half miles long and one-half mile wide, with a maximum depth of sixty to seventy feet. The lake surface is approximately six hundred feet higher than that of Lake Erie; elevation is eleven hundred forty-three feet. The surface area of the lake is two hundred plus acres. More than seventy springs located along the west bank provide the water source for Congress Lake (Yoder, 2003). The name of the lake was derived from the Congress Lands; the first seven townships west of the Pennsylvania border. These lands were the first lands sold by "Acts of Congress" directly to settlers (Herbert, Stillwell, & Ream, 1964). An 1896 prospectus of the property included three hundred fifteen acres of timber and farmland and two hundred forty acres of water (Herbert, et al., 1964).

The area was serviced by a railroad from 1870 to 1937 moving both passengers and produce. A water stop and depot were located on Congress Lake bringing as many as seven passenger trains a day. A hotel, cottages and pavilion drew visitors for special events, conventions, or recreation, which included fishing and golf. In 1893 the railroad went into receivership allowing the land around the lake to be purchased by the Canton Outing Club (Herbert, et al., 1964). In 1896 the name was changed to the Congress Lake Country Club Company. Eventually shares were sold and a private community developed around the lake and country club. Congress Lake is unique in that the land and water are privately owned. When ownership was applied for it was called a swamp. The club maintained the lake by dredging; exact dates are unknown (Herbert, et al, 1964). During the first half of the twentieth century the lake was stocked with game fish including: walleye, muskellunge, bass, crappie, perch, sunfish, bluegill, and catfish for "the followers of Walton" (Herbert, et al., 1964).

2.4 History of the Congress Lake Outlet

The 1896 prospectus of Congress Lake Country Club Company made reference to the outlet stating "the outlet or overflow wall is protected by heavy stone abutments, as a precaution to draining the lake to the level of the second outlet of dam" (Herbert, Stillwell, & Ream, 1964). The second or sub outlet was reportedly about one-quarter mile in length. Today a concrete spillway can be seen from Congress Lake Road at the east end of the lake. The outlet flows eastward approximately four miles before taking a more northerly direction toward the confluence with the Cuyahoga River near Kent, Ohio. The first four miles have been channelized to provide drainage for agriculture. Initially this section of stream was referred to as the Stark Portage Ditch (Yoder, 2003).

The Congress Lake Outlet is the headwaters area of the Breakneck Creek watershed, which is approximately eleven miles north to south and six miles wide, east to west. Portions of eight townships and two cities are included in the watershed. Several miles downstream in Breakneck Creek a feeder canal branches called the Congress Lake Outlet Feeder Canal. The canal feeds Sandy Lake and Lake Hodgson, which provides drinking water for portions of the cities of Kent and Ravenna. The feeder canal was not included in this study. Congress Lake is fed by springs and multiple small tributaries therefore making the Congress Lake Outlet a second order stream.

2.5 Watershed Land Use

Current land use in the watershed is very diverse. The Congress Lake Outlet flows easterly from the lake crossing Congress Lake Road and becoming the southern boundary of Quail Hollow State Park before entering an intensely farmed agricultural area. The area, once a "swamp", was drained in the early 1900's and cultivated due to the huge deposit of Carlisle, Willette, and Linwood soils (ODNR, 1968). All three soils are identified as hydric soils in the soil survey performed by the Natural Resources Conservation Service (NCRS) division of the United States Department of Agriculture (USDA) (NCRS, 2005). Approximately two thousand acres are currently under agriculture in the Stark County portion of the Congress Lake Outlet watershed (McPherson, 1976).

Hydric soil formation occurs during times of saturation, flooding, or standing water resulting in the development of anaerobic conditions in the top layer (NCRS, 2005). Characteristics used in the identification of hydric soils include hydrophytic vegetation, hydrology of the area, and soil color. Hydric soils are dark colored, rich in organic matter and very poorly drained (NCRS, 2005). The dark, poorly drained, organically rich soil is commonly referred to as "muck". The muck ranges in depth from a few inches to several feet (Yoder, 2003). Currently the muck farms produce a variety of vegetables and sod. As many as six hundred migrant workers reside in barracks type dwellings on site and tend the crops each spring and summer (McPherson, 1976).

A new housing development is taking shape directly across the road from the stream and Quail Hollow State Park. This area has undergone severe hydro-modifications, primarily channelization. Many outflows enter the stream throughout the agricultural area.

A combination of housing and agriculture comprise land uses in the first six miles of the watershed. When the northerly flowing stream enters southern Portage County, soil types and topography change slightly. Hydro-modifications are not as widespread and severe, and continue to diminish moving downstream. The stream enters an area of gently rolling hills with varying soil types. Soil types, according to the Portage County soil survey, include Canfield Series, Ravenna Series, Sebring Series, and Wooster Series. These soils vary from poorly drained to well drained, and are found from wetlands to upland areas. Vast areas of wetlands occur in the riparian zone as the stream continues northward through primarily residential areas.

Continuing downstream (northward) within the previously non-assessed study area, in Randolph Township, one manufacturing firm, two mobile home parks and a church/school hold National Pollution Discharge Elimination System (NPDES) permits, allowing discharge into the stream. The mobile home park permits each allow the discharge of 40,000 gallons per day (GPD) of treated sewage; one discharges directly into the stream, the other into an unnamed tributary (UT) of the stream. The wastewater treatment plant at St. Joseph's Parish is allowed to discharge 15,000 GPD into Cranberry Creek, a tributary of the Congress Lake Outlet. A manufacturing firm is also located in the area adjacent to the stream.

The study area concludes at Tallmadge Road, also known as RT 18. For purposes of identification this site is referred to as the CLO6/BNC site. The site is located at river mile (RM) 12.70 on Breakneck Creek and has served as a reference site for previous EPA studies. River mile is defined as the distance from the mouth of the stream, in this case the confluence with the Cuyahoga River.

2.5.1 National Pollution Discharge Elimination System Permit (NPDES)

National Pollution Discharge Elimination Permit System permits are designed to regulate point source discharges into streams. This permitting process was introduced in 1972 as an extension of the Clean Water Act and is used as a tool to improve or restore water quality by regulating the volume of pollutants discharged into a water body. The process addresses the types and volumes of chemical pollutants being discharged within a watershed. Discharges covered include those from: industrial sources, commercial sources, animal feedlots, and municipal facilities. On-site residential septic systems are not included. Currently changes are being implemented in the NPDES permitting system to include various sources of storm water discharges, most notably runoff from construction sites. NPDES permits are valid for a term of five years and are granted by the state EPA. NPDES permits are directly linked to the TMDL for the watershed. Four NPDES permits are in effect within the study area.

2.5.2 Total Maximum Daily Load (TMDL)

A Total Maximum Daily Load (TMDL) is best described as a process developed to both identify and restore impaired surface waters, in accordance with the CWA (EPA 2000). Each state is given the responsibility of identifying and prioritizing water quality limited segments or streams where current legislation is not stringent enough to achieve the required water quality standards (WQS). The authorization is borne of the CWA section 303(d) and Chapter 40 of the Code of Federal Regulations Section 130.7 (EPA 2000). The Total Maximum Daily Load (TMDL) is a predetermined amount of a given pollutant that may be discharged within a watershed based on the watershed's ability to assimilate the pollutant without jeopardizing the water quality or integrity of the stream. The end goal of a TMDL is to recommend controls required for a water body to meet the Water Quality Standards (WQS). The TMDL process allows for trading of credits between permit holders.

The equation used to determine a TMDL is:

TMDL = WLA + LA + BA

TMDL = Loading capacity of the stream

WLA = Wasteload allocation for point source loads

LA = Load allocation for nonpoint loads

BA = Background allocation for headwater and tributary loads

Streams that fail to meet designated use according to WQS are listed on the state's 303(d) list. Once on the 303(d) list the cause of impairment must be identified and a TMDL must be prepared aimed at reducing or eliminating the cause of impairment and restoring the stream quality to its acceptable designated use according to the WQS. Causes of impairment vary and may be physical, chemical, or biological.

The TMDL process addresses both point and non-point sources when establishing discharge limits. Examples of non-point sources considered in the TMDL process may include: runoff from urban, agricultural, and other sources, septic systems, erosion from construction and forestry practices, leaking underground storage tanks, oil and gas production sites, damaged riparian zones, leaking underground storage tanks, and hydro-modifications (EPA 2005).

The primary steps of the TMDL process are:

1). Identify waters that do not meet water quality standards.

2). Identify and quantify the cause(s) of impairment.

3). Prioritize non-compliant streams or stream segments.

4). Establish a TMDL for each pollutant or impairment to be reduced.

5). Develop a strategy to reduce the pollutant and a means to measure the progress. This step may involve partnering with stakeholders or other government entities. A stakeholder is anyone or entity that has an interest in the watershed. Common stakeholders involve landowners, schools, and local government including water departments, regional planning boards, and health departments.

Currently the goal for the state of Ohio is 80% of all rivers to meet WQS for attainment of warm water habitat (WWH) status by the year 2010. However, not all streams may be conducive to meeting the stringent criteria of the WWH designated use. Other less stringent designated uses exist. Water quality standards and designated uses are discussed in greater depth in chapter 2 section 2.6.

The Cuyahoga River has been listed on the 303(d) list; a TMDL was prepared in the year 2000. The TMDL addresses concerns within the river and its tributaries, including the Breakneck Creek watershed.

2.6 Previous Studies

According to a recent telephone conversation with Jeff Deshon of the OEPA Division of Surface Water, Columbus, Ohio, there have "been no prior studies performed on the Congress Lake Outlet." Steve Tuckerman, of the OEPA Twinsburg office, during a conversation in the fall of 2004, referred to the lack data for the Congress Lake Outlet, calling the area "a black box." Various studies have been performed on Potter Creek, Breakneck Creek, and the Congress Lake Outlet Feeder Canal. The feeder canal is located downstream below the confluence of Potter Creek and the Congress Lake Outlet and serves to supply water to Sandy Lake and Lake Hodgson, the latter being a drinking water source for sections of Kent and Ravenna. As of 1999, the creek was providing drinking water for 60,000 residents of the cities of Kent and Ravenna. The Congress Lake Outlet feeder canal is not included in this study.

According to the OEPA in the *Biological and Water Quality Study of the Cuyahoga River and Selected Tributaries* of 1999, sections of Breakneck Creek were at various levels of Warm Water Habitat attainment. During the 1999 survey the Congress Lake Outlet was not assessed due to a lack of funding. Potter Creek, which joins the Congress Lake Outlet to create Breakneck Creek was in non-attainment status in 1996 due to poor quality within the fish community. Breakneck Creek beginning at the confluence of Potter Creek and Congress Lake Outlet and extending several miles downstream, was in full attainment status. Refer to Chapter 2, Figure 1 for the attainment status map resulting from the 1996 study.

Various sampling was performed in the Breakneck Creek watershed from 1984 through 1999. River mile 15.6 was the furthest sampling point upstream during any previous studies according to Jeff Deshon of the OEPA.

For comparative purposes this study will utilize previous data from three sites, one located on Potter Creek and two sites located on Breakneck Creek, refer to Chapter 2, Table 2. These sites are the closest in proximity to the study area and support similar land uses. The OEPA regional reference site located at RM 12.7, on Tallmadge Rd. was included in this study.

Table 2. Previously Sampled Comparable Sites

Site	RM	Year	Type of sample
Potter Creek	1.5	2000	Physical (QHEI) *OEPA Regional Reference Site
	1.6	1996	Water chemistry, sediment
	1.8	1996	Macro-invertebrates
	1.5	1996	Fish
	1.5	1984	Sediment
Breakneck Creek	14.7	1996	Macro-invertebrates
	14.6	1996	Water chemistry, sediment (metals, VOC's,
		1987	pesticides)
	12.7	1996	Sediment (metals, VOC's, pesticides)
		1987	*OEPA regional reference site

2.6.1 Chemical Data

Potter Creek was listed as having "No Exceedences" as of the 1996 study. Exceedences refer to the Warmwater Habitat criteria for chemical and/or physical parameters (OEPA, 1999). Agriculture is cited as the probable cause of higher than normal levels of total phosphorous and suspended solids found in Potter Creek during the 1996 study. Overall surface water quality in Potter Creek was higher than that of Breakneck Creek.

No exceedences were reported within the study area during the 1996 study; one exceedence was listed in Breakneck Creek; a dissolved oxygen (DO) level of 4.7 mg/l (milligrams per liter). This reading was taken at RM 3.1, which is considerably further downstream from the sites used for this study.

Breakneck Creek from RM 14.6 downstream was found to be compliant with chemical WQS criteria during the 1996 study (OEPA, 1999). A note of interest; the highest concentrations of pesticides found in the Cuyahoga River mainstream occurred downstream from Breakneck Creek, near Kent.

2.6.2 Biological Data

Potter Creek was sampled for macro-invertebrates in both 1984 and 1996 by the OEPA, and produced Invertebrate Community Index (ICI) scores of 34 and 36 respectively. These scores exceeded the 25th percentile for the ecoregion and suggested good performance. The ICI seeks to define the relationship of water chemistry to biotic health. Macro-invertebrate sampling performed by the OEPA utilized multiple plate artificial samplers. Macro-invertebrate sampling on Breakneck Creek at RM 14.55 during 1987 and again in 1996 produced ICI scores of 42 and 50, respectively.

2.6.3 Previous Physical Data

Potter Creek RM 1.5 was assigned a QHEI value of 41 during the 1996 survey and a narrative evaluation of "Poor." This stream was previously channelized and contained low head dams. The stream is in the recovery process and is currently becoming a free flowing stream once again. Improvement is seen in the riparian zone but the aquatic habitat remains compromised by embedded silt and low sinuosity. The OEPA report from the 1996 survey describes the stream as being of "limited ability to support normal warmwater stream communities." An OEPA biological study performed during 2000, at the same location, produced a QHEI score of 62.0, which is within the lower range for a rating of "Good."

Breakneck Creek was described in the 1999 Biological and Water Quality Study… as a "low gradient swamp stream" with "a relatively high proportion of modified attributes" (OEPA, 1999). However, the study found the stream to possess a mean QHEI of 67.5, and to be "generally conducive" to warmwater aquatic communities. This habitat quality is the result of a high quality forested riparian zone and plentiful instream cover. Detrimental attributes found within Potter Creek included heavy siltation and hydro-modifications.

2.7 Water Quality Standards (WQS)

According to the CWA of 1972, each state must establish a set of water quality standards. Ohio's water quality standards are set forth in Chapter 3745-1 of the Ohio Administrative Code (OAC). The primary goal is to achieve and maintain a level of water quality that will provide for "swimmable/fishable" waters (EPA, 2004). Therefore the key components of water quality standards, designated uses and numerical or narrative criteria seek to protect and measure attainment of the designated uses (EPA 2005).

Ohio's water use designations are supported by state wide chemical specific criteria (EPA, 2005). Additional requirements apply to the Lake Erie drainage basin. Where multiple designations exist the most stringent chemical specific requirements apply. Chemical specific criteria are presented as "Outside Mixing Zone" or "Inside Mixing Zone Maximum." The mixing zone pertains to an area where effluent enters a water body. "Inside Mixing Zone Maximum" generally applies to end-of-pipe maximum effluent limits or requirements to be met within a short distance from the discharge pipe. "Outside Mixing Zone" generally applies to an area away from inflows of effluent where the two sources have sufficient opportunity to become homogeneous or mixing has taken place. One exception to this rule occurs when biological criteria provide a direct measure of attainment of warmwater habitat requirements. In this case the biological data would override the chemical specific data.

Ohio utilizes a comprehensive watershed approach employing ambient standards as opposed to standards based on discharges into a water body and utilizing information from total maximum daily loads or TMDL's, when determining National Pollution Discharge Elimination System (NPDES) permit limitations that regulate the discharge of pollutants into streams. The National Pollution Discharge Elimination System (NPDES) permit system is a tool provided by the Clean Water Act (CWA) to protect, maintain, or restore water quality. The four primary components of Ohio's water quality standards, as set forth by the EPA, are:

1). beneficial use designations

2). narrative "free froms"

3). numeric criteria

4). anti-degradation provisions

2.7.1 Beneficial Use Designations

Beneficial use designations consider the existing and or potential uses of the water body. The four primary beneficial use categories are: aquatic life habitat, nuisance prevention, water supply, and recreation. The nuisance prevention category is being phased out and is no longer utilized. The three remaining categories are further delineated accordingly. All water bodies are assigned one or more designations for each of the parameters: aquatic life habitat, water supply, and recreation.

Table 3.

Beneficial Use Designations		
Aquatic Life (Habitat)	**Water Supply**	**Recreational**
1. Warmwater (WWH)	1. Public Sources	1.Bathing Waters
2. Limited Warmwater (LWH)	2.Agricultural	2. Primary Contact
3. Exceptional Warmwater (EWH)	3.Recreational	3. Secondary Contact
4. Modified Warmwater (MWH)		
5. Seasonal Salmonid Habitat (SSH)		
6. Coldwater Habitat (CWH)		
7. Limited Resource Water (LWR)		

The focus of this study is the attainment or non-attainment of the aquatic life designation of warmwater habitat within the Congress Lake Outlet.

Warmwater (WWH) streams are "capable of supporting and maintaining a balanced, integrated, adaptive community of warmwater aquatic organisms having a species composition, diversity, and functional organization comparable to the 25^{th}

percentile of the identified reference site" (OEPA, 2005) within a specific eco-region. The study area lies within the Erie/Ontario lake plains eco-region. Other eco-regions utilize the 90th percentile of identified reference sites. All eco-regions rely on biological indices for quantification of species composition, diversity and functional organization. Ohio has a goal of eighty percent achievement of WWH status for all streams by the year 2010; exceptions would be any stream exceeding the designation.

Limited warmwater (LWH) is a temporary designation used in the 1978 water quality standards for streams not meeting warmwater criteria. Support criteria for warmwater and limited warmwater designations are the same; "individual criteria are varied on a case by case basis and supersede the criteria for warmwater habitat where applicable" (OEPA, 2005). Limited warmwater streams will be analyzed for use attainability and designations will be changed accordingly. The limited warmwater designation is no longer used.

Exceptional warmwater (EWH) streams "are capable of supporting and maintaining an exceptional or unusual community of warmwater aquatic organisms having a species composition, diversity, and functional organization comparable to the 75th percentile of the identified reference sites on a statewide basis." In addition to streams or stream segments " all lakes and reservoirs, except upground storage reservoirs, are designated exceptional warmwater habitats" (OEPA, 2005).

Modified warmwater (MWH) streams have been subjected to "a use attainability analysis and have been found to be incapable of supporting and maintaining a balanced, integrated, adaptive community of warmwater organisms due to irretrievable modifications of the physical habitat" (OEPA, 2005). Any modifications would be considered long term and last twenty years or longer. All streams or stream segments receiving this designation will be reviewed every three years.

All WWH, LWH, EWH, and MWH designated streams utilize biological indices to quantify the attributes of species composition, diversity and functional organization. The indices are the Invertebrate Community Index (ICI), Index of Biotic Integrity (IBI), and the Modified Index of Well-Being (MIWB). Both the MWB and IBI indices apply to fish; the ICI applies to macro-invertebrates. Three designations are applied to attainment status: full, partial, or non-attainment.

Table 4. Attainment Levels of Use Designations

	Attainment Levels
Full Attainment	All three indices (or those available) meet the applicable biological criteria.
Partial Attainment	At least one of the indices does not attain a performance of at least fair.
Non-Attainment	All indices fail to attain or any index indicates poor to very poor performance.

Both partial and non-attainment status are indicative of impaired water and do not meet Ohio Water Quality Standards (WQS) designated use criteria.

Limited resource water (LRW) waters have been analyzed for "use attainability and have been found to lack the potential for any resemblance of any other aquatic life habitat as determined by biological data" (OEPA, 2005). The impairment of these streams may be due to natural causes or irretrievable anthropocentric conditions. Limited resource waters are reviewed every three years. Streams within the Lake Erie basin receiving this designation "shall include demonstrations that the "Outside Mixing Zone Average" water quality criteria and values and chronic whole effluent toxicity levels are not necessary to protect the designated uses and aquatic life pursuant to rule 3745-1-35 of the Administrative Code," (OEPA, 2005). The limited resource designation may be applied to streams with acid mine drainage. Streams impaired by acid mine drainage would have a pH "below 4.1 or intermittent acidic conditions combined with severe streambed siltation, and have a demonstrated biological performance below that of the modified warmwater habitat biological criteria" (OEPA, 2005). Other specified conditions may apply.

The water supply designation encompasses public sources, agricultural, and recreational. Public is described as waters that may become suitable for human consumption, meeting federal regulations for drinking water, with conventional treatment. Designated public water supplies include publicly owned lakes, reservoirs (except Piedmont), all privately owned lakes and reservoirs used for public drinking water, all surface waters within five hundred yards of an existing public water supply or intake, all surface water used for water supply emergencies (EPA, 2005).

Recreational uses are in effect May 1st to October 15th and include three categories: bathing waters, primary contact, and secondary contact. Bathing waters are described as suitable for swimming where a lifeguard and or bathhouse facilities are present. Primary contact waters are suitable for full body contact such as swimming, canoeing, and diving. Secondary contact waters are suitable for partial body contact such as wading. Both primary and secondary contact waters present minimal threat to public health (EPA, 2005).

2.8 Narrative "free froms"

The narrative "free froms" rule states that surface waters shall be free from "debris, oil and scum, color and odor producing materials, substances that are detrimental to human, animal or aquatic life, and nutrients in concentrations that may cause algal bloom" (OEPA, 2005). A eutrophic waterbody would be in violation of the "free froms" rule.

2.9 Numeric Criteria

Numeric criteria encompass chemical criteria, whole effluent toxicity levels, and biological criteria. Estimations are made "of concentrations of chemicals and degree of aquatic life toxicity allowed in a waterbody without adversely impacting its beneficial uses" (OEPA, 2005). Numeric criteria are primarily used through the NPDES permitting program to regulate discharges into waterbodies.

Chemical criteria used for aquatic life and human health is derived from laboratory studies on biological organisms' sensitivity to specific chemicals or combinations thereof. Fish, macro-invertebrates, and zooplankton are used for aquatic life determinations. Rats and mice are generally used for human health testing. The United States Environmental Protection Agency (USEPA) establishes chemical criteria guidelines for human health. Establishing chemical criteria is an ongoing process undergoing changes as technology and scientific information become available.

Chemical criteria are also applied to the Agricultural Water Supply designation. The goal is to protect crops and livestock from adverse effects due to irrigation or crops or water consumption by livestock.

Biological criteria measure both the structure and functions of aquatic communities. The data are used to determine the attainment of aquatic life uses. Three biotic indices are employed: Index of Biotic Integrity (IBI) that pertains to fish, Modified Index of Well Being (MIWB) that pertains to fish, and the Invertebrate Community Index (ICI) that pertains to macro-invertebrates. The three indices provide data on "species richness, trophic composition, diversity, presence of pollution tolerant individuals or species, abundance of biomass, and the presence of diseased or abnormal organisms" (OEPA, 2005).

2.10 Anti-degradation Provisions

Anti-degradation provisions establish a forum to lower water quality within surface waters. Water quality must be maintained unless a lower water quality is "deemed necessary to allow important economic or social development" (OEPA, 2005).

2.11 Preservation Efforts

A Breakneck Creek coalition has formed in an effort to develop a Watershed Action Plan as set forth by the EPA Guide to Developing Local Watershed Action Plan, appendix 8. The coalition includes: Portage County Parks District, Portage County Planning Dept., a representative from Ohio State University, Kent State University, Kent Environmental Council, Kent Water Department, City of Kent, Ravenna Water

Resources, Davey Resource Group, American Heritage Rivers, Portage Land Association for Conservation and Education (PLACE), and Portage County Soil and Water.

The coalition has recently applied for a section 319 grant for a restoration project on Potter Creek. The project would include plantings along the stream bank to improve the riparian zone and hence improve water quality.

3.0 METHODS AND PROCEDURES (for sampling and analysis)

3.1 Chemical

3.1.2 General Water Characteristics

Water temperature, pH, dissolved oxygen, conductivity, and turbidity readings were recorded with a Yellow Springs Instrument (YSI) model #6600-M probe and data logger. The unit was calibrated prior to each use. Calibration procedures were performed for pH using both 7.0 and 10.0 buffer solutions, for dissolved oxygen, and turbidity. The membrane located on the dissolved oxygen port was changed prior to use. The o-ring was removed and the existing membrane was replaced taking care to eliminate any air bubbles. All calibrations were performed in the Youngstown State University Biology Lab in accordance with the manufacturers instructions. All data were downloaded using Eco-watch software.

Water sampling and collection was performed directly from the stream into the sample bottle when possible. The other method used was collection into a one quart plastic bowl attached by duct tape to a six foot oak pole. The bowl was rinsed with de-ionized water prior to each use. The water was then transferred to the appropriate collection bottle. Samples for nutrient analysis were stored in one-liter polypropylene bottles with threaded caps. The bottles and caps were washed with a 20% hydrochloric acid and de-ionized water solution prior to collection. All samples were taken either upstream or away from the area of disturbance when wading. Winter sampling was performed during December and January; spring sampling during March and April.

3.1.3 Nutrient Analyses

Nutrients analyzed were: total phosphorous, soluble reactive phosphorous, ammonia, and nitrate. All analyses were performed in the Environmental Water Quality Laboratory at Youngstown State University.

Controls using de-ionized water were run in triplicate for all nutrients. Controls and standard curves were repeated each time an analysis was performed. Nutrient analysis was performed twice, winter and spring. Absorbance was determined on a Bausch & Lomb Spectronic #1001.

Samples of unfiltered water were analyzed for total phosphorous using the 4500-P A. Persulfate Digestion Method (Clesceri, Greenberg, & Eaton, 1998).

Samples of filtered water were analyzed for soluble reactive phosphorous using the 4500-P-E Ascorbic Acid Method (Clesceri, Greenberg, & Eaton, 1998).

Nitrate analyses were performed according to the Cadmium Reduction Method. The first analysis was performed using the Hach version of the Cadmium Reduction Method. Hach powder pillows of prepared reagents are used for this simplified process of the cadmium reduction method (Lind, 1985). The second analysis was performed using the 4500-NO_3-E Cadmium Reduction Method whereby a column filled with copperized cadmium filings was utilized (Clesceri, Greenberg, & Eaton, 1998).

Ammonia was analyzed using the 4500-NH_3 F, Phenate Method (Clesceri, Greenberg, & Eaton, 1998).

3.1.4 Sediment

Sediment samples were collected, handled, and stored according to the Ohio EPA *Sediment Sampling Guide and Methodologies, 2001* (2nd Edition). Sediment collection was performed using an Eckman B196-13 stainless steel dredge or a one quart plastic bowl taped to an oak pole, or a spoon. The method used was determined by the location and stream access limitations. The dredge was used on bridges; the bowl was used in Congress Lake; the spoon at Quail Hollow site CLO1. Duplicate field samples were taken at three locations, CL, CLO1 and CLO2. Refer to Chapter 1, Figure 2 for site location map; Chapter 1, Table 1 for sites and land use. Neoprene rubber gloves were worn to eliminate contamination. All tools, bowls, and spoons were washed with phosphate free soap and rinsed in de-ionized water prior to use. Equipment was rinsed with de-ionized water between each sample. All sample jars were immediately sealed and labeled with the site number and date.

Weights were determined for wet and dry sediment. Wet sediment was weighed and dried on a Nasco-Guard specimen paper filter it was then placed in an oven for 24 hours at 105° C, and weighed again. Weights were obtained using a Denver Instrument M-120 digital scale.

Sediment analysis of Volatile Organic Compounds-VOC's

Sediment collected for volatile organic compound (VOC) analysis was not mixed. The unmixed sediment was placed in I-Chem 60 ml clear glass jars with Teflon lined lids. The containers were filled completely to eliminate headspace. The sediment samples were immediately refrigerated until analysis. Samples were packed in a cooler covered with ice and shipped via United Parcel Service to Heidelberg College for analysis. They were analyzed at the Water Quality Laboratory at Heidelberg College in Tiffin, Ohio using the EPA purge and trap method #524.

Sediment analysis of Pesticides

Sediment collected for pesticide analysis was mixed in a stainless steel bowl to achieve a homogenous sample. More than one grab or sample was taken. It was then placed in I-Chem 500 ml wide mouth amber glass jars with Teflon lined lids and refrigerated until analysis.

Pesticide analysis was performed in the Biology Lab at Youngstown State University according to EPA Sonication Extraction method #3550. This is a high concentration extraction method designed for concentrations of organics (>20 mg/kg). This process and method were discussed in detail with the director of the Water Quality Laboratory at Heidelberg College, Tiffin, Ohio. The discussion occurred during a visit in October 2004. The Water Quality Lab performs sediment analysis and myriad water quality tests for the Ohio EPA. This lab performed the analyses of Breakneck Creek sediment for previous studies. The Breakneck Creek sediment collection sites include one site contained in this current study. Refer to Chapter 1, Figure 2 for site locations.

Trial extractions were performed using 2g sediment samples. A total of four 2g samples were extracted as part of the trial. These samples were all from the CLO2 location.

First method follows:

Two grams of wet sediment were placed in a 15ml glass cone tube, 2g of sodium sulfate was added and mixed to form a free-flowing powder. Hexane was added to make 5ml total volume. The mixture was capped and sonicated 10 minutes. It was then filtered through a Pasteur pipette with 2-3 cm of glass wool capturing 5ml. The 5ml was reduced to 1ml using a nitrogen evaporator. The samples were then injected into a Hewlett Packard Gas Chromatograph Mass Spectrometer (GC/MS).

Second attempt:

The only deviation, from the first attempt, was to capture all media filtered through the pipette and reduce it to 1ml. The captured volume was 6.5 and 7.0 ml.

Third attempt:

Sediment from all 7 sites was used.

Five grams of sodium sulfate was added to 5g of wet sediment in a 15ml glass tube and mixed well to form a free-flowing powder. Next 11ml of hexane was added. The tubes were capped and sonicated 20 minutes. The mix was filtered through a glass wool packed Pasteur pipette capturing all media. A nitrogen evaporator was used to reduce the mix to 200μg.

The samples were analyzed on a Hewlett Packard Gas Chromatograph Mass Spectrometer under the direction of Dr. Roland Riesen. A DB-5 column was used. The injector temperature was 250° C, the oven temperature program was 50° C for 3 minutes then increasing temperature 1.5° C per minute until reaching 300° C. The temperature was ramped quickly to maximum temperature of column for cleaning.

Standard used was Ultra Scientific NPM 525C (Supelco). The standard was diluted with optima grade hexane to 50ppb. 1ml was injected into GCMS Extraction surrogates were 5 deuteurated compounds of 525 series. Usually a 95-100% recovery was achieved with generally no correction for recovery necessary.

Internal standards are dependent on the pesticides present. Concentrations observed were <5mg/l (ppm). The standard curve was 1,3,5,7,10,20, and 50 mg/l (ppm).

The column maintenance was minimal unless samples were very dirty. The Water Quality Laboratory at Heidelberg College provided the analysis program information.

3.2 Biological

3.2.1 Macro-invertebrates

Collection of macro-invertebrates was attempted at all sites. Not all sites had substrate conducive to macro-invertebrate collection. Four methods were utilized, kick seining, Suber net, core sampling, and a plastic bowl attached to an oak pole when other methods failed to produce results.

Kick seining was performed using a fine mesh cloth screen attached to two wooden poles. The seine was placed in the stream in a shallow riffle area. An area of one meter on the upstream side of the net was "stirred" using hands and feet. The resulting suspended sediment, debris, and insects were caught in the net. The net was carefully removed from the stream. Macro-invertebrates were hand picked, using forceps, identified and counted.

The Suber filter was placed on the stream bottom, which was then stirred to dislodge any macro-invertebrates upstream from the filter bag. The bag was then turned inside out; the collected material was carefully examined for macro-invertebrates.

Core samples were obtained using a clear plastic tube with end caps. The core sampler measures 1-7/8" inside diameter.

The plastic bowl attached to an oak pole was used as a scoop when all other methods failed. The bowl is 4" deep and 4-1/2" inside diameter.

Samples collected by either the core method or by the plastic bowl were carefully sorted and macro-invertebrates were hand collected.

3.2.2 Fecal Coliform Bacteria

Water was collected from the stream directly into a 100ml sealed plastic bottle, when possible. Otherwise water was collected in a one quart plastic bowl and transferred to the 100ml sealed sample bottles. Samples were refrigerated immediately. Analyses were performed in the Environmental Health Laboratory at Youngstown State University under the guidance of Dan Sahli, Environmental Scientist, Department of Environmental & Occupational Health & Safety. Water samples were analyzed within twenty-four hours of collection using the EPA 600/R-00-013 Membrane Filter (MF) procedure. Controls were performed, using autoclaved water, as part of the analysis. After an incubation period of 22 to 24 hours, at 35° C, the agar plates were removed and the colony units counted and recorded.

3.3 Physical

3.3.1 Qualitative Habitat Evaluation (QHEI)

A Qualitative Habitat Evaluation Index (QHEI) is a method developed by the Ohio Environmental Protection Agency (OEPA) that seeks to establish a value of the physical habitat of a free flowing stream as it relates to aquatic communities. The method seeks to derive a quantitative value for the overall quality of the physical condition of a stream with a focus on the physical condition of the stream, not the influences which determine or change the physical attributes. Examples of influences that affect the physical characteristics of a stream would be velocity, depth, or substrate size.

The QHEI method employs visual observations applied to six physical habitat categories or metrics which include: 1) substrate, 2) in-stream cover, 3) channel morphology, 4) riparian zone and bank erosion, 5) pool/glide and riffle/run quality, and 6) gradient (Rankin, 1989). The six metrics contain various attributes, each with an assigned value, which reflect the impact on aquatic life. Refer to Chapter 3, Figures 5 and 6. Aquatic life applies to both fishes and macro-invertebrates. Completion of the QHEI is to be performed in the field by knowledgeable individuals or groups. Based on the assigned values QHEI scores range from a low score of 12 to 100, the highest possible score (OEPA, 2000). Refer to Chapter 3, Table 5 for QHEI scores. This index is not designed for use in lakes, ponds, or wetlands.

Figure 5. Qualitative Habitat Evaluation Index Form

OhioEPA Qualitative Habitat Evaluation Index Field Sheet QHEI Score: [ ]

Stream______________ RM______ Date______ River Code______
Location______________ Scorers Name:______

1] SUBSTRATE (Check *ONLY* Two Substrate *TYPE BOXES*; Estimate % or note every type present);

TYPE	POOL RIFFLE		POOL RIFFLE	SUBSTRATE ORIGIN		SUBSTRATE QUALITY
				Check ONE (OR 2 & AVERAGE)		Check ONE (OR 2 & AVERAGE)
☐ ☐-BLDR /SLABS[10]	___ ___	☐ ☐-GRAVEL [7]	___ ___	☐ -LIMESTONE [1]	SILT:	☐ -SILT HEAVY [-2]
☐ ☐-BOULDER [9]	___ ___	☐ ☐-SAND [6]	___ ___	☐ -TILLS [1]		☐ -SILT MODERATE [-1]
☐ ☐-COBBLE [8]	___ ___	☐ ☐-BEDROCK[5]	___ ___	☐ -WETLANDS[0]		☐ -SILT NORMAL [0]
☐ ☐-HARDPAN [4]	___ ___	☐ ☐-DETRITUS[3]	___ ___	☐ -HARDPAN [0]		☐ -SILT FREE [1]
☐ ☐-MUCK [2]	___ ___	☐ ☐-ARTIFICIAL[0]	___ ___	☐ -SANDSTONE [0]	EMBEDDED	☐ -EXTENSIVE [-2]
☐ ☐-SILT [2]	___			☐ -RIP/RAP [0]	NESS:	☐ -MODERATE [-1]
				☐ -LACUSTRINE [0]		☐ -NORMAL [0]
				☐ -SHALE [-1]		☐ -NONE [1]
				☐-COAL FINES [-2]		

NOTE: (ignore sludge that originates from point-sources; score on natural substrates)
NUMBER OF SUBSTRATE TYPES: ☐-5 or More [2] ☐-4 or Less [0]
COMMENTS______________

Substrate [ ] Max 20

2] INSTREAM COVER

TYPE: (Check *All* That Apply)

☐ -UNDERCUT BANKS [1]
☐ -OVERHANGING VEGETATION [1]
☐ -SHALLOWS (IN SLOW WATER) [1]
☐ -ROOTMATS [1]
☐ -DEEP POOLS> 70 cm [2]
☐ -ROOTWADS [1]
☐ -BOULDERS [1]
☐ -OXBOWS [1]
☐ -AQUATIC MACROPHYTES [1]
☐ -LOGS OR WOODY DEBRIS [1]

COMMENTS:______________

AMOUNT: (Check *ONLY* One or check 2 and *AVERAGE*)

☐ - EXTENSIVE > 75% [11]
☐ - MODERATE 25-75% [7]
☐ - SPARSE 5-25% [3]
☐ - NEARLY ABSENT < 5% [1]

Cover [ ] Max 20

3] CHANNEL MORPHOLOGY: (Check *ONLY* One PER Category OR check 2 and *AVERAGE*)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATIONS/OTHER	
☐ - HIGH [4]	☐ - EXCELLENT [7]	☐ - NONE [6]	☐ - HIGH [3]	☐ - SNAGGING	☐ - IMPOUND.
☐ - MODERATE [3]	☐ - GOOD [5]	☐ - RECOVERED [4]	☐ - MODERATE [2]	☐ - RELOCATION	☐ - ISLANDS
☐ - LOW [2]	☐ - FAIR [3]	☐ - RECOVERING [3]	☐ - LOW [1]	☐ - CANOPY REMOVAL	☐ - LEVEED
☐ - NONE [1]	☐ - POOR [1]	☐ - RECENT OR NO RECOVERY [1]		☐ - DREDGING	☐ - BANK SHAPING
				☐ - ONE SIDE CHANNEL MODIFICATIONS	

COMMENTS:______________

Channel [ ] Max 20

4]. RIPARIAN ZONE AND BANK EROSION - (check ONE box per bank or check 2 and AVERAGE per bank) ★River Right Looking Downstream★

RIPARIAN WIDTH	FLOOD PLAIN QUALITY (PAST 100 FOOT RIPARIAN)		BANK EROSION
L R (Per Bank)	L R (Most Predominant Per Bank)	L R	L R (Per Bank)
☐ ☐-WIDE > 50m [4]	☐ ☐-FOREST, SWAMP [3]	☐ ☐-CONSERVATION TILLAGE [1]	☐ ☐ -NONE/LITTLE [3]
☐ ☐ - MODERATE 10-50m [3]	☐ ☐-SHRUB OR OLD FIELD [2]	☐ ☐ -URBAN OR INDUSTRIAL [0]	☐ ☐ -MODERATE [2]
☐ ☐-NARROW 5-10 m [2]	☐ ☐-RESIDENTIAL,PARK,NEW FIELD [1]	☐ ☐ -OPEN PASTURE,ROWCROP [0]	☐ ☐ -HEAVY/SEVERE[1]
☐ ☐- VERY NARROW <5 m[1]	☐ ☐ -FENCED PASTURE [1]	☐ ☐ -MINING/CONSTRUCTION [0]	
☐ ☐- NONE [0]			

COMMENTS:______________

Riparian [ ] Max 10

5.]POOL/GLIDE AND RIFFLE/RUN QUALITY

MAX. DEPTH (Check 1 ONLY!)	MORPHOLOGY (Check 1 or 2 & AVERAGE)	CURRENT VELOCITY [POOL & RIFFLES!] (Check *All* That Apply)	
☐ - >1m [6]	☐-POOL WIDTH > RIFFLE WIDTH [2]	☐-EDDIES[1]	☐-TORRENTIAL[-1]
☐ - 0.7-1m [4]	☐ -POOL WIDTH = RIFFLE WIDTH [1]	☐-FAST[1]	☐-INTERSTITIAL[-1]
☐ - 0.4-0.7m [2]	☐-POOL WIDTH < RIFFLE W. [0]	☐-MODERATE [1]	☐-INTERMITTENT[-2]
☐ - 0.2- 0.4m [1]		☐-SLOW [1]	
☐ - < 0.2m [POOL=0]			

COMMENTS:______________

Pool/Glide [ ] Max 12

CHECK ONE OR CHECK 2 AND AVERAGE

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
☐ - GENERALLY >10 cm;MAX > 50 [4]	☐-STABLE (e.g.,Cobble, Boulder) [2]	☐ - NONE [2]
☐ - GENERALLY >10 cm; MAX < 50[3]	☐-MOD. STABLE (e.g.,Large Gravel) [1]	☐ - LOW [1]
☐ - GENERALLY 5-10 cm[1]	☐-UNSTABLE (Fine Gravel,Sand) [0]	☐ - MODERATE [0]
☐ - GENERALLY < 5 cm [RIFFLE=0]		☐ - EXTENSIVE [-1]

COMMENTS:______________ ☐ - NO RIFFLE [Metric=0]

Riffle/Run [ ] Max 8

6] GRADIENT (ft/mi):______ DRAINAGE AREA (sq.mi.):______ %POOL: [ ] %GLIDE: [ ] %RIFFLE: [ ] %RUN: [ ]

Gradient [ ] Max 10

Figure 6. Gradient Chart for QHEI

Table 1: Classification of stream gradients for Ohio by stream size. Modified from Trautman (p 139, 1981). Scores were derived from plots of IBI versus stream gradient for each stream size category.

Stream Width	Drainage Area (sq mi)	Gradient (feet/mile)						
		Very Low	Low	Low-Moderate	Moderate	Moderate-High	High	Very High[1]
≤4.7	<9.2	0 - 1.0 2	1.1 - 5.0 4	5.1 - 10.0 6	10.1 - 15.0 8	15.1 - 20 10	20.1 - 30 10	30.1 - 40 8
4.8 - 9.2	9.2 - 41.6	0 - 1.0 2	1.1 - 3.0 4	3.1 - 6.0 6	6.1 - 12.0 10	12.1 - 18 10	18.1 - 30 8	30.1 - 40 6
9.3 - 13.8	41.7 - 103.7	0 - 1.0 2	1.1 - 2.5 4	2.6 - 5.0 6	5.1 - 7.5 8	7.6 - 12 10	12.1 - 20 8	20.1 - 30 6
13.9 - 30.6	103.8 - 622.9	0 - 1.0 4	1.1 - 2.0 6	2.1 - 4.0 8	4.1 - 6.0 10	6.1 - 10 10	10.1 - 15 8	15.1 - 25 6
> 30.6	> 622.9		0 - 0.5 6	0.6 - 1.0 8	1.1 - 2.5 10	2.6 - 4.0 10	4.1 - 9 10	> 9 8

[1]Any site with a gradient greater than the upper bound of the "very high" gradient classification is assigned a score of 4.

Table 5. OEPA Qualitative Habitat Evaluation Index Scores (Rankin, 1989)

75 to 100	Excellent stream habitat
60 to 75	Good stream habitat
45 to 60	*Need further evaluation by trained personnel
45 or less	Not conducive to Warm Water Habitat (WWH)

3.3.2 Flow/Velocity

A Global Flow Probe Model FP101 propeller type flow meter was used to record stream velocity. The flow meter was factory calibrated.

3.3.3 Site Location/Identification

Global positioning (GPS) information for each site was obtained using a Magellan SporTrak Map unit. Latitude and longitude readings were recorded at all sampling sites.

4.0 RESULTS AND DISCUSSION

The determination of water quality is an interdisciplinary science involving chemical, biological, and physical characteristics. Each characteristic, none withstanding, plays a vital role in the overall water quality of a stream or water body. Therefore this study employed various methods within each scientific area to obtain relevant data across the sciences.

Seasonal changes are reflected in water quality. Water levels are generally higher during the winter and spring; lower in summer and fall. The higher water levels of winter and spring serve to dilute the contaminants within a stream; lower water levels of summer and fall coupled with increased temperatures serve to concentrate contaminants and exacerbate pollution related problems.

Dissolved oxygen levels respond to changes in temperature; higher water temperatures result in lower dissolved oxygen levels, lower water temperatures result in higher dissolved oxygen levels. Higher water temperatures can cause an increase in aquatic vegetation and decomposition, both of which deplete oxygen.

Physical and chemical stream characteristics tend to be independent or "stand alone" while biological characteristics are a dependent variable. The biological communities within a water body may be directly affected by either physical attributes and/or water chemistry.

There is no previous data available for the Congress Lake Outlet according to Jeff Deshon of the OEPA, Columbus, Ohio. The Congress Lake Outlet from its origin at the spillway to its confluence with Potter Creek has never been assessed. Steve Tuckerman of the OEPA, Twinsburg, Ohio office referred to the area as a "black box." Data from this study will be compared to data from three previously studied sites. The three sites are in close proximity and include two regional reference sites, one on Potter Creek RM 1.5 and one on Tallmadge Rd. RM 12.7; a third site is located at RM 14.55. Both the Tallmadge Rd. RM 12.7 site and RM 14.55 are located on Breakneck Creek. The Tallmadge Rd. site is also part of this study and is identified as CLO6/BNC. Refer to Chapter 2, Table 2 for information on previously studied sites.

4.1 Chemical

Since the primary water source for the Congress Lake Outlet originates at Congress Lake the lake was also sampled, but for general water quality only. Water quality standards for streams cannot be effectively applied to a lake. Water levels within the lake fluctuated approximately two to three feet between winter and spring; winter being the lowest level.

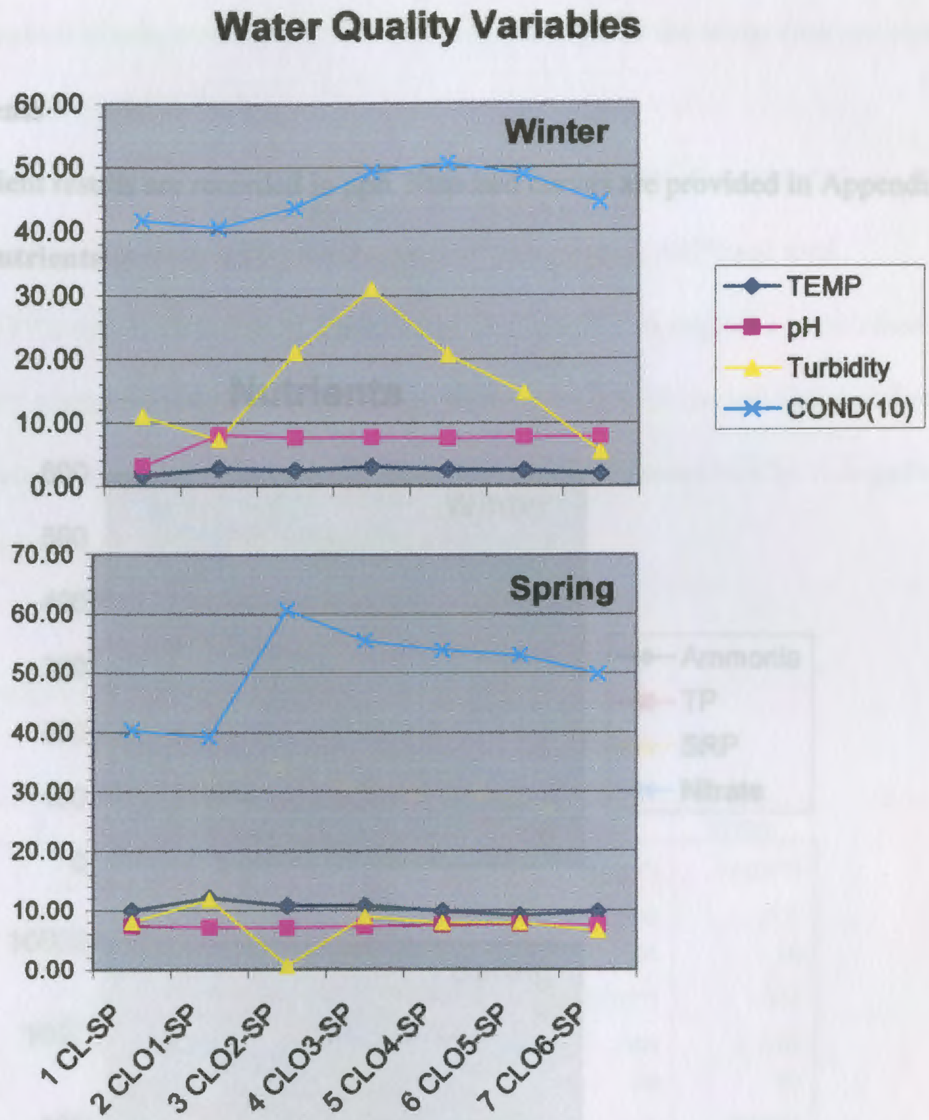
Sampling and testing was performed four times, December, January, March and April. December and January results were combined to create winter data; March and April for spring.

For analytical purposes outliers were dropped, a trim mean of 10% was applied, and averages were obtained. These averages are reflected in the Water Quality Variables and Nutrient charts located in Chapter 4, Figures 7 and 8.

4.1.1 General Water Characteristics

General water quality variables including temperature, pH, turbidity, and conductivity are presented in the following chart labeled Figure 7.

Figure 7. Water Quality Variables



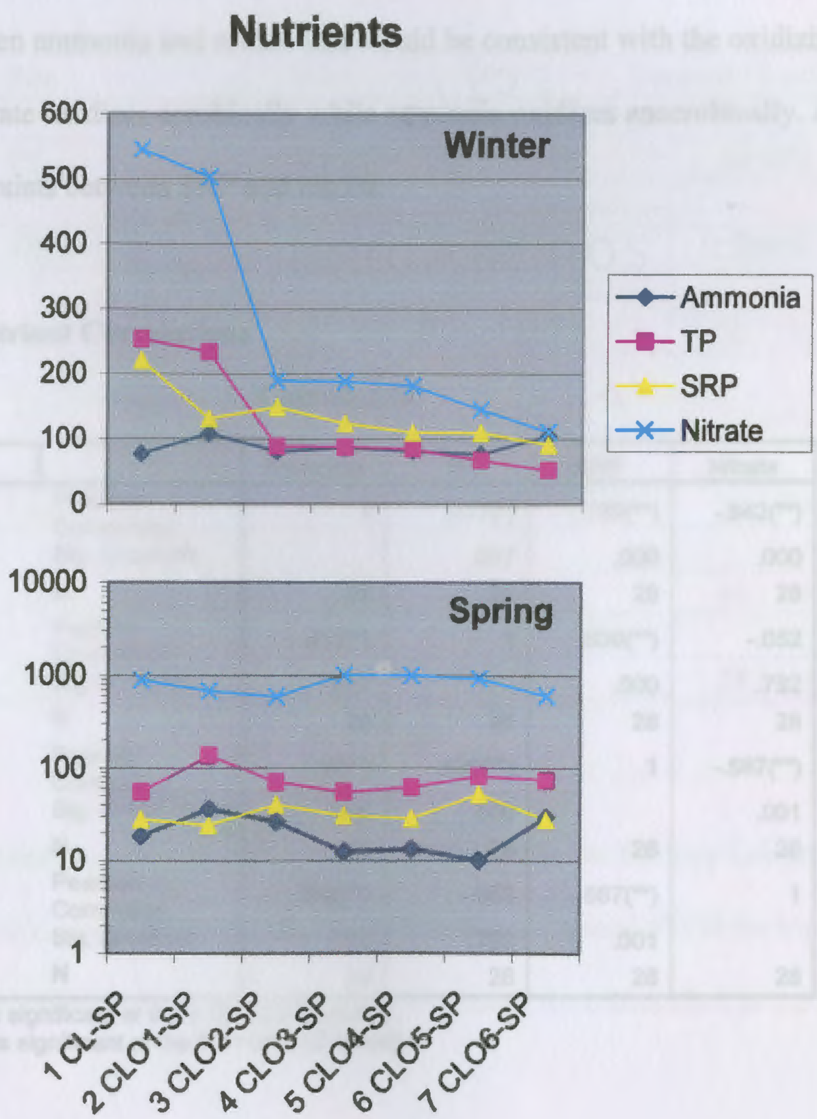
Temperatures during both winter and spring remained consistent throughout the study area. Readings for pH were in the normal range 6.5 to 9.0. With the exception of Congress Lake, which provided very low ph readings during winter ranging from 2.5 to 3.7. The pH of Congress Lake returned to a normal level during the spring. Turbidity and conductivity readings were typical when compared to other sites within the watershed.

Dissolved oxygen readings were inconsistent and therefore abandoned. All general water quality variables were compliant with WQS for Aquatic Life use designation.

4.1.2 Nutrients

Nutrient results are recorded in ppb. Standard curves are provided in Appendix A.

Figure 8. Nutrients



The highest nutrient levels were recorded during the spring season with nitrate being the most abundant nutrient. Ammonia was the only exception. Congress Lake, site CL had the overall highest nitrate readings. Nitrate readings throughout the study area increased significantly from winter to spring.

A Pearson correlation was applied to the nutrient data. Positive correlations identified are: ammonia with both soluble reactive phosphorus (SRP) and total phosphorus (TP), with both forms of phosphorus SRP and TP. A negative correlation exists between ammonia and nitrate and would be consistent with the oxidizing abilities of each. Nitrate oxidizes aerobically while ammonia oxidizes anaerobically. A negative correlation exists between SRP and nitrate.

Table 6. Nutrient Correlations

Correlations

		Ammonia	TP	SRP	Nitrate
Ammonia	Pearson Correlation	1	.417(*)	.739(**)	-.842(**)
	Sig. (2-tailed)		.027	.000	.000
	N	28	28	28	28
TP	Pearson Correlation	.417(*)	1	.639(**)	-.052
	Sig. (2-tailed)	.027		.000	.792
	N	28	28	28	28
SRP	Pearson Correlation	.739(**)	.639(**)	1	-.587(**)
	Sig. (2-tailed)	.000	.000		.001
	N	28	28	28	28
Nitrate	Pearson Correlation	-.842(**)	-.052	-.587(**)	1
	Sig. (2-tailed)	.000	.792	.001	
	N	28	28	28	28

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

4.1.3 Sediment

Sediment was collected during the spring at all seven sites. Samples were weighed and dried for twenty-four hours at 105 degrees C to obtain a percentage of moisture. Percentage of moisture ranged from 7.94 % to 61.31% with an mean of 35.31%.

Table 7. Sediment Weights

Sediment Weights

Site	Wet	Dry	Percent Moisture
CL	5.0082	2.1800	56.48%
CLO1	5.0480	4.6473	7.94%
CLO2	5.1544	1.9944	61.31%
CLO3	5.2335	4.0359	22.89%
CLO4	5.3190	3.7579	29.35%
CLO5	5.0655	2.7797	45.13%
CLO6	5.1248	3.8896	24.11%

Sediment samples were analyzed for pesticides in the Biology Lab at Youngstown State University. Using the EPA Sonication Extraction method #3550 for high concentrations of organics (>20 mg/kg), no pesticides were identified in the sediment samples.

Sediment samples were analyzed at Heidelberg College for volatile organic compounds. The results are presented in Chapter 4, Table 8.

Table 8. VOC's (ppb)

VOC's ppb	WQS	WQS	WQS								
	Wildlife	Human D/W	Human	Blank	Blank	CL	CLO1	CLO3	CLO4	CLO5	CLO6
	OZMA	OZMA	OZMA	Sed	Sed	2.921g	7.511g	7.52g	3.311g	3.619g	11.337g
dichlorodifluoromethane	ID	ID	ID	0.184	0.139	0.401	0.239	0.414			2.211
trichlorofluoromethane				0.225	0.24		0.364	0.365			0.664
methylene chloride	1900	47	2600	0.987	0.095			68.766	5.228	1.597	
benzene	160	12	310	0.029	0.03		0.045	0.042			0.145
toluene	62	5600	51000	0.655	0.672		0.991	0.993			1.492
P, M xylene	27	31,000	83,000	0.48	0.526		0.771	0.760			1.095
1,3 dichlorobenzene	22	5200	9300	0.225	0.287		0.389	0.381			
ethylbenzene	61	2100	8900		0.755		1.131				
n propylbenzene	ID	ID	ID		0.593		0.877				
sec butylbenzene	ID	ID	ID		0.759		1.136	1.142			
4 isopropyltoluene	16				0.628		0.945				1.415
chlorobenzene	47	470	3200		0.267		0.389	0.454			
1,2,4 trimethylbenzene	15	49	86		0.737		1.103				
bromobenzene					0.305		0.397				
4 chlorotoluene					0.48		0.696				
tert butylbenzene	ID	ID	ID		0.615		0.918				

* ID means insufficient data to calculate criterion per OEPA

The highlighted numbers represent the highest concentration of the sixteen VOC's found in blank samples. The figures located to the right represent levels at all sites that exceed the levels found in blanks. Water quality standard levels are presented in the three columns on the left labeled Wildlife and Human. There were no exceedences of Aquatic Life, Wildlife, use standards. One exceedence was found for Human Health standards pertaining to drinking water. That exceedence was methylene chloride with a reading of 69 versus the standard of 47.

4.2 Biological

4.2.1 Macro-invertebrates

Macro-invertebrates are an excellent indicator of stream conditions since they respond quickly to ambient conditions and maintain a sessile existence (OEPA, 1988). The very limited migratory pattern of macro-invertebrates makes them ideal for the determination of stream conditions within the immediate area. Macro-invertebrates are categorized by their tolerance or intolerance to pollution. Species are either pollution tolerant, intolerant, or somewhat tolerant. Hence, the ability to establish stream conditions at several locations relatively quickly and inexpensively is possible through the collection of macro-invertebrates. They are also the primary food for many fish species; macro-invertebrate populations directly effect fish populations.

For the purposes of this study all data derived was from natural substrates. A thorough collection of macro-invertebrates was not performed due to limitations of the stream substrates, fluctuating water levels, and seasonal variability. Macro-invertebrate collection is most effective during the summer months, June through September.

For the purposes of this study macro-invertebrates are being qualified based on their respective tolerance to pollution. Refer to Chapter 4, Table 9 for macro-invertebrates collected. The macro-invertebrates are divided into three categories:

Group One Taxa – Pollution sensitive organisms, found in good quality water

Group Two Taxa – Somewhat pollution tolerant, found in fair quality water

Group Three Taxa – Pollution tolerant, can be found in poor quality water.

Both the Izaak Walton League of America and the Ohio Scenic Rivers Association use this method of qualification.

Table 9. Macro-invertebrates collected

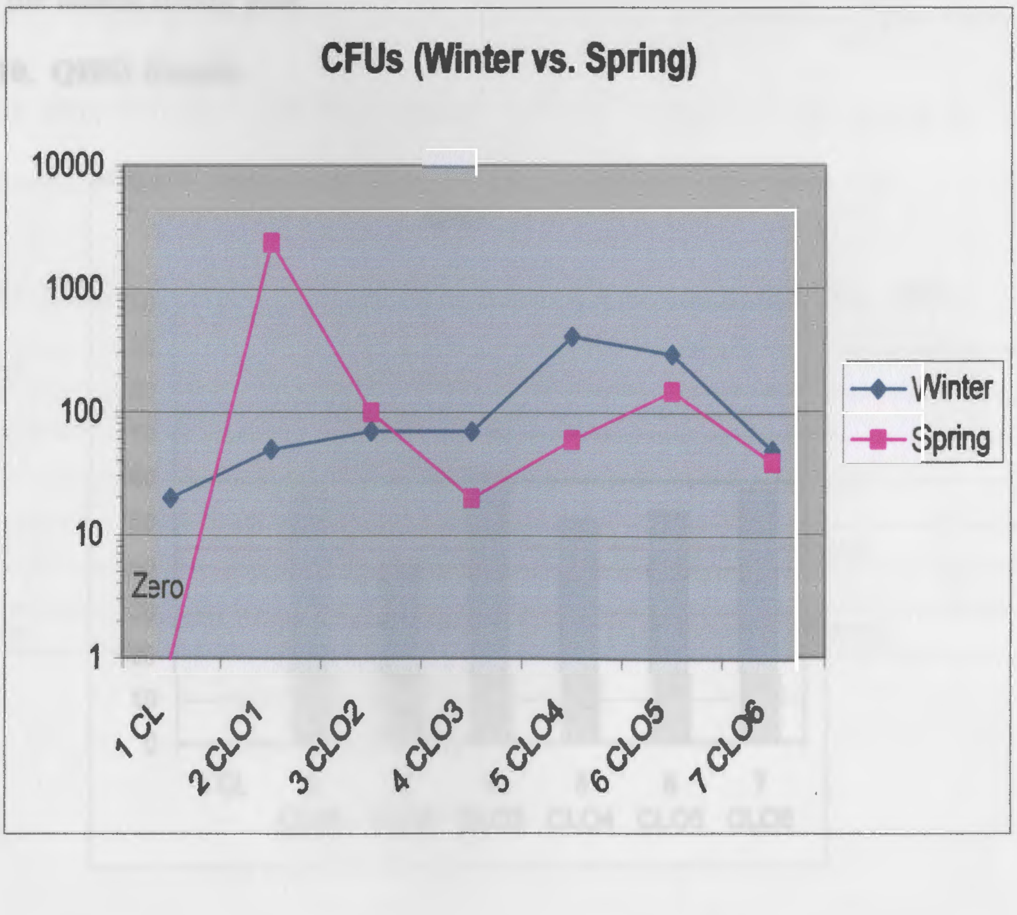
Site	Macro-invertebrate	Order	Taxa Group
CL	N/A		
CLO1	Leech	Hirudinea	3
	Aquatic worm	Oligochaeta	3
	Scud	Crustacea	2
	Midge	Diptera	3
CLO2	Aquatic worm	Oligochaeta	3
CLO3	Riffle beetle	Coleoptera	1
	Crane fly	Diptera	2
	Beetle larva	Coleoptera	2
	Aquatic worm	Oligochaeta	3
CLO4	Dragonfly	Odonata	3
	Aquatic worm	Oligochaeta	3
CLO5	Aquatic worm	Oligochaeta	3
CLO6/BNC	Aquatic worm	Oligochaeta	3
	Crayfish	Crustacea	2

4.2.2 Fecal Coliform Bacteria

Fecal coliform tests were performed at all sites in January and April. Colony forming units, per 100ml of water, were counted. Colony forming units appeared bluish/green in color on the agar plates.

Overall fecal coliform levels were higher during the spring. The highest level recorded, 2390 colony forming units, occurred in April at site CLO1, Quail Hollow Park. A reading of 420 CFU's was recorded at site CLO4, Waterloo Rd. during the January testing. There are no standards for fecal coliform as it relates to the WWH Aquatic Life use designation. The elevated levels recorded at CLO1 and CLO4 are in violation of the Human Health standards for drinking water and primary contact.

Figure 9. Fecal Coliform Bacteria Colony Forming Units



4.3 Physical

4.3.1 Qualitative Habitat Evaluation Index

The results of the QHEI evaluations produced results ranging from a low of 41 at site 3 CLO2 to a high of 61 at site 4 CLO3. Site CLO3, Alexander Rd. was the only location where fish were observed. This site is located in an agricultural area, although not as intensely farmed as the Pinedale Rd. location, site CLO2. Severe hydro-modification remains obvious at this location with little indication of recovery to a free flowing stream and natural sinuosity. Anthropocentric impacts often require anthropocentric assistance to recover.

Pinedale Rd. site CLO2 is the most severely modified stream site sampled. No recovery has taken place, stream cover is nearly non-existent, and siltation is excessive. Aquatic life habitat is very poor.

Figure 10. QHEI Results

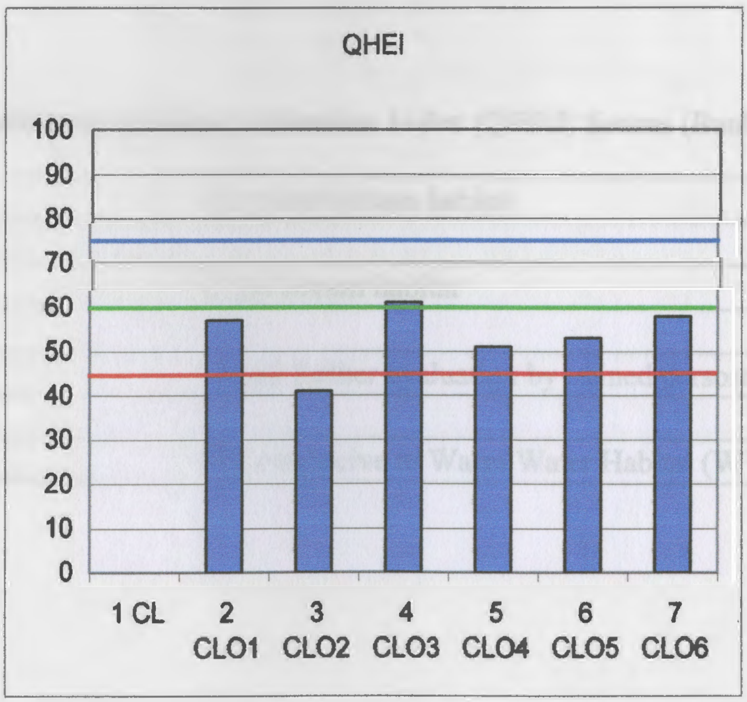


Table10.

Qualitative Habitat Evaluation Index Rating

Site	*CL	CLO1	CLO2	CLO3	CLO4	CLO5	CLO6/BNC
Substrate	N/A	12	8	14	10	10	10
Instream Cover	N/A	8	4	6	6	5	6
Channel Morphology	N/A	11	5	10	13	13	12
Riparian Zone	N/A	6	5	8	5	5	8
Pool/Glide/Run	N/A	9	5	8	5	8	9
Riffle/Run/Depth	N/A	3	4	5	4	4	5
Gradient	N/A	8	10	10	8	8	8
Total Score	N/A	57	41	61	51	53	58

*** The CL site is Congress Lake; the Qualitative Habitat Evaluation Index applies to streams only.**

Table 11. Qualitative Habitat Evaluation Index (QHEI) Scores (Rankin, 1989)

75 to 100	Excellent stream habitat
60 to 75	Good stream habitat
45 to 60	*Need further evaluation by trained personnel
45 or less	Not conducive to Warm Water Habitat (WWH)

A Pearson correlation of all variables reiterated the previous results of nutrients correlations. Additional correlations were indicated based primarily on relationships between nutrients/temperature and nutrients/turbidity. Nitrate and temperature were positively correlated, whereas both ammonia and SRP were negatively associated with temperature. Total phosphorus and pH were negatively correlated.

A lack of correlation between QHEI and any water quality variables is noteworthy. Fecal coliform bacteria was not correlated to any of the variables.

Table 12. Multiple Variable Correlations

Correlations

		Temp	pH	Turbidity	Conduct	Ammonia	TP	SRP	Nitrate	FecalCFU	QHEI
Temp	Pearson Correlation	1	.144	-.502	.343	-.915**	-.367	-.884**	.807**	.333	.020
	Sig. (2-tailed)		.624	.068	.229	.000	.197	.000	.000	.245	.952
	N	14	14	14	14	14	14	14	14	14	12
pH	Pearson Correlation	.144	1	.090	.186	-.005	-.604*	-.516	-.122	.024	.276
	Sig. (2-tailed)	.624		.760	.523	.987	.022	.059	.678	.936	.385
	N	14	14	14	14	14	14	14	14	14	12
Turbidity	Pearson Correlation	-.502	.090	1	-.169	.434	-.001	.454	-.536*	.071	.105
	Sig. (2-tailed)	.068	.760		.565	.121	.997	.103	.048	.810	.746
	N	14	14	14	14	14	14	14	14	14	12
Conduct	Pearson Correlation	.343	.186	-.169	1	-.462	-.524	-.381	.228	-.343	-.272
	Sig. (2-tailed)	.229	.523	.565		.097	.055	.178	.434	.230	.392
	N	14	14	14	14	14	14	14	14	14	12
Ammonia	Pearson Correlation	-.915**	-.005	.434	-.462	1	.427	.769**	-.858**	-.102	.084
	Sig. (2-tailed)	.000	.987	.121	.097		.128	.001	.000	.729	.796
	N	14	14	14	14	14	14	14	14	14	12
TP	Pearson Correlation	-.367	-.604*	-.001	-.524	.427	1	.651*	-.052	.121	.137
	Sig. (2-tailed)	.197	.022	.997	.055	.128		.012	.859	.681	.672
	N	14	14	14	14	14	14	14	14	14	12
SRP	Pearson Correlation	-.884**	-.516	.454	-.381	.769**	.651*	1	-.599*	-.257	-.157
	Sig. (2-tailed)	.000	.059	.103	.178	.001	.012		.024	.374	.625
	N	14	14	14	14	14	14	14	14	14	12
Nitrate	Pearson Correlation	.807**	-.122	-.536*	.228	-.858**	-.052	-.599*	1	.033	.118
	Sig. (2-tailed)	.000	.678	.048	.434	.000	.859	.024		.911	.714
	N	14	14	14	14	14	14	14	14	14	12
FecalCFU	Pearson Correlation	.333	.024	.071	-.343	-.102	.121	-.257	.033	1	.123
	Sig. (2-tailed)	.245	.936	.810	.230	.729	.681	.374	.911		.704
	N	14	14	14	14	14	14	14	14	14	12
QHEI	Pearson Correlation	.020	.276	.105	-.272	.084	.137	-.157	.118	.123	1
	Sig. (2-tailed)	.952	.385	.746	.392	.796	.672	.625	.714	.704	
	N	12	12	12	12	12	12	12	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.3.2 Location/Depth/Velocity

A GPS unit was used to identify all site locations by latitude and longitude. Depths and velocities were measured.

Table 13. GPS Data, Depth, Velocity

Sites	GPS	Depth (sampled)	Velocity	Average Velocity
CL Congress Lake	40 58.627N	2'	N/A	N/A
	81 19.768W			
CLO1 Quail Hollow	40 58.339N	0.8'	.5 feet	1.07 feet
	81 19.334W			
CLO2 Pinedale	40 58.912N	2'	.5 feet	.93 feet
	81 17.441W			
CLO3 Alexander Rd.	41 01.572N	2'+	1.5 feet	.99 feet
	81 17.441W			
CLO4 Waterloo Rd.	41 01.987N	2'+	.5 feet	.80 feet
	81 15.434W			
CLO5 Hartville Rd.	41 03.101N	1.4'	.5 feet	.75 feet
	81 16.117W			
CLO6/BNC	41 05.999N	5'+	.5 feet	.54 feet
.	81 16.332W			

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Chemical

The analyses of sediment for pesticides in high concentrations (>20 mg/kg), performed in the Youngstown State University Biology Lab, did not identify any pesticides. High flows may have reduced or removed pesticides from the stream at the time of sample collection. Pesticide levels may fluctuate seasonally and may be present in identifiable concentrations at certain times of the year, possibly summer.

I would recommend collecting and analyzing sediment for pesticides, during the summer, using the EPA #3550 Sonication Extraction low concentration method.

Sixteen volatile organic compounds (VOC's) were identified in quantifiable amounts. The water quality lab provided two blanks run with sediment and one blank with soil. Chapter 4, Table 8 depicts all VOC site readings that exceeded the readings provided by the blank, both sediment and soil. All VOC's identified are within the allowable amounts as stipulated by the chemical criteria for water quality standards (WQS) pertaining to aquatic life usage. The concentration of methylene chloride detected at site CLO3 Pinedale Rd., was 69 ppb which exceeds the maximum outside mixing zone average (OZMA) of 47 ppb WQS for human health, drinking water. Methylene chloride was detected at three sites CLO3, CLO4, and CLO5 decreasing downstream. Seven VOC's were found in both the current study and the three comparable sites. All were in compliance of WQS chemical criteria.

Results for VOC's at the three previously sampled comparable sites were in compliance. No alarming trends were found and VOC's do not seem to be problematic within the study area.

General water quality variables including temperature, pH, turbidity, and conductivity are presented in chapter 4, figure 7. Temperatures remained consistent throughout the area during winter and spring. Dissolved oxygen readings were inconsistent and therefore abandoned. Readings for pH were within the normal range of 6.5 – 9.0. Temperature, pH, turbidity and conductivity were typical and compliant with WQS for WWH Aquatic Life Use designation at all stream sites.

Congress Lake had extremely low pH readings during December and January ranging from a 2.5 to 3.7. The readings appear to be legitimate. The probe and data logger were calibrated for ph before each use. Readings taken at other sites on the same day are normal. The probe was rinsed with de-ionized water before each use. I suggest ongoing monitoring of pH in Congress Lake at multiple sites.

Nutrient data are provided in Chapter 4, figure 7. Nutrients readings were generally lower during the winter, with the exception of ammonia. This is further evidenced by the negative correlation between ammonia and temperature shown in the Multiple Variable Correlation table 12, in Chapter 4. Nitrate was the most abundant nutrient and can be seen decreasing downstream. A steep drop off of nitrate and phosphorus occurred during the winter between Congress Lake and sites CLO1 and CLO2. The data suggests nutrient loading occurring in Congress Lake and being dispersed or assimilated downstream. A positive correlation exists between nitrate and temperature. Ratios of nitrogen to phosphorus found in Congress Lake indicate that phosphorus may be nitrogen limited during spring. Nitrate levels were high enough during the spring throughout the watershed to support eutrophic conditions.

A negative correlation exists between ammonia and nitrate and would be consistent with the oxidizing abilities of each. Nitrate oxidizes aerobically while ammonia oxidizes anaerobically. A negative correlation exists between SRP and nitrate. Nutrient levels increased and were fairly consistent throughout the study area during spring.

Results of TP and SRP during the winter for sites CLO2 through CLO6 are inconsistent. Data shows SRP levels exceeding TP. After further discussion with Dr. Scott Martin, I have no explanation for this discrepancy. Phosphorus data for sites CL and CLO1 appear to be correct. Due to inconsistencies no conclusions are being drawn from these data. Phosphorus levels are high enough throughout the study area to support substantial algal or plant growth and create eutrophic or borderline hyper eutrophic conditions.

The highest levels of nutrients are linked to Congress Lake and site CLO1 directly downstream from the spillway.

Additional negative correlations from the Multiple Variable Correlation table include: SRP and temperature, TP and pH, nitrate and ammonia, nitrate and SRP, and nitrate and turbidity. Ammonia and SRP, and TP and SRP are positively correlated.

Fecal coliform bacteria was not correlated to any of the variables. A lack of correlation on the between QHEI and any water quality variables is noteworthy refer to Chapter 4, Table 12.

5.2 Biological

The macro-invertebrate data presented herein is inconclusive and reported for the record only. No conclusions should be drawn from this information. If possible, I recommend a colonization type collection of macro-invertebrates during the months of June through September employing Hester-Dendy multiple plate artificial substrate samplers. Due to heavy siltation in some locations collection by Hester-Dendy samplers may not be possible; scouring at other sites may not produce good results either. The collection of additional biological data could then be applied to the Invertebrate Community Index (ICI) to establish a numeric value.

A fish survey should be conducted and data applied to the Index of Biotic Integrity (IBI). The ICI and IBI would be compared to regional sites within the Lake Erie Basin eco-region to determine the biological integrity and the attainment status of the Aquatic Life use designation. The third biological index, Miwb, does not apply to streams of this size.

Since biological data collected during this study is inconclusive an attempt to ascertain attainment status will be dependent on physical and chemical variables.

Fecal coliform bacteria levels were slightly elevated at two sites during the winter. The spring sampling at site CLO1 produced an elevated level of bacteria that would be non-compliant with either bathing water or primary contact under the recreational use designations. Refer to Figure 8 in chapter 4, for fecal coliform data. Fecal coliform readings are not applicable to the aquatic life use designation.

5.3 Physical

The results of the QHEI evaluations produced results ranging from a low of 41 at site CLO2 to a high of 61 at site CLO3. Results indicate one site that achieved a rating of "Good," four sites "Need further evaluations," and one site rated "Not conducive to Warm Water Habitat" criteria. The QHEI process applies to streams only therefore Congress Lake is not included.

The physical habitat in the portions of study area from the Congress Lake spillway north to the Portage County line may be degraded beyond recovery. The degradation is the result of severe hydro-modifications, primarily channelization and dredging which have occurred for more than a century. The hydro-modifications are most prevalent from site CLO1 north to the Portage County line.

The site CLO1 located at Quail Hollow State Park has shown elevated nutrients and a benthic community indicative of poor water quality. Invertebrates collected at this site, two times, during the fall and spring were pollution tolerant varieties. A private residence, containing a second spillway and pond are located approximately two hundred upstream from the sampling site. The pond is eutrophic during the summer. The short section of stream located adjacent to Quail Hollow State Park contains sand and gravel substrate, some sinuosity, abundant instream cover, and has the potential to recover or be restored, if upstream problems are abated.

Hydro-modifications are obvious as you leave the park property and continue northeast. The effects of which are evidenced by the QHEI rating of 41 at the Pinedale Rd. site CLO2. Refer to Chapter 4, table 10 for QHEI results and table 11 for scoring. The QHEI rating of 41is the same as 1996 evaluation of the Potter Creek site RM 1.5, an

OEPA reference site used for comparison purposes in this study. Both sites have undergone severe hydro-modifications for agricultural use. The Potter Creek site is showing signs of recovery to a free flowing stream. During a 2000 evaluation the Potter Creek site achieved a QHEI rating of 62 giving the stream a "good" rating for stream habitat. This alleged recovery from a QHEI of 41 to 62 in four years seems nearly incomprehensible, further evaluation may be needed. Agricultural land use along Potter Creek has lessened. The Potter Creek site has a gradient of 10.0 feet per mile, steeper than the area around Pinedale, and a drainage area of 3.2 square miles. The land use designation is RN meaning rural, natural forested areas or parkland. The designation is based on land use upstream from the site. The riparian zone near the Potter Creek site is wooded and land use is becoming more residential, as opposed to the Pinedale site CLO2 that is located within an intensely agricultural area and contains highly erodible banks.

CLO2 site on Pinedale Rd., in northern Stark County rated the poorest site overall. The QHEI, a rating of natural physical attributes, was the lowest within the study area with a score of 41, which equates to "Not Conducive to Warmwater Habitat." No signs of recovery were observed.

The Alexander Rd. site CLO3 provided the most promise with the highest QHEI score of 61, indicative of good stream habitat. Biologically speaking the macro-invertebrates collected represented the highest quality and most diversity, keeping in mind the limited sampling performed, refer to Chapter 4, table 9 for list of macro-invertebrates. The substrate was conducive to macro-invertebrates with cobble, gravel, some sand, and riffle areas. Evidence of channelization is still evident. Although agriculture remains the primary land use, all animals observed were fenced away from the stream. A wide riparian zone exists with a shrub and forest area established on one side. The addition of instream cover may serve to improve the overall quality. This is the only site where fish were observed. Best water clarity was observed at this site.

Waterloo Rd. site CLO4 still shows signs of hydro-modifications but to a lesser degree. The stream contains structure such as woody debris and overhanging vegetation. The riparian zone on the right is becoming forested. One other improvement is the Randolph sewer project currently underway which will serve a mobile home park currently discharging into the stream.

Hartville Rd. site CLO5 is heavily silted and lacks sand, cobble, and/or boulders. Riparian zone is poor on both sides.

Tallmadge Rd. CLO6/BNC has a scoured bottom and poor substrate. The stream velocity at this site is relatively slow and flooding is frequent.

Dr. Tom Diggins and I visited all seven sites on Monday, July 11. We found culturally eutrophic conditions at Congress Lake, CLO1, and CLO2.

Congress Lake was hyper-eutrophic allowing little light penetration and possibly causing oxygen depletion. Little emergent vegetation was observed. Algal blooms were also evident at other downstream sites.

One violation of WQS was obvious. The narrative "free froms" rule, referred to in Section 2.8, addresses detrimental substances that affect human, animal, or aquatic life. According to this rule surface waters must be free from "nutrients in concentrations that may cause algal bloom." Eutrophic conditions are a violation of the "free froms" rule. No other violations of the WWH Aquatic Life Use designation were identified.

Overall the physical degradation of the Congress Lake Outlet does not lend itself to being conducive to a use designation of WWH status for aquatic life use. The effects of long term and ongoing anthropocentric activities in the upper reaches of the stream render the water quality to more closely resemble a LRW Limited Resource Water or possible MWH Modified Warmwater Habitat. Abatement of the issues of nutrient loading and physical factors must be addressed to provide improvement in the water quality and the ability to support a viable aquatic community. The lack of correlation between QHEI ratings and any other variables on the Multiple Variable Correlation, Chapter 4, table 12, may indicative of the role of land use in the watershed. The study area may also be strongly influenced by Congress Lake.

5. 4 Recommendations

Overall I recommend public outreach and education regarding the benefits of clean water for recreation, water supply including human and agricultural, and aquatic life, this may influence decisions being made that affect the watershed. A joint effort between Stark and Portage counties could result in a synergistic effect.

A review of all point sources and possible non-point sources within the study area should be conducted.

Efforts should be made to determine and abate sources of runoff and to control soil loss through wind and water erosion especially in the agricultural areas.

More specifically ongoing additional studies should be performed at Congress Lake due to extremely low pH readings, during the winter months, and elevated nutrients.

Identification of sources may lead to examination of septic systems surrounding the lake and possibly alternative lawn treatments for homeowners and the golf course.

Agricultural Best Management Practices (BMP's) including: buffer zones to prevent runoff, windbreaks to lessen the effects of erosion, no-till farming, leaving fields in fallow may provide improvement in water quality. Incentives may be needed to encourage participation. Support can be obtained from the National Resource Conservation Service (NCRS).

Additional sampling should be performed for fecal coliform bacteria at site CLO1 where colony forming units exceeded the OEPA Human Health criteria for drinking water.

Financial resources are available through various grants such as the section 319 program. Funding for conservation easements is available through the Portage County Soil and Water District. Work may be performed by various groups including: the Breakneck Creek Coalition, students from Portage County schools including Kent State and Hiram College, local Boy Scout troops, and others.

I recommend that the Congress Lake Outlet be included in the five year watershed sampling plan and in the next upcoming biological survey.

REFERENCES

Baskin, John and O'Bryant, Michael, 2004. *Ohio Almanac*. Wilmington, Ohio: Orange Frazer Press.

Clements, John, 1988. *Ohio Facts A Comprehensive Look at Ohio County by County*. Dallas, Texas: Clements Research III Inc.

Clesceri, Lenore S., Arnold E. Greenberg, and Andrew D. Eaton (Eds.). 1998. *Standard Methods for the examination of Water and Wastewater* (20th ed.). American Public Health Association, American Water Works Association, Water Environment Federation. pp. 4-99, 102-103, 139-142, 146-147.

Cramer, Jack, & Ewing, Ellen, Personal interview. October 2004. Heidelberg College, Water Quality Lab, Tiffin, Ohio.

Cunningham, William P., Mary Ann Cunningham and Barbara Saigo, 2005. *Environmental Science A Global Concern* (8th ed). McGraw Hill. Boston. pp. 394

Environmental Protection Agency, 2005. Office of Wastewater Management. National Pollutant Discharge Elimination System (NPDES). http://cfpub.epa.gov/npdes/index.cfm

Environmental Protection Agency, 1999. *Stormwater Effects Handbook, Benthic Community Assessment.* www.epa.gov/ednnrmrl/publish/book/handbook/appb.pdf

Herbst, Mrs. Mark, Stillwell, Mrs. Clair, & Ream, Mrs. Donald, 1964. *History of Congress Lake.* Congress Lake Garden Club.

Lind, Owen T., 1985. *Chemical Limnology Handbook of Common Methods in Limnology.* (2nd ed.). Kendall/Hunt Publishing Co. pp. 77-78.

McPherson, James W. III., 1976. *A History of Hartville.* Hartville, Ohio: The Knowles Press Inc.

Natural Resources Conservation Service, 2005. *Hydric Soils-Introduction.* United States Department of Agriculture. http://soils.usda.gov/use/hydric/intro.html

Ohio Watershed Academy, 2003. Clean Water Act Module. http://www.epa.gov/watertrain/cwa/rightindex.htm

Ohio Department of Natural Resources, 1968. *General Soil Map of Stark County.* Division of Lands and Soils.

REFERENCES cont'd

Ohio Environmental Protection Agency, 1999. *Biological and Water Quality Study of the Cuyahoga River and Selected Tributaries*. Division of Surface Water. Monitoring and Assessment Section, Columbus, Ohio and Surface Water Section, Twinsburg, Ohio.

Ohio Environmental Protection Agency, 2001. *Sediment Sampling Guide and Methodologies* (2nd ed.).

Ohio Environmental Protection Agency, *Stormwater Effects Handbook*. http://www.epa.gov/ednnrmrl/publish/book/handbook/appb.pdf

Ohio Environmental Protection Agency, 2000. *Total Maximum Daily Loads for the Middle Cuyahoga River Final Report*. Division of Surface Water.

Ohio Environmental Protection Agency, 2005. *Water Quality Standards*. Division of Surface Water.
http://www.epa.state.oh.us/dsw/wqs.html

Rankin, Edward T., 1989. *Qualitative Habitat Evaluation Index*. Ohio EPA Division of Surface Water.

Yoder, Elmer S. (Ed.), 2003. *Introducing Lake Township, Rooted in the Past, Reaching for the Future*. Publication of the Lake Township Historical Society. Sugar Creek, Ohio: Carlisle Printing.

Acronyms

AMD	Acid Mine Drainage
BMP	Best Management Practice
CWA	Clean Water Act of 1972
CWH	Coldwater Habitat
EPA	Environmental Protection Agency – Federal
EOLP	Erie/Ontario Lake Plain (eco-region designation)
EWH	Exceptional Warmwater Habitat
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
LRW	Limited Resource Water
LWH	Limited Warmwater Habitat
MIWB	Modified Index well being
MWH	Modified Warmwater Habitat
NPDES	National Pollutant Discharge Elimination System
OEPA	Ohio Environmental Protection Agency
ppb	Part per billion
ppm	Part per million
QHEI	Qualitative Habitat Evaluation Index
TMDL	Total Maximum Daily Load
WET	Whole Effluent Toxicity
WLA	Waste Load Allocation
WQS	Water Quality Standards
WWH	Warmwater Habitat

APPENDIX A

Ammonia

Ammonia - 1st Time

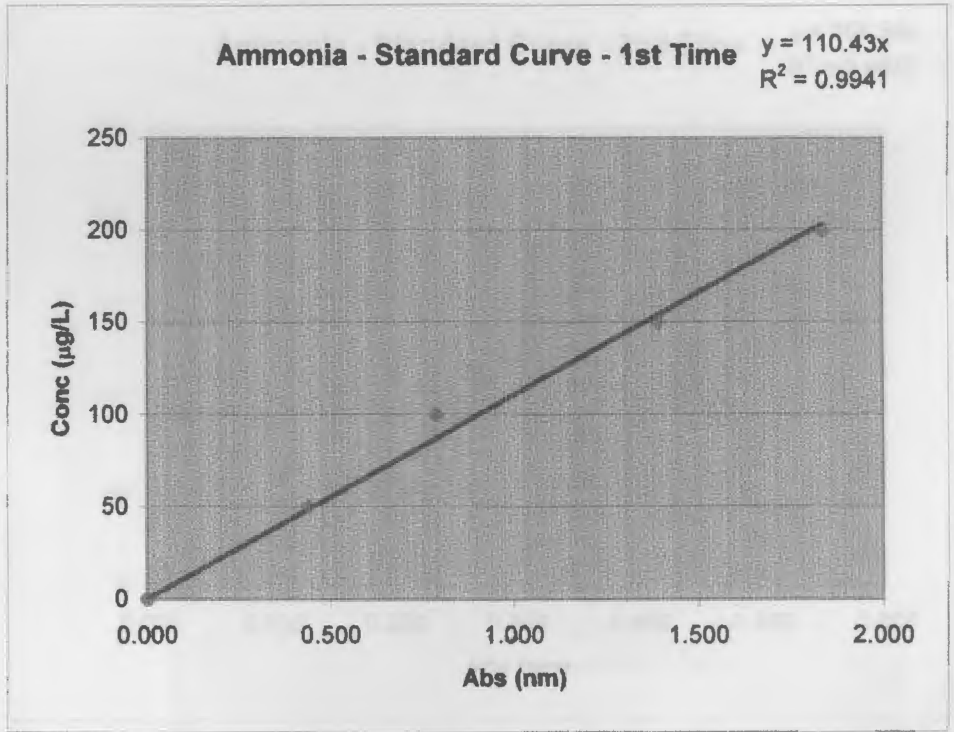
Sample #	Content	Abs	Conc (mg/l)
1	Blank	0.000	[illegible]
2	Blank	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	83.92
13	CL03-A	0.752	83.04
14	CL03-B	0.819	90.44
15	CL04-A	0.846	93.42
16	CL04-B	0.625	69.02
17	CL05-A	0.600	66.26
18	CL05-B	0.788	87.02
19	CL06-A	0.917	101.26
20	CL06-B	0.968	106.90
Date: 01/05/2005		R^2 = 0.9941	y=110.43x
	λ=640nm	5cm holder	

A - 1

Ammonia

Ammonia - 1st Time

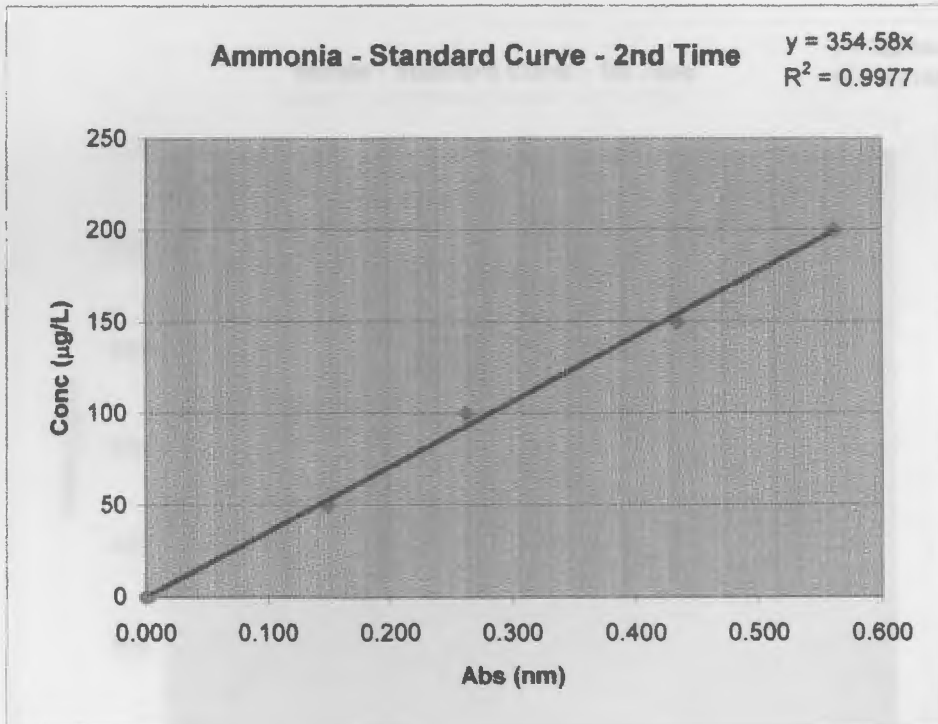
Sample #	Content	Abs.	Conc (mg/L)
1	Blank	0.000	0
2	Blank	0.002	0
3	1.0 mL	0.439	50
4	2.0 mL	0.788	100
5	3.0 mL	1.395	150
6	4.0 mL	1.837	200
7	CL-A	0.692	76.42
8	CL-B	0.692	76.42
9	CL01-A	1.150	126.99
10	CL01-B	0.809	89.34
11	CL02-A	0.696	76.86
12	CL02-B	0.759	83.82
13	CL03-A	0.752	83.04
14	CL03-B	0.819	90.44
15	CL04-A	0.846	93.42
16	CL04-B	0.625	69.02
17	CL05-A	0.600	66.26
18	CL05-B	0.788	87.02
19	CL06-A	0.917	101.26
20	CL06-B	0.968	106.90
Date: 01/05/2005		R^2= 0.9941	y=110.43x
	λ=640nm	5cm holder	



Ammonia

Ammonia - 2nd Time

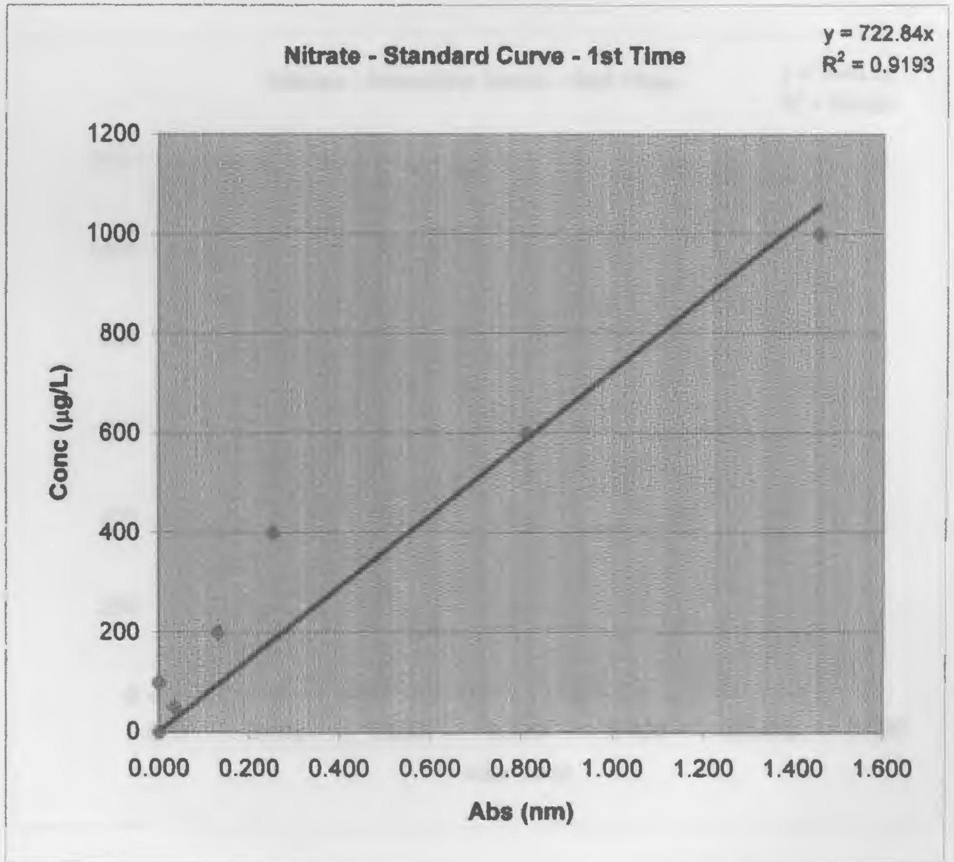
Sample #	Content	Abs.	Conc (mg/L)
1	Blank	0.000	0
2	Blank	0.002	0
3	1.0 mL	0.149	50
4	2.0 mL	0.262	100
5	3.0 mL	0.435	150
6	4.0 mL	0.562	200
7	CL-A	0.077	27.30
8	CL-B	0.027	9.57
9	CL01-A	0.106	37.59
10	CL01-B	0.096	34.04
11	CL02-A	0.074	26.24
12	CL02-B	0.075	26.59
13	CL03-A	0.031	10.99
14	CL03-B	0.039	13.83
15	CL04-A	0.037	13.12
16	CL04-B	0.038	13.47
17	CL05-A	0.021	7.45
18	CL05-B	0.036	12.76
19	CL06-A	0.085	30.14
20	CL06-B	0.080	28.37
Date: 04/13/2005		R^2= 0.9977	y=354.58x
	λ=640nm	1cm Cell	



Nitrate

Nitrate - 1st Time

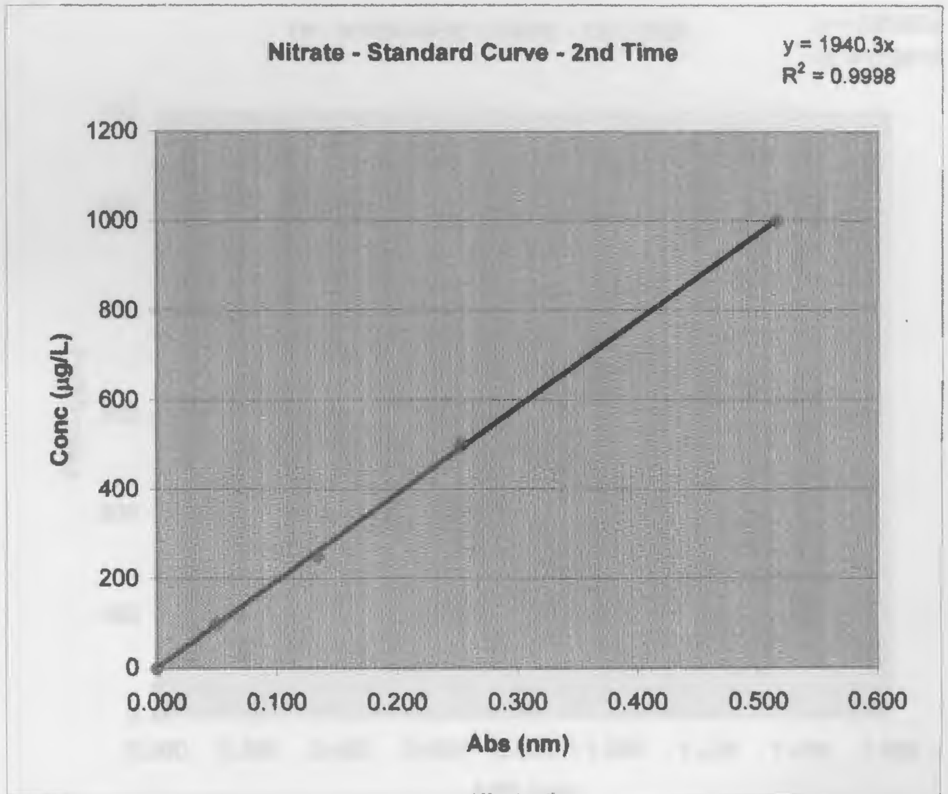
Sample #	Content	Abs.	Conc (µg/L)
1	Blank	0.000	0
2	Blank	0.002	0
3	1.0 mL	0.035	50
4	2.0 mL	0.000	100
5	4.0 mL	0.132	200
6	8.0 mL	0.255	400
7	12.0 mL	0.813	600
8	20.0 mL	1.459	1000
9	CL-A	0.747	539.96
10	CL-B	0.762	550.80
11	CL01-A	0.691	499.48
12	CL01-B	0.700	505.99
13	CL02-A	0.273	197.34
14	CL02-B	0.251	181.43
15	CL03-A	0.264	190.83
16	CL03-B	0.257	185.77
17	CL04-A	0.247	178.54
18	CL04-B	0.255	184.32
19	CL05-A	0.199	143.85
20	CL05-B	0.202	146.01
21	CL06-A	0.137	99.03
22	CL06-B	0.169	122.16
Date: 01/05/2005		R^2= 0.9193	y=722.84x
	λ=500nm	1cm Cell	



Nitrate

Nitrate - 2nd Time

Sample #	Content	Abs.	Conc (µg/L)
1	Blank	0.000	0
2	Blank	0.000	0
3	2.0 mL	0.050	100
4	5.0 mL	0.134	250
5	10.0 mL	0.254	500
6	20.0 mL	0.516	1000
9	CL-A	0.446	865.37
10	CL-B	0.462	896.42
11	CL01-A	0.346	671.34
12	CL01-B	0.346	671.34
13	CL02-A	0.306	593.73
14	CL02-B	0.299	580.15
15	CL03-A	0.510	989.55
16	CL03-B	0.519	1007.02
17	CL04-A	0.512	993.43
18	CL04-B	0.512	993.43
19	CL05-A	0.469	910.00
20	CL05-B	0.473	917.76
21	CL06-A	0.309	599.55
22	CL06-B	0.303	587.91
Date: 04/13/2005		R^2= 0.9998	y=1940.3x
	λ=543nm	1cm Cell	



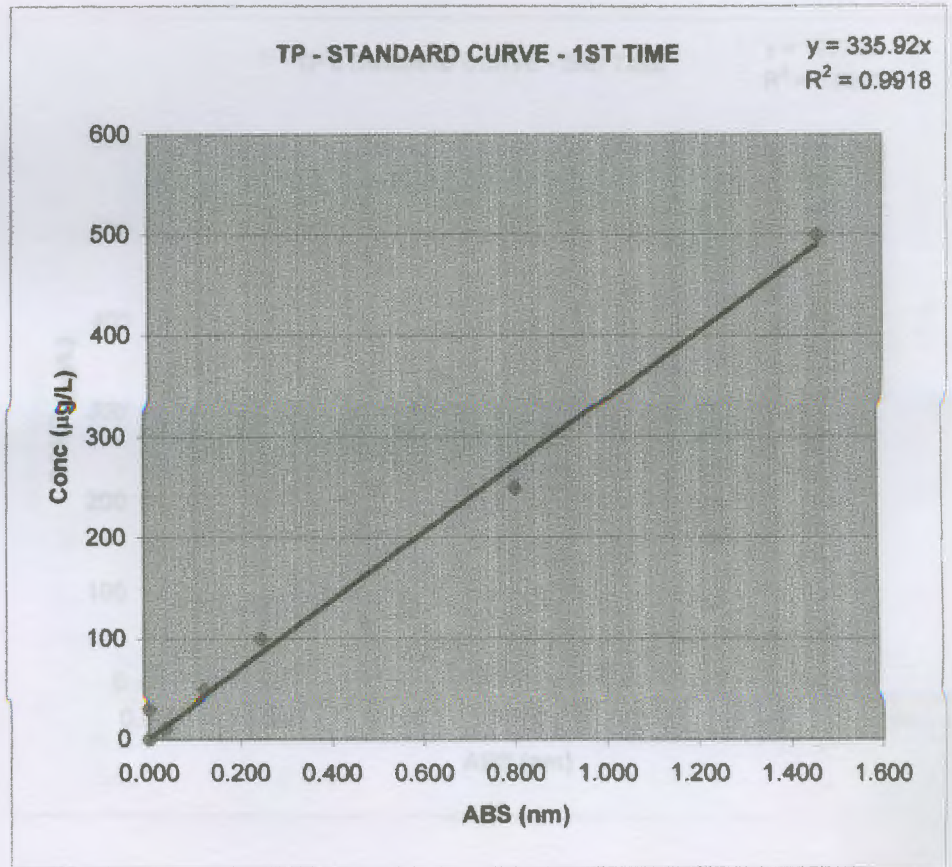
Nitrate 1st time method Hawk packets

Nitrate 2nd time method cadmium reduction

Total Phosphorus

TP - 1st Time

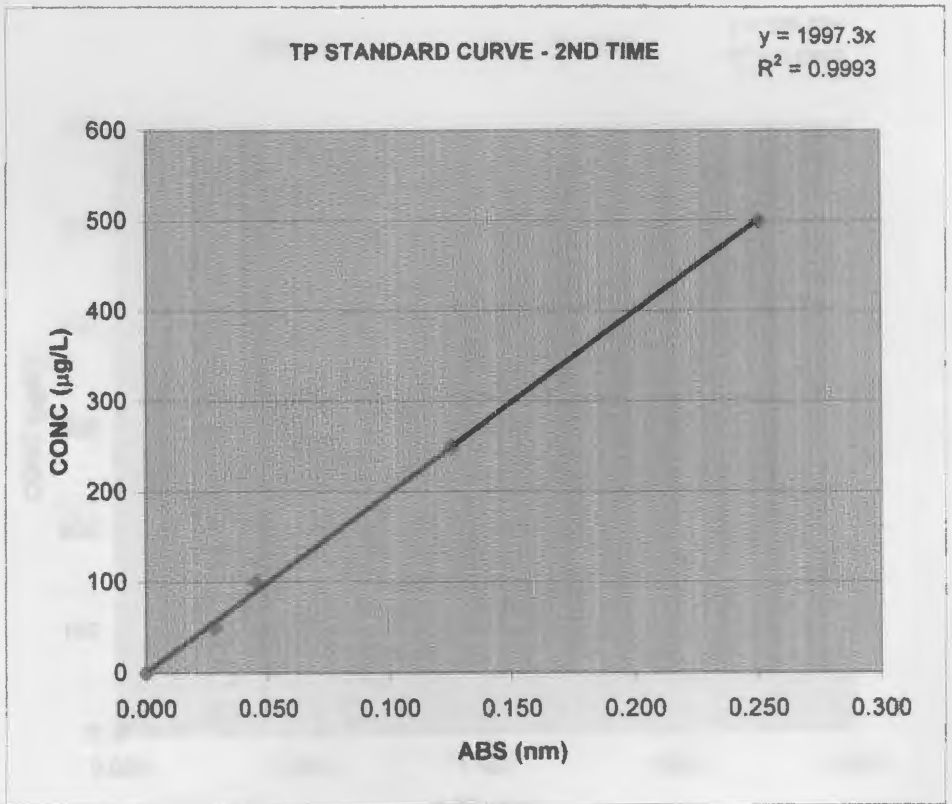
Sample #	Content	Abs.	Conc (µg/L)
1	Blank	0.000	0
2	Blank	0.002	0
3	1.0 mL	0.035	10
4	3.0 mL	0.000	30
5	5.0 mL	0.132	50
6	10.0 mL	0.255	100
7	25.0 mL	0.813	250
8	50.0 mL	1.459	500
7	CL-A	0.747	250.93
8	CL-B	0.762	255.97
9	CL01-A	0.691	232.12
10	CL01-B	0.700	235.14
11	CL02-A	0.273	91.71
12	CL02-B	0.251	84.32
13	CL03-A	0.264	88.68
14	CL03-B	0.257	86.33
15	CL04-A	0.247	82.97
16	CL04-B	0.255	85.66
17	CL05-A	0.199	66.85
18	CL05-B	0.202	67.86
19	CL06-A	0.137	46.02
20	CL06-B	0.169	56.77
Date: 01/07/2005		R^2= 0.9918	y=335.92x
	λ=880nm	5cm Cell	



Total Phosphorus

TP - 2nd Time

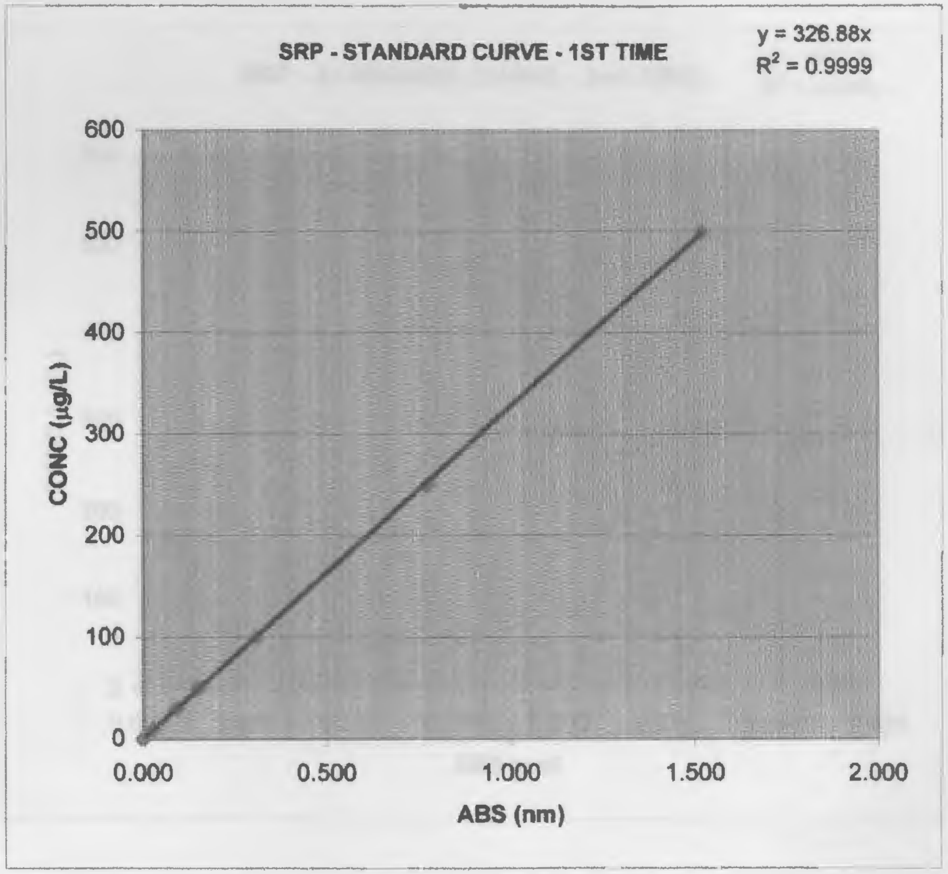
Sample #	Content	Abs.	Conc (µg/L)
1	Blank	0.000	0
2	Blank	0.000	0
3	5.0 mL	0.028	50
4	10.0 mL	0.045	100
5	25.0 mL	0.125	250
6	50.0 mL	0.251	500
7	CL-A	0.030	59.92
8	CL-B	0.025	49.93
9	CL01-A	0.065	129.82
10	CL01-B	0.070	139.81
11	CL02-A	0.036	71.90
12	CL02-B	0.034	67.91
13	CL03-A	0.027	53.93
14	CL03-B	0.028	55.92
15	CL04-A	0.032	63.91
16	CL04-B	0.030	59.92
17	CL05-A	0.041	81.89
18	CL05-B	0.041	81.89
19	CL06-A	0.036	71.90
20	CL06-B	0.038	75.90
Date: 04/11/2005		R^2= 0.9993	y=1997.3x
	λ=880nm	1cm Cell	



Soluble Reactive Phosphorus

SRP - 1st Time

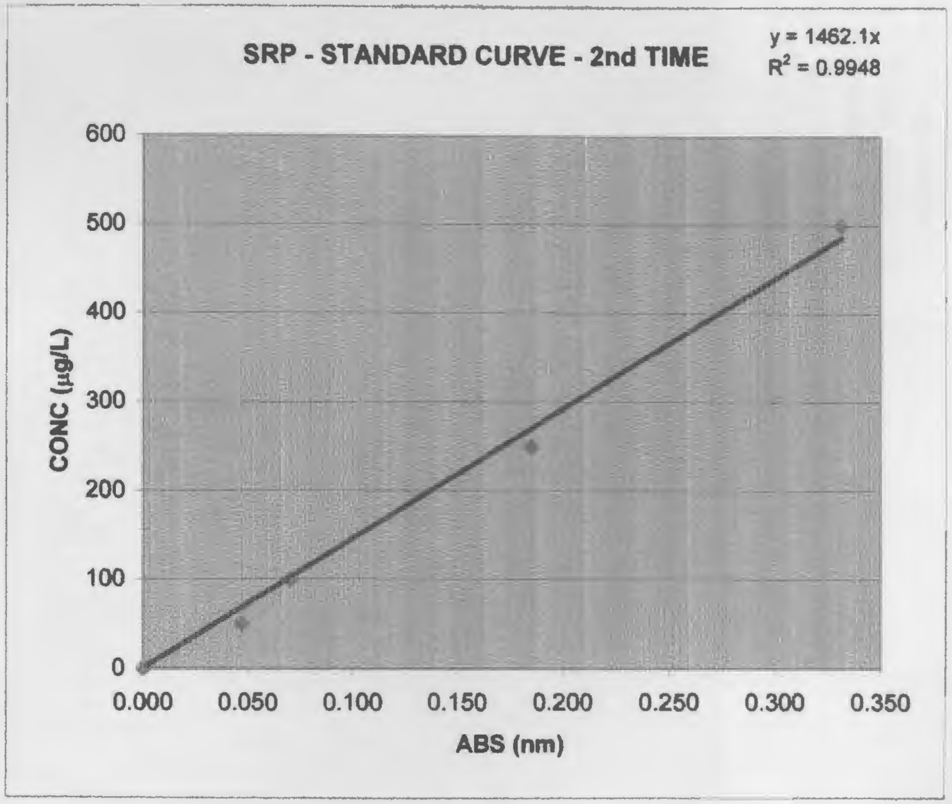
Sample #	Content	Abs.	Conc (µg/L)
1	Blank	0.000	0
2	Blank	0.000	0
3	1.0 mL	0.029	10
4	3.0 mL	0.089	30
5	5.0 mL	0.150	50
6	10.0 mL	0.308	100
7	25.0 mL	0.774	250
8	50.0 mL	1.525	500
9	CL-A	0.551	180.11
10	CL-B	0.797	260.52
11	CL01-A	0.409	133.69
12	CL01-B	0.393	128.46
13	CL02-A	0.453	148.08
14	CL02-B	0.456	149.06
15	CL03-A	0.393	128.46
16	CL03-B	0.365	119.31
17	CL04-A	0.340	111.14
18	CL04-B	0.332	108.52
19	CL05-A	0.336	109.83
20	CL05-B	0.334	109.18
21	CL06-A	0.284	92.83
22	CL06-B	0.272	88.91
Date: 01/05/2005		R^2= 0.9999	y=326.88X
	λ=880nm	5cm Cell	



Soluble Reactive Phosphorus

SRP - 2nd Time

Sample #	Content	Abs.	Conc (μg/L)
1	Blank	0.000	0
2	Blank	0.000	0
3	5.0 mL	0.047	50
4	10.0 mL	0.070	100
5	25.0 mL	0.185	250
6	50.0 mL	0.332	500
7	CL-A	0.017	24.86
8	CL-B	0.021	30.70
9	CL01-A	0.017	24.86
10	CL01-B	0.016	23.39
11	CL02-A	0.022	32.17
12	CL02-B	0.033	48.25
13	CL03-A	0.021	30.70
14	CL03-B	0.021	30.70
15	CL04-A	0.016	23.39
16	CL04-B	0.023	33.63
17	CL05-A	0.039	57.02
18	CL05-B	0.032	46.79
19	CL06-A	0.021	30.70
20	CL06-B	0.017	24.86
Date: 04/11/2005		R^2= 0.9948	y=1462.1x
	λ=880nm	1cm Cell	



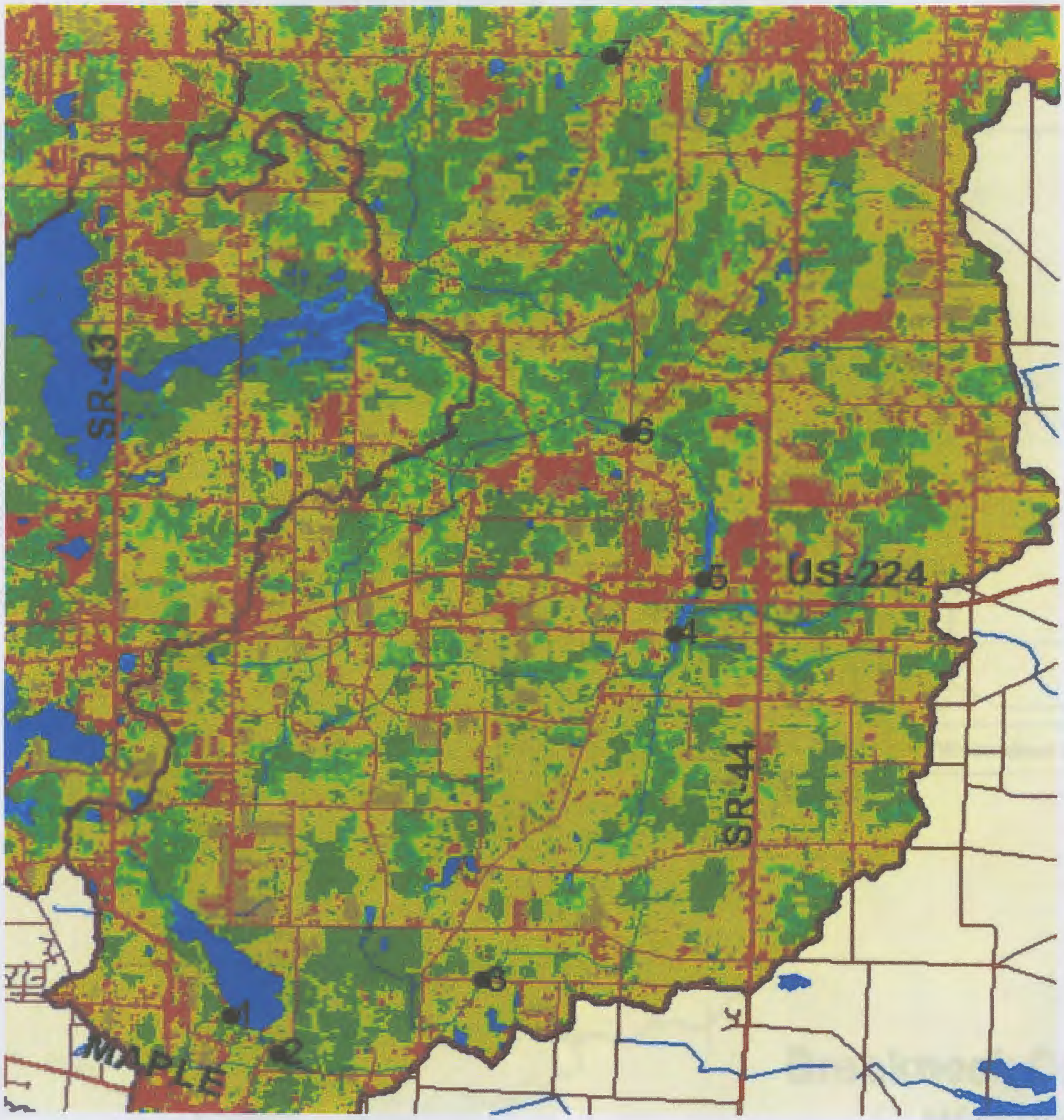
APPENDIX B

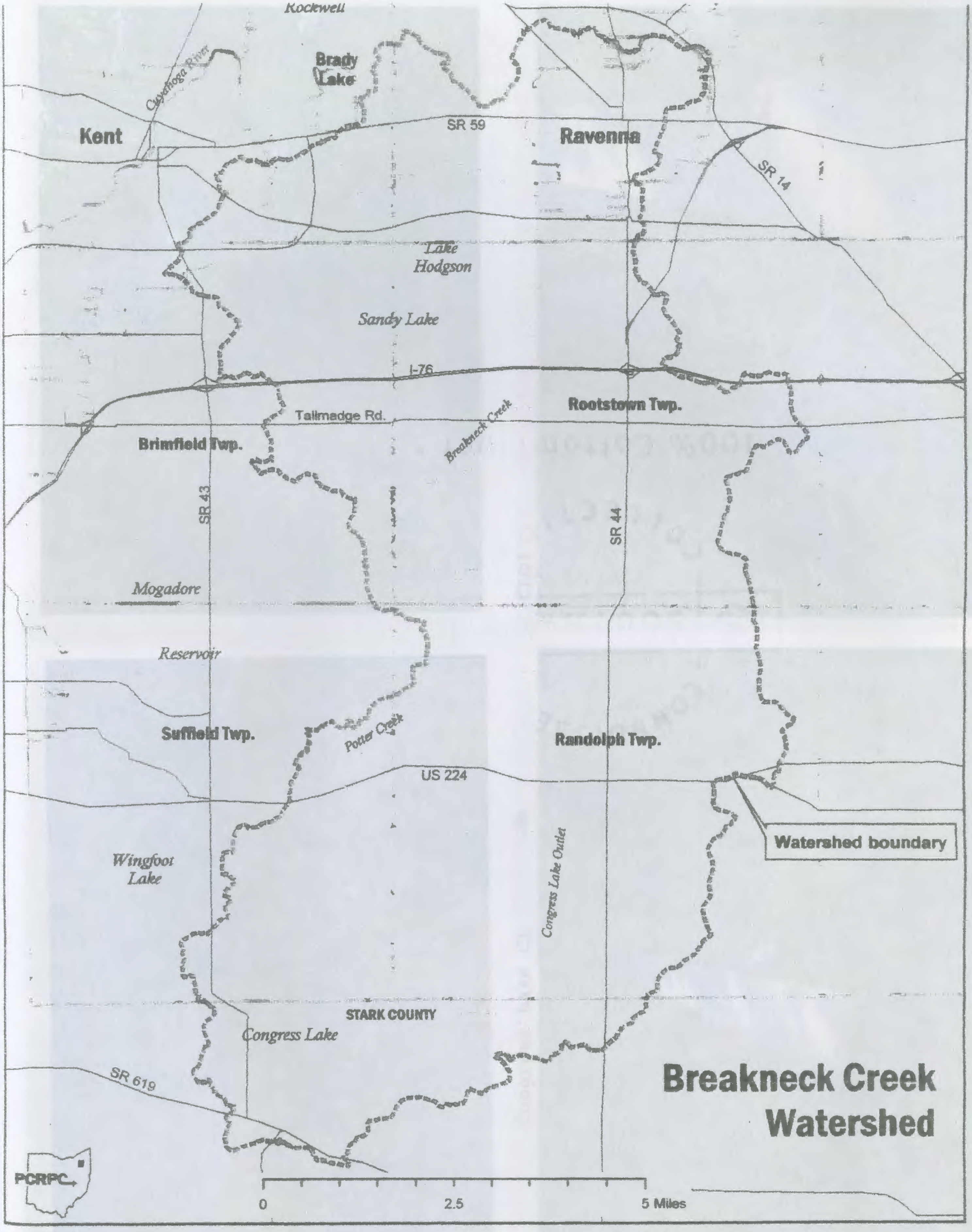
Land Use within the

Legend: Blue = Water
Yellow = Agriculture
Red = Urban and
Tan = Barren
Bright Green = Wetlands
Dark Green = Forest

Land Use within the Congress Lake Outlet Study Area

Legend Blue = Water
Yellow = Agriculture or Grass
Red = Urban and Roads
Tan = Barren
Bright Green = Wetlands
Dark Green = Forest





Breakneck Creek Watershed

Congress Lake CL

CL01

CL02

CL03

CL04

CL05


CL06


Sediment