Evaluation of a Channelized Stream Using Water Quality and Macroinvertebrate Studies

by

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Abstract

Water is the human population’s most scarce resource. Human impacts such as urbanization, agriculture and channelization have an effect on water and stream quality. Channelization, the straightening of streams to better fit human land use needs, was a common practice in northeast Ohio. While the channelization of streams is useful for agriculture and for other purposes, it is a major stress for natural aquatic systems. A 4 km-long (~2.5 miles) portion of Snyder Ditch, Orwell, NE Ohio, was channelized in the early 1900s for agricultural drainage. This study evaluates stream quality of this channelized system utilizing water chemistry, macroinvertebrate diversity studies and stream habitat assessment. Stream quality was compared against Ohio EPA stream use designation of warmwater habitat for three sampling dates: May, August and October 2013.

It was initially hypothesized that stream quality would not reach warmwater habitat standards, as designated by the Ohio EPA. The results surpassed the original expectation of the stream; however, still did not reach warmwater habitat designation criteria. Dissolved oxygen levels were near the required 5 mg/L with most of the sampling dates having low levels of nutrients (nitrate, phosphate and ammonia). There was good overall diversity and density of macroinvertebrates and a higher than anticipated number of pollution sensitive taxa. The largest difference in stream quality was due to the stream habitat or lack thereof. Areas that contained some stream sinuosity, better substrate or more diverse riparian area had better density and diversity of macroinvertebrates. Therefore, with some habitat alterations or restoration, the stream quality has the potential to improve to warmwater criteria. This work, in addition to other ongoing projects, may lead to a better understanding of environmental parameters at this site, which would help land-owners develop better strategies for land management and restoration.

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A special thanks goes to the Western Reserve Land Conservancy for their mission and for coming to us with a concern for the impact Snyder Ditch could have downstream and wanting to fix the impaired stream. Last, but, not least thank you to those at YSU, and other family and friends for the listening ear, support and guidance throughout this experience!

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Chapter 1 Introduction

1.0 Introduction

Human impact is a big concern when it comes to stream quality. There are multiple anthropogenic sources of stress on a stream, including urbanization, logging, agriculture, pollution and overuse of the water resources. These activities reduce water quality by increasing inputs of sediment, nutrients, and pollutants and by disrupting water flow, all of which stress the biological stream community (Hrodey et al. 2009). Channelization is another way humans severely impact stream quality. Channelization is when streams are straightened or changed in order to better fit our land use needs. Channelization of streams can be helpful when new construction projects occur or for agricultural purposes; however, it too often causes stress for the aquatic life and changes the dynamics of the stream's nutrient transport (Hrodey et al. 2009).

Many studies have looked at individual aspects of stream quality by using either chemical methods, macroinvertebrate methods, or others; however, few include multiple parameters. Although chemical parameters can change over daily to seasonal timescales, it is important to find the range of these chemical parameters to help determine which has the greatest influence on water quality and macroinvertebrate diversity. Parameters that are commonly investigated include: pH, biological oxygen demand, dissolved oxygen, nitrate and nitrite concentrations, ammonium concentrations, total solids, fluoride levels, total hardness, fecal coliforms and *E-coli* occurrence (Akoto et al. 2009, Brisbois et al. 2008).

Macroinvertebrate studies provide a long-term indication of stream quality, whereas chemical parameters provide a snapshot of water quality. Macroinvertebrates have been used by the Ohio EPA for many years to assess stream health and water quality (OH EPA 2013). Macroinvertebrates are small animals that lack a backbone and can be seen with the naked eye (usually retained in a 0.25mm mesh) (OH EPA 2013). Aquatic macroinvertebrates include insects (many larva and pupa forms), crustaceans, mollusk, arachnids and annelids. These organisms live in or on the water for all or part of their life cycle and they are an important part of the aquatic food web providing a food source to larger animals such as fish and birds. Macroinvertebrates are sensitive to different chemical and physical conditions. As the stream water quality varies due to changes in land use, effluent discharge, dumping or other activities, the macroinvertebrate diversity and community structure will also change (OH EPA 2013). Furthermore, because they are unable to move great distances, the macroinvertebrate community structure is directly related to localized conditions, making them excellent indicators of local water quality conditions. For example, some macroinvertebrates, such as stoneflies and mayflies, are very pollution sensitive and will not be readily found in low quality waters. Other macroinvertebrates, such as aquatic worms and midge larva, are very pollution tolerant and are found across the spectrum of water quality types. Additionally, there are some macroinvertebrates that are somewhat pollution tolerant (e.g. scuds and dragonfly larva) (OH EPA 2013).

The Qualitative Habitat Evaluation Index (QHEI) is a method of evaluating habitat based on a scoring system for a site along a stream. This scoring system is the best indicator of the quality of macroinvertebrate substrate or habitat. A lower abundance of benthic macroinvertebrate taxa is correlated with increased bank erosion and channelization associated with anthropogenic disturbance and lower QHEI scores (Hrodey et al. 2009).

This study investigates stream quality using water chemistry, macroinvertebrate and habitat methods along a 4 km-long (~2.5 miles) portion of Snyder Ditch, within the Western Reserve Land Conservancy Grand Valley site, which has been channelized for agricultural purposes. An additional objective of the research is to provide suggestions to the land-owners on what the best strategies are in order to restore the land based on the data received from the study. This is the first of many analyses that may be needed in order to determine the correct course of action.

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1.1 Study Site

The Western Reserve Land Conservancy (WRLC) is a nonprofit conservation agency covering much of northern Ohio and is dedicated to preserving Ohio's natural resources. According to its mission statement WRLC, "seeks to preserve the scenic beauty, rural character, and natural resources of northern Ohio" (WRLC 2010). The Grand Valley Ranch is one of the properties owned by the WRLC and plans are currently underway to re-naturalize some of its disturbed lands. A major feature of this site is Snyder Ditch, a stream that was channelized more than 100 years ago to create more area for the agricultural land use, which is still maintained today (Figure 1.0). It resulted in the draining of an organic rich bog that once covered the area. The main focus of ongoing stream research undertaken by Youngstown State University and the WRLC is a 4 km-long (~2.5 miles) section of the 10 km-long modified stream. This segment of straight channel is surrounded mainly by agricultural fields (30%) and forest/wooded areas (28%) (Figure 1.1). The remainder of the land-cover surrounding the channel consists of about 20% wetlands and about 22% shrub and pasture areas (Figure 1.2).

For stream channelization to benefit human land use, the area surrounding the channelized stream needs to have little change in elevation, as flat terrain better accommodates housing developments and farming. Elevation changes across the sub-watershed (Figure 1.3) indicate that the greatest change in elevation is 40 meters in the far northeast corner of the sub-watershed while most of the area is topographically less pronounced with less than 8 m of change. The terrain immediately surrounding Snyder Ditch is characterized by very low-gradient slopes and flatland, indicated by small changes in SL-factor (Figure 1.4). The SL-factor is the topographical factor determined by the gradient or slope steepness and length of the slope, two values used in the universal soil loss equation (USLE; Wischmeier and Smith, 1978) to estimate erosion. The values presented in Figure 1.4 were determined with the use of GIS (Arc GIS 10.1, Stull and Mattheus, 2014). The greater the SL factor, the greater potential for soil erosion and sediment contributions to the ditch, as inferred by the USLE.

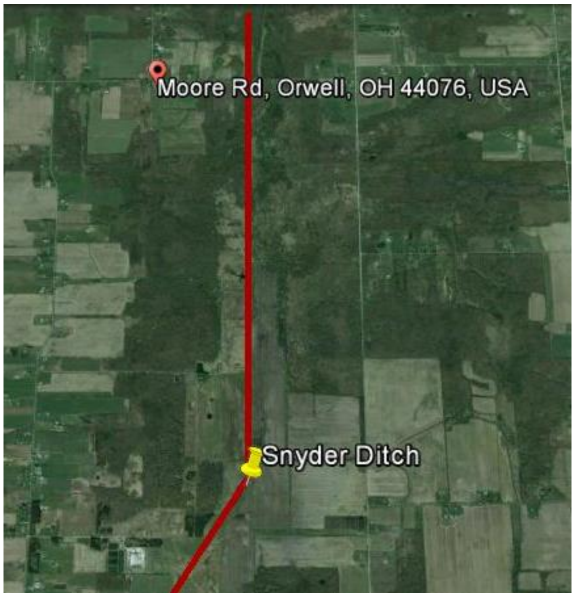

Figure 1.0 Snyder Ditch in Orwell, Ohio (Google Earth 7.1.2.2041).

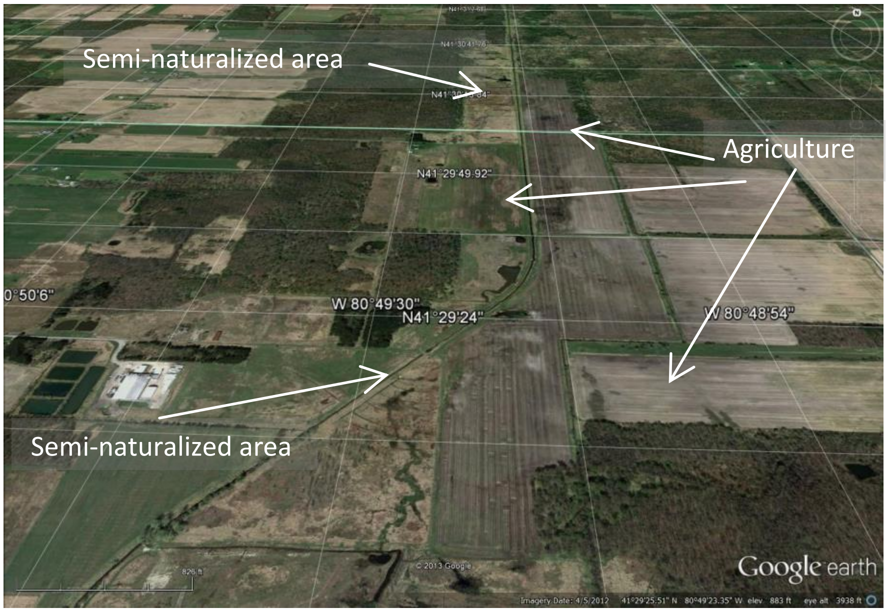

Figure 1.1 Channelized Snyder Ditch and land use areas, most notably agricultural fields (Google Earth 7.1.2.2041).

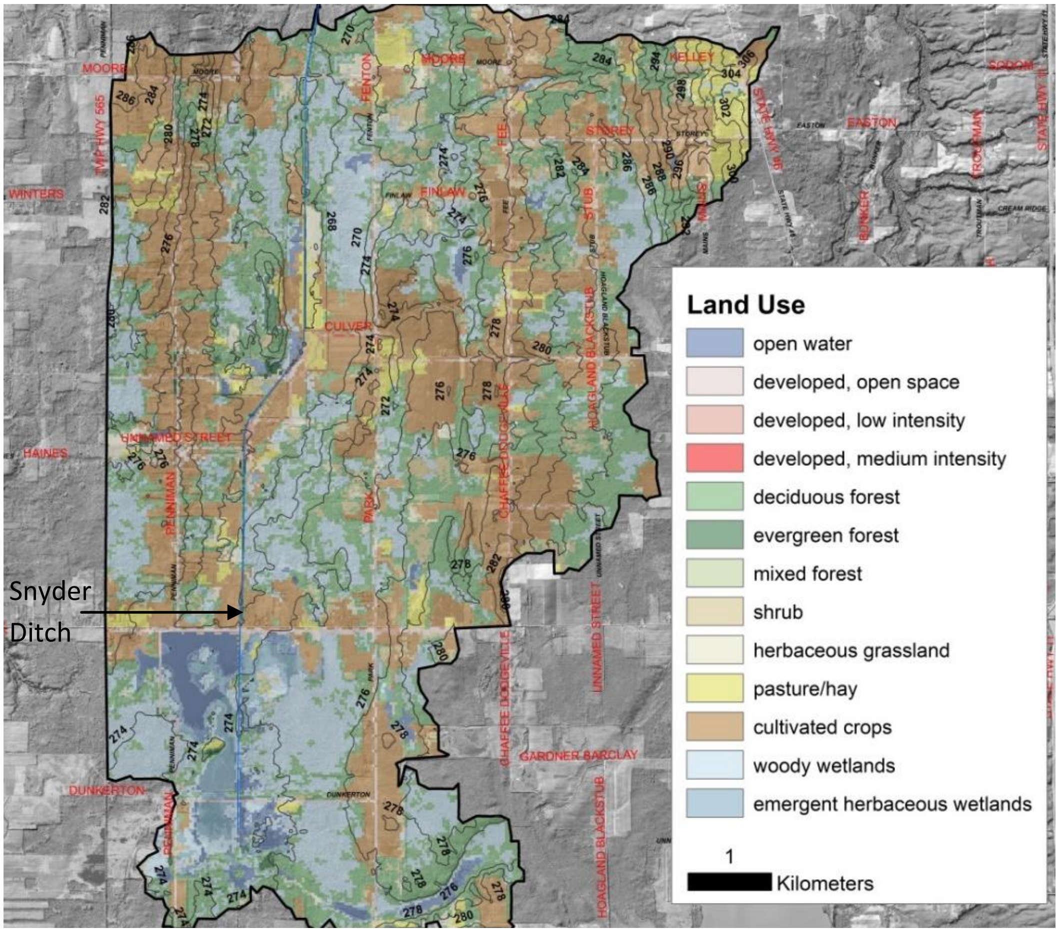

Figure 1.2 ArcGIS map showing watershed land use designations around Snyder Ditch (Stull and Mattheus 2014, ArcGIS 10.1).

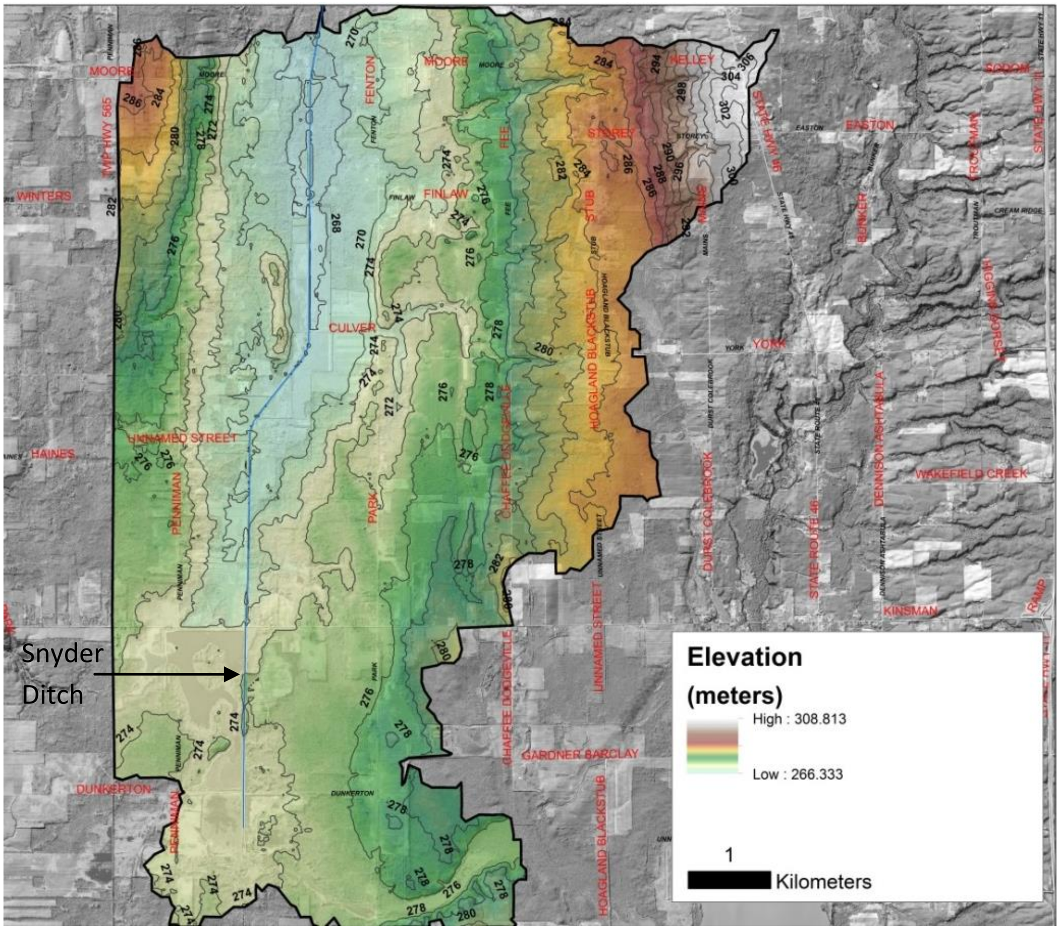

Figure 1.3 ArcGIS-based elevation map showing the flat areas alongside the channel in light blue and green colors; higher gradient upland regions distal to the channel are in yellows-browns (Stull and Mattheus 2014, ArcGIS 10.1).

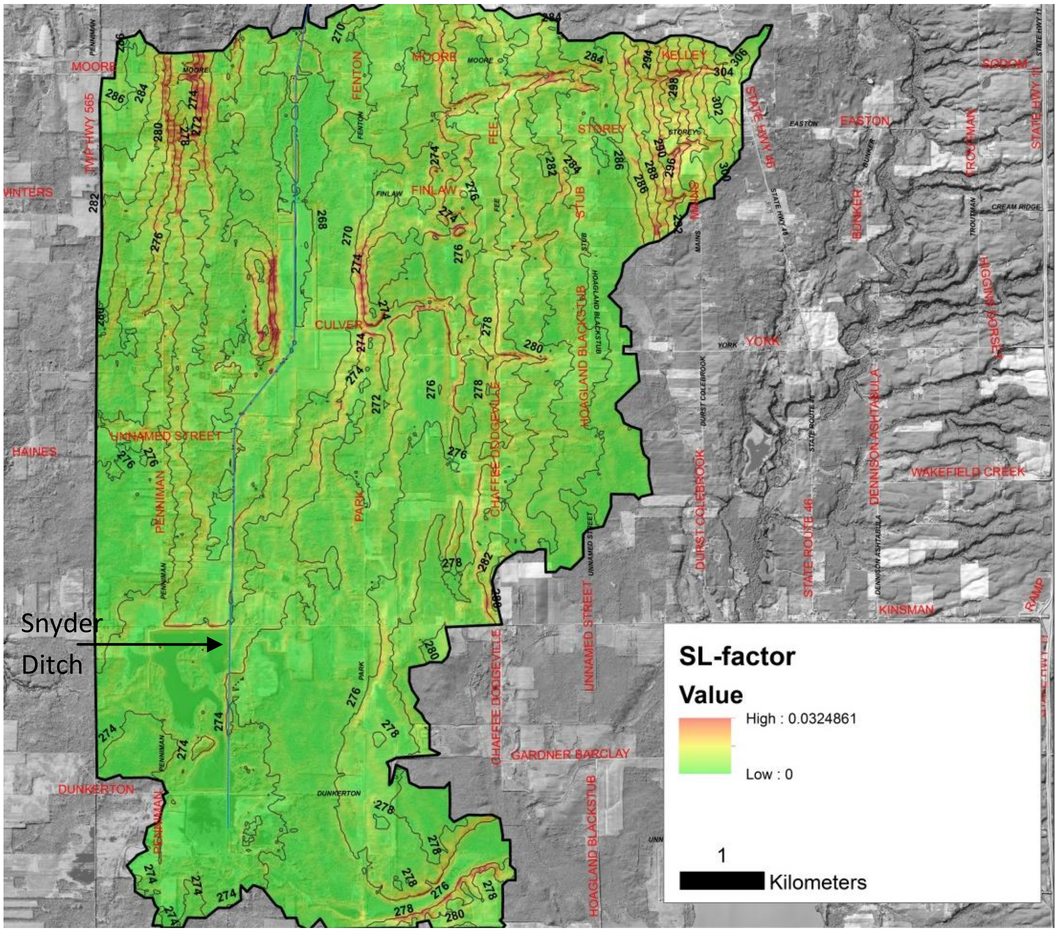

Figure 1.4 ArcGIS map showing the SL-factor for the terrain surrounding Snyder Ditch. The red color values indicate high values while green colors indicate low values; the SL factor is a combined factor that takes slope steepness and length into account (Stull and Mattheus 2014, ArcGIS 10.1).

Snyder Ditch is part of the Upper Grand River Sub-Watershed which is a 60 km^2 (23 mi^2) watershed, located in northeast Ohio (Figure 1.5). The watershed flows through four counties including Ashtabula, Geauga, Portage and Trumbull. Snyder Ditch originates near North Bloomfield and runs into Rock Creek which drains into the Grand River then into Lake Erie.

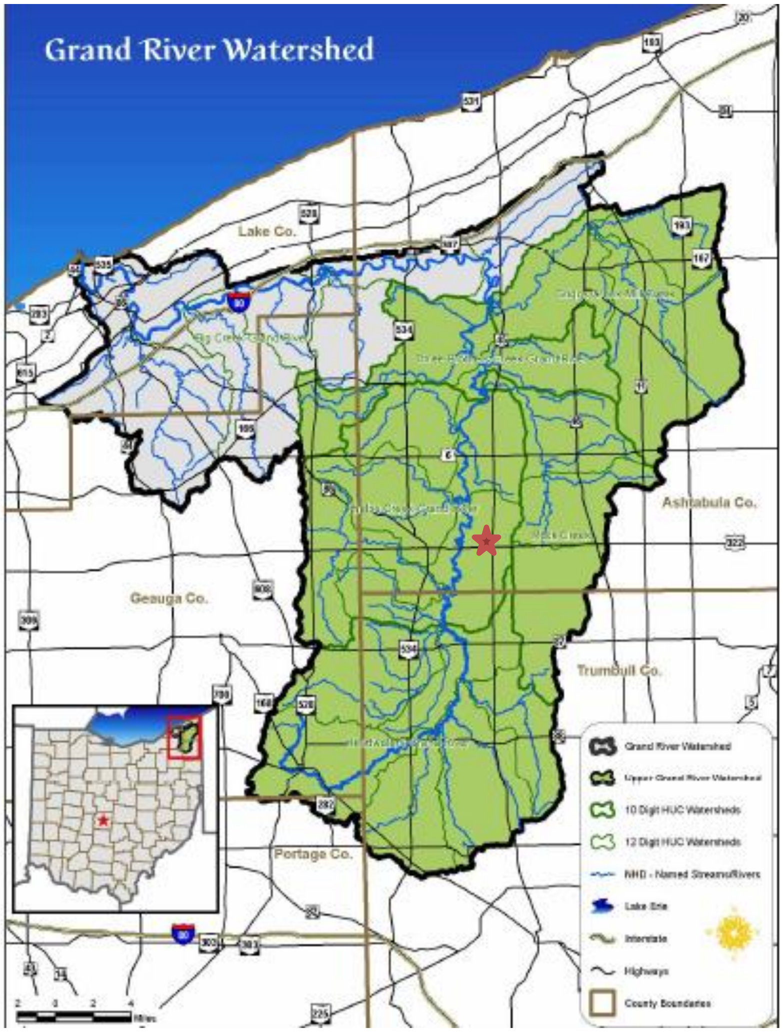

Figure 1.5 Location of the Grand River Watershed in northeast Ohio where the research site is located (UGRWAP). The red star in the middle indicates the approximate location of Snyder Ditch in Orwell, Ohio.

1.2 Thesis Hypothesis

It is hypothesized that the 4 km-long (~2.5 miles) channelized section of Snyder Ditch located near Orwell, Ohio, will have low stream quality due to several factors including sediment composition, quality of habitat, biological composition and nutrient loading. Furthermore, the water quality will not meet warmwater standards as outlined by Ohio EPA (OH EPA 2011). Secondly, it is hypothesized that the type of land use (agriculture or semi-naturalized areas) will result in different stream qualities with agricultural areas having lower stream quality than semi-naturalized areas.

1.2.0 Thesis Objectives

1. Successfully establish the water quality of Snyder Ditch and determine if warmwater quality is met.
2. Assess what effects sediment composition, habitat, nutrients or other water chemistry parameters have on stream quality.
3. Evaluate how land use has affected the stream quality.
4. Ascertain potential wetland or stream restoration success based on preliminary data.

Chapter 2 Literature Review

2.0 Channelization Effects

Channelized streams create many problems, including habitat loss for the biota living in the stream and a lack of riparian zone or wetlands surrounding the stream. This lack of high quality riparian zone or wetlands can result in increased pollution loading (i.e. nutrients, sediment, pesticides, oil and acid mine drainage) to the stream (Smiley et al. 2010). In a case study from central Ohio, a channelized stream was found to have higher ammonia, nitrate and nitrite levels than what was found in associated natural streams (Smiley et al. 2010). These increased nutrients can cause algal blooms and a disruption in macroinvertebrate community structure.

2.1 Land Use Effects

Healthy and well-functioning streams will have stable dimensions (i.e. pattern and profile), be connected to floodplains, have wide and vegetated riparian corridors, which provide stream cover, and foster aquatic habitats (such as gravel substrates) (FISRWG 1998). Land use has been shown to affect stream water quality. Factors such as system size, elevation, percent sand in soils, riparian condition, habitat quality, stream water nitrates and benthic macroinvertebrates and fish can be altered depending on the land use (Maloney et al. 2010). The land use impacts on warmwater stream quality showed that agricultural land use was the most impactful to any stream water quality tests (Hrodey et al. 2009). This is due to the multiple factors impacted that influence stream quality. Increased nutrient and sediment inputs from farming degrade water quality. Additionally, stream channelization leads to loss of riparian buffer zones and decreased woody debris loading; furthermore, it is linked to temperature increases, which affects other factors such as dissolved oxygen levels (Hrodey et al. 2009).

Stream macroinvertebrates respond negatively to increased sedimentation and habitat loss, which are associated with agriculture and stream channelization. Agricultural land use generally creates a homogenous macroinvertebrate community composition characterized by low diversity of taxa (Hrodey et al. 2009). Chironomids, which are relatively pollution tolerant, are typically the most abundant dipteran taxa found in agricultural streams in the Midwest United States (Smiley et al. 2010).

2.2 Use of Macroinvertebrates in Determining Water and Habitat Quality

Macroinvertebrates in channelized streams have low estimates of productivity, diversity and density. Poulton et al. (2001) utilized multiple methods of macroinvertebrate collection for the study of stream quality. The methods that were evaluated included kick net method, rock basket method and ponar sampling. Kick net sampling is when a net is positioned downstream while slightly upstream the substrate is “kicked” to release the macroinvertebrates into the water column which are then trapped by the kick net. The advantages of this particular method are that it is fairly easy to collect samples, kick nets are fairly inexpensive and one can collect large amounts of data for comparison (OH EPA 2013). Rock basket sampling places large gravel in a cage that is left at the bottom of a stream for six to eight weeks, allowing for colonization of the rock basket. A benefit of this method is that site comparisons are made easier by a lack in substrate variance provided by the rock baskets. A ponar sampler is a bottom sampler that is able to retrieve substrate samples that range from clay to gravel in particle size (OH EPA 2013). The research by Poulton et al. (2001) determined that the method of sampling that gave the most precise results was the kick net method. One of the outcomes of this research was that using multiple methods of sampling and using upstream and downstream comparisons was the best way to determine the effects of anthropogenic sources on streams (Poulton 2001).

2.3 Macroinvertebrates and Restoration Techniques

Stream restoration refers to altering a stream that has been previously impacted by anthropogenic activity to improve its ecologic function and geomorphic structure. The anthropogenic impact can include inputs of pollution (including sediment), channelization or other changes in structure (i.e. straightening and bank fortification, etc.), emplacement of rip-rap or other debris, among others. The restoration can be as simple as removing debris to relocating the entire stream channel to mimic its former pathway. Pre and post monitoring is done in order to determine the success of any restoration effort.

There are many types of restoration; however, natural channel design has become a main focus over other types of restoration due to its lower impact on the stream and therefore a greater chance of recovery (Noble 2013). Natural channel design includes physical enhancement, habitat enhancement, sediment load reduction/management, pollutant reduction, or a combination thereof based on the project goals. Restoration project success is based on improvements documented in the post-construction data (2-10 years after construction) as compared to pre-construction data. Greater biological diversity, habitat heterogeneity, increased carrying capacity, increased taxa and return of locally extirpated species could all be measures of success (Noble 2013).

In a case study by Herbst and Kane (2004), macroinvertebrates were used in the pre and post monitoring data before and after restoration as they are sensitive to different chemical and physical conditions. The purpose of the study was to establish a biological baseline and reference conditions for a restoration project on lower Bagley Valley Creek in Alpine County, California (Herbst and Kane 2004). The channel includes a small, perennial stream. The stream was eroded and incised by flood events and slope failure following recent livestock grazing operations and the construction of irrigation ditches and roads beginning in the 19th century. Completed in 2001, the restoration project was to reconfigure the geomorphic structure of a section of the stream.

They had two restoration goals including: restoring the connectivity of the stream with its known floodplain and stopping the erosion of gullies (Herbst and Kane 2004).

The restoration was seen as a success due to the information found using macroinvertebrate data (Herbst and Kane 2004). Taxa richness went from 45-54 taxa identified pre-construction to about 49-78 taxa post-construction. EPT stands for Ephemeroptera**,** Plecoptera, and Trichoptera (mayfly, stonefly and caddisfly, respectively). More than twice the number of EPT genera was found at the restored site. These are some of the least pollution tolerant species and to find more of them after a restoration project means that the water and/or substrate quality did improve. Two years after the restoration project, overall invertebrate richness and diversity increased, dominance of one single species decreased, EPT diversity increased, and the diversity, abundance and frequency of larger size macroinvertebrates increased. This is an indicator of better water quality because larger invertebrates tend to live longer in the water, and therefore, require better water, substrate and stream quality (Herbst and Kane 2004). Long term studies are needed to completely evaluate the success of ecological restoration.

Generally it is believed that macroinvertebrate diversity and community structure change quickly after a disturbance or restoration activity. However, Maloney (2010) found that macroinvertebrate habitat was slow to recover in a small stream. This could give indication that macroinvertebrates may not recover as quickly as researchers might hope. Thus, a long term evaluation of streams before and after a disturbance or restoration is truly needed to determine stream health (Maloney 2010).

Longing and Haggard (2009) performed a biological assessment on the ecological impact that restoration can have. The sampling occurred in one year period in October 2006 and April and October 2007 (Longing and Haggard 2009). The lack of sampling in the summer could be a detriment, since macroinvertebrates are best sampled in the summer (OH EPA 2013).

Chapter 3 Methodology

3.0 Sampling Sites and Conditions

There were seven sample sites referred to as site 0, site 1, site 2, site 3, site 4, site 5, and site 6. Site 0 is the southernmost sampling point (furthest upstream) and site 6 is the northernmost sampling point (furthest downstream). Site 5 is not part of the main stream channel; it is a channel that enters Snyder Ditch from the east, on the north side of the agricultural fields. Site 4 is the mouth of this side stream coming into the channel. Refer to Figure 3.0 for a map of the sampling points and to Table 3.0 for a list of the sampling sites, the associated UTM and a site description.

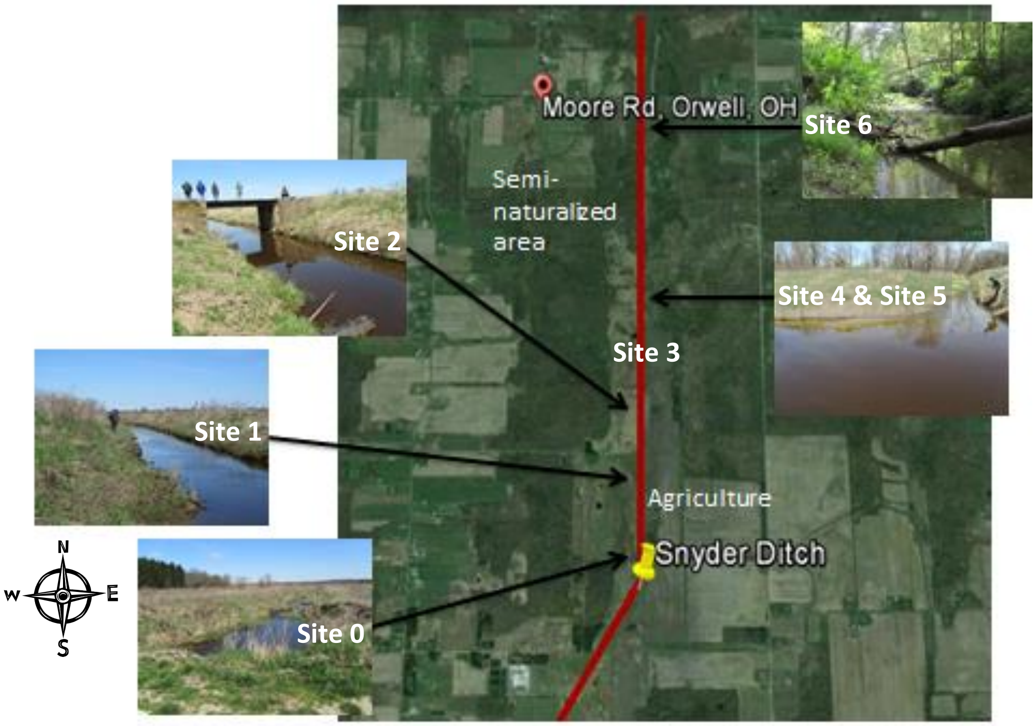

Figure 3.0 A map of Snyder Ditch with pictures of five of the sampling locations (from south to north): site 0, site 1, site 2, site 4, site 5 and site 6 (Google Earth 7.1.2.2041) (Inset photographs courtesy of FP Armstrong).

Table 3.0 Site numbers, UTM locations, and site descriptions for each sampling location.

Site	UTM		Site Description
Site 0	N 0514715	E 4592827	The southernmost sampling point; it is surrounded by agricultural fields with a very small riparian zone. It has a rocky substrate and small riffles which are conducive to aquatic life within a stream. Classified for this study as semi-naturalized.
Site 1	N 0514881	E 4596021	The site is completely surrounded by agriculture with no riparian zone. The substrate is sandy here and the stream is slower moving than at site 0 with no riffles.
Site 2	N 0514961	E 4594010	The site is directly under a bridge going over the channel. This site is completely surrounded by agricultural fields with no riparian zone. The substrate here can be described as muck.
Site 3	N 0514968	E 4594375	This site is just downstream of site 2 and is very similar in nature to site 2. At times (in summer) this area was completely covered in aquatic plants. The substrate here is made up of thicker muck than site 2.
Site 4	N 0514973	E 4594880	This is the mouth of site 5, a “side stream” that comes into the channel. The site has influence from the secondary stream and has a sandy substrate.
Site 5	N 0515004	E 4594887	The side stream site is a drainage area from the agricultural area. Surprisingly, this area has a small riparian zone and a mix of sand and clay for substrate.
Site 6	N 0514988	E 4596434	This sample was taken from the Moore Road bridge in Orwell, Ohio. This is the most natural area of the study site with no adjacent agricultural influence. This area has gravel substrate, good riffles and stronger flow than any other sample site in the stream. It is classified for this study as semi-naturalized

Sampling occurred on May 23, 2013, August 25, 2013, September 14, 2013 (The site was too overgrown to get to some samples in August, so the extra sampling day was added in September to get the remaining sites from the missed August sampling) and October 26, 2013. Water samples and macroinvertebrate samples were taken during each sampling day. The H-Ds were placed in sites that had the required 0.3 ft/sec flow rate (OH EPA 2013) (sites 0, 5 and 6) on

September 14 and collected on October 26. The QHEI scores and sediment samples were taken during the August sampling trip.

3.1 Water Quality Sampling

Multiple water samples were taken from the stream at locations defined by the types of land use (agriculture and semi-naturalized). Water samples were collected in screw cap plastic bottles and transported in an ice cooler to the Environmental Science research facilities at Youngstown State University for analysis of water quality parameters.

The water quality parameters that were analyzed in each water sample included specific conductivity, dissolved oxygen, pH, stream flow, temperature, biological oxygen demand, chemical oxygen demand, total and fecal bacteria, hardness, ammonia, nitrate, soluble reactive phosphorus and soluble metals (aluminum, arsenic, barium, calcium, iron, lead, magnesium, manganese, potassium and sodium). The solids portion of the data (i.e. sediment loads) was analyzed by Hannah Stull (Youngstown State University, M.S. candidate in Geological and Environmental Science) conducting a study on the sediment transport within Snyder Ditch during the same time frame as this research.

Conductivity is the measure of the ability of water to pass an electrical current. Conductivity in water is affected by inorganic dissolved solids such as nitrate, phosphate, sodium or aluminum ions. Conductivity is affected by temperature: the warmer the water, the higher the conductivity. Conductivity is measured in micro Siemens per centimeter (µS/cm). Distilled water has a conductivity range of 0.5 to 3 µS/cm. The conductivity of rivers in the United States generally ranges from 50 to 1500 µS/cm (US EPA 2012b).

Dissolved oxygen is very important for aquatic organisms and is a measure of the amount of oxygen within the stream water. Macroinvertebrates need plentiful dissolved oxygen to survive. A dissolved oxygen reading at 5 mg/L or higher is usually an indicator of good water quality (OH EPA 2011). Dissolved oxygen is also inversely affected by temperature; the higher the temperature, the less dissolved oxygen the water can hold.

Temperature has an effect on macroinvertebrates as well. Since macroinvertebrates go through much of their life cycle in the summer, they survive best in warm temperatures. There is a point at which it is too hot for them to survive; this level depends on the aquatic organism. The problem with channelized streams is the lack of riparian zone and therefore in stream cover. The lack of cover causes more direct sunlight and a much higher than normal temperature, detrimental conditions to aquatic life. Temperature, specific conductivity and dissolved oxygen were measured in the field using an YSI 80 meter.

The preferred pH level for macroinvertebrates to thrive is between 6.5-7.5. pH was measured in stream using a portable Oakton pH meter. Stream flow was measured in the field using a JDC Flowwatch flow meter. Flow was taken at each macroinvertebrate sampling site and recorded in meters/second. With the exception of water quality, flow speed tends to have the most effect on the quality of macroinvertebrates found in the stream (OH EPA 2013).

The remaining parameters were analyzed using the tests given in the 1998 20th Edition of Standard Methods for the Examination of Water and Wastewater. Further details including the standard method used, the holding time, the preservation method for each test and any deviation from the standard methods can be found in Table 3.1. Table 3.2 outlines the reason behind the need to test for each parameter. The results of each test were compared to the Ohio Environmental Protection Agency’s chemical parameters for warm water quality habitat (Table 3.3).

Table 3.1 The water chemical parameter tested for along with the method that was used to analyze the specific parameter, the holding time of the samples before testing had to occur and the preservation method of the sample. Also shown are deviations from the standard method, if any existed.

Parameter Tested	**Specific Test Used**	**Holding Time**	**Preservative**	**Deviations from Standard Method**
Coliform-Total	9222 B. Standard Total Coliform Membrane Filter	6 hours	Cool, 4°C	No deviations
Coliform-Fecal	9222 D. Fecal Coliform Membrane Filter	6 hours	Cool, 4°C	No deviations
Biological Oxygen Demand	5210 B. 5-day BOD test	48 hours	Cool, 4°C	No deviations
Soluble Reactive Phosphorus	4500-P E. Ascorbic Acid Method	48 hours	Cool, 4°C H_2SO_4 to pH < 2	No deviations
Ammonia	4500-NH_3 D. Phenate Method	28 days	Cool, 4°C H_2SO_4 to pH < 2	Used 15 mL sample: 1 mL EDTA Reagent, 2 mL phenol-nitroprusside, 4 mL buffered hypochlorite in 25 mL flask
Chemical Oxygen Demand	5220 D. Closed Reflux, Colorimetric Method	28 days	Cool, 4°C H_2SO_4 to pH < 2	No deviations
Nitrate	4500-NO_3^- E. Cadmium Reduction Method 4500-NO_3^- D. Nitrate Electrode	28 days	Cool, 4°C H_2SO_4 to pH < 2	Used Cadmium Reduction method for May samples, Nitrate Electrode method for August and October samples
Hardness	2340 C. EDTA Titrimetric Method	6 months	HNO_3 to pH < 2	No deviations
Soluble Metals	3120 B. Inductively Coupled Plasma (ICP) Method	6 months	HNO_3 to pH < 2	No deviations

Table 3.2 The parameter tested and the importance it holds on aquatic life.

Parameter Tested	Reason for Testing
Coliform	This is a measure of both total and fecal bacteria in the water. This would be used to determine if there was pollution from bacteria that could potentially cause diseases. A potential cause of coliform bacteria would be manure.
Biological Oxygen Demand	Biological Oxygen Demand (BOD) is the amount of oxygen that bacteria take from water when they oxidize organic matter. This organic matter comes from natural sources or pollution. Measuring the BOD is a means of determining the degree of water pollution. If water of a high BOD value flows into a river, the bacteria in the river will oxidize the organic matter, consuming the oxygen in the water faster than it dissolves back in from the air. This causes harm to the aquatic life due to lack of oxygen (WQP no date).
Soluble Reactive Phosphorus	Excessive phosphorus has the potential to cause eutrophication in a stream, depleting oxygen and causing harm to aquatic life.
Ammonia	Ammonia is very harmful because it is so highly toxic to aquatic life. It can be found in fish waste and agricultural fertilizers.
Chemical Oxygen Demand	Chemical Oxygen Demand is used to indirectly measure the organic compounds in water. It is a test that measures the oxygen of a sample that is susceptible to oxidation (WQP no date). Therefore, it determines if there are any organic pollutants in the water such as pesticides.
Nitrate	Nitrate is naturally in waters. It becomes a problem in huge quantities; however, it has been seen to have little to no effect even in larger quantities (WQP no date). The main concern with excess nitrate in the water is eutrophication though, phosphorus is the limiting growth factor in aquatic plants.
Hardness	Hardness is a measure of ions in the water and can be telling only if other tests are run. Hard water is not necessarily a pollution problem, unless a decline in health of aquatic organisms is observed.
Soluble Metals	Metals have a range from non-toxic and even beneficial to extremely toxic.

Table 3.3 The parameter tested and the range for warmwater habitat as outlined by the Ohio EPA (OH EPA 2011).

Parameter Tested	**Range for warmwater habitat as outlined by the Ohio EPA**
Specific Conductivity	50 to 1500 µS/m
pH	Between 6.5-7.5
Dissolved Oxygen	> 5.0 mg/L
Coliform	May to October: Not more than 1 positive out of 5 samples within a 30 day period. November to April: Not more than 2 positive out of 5 samples within a 30 day period
Biological Oxygen Demand	4-10 mg/L is considered good quality >15 mg/L is of very high concern
Soluble Reactive Phosphorus	Total Phosphorus shall be limited to the extent necessary to prevent nuisance growths of algae, weeds, and slimes that result in a violation of the water quality criteria. Total Phosphorus should not exceed 0.05 mg/L in a stream at a point where it enters a lake or reservoir. Total Phosphorus should not exceed 0.1 mg/L in streams that do not discharge directly into lakes or reservoirs. Levels between 0.03-0.1 mg/L can trigger an algae bloom.
Ammonia	pH<7.8: 13.0 mg/L pH>7.8: 8.0 mg/L pH>8.2: 5.0 mg/L
Nitrate	The range in natural waters is between 0.9 to 3.15 mg/L In unpolluted waters, less than 4.0 mg/L
Hardness	0-75 mg/L Soft 75-150 mg/L Moderately Hard 150-300 mg/L Hard 300 up mg/L Very Hard
Soluble Metals	See results and discussion sections for more information

3.2 Macroinvertebrate Sampling

Macroinvertebrates were collected by multiple methods depending on water flow, depth, substrate type and time of year. The methods included Hester-Dendy (H-D) (a plate sampler), surber sampling, Ponar sampling and Ekman sampling. All macroinvertebrate samples were preserved with alcohol in the field or kept in a cooler before transport back to Youngstown State University to be identified and compared to the OH EPA Invertebrate Community Index (ICI) or other diversity measures (OH EPA 2011).

H-D samplers are used as a place for the macroinvertebrates to live, this makes the substrate type normalized throughout the stream. The H-D is constructed of 1/8 inch tempered hardboard cut into 3 inch square plates and 1 inch square spacers. A total of eight plates and twelve spacers are used for each sampler. The total surface area of the sampler is 1 square foot. H-Ds require a stream flow rate of 0.3 ft/sec or higher to have adequate water flow for macroinvertebrate habitat. The sampler goes into the stream for a six week period beginning no earlier than June 15 and ending no later than September 30 (OH EPA 2013). Therefore other sampling methods (surber, Ponar and Ekman) were used to collect samples intermediately.

A surber sampler is a 900 cm^2 frame with a 500 µm mesh net attached to the back. The frame is placed facing downstream and the area within the frame is agitated allowing macroinvertebrates to pass through and get caught in the net. Ideally, this sampler is placed in rocky substrate in the center of a riffle and is restricted to a depth of no more than 0.3 m. Three replicates are taken at each site where the surber can be used (US EPA 2012c). The surber sampler is semi-quantitative and is similar to the kick net method in that it uses similar mesh size net and agitation of the substrate to release the organisms. The research done by Poulton et al. (2001) found kick netting resulted in the most diverse macroinvertebrates.

Ponar and Ekman samplers are two different versions of bottom grabbing samplers. These work well for types of substrate that macroinvertebrates may burrow into, such as clay and silt. These samplers are dropped into the substrate where they grab approximately a 225 cm^2 substrate sample.

Macroinvertebrate diversity was determined by taking the total area sampled (900 cm^2 for surber and 225 cm^2 for the ponar or Ekman) converted to m^2 by dividing the total area by 10,000cm^2/m^2; this was multiplied by the total number of organisms found in the samples to yield total macroinvertebrate density per m^2. Equation 3.0, 3.1 and 3.2 show three different calculations used to determine macroinvertebrate measures as an indicator of stream health.

Equation 3.0 % EPT Density within macroinvertebrate data

$$\%EPT = \frac{Number\ EPT\ organisms\ per\ m^2}{Family\ density\ per\ m^2} * 100$$

Equation 3.1 % EPT Family Richness within macroinvertebrate data

$$\%EPT = \frac{EPT\ family\ richness}{Overall\ family\ richness\ of\ Snyder\ Ditch} * 100$$

Equation 3.2 % Oligochaeta Density within macroinvertebrate data

$$\%Oligochaeta = \frac{Number\ Oligochaeta\ per\ m^2}{Family\ Density\ per\ m^2} * 100$$

3.3 Habitat Analysis

At each site, a GPS was used to mark the site being sampled for future reference and for GIS mapping (Stull and Mattheus, 2014). Each site was scored based on its habitat using the United States Environmental Protection Agency’s Qualitative Habitat Evaluation Index (QHEI). The form used for this scoring method can be found in the Appendix A.

Sediment samples were taken at each site via screw cap bottles and transported back to Youngstown State University for analysis. The samples were dried in an oven for 24 hours at

100°C and allowed to cool. They were then weighed and placed in a 500°C oven to measure organic matter through loss-on-ignition method (Equation 3.3). After cooling, they were weighed again to calculate the organic matter content in the sediment.

Equation 3.3 % loss-on-ignition to determine % sediment organic matter

$$\%LOI = \frac{(wt.at\ 105^{o}C) - (wt.at\ 500^{o}C) \times 100}{wt.at\ 105C^{o}}$$

Once the organic matter was removed, the dried sediments were sieved and analyzed for their particle-size distribution. Sediment particles smaller than 1 mm in size, having been removed using a sieve, were analyzed using a CILAS 1190 Laser Particle Size Analyzer. The Particle Size Analyzer cannot analyze anything over 1 mm, so, the samples were sieved through a 2 mm mesh and a 1 mm mesh. This holds significance as pollution sensitive macroinvertebrates tend to like bigger size particles for their habitat and feeding purposes (OH EPA 2013). The CILAS computes percentages for 100 size classes ranging from fine clay to coarse sand, which are tabulated and can be exported into Excel and/or other auxiliary programs. The percent clay/silt fractions of the sediment samples (<63 µm) were imported as a .txt file into ArcGIS 10.1 and gridded using the nearest neighbor algorithm of point interpolation for a visual display of the variance in channel-bottom fabric.

Chapter 4 Results

4.0 Water Quality Results

Water quality includes both on-site and laboratory analysis. All sampling dates fall within the low range of specific conductivity for warmwater habitat criteria (Figure 4.0). The specific conductivity ranged from 141 µS/m to 377 µS/m. Dissolved oxygen was near 5.0 mg/L during the May sampling date, which meets the warmwater quality habitat requirement (Figure 4.1). All other sampling dates showed readings exceeding 10 mg/L which may be due to errors. Readings of pH were all within neutral range (6.5-7.5) and some even became close to being very basic (pH 9-14) (Figure 4.2). Aquatic life prefers neutral pH, as levels too high or low could cause harm. Flow rates at site 0 and site 6 were visually higher than along the remainder of the stream channel, which was very slow moving (Figure 4.3). Temperature affects several water quality parameters including conductivity and dissolved oxygen. May and August had higher temperatures (15-23 °C) than October (6-7 °C) (Figure 4.4).

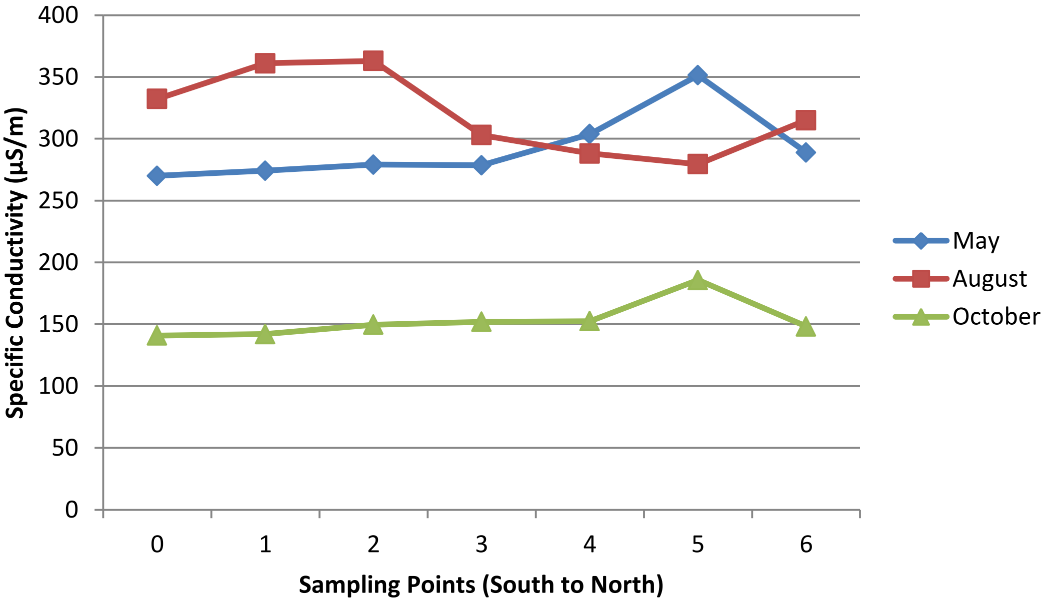

Figure 4.0 Specific Conductivity of each sampling site following the flow of water from the southernmost point (site 0) to the northernmost point (site 6) on each sampling day, measured in µS/m. Warmwater habitat range is expected to be between 50 to 1500 µS/m.

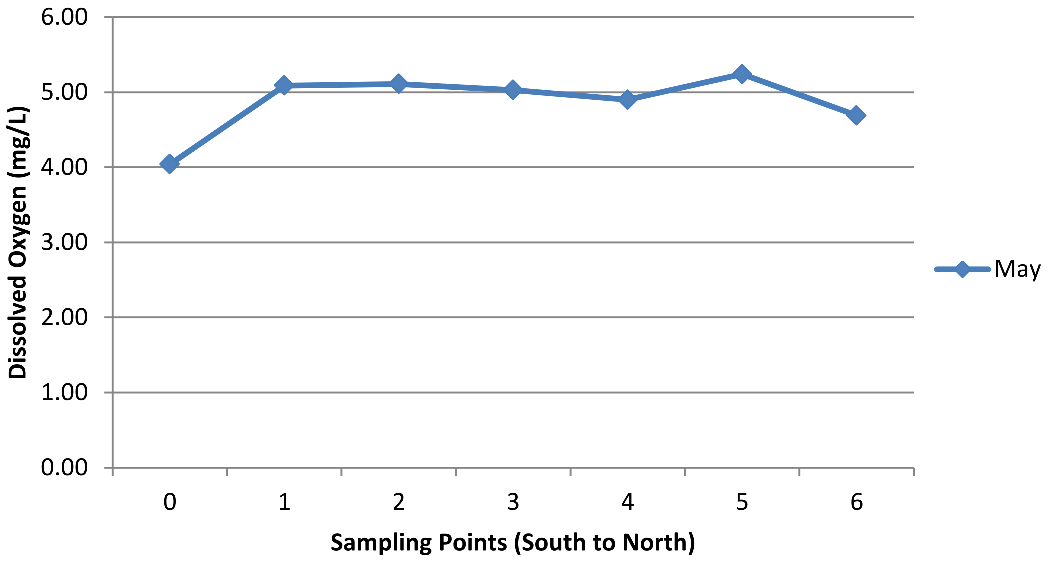

Figure 4.1 Dissolved Oxygen of each sampling site following the flow of water from the southernmost point (site 0) to the northernmost point (site 6) on each sampling day, measured in mg/L. Warmwater habitats require no less than 5.0 mg/L. August and October readings are not shown due to instrumentation or other problems resulting in erroneous readings.

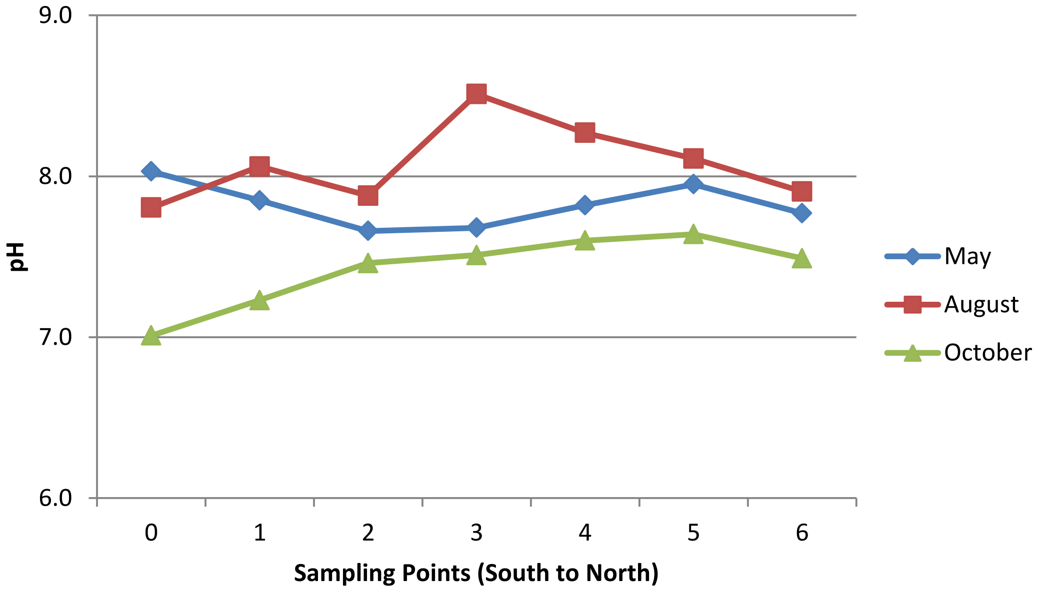

Figure 4.2 pH of each sampling site following the flow of water from the southernmost point (site 0) to the northernmost point (site 6) on each sampling day. Warmwater habitat requires a pH between 6.5 and 9.0.

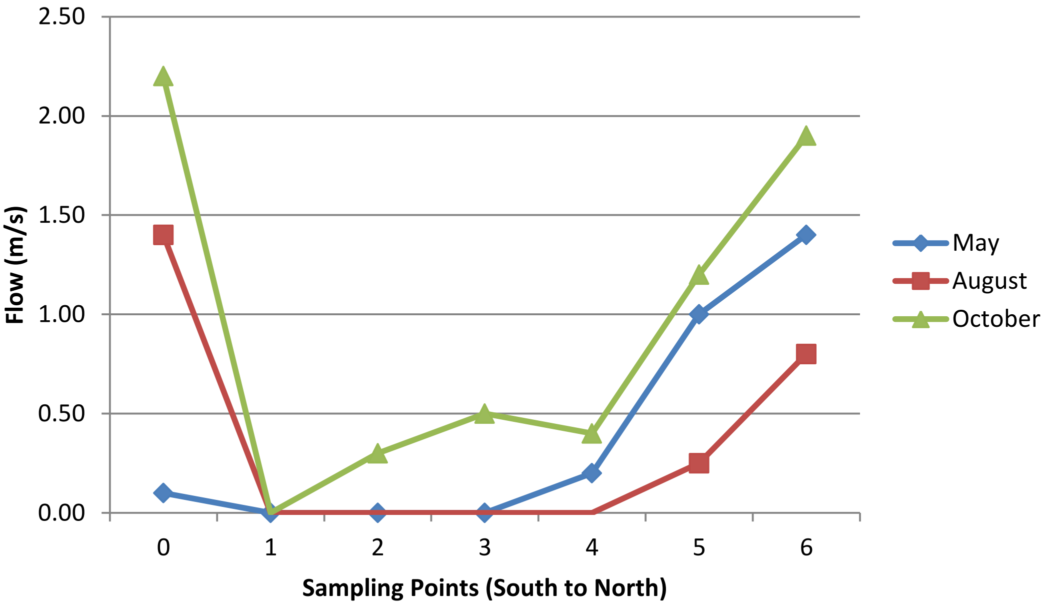

Figure 4.3 Flow of each sampling site following the flow of water from the southernmost point (site 0) to the northernmost point (site 6) on each sampling day, measured in m/s.

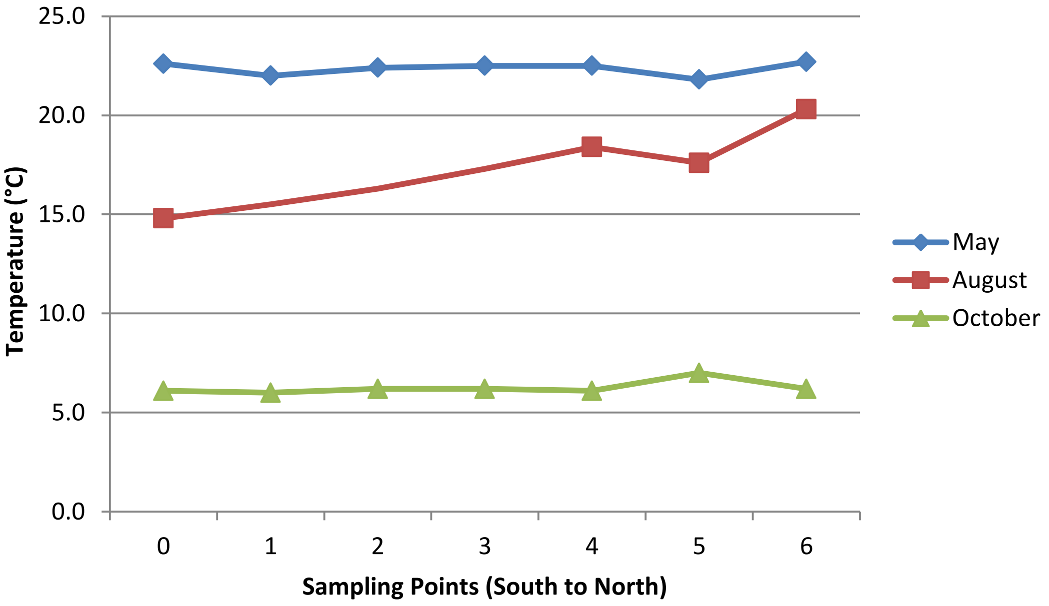

Figure 4.4 Temperature of each sampling site following the flow of water from the southernmost point (site 0) to the northernmost point (site 6) on each sampling day, measured in °C.

Biological Oxygen Demand (BOD) is the amount of oxygen that bacteria take from water when they oxidize organic matter (Hach et al. 1997). This organic matter comes from natural sources or pollution. A low (4-10 mg/L) BOD reading is ideal for warmwater habitats (Hach et al. 1997). BOD readings ranged from less than 1 mg/L to 8.6 mg/L which fall within the warmwater habitat criteria (Figure 4.5).

The chemical results showed variable Soluble Reactive Phosphorus (Figure 4.6). Total phosphorus levels between 30-100 µg/L can cause an algal bloom and total phosphorus above 100 µg/L is toxic to aquatic life. Soluble reactive phosphorus is a portion of the total phosphorus that is most available for plants and algae. The phosphorus was the highest in May with an average of 78 µg/L and seemed to drop off in August and October with average concentrations of 43 µg/L and 44 µg/L, respectively (Figure 4.6).

The toxicity of ammonia in a stream is influenced by the pH. It is inversely related to pH, so, the higher the pH, the lower the ammonia concentration is expected to be (OH EPA 2011). All ammonia concentrations were below 1 mg/L which is well below the maximum standard concentration for warmwater habitat of 5.0-13.0 mg/L at all pH levels (Figure 4.7).

Nitrate in a stream is usually relatively nontoxic unless it is found in excess levels (>4 mg/L). Excess levels can cause eutrophication, or overpopulation of plants or algae to result. May and October were within the range for warmwater quality with most concentrations ranging from 0-1.5 mg/L. There was excess nitrate in four of the seven sites during the August sampling date (Figure 4.8).

Hardness is a measurement of the ions in the water. This has little effect on water quality and aquatic life. However, very hard water can be an indication that other water quality tests are needed to determine what ions are in the water. Snyder Ditch samplings were primarily 116-220 mg $CaCO_3$/L with an average hardness of 166 mg $CaCO_3$/L. A majority of samples fell on the lower range of 150-300 mg $CaCO_3$/L for hard water (Figure 4.9).

Primary metals of interest, due to their toxicity to aquatic organisms included copper, iron, cadmium, zinc and lead (WQP no date). Water characteristics such as pH, hardness, suspended particles and organic compounds can affect the metals toxicity. The total dissolved metals concentration ranged from 0.27 mg/L to 4.42 mg/L with 95-99.9% of the concentration of metals due to iron in the water. Without iron, concentrations of toxic metals ranged from 0.0002 mg/L (BDL) to 0.07 mg/L (Appendix D).

Coliform and chemical oxygen demand readings were taken in the lab, however, due to inconsistencies within the data and less than significant results, it was not included in the analysis. For more information please see Appendix D.

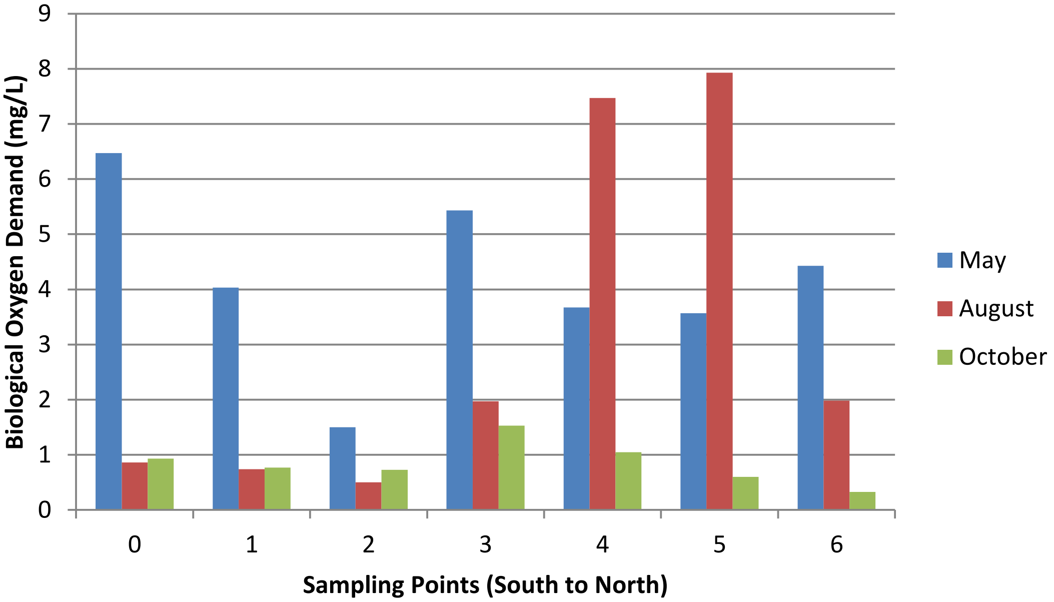

Figure 4.5 The Biological Oxygen Demand of each sampling site following the flow of water from the southernmost point (site 0) to the northernmost point (site 6) on each sampling day, measured in mg/L.

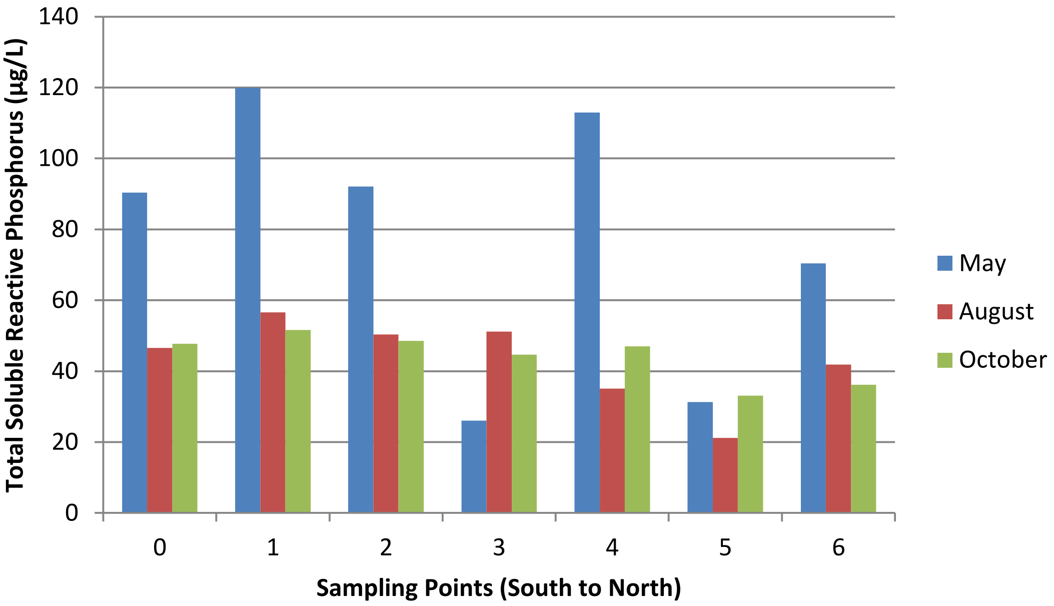

Figure 4.6 Total Soluble Reactive Phosphorus of each sampling site following the flow of water from the southernmost point (site 0) to the northernmost point (site 6) on each sampling day, measured in µg/L.

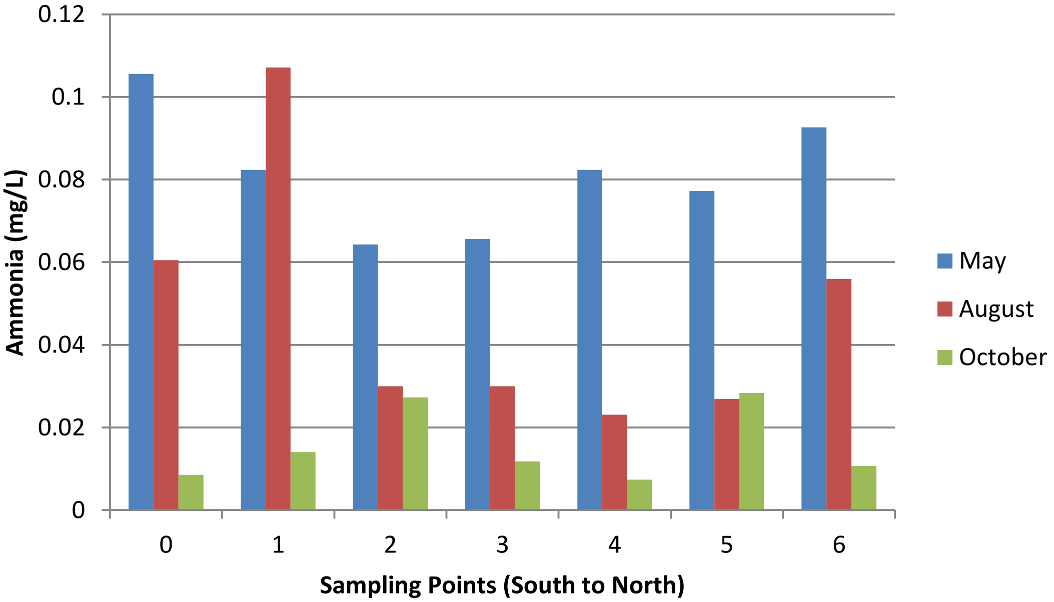

Figure 4.7 Ammonia concentration of each sampling site following the flow of water from the southernmost point (site 0) to the northernmost point (site 6) on each sampling day, measured in mg/L.

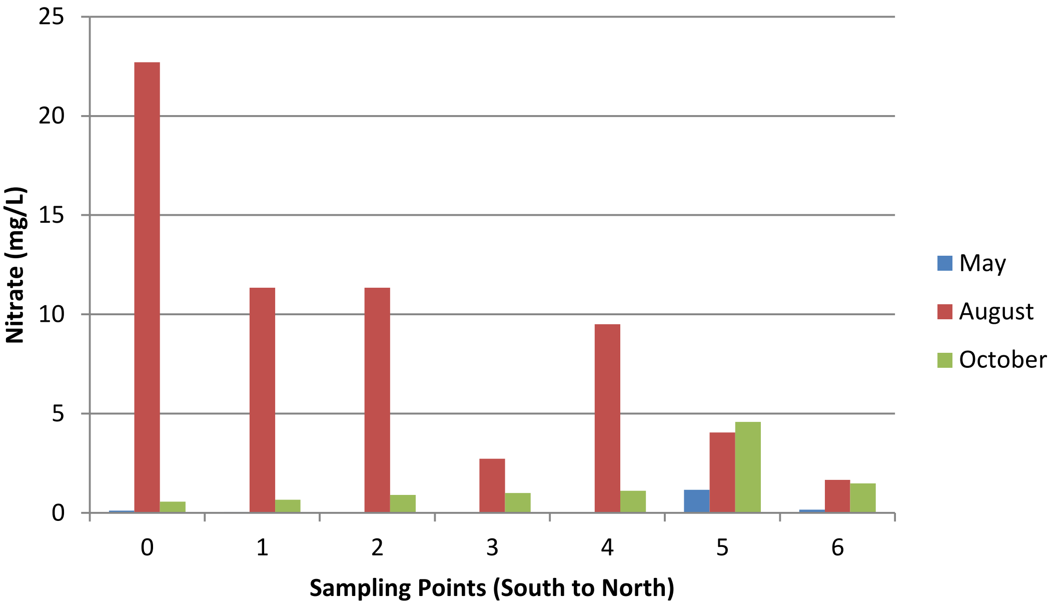

Figure 4.8 Nitrate concentrations of each sampling site following the flow of water from the southernmost point (site 0) to the northernmost point (site 6) on each sampling day, measured in mg/L.

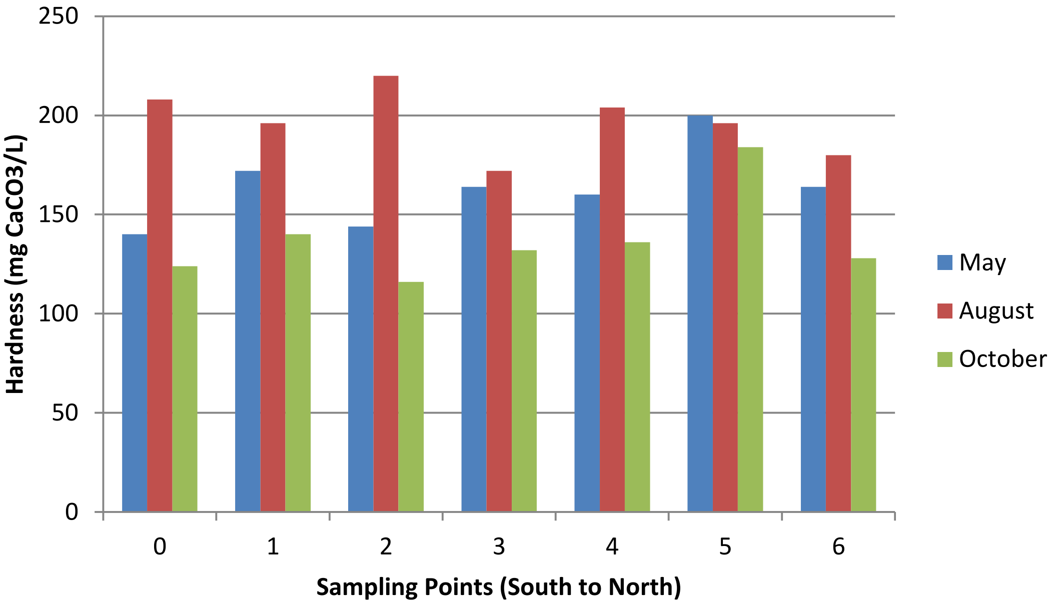

Figure 4.9 Hardness of each sampling site on each sampling day following the flow of water from the southernmost point (site 0) to the northernmost point (site 6), measured in mg $CaCO_3$/L.

4.1 Macroinvertebrate Results

Hester Dendy (H-D) samplers were set and picked up six weeks later as required for determination for Invertebrate Community Index (ICI). The sampling resulted in low density and diversity of macroinvertebrates.

The macroinvertebrate sampling from surber, Ponar and Ekman samplers were combined and semi-quantitatively analyzed for diversity, density and richness. The overall density varied greatly based on the location of the sample with low values at <10 organisms/m^2 to as high as >4000 organisms/m^2 (Figure 4.10). Family Richness is the number of families per sample which also had a large range from lows of only three families present to high richness of seventeen families present (Figure 4.11). The percent of total macroinvertebrate density comprising EPT per m^2 (Figure 4.12) is a measurement of the families of Ephemeroptera, Plecoptera and Trichoptera or mayfly, stonefly and caddisfly, respectively. These are the least pollution tolerant families, and finding them is very promising for stream health. Sample sites 0, 5 and 6 had the highest percentage EPT of total macroinvertebrate density during sampling. EPT family richness (Figure 4.13) and percent EPT of total family richness (Figure 4.14) were also measured. The percent Oligochaeta measurement is of that family of aquatic worms. These worms are very pollution tolerant and having many of these and only these points to a polluted stream. None of the sampling sites had an overabundance (>5000/m^2) (TP Diggins; personal communication 2014) of Oligochaeta (Figure 4.15). The most aquatic worms were found at site 3 and site 4, two of the sites with muck as the dominant substrate.

The chironomid abundances in the stream were at the levels expected for an unpolluted stream. Chironomids are generally pollution tolerant; however, are very diverse at the genus level. The diversity of the chironomid family is also significant. There was a good amount of diversity between genus level identifications of the Chironomids (Figure 4.16) (Appendix F).

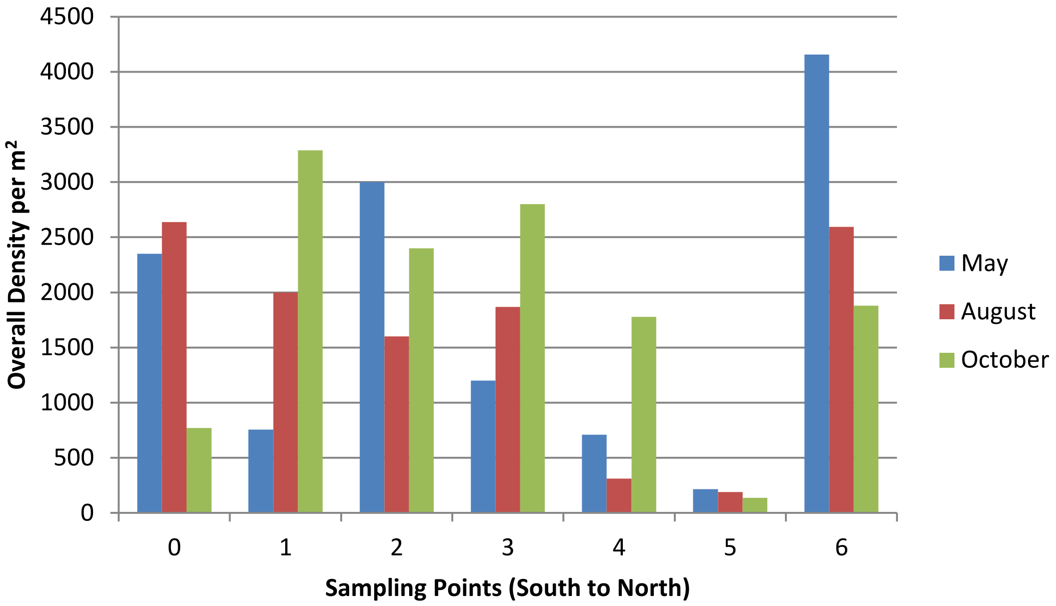

Figure 4.10 Overall densities of organisms per m^2 of each sampling site on each sampling day.

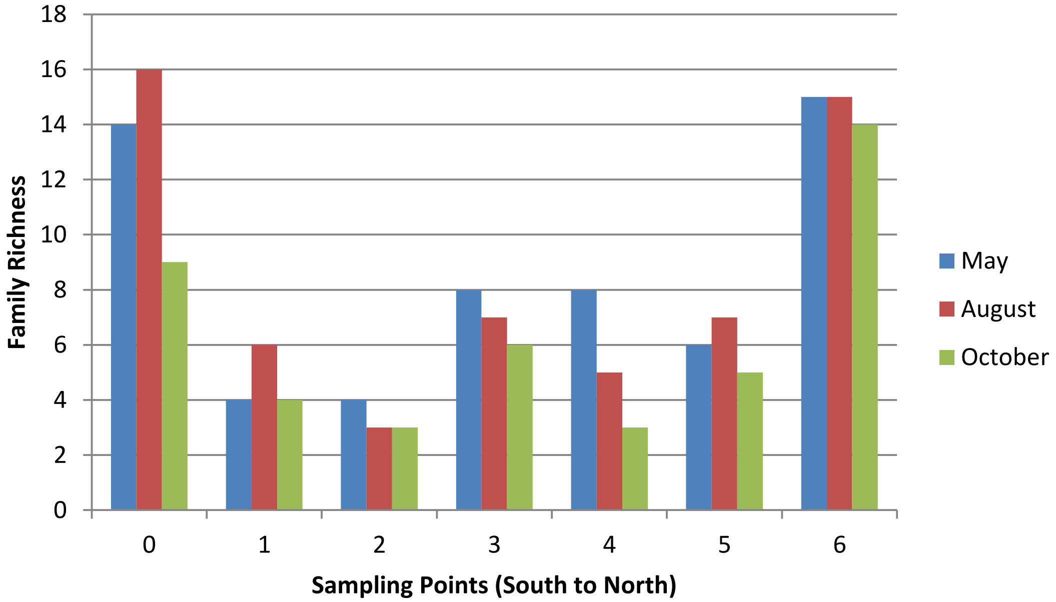

Figure 4.11 Family Richness of each sampling site on each sampling day. Family Richness is the number of families at one sampling location.

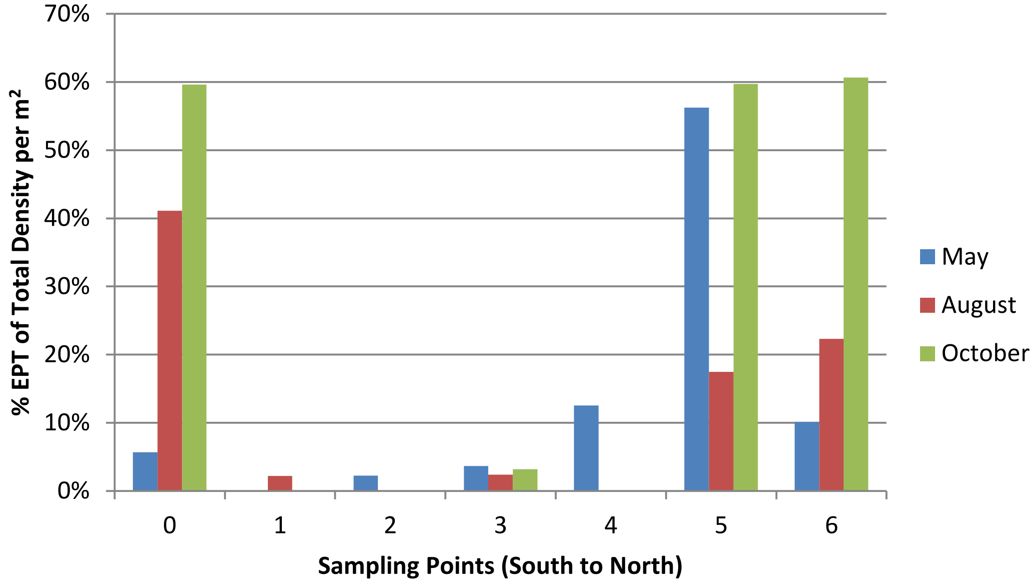

Figure 4.12 The percent EPT is a measurement of the percentage of the families of Ephemeroptera, Plecoptera and Trichoptera of each sampling site on each sampling day. EPT taxa are the most pollution intolerant; an abundance of EPT taxa is a very good indicator for stream health.

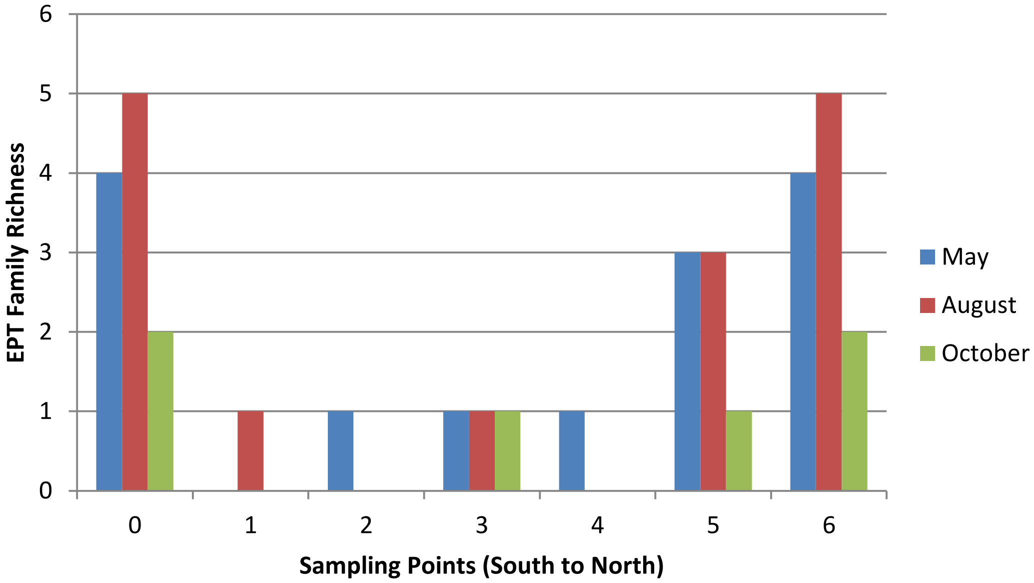

Figure 4.13 EPT Family Richness of each sampling site on each sampling day. EPT Family Richness is the number of EPT families at one sampling location.

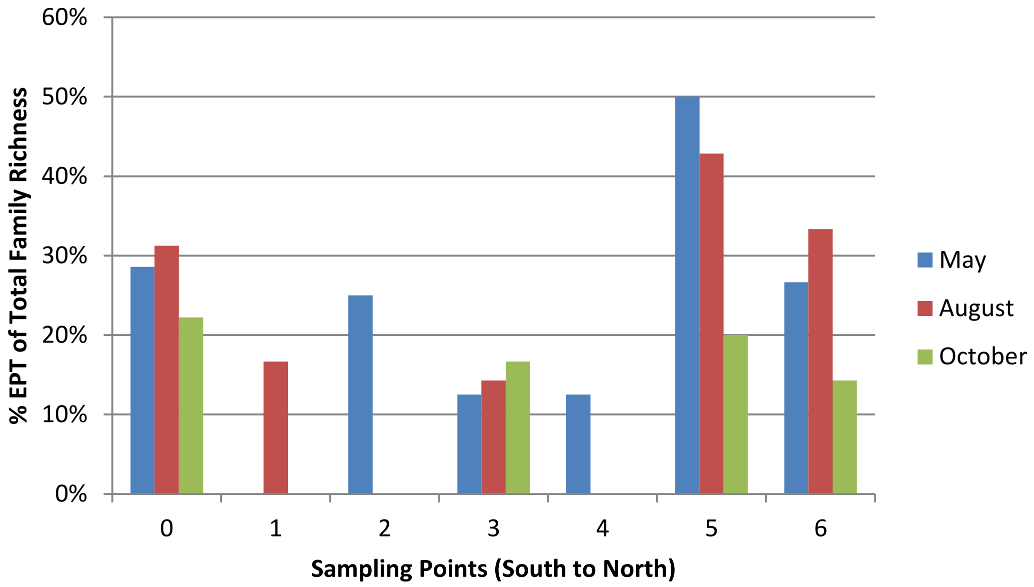

Figure 4.14 The percent EPT of total family richness of each sampling site on each sampling day. This shows a comparison between the species richness of each sampling day and the species richness of the EPT families on each sampling day.

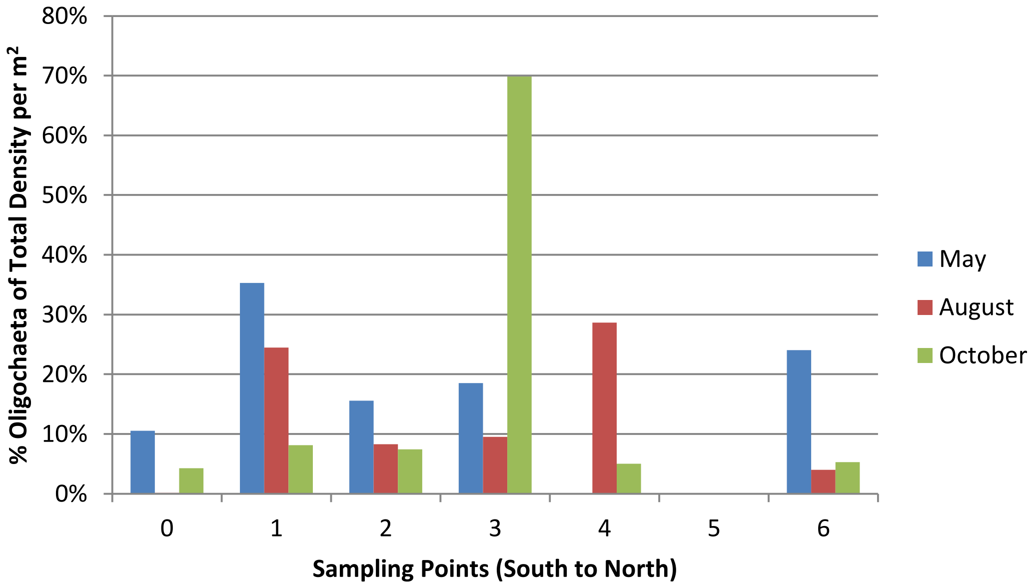

Figure 4.15 The percent Oligochaeta is a measurement of the family of aquatic worms of each sampling site on each sampling day. Aquatic worms are very pollution tolerant and finding an overabundance and only this type of species could indicate poor stream health.

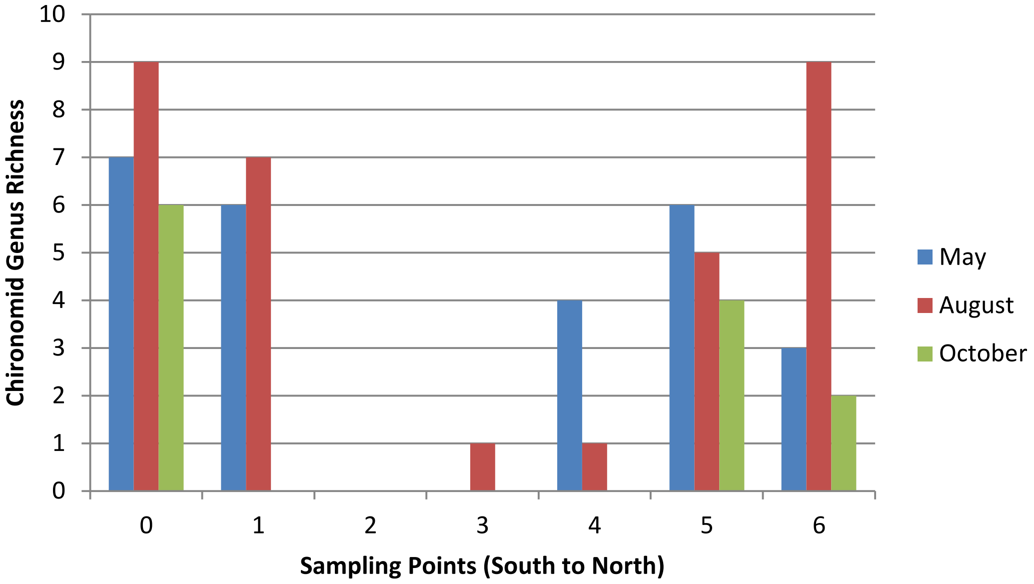

Figure 4.16 Chironomid Genus Richness of each sampling site on each sampling day. The chironomid family of macroinvertebrates is relatively pollution tolerant. For the purposes of this research, the Chrionomids were identified to genus level to determine the richness of the genus.

4.2 Habitat Results

The Quality Habitat Evaluation Index (QHEI) scores for Snyder Ditch were all low and ranged from 27 to 55 (Figure 4.17). The minimum QHEI score to qualify as warmwater habitat is 60. The sites that scored higher (site 0 and 6) had better riparian zone and gravel, very coarse sand or coarse sand types of substrate as opposed to fine sand, silt or clay.

Some of the substrates within the channel had a low percentage of organic matter within the sediment (<3%). Most were less than 8% organic matter except for site 3, which had over 15% (Figure 4.18). All sediments were primarily fine sand or clay/silt except for the samples from site 0 and 6. These, visually, had more of a gravel substrate than all other areas (> than the 2 mm sieve). The other areas were visually mostly muck or sand. Site 0 and 6 are also the sites with the best QHEI scores (Figure 4.19 through Figure 4.25 outline the breakdown of each sampling site sediment type). Figure 4.26 shows the breakdown graph after running the sediment through the Sediment Particle Size Analyzer and Figure 4.27 shows a map of the amount of clay/silt found at each sampling point.

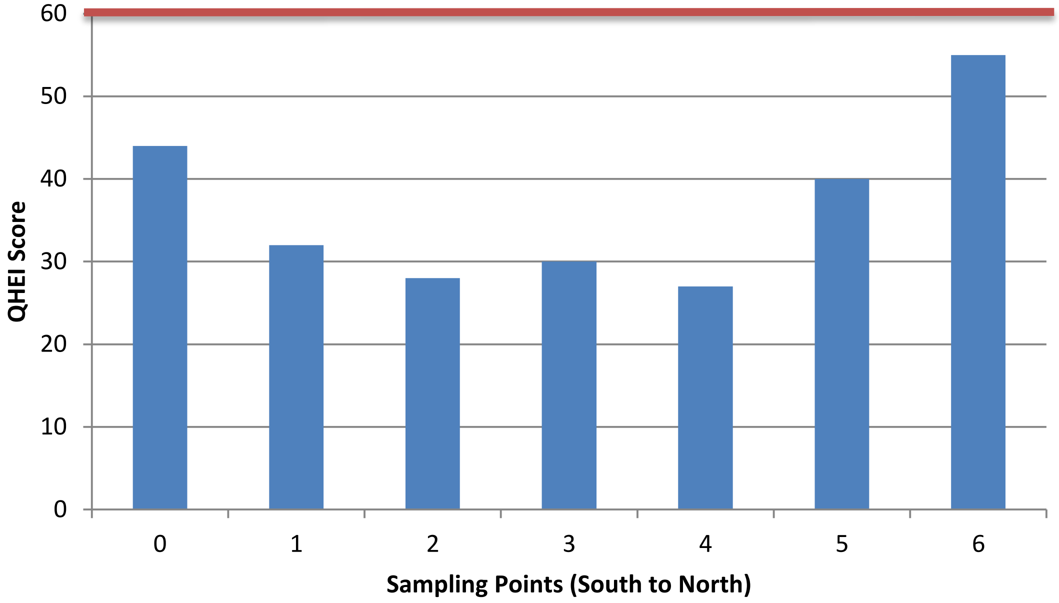

Figure 4.17 QHEI scores for each site following the flow of water from the southernmost point (site 0) to the northernmost point (site 6). Sixty is the acceptable QHEI score for warmwater habitat, as indicated by the red line.

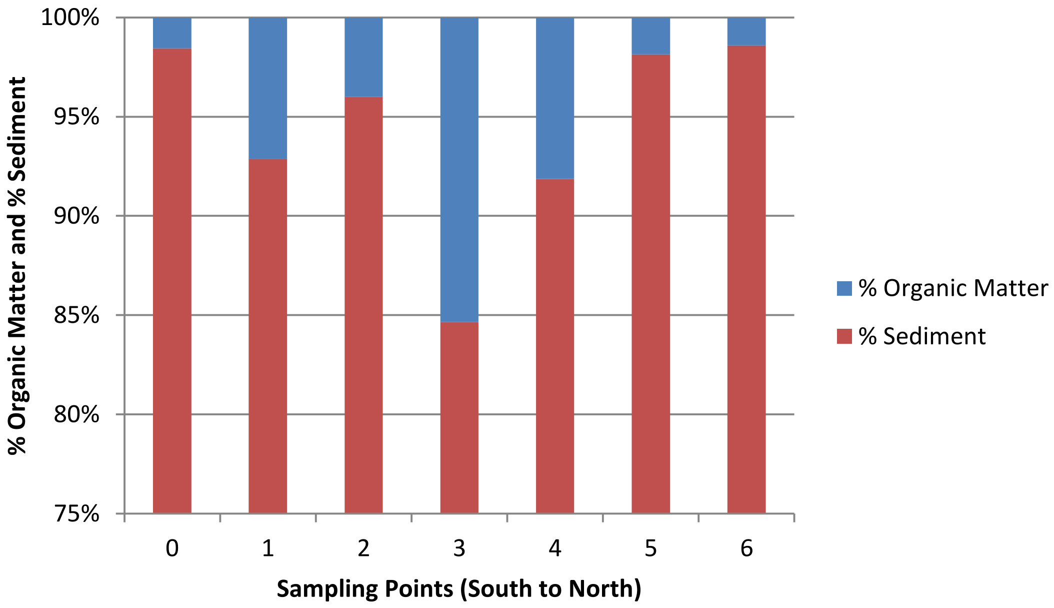

Figure 4.18 The percent organic matter in all samples and the percent sediment.

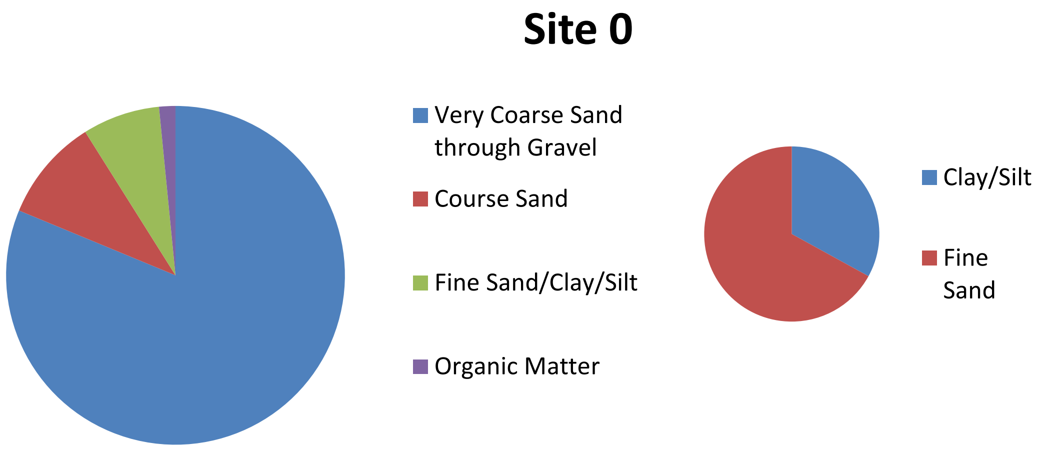

Figure 4.19 A breakdown of the Very Coarse Sand through Gravel, Coarse Sand, Find Sand/Clay/Silt and Organic Matter for Site 0. The Fine Sand and Clay/Silt were analyzed on the Particle Size Analyzer allowing for further breakdown of the components between Clay/Silt and Fine Sand.

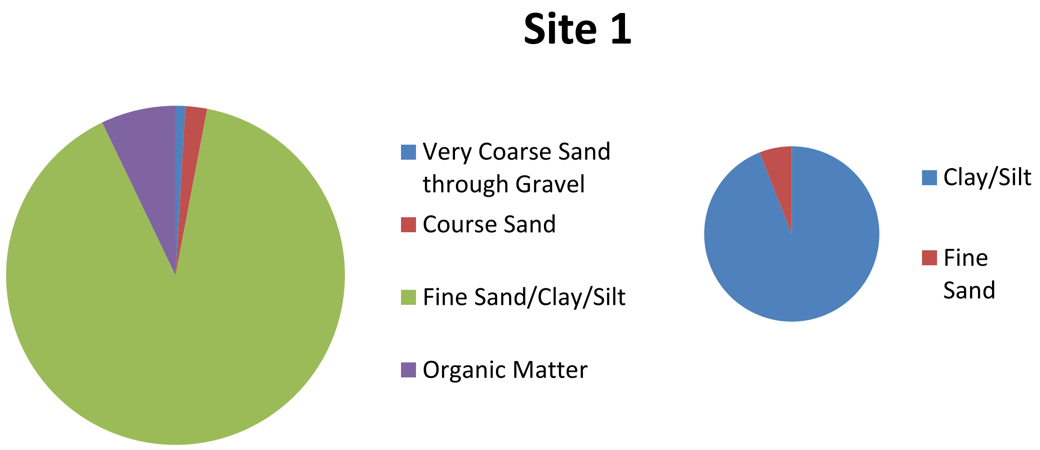

Figure 4.20 A breakdown of the Very Coarse Sand through Gravel, Coarse Sand, Find Sand/Clay/Silt and Organic Matter for Site 1. The Fine Sand and Clay/Silt were analyzed on the Particle Size Analyzer allowing for further breakdown of the components between Clay/Silt and Fine Sand.

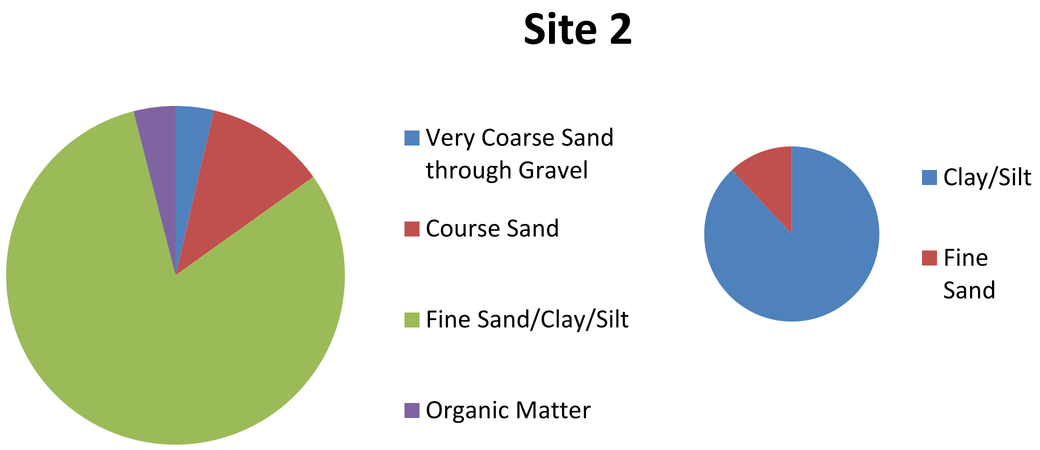

Figure 4.21 A breakdown of the Very Coarse Sand through Gravel, Coarse Sand, Find Sand/Clay/Silt and Organic Matter for Site 2. The Fine Sand and Clay/Silt were analyzed on the Particle Size Analyzer allowing for further breakdown of the components between Clay/Silt and Fine Sand.

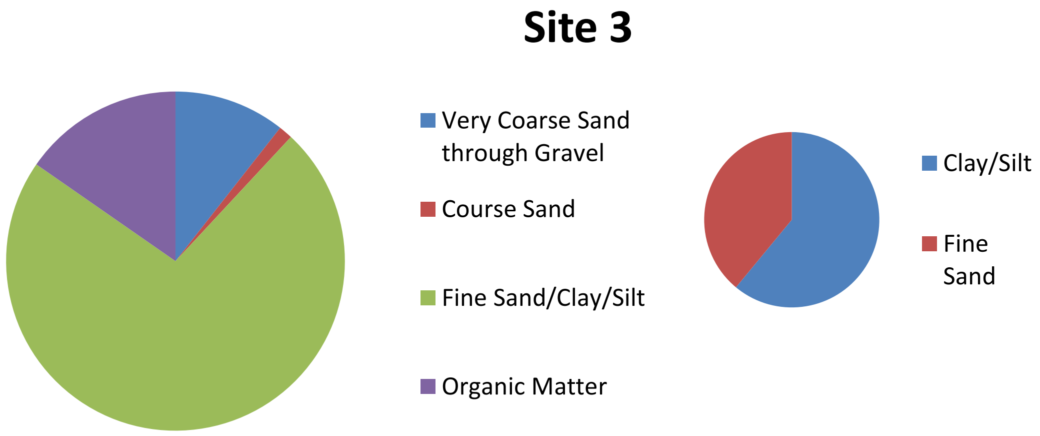

Figure 4.22 A breakdown of the Very Coarse Sand through Gravel, Coarse Sand, Find Sand/Clay/Silt and Organic Matter for Site 3. The Fine Sand and Clay/Silt were analyzed on the Particle Size Analyzer allowing for further breakdown of the components between Clay/Silt and Fine Sand.

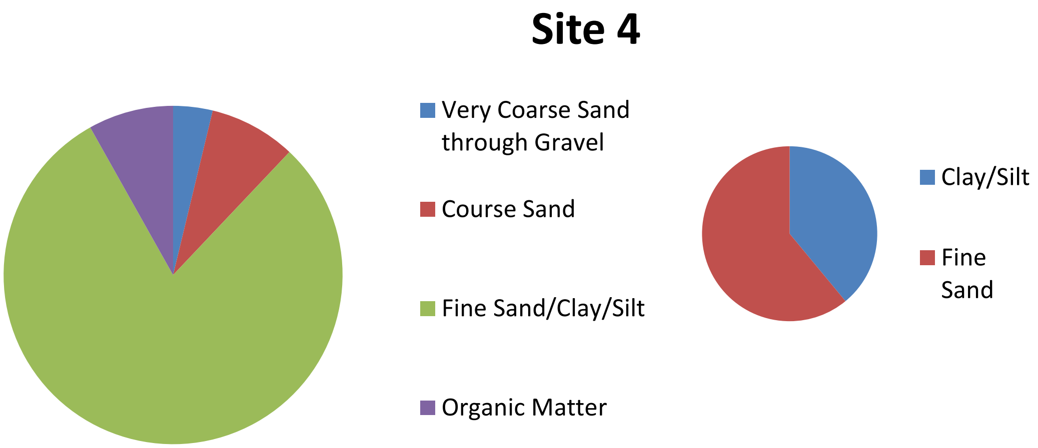

Figure 4.23 A breakdown of the Very Coarse Sand through Gravel, Coarse Sand, Find Sand/Clay/Silt and Organic Matter for Site 4. The Fine Sand and Clay/Silt were analyzed on the Particle Size Analyzer allowing for further breakdown of the components between Clay/Silt and Fine Sand.

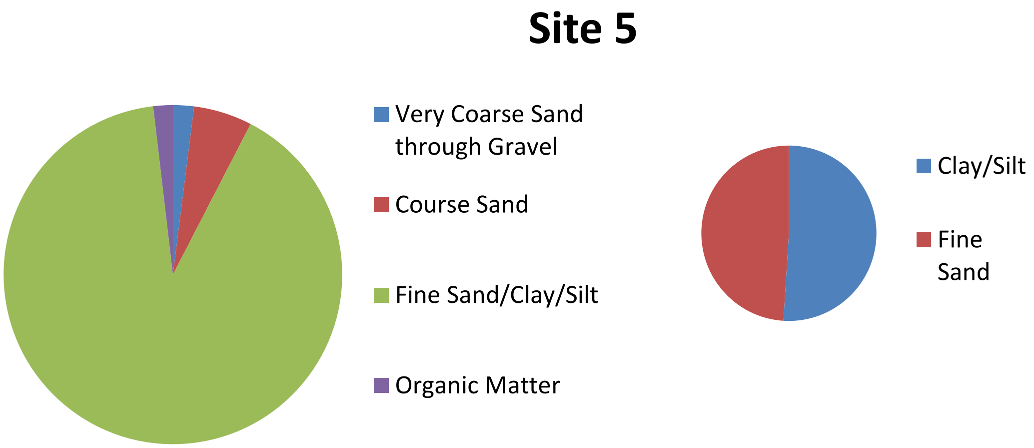

Figure 4.24 A breakdown of the Very Coarse Sand through Gravel, Coarse Sand, Find Sand/Clay/Silt and Organic Matter for Site 5. The Fine Sand and Clay/Silt were analyzed on the Particle Size Analyzer allowing for further breakdown of the components between Clay/Silt and Fine Sand.

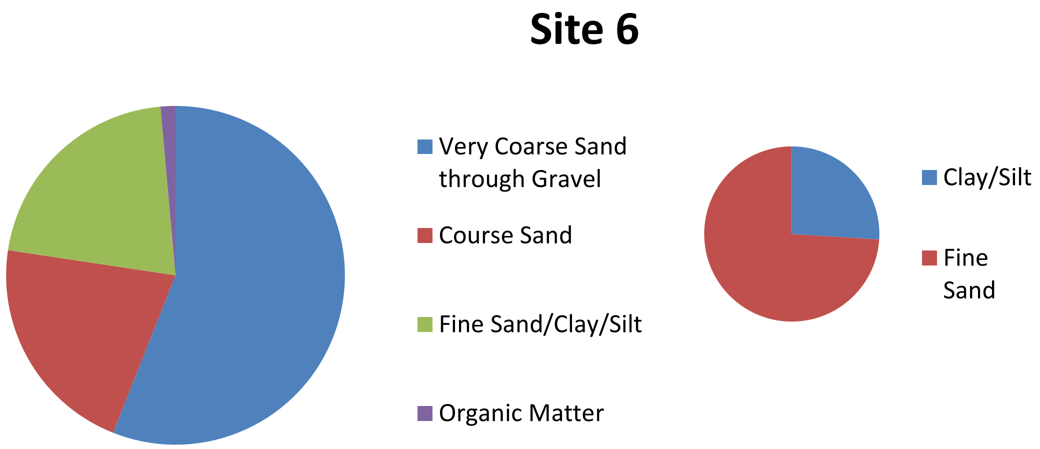

Figure 4.25 A breakdown of the Very Coarse Sand through Gravel, Coarse Sand, Find Sand/Clay/Silt and Organic Matter for Site 6. The Fine Sand and Clay/Silt were analyzed on the Particle Size Analyzer allowing for further breakdown of the components between Clay/Silt and Fine Sand.

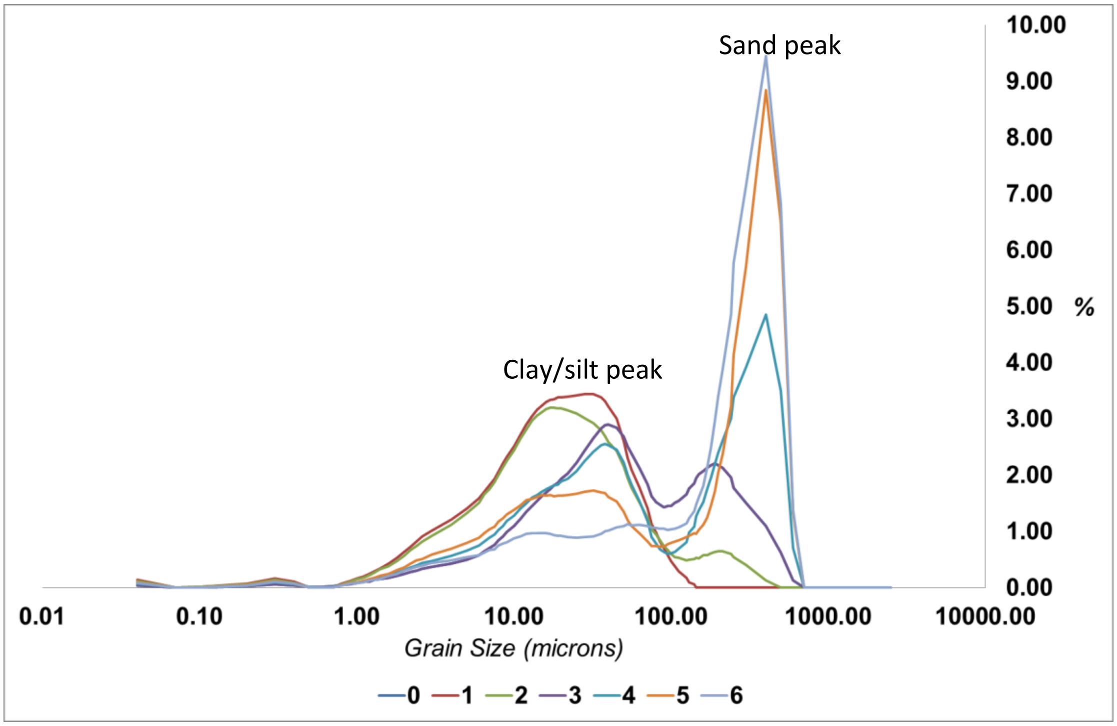

Figure 4.26 The graph created from the analysis of the Fine Sand/Clay/Silt breakdown using the Sediment Particle Size Analyzer (Mattheus 2014). The peaks indicate this is a bimodal substrate with clay/silt and sand. The peak on the left represents the clay/silt and the peak on the right represents sand.

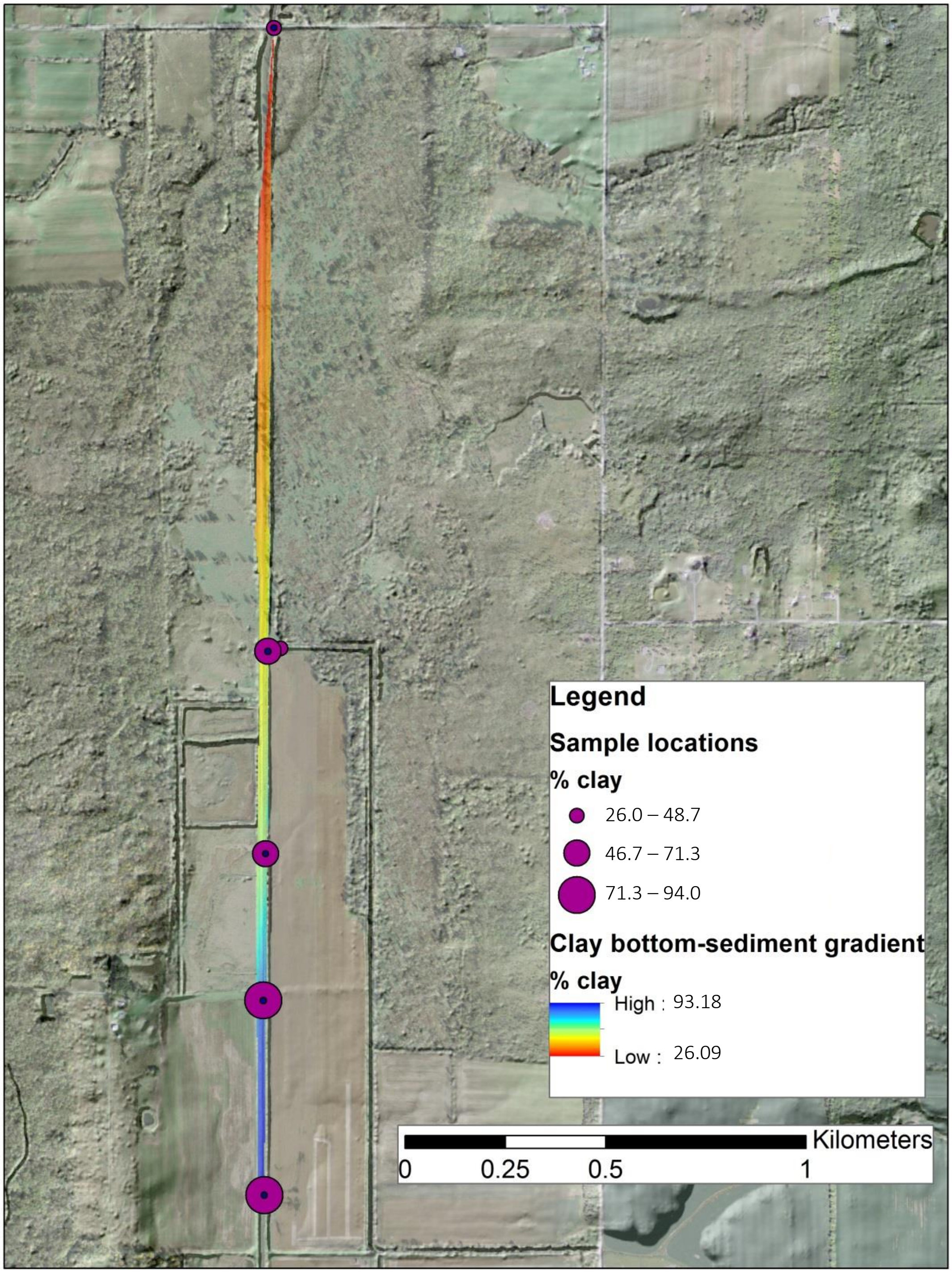

Figure 4.27 The GIS map of Snyder Ditch following the flow of water from the southernmost point (site 0) to the northernmost point (site 6) with the amount of clay/silt found in each sample location indicated by the size of the pink circle (Mattheus 2014, ArcGIS 10.1).

Chapter 5 Discussion

5.0 Water Chemistry Data and Warmwater Quality Comparison

Most of the field and chemical results were within the warmwater quality habitat parameters as defined by the Ohio EPA. One exception included high levels of nitrate in August. The excess nitrate may be coming from runoff from the fields or upstream from other land use activities. The high levels also could be due to the change in testing method used August. A nitrate electrode (that may have been out of date) was used for chemical analysis rather than the initial method outlined in the standard methods.

The high soluble reactive phosphorus readings from a few sampling sites in May were another exception. The high soluble phosphorous in May could be due to the washing out of plant remains from the surrounding fields in the spring snowmelt. It could also be due to fertilizer runoff from agricultural activities. The phosphorus levels were high enough to potentially trigger an algal bloom or excessive plant growth. This could be compared with visual observations of a high amount of plant material in the channel during the August sampling trip. Eutrophication is a concern due to high phosphorus (as seen in May) (WQP no date). Plants and algae grow readily due to the high amount of phosphorus. When there are too many plants and algae in the water, it will starve the other biota in the stream of oxygen. The excess phosphorus would need to be tested annually to determine the cause.

Dissolved oxygen is important in a stream because it allows for aquatic life. All life centers on oxygen, even the macroinvertebrates in the stream. The higher the dissolved oxygen, the more life can be in the stream. This dissolved oxygen is thought to be the main reason why there are still macroinvertebrates in Snyder Ditch. This is also a major criterion for the stream to meet the warmwater quality. The high dissolved oxygen readings for October and August were under suspect (Appendix C). This high (>10 mg/L) dissolved oxygen is thought to be due to a malfunction in the meter or incorrect calibration, because it is very unusual for a channelized stream with low flow rates, few riffles, and few inputs of additional water streams to have such high dissolved oxygen readings. Despite this setback, the May data is very promising for stream health.

5.1 Macroinvertebrate Indicators

The macroinvertebrate results were much better than anticipated. Pollution tolerant species are those that are able to live in polluted streams and rivers. These include organisms such as Chironomids (midges) and Oligochaeta (aquatic worms). It is important to note that pollution tolerant taxa are able to live in non-polluted streams. Having an overabundance is a concern for stream health. Pollution sensitive taxa include Ephemeroptera (Mayfly), Plecoptera (Stonefly) and Trichoptera (Caddisfly). These taxa will only be found in non-polluted streams and are a great indicator for stream health.

The overall organism density per m^2 was much higher than expected with site 6 exhibiting the highest number of organisms. The moderate family richness and diversity and relatively high number of EPT taxa also showed good water quality. Originally a low macroinvertebrate density was expected because of the low flow rate, the lack of substrate heterogeneity and substrate habitat. However, due to the generally sufficient oxygen, the macroinvertebrates may have adapted to this type of substrate. In other words, the dissolved oxygen could be compensating for the generally poor habitat.

The H-D samplers were set out later than recommended dates and were not picked up until the end of October. This delay in sampling resulted in low abundance of organisms that used the H-D as shelter. This lack of organisms could also be due to the lack of flow and depth for ideal situations for H-D success. Consequently ICI could not be established for this sampling period (Appendix F).

5.2 Stream Habitat for Warmwater Environments

Snyder Ditch QHEI scores for all sites were less than the 60 points needed for warmwater habitat. This is mostly due to the lack of heterogeneous substrate, lack of in stream cover and lack of riparian zone surrounding the stream. The lack of riparian zone is due to the channelization of the stream. When a stream is straightened, the trees and shrubs surrounding the stream are removed to make it easier for machinery and equipment to get through. Furthermore, this stream had the stream banks raised above normal elevation to prevent high water flow from getting into the agricultural fields. These banks were about one meter in elevation with the highest found from site 1 - site 4. The outcome of these modifications for most areas of the stream is zero riparian zone. If native riparian vegetation is not replaced, there is little chance for successional growth of vegetation due to the alteration of channelization.

The substrate within the stream did not lend itself to meeting warmwater quality habitat. Pollution sensitive macroinvertebrates prefer a coarse substrate type (gravel or small boulders), so this is a major determining factor in stream health. Most of the substrate within the stream was clay, silt and sand. The analysis of sediment from sites 0 and 6 verified the visual differences that were noted in substrate. These two sites (0 and 6) had better substrate and also had the higher QHEI scores compared to all the other sampling points. Another indicator of better warmwater habitat from sites 0 and 6 were the higher diversity, higher density and higher % EPT values than the other sites. This aligns with the fact that the higher the QHEI score, the higher the density of organisms at a specific site because of the better habitat.

Hypothesis 1 stated that Snyder Ditch would not reach warmwater quality habitat as outlined by the Ohio EPA. Because the water chemistry data was much better than anticipated, and macroinvertebrate density and diversity was better than anticipated, hypothesis 1 is tentatively rejected. With the exception of the habitat, overall warmwater quality was met in all cases. More data is needed to definitively reject hypothesis 1.

5.3 Semi-Naturalized Area Analysis

Habitat plays one of the biggest roles in the health of this stream. It is clear that the sampling sites are heavily impacted by agriculture because of the lack of in stream cover and substrate and not because of the additions of chemical nutrients. Hypothesis 2 stated that the sites that were semi-naturalized would have better stream quality as defined by Ohio EPA warmwater habitat criteria than those that are heavily impacted by agriculture. It was expected that less pollutants and sediments would be running into the stream in the semi-naturalized areas as compared to the agricultural areas because of the use of fertilizers and machinery used on the agricultural fields. Riparian zones are responsible for intercepting pollutants and sediment before they enter the stream, resulting in better water quality. The two semi-naturalized sites were site 0 and site 6. Site 0 is on the south part of the evaluated section of stream and contained more sinuosity in the river channel, less steep and more developed riparian zone, and some larger riparian plant growth such as willows. Site 6 was the northern most site on the stream which had semi-naturalized land use, canopy cover, and more diverse plant riparian zone.

The chemical results showed no great deviation between the semi-naturalized sites and the agriculturally impacted sites, indicating that there was little affect by riparian zone or habitat characteristics. This perhaps signifies that no excess fertilizers are used on the agricultural land or the input of nutrients is due to either downstream additions flowing into the area or due to agricultural drainage bypassing the riparian zone via tile drains from the agricultural fields. In addition there was better substrate containing gravel, pebbles and rocks at the bottom of the stream at both semi-naturalized sites. Results show that in the semi-naturalized areas there was less organic matter in the sediment and more gravel, much higher flow than the other sites and higher QHEI scores. The results were consistent with visual observation.

Across all months the highest levels of organism density, species richness and EPT taxa were catalogued at the sites with the highest QHEI scores. The semi-naturalized sites (0 and 6) had higher QHEI scores and were the least impacted by agriculture, which may have allowed pollution sensitive taxa to succeed here.

Most of the field results (pH, temperature, conductivity, dissolved oxygen) for the agriculturally impacted sites versus the more semi-naturalized areas were similar. The only difference between them was water flow rate. Flow is an important factor in stream health—if flow is too slow it creates a “dead” stream with no oxygen: if too fast it does not allow any excess nutrients to be degraded and creates increase bank erosion (WQP no date). The higher flow rate found at the semi-naturalized sites (0 and 6) was a suitable flow rate for macroinvertebrates and created riffle areas which are preferred by the macroinvertebrates.

Hypothesis 2 on land use affects was accepted based on the data collected. However, a more long term study would be beneficial in determining the important characteristic influencing stream health at each site. Furthermore, it was concluded that the lack of riparian zone is not the only reason for the stream health differences. The lack of in stream cover and lack of substrate for the macroinvertebrates contributed to the difference in stream health. The difference in biological communities between the semi-naturalized areas and agricultural areas is a good indicator that simple restoration techniques and increase of near stream riparian vegetation may improve stream health to meet warmwater habitat criteria. Any future restoration should be passive in nature and allow for natural processes to become established. Since all parameters meet or come very close to meeting warmwater quality habitat, the major restoration should focus on the habitat.

Chapter 6 Conclusion

6.0 Conclusion

As with most biological studies, more research is beneficial to strengthen the conclusions on the stream health of Snyder Ditch. Based on the data acquired, it is clear that Snyder Ditch is not as polluted or impacted by channelization and/or land use as originally suspected. Evaluation of chemical nutrients, field conditions, and habitat quality indicate that habitat characteristics had the most effect on the macroinvertebrate community and stream health. The chemical and field results were fairly consistent throughout the stream and were close to the Ohio EPA requirements for warmwater habitat. The semi-naturalized areas, with better habitat conditions, had considerably higher diversity and density of macroinvertebrates. The habitat characteristics that seemed to have the most effect were the type of substrate and riparian characteristics as well as the occurrence of riffles. This is promising for the future restoration techniques, making Snyder Ditch a great candidate for habitat restoration.

Future restoration should focus on improvements to in stream habitat and the riparian zone. Increasing sediment heterogeneity, lessening the organic matter, adding shade and riparian zone and altering the channel to produce more natural sinuosity would create riffles and would possibly allow the stream to meet warmwater criteria in a few years. Chemical and field monitoring before and during restoration would be required to examine whether there is impact to downstream conditions. After the restoration, chemical and field monitoring along with biological sampling will need to continue to determine if the restoration was successful.

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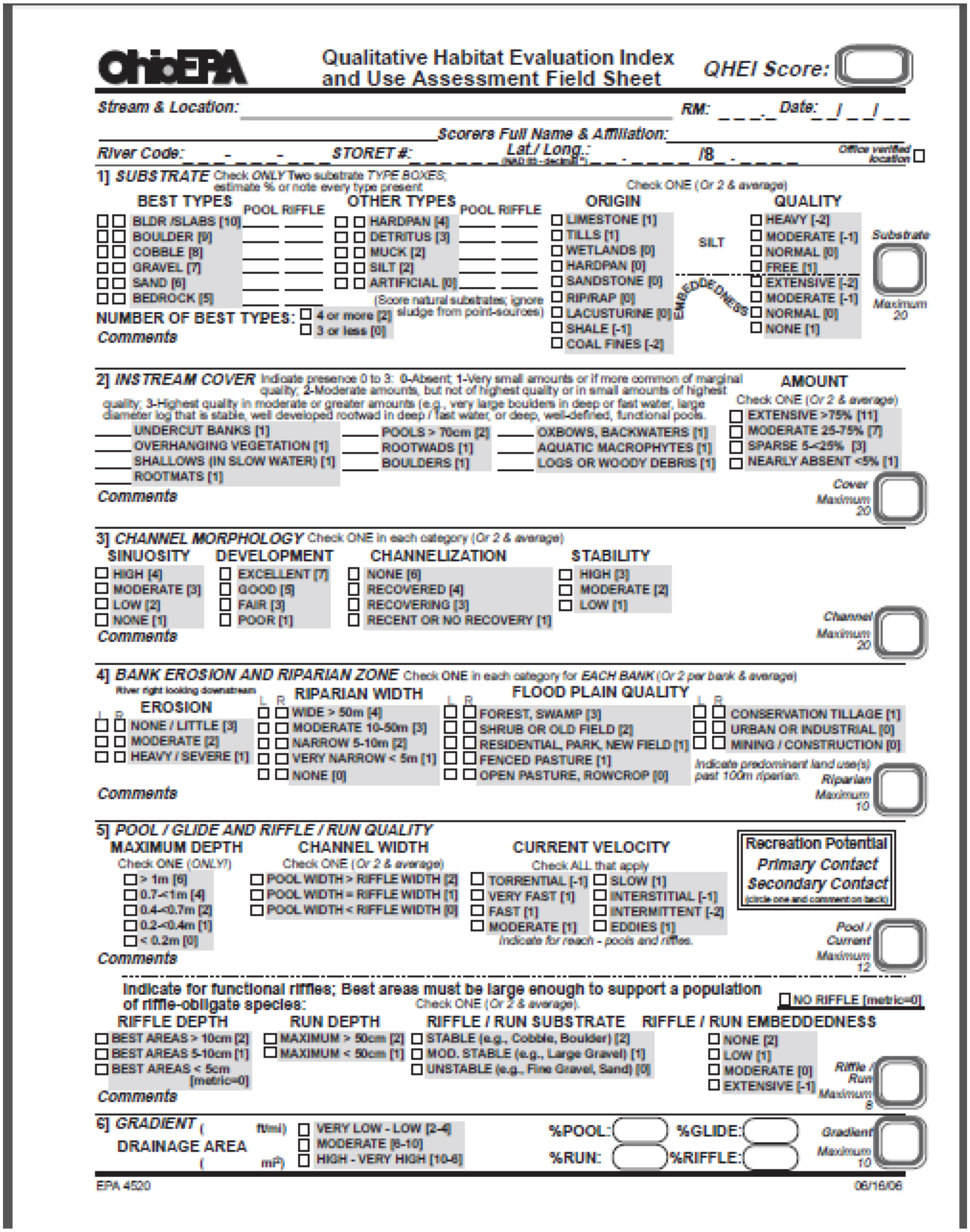
Appendix A

Qualitative Habitat Evaluation Index form



OhioEPA **Qualitative Habitat Evaluation Index and Use Assessment Field Sheet** *QHEI Score:* ☐

Stream & Location: ____________ *RM:* _ _ _ . _ *Date:* _ _ / _ _ / _ _

____________ *Scorers Full Name & Affiliation:* ____________

River Code: _ _ - _ _ _ - _ _ _ *STORET #:* ________ *Lat./ Long.:* (NAD 83 - decimal °) _ _ . _ _ _ _ _ /8 _ . _ _ _ _ _ Office verified location ☐

1] *SUBSTRATE* Check *ONLY* Two substrate *TYPE BOXES*; estimate % or note every type present

BEST TYPES POOL RIFFLE
- ☐ ☐ BLDR /SLABS [10] ___ ___
- ☐ ☐ BOULDER [9] ___ ___
- ☐ ☐ COBBLE [8] ___ ___
- ☐ ☐ GRAVEL [7] ___ ___
- ☐ ☐ SAND [6] ___ ___
- ☐ ☐ BEDROCK [5] ___ ___

NUMBER OF BEST TYPES:
- ☐ 4 or more [2]
- ☐ 3 or less [0]

OTHER TYPES POOL RIFFLE
- ☐ ☐ HARDPAN [4] ___ ___
- ☐ ☐ DETRITUS [3] ___ ___
- ☐ ☐ MUCK [2] ___ ___
- ☐ ☐ SILT [2] ___ ___
- ☐ ☐ ARTIFICIAL [0] ___ ___

(Score natural substrates; ignore sludge from point-sources)

Check ONE (*Or 2 & average*)

ORIGIN
- ☐ LIMESTONE [1]
- ☐ TILLS [1]
- ☐ WETLANDS [0]
- ☐ HARDPAN [0]
- ☐ SANDSTONE [0]
- ☐ RIP/RAP [0]
- ☐ LACUSTURINE [0]
- ☐ SHALE [-1]
- ☐ COAL FINES [-2]

QUALITY

SILT
- ☐ HEAVY [-2]
- ☐ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ FREE [1]

EMBEDDEDNESS
- ☐ EXTENSIVE [-2]
- ☐ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ NONE [1]

Comments

Substrate ☐ *Maximum 20*

2] *INSTREAM COVER* Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

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

AMOUNT

Check ONE (*Or 2 & average*)
- ☐ EXTENSIVE >75% [11]
- ☐ MODERATE 25-75% [7]
- ☐ SPARSE 5-<25% [3]
- ☐ NEARLY ABSENT <5% [1]

Comments

Cover Maximum 20 ☐

3] *CHANNEL MORPHOLOGY* Check ONE in each category (*Or 2 & average*)

SINUOSITY
- ☐ HIGH [4]
- ☐ MODERATE [3]
- ☐ LOW [2]
- ☐ NONE [1]

DEVELOPMENT
- ☐ EXCELLENT [7]
- ☐ GOOD [5]
- ☐ FAIR [3]
- ☐ POOR [1]

CHANNELIZATION
- ☐ NONE [6]
- ☐ RECOVERED [4]
- ☐ RECOVERING [3]
- ☐ RECENT OR NO RECOVERY [1]

STABILITY
- ☐ HIGH [3]
- ☐ MODERATE [2]
- ☐ LOW [1]

Comments

Channel Maximum 20 ☐

4] *BANK EROSION AND RIPARIAN ZONE* Check ONE in each category for *EACH BANK* (*Or 2 per bank & average*)

River right looking downstream

EROSION L R
- ☐ ☐ NONE / LITTLE [3]
- ☐ ☐ MODERATE [2]
- ☐ ☐ HEAVY / SEVERE [1]

RIPARIAN WIDTH L R
- ☐ ☐ WIDE > 50m [4]
- ☐ ☐ MODERATE 10-50m [3]
- ☐ ☐ NARROW 5-10m [2]
- ☐ ☐ VERY NARROW < 5m [1]
- ☐ ☐ NONE [0]

FLOOD PLAIN QUALITY L R
- ☐ ☐ FOREST, SWAMP [3]
- ☐ ☐ SHRUB OR OLD FIELD [2]
- ☐ ☐ RESIDENTIAL, PARK, NEW FIELD [1]
- ☐ ☐ FENCED PASTURE [1]
- ☐ ☐ OPEN PASTURE, ROWCROP [0]

L R
- ☐ ☐ CONSERVATION TILLAGE [1]
- ☐ ☐ URBAN OR INDUSTRIAL [0]
- ☐ ☐ MINING / CONSTRUCTION [0]

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian Maximum 10 ☐

5] *POOL / GLIDE AND RIFFLE / RUN QUALITY*

MAXIMUM DEPTH

Check ONE (*ONLY!*)
- ☐ > 1m [6]
- ☐ 0.7-<1m [4]
- ☐ 0.4-<0.7m [2]
- ☐ 0.2-<0.4m [1]
- ☐ < 0.2m [0]

CHANNEL WIDTH

Check ONE (*Or 2 & average*)
- ☐ POOL WIDTH > RIFFLE WIDTH [2]
- ☐ POOL WIDTH = RIFFLE WIDTH [1]
- ☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY

Check ALL that apply
- ☐ TORRENTIAL [-1]
- ☐ VERY FAST [1]
- ☐ FAST [1]
- ☐ MODERATE [1]
- ☐ SLOW [1]
- ☐ INTERSTITIAL [-1]
- ☐ INTERMITTENT [-2]
- ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential
Primary Contact
Secondary Contact
(circle one and comment on back)

Comments

Pool / Current Maximum 12 ☐

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (*Or 2 & average*).

☐ NO RIFFLE [metric=0]

RIFFLE DEPTH
- ☐ BEST AREAS > 10cm [2]
- ☐ BEST AREAS 5-10cm [1]
- ☐ BEST AREAS < 5cm [metric=0]

RUN DEPTH
- ☐ MAXIMUM > 50cm [2]
- ☐ MAXIMUM < 50cm [1]

RIFFLE / RUN SUBSTRATE
- ☐ STABLE (e.g., Cobble, Boulder) [2]
- ☐ MOD. STABLE (e.g., Large Gravel) [1]
- ☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]

RIFFLE / RUN EMBEDDEDNESS
- ☐ NONE [2]
- ☐ LOW [1]
- ☐ MODERATE [0]
- ☐ EXTENSIVE [-1]

Comments

Riffle / Run Maximum 8 ☐

6] *GRADIENT* (ft/mi)

DRAINAGE AREA (mi²)
- ☐ VERY LOW - LOW [2-4]
- ☐ MODERATE [6-10]
- ☐ HIGH - VERY HIGH [10-6]

%POOL: ☐ %GLIDE: ☐

%RUN: ☐ %RIFFLE: ☐

Gradient Maximum 10 ☐

EPA 4520

06/16/06

A] SAMPLED REACH
Check ALL that apply

Comment RE: Reach consistency/ Is reach typical of steam?, *Recreation/* Observed - Inferred, *Other/* Sampling observations, Concerns, Access directions, etc.

METHOD
☐ BOAT
☐ WADE
☐ L. LINE
☐ OTHER

STAGE
1st -sample pass- 2nd
☐ HIGH ☐
☐ UP ☐
☐ NORMAL ☐
☐ LOW ☐
☐ DRY ☐

DISTANCE
☐ 0.5 Km
☐ 0.2 Km
☐ 0.15 Km
☐ 0.12 Km
☐ OTHER
______ meters

CLARITY
1st —sample pass— 2nd
☐ < 20 cm ☐
☐ 20-<40 cm ☐
☐ 40-70 cm ☐
☐ > 70 cm/ CTB ☐
☐ SECCHI DEPTH ☐
1st ________ cm
pass
2nd ________ cm

CANOPY
☐ > 85% OPEN
☐ 55%-<85%
☐ 30%-<55%
☐ 10%-<30%
☐ <10% CLOSED

B] AESTHETICS
☐ NUISANCE ALGAE
☐ INVASIVE MACROPHYTES
☐ EXCESS TURBIDITY
☐ DISCOLORATION
☐ FOAM / SCUM
☐ OIL SHEEN
☐ TRASH / LITTER
☐ NUISANCE ODOR
☐ SLUDGE DEPOSITS
☐ CSOs/SSOs/OUTFALLS

C] RECREATION
AREA DEPTH
POOL: ☐>100ft² ☐>3ft

D] MAINTENANCE
PUBLIC / PRIVATE / BOTH / NA
ACTIVE / HISTORIC / BOTH / NA
YOUNG-SUCCESSION-OLD
SPRAY / SNAG / REMOVED
MODIFIED / DIPPED OUT / NA
LEVEED / ONE SIDED
RELOCATED / CUTOFFS
MOVING-BEDLOAD-STABLE
ARMOURED / SLUMPS
ISLANDS / SCOURED
IMPOUNDED / DESICCATED
FLOOD CONTROL / DRAINAGE

Circle some & *COMMENT*

E] ISSUES
WWTP / CSO / NPDES / INDUSTRY
HARDENED / URBAN / DIRT&GRIME
CONTAMINATED / LANDFILL
BMPs-CONSTRUCTION-SEDIMENT
LOGGING / IRRIGATION / COOLING
BANK / EROSION / SURFACE
FALSE BANK / MANURE / LAGOON
WASH H_2O / TILE / H_2O TABLE
ACID / MINE / QUARRY / FLOW
NATURAL / WETLAND / STAGNANT
PARK / GOLF / LAWN / HOME
ATMOSPHERE / DATA PAUCITY

F] MEASUREMENTS
$\bar{x}$ width
$\bar{x}$ depth
max. depth
$\bar{x}$ bankfull width
bankfull $\bar{x}$ depth
W/D ratio
bankfull max. depth
floodprone x^2 width
entrench. ratio
Legacy Tree:

Stream Drawing:

Appendix B

Equations for macroinvertebrate information

Site 0 % EPT May	$\frac{133\ EPT\ organisms}{2350\ overall\ density} * 100 = 5.66\%$	Site 0 %EPT Family Richness May	$\frac{4\ EPT\ Richness}{14\ Overall\ Richness} * 100 = 28.57\%$	Site 0 % Oligochaeta May	$\frac{248\ Oligochaeta\ organisms}{2350\ overall\ density} * 100 = 10.55\%$
Site 0 % EPT August	$\frac{1084\ EPT\ organisms}{2638\ overall\ density} * 100 = 41.09\%$	Site 0 %EPT Family Richness August	$\frac{5\ EPT\ Richness}{16\ Overall\ Richness} * 100 = 31.25\%$	Site 0 % Oligochaeta August	$\frac{4\ Oligochaeta\ organisms}{2638\ overall\ density} * 100 = 0.15\%$
Site 0 % EPT October	$\frac{459\ EPT\ organisms}{770\ overall\ density} * 100 = 59.61\%$	Site 0 %EPT Family Richness October	$\frac{2\ EPT\ Richness}{9\ Overall\ Richness} * 100 = 22.22\%$	Site 0 % Oligochaeta October	$\frac{33\ Oligochaeta\ organisms}{770\ overall\ density} * 100 = 4.29\%$
Site 1 % EPT May	$\frac{0\ EPT\ organisms}{756\ overall\ density} * 100 = 0.00\%$	Site 1 %EPT Family Richness May	$\frac{0\ EPT\ Richness}{4\ Overall\ Richness} * 100 = 0.00\%$	Site 1 % Oligochaeta May	$\frac{267\ Oligochaeta\ organisms}{756\ overall\ density} * 100 = 35.29\%$
Site 1 % EPT August	$\frac{44\ EPT\ organisms}{2000\ overall\ density} * 100 = 2.20\%$	Site 1 %EPT Family Richness August	$\frac{1\ EPT\ Richness}{6\ Overall\ Richness} * 100 = 16.67\%$	Site 1 % Oligochaeta August	$\frac{489\ Oligochaeta\ organisms}{2000\ overall\ density} * 100 = 24.45\%$
Site 1 % EPT October	$\frac{0\ EPT\ organisms}{3289\ overall\ density} * 100 = 0.00\%$	Site 1 %EPT Family Richness October	$\frac{0\ EPT\ Richness}{4\ Overall\ Richness} * 100 = 0.00\%$	Site 1 % Oligochaeta October	$\frac{267\ Oligochaeta\ organisms}{3289\ overall\ density} * 100 = 8.12\%$
Site 2 % EPT May	$\frac{67\ EPT\ organisms}{3000\ overall\ density} * 100 = 2.23\%$	Site 2 %EPT Family Richness May	$\frac{1\ EPT\ Richness}{4\ Overall\ Richness} * 100 = 25.50\%$	Site 2 % Oligochaeta May	$\frac{467\ Oligochaeta\ organisms}{3000\ overall\ density} * 100 = 15.57\%$
Site 2 % EPT August	$\frac{0\ EPT\ organisms}{1600\ overall\ density} * 100 = 0.00\%$	Site 2 %EPT Family Richness August	$\frac{0\ EPT\ Richness}{3\ Overall\ Richness} * 100 = 0.00\%$	Site 2 % Oligochaeta August	$\frac{133\ Oligochaeta\ organisms}{1600\ overall\ density} * 100 = 8.31\%$
Site 2 % EPT October	$\frac{0\ EPT\ organisms}{2400\ overall\ density} * 100 = 0.00\%$	Site 2 %EPT Family Richness October	$\frac{0\ EPT\ Richness}{3\ Overall\ Richness} * 100 = 0.00\%$	Site 2 % Oligochaeta October	$\frac{178\ Oligochaeta\ organisms}{2400\ overall\ density} * 100 = 7.42\%$
Site 3 % EPT May	$\frac{44\ EPT\ organisms}{1200\ overall\ density} * 100 = 3.67\%$	Site 3 %EPT Family Richness May	$\frac{1\ EPT\ Richness}{8\ Overall\ Richness} * 100 = 12.50\%$	Site 3 % Oligochaeta May	$\frac{222\ Oligochaeta\ organisms}{1200\ overall\ density} * 100 = 18.52\%$

Site 3 % EPT August	$\frac{44\ EPT\ organisms}{1867\ overall\ density} * 100 = 2.36\%$	Site 3 %EPT Family Richness August	$\frac{1\ EPT\ Richness}{7\ Overall\ Richness} * 100 = 14.29\%$	Site 3 % Oligochaeta August	$\frac{178\ Oligochaeta\ organisms}{1867\ overall\ density} * 100 = 9.53\%$
Site 3 % EPT October	$\frac{89\ EPT\ organisms}{2800\ overall\ density} * 100 = 3.18\%$	Site 3 %EPT Family Richness October	$\frac{1\ EPT\ Richness}{6\ Overall\ Richness} * 100 = 16.67\%$	Site 3 % Oligochaeta October	$\frac{1956\ Oligochaeta\ organisms}{2800\ overall\ density} * 100 = 69.86\%$
Site 4 % EPT May	$\frac{89\ EPT\ organisms}{711\ overall\ density} * 100 = 12.52\%$	Site 4 %EPT Family Richness May	$\frac{1\ EPT\ Richness}{8\ Overall\ Richness} * 100 = 12.50\%$	Site 4 % Oligochaeta May	$\frac{0\ Oligochaeta\ organisms}{711\ overall\ density} * 100 = 0.00\%$
Site 4 % EPT August	$\frac{0\ EPT\ organisms}{311\ overall\ density} * 100 = 0.00\%$	Site 4 %EPT Family Richness August	$\frac{0\ EPT\ Richness}{5\ Overall\ Richness} * 100 = 0.00\%$	Site 4 % Oligochaeta August	$\frac{89\ Oligochaeta\ organisms}{311\ overall\ density} * 100 = 28.62\%$
Site 4 % EPT October	$\frac{0\ EPT\ organisms}{1778\ overall\ density} * 100 = 0.00\%$	Site 4 %EPT Family Richness October	$\frac{0\ EPT\ Richness}{3\ Overall\ Richness} * 100 = 0.00\%$	Site 4 % Oligochaeta October	$\frac{89\ Oligochaeta\ organisms}{1778\ overall\ density} * 100 = 5.01\%$
Site 5 % EPT May	$\frac{122\ EPT\ organisms}{217\ overall\ density} * 100 = 56.22\%$	Site 5 %EPT Family Richness May	$\frac{3\ EPT\ Richness}{6\ Overall\ Richness} * 100 = 50.00\%$	Site 5 % Oligochaeta May	$\frac{0\ Oligochaeta\ organisms}{217\ overall\ density} * 100 = 0.00\%$
Site 5 % EPT August	$\frac{33\ EPT\ organisms}{189\ overall\ density} * 100 = 17.46\%$	Site 5 %EPT Family Richness August	$\frac{3\ EPT\ Richness}{7\ Overall\ Richness} * 100 = 42.86\%$	Site 5 % Oligochaeta August	$\frac{0\ Oligochaeta\ organisms}{189\ overall\ density} * 100 = 0.00\%$
Site 5 % EPT October	$\frac{83\ EPT\ organisms}{139\ overall\ density} * 100 = 59.71\%$	Site 5 %EPT Family Richness October	$\frac{1\ EPT\ Richness}{5\ Overall\ Richness} * 100 = 20.00\%$	Site 5 % Oligochaeta October	$\frac{0\ Oligochaeta\ organisms}{139\ overall\ density} * 100 = 0.00\%$
Site 6 % EPT May	$\frac{422\ EPT\ organisms}{4156\ overall\ density} * 100 = 10.15\%$	Site 6 %EPT Family Richness May	$\frac{4\ EPT\ Richness}{15\ Overall\ Richness} * 100 = 26.67\%$	Site 6 % Oligochaeta May	$\frac{1000\ Oligochaeta\ organisms}{4156\ overall\ density} * 100 = 24.06\%$
Site 6 % EPT August	$\frac{578\ EPT\ organisms}{2593\ overall\ density} * 100 = 22.29\%$	Site 6 %EPT Family Richness August	$\frac{5\ EPT\ Richness}{15\ Overall\ Richness} * 100 = 33.33\%$	Site 6 % Oligochaeta August	$\frac{104\ Oligochaeta\ organisms}{2593\ overall\ density} * 100 = 4.01\%$
Site 6 % EPT October	$\frac{1141\ EPT\ organisms}{1881\ overall\ density} * 100 = 60.66\%$	Site 6 %EPT Family Richness October	$\frac{2\ EPT\ Richness}{14\ Overall\ Richness} * 100 = 14.29\%$	Site 6 % Oligochaeta October	$\frac{99\ Oligochaeta\ organisms}{1881\ overall\ density} * 100 = 5.26\%$

Appendix C

Field Data

Sampling conditions during each sampling event

Date	Time	Weather
May 23, 2013	11:00 AM-3:00 PM	Overcast with spots of sun and a temperature near 80°F
August 25, 2013	11:00 AM-3:00 PM	Sunny with a temperature above 80°F
September 14, 2013	11:00 AM-5:00 PM	Sunny with temperature in the 70°F range
October 26, 2013	11:00 AM-3:00 PM	Overcast with temperature around 50°F

Site name, location and QHEI score.

Site Nickname	Abbreviation	Site Number	UTM		QHEI Score
Land Bridge-Gravel	LBG	Site 0	N 0514715	E 4592827	44
Land Bridge-Sand	LBS	Site 1	N 0514881	E 4593021	32
Wood Bridge	WB	Site 2	N 0514961	E 4594010	28
Downstream of wood bridge	DWB	Site 3	N 0514968	E 4594375	30
Mouth of Side Stream	MSS	Site 4	N 0514973	E 4594880	27
Side Stream	SS	Site 5	N 0515004	E 4594887	40
Moore Road Bridge	MRB	Site 6	N 0514988	E 4596434	55

Field Data

Location	Site #	Date	Temp (°C)	pH	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/m)	Flow (m/s)
Land Bridge-Gravel	0	5/23/2013	22.60	8.03	45.70	4.04	270.00	0.10
Land Bridge-Sand	1	5/23/2013	22.00	7.85	58.10	5.09	274.10	< 0.1
Wood Bridge	2	5/23/2013	22.40	7.66	58.50	5.11	279.00	< 0.1
Downstream of wood bridge	3	5/23/2013	22.50	7.68	57.70	5.03	278.50	< 0.1
Mouth of Side Stream	4	5/23/2013	22.50	7.82	57.10	4.90	303.70	0.20
Side Stream	5	5/23/2013	21.80	7.95	60.00	5.24	351.30	1.00
Moore Road Bridge	6	5/23/2013	22.70	7.77	54.40	4.69	288.90	1.40
Land Bridge-Gravel	0	8/25/2013		7.99	103.50	8.80	377.00	0.90
Land Bridge-Sand	1	8/25/2013		8.06	132.50	11.70	361.00	< 0.1
Wood Bridge	2	8/25/2013		7.88	98.10	8.67	363.00	< 0.1
Downstream of wood bridge	3	8/25/2013		8.51	174.10	15.61	303.00	< 0.1
Moore Rd Bridge	6	8/25/2013		7.93	112.70	9.59	315.00	not taken
Land Bridge-Gravel	0	9/14/2013	14.80	7.62	82.50	8.26	287.30	1.90
Side Stream	5	9/14/2013	17.60	8.11	110.60	10.52	279.40	0.25
Mouth of Side Stream	4	9/14/2013	18.40	8.27	128.10	12.20	288.10	not taken
Moore Rd Bridge	6	9/14/2013	20.30	7.88	110.70	9.99	297.30	0.80
Reference Stream-South	NA	9/14/2013	14.70	7.70	58.30	5.85	54.60	<0.1
Reference Stream-North	NA	9/14/2013	14.70	7.12	56.60	5.93	53.80	<0.1
Land Bridge-Gravel	0	10/26/2013	6.10	7.01	93.10	11.59	140.80	2.20
Land Bridge-Sand	1	10/26/2013	6.00	7.23	99.40	12.15	142.00	slow
Wood Bridge	2	10/26/2013	6.20	7.46	121.80	14.40	149.70	0.30
Downstream of wood bridge	3	10/26/2013	6.20	7.51	117.20	14.47	152.00	0.50
Mouth of Side Stream	4	10/26/2013	6.10	7.60	118.60	14.52	152.50	0.40
Side Stream	5	10/26/2013	7.00	7.64	99.50	12.07	185.70	1.20
Moore Road Bridge	6	10/26/2013	6.20	7.49	100.10	12.32	148.20	1.90

Appendix D

Water Quality Data

Coliform-Fecal and Total

$$\textit{(total)}\ \text{coliform}/100\text{mL} = \frac{\text{coliform colonies counted} * 100}{\text{mL sample filtered}}$$

$$\text{total number of colonies} = \frac{(\text{colonies from plate 1} + \text{colonies from plate 2})}{(\text{volume of filtered water for plate 1} + \text{volume of filtered water for plate 2})} * 100$$

Acceptable range 20-80 colonies
Italics = estimated coliform colonies, either <20 or >80 colonies on plate

Location	**Date**	**Volume of Water (mL)**	**Total Coliform Colonies Counts**	**Total Coliform per 100 mL**	**Fecal Coliform Colonies Count**	**Fecal Coliform per 100 mL**
Land Bridge-Gravel	5/23/2013	0.1	3		0	0
		1	1		0	0
		10	0	0	7	
Land Bridge-Sand	5/23/2013	0.1	1		0	0
		1	5		1	
		10	**25**	**250**	**26**	**260**
Wood Bridge	5/23/2013	0.1	2		0	0
		1	1		1	
		10	0	0	4	
Downstream of Wood Bridge	5/23/2013	0.1	0	0	0	0
		1	0	0	0	0
		10	0	0	4	
Mouth of Side Stream	5/23/2013	0.1	1		0	0
		1	3		3	
		10	11	*110*	*16*	*160*
Side Stream	5/23/2013	0.1	1		1	
		1	*11*		5	
		10	*18*	*263.6*	55	550
Moore Road Bridge	5/23/2013	0.1	1		0	0
		1	4		0	0
		10	14	*140*	8	*80*
Blank 1			0		0	
Blank 2			0		0	

Location	**Date**	**Volume of Water (mL)**	**Total Coliform Colonies Counts**	**Total Coliform per 100 mL**	**Fecal Coliform Colonies Count**	**Fecal Coliform per 100 mL**
Land Bridge-Gravel	8/25/2013	0.1	0	*0*	0	*0*
		1	8	*800*	1	*100*
		10	**48**	***480***	12	*120*
Land Bridge-Sand	8/25/2013	0.1	0	*0*	0	*0*
		1	11	*1100*	3	*300*
		10	**20**	***200***	19	*190*
Wood Bridge	8/25/2013	0.1	0	*0*	2	*2000*
		1	1	*100*	4	*400*
		10	**46**	***460***	**37**	***370***
Downstream of Wood Bridge	8/25/2013	0.1	0	*0*	1	*1000*
		1	7	*700*	1	*100*
		10	**36**	***360***	**30**	***300***
Moore Road Bridge	8/25/2013	0.1	4	*4000*	1	*1000*
		1	19	*1900*	4	*400*
		10	**22**	***220***	**22**	***220***
Blank 1			0	0	0	*0*
Blank 2			0	0	0	*0*

Location	**Date**	**Volume of Water (mL)**	**Total Coliform Colonies Counts**	**Total Coliform per 100 mL**	**Fecal Coliform Colonies Count**	**Fecal Coliform per 100 mL**
Mouth of Side Stream	9/14/2013	0.1	3	*3000*	0	*0*
		1	5	*500*	1	*100*
		10	**20**	***200***	7	*70*
Side Stream	9/14/2013	0.1	4	*4000*	1	*1000*
		1	**29**	***2900***	4	*400*
		10	**64**	***640***	**21**	***210***
Reference Stream	9/14/2013	0.1	12	*12000*	2	*2000*
		1	**64**	***6400***	16	*1600*
		10	**72**	***720***	**59**	***590***
Blank 1			0	0	0	0
Blank 2			0	0	0	0

Location	**Date**	**Volume of Water (mL)**	**Total Coliform Colonies Counts**	**Total Coliform per 100 mL**	**Fecal Coliform Colonies Count**	**Fecal Coliform per 100 mL**
Land Bridge-Gravel	10/26/2013	0.1	1	1000	0	0
		1	1	100	1	100
		10	**24**	**240**	16	160
Land Bridge-Sand	10/26/2013	0.1	1	1000	1	1000
		1	1	100	1	100
		10	**26**	**260**	**24**	**240**
Wood Bridge	10/26/2013	0.1	0	0	0	0
		1	0	0	1	100
		10	0	0	**27**	**270**
Downstream of Wood Bridge	10/26/2013	0.1	0	0	0	0
		1	9	900	2	200
		10	17	170	17	170
Mouth of Side Stream	10/26/2013	0.1	0	0	0	0
		1	0	0	2	200
		10	0	0	*19*	190
Side Stream	10/26/2013	0.1	3	3000	3	3000
		1	*11*	1100	10	1000
		10	***48***	**480**	**35**	**350**
Moore Road Bridge	10/26/2013	0.1	5	5000	0	0
		1	11	1100	2	200
		10	18	180	15	150
Blank 1			0	*0*	0	0
Blank 2			0	*0*	0	*0*

Chemical Oxygen Demand

Location	**Date**	**Absorbance**	**Concentration COD, mg/L**
Land Bridge-Gravel 1	5/23/2013	0.388	29.531
Land Bridge-Gravel 2	5/23/2013	0.639	-48.906
	5/23/2013*	0.312	53.281
Land Bridge-Sand 1	5/23/2013	0.507	-7.656
Land Bridge-Sand 2	5/23/2013	0.439	13.594
	5/23/2013*	0.338	45.156
Wood Bridge 1	5/23/2013	0.292	59.531
Wood Bridge 2	5/23/2013	0.428	17.031
	5/23/2013*	0.330	47.656
Downstream Wood Bridge 1	5/23/2013	0.357	39.219
Downstream Wood Bridge 2	5/23/2013	0.320	50.781
	5/23/2013*	0.334	46.406
Mouth of Side Stream 1	5/23/2013	0.524	-12.969
Mouth of Side Stream 2	5/23/2013	0.305	55.469
	5/23/2013*	0.367	36.094
Side Stream 1	5/23/2013	0.406	23.906
Side Stream 2	5/23/2013	0.414	21.406
	5/23/2013*	0.486	-1.094
Moore Road Bridge 1	5/23/2013	0.517	-10.781
Moore Road Bridge 2	5/23/2013	0.505	-7.031
	5/23/2013*	0.386	30.156

* Second analysis b/c of inconsistencies in results

Standard COD (ppm)		**Absorbance**	
150		0	
100		0.165	
75		0.226	
50		0.324	
25		0.417	
0		0.474	

Location	**Date**	**Absorbance**	**Concentration COD, mg/L**
Land Bridge-Gravel 1	8/25/2013	0.359	39.75
Land Bridge-Gravel 2	8/25/2013	0.361	39.13
Land Bridge-Sand 1	8/25/2013	0.403	26.00
Land Bridge-Sand 2	8/25/2013	0.383	32.25
Wood Bridge 1	8/25/2013	0.368	36.94
Wood Bridge 2	8/25/2013	0.413	22.88
Downstream Wood Bridge 1	8/25/2013	0.361	39.13
Downstream Wood Bridge 2	8/25/2013	0.397	27.88
Mouth of Side Stream 1	9/14/2013	0.488	-0.56
Mouth of Side Stream 2	9/14/2013	0.435	16.00
Side Stream 1	9/14/2013	0.635	-46.50
Side Stream 2	9/14/2013	0.537	-15.88
Moore Road Bridge 1	8/25/2013	0.374	35.06
Moore Road Bridge 2	8/25/2013	0.401	26.63
Reference Stream 1	9/14/2013	0.613	-39.63
Reference Stream 2	9/14/2013	0.404	25.69
Standard COD (ppm)		**Absorbance**	
150		0	
100		0.169	
50		0.322	
25		0.414	
0		0.480	

Location	**Date**	**Absorbance**	**Concentration COD, mg/L**
Land Bridge-Gravel 1	10/26/2013	0.321	51.6875
Land Bridge-Gravel 2	10/26/2013	0.335	47.3125
Land Bridge-Sand 1	10/26/2013	0.321	51.6875
Land Bridge-Sand 2	10/26/2013	0.31	55.125
Wood Bridge 1	10/26/2013	0.322	51.375
Wood Bridge 2	10/26/2013	0.358	40.125
Downstream Wood Bridge 1	10/26/2013	0.351	42.3125
Downstream Wood Bridge 2	10/26/2013	0.335	47.3125
Mouth of Side Stream 1	10/26/2013	0.294	60.125
Mouth of Side Stream 2	10/26/2013	0.357	40.4375
Side Stream 1	10/26/2013	0.398	27.625
Side Stream 2	10/26/2013	0.402	26.375
Moore Road Bridge 1	10/26/2013	0.362	38.875
Moore Road Bridge 2	10/26/2013	0.361	39.1875
Standard COD (ppm)		**Absorbance**	
150		0	
100		0.182	
50		0.342	
25		0.421	
0		0.463	

Biochemical Oxygen Demand

BOD_5 Equation		$BOD_5 = [(D1-D2)-(B1-B2)]/P$					
Location	**Date**	**Amount (mL)**	**Initial DO D1 (May 24, 2013 at 6:40 pm)**	**Final DO D2 (May 29, 2013 at 4:30 pm)**	**D1-D2**	**P**	**BOD5 mg/L**
Land Bridge-Gravel	5/23/2013	25	7.98	4.88	3.10	0.08	13.56
	5/23/2013	50	8.11	5.11	3.00	0.17	6.18
	5/23/2013	100	8.36	5.09	3.27	0.33	3.90
	5/23/2013	200	8.79	5.32	3.47	0.67	2.25
Land Bridge-Sand	5/23/2013	25	7.93	5.48	2.45	0.08	5.76
	5/23/2013	50	8.04	5.14	2.90	0.17	5.58
	5/23/2013	100	8.19	5.35	2.84	0.33	2.61
	5/23/2013	200	8.55	5.14	3.41	0.67	2.16
Wood Bridge	5/23/2013	25	7.95	5.68	2.27	0.08	3.60
	5/23/2013	50	7.97	5.85	2.12	0.17	0.90
	5/23/2013	100	8.11	5.88	2.23	0.33	0.78
	5/23/2013	200	8.39	5.94	2.45	0.67	0.71
Downstream of Wood Bridge	5/23/2013	25	7.96	5.07	2.89	0.08	11.04
	5/23/2013	50	7.95	5.06	2.89	0.17	5.52
	5/23/2013	100	7.98	5.12	2.86	0.33	2.67
	5/23/2013	200	8.07	4.44	3.63	0.67	2.49
Mouth of Side Stream	5/23/2013	25	7.99	5.48	2.51	0.08	6.48
	5/23/2013	50	8.10	5.16	2.94	0.17	5.82
	5/23/2013	100	8.34	5.85	2.49	0.33	1.56
	5/23/2013	200	8.84	6.33	2.51	0.67	0.81
Side Stream	5/23/2013	25	7.97	5.44	2.53	0.08	6.72
	5/23/2013	50	8.03	5.54	2.49	0.17	3.12
	5/23/2013	100	8.25	5.20	3.05	0.33	3.24
	5/23/2013	200	8.55	5.79	2.76	0.67	1.19
Moore Road Bridge	5/23/2013	25	7.91	5.34	2.57	0.08	7.20
	5/23/2013	50	8.02	5.12	2.90	0.17	5.58
	5/23/2013	100	8.21	5.08	3.13	0.33	3.48
	5/23/2013	200	8.56	5.63	2.93	0.67	1.44
GGA 1 (198 +/- 30 mg/L)		6	7.92	2.09	5.83	0.02	193.00
GGA 2 (198 +/- 30 mg/L)		6	7.84	1.94	5.90	0.02	196.50
Blank 1 (goal <0.2 mg/L)			7.89	7.44	0.45		
Blank 2 (goal <0.2 mg/L)			7.87	7.61	0.26		
Seeded Blank 1 (B1-B2)			7.86	5.89	1.97		
Seeded Blank 2 (B1-B2)			7.85	5.88	1.97		

Location	Date	Amount (mL)	Initial DO D1 (Aug 26, 2013 at 4 pm)	Final DO D2 (May 29, 2013 at 4:30 pm)	D1-D2	P	BOD5 mg/L
Land Bridge-Gravel	8/25/2013	25	7.96	7.14	0.82	0.08	
	8/25/2013	50	8.13	7.17	0.96	0.17	
	8/25/2013	100	8.39	7.23	1.16	0.33	0.03
	8/25/2013	200	8.86	6.59	2.27	0.67	1.68
Land Bridge-Sand	8/25/2013	25	8.18	7.17	1.01	0.08	
	8/25/2013	50	8.36	7.40	0.96	0.17	
	8/25/2013	100	8.66	7.48	1.18	0.33	0.09
	8/25/2013	200	9.57	7.50	2.07	0.67	1.38
Wood Bridge	8/25/2013	25	8.12	7.16	0.96	0.08	
	8/25/2013	50	8.17	7.28	0.89	0.17	
	8/25/2013	100	8.32	7.44	0.88	0.33	
	8/25/2013	200	8.77	7.29	1.48	0.67	0.50
Downstream of Wood Bridge	8/25/2013	25	8.24	7.36	0.88	0.08	
	8/25/2013	50	8.57	7.21	1.36	0.17	1.26
	8/25/2013	100	9.30	7.27	2.03	0.33	2.64
	8/25/2013	200	10.44	8.47	1.97	0.67	1.23
Moore Road Bridge	8/25/2013	25	8.09	6.71	1.38	0.08	2.76
	8/25/2013	50	8.22	7.05	1.17	0.17	0.12
	8/25/2013	100	8.46	6.06	2.4	0.33	3.75
	8/25/2013	200	8.93	6.92	2.01	0.67	1.29
GGA 1 (198 +/- 30 mg/L)		6	8.01	3.09	4.92	0.02	188.50
GGA 2 (198 +/- 30 mg/L)		6	7.93	3.05	4.88	0.02	186.50
Blank 1 (goal <0.2 mg/L)			7.95	7.75	0.2		
Blank 2 (goal <0.2 mg/L)			7.95	7.78	0.17		
Seeded Blank 1 (B1-B2)			7.93	6.78	1.15		
Seeded Blank 2 (B1-B2)			7.90	6.54	1.36		

Location	**Date**	**Amount (mL)**	**Initial DO D1 (Aug 26, 2013 at 4 pm)**	**Final DO D2 (May 29, 2013 at 4:30 pm)**	**D1-D2**	**P**	**BOD5 mg/L**
Mouth of Side Stream	9/14/2013	25	9.60	7.27	2.33	0.08	14.16
	9/14/2013	50	9.88	7.33	2.55	0.17	8.40
	9/14/2013	100	10.55	7.93	2.62	0.33	4.41
	9/14/2013	200	11.71	8.63	3.08	0.67	2.90
Side Stream	9/14/2013	25	9.44	7.01	2.43	0.08	15.36
	9/14/2013	50	9.65	7.09	2.56	0.17	8.46
	9/14/2013	100	10.07	7.27	2.8	0.33	4.95
	9/14/2013	200	10.91	7.80	3.11	0.67	2.94
Reference Stream	9/14/2013	25	9.50	7.01	2.49	0.08	16.08
	9/14/2013	50	9.56	6.85	2.71	0.17	9.36
	9/14/2013	100	9.81	6.91	2.9	0.33	5.25
	9/14/2013	200	10.39	6.76	3.63	0.67	3.72
GGA 1 (198 +/- 30 mg/L)		6	9.40	2.74	6.66	0.02	275.50
GGA 2 (198 +/- 30 mg/L)		6	9.32	3.25	6.07	0.02	246.00
Blank 1 (goal <0.2 mg/L)			9.31	8.26	1.05		
Blank 2 (goal <0.2 mg/L)			9.33	8.28	1.05		
Seeded Blank 1 (B1-B2)			9.29	6.98	2.31		
Seeded Blank 2 (B1-B2)			9.30	7.03	2.27		

Location	**Date**	**Amount (mL)**	**Initial DO D1 (October 28, 2013 at 1:30 pm)**	**Final DO D2 (November 2, 2013 at 11:30 am)**	**D1-D2**	**P**	**BOD5 mg/L**
Land Bridge-Gravel	10/26/2013	25	8.63	6.65	1.98	0.08	0.12
	10/26/2013	50	8.83	6.71	2.12	0.17	0.90
	10/26/2013	100	9.07	6.81	2.26	0.33	0.87
	10/26/2013	200	9.84	6.64	3.20	0.67	1.85
Land Bridge-Sand	10/26/2013	25	8.74	6.69	2.05	0.08	0.96
	10/26/2013	50	8.94	6.85	2.09	0.17	0.72
	10/26/2013	100	9.16	7.11	2.05	0.33	0.24
	10/26/2013	200	10.18	7.44	2.74	0.67	1.16
Wood Bridge	10/26/2013	25	8.80	7.00	1.80	0.08	
	10/26/2013	50	9.04	7.23	1.81	0.17	
	10/26/2013	100	9.25	7.23	2.02	0.33	0.15
	10/26/2013	200	10.71	7.87	2.84	0.67	1.31
Downstream of Wood Bridge	10/26/2013	25	8.78	6.55	2.23	0.08	3.12
	10/26/2013	50	9.05	7.29	1.76	0.17	
	10/26/2013	100	9.42	7.44	1.98	0.33	0.03
	10/26/2013	200	10.76	7.82	2.94	0.67	1.46
Mouth of Side Stream	10/26/2013	25	8.81	7.08	1.73	0.08	
	10/26/2013	50	9.07	7.42	1.65	0.17	
	10/26/2013	100	9.45	7.50	1.95	0.33	
	10/26/2013	200	10.73	8.06	2.67	0.67	1.05
Side Stream	10/26/2013	25	8.75	6.91	1.84	0.08	
	10/26/2013	50	8.94	7.46	1.48	0.17	
	10/26/2013	100	9.16	7.47	1.69	0.33	
	10/26/2013	200	10.22	7.85	2.37	0.67	0.60
Moore Road Bridge	10/26/2013	25	8.71	6.91	1.80	0.08	
	10/26/2013	50	8.86	7.32	1.54	0.17	
	10/26/2013	100	9.08	7.48	1.60	0.33	
	10/26/2013	200	9.99	7.80	2.19	0.67	0.33
GGA 1 (198 +/- 30 mg/L)		6	8.54	2.63	5.91	0.02	197.00
GGA 2 (198 +/- 30 mg/L)		6	8.49	2.40	6.09	0.02	206.00
Blank 1 (goal <0.2 mg/L)			8.49	8.07	0.42		
Blank 2 (goal <0.2 mg/L)			8.52	8.05	0.47		
Seeded Blank 1 (B1-B2)			8.51	6.78	1.73		
Seeded Blank 2 (B1-B2)			8.52	6.84	1.68		

Soluble Reactive Phosphorus

Location	**Date**	**Absorbance**	**Conc. mg/L**	**DF**	**Total SRP, mg/L**	**Total SRP, µg/L**
Land Bridge-Gravel 1	5/23/2013	0.053	0.079	1.160	0.092	92.091
Land Bridge-Gravel 2	5/23/2013	0.051	0.076	1.160	0.089	88.616
Land Bridge-Sand 1	5/23/2013	0.070	0.105	1.160	0.122	121.630
Land Bridge-Sand 2	5/23/2013	0.068	0.102	1.160	0.118	118.155
Wood Bridge 1	5/23/2013	0.052	0.078	1.160	0.090	90.354
Wood Bridge 2	5/23/2013	0.054	0.081	1.160	0.094	93.829
Downstream Wood Bridge 1	5/23/2013	0.015	0.022	1.160	0.026	26.064
Downstream Wood Bridge 2	5/23/2013	0.015	0.022	1.160	0.026	26.064
Mouth of Side Stream 1	5/23/2013	0.065	0.097	1.160	0.113	112.942
Mouth of Side Stream 2	5/23/2013	0.065	0.097	1.160	0.113	112.942
Side Stream 1	5/23/2013	0.019	0.028	1.160	0.033	33.014
Side Stream 2	5/23/2013	0.017	0.025	1.160	0.030	29.539
Moore Road Bridge 1	5/23/2013	0.040	0.060	1.160	0.070	69.503
Moore Road Bridge 2	5/23/2013	0.041	0.061	1.160	0.071	71.240
Standard Phosphate (ppm)		**Absorbance**				
0.200		0.146				
0.600		0.433				
0.800		0.580				
1.000		0.710				
1.500		0.934				

Location	**Date**	**Absorbance**	**Conc. mg/L**	**DF**	**Total SRP, mg/L**	**Total SRP, µg/L**
Land Bridge-Gravel 1	8/25/2013	0.030	0.040	1.160	0.047	46.518
Land Bridge-Gravel 2	8/25/2013	0.030	0.040	1.160	0.047	46.518
Land Bridge-Sand 1	8/25/2013	0.036	0.048	1.160	0.056	55.821
Land Bridge-Sand 2	8/25/2013	0.037	0.049	1.160	0.057	57.372
Wood Bridge 1	8/25/2013	0.032	0.043	1.160	0.050	49.619
Wood Bridge 2	8/25/2013	0.033	0.044	1.160	0.051	51.170
Downstream Wood Bridge 1	8/25/2013	0.033	0.044	1.160	0.051	51.170
Downstream Wood Bridge 2	8/25/2013	0.033	0.044	1.160	0.051	51.170
Moore Road Bridge 1	8/25/2013	0.028	0.037	1.160	0.043	43.417
Moore Road Bridge 2	8/25/2013	0.026	0.035	1.160	0.040	40.315
Standard Phosphate (ppm)		**Absorbance**				
0		0				
0.010		0.010				
0.050		0.039				
0.100		0.078				
0.200		0.152				
0.400		0.297				

Location	**Date**	**Absorbance**	**Conc. mg/L**	**DF**	**Total SRP, mg/L**	**Total SRP, µg/L**
Mouth of Side Stream 1	9/14/2013	0.033	0.030	1.160	0.035	35.048
Mouth of Side Stream 2	9/14/2013	0.033	0.030	1.160	0.035	35.048
Side Stream 1	9/14/2013	0.025	0.019	1.160	0.022	22.007
Side Stream 2	9/14/2013	0.024	0.018	1.160	0.020	20.377
Reference Stream 1	9/14/2013	0.067	0.078	1.160	0.090	90.472
Reference Stream 2	9/14/2013	0.068	0.079	1.160	0.092	92.102
Standard Phosphate (ppm)		**Absorbance**				
0		0				
0.010		0.080				
0.050		0.372				
0.100		0.721				
0.200		0.971				
0.400		1.125				

Location	**Date**	**Absorbance**	**Conc. mg/L**	**DF**	**Total SRP, mg/L**	**Total SRP, µg/L**
Land Bridge-Gravel 1	10/26/2013	0.030	0.042	1.160	0.049	48.514
Land Bridge-Gravel 2	10/26/2013	0.029	0.040	1.160	0.047	46.969
Land Bridge-Sand 1	10/26/2013	0.033	0.046	1.160	0.053	53.149
Land Bridge-Sand 2	10/26/2013	0.031	0.043	1.160	0.050	50.059
Wood Bridge 1	10/26/2013	0.030	0.042	1.160	0.049	48.514
Wood Bridge 2	10/26/2013	0.030	0.042	1.160	0.049	48.514
Downstream Wood Bridge 1	10/26/2013	0.028	0.039	1.160	0.045	45.424
Downstream Wood Bridge 2	10/26/2013	0.027	0.038	1.160	0.044	43.879
Mouth of Side Stream 1	10/26/2013	0.029	0.040	1.160	0.047	46.969
Mouth of Side Stream 2	10/26/2013	0.029	0.040	1.160	0.047	46.969
Side Stream 1	10/26/2013	0.021	0.030	1.160	0.035	34.608
Side Stream 2	10/26/2013	0.019	0.027	1.160	0.032	31.518
Moore Road Bridge 1	10/26/2013	0.022	0.031	1.160	0.036	36.153
Moore Road Bridge 2	10/26/2013	0.022	0.031	1.160	0.036	36.153
Standard Phosphate (ppm)		**Absorbance**				
0		0				
0.010		0.008				
0.050		0.035				
0.100		0.073				
0.200		0.145				
0.400		0.301				

Ammonia

Location	**Date**	**Absorbance**	**Concentration mg/L**
Land Bridge-Gravel 1	5/23/2013	0.057	0.10555
Land Bridge-Sand 1	5/23/2013	0.039	0.08236
Wood Bridge 1	5/23/2013	0.025	0.06431
Downstream Wood Bridge 1	5/23/2013	0.026	0.06560
Mouth of Side Stream 1	5/23/2013	0.039	0.08236
Side Stream 1	5/23/2013	0.035	0.07720
Moore Road Bridge 1	5/23/2013	0.047	0.09267
Standard Ammonia (ppm)		**Absorbance**	
0		0	
0.1		0.060	
0.2		0.117	
0.4		0.281	
0.6		0.395	
1		0.782	

Location	**Date**	**Absorbance**	**Concentration mg/L**
Land Bridge-Gravel 1	8/25/2013	0.023	0.05365
Land Bridge-Gravel 2	8/25/2013	0.032	0.06740
Land Bridge-Sand 1	8/25/2013	0.054	0.10102
Land Bridge-Sand 2	8/25/2013	0.062	0.11325
Wood Bridge 1	8/25/2013	0.004	0.02461
Wood Bridge 2	8/25/2013	0.011	0.03530
Downstream Wood Bridge 1	8/25/2013	0.004	0.02461
Downstream Wood Bridge 2	8/25/2013	0.011	0.03530
Mouth of Side Stream 1	9/14/2013	0.003	0.02308
Mouth of Side Stream 2	9/14/2013	0.003	0.02308
Side Stream 1	9/14/2013	0.007	0.02919
Side Stream 2	9/14/2013	0.004	0.02461
Moore Road Bridge 1	8/25/2013	0.028	0.06129
Moore Road Bridge 2	8/25/2013	0.021	0.05059
Reference Stream 1	9/14/2013	0.101	0.17286
Reference Stream 2	9/14/2013	0.098	0.16827
Standard Ammonia (ppm)		**Absorbance**	
0		0	
0.1		0.027	
0.2		0.108	
0.4		0.248	
0.6		0.433	
1		0.616	

Location	**Date**	**Absorbance**	**Concentration mg/L**
Land Bridge-Gravel 1	10/26/2013	0.005	0.0096185
Land Bridge-Gravel 2	10/26/2013	0.003	0.0074111
Land Bridge-Sand 1	10/26/2013	0.01	0.015137
Land Bridge-Sand 2	10/26/2013	0.008	0.0129296
Wood Bridge 1	10/26/2013	0.011	0.0162407
Wood Bridge 2	10/26/2013	0.031	0.0383147
Downstream Wood Bridge 1	10/26/2013	0.008	0.0129296
Downstream Wood Bridge 2	10/26/2013	0.006	0.0107222
Mouth of Side Stream 1	10/26/2013	0.002	0.0063074
Mouth of Side Stream 2	10/26/2013	0.004	0.0085148
Side Stream 1	10/26/2013	0.031	0.0383147
Side Stream 2	10/26/2013	0.013	0.0184481
Moore Road Bridge 1	10/26/2013	0.007	0.0118259
Moore Road Bridge 2	10/26/2013	0.005	0.0096185
Standard Ammonia (ppm)		**Absorbance**	
0		0	
0.1		0.092	
0.2		0.235	
0.4		0.456	
0.6		0.691	
1		1.089	

Nitrate

Location	**Date**	**Absorbance**	**Concentration mg/L**
Land Bridge-Gravel 1	5/23/2013	0.031	0.1063
Land Bridge-Gravel 2	5/23/2013	0.037	0.1284
Land Bridge-Sand 1	5/23/2013	0.021	0.0695
Land Bridge-Sand 2	5/23/2013	0.015	0.0475
Wood Bridge 1	5/23/2013	0	0.0000
Wood Bridge 2	5/23/2013	0	0.0000
Downstream Wood Bridge 1	5/23/2013	0	0.0000
Downstream Wood Bridge 2	5/23/2013	0	0.0000
Mouth of Side Stream 1	5/23/2013	0.002	0.0000
Mouth of Side Stream 2	5/23/2013	0.003	0.0033
Side Stream 1	5/23/2013	0.257	0.9378
Side Stream 2	5/23/2013	0.386	1.4124
Moore Road Bridge 1	5/23/2013	0.046	0.1615
Moore Road Bridge 2	5/23/2013	0.053	0.1873
Standard Nitrate (ppm)		**Absorbance**	
0		0	
0.05		0.022	
0.1		0.025	
1		0.274	

Nitrate concentrations using a ion selective electrode

Location	**Date**	**Electrode Reading**	**Concentration mg/L**
Land Bridge-Gravel 1	8/25/2013	143.1	1.3559
Land Bridge-Sand 1	8/25/2013	147.0	1.0549
Wood Bridge 1	8/25/2013	147.0	1.0549
Downstream Wood Bridge 1	8/25/2013	155.0	0.4376
Mouth of Side Stream 1	9/14/2013	148.0	0.9778
Side Stream 1	9/14/2013	152.8	0.6073
Moore Road Bridge 1	8/25/2013	157.8	0.2215
Reference Stream 1	9/14/2013	170.9	-0.7895
Standard Nitrate (ppm)	**log (Conc)**	**Electrode Reading**	
0		175.9	
0.05	-1.301	174.1	
0.1	-1.000	172.6	
0.2	-0.699	172.6	
0.5	-0.301	169.1	
1	0.000	160.7	
2	0.301	155.0	
4	0.602	153.9	
10	1.000	145.5	

Location	**Date**	**Electrode Reading**	**Concentration mg/L**
Land Bridge-Gravel 1	10/26/2013	110.8	0
Land Bridge-Sand 1	10/26/2013	104.6	0
Wood Bridge 1	10/26/2013	96.7	0
Downstream Wood Bridge 1	10/26/2013	94.5	0.0007
Mouth of Side Stream 1	10/26/2013	91.6	0.0524
Side Stream 1	10/26/2013	57.4	0.6618
Moore Road Bridge 1	10/26/2013	84.9	0.1718
Standard Nitrate (ppm)	**log (Conc)**	**Electrode Reading**	
0		110.8	
0.5	-0.3010	109.1	
1	0	96.7	
2	0.3010	78.7	
4	0.6020	61.1	
10	1	37.2	

Hardness concentrations using titration

Location	**Date**	**mL titration for sample**	**Hardness mg $CaCO_3$/L**
Blank		0	0
Land Bridge-Gravel 1	5/23/2013	3.5	140
Land Bridge-Sand 1	5/23/2013	4.3	172
Wood Bridge 1	5/23/2013	3.6	144
Downstream Wood Bridge 1	5/23/2013	4.1	164
Mouth of Side Stream 1	5/23/2013	4	160
Side Stream 1	5/23/2013	5	200
Moore Road Bridge 1	5/23/2013	4.1	164
Land Bridge-Gravel 1	8/25/2013	5.2	208
Land Bridge-Sand 1	8/25/2013	4.9	196
Wood Bridge 1	8/25/2013	5.5	220
Downstream Wood Bridge 1	8/25/2013	4.3	172
Mouth of Side Stream 1	9/14/2013	5.1	204
Side Stream 1	9/14/2013	4.9	196
Moore Road Bridge 1	8/25/2013	4.5	180
Reference Stream	9/14/2013	1.1	44
Land Bridge-Gravel 1	10/26/2013	3.1	124
Land Bridge-Sand 1	10/26/2013	3.5	140
Wood Bridge 1	10/26/2013	2.9	116
Downstream Wood Bridge 1	10/26/2013	3.3	132
Mouth of Side Stream 1	10/26/2013	3.4	136
Side Stream 1	10/26/2013	4.6	184
Moore Road Bridge 1	10/26/2013	3.2	128
$CaCO_3$		25.2	1008

Select soluble metals from water samples

Elem	Cd2144	Cu2199	Fe2598	Ni2216	Pb2203	Zn2138
Site	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
LBG-5	.0003	.0022	2.377	.0037	.0014	.0044
LBG-8	.0001	.0006	0.8114	.0054	.0024	.0212
LBG-10	.0002	.0049	0.5272	.0055	.0019	.0188
LBS-5	.0002	.0014	2.417	.0038	.0024	.0077
LBS-8	.0001	-.0004	1.002	.0031	.0019	.0042
LBS-10	.0000	.0027	0.6429	.0346	.0012	.0114
WB-5	.0000	.0000	1.228	.0031	.0002	0
WB-8	.0001	.0026	1.528	.0034	.0026	.0105
WB-10	.0000	.0033	0.6205	.0388	.0017	.0115
DWB-5	.0000	.0001	1.174	.0027	.0010	.0017
DWB-8	.0001	.0002	0.7498	.0014	.0008	.0014
DWB-10	.0000	.0023	0.6929	.0059	.0020	.0151
MSS-5	.0001	.0011	1.938	.0034	.0030	.0058
MSS-8	0	.0007	0.7125	.0020	.0010	.0031
MSS-10	.0000	.0036	0.5839	.0075	.0001	.0031
SS-5	.0001	.0018	0.7944	.0039	.0019	.0032
SS-8	.0001	.0000	0.856	.0053	.0017	.0121
SS-10	.0000	.0016	0.2716	.0015	0	0
MRB-5	.0001	.0035	0.9596	.0036	.0011	.0046
MRB-8	.0007	.0178	4.343	.0113	.0240	.0391
MRB-10	.0001	.0040	0.4742	.0065	.0003	.0061
RS-8	.0001	.0021	2.577	.0024	.0010	.0053
QC-1	.9944	1.164	0.9491	1.110	1.031	.9852
QC-1	1.012	1.179	0.9367	1.126	1.042	.9992
QC-1	1.013	1.184	0.9389	1.129	1.044	1.001
Blank	.0000	.0005	0.0001	.0003	.0001	.0020
0.1 ppm	.0626	.0060	0.0008	.0261	.0055	.0508
0.5 ppm	.3017	.0264	0.003	.1252	.0263	.2395
1.0 ppm	.5899	.0521	0.0056	.2465	.0515	.4730
2.5 ppm	1.463	.1292	0.014	.6141	.1281	1.162
5.0 ppm	2.827	.2524	0.0272	1.208	.2499	2.231

Appendix E

Solids and Organic Matter

Organic matter and sediment fractions in water samples

Location	Crucible and sediment before burning (g)	Crucible and sediment after burning (g)	crucible (g)	Sediment before burning (g)	Sediment after burning (g)	Organic material burnt off (g)	% Organic Matter	% Sediment
Land Bridge-Gravel	34.13	33.86	16.8	17.33	17.06	0.27	1.56%	98.44%
Land Bridge-Sand	22.07	21.69	16.74	5.33	4.95	0.38	7.13%	92.87%
Wood Bridge	21.73	21.5	15.98	5.75	5.52	0.23	4.00%	96.00%
Downstream Wood Bridge	21.18	20.37	15.9	5.28	4.47	0.81	15.34%	84.66%
Mouth of Side Stream	22.78	22.24	16.14	6.64	6.1	0.54	8.13%	91.87%
Side Stream	17.36	17.23	10.38	6.98	6.85	0.13	1.86%	98.14%
Moore Road Bridge	29.52	29.33	16.13	13.39	13.2	0.19	1.42%	98.58%

Breakdown of sediment analysis

Location	Weight of full sample before burning (g)	Very Coarse Sand through Gravel	Course Sand	Fine Sand/ Clay/Silt	Organic Matter	Clay/Silt	Fine Sand
Land Bridge-Gravel	17.33	14.08	1.7	1.28	0.27	33	67
Land Bridge-Sand	5.33	0.05	0.11	4.79	0.38	94	6
Wood Bridge	5.75	0.21	0.66	4.65	0.23	88	12
Downstream Wood Bridge	5.28	0.56	0.07	3.84	0.81	61	39
Mouth of Side Stream	6.64	0.25	0.55	5.3	0.54	39	61
Side Stream	6.98	0.14	0.39	6.32	0.13	51	49
Moore Road Bridge	13.39	7.5	2.86	2.84	0.19	26	74

Appendix F

Macroinvertebrate Data

Macroinvertebrate Data for Hester-Dendy Samplers

Common Name	**Site No.**	**Midge**	**Flat Headed Mayfly**	**Damselfly**	**Scud**	**Caddisfly (case building)**	**Caddisfly (net spinning)**	**Aquatic Worm**	**Asian Clam**	**Snail**	**Gilled Snail**	**Total**
Land Bridge-Gravel 1	0	0	16	0	0	0	2	0	0	0	0	18
Land Bridge-Gravel 2	0	4	7	0	1	0	2	0	0	1	2	17
Land Bridge-Gravel 3	0	3	9	0	0	0	4	0	0	0	0	16
Land Bridge Gravel Total	0	**7**	**32**	**0**	**1**	**0**	**8**	**0**	**0**	**1**	**2**	**51**
Side Stream 1	5	2	0	0	0	0	1	1	0	0	0	4
Side Stream 2	5	2	0	0	1	0	3	0	1	0	1	8
Side Stream 3	5	2	0	0	0	0	23	0	0	0	0	25
Side Stream Total	5	**6**	**0**	**0**	**1**	**0**	**27**	**1**	**1**	**0**	**1**	**37**
Moore Road Bridge Total (3 samples combined)	6	**7**	**0**	**7**	**3**	**1**	**11**	**0**	**0**	**0**	**1**	**30**
Total		33	64	7	7	1	81	2	2	2	7	206
EPT total							160					
Scientific Taxonomy												
Kingdom		Animalia										
Phylum		Arthropoda						Annelida	Mollusca			
Class		Insecta			Crustacea	Insecta		Oligochaeta	Bivalvia	Gastropoda		
Order		Diptera	Ephemeroptera	Odonata	Amphipoda	Trichoptera			Veneroida			
Famiy		Chironomidae	Heptageniidae	Calopterygidae		Limnephilidae			Corbiculidae	Planorbidae	Viviparidae	
Genus									Corbicula			
Species									C. fluminea			

Macroinvertebrate from all sampling sites and dates normalized (red numbers) to determine density (part 1).

Site No.	**May Sampling**	Common Name Sampling Date	Midge	Burrowing Mayfly	flat headed mayfly	Spiny Crawler Mayfly	Combmouthed minnow mayfly	Small minnow mayfly	Stonefly	Caddisfly (case building)	Caddisfly (net spinning)	Dragonfly	Damselfly	Scud	Riffle Beetle Adult	Riffle Beetle Larvae	Predacious Diving Beetle	Predacious Diving Beetle - Adult	Crawling water beetles-Larvae	Crawling water beetles-Adult
0	Land Bridge-Gravel 1	5/24/2013	1	0	0	0	0	0	33	0	0	0	0	3	81	316	0	0	2	0
	Land Bridge- Gravel 2	5/24/2013	17	0	0	0	1	0	0	0	0	0	0	13	7	60	0	0	0	0
	Land Bridge- Gravel 3	5/24/2013	4	0	0	0	0	1	0	0	1	0	0	4	0	9	0	0	0	0
	per m2 site 0		81	0	0	0	4	4	122	0	4	0	0	74	326	1425	0	0	7	0
1	Land Bridge-Sand	5/24/2013	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	per m2 site 1		356	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Wood Bridge Ponar 1	5/24/2013	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Wood Bridge Ponar 2	5/24/2013	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
	per m2 site 2		0	0	0	0	0	0	0	67	0	0	0	0	0	0	0	0	0	0
3	Downstream Wood Bridge	5/24/2013	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
	per m2 site 3		0	0	0	0	0	0	0	44	0	0	0	0	0	0	0	0	44	0
4	Mouth of Side Stream	5/24/2013	4	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0
	per m2 site 4		178	0	0	0	0	0	0	89	0	0	0	44	0	0	0	0	0	0
5	Side Stream 1	5/24/2013	3	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0
	Side Stream 2	5/24/2013	10	0	0	1	13	7	0	0	0	0	0	0	0	0	0	0	0	0

	per m2 site 5		72	0	0	6	78	39	0	0	0	0	0	0	0	17	0	0	0	0
6	Moore Road Bridge Surber 1	5/24/2013	2	0	0	0	1	0	27	2	6	0	0	1	5	44	0	0	0	0
6	Moore Road Bridge Surber 2	5/24/2013	2	0	0	0	0	0	14	7	32	0	0	3	4	70	0	0	0	0
	Moore Road Bridge Ponar 1	5/24/2013	0	0	0	0	0	0	1	5	0	0	0	1	0	0	0	0	0	0
	Moore Road Bridge Ponar 2	5/24/2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	per m2 site 6		18	0	0	0	4	0	187	62	169	0	0	22	40	507	0	0	0	0
	August/September Sampling																			
0	Land Bridge-Gravel 1	8/25/2013	33	0	0	0	12	12	0	0	138	0	0	0	4	10	0	2	0	5
	Land Bridge-Gravel 2	8/25/2013	93	0	1	0	3	9	1	0	113	0	0	8	3	59	0	0	0	0
	Land Bridge-Gravel 3	8/25/2013	6	0	0	0	1	1	0	0	2	0	0	0	0	1	0	0	0	0
	per m2 site 0		488	0	4	0	59	81	4	0	936	0	0	30	26	259	0	7	0	19
1	Land Bridge-Sand	8/25/2013	20	0	0	0	0	1	0	0	0	0	0	2	0	0	1	0	0	0
	per m2 site 1		889	0	0	0	0	44	0	0	0	0	0	89	0	0	44	0	0	0
2	Wood Bridge	8/25/2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	per m2 site 2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Downstream Wood Bridge	8/25/2013	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	per m2 site 3		44	0	0	0	0	0	0	44	0	0	0	0	0	0	0	0	0	0
4	Mouth of Side Stream	9/14/2013	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	per m2 site 4		89	0	0	0	0	0	0	0	0	0	0	44	0	0	0	0	0	0
5	Side Stream 1	9/14/2013	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Side Stream 2	9/14/2013	6	1	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0
	per m2 site 5		78	6	0	0	17	0	0	0	11	0	0	0	0	0	0	0	0	0
6	Moore Road Bridge-Surber 1	8/25/2013	65	0	0	0	0	1	0	0	93	0	0	0	2	22	0	0	0	0
	Moore Road Bridge-Surber 2	8/25/2013	20	0	0	0	0	2	0	1	17	0	0	2	2	56	0	0	0	0
	Moore Road Bridge-Ponar	8/25/2013	8	0	0	1	1	0	0	1	0	2	0	0	0	0	0	0	0	0
	per m2 site 6		459	0	0	5	5	15	0	10	543	10	0	10	20	385	0	0	0	0
	October Sampling																			
0	Land Bridge-Gravel 1	10/26/2013	24	0	0	0	0	0	0	0	53	0	0	0	1	15	0	0	0	0

	Land Bridge-Gravel 2	10/26/2013	10	0	1	0	0	0	0	0	30	0	0	0	0	1	0	0	0	0
	Land Bridge-Gravel 3	10/26/2013	8	0	0	0	0	0	0	0	40	0	0	0	0	2	0	0	0	0
	per m2 site		155	0	3.7	0	0	0	0	0	455	0	0	0	3.7	66.6	0	0	0	0
1	Land Bridge-Sand	10/26/2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	per m2 site		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Wood Bridge	10/26/2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	per m2 site		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Downstream Wood Bridge	10/26/2013	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	per m2 site		0	88.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Mouth of Side Stream	10/26/2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	per m2 site		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Side Stream 1	10/26/2013	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
	Side Stream 2	10/26/2013	6	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0
	per m2 site		33.3	0	0	0	0	0	0	0	83.3	0	0	0	0	0	0	0	0	0
6	Moore Road Bridge-Ponar	10/26/2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Moore Road Bridge-Surber 1	10/26/2013	6	0	0	0	0	0	0	0	128	0	1	0	0	23	0	0	0	0
	Moore Road Bridge-Surber 2	10/26/2013	2	0	0	0	0	0	0	1	102	0	0	2	1	28	0	0	0	0
	per m2 site		39.5	0	0	0	0	0	0	4.94	1136	0	4.94	9.88	4.94	252	0	0	0	0

Macroinvertebrate from all sampling sites and dates normalized (red numbers) to determine density (part 2).

Site No.	May Sampling	Common Name Sampling Date	Water scavenger beetles -Larvae	Water scavenger beetles-Adult	Whirligig beetle	Horse Fly	Crane Fly	Hairy eyed crane fly	Black Fly Larva	Water boatman	Aquatic Worm	Leech	Butterworm	Alderfly	Asian Clam	fingernail clam	River Mussels	Snail	Chinese Valve Snail	Gilled snail	Totals
0	Land Bridge-Gravel 1	5/24/2013	0	0	0	0	3	0	0	0	5	1	0	0	3	0	0	0	0	0	448
	Land Bridge- Gravel 2	5/24/2013	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	105
	Land Bridge- Gravel 3	5/24/2013	0	0	0	0	0	0	0	1	55	0	0	0	2	5	0	0	0	0	82
	per m2 site 0		0	0	0	0	11	0	0	4	248	4	0	0	19	19	0	0	0	0	2350
1	Land Bridge-Sand	5/24/2013	0	0	0	0	0	0	0	0	6	0	0	0	1	2	0	0	0	0	17
	per m2 site 1		0	0	0	0	0	0	0	0	267	0	0	0	44	89	0	0	0	0	756
2	Wood Bridge Ponar 1	5/24/2013	0	0	0	0	0	0	0	0	15	0	0	0	43	3	0	0	0	0	62
	Wood Bridge Ponar 2	5/24/2013	0	0	0	0	0	0	0	0	6	0	0	0	54	11	0	0	0	0	73
	per m2 site 2		0	0	0	0	0	0	0	0	467	0	0	0	2156	311	0	0	0	0	3000
3	Downstream Wood Bridge	5/24/2013	0	0	1	0	0	0	0	0	5	0	1	0	9	8	0	1	0	0	27
	per m2 site 3		0	0	44	0	0	0	0	0	222	0	44	0	400	356	0	44	0	0	1200
4	Mouth of Side Stream	5/24/2013	0	1	0	0	0	0	0	0	0	0	0	0	2	4	1	0	0	1	16
	per m2 site 4		0	44	0	0	0	0	0	0	0	0	0	0	89	178	44	0	0	44	711
5	Side Stream 1	5/24/2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
	Side Stream 2	5/24/2013	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32
	per m2 site 5		6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	217
6	Moore Road Bridge Surber 1	5/24/2013	0	1	0	0	0	0	0	0	158	1	0	0	141	126	0	0	0	0	515

	Moore Road Bridge Surber 2	5/24/2013	1	0	0	0	0	0	0	0	56	0	0	0	61	42	0	1	0	3	296
6	Moore Road Bridge Ponar 1	5/24/2013	0	0	0	0	0	0	0	0	5	0	0	0	51	9	0	0	1	2	75
	Moore Road Bridge Ponar 2	5/24/2013	0	0	0	0	0	0	0	0	6	0	0	0	33	10	0	0	0	0	49
	per m2 site 6		4	4	0	0	0	0	0	0	1000	4	0	0	1271	831	0	4	4	22	4156
	August/September Sampling																				
0	Land Bridge-Gravel 1	8/25/2013	0	0	0	0	0	0	153	0	0	0	0	0	2	0	0	0	0	0	371
	Land Bridge-Gravel 2	8/25/2013	0	0	0	0	0	0	18	0	1	2	0	1	18	0	0	0	0	1	331
	Land Bridge-Gravel 3	8/25/2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
	per m2 site 0		0	0	0	0	0	0	633	0	4	7	0	4	74	0	0	0	0	4	2638
1	Land Bridge-Sand	8/25/2013	0	0	0	0	0	0	0	0	11	0	0	0	10	0	0	0	0	0	45
	per m2 site 1		0	0	0	0	0	0	0	0	489	0	0	0	444	0	0	0	0	0	2000
2	Wood Bridge	8/25/2013	0	0	0	0	0	0	0	0	3	0	0	0	20	13	0	0	0	0	36
	per m2 site 2		0	0	0	0	0	0	0	0	133	0	0	0	889	578	0	0	0	0	1600
3	Downstream Wood Bridge	8/25/2013	0	1	0	0	0	0	0	0	4	0	0	0	28	0	0	2	0	5	42
	per m2 site 3		0	44	0	0	0	0	0	0	178	0	0	0	1244	0	0	89	0	222	1867
4	Mouth of Side Stream	9/14/2013	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	1	7
	per m2 site 4		0	0	0	0	0	0	44	0	89	0	0	0	0	0	0	0	0	44	311
5	Side Stream 1	9/14/2013	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	7	16
	Side Stream 2	9/14/2013	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	18
	per m2 site 5		0	0	0	0	0	0	33	0	0	0	0	0	0	6	0	0	0	39	189
6	Moore Road Bridge-Surber 1	8/25/2013	0	0	0	0	0	0	17	0	16	0	0	0	27	16	0	0	0	0	259
	Moore Road Bridge-Surber 2	8/25/2013	0	0	0	0	0	0	2	0	5	2	0	0	31	15	0	0	1	0	156
	Moore Road Bridge-Ponar	8/25/2013	0	0	0	0	0	0	0	0	0	0	0	0	47	50	0	0	0	0	110
	per m2 site 6		0	0	0	0	0	0	94	0	104	10	0	0	519	400	0	0	5	0	2593
	October Sampling																				
0	Land Bridge-Gravel 1	10/26/2013	0	0	0	0	0	0	0	0	2	2	0	0	1	3	0	0	0	0	101

	Land Bridge-Gravel 2	10/26/2013	0	0	0	0	0	0	1	0	5	0	0	0	1	0	0	0	0	0	49
	Land Bridge-Gravel 3	10/26/2013	0	0	0	0	0	0	2	0	2	1	0	0	2	1	0	0	0	0	58
	per m2 site		0	0	0	0	0	0	11.1	0	33.3	11.1	0	0	14.8	14.8	0	0	0	0	770
1	Land Bridge-Sand	10/26/2013	0	0	0	0	0	0	0	0	6	0	0	0	63	3	0	0	0	2	74
	per m2 site		0	0	0	0	0	0	0	0	267	0	0	0	2800	133	0	0	0	88.9	3289
2	Wood Bridge	10/26/2013	0	0	0	0	0	0	0	0	4	0	0	0	48	2	0	0	0	0	54
	per m2 site		0	0	0	0	0	0	0	0	178	0	0	0	2133	88.9	0	0	0	0	2400
3	Downstream Wood Bridge	10/26/2013	0	0	0	0	0	0	0	0	44	0	0	0	11	3	0	0	1	2	63
	per m2 site		0	0	0	0	0	0	0	0	1956	0	0	0	489	133	0	0	44.4	88.9	2800
4	Mouth of Side Stream	10/26/2013	0	0	0	0	0	0	0	0	2	0	0	0	36	2	0	0	0	0	40
	per m2 site		0	0	0	0	0	0	0	0	88.9	0	0	0	1600	88.9	0	0	0	0	1778
5	Side Stream 1	10/26/2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
	Side Stream 2	10/26/2013	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	22
	per m2 site		0	0	0	0	0	11.1	0	0	0	0	0	0	5.56	0	0	0	0	5.56	139
6	Moore Road Bridge-Ponar	10/26/2013	0	0	0	0	0	0	0	0	2	0	0	0	31	11	0	0	1	0	45
	Moore Road Bridge-Surber 1	10/26/2013	0	0	0	0	0	0	1	0	0	0	0	0	9	3	0	0	0	1	172
	Moore Road Bridge-Surber 2	10/26/2013	1	0	0	0	1	0	0	0	18	0	0	0	4	4	0	0	0	0	164
	per m2 site		4.94	0	0	0	4.94	0	4.94	0	98.8	0	0	0	217	88.9	0	0	4.94	4.94	1881

Chironomid genus levels identification from all sampling sites and dates.

Genus			Thienemannimyia	Ablabesmyia	Natarsia	Procladius	Pentaneura	Glabrescens	Rheotanytarsus	Guerlus	Paratanytarsus	Chironomus	Saetheria	Stictochironomus	Tribelos	Microtendipes	Polypedilum	Endochironomus	Dicrotendipes	Chryptochironomus	UNKNOWN Chironomini	Cricotopus	Cricotopus	Cricotopus	Diplocladius	Eukiefferiella	Parakiefferiella	Metriocnemus	Orthocladius	Parametriocnemus	UNKNOWN Orthocladiinae		
Species		**Total Chironomid**																	Neomodestus			Bicinctus	Trifascia	Tremulus		discoloripes or gracei			Obumbratus			UNKNOWN	**Total**
Land Bridge-Gravel 1	5/24/2013	**1**	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Land Bridge- Gravel 2	5/24/2013	**17**	2	0	0	0	0	0	0	1	3	0	0	0	0	1	1	0	0	0	0	0	4	5	0	0	0	0	0	0	0	0	**17**
Land Bridge- Gravel 3	5/24/2013	**4**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	1	0	0	0	0	0	0	0	0	**4**
Land Bridge-Sand	5/24/2013	**8**	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	1	0	0	0	1	1	1	0	0	0	0	0	0	**8**
Mouth of Side Stream	5/24/2013	**4**	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**4**
Side Stream 1	5/24/2013	**3**	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Side Stream 2	5/24/2013	**10**	0	0	0	0	0	0	0	8	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**10**
Moore Road Bridge Surber 1	5/24/2013	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Moore Road Bridge Surber 2	5/24/2013	**2**	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Total (May)		**51**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**12**	**3**	**2**	**0**	**2**	**1**	**2**	**3**	**0**	**6**	**1**	**1**	**0**	**5**	**7**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**51**
Land Bridge-Gravel 1	8/25/2013	**33**	7	0	1	0	1	0	0	0	0	0	0	0	0	5	15	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	**33**
Land Bridge-Gravel 2	8/25/2013	**31**	3	0	1	0	0	0	0	0	0	0	0	0	0	15	6	1	0	1	0	4	0	0	0	0	0	0	0	0	0	0	**31**
Land Bridge-Gravel 3	8/25/2013	**6**	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	**6**
Land Bridge-Sand	8/25/2013	**20**	1	0	0	0	1	0	0	9	0	0	0	0	0	0	2	0	2	0	0	3	0	0	0	0	0	0	0	0	0	2	**20**

Downstream Wood Bridge	8/25/2013	**1**	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Mouth of Side Stream	9/14/2013	**2**	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Side Stream 1	9/14/2013	**8**	0	0	0	0	0	0	0	6	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**8**
Side Stream 2	9/14/2013	**6**	0	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**6**
Moore Road Bridge-Surber 1	8/25/2013	**32**	3	0	0	0	0	0	0	0	0	0	0	0	0	3	25	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**32**
Moore Road Bridge-Surber 2	8/25/2013	**20**	3	0	0	0	0	1	1	0	0	0	0	0	0	0	13	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**20**
Moore Road Bridge-Ponar	8/25/2013	**8**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**8**
Total (August)		**167**	**17**	**4**	**2**	**1**	**4**	**1**	**1**	**16**	**0**	**0**	**1**	**0**	**0**	**24**	**69**	**4**	**3**	**5**	**1**	**10**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**167**
Land Bridge-Gravel 1	10/26/2013	**24**	3	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	2	0	0	0	0	6	0	0	1	**24**
Land Bridge-Gravel 2	10/26/2013	**10**	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	6	0	1	0	**10**
Land Bridge-Gravel 3	10/26/2013	**8**	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	**8**
Side Stream 2	10/26/2013	**6**	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	1	0	**6**
Moore Road Bridge-Surber 1	10/26/2013	**6**	1	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**6**
Moore Road Bridge-Surber 2	10/26/2013	**2**	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Total (October)		**56**	**8**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**22**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**19**	**1**	**2**	**2**	**56**
Land Bridge-Gravel HD 2	10/26/2013	**4**	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**
Land Bridge-Gravel HD 3	10/26/2013	**3**	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**3**
Side Stream HD 1	10/26/2013	**2**	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Side Stream HD 2	10/26/2013	**2**	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**2**
Side Stream HD 3	10/26/2013	**2**	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**2**
Moore Road Bridge HD	10/26/2013	**7**	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	**7**
Total (H-D)		**20**	**8**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**3**	**0**	**1**	**0**	**0**	**4**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**20**