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The Potential impact of riparian buffer zones on sediment and phosphorus loading in two Canandaigua Lake subwatersheds

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The Potential Impact of Riparian Buffer Zones on Sediment and Phosphorus Loading in Two Canandaigua Lake Subwatersheds

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Abstract

Thousands rely on the water of Canandaigua Lake for drinking water, fishing, boating and swimming each year. The Canandaigua Lake Watershed Council (CLWC) was formed with the goal of protecting the high quality of this water source. The CLWC has been monitoring the lake and its tributaries for thirteen years. The lake remains in good condition, but testing has revealed an overall increase in total phosphorus (TP) and total suspended solids (TSS).

This study identifies potential TSS and TP sources in the Eelpot Creek subwatershed. This creek has some of the highest concentrations of these pollutants in the entire Canandaigua Lake watershed. The area was compared to the Grimes Creek subwatershed, an adjacent watershed with similar characteristics but some of the lowest pollutant concentrations in the watershed. It was posited that the paucity of riparian forested buffers contributes to higher TSS and TP concentrations in Eelpot. GIS, ground-truthing, and chemical and macroinvertebrate analyses were used to locate potential pollutant hotspots throughout the subwatershed. Results showed no significant difference in macroinvertebrate community composition, except EPT richness, between the two subwatersheds or among sites. The results did demonstrate slight impact at some Eelpot sites, and one Grimes sampling site. GIS and ground-truthing revealed several areas of concern that appear to support the macroinvertebrate results. Cultivation appears to be a probable factor contributing to pollution in Eelpot, as well as heavy stream bank erosion found along some branches. Preliminary stormwater results appear to also support these conclusions, however there were too few samples to statistically analyze the results.

The results of this study support the belief that much of the TSS and TP in Eelpot Creek stems from unbuffered cultivated land and/or stream bank erosion. It is therefore recommended that forested buffers be strongly considered in protecting this valuable water source.

Acknowledgements

Completion of this thesis depended on the patience, support and guidance of many. Most notably, Dr. John Waud, RIT professor of environmental science, served as my advisor for this project. His guidance in selecting, designing and implementing this project helped to focus my passion for water quality issues and complete this master's thesis. He has also been instrumental in patiently guiding me to completion and helping me through patches of confusion and doubt. I am truly grateful for all he has done. Other members of my committee were also instrumental in providing specialized knowledge in various aspects of this project. Without their help, this thesis would have been severely limited in its scope. Kevin Olvany at the Canandaigua Lake Watershed Council helped collect chemical and macroinvertebrate samples, arranged and provided funding for professional chemical analysis and acted as a liaison between myself and landowners in the watershed. Dr. Richard Shearman, RIT professor of science, technology and society, provided input on the social aspect of this project – working with landowners to reach reasonable solutions to environmental issues. Dr. Shearman also assisted in macroinvertebrate sampling. Dr. Gary Neuderfer, RIT and SUNY Brockport professor of environmental science and recently retired environmental toxicologist with the New York State Department of Environmental Conservation, spent countless hours helping me identify macroinvertebrates and analyze community index results.

I would also like to extend my gratitude to Dr. Karl Korfmacher, Director of the Environmental Science Program at RIT; Dr. David Mathiason, professor of statistics and data analysis at RIT; fellow graduate students Phil Nau and Natalie McLenaghan; Nikki Bruno-Collins, staff assistant for the RIT Department of Biological Sciences; my family; and Brian Garrison for their assistance, support, encouragement, and patience.

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Introduction

About 60,000 people rely on the water of Canandaigua Lake for their drinking supply, and thousands more utilize this resource for fishing, boating and swimming each year. The lake's surface area is 16.6 square miles, and the total volume is about 429 billion gallons (City of Canandaigua). The lake's watershed covers 174 square miles and is shared between thirteen towns, two villages and one city (CLWC, 2005). The Canandaigua Lake Watershed Council (CLWC) was formed to unite the various municipalities throughout the watershed with the goal of "[maintaining and enhancing] the high water quality of the Canandaigua Lake Watershed through education, research, restoration and if necessary regulation (CLWC)." Toward this goal, the CLWC has been periodically monitoring Canandaigua Lake and its tributaries for thirteen years. The most extensive monitoring program began in the spring of 2003, and has been repeated annually. Monitored characteristics include temperature, dissolved oxygen (DO), conductivity, turbidity (water clarity), chlorophyll *a* (algal abundance), chloride, and nutrient (nitrate/nitrite and total phosphorus) measurements. TSS (the concentration of solid particles suspended in the water column) is also monitored.

The CLWC uses this data to create profiles of temperature and dissolved oxygen in the water column to record seasonal stratification. Seasonal changes in stratification (seasonal turnovers) are important because nutrients and oxygen are redistributed in the water column, helping organisms at all depths to survive (Gilman and Olvany, 2006). Through this program, the CLWC and its partners have found that water quality in the lake has remained in very good condition. Despite this trend, their results do demonstrate an overall increase in total phosphorus (TP) and total suspended solids (TSS) over the sampling period (Gilman and Olvany, 2006). This leads to some concerns that water quality in the lake may be diminished in the future. Sources of these pollutants should therefore be identified and reduced where feasible.

Because the Canandaigua Lake watershed is primarily agricultural and characterized by steep slopes, it is suspected that most of these pollutants come from agricultural runoff and stream bank erosion. In 1983, six of the EPA's ten regions reported that nonpoint pollution is the greatest perpetrator of water pollution within their respective regions, and eight of these ten EPA regions reported that agriculture contributed most to polluting runoff (Duda, 1985). Agricultural runoff carries with it sediment, nutrients and pesticides, causing environmental degradation that lowers biodiversity and makes the water less useful for humans (Duda, 1985).

This study focused on the use of riparian forested buffers (RFB) as a means of reducing water pollution via runoff. The effectiveness of RFBs in slowing the flow of water and capturing nutrients makes them a strong candidate for agricultural pollution control (Anbumozhi, *et al*., 2005; Correll, 2005; Lovell and Sullivan, 2005).

Riparian Forested Buffers

The Natural Resources Conservation Service (NRCS, 2006) defines RFBs as areas that are "predominantly trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies." The general recommendation for RFB width is 30m, which is seen as most effective when divided into three zones (Correll, 2005). The U.S. Forest Service recommends that a buffer contain a narrow forested zone of 4.5 meters that is adjacent to the water and never disturbed, a wider forested zone of about 18 meters that may be harvested, and a 6 meter grassy zone for the capturing of sediment (Figure 1)(Correll, 2005). Effective buffer width is subject to change, however, depending on the length of the buffer and other environmental factors (Correll, 2005).

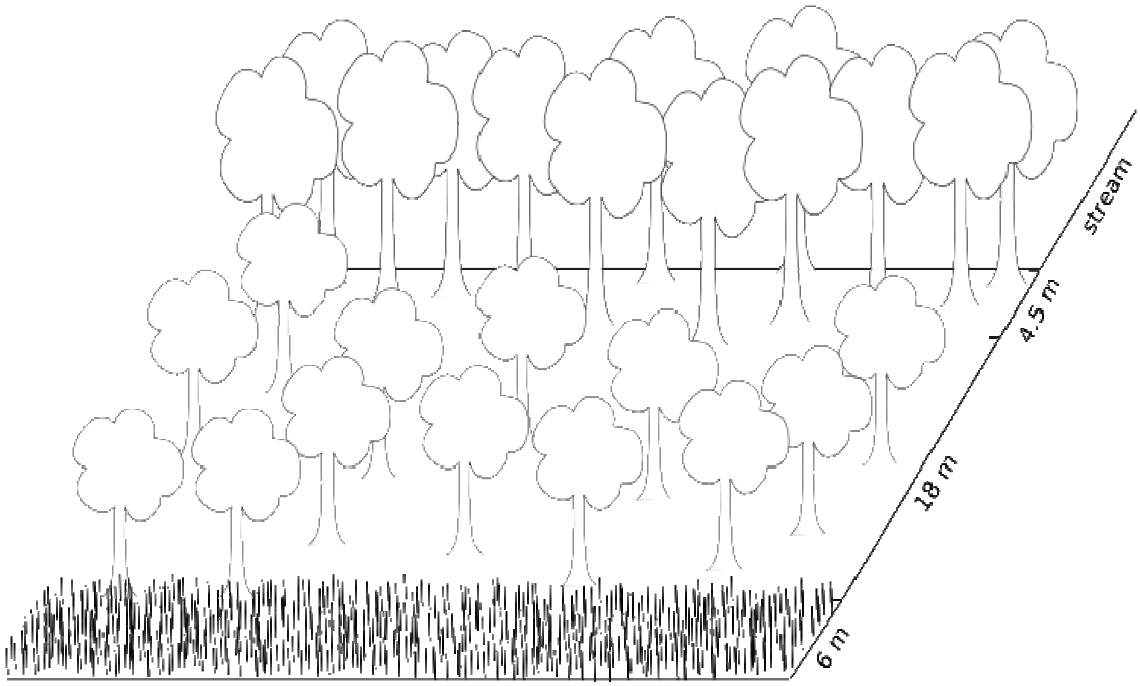


Figure 1 – U.S. Forest Service generalized buffer. USFS recommends a layered buffer with 6 meter grass zone to slow the flow of water and capture sediments, an 18 meter harvestable shrub zone, and a 4.5 meter zone of undisturbed mature forest. The shrub and forest zones serve to filter excess nutrients and stabilize bank soils, respectively.

Significant water quality and ecosystem function benefits of RFBs have been recorded, even in the absence of anthropogenic disturbance in deforested areas (Sweeney et al, 2004). RFBs serve to filter out nutrients and sediments (Lovell and Sullivan, 2005). RFBs also improve the in-stream processing of pollutants that make it past the buffer by slowing the flow of water. When there is a decrease in flow with no significant increase in volume, there is more contact time between the water and organisms in the stream that process nutrients. Increased processing time allows organisms to break down and consume more nutrients, thus improving water quality downstream. These changes cause forested streams (where the forest slows the overland flow of water) to process more organic matter than unforested stretches (Sweeney, *et al.*, 2004). Other benefits of RFBs include lower water temperature through shading and habitat for both aquatic and terrestrial wildlife. Buffers also provide organic material for steam communities. These benefits strongly influence ecosystem health and biodiversity (Correll, 2005; Lovell and Sullivan, 2005; Sweeney, *et al.*, 2004). Biodiversity has been shown by others to have a positive linear relationship with buffer area (Anbumozhi, *et al*., 2005; Quinn, *et al.*, 2004). For example, Quinn, *et al*., (2004) demonstrated that macroinvertebrate biodiversity and density were highest where no logging was carried out along the streamside, and lowest where trees were cut to the edge, demonstrating that maintaining an undisturbed buffer zone during timber harvesting has a positive impact on some species.

The benefits outlined above, however, have only been investigated at a local level and on a short-term scale. Correll (2005) emphasizes that although RFBs are important, they should not be the only measure protecting waterways. Best management practices (BMPs) such as contour cropping and low- or no-till agriculture should be used in upland areas. RFBs serve more as a supplemental protection against pollution to insure the health of waterways than an overall solution. For example, strip cropping is used in agriculture to prevent runoff into streams. However, some sediment still passes beyond crop rows, and these would be caught by a buffer.

Likewise, location and continuity of these buffers is paramount in their effectiveness. Correll (2005) notes that the most important location for buffer protection is along the headwaters, and evidence has shown that even if it's narrow, one continuous zone can be far more effective in stream protection than scattered buffers, since continuity provides protection from most upstream sources. However, it is most important to focus on parts of the stream where pollutants enter. Watersheds with undisturbed headwaters and well-developed floodplains might therefore benefit most from buffers along the more developed portions.

The use of RFBs is also not easily generalized. Different plant species respond to varying soil types and topography, altering the effectiveness of a buffer (Schultz *et al.*, 2004). Correll

(2005) discusses vegetation layers within a buffer recommended by the US Forest Service to perform various tasks. Wang, *et al*., (2005) discuss the benefits of several buffer structures scattered throughout a watershed, rather than contained in one strip. In their watershed of study in Northern China, stone dams adjacent to villages served as flow retardants and primary filter structures. Further downstream, roadside grassed ditches served to redirect and filter runoff. In shallower portions of the stream with little slope, vegetated filter strips of wetland vegetation were used as nutrient filters. These filters were supported by riparian forested buffer strips near agricultural fields. Scattered throughout the landscape were dry ponds, which held excess runoff during rain events and contributed to the management of water volume. The study showed that diversification of structure functions helps pull out a large variety of pollutants and leads to overall water quality improvement downstream. Such results clearly demonstrate that not all buffers must be forested to effectively improve water quality, and some alternatives should be considered in areas where creating an RFB may be harmful to the environment or perhaps where it is too costly for landowners. Steiger, *et al.,* (2002) showed that certain vegetation (i.e., grass) is more suitable for collecting sediments than trees and shrubs, once again supporting the idea that diversification of buffers leads to the greatest improvement in water quality. Anbumozhi, *et al*. (2005) also support the idea of diversification of individual buffer plots to assist with quality control, and further suggest that buffers should have some economic benefit to provide an incentive for landowners.

Eutrophication

The threat of eutrophication is a growing concern for the CLWC. This phenomenon is a natural process of nutrient loading in a water body, but can be accelerated by human impacts

(Yanamadala, 2005). Eutrophication can disturb the balance of communities living within a water body and decrease water quality (Painting *et al*., 2007).

When anthropogenic point and non-point sources lead to increased nutrient loading, this is known as "cultural eutrophication" (Yanamadala, 2005). Although both nitrogen (N) and phosphorus (P) influence primary production in water bodies, P is the main limiting nutrient in freshwater systems (Roberts and Santschi, 2004; Håkanson *et al*., 2007). When a freshwater body is loaded with excess P, it experiences a rapid increase in plant and algal growth. This blocks light in the water column, resulting in a die off of plants and phototrophic organisms. Oxygen is used up in the decay of this excess material, resulting in anoxic conditions (no oxygen in the water). While phosphorus levels are generally low in Canandaigua Lake, the watershed council has seen a gradual increase in total phosphorus (TP) over the past few years, which leads to the council's concern. Sources of cultural eutrophication include agricultural (manure, fertilizer) and residential runoff (fertilizers, grass clippings from driveways and roads, leaves, and sometimes waste from sewer cross connections) (CCE, 2000).

Sedimentation

Water traveling over the ground picks up loose soil particles which are then carried into the water column. This process is known as sedimentation and is typically measured as total suspended solids (TSS). Particles in the water column block sunlight, and an excess of these particles prevents primary producers from carrying out photosynthesis (Thomas, 1969), which can affect other trophic levels. Suspended solids also inhibit filter feeding, negatively influencing bivalve and other filter feeder populations (Ellis, *et al.*, 2002). Settled sediments cover fish nests, reduce valuable rocky habitat, and in some studies have been shown to increase the rate of flow in streams by smoothing the substrate (Jowett and Boustead, 2001). Phosphorus may also bind to soil particles that are carried into the water column through runoff.

The CLWC is concerned with levels of TSS in the lake, and the organization lists impervious surfaces (which increase the rate and amount of runoff), construction, road bank erosion, steep slopes and agriculture as factors that cause erosion (leading to high TSS) in the watershed. Best management practices (BMPs) such as low-till agriculture and strip cropping are the preferred way to prevent erosion. For instance, strip cropping helps prevent the loss of topsoil by maintaining continuous coverage in strips perpendicular to the slope, which slows the flow of water (Lovell and Sullivan, 2005). These methods however only serve to reduce soil loss. When erosion does occur, nutrients and sediment are able to reach the water body easily if no measures are in place to stop or slow runoff. RFBs can be used to help trap excess sediment; buffer vegetation also utilizes excess nutrients that are carried by the sediment.

Canandaigua Lake

There are thirty four subwatersheds within the Canandaigua Lake Watershed. While most of the tributaries leading to the lake from these are of good quality, some demonstrate high levels of TSS and TP, particularly during rainstorm events (Gilman and Olvany, 2006). The two areas of interest (AOI) for this study are the subwatersheds of Eelpot and Grimes Creeks, which are adjacent to one another at the south end of the lake. Of the thirty four, Eelpot Creek is the second highest in terms of TSS and TP, while Grimes Creek is among the five lowest with respect to these factors. This study focuses on factors within the two subwatersheds that might lead to these differences. Changes in aquatic communities, water quality and the availability of rocky bottom habitats resulting from increased sedimentation and phosphorus have the potential to negatively affect fish diversity or abundance, ultimately damaging Canandaigua Lake's sport fishing industry. These effects also negatively impact the quality of drinking water for watershed residents.

The purpose of the present investigation was to initiate a long-term study to address the localized effects of RFBs in the subwatersheds of Eelpot and Grimes Creeks. This relationship was evaluated through macroinvertebrate sampling and the use of GIS to assess slopes, land use and land cover, erosion and runoff; results were compared to chemical results for storm event samples of TSS and TP.

Materials and Methods

Selecting Sample Locations

The Canandaigua Lake Watershed (CLW) is comprised of thirty four subwatersheds (each tributary has its own watershed). Grimes and Eelpot (Figure 2) were selected as areas of focus based on chemical analysis results from the CLWC. Limiting the study to two watersheds helped make data collection and analysis more manageable and reduced errant land use comparisons.

Three sites were selected for kick sampling in the Grimes Creek subwatershed. Each site is representative of one of the three major branches of Grimes Creek (Figure 3). The tributaries of Eelpot Creek are more complex with five major branches (Figure 4), so five locations were selected. Kick sampling sites were selected based on the following criteria:

> Sample location should be a long, relatively shallow riffle or run with a flow of about 0.4 m/s or more. The area should have good canopy cover but be representative of the overall stream (glancing up and down the stream to see the general cover and habitat

is sufficient). The stream bottom should also be primarily gravel with rocks and pebbles, as this is prime habitat for macroinvertebrates. (Bode *et al*., 2002)

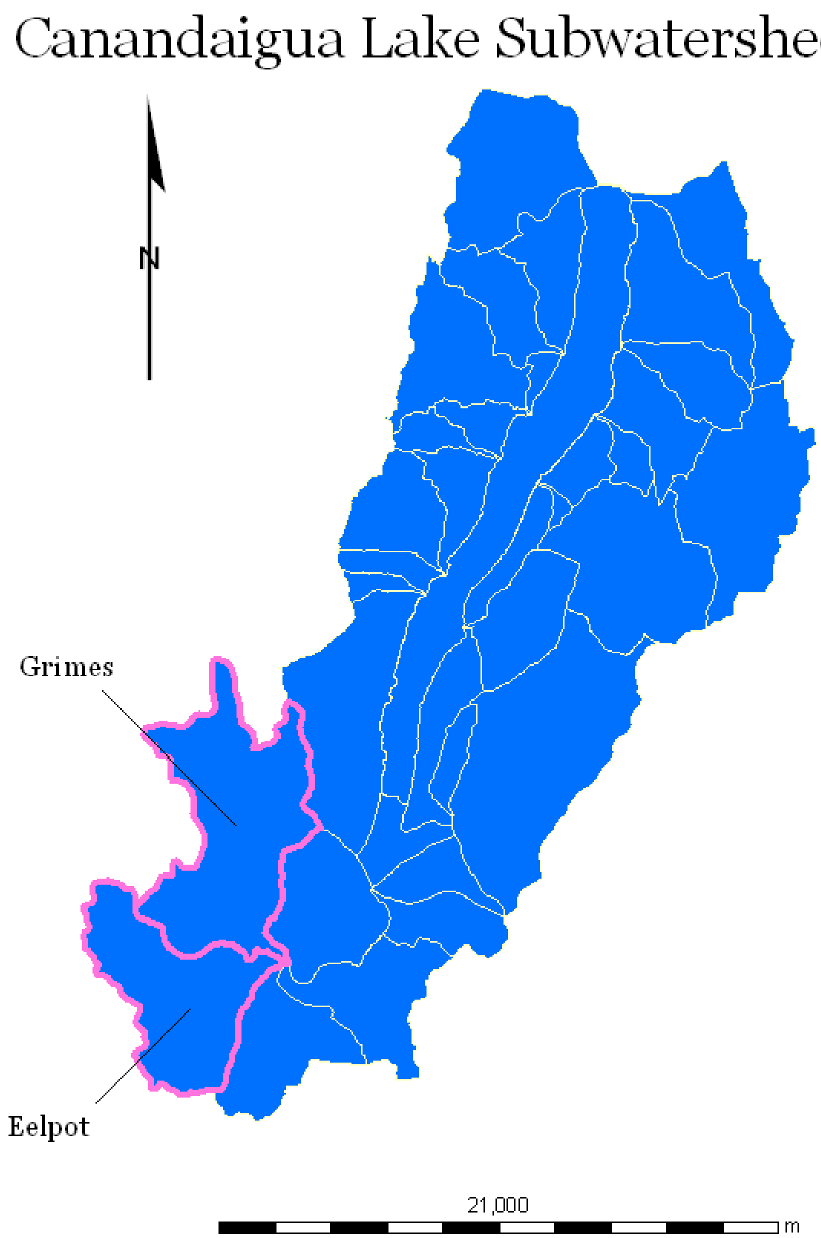


Figure 2 – Canandaigua Lake subwatersheds. Canandaigua Lake has 21 subwatersheds. The study watersheds, Eelpot (south) and Grimes (north) are outlined in pink. The southern tip of the lake is east of the Grimes Creek subwatershed.

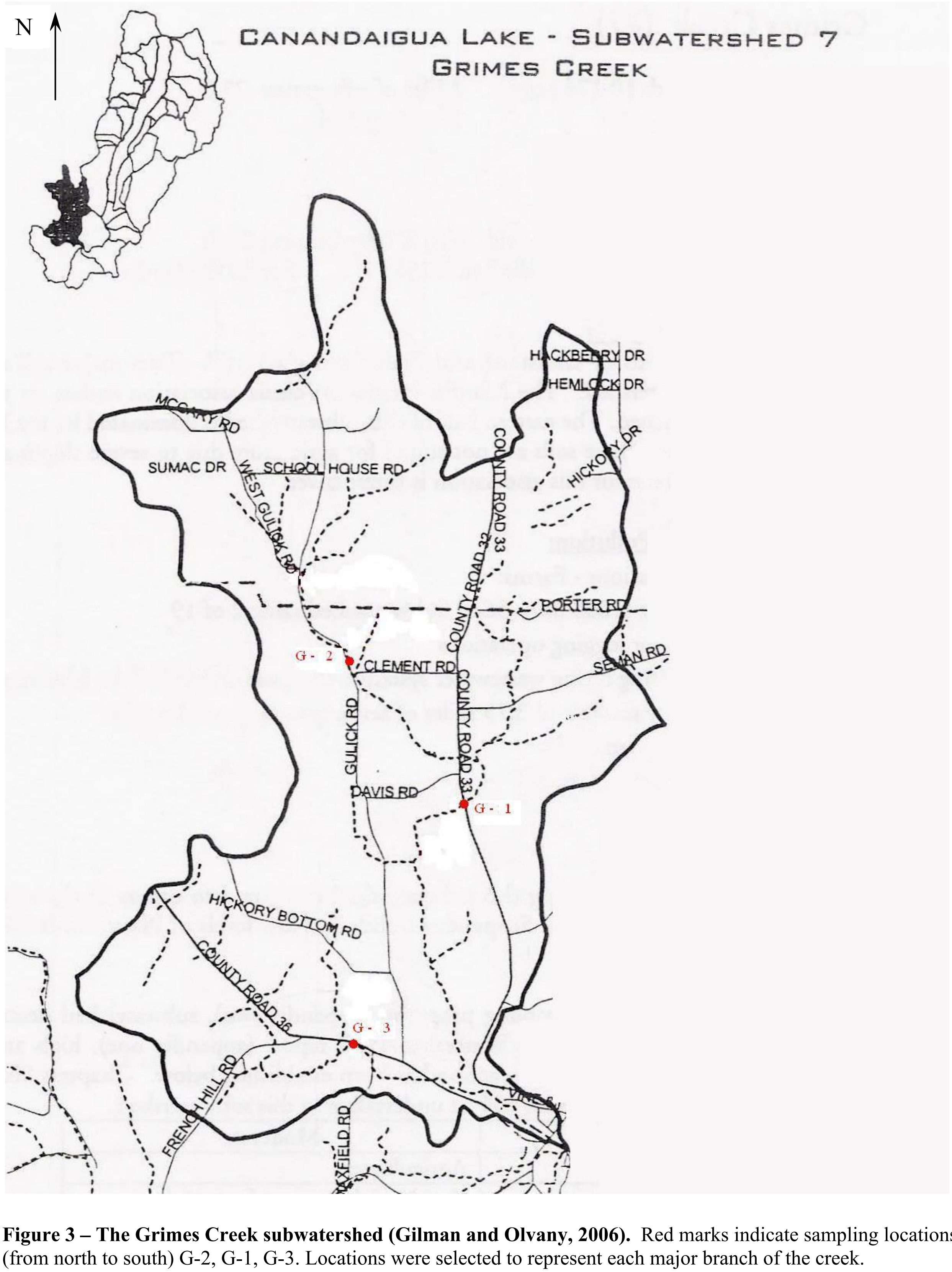


Figure 3 – The Grimes Creek subwatershed (Gilman and Olvany, 2006). Red marks indicate sampling locations (from north to south) G-2, G-1, G-3. Locations were selected to represent each major branch of the creek.

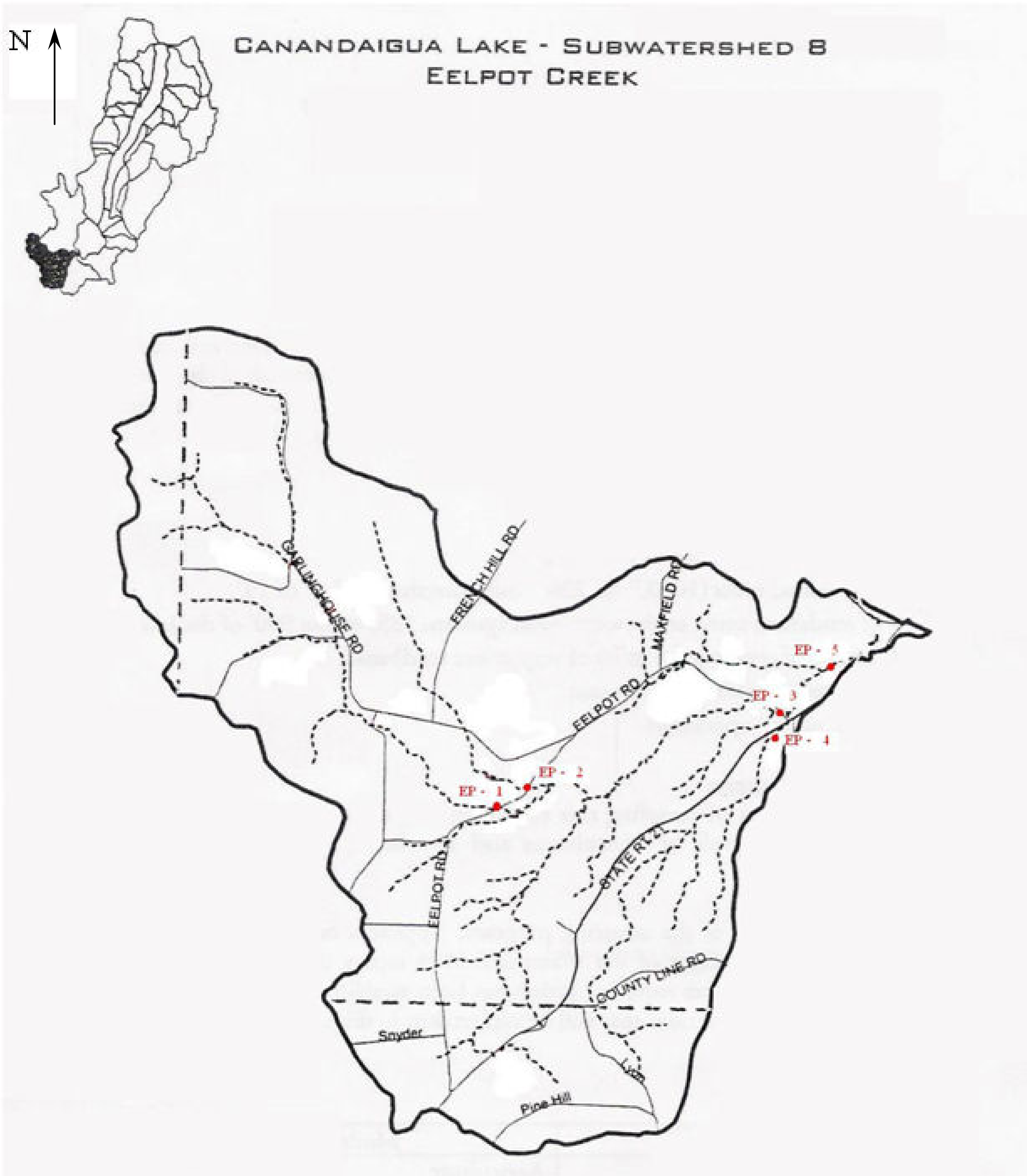


Figure 4 – The Eelpot Creek subwatershed (Gilman and Olvany, 2006). This watershed is quite complex with five major branches. Red marks indicate sampling locations (from west to east) EP-1, EP-2, EP-4, EP-3 and EP-5. Locations were selected to represent each major branch of the creek.

Site selection was also limited by accessibility. Where possible, sites adjacent to a road or on public land were chosen. For sites located on private lots, landowners were identified using a tax map in ArcGIS and contacted for permission to enter the stream (EP-4, EP-5, and G-2).

Macroinvertebrate Analysis

The CLWC has focused on stormwater stress-stream analysis for their TSS and TP information. These represent only a snapshot in time, while macroinvertebrate analysis integrates water quality over time. Multiple samples provide a seasonal understanding of species distribution and abundance throughout the subwatersheds, as well as a more robust data set. There were four kick sampling events during this study - November 2006, June 2007, September 2007, and November 2007.

Macroinvertebrates were collected from stream riffles using the kick sampling technique outlined in Bode, *et al.* (2002). Materials required include a D-frame aquatic net, hip waders, calibrated DO meter (YSI Model 83), large container to hold DO sample water, calibrated pH meter (Beckman Model 11), small container to hold pH sample water, 50-meter tape, yard stick, sample pans, a separate labeled bottle for each sample location, forceps, and 100% ethyl alcohol preservative (enough to completely cover each sample)(Gary Neuderfer, personal communication, 20 Oct. 2006; Bode *et al*., 2002).

Upon arrival at the sampling site, containers for DO and pH were filled with water from the sample location, and the DO and pH probes were inserted into the respective containers and left to acclimate to the water conditions while kick sampling. These containers remained in the stream throughout sampling to regulate water temperature (Gary Neuderfer, personal communication, 20 October, 2006). A straight five meter stretch along the stream was measured and marked. Standing to one side of the channel at the upstream mark, the sampler held the aquatic net in front of his or her self and vigorously disturbed the substrate by kicking to dislodge macroinvertebrates from the substrate. While kicking vigorously, the sampler moved slowly downstream. Sampling should cover the five meter stretch in approximately five minutes, moving diagonally across the channel while moving downstream (Bode *et al*., 2002).

The entire sample was then emptied into the pan and any specimens stuck in the net were loosened by gently agitating the net in the stream and rinsed into the pan. Excess water was removed by concentrating the sample into a small aquarium net before transferring it to the bottle. Preservative was added to completely cover the sample. During fall samplings, leaf litter increased sample volumes. As a result there was an insufficient amount of preservative on hand. In this event, Megaloptera larvae were preserved to avoid predation of the sample, and the sample was preserved within a few hours.

After collecting the macroinvertebrate sample, pH and DO were measured following instrument instructions. To calculate flow volume, the width of the stream was measured and divided into intervals. The number and width of intervals depended on stream width and variability in depth. Using a meter stick, depth to the substrate surface was measured at each interval. Large rocks and indentations in the substrate were avoided. At each of these intervals, a flow meter was held near the substrate, away from eddies or objects that could interrupt flow. The flow meter is held toward the bottom of a stream to avoid surface conditions that may affect flow (e.g., wind), but does not touch the substrate surface. Width, depth and velocity at each interval were used to calculate interval flow (Equation 1). These values were summed to approximate stream flow.

Interval Flow = Width * Depth * Velocity *(Equation 1)*

Visual observations recorded in the field include weather conditions, substrate embeddedness, and canopy cover. Sampling date and time of day were also recorded.

In the lab, the sampling pan was divided into 20 equal sections. The sample was evenly spread in the pan, and sections were randomly selected using a 20-sided die. Contents of the section number rolled were gently scraped from the pan and placed in a petri dish, and a microscope was used to pull out invertebrates. This process was repeated until approximately 100 individuals were collected from the sample. It is strongly recommended that future studies involve collection of subsamples without magnification to ease the identification process, or adhere to the suggested rule of only selecting organisms greater than 1.5 mm in total length (Bode *et al.*, 2002).

Freshwater Macroinvertebrates of Northeastern North America (Peckarsky *et al.,* 1990) was used to identify the subsamples to the genus level. Non-aquatic individuals, fish and pupae were excluded from all samples. The total number of individuals of each genus was counted, and the number was adjusted to be representative of a 100-specimen sample. Genus richness, EPT richness, Shannon-Wiener genus diversity, Hilsenhoff biotic index and percent model affinity were then calculated and applied to the Biological Assessment Profile of Index Values for Riffle Habitats (Bode *et al*., 2002) to describe the water quality of Grimes and Eelpot Creeks.

Statistical Analysis

Macroinvertebrate results were subjected to statistical analysis to indicate differences between subwatersheds and between sites within each subwatershed. Because of this tiered design, a two-factor ANOVA would indicate any statistically significant differences in the data, but post-hoc tests would not be useful in determining where the differences lie. Therefore, a two-factor nested ANOVA design was used with SITE (sample location) and GROUP (subwatershed) variables, where SITE variables 1-3 indicated Grimes sites 1-3, and SITE variables 4-8 indicated Eelpot sites 1-5, respectively (Figure 5).

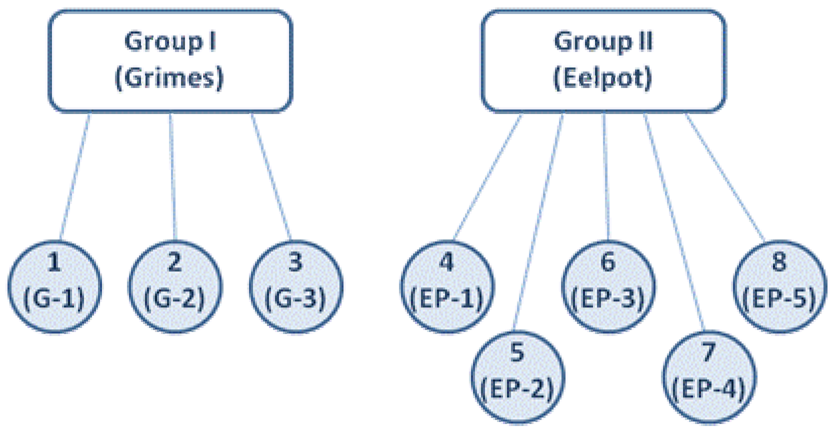


Figure 5 – Nested ANOVA design for macroinvertebrate analysis. Data was separated into GROUP (average values for entire watersheds) and SITE (individual site averages) variables. These were applied to a two-factor nested ANOVA design to compare the two subwatersheds, as well as compare sites within each watershed.

Chemical Analysis

Storm event sampling conducted by the CLWC has revealed that Eelpot has high levels of TSS and TP. These samples, however, are representative of the entire subwatershed and make no distinction between the various branches of Eelpot Creek. A stress-stream analysis of Eelpot Creek is included in this study to determine potential pollutant origins. Storm event samples were collected in Eelpot Creek seven times throughout the course of the study and analyzed for total phosphorus (TP), total suspended solids (TSS) and nitrate/nitrite (N). There were a total of 11 chemical sample sites along Eelpot Creek, including the 5 macroinvertebrate kick-sampling sites. No samples were taken along Grimes Creek because this watershed has historically low TSS, TP and N levels.

During runoff events, one acid-treated (for nitrate/nitrites) and one untreated bottle (for TSS and TP) were filled with stream water from each site. Using the untreated bottle, water was collected from a spot in the stream with flowing water; the mouth of the bottle was held underwater to avoid surface contamination, without touching the substrate to avoid contamination from nutrients in the sediment. This sample was then poured into the acid-treated bottle and the untreated bottle was filled again. Samples were stored in a cooler during collection to block sunlight and keep the temperature constant and brought to Life Science Laboratories (LSL) in the City of Canandaigua. Chemical analysis was performed by this accredited laboratory so the results could be used by the CLWC. For this reason, the council also covered the cost of analysis.

GIS Analysis

Two geographical information systems, ArcGIS ArcMap version 9.2 and IDRISI Kilimanjaro, were used to analyze slope, land use/land cover (LULC), erosion, and runoff. The analysis focused on a 'buffer' on either side of the streams in Grimes and Eelpot Creeks.

GIS analysis of the two watersheds was used to identify land use within 30 m of the streams, showing the total buffer area throughout both watersheds. The prevalence of steep slopes in each watershed was also addressed. Gilman and Olvany (2006) briefly discuss that Eelpot has glacial moraine soils which are susceptible to erosion. Since the erodibility of soils can influence sedimentation and impervious surfaces can influence runoff, revised universal soil loss equation (RUSLE) and long-term hydrologic impact assessment (L-THIA) models were also run in IDRISI to locate potential hotspots in the watersheds.

Slope

Erosion and runoff are influenced by the steepness of a landscape. Preliminary ground-truthing verified that both Grimes and Eelpot subwatersheds are characterized by steep slopes. To quantify this characteristic, the SLOPE function in IDRISI Kilimanjaro was run on the digital elevation model (DEM) of the watersheds. The resulting image was classified into slope categories to reduce noise in the image.

The crosstab function in IDRISI was then used to quantify the total land area of each slope category. The resulting table produces the number of pixels of each slope, which was then multiplied by 900 m^2 to calculate the total land area (the DEM image has 30 by 30 m resolution). To compare the two watersheds, these values were converted into the percentage of total land area.

Land Use and Land Cover

Land use and land cover (LULC) maps were acquired from the Ontario County planning department and used to assess land cover on slopes and near streams. Ground-truthing was conducted in select areas of the watershed to verify accuracy of the maps used; no major discrepancies were noted.

Long-Term Hydrologic Impact Assessment (L-THIA)

The L-THIA model was designed to evaluate impervious cover and estimate the volume of annual runoff within a watershed, and it is used here to compare estimated runoff between the two watersheds. L-THIA works by assigning curve numbers to determine the contribution of each land cover to overall runoff – the higher the number, the more runoff from the surface. Values were assigned based on the percentage of impervious cover, or ground cover that is impenetrable by water (leading to runoff). Curve numbers were taken from USDA Technical Release 55 (USDA, 1986). For this analysis, it was assumed that contour plowing and crop residue are practiced by all farmers. Understanding that not all farmers practice these conservation strategies (or practicing them well), the values associated with "poor" use of these techniques were used. Because this is a relatively low density region, average residential lot sizes of 2 acres in a low density area, and ¼ acre per plot in the higher density areas were used. Woods and urban grasses are thick and in good condition wherever they are present, as are hay and fallow fields. Therefore, these were all assigned "good" values. Scrub/shrub areas were treated as "good" woods/grass combination areas, accounting for any vineyards that might have been misclassified. It is expected that runoff in these areas is slightly higher than in forests.

Revised Universal Soil Loss Equation (RUSLE)

The RUSLE soil erosion model estimates the average annual soil loss (A) of an area in tons/acre/year. The model does this using land cover (C), slope steepness and length (LS), soil erodibility (K), agricultural practice (P) and runoff erosivity (R) (equation 2).

$$\mathbf{A = R * K * LS * C * P} \qquad \textit{(equation 2)}$$

An elevation map of the two subwatersheds was acquired from the USGS National Seamless Server. The model uses this image to determine the slope steepness and length of slope (LS) used in the analysis. Soil data was downloaded from the NRCS Web Soil Survey and used to generate an appropriate erodibility factor (K). The NRCS has assigned K factors to each soil type, and these were used to classify the soils image.

The P factor is an assigned value between 0 and 1 that represents conservation practices used on cropland (BMPs). A value of 0 indicates perfect erosion control (no erosion) and a value of 1 indicates no erosion control on cultivated areas (maximum erosion).The difference between cultivated areas that use BMPs and those that don't is not distinguished in the available LULC images. It was assumed that both subwatersheds have a similar proportion of landowners using BMPs, and that the two watersheds are therefore comparable at any P value, so the P factor ultimately plays a small role in this analysis. P increases with increasing slope, and both watersheds are characterized by steep slopes. Thus, it was assumed that the slopes in both subwatersheds contribute to increased erosion and a P of 1 was assigned.

The R factor is a constant that is an estimate of susceptibility to erosion and runoff during a storm event. The average R factor for Western New York, 113, was used for this analysis.

The land use/land cover (LULC) map was used to assign C factors to each cover type. The C factor for a land cover compares soil loss under the specific land use to soil loss assuming unmanaged, continuous cover. Because it is known that many farmers in the region do exercise best management practices (BMP), it was assumed all agricultural fields maintained cover that helps prevent erosion. To account for any fields that may not have adequate cover, vegetative cover on all cultivated fields was assumed to be in poor condition.

The slope threshold was set at 3%, since slopes less than 3% are considered level (Soil Survey Division Staff, 1993). Steeper slopes are vulnerable to erosion and should not be used for agriculture. The minimum slope length was set at 150 feet. The area threshold was set at 15,000 pixels. While this is much larger than desired, there were limitations in the available GIS software that made it unable to handle smaller areas.

To demonstrate high erosion concerns within a 30m buffer, the RUSLE results were overlaid by a stream buffer mask. CrossTab was again used, this time to determine the total area of high erosion patches within 30m of the stream.

Results

Macroinvertebrate Analysis

Because habitat conditions can influence macroinvertebrate community composition, mean flow, mean temperature and mean pH were calculated using data collected during each sample event. Embeddedness and cover were visually estimated during the November 3, 2006 sample event and did not appear to change significantly throughout the course of the study. Table 1 includes the mean flow and visual assessment observations for each sample location.

Table 1 – Chemical and physical characteristics. Mean temperature, pH, dissolved oxygen, flow and visual characteristics were recorded at all sample locations. Visual characteristics were unlikely to change over the span of the study and were therefore only recorded once. All other characteristics were recorded during each sample event.

	G-1	G-2	G-3	Mean	EP-1	EP-2	EP-3	EP-4	EP-5	Mean
Temperature (°C)	12.97	12.97	14.27	13.40	11.63	12.33	12.40	12.43	12.80	12.32
pH	8.42	8.44	8.40	8.42	8.40	8.54	8.42	8.22	8.48	8.42
Dissolved Oxygen	8.85	9.00	8.60	8.82	9.45	9.30	9.62	8.88	9.45	9.34
Flow	2.84	1.41	1.22	1.82	2.01	0.93	6.22	0.84	7.22	3.44
Embeddedness	20	20	50	30	55	40	10	40	20	33
Canopy Cover	20	70	80	56.7	75	90	90	100	90	89

There is little variation among the sites for DO, pH and temperature. However embeddedness, a visual measure of the amount of sedimentation in the stream bed, appears to be higher at G-3, EP-1, EP-2 and EP-4 than at the other study sites. This is not surprising at site G-3 because of severe stream-bank erosion at the study site. High embeddedness at the EP sites suggests possible erosion problems upstream. Flow is highest at sites EP-3 and EP-5, and lowest at EP-2 and EP-4. EP-3 and EP-5 are fourth- and seventh-order streams, respectively, so higher flow was expected. There is little difference in flow among Grimes sites. Overall, Eelpot Creek has a larger volume of water passing through than Grimes.

As one of the most basic measures of community integrity, richness is simply the total number of taxonomic groups collected in a sample; higher richness is generally associated with higher quality water (Bode *et al.*, 2002). Genus richness by site and sample date is shown in Table 2. The richness boxplot in Figure 6 illustrates mean richness for each sampling site within the two watersheds.

Table 2 – Genus Richness. This table shows genus richness by location and sample date. Richness is simply the total number of genera counted in a sample.

	G-1	G-2	G-3	Mean	EP-1	EP-2	EP-3	EP-4	EP-5	Mean
3 Nov 2006	15	19	22	18.67	11	22	22	18	11	16.80
12 Jun 2007	21	19	28	22.67	17	29	20	22	23	22.2
7 Sep 2007	27	33	18	26.00	18	23	18	23	18	20.00
9 Nov 2007	27	25	25	25.67	21	23	21	23	22	22.00
Mean	22.5	24.0	23.25	**23.25**	16.75	24.25	20.25	21.5	18.5	**20.5**

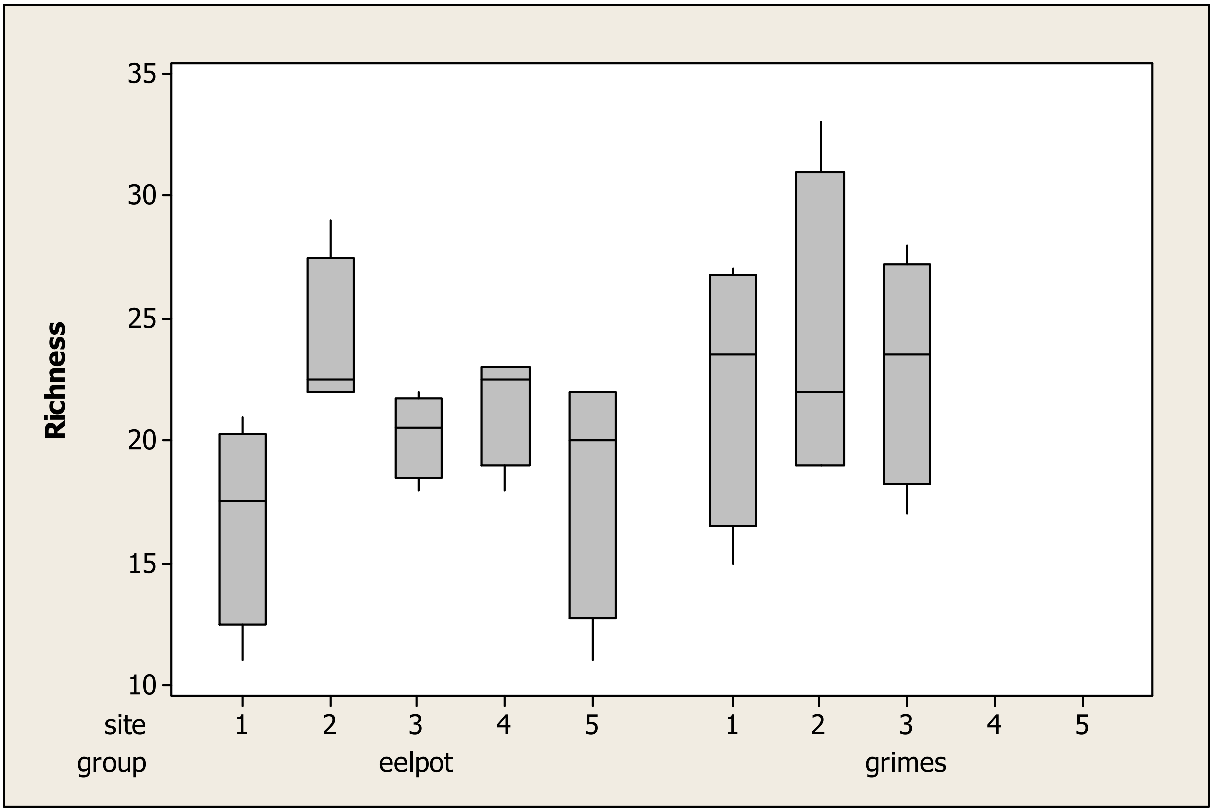


Figure 6 – Boxplot of Genus Richness. The sites were separated into the two subwatersheds and charted in a boxplot. There is no statistically significant difference in genus richness between or within the two subwatersheds.

While visually it may appear that EP-1 has lower richness than the other sites (particularly as compared to G-1 and G-3), there is insufficient evidence to conclude that there is a significant difference in richness between (p-value = 0.086) or within the two subwatersheds (p-value = 0.387).

One drawback to richness alone is that it does not take into account the types of organisms found. Members of Ephemeroptera, Plecoptera and Tricoptera orders (shortened as EPT) are typically found in clean, cool, fast-flowing headwater streams (Peckarsky, *et al.,* 1990). Because they are most commonly found in clean water and many EPT genera are intolerant of low oxygen or high nutrient conditions, the presence of these groups is used as an indicator of good water quality (Bode, *et al.,* 2002). EPT richness by site and sample date is shown in Table 3. The EPT richness boxplot in Figure 7 illustrates mean EPT richness for each sampling site within the two watersheds.

Table 3 – EPT Genus Richness. Certain orders are less tolerant of pollution than others. Healthy communities of Ephemeroptera, Plecoptera and Tricoptera are commonly used to indicate good water quality. This table shows the richness of these three orders in the subwatersheds.

	G-1	G-2	G-3	Mean	EP-1	EP-2	EP-3	EP-4	EP-5	Mean
3 Nov 2006	13	12	12	12.33	8	15	12	12	6	11.45
12 Jun 2007	13	11	10	11.33	13	19	12	8	11	11.66
7 Sep 2007	13	21	6	13.33	10	13	7	10	7	11.35
9 Nov 2007	15	15	12	14.00	15	16	10	16	9	12.33
Mean	13.50	14.75	10.00	**12.75**	11.50	15.75	10.25	11.50	8.25	**11.70**

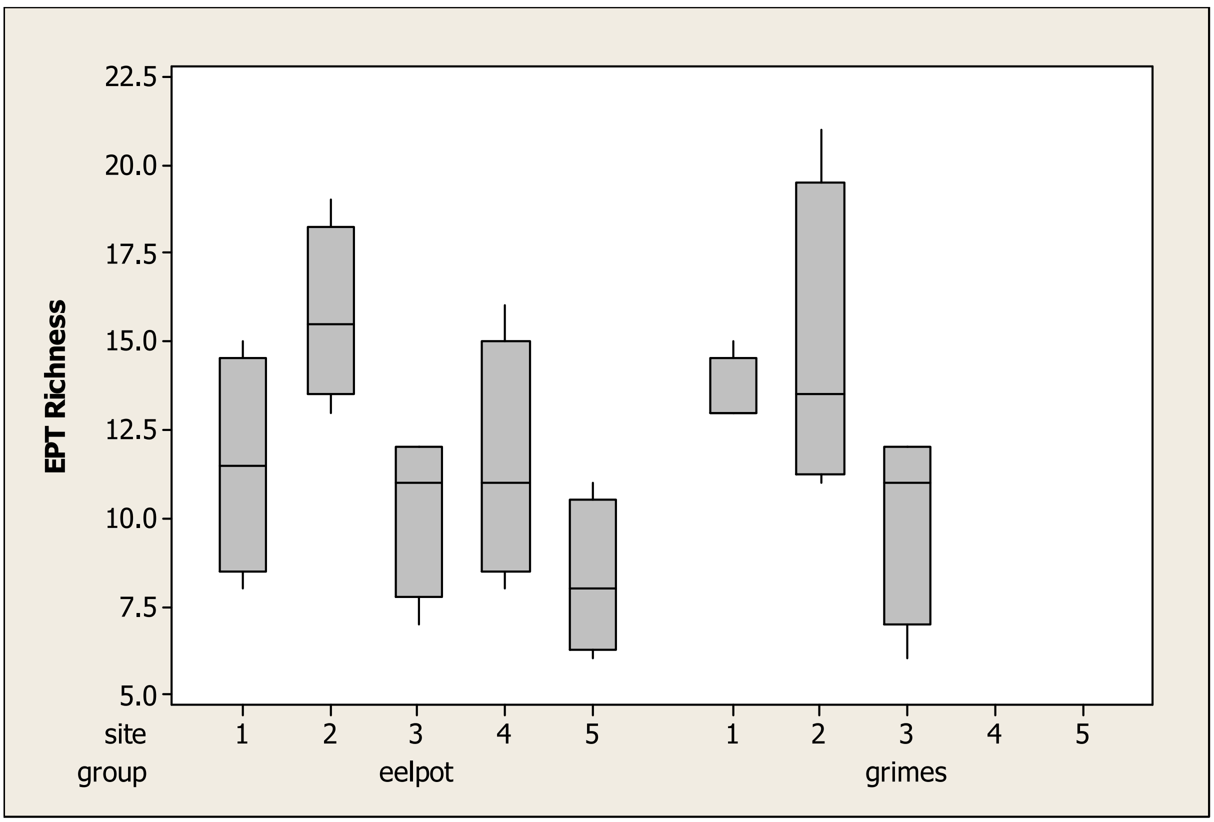


Figure 7 – Boxplot of EPT Genus Richness. The sites were separated into the two subwatersheds and charted in a boxplot. ANOVA results showed a significant difference within watersheds (p-value = 0.015). Based on this boxplot, the difference appears to be between EP-2 and EP-5.

Results of the nested ANOVA suggest that there is not enough evidence to conclude that there is a significant difference between watersheds (p-value = 0.232). However, the results *do* demonstrate a significant difference within the subwatersheds (p-value = 0.015). A one-way ANOVA with Tukey's post-hoc test revealed a significant difference between EP-2 and EP-5 (p-value = 0.023), which can be clearly seen in Figure 7. The results of the post-hoc test are shown in Table 4; the result for EP-2 versus EP-5 is highlighted in gray.

TABLE 4 – Tukey Multiple Comparison results for EPT Genus Richness. There is a significant difference between the EPT Richness of EP-2 and EP-5 (p-value = 0.023). Mean difference is significant at 0.05.

(I) Site	(J) Site	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
G-1	2	-1.2500	2.0514	.998	-8.0442	5.5442
	3	3.5000	2.0514	.684	-3.2942	10.2942
	4	2.0000	2.0514	.974	-4.7942	8.7942
	5	-2.2500	2.0514	.951	-9.0442	4.5442
	6	3.2500	2.0514	.755	-3.5442	10.0442
	7	2.0000	2.0514	.974	-4.7942	8.7942
	8	5.2500	2.0514	.219	-1.5442	12.0442
G-2	1	1.2500	2.0514	.998	-5.5442	8.0442
	3	4.7500	2.0514	.326	-2.0442	11.5442
	4	3.2500	2.0514	.755	-3.5442	10.0442
	5	-1.0000	2.0514	1.000	-7.7942	5.7942
	6	4.5000	2.0514	.390	-2.2942	11.2942
	7	3.2500	2.0514	.755	-3.5442	10.0442
	8	6.5000	2.0514	.068	-.2942	13.2942
G-3	1	-3.5000	2.0514	.684	-10.2942	3.2942
	2	-4.7500	2.0514	.326	-11.5442	2.0442
	4	-1.5000	2.0514	.995	-8.2942	5.2942
	5	-5.7500	2.0514	.141	-12.5442	1.0442
	6	-.2500	2.0514	1.000	-7.0442	6.5442
	7	-1.5000	2.0514	.995	-8.2942	5.2942
	8	1.7500	2.0514	.988	-5.0442	8.5442
EP-1	1	-2.0000	2.0514	.974	-8.7942	4.7942
	2	-3.2500	2.0514	.755	-10.0442	3.5442
	3	1.5000	2.0514	.995	-5.2942	8.2942
	5	-4.2500	2.0514	.459	-11.0442	2.5442
	6	1.2500	2.0514	.998	-5.5442	8.0442
	7	.0000	2.0514	1.000	-6.7942	6.7942
	8	3.2500	2.0514	.755	-3.5442	10.0442
EP-2	1	2.2500	2.0514	.951	-4.5442	9.0442
	2	1.0000	2.0514	1.000	-5.7942	7.7942
	3	5.7500	2.0514	.141	-1.0442	12.5442
	4	4.2500	2.0514	.459	-2.5442	11.0442
	6	5.5000	2.0514	.177	-1.2942	12.2942
	7	4.2500	2.0514	.459	-2.5442	11.0442
	8	7.5000	2.0514	.023	.7058	14.2942
EP-3	1	-3.2500	2.0514	.755	-10.0442	3.5442
	2	-4.5000	2.0514	.390	-11.2942	2.2942
	3	.2500	2.0514	1.000	-6.5442	7.0442
	4	-1.2500	2.0514	.998	-8.0442	5.5442
	5	-5.5000	2.0514	.177	-12.2942	1.2942
	7	-1.2500	2.0514	.998	-8.0442	5.5442
	7	2.0000	2.0514	.974	-4.7942	8.7942

(I) Site	(J) Site	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
EP-4	1	-2.0000	2.0514	.974	-8.7942	4.7942
	2	-3.2500	2.0514	.755	-10.0442	3.5442
	3	1.5000	2.0514	.995	-5.2942	8.2942
	4	.0000	2.0514	1.000	-6.7942	6.7942
	5	-4.2500	2.0514	.459	-11.0442	2.5442
	6	1.2500	2.0514	.998	-5.5442	8.0442
	8	3.2500	2.0514	.755	-3.5442	10.0442

While the total number of taxonomic groups represented is important, so is their distribution. A well-balanced community is a sign of good water quality. The Shannon-Weiner diversity calculation takes both the richness and evenness of a community into account. Lower diversity indicates stress or impairment (Bode *et al.,* 2002). Genus diversity by site and sample date is shown in Table 5. The diversity boxplot shown in Figure 8 illustrates mean genus diversity for each sampling location within the two subwatersheds.

Table 5 – Shannon-Weiner genus diversity. This table contains diversity values calculated with the Shannon-Weiner diversity index for both subwatersheds. Diversity is a measure that takes both richness and evenness of a community into account.

	G-1	G-2	G-3	Mean	EP-1	EP-2	EP-3	EP-4	EP-5	Mean
3-Nov-06	2.26	2.44	2.32	2.34	1.84	2.56	2.65	2.58	1.95	2.32
12-Jun-07	2.5	2.48	2.97	2.65	2.16	2.75	2.46	2.57	2.44	2.48
7-Sep-07	2.67	3.13	2.35	2.72	2.36	2.24	2.24	2.58	2.42	2.37
9-Nov-07	2.51	2.62	2.78	2.64	2.66	2.51	2.6	1.95	2.72	2.49
Mean	2.49	2.67	2.61	**2.59**	2.26	2.52	2.49	2.42	2.38	**2.41**

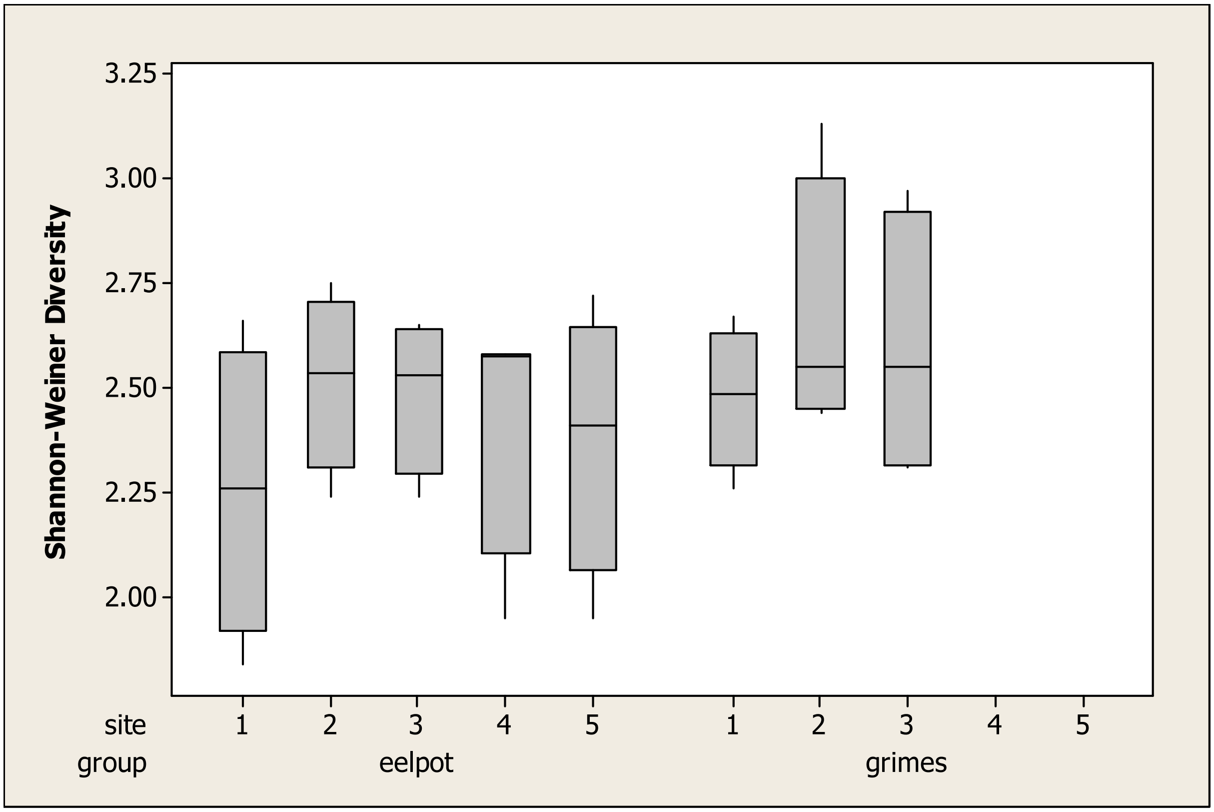


Figure 8 – Boxplot of Shannon-Weiner genus diversity. The sites were separated into the two subwatersheds and charted in a boxplot. ANOVA results showed no significant difference within or between the subwatersheds.

Although diversity appears to be slightly higher in Grimes and different between sampling locations, statistically there is insufficient evidence to suggest that there is a difference in diversity between the two watersheds (p-value = 0.065) or between sites within each watershed (p-value = 0.072).

As mentioned, some taxa (e.g., orders EPT) are intolerant of organic and other pollutants and are therefore most commonly found in less-impacted streams. The Hilsenhoff Biotic Index (HBI) assigns tolerance values to each genus or species within an order. Higher tolerance scores mean an organism is better able to cope with organic pollutants. Thus, unlike the other measures used in this study, higher HBI scores indicate more impacted streams (Bode *et al.*, 2002). HBI scores by site and sample date are shown in Table 6. The HBI boxplot (Figure 9) illustrates mean HBI for each sampling site within the two watersheds.

Table 6 – Hilsenhoff Biotic Index scores. The HBI index is used to assess a community based on the tolerance of organic (sewage) pollutants. This table shows HBI scores for samples collected in the two subwatersheds. Although some appear higher than others, all of these values are generally low.

	G-1	G-2	G-3	Mean	EP-1	EP-2	EP-3	EP-4	EP-5	Mean
3-Nov-06	2.6	2.5	3	2.70	3.45	2.97	2.62	2.28	3.09	2.88
12-Jun-07	2.97	2.9	4.8	3.56	1.88	2.06	3.47	4.74	4.46	3.32
7-Sep-07	3.14	3.7	3.8	3.55	3.46	3.77	4.22	3.73	4.21	3.88
9-Nov-07	2.9	2.4	3.8	3.03	3.25	2.29	3.4	1.7	3.28	2.78
Mean	2.90	2.88	3.85	**3.21**	3.01	2.77	3.43	3.11	3.76	**3.22**

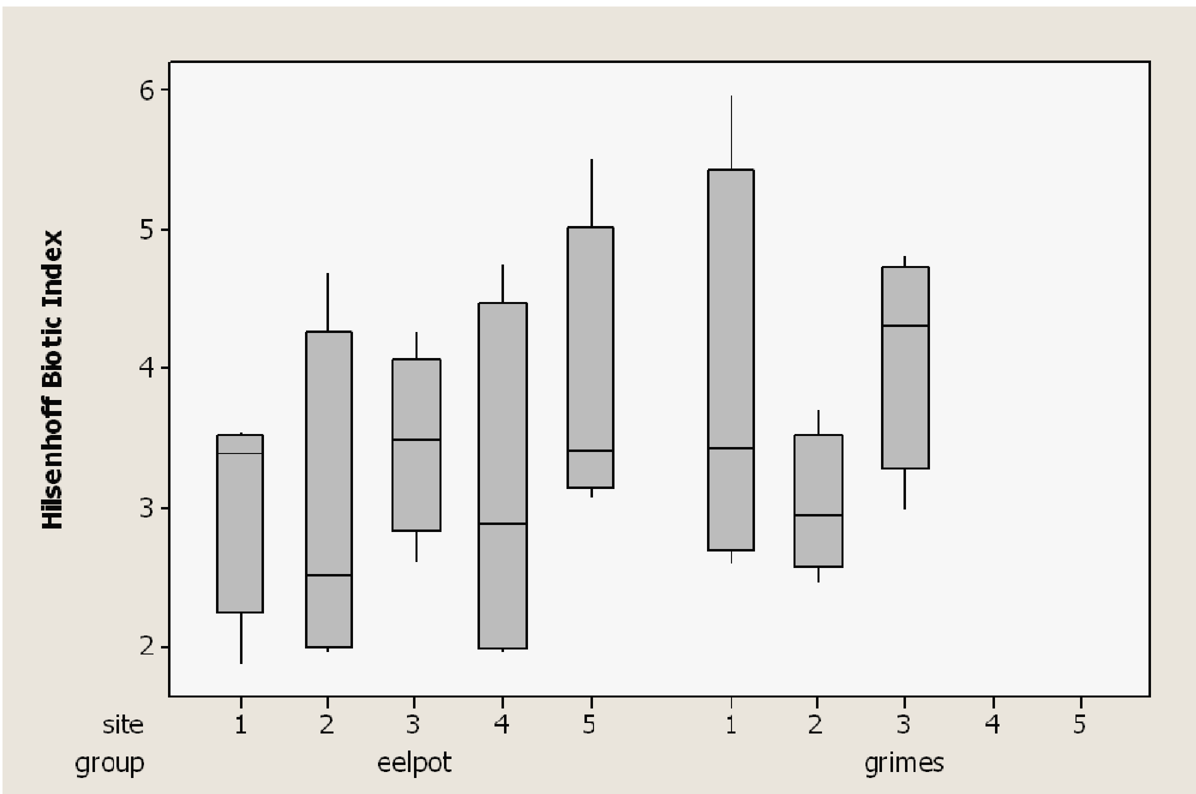


Figure 9 – Boxplot of Hilsenhoff Biotic Index scores. The sites were separated into the two subwatersheds and charted in a boxplot. Index scores below 4.5 are considered to represent "non-impacted" streams. Because all of the means are below 4.5, there is little concern that organic pollutants affect these watersheds. Likewise, there is no significant difference between or within subwatersheds.

There is insufficient evidence to conclude that there is a difference between (p-value = 0.336) or within the two subwatersheds (p-value = 0.625) based on the results of the nested ANOVA. According to Bode *et al.* (2002), HBI index scores lower than 4.5 are indicative of non-impacted streams. Because the mean of each sample location is below 4.5, the watersheds are likely not affected by organic pollutants (sewage, waste, etc.). However, G-3 was consistently higher than all other sampling locations, and exceeded this score threshold for one of the sample dates. The possibility that G-3 may be slightly impacted by organic pollutants should not be ruled out, though this result could also be a product of heavy erosion at the sample site.

It is difficult to interpret results of the indices discussed thus far without knowing what the communities should look like. Percent Model Affinity (PMA) is a measure that compares community composition in the sample to the theoretical composition of a community living in ideal conditions. The sample is broken down by major groups, and the percent represented of each group is compared to an ideal community. Higher percent similarity indicates less impact on the stream. PMA values by site and sample date are shown in Table 7. The PMA boxplot in Figure 10 illustrates mean PMA at each sampling site within the two watersheds.

Table 7 – Percent Model Affinity values. PMA is a measure of how close the sample community is to a model macroinvertebrate community living in ideal conditions. This table shows PMA values for the sample sites.

	G-1	G-2	G-3	Mean	EP-1	EP-2	EP-3	EP-4	EP-5	Mean
3-Nov-06	66	61	41	56.00	32	66	62	66	57	56.60
12-Jun-07	74	96	79	83.00	89	74	100	120	112	99.00
7-Sep-07	78	71	64	71.00	50	40	57	62	100	61.80
9-Nov-07	78	87	62	75.67	71	80	80	44	79	70.80
Mean	74.00	78.75	61.50	**71.42**	60.50	65.00	74.75	73.00	87.00	**72.05**

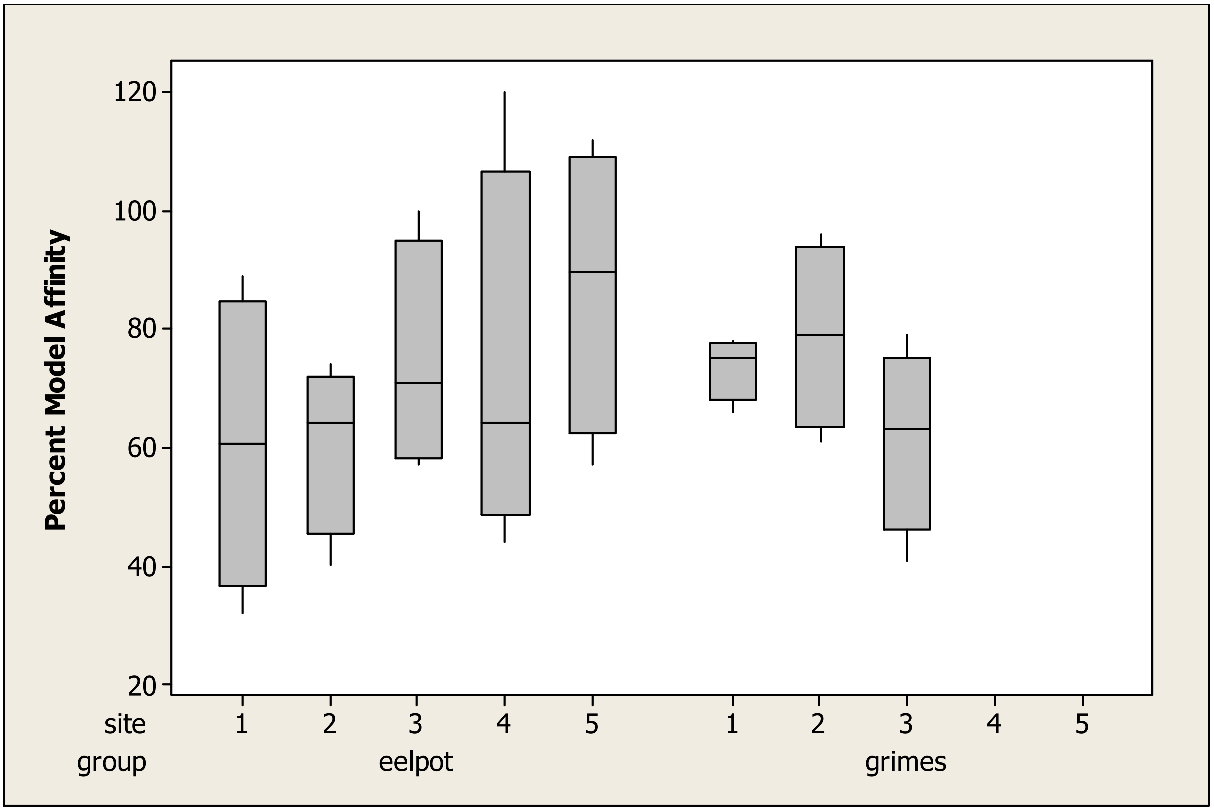


Figure 10 – Boxplot of Percent Model Affinity values. The sites were separated into the two subwatersheds and charted in a boxplot. There is no significant difference in PMA between or within the two subwatersheds. The PMA values shown here are also relatively high, supporting the idea that these streams are not seriously impacted.

Results of the nested ANOVA suggest that there is not enough evidence to conclude that there is a significant difference between (p-value = 0.989) or within the two subwatersheds (p-value = 0.433). Interestingly, EP-5 has the highest PMA despite falling short in richness and EPT richness, and Eelpot averages higher PMA than Grimes overall. This is surprising since Eelpot appears more impacted than Grimes in all other measures.

It is difficult to use the individual water quality indices summarized above to compare overall water quality between the two subwatersheds. Bode *et al.* (2002) use a Mean Assessment Profile Value to represent these water quality index results in a single value. This general index value can be used to directly compare a number of sample locations. Figure 11 illustrates the relationships between individual site profile values as well as overall mean profile assessment scores for Grimes and Eelpot.

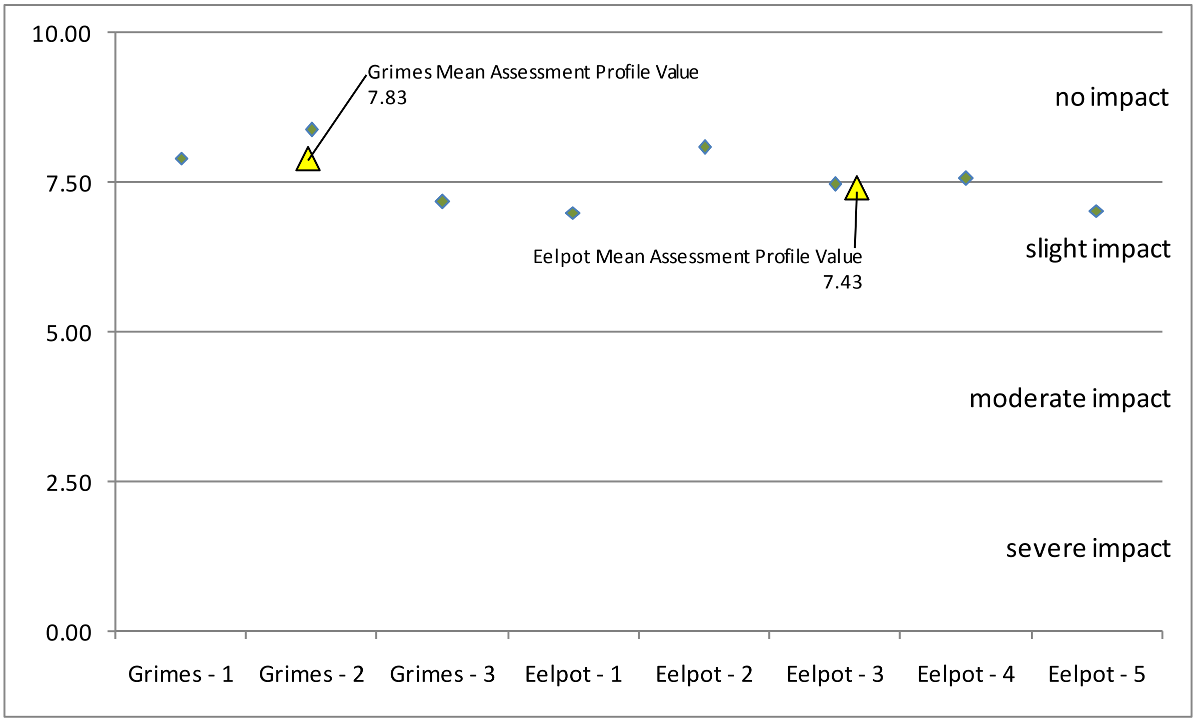


Figure 11 – Scatter plot of Mean Assessment Profile Values. This value, as outlined in Bode *et al.*(2002), is a calculation that represents overall impact based on richness, EPT richness, diversity, PMA, and HBI. This formula allows us to assess each site as compared overall to the other sites. Bode *et al.*(2002) have also categorized these values to indicate the level of impaction at a sample site. All sites in both watersheds are either not impacted or only slightly impacted.

Even though there is no statistically significant difference between the sites for each water quality measure, it can be seen in Figure 11 that Grimes Creek shows "no impact," while Eelpot Creek is "slightly impacted." Of the individual sites, G-3, EP-1, EP-3 and EP-5 are all "slightly impacted."

GIS

Slope

Slope was first classed into seven categories based on the general classifications (as previously mentioned, slopes less than 3% are considered flat enough for agriculture): 0, 1-<3, 3-<6, 6-<9, 9-<12, 12-<15, >15 percent slope. Seven slope categories made the resulting image difficult to interpret. The subwatersheds in Figure 12 were therefore classified with 5% ranges (0, 1-< 5, 5-< 10, 10-<15, >15).

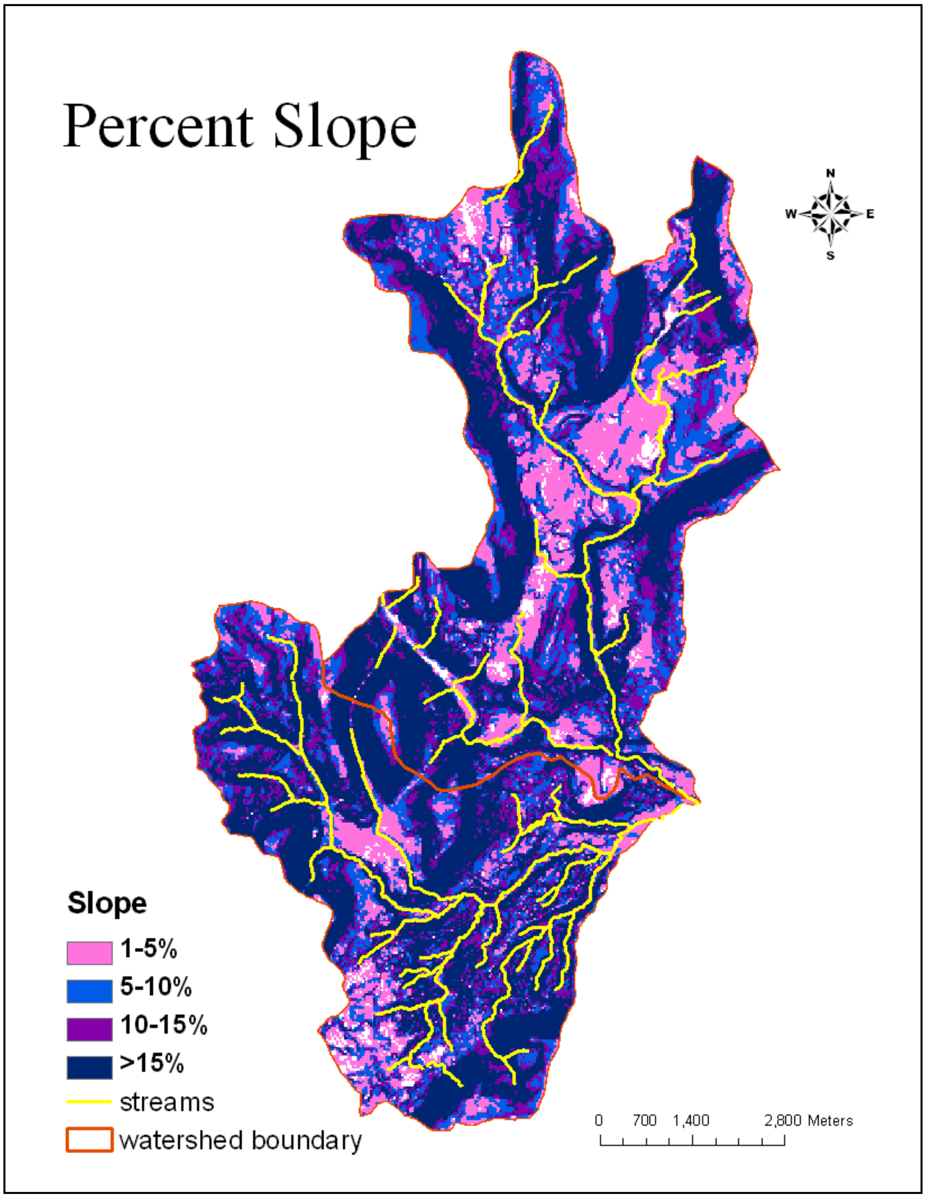


Figure 12 – Slope in Grimes and Eelpot. This image represents the slopes throughout the Grimes and Eelpot subwatersheds (outlined in red). Darker purple represents steeper slopes. It can be seen in this image that the steepest slope category appears to dominate in both subwatersheds.

Figure 12 reveals two important considerations: (1) the majority of slopes in both watersheds are steeper than 15% and (2) steep slopes occur throughout both watersheds, including the headwaters. Further, there appears to be little difference between the total areas of each slope class in the two watersheds, aside from Eelpot having slightly more slopes >15%. To quantify this, crosstab was run; the results are reported in Figure 13.

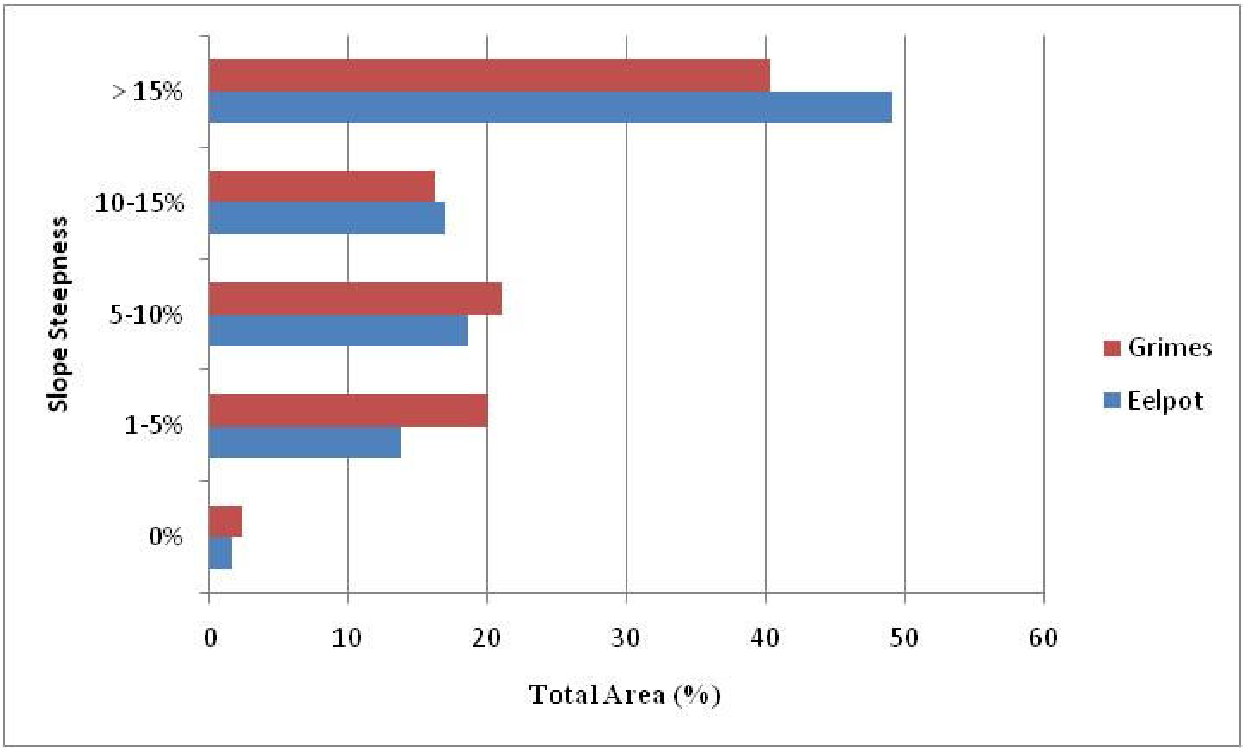


Figure 13 – Percent slope by total land area. Slope categories were quantified and compared to help visualize slope composition. It can be seen that the two subwatersheds are very similar, but that Eelpot has about 10% more slopes by area in the steepest category.

These results verify that Grimes and Eelpot are both highly susceptible to erosion. Although the two watersheds have similar slope composition, Grimes has approximately 6% more slopes of 1-5% steepness than Eelpot, and approximately 8% less land characterized by slopes greater than 15%, putting Eelpot at slightly higher risk for erosion-related issues.

L-THIA

As with the slope results, it is clear that there is little difference between the two watersheds in the amount of runoff by area (Table 8).

Table 8 – L-THIA model results. The L-THIA model is used to estimate the total volume of runoff in a selected area. The model is based on land cover, impervious surfaces, and slopes. Because it is partially based on the *quality* of cover, several assumptions must be made. The assumptions should not however change the ability to compare of the two subwatersheds as long as the practices used in both areas are similar.

	Eelpot	Grimes
Runoff Volume	253 acre-ft	266 acre-ft
Total Area	6,975 acres	10,134 acres
Feet per Year	0.04 feet	0.03 feet

LULC

The two subwatersheds have similar land covers but differ in the proportion of agricultural and forest cover, which can influence water quality. Typically, agriculture increases the amount of erosion, runoff, and organic pollutants reaching the stream. Other land uses that likely impact water quality are listed in Table 9. Figure 14 is the LULC map used for GIS analysis in this study. Total percent cover of each land use in the two subwatersheds was quantified and is represented in Figure 15.

Table 9 – Land Use Land Cover. This table quantifies the percent representation of cover types which likely influence water quality in Grimes and Eelpot subwatersheds.

Cover Type	**Eelpot Creek (%)**	**Grimes Creek (%)**
Crop	20	3
Forest	54	68
Pasture	0.5	1.6
Residential/Urban	5.5	4.4
Open Uplands	12.9	11.5
Ponds/Wetlands	2.6	3.1

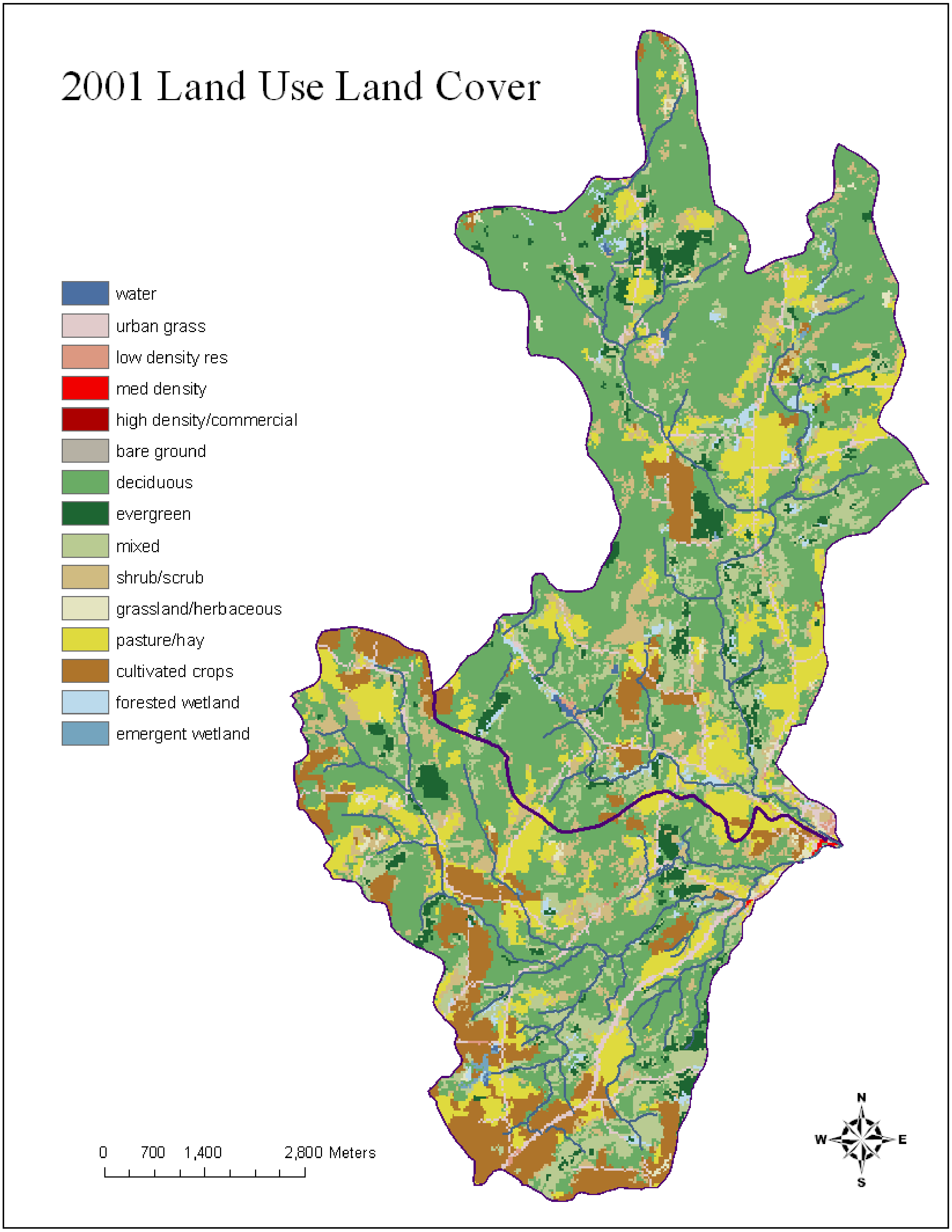


Figure 14 – Land Use Land Cover in Grimes and Eelpot. Land use/cover plays a major role in determining how concentrated pollutants will be in a water body. This LULC image was provided by the Ontario County Planning

Department (developed in 2004).

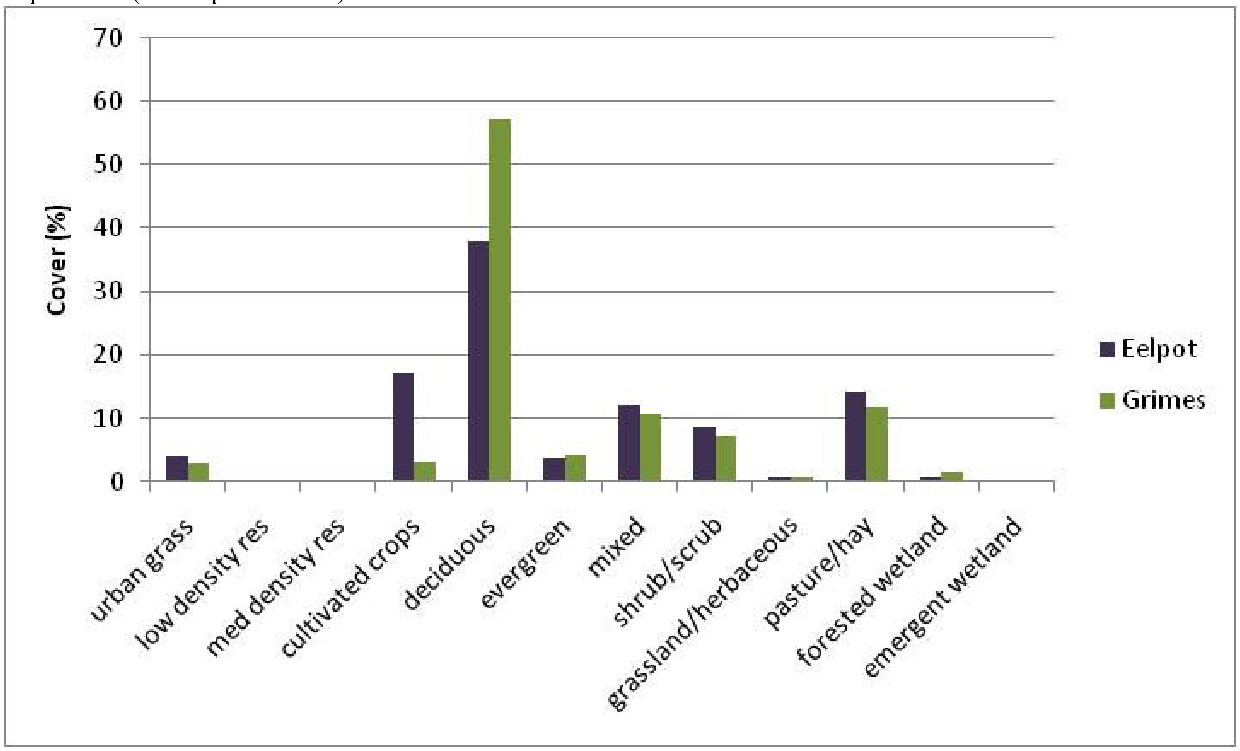


Figure 15 – Percent of each cover type by total land area. This image quantifies the LULC map to compare the represented cover types in each subwatershed. The only categories that stand out are cultivated crops and deciduous forests.

Note that most of the agriculture in Eelpot is situated on or near steep slopes in the headwaters of each branch (Figure 14). Grimes, however, appears to only have agriculture along shallower slopes, and almost no agricultural fields in the headwaters. Likewise, Grimes has almost 20% more forested cover than Eelpot and over 10% less cultivated land (Figure 15). Agriculture and slope alone do not guarantee that pollutants will reach the stream. To quantify the amount of 30-m buffers along the streams, a mask was made to portion out 30 meters along both sides of the creeks (Figure 16).

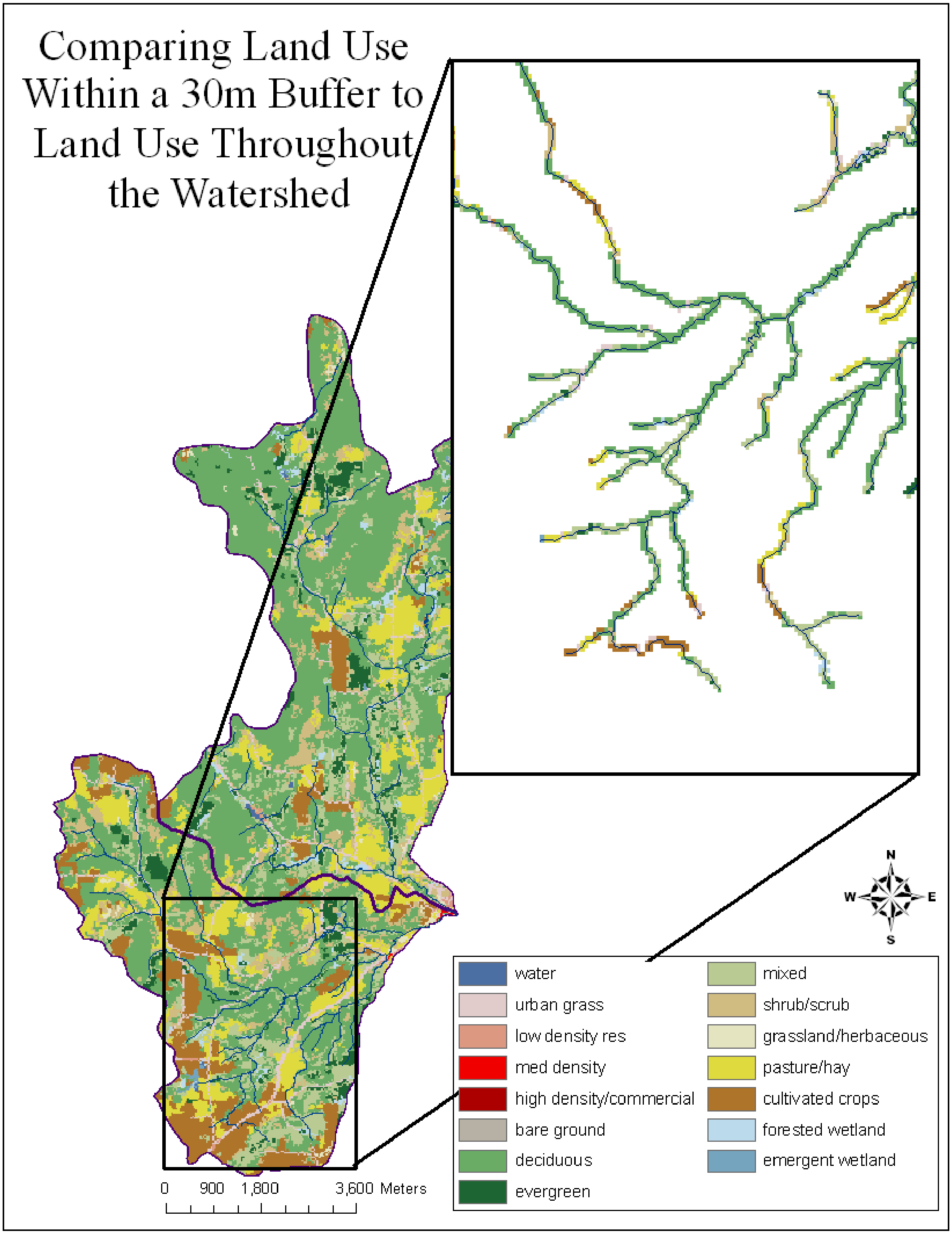


Figure 16 – Buffered inset of Land Use Land Cover in Grimes and Eelpot. To look more closely at land use within 30 meters of the streams, a buffer mask was applied to the watersheds. This image represents the composition of land use within the buffer in one of the Eelpot areas of concern.

In some areas, particularly in Eelpot, there is agriculture pushing directly up to the stream. For instance the southwest portion of Eelpot has large areas dedicated to cultivation directly adjacent to the headwaters of one of the main tributary branches. Figure 17 illustrates percent total cover of each land use within the buffer.

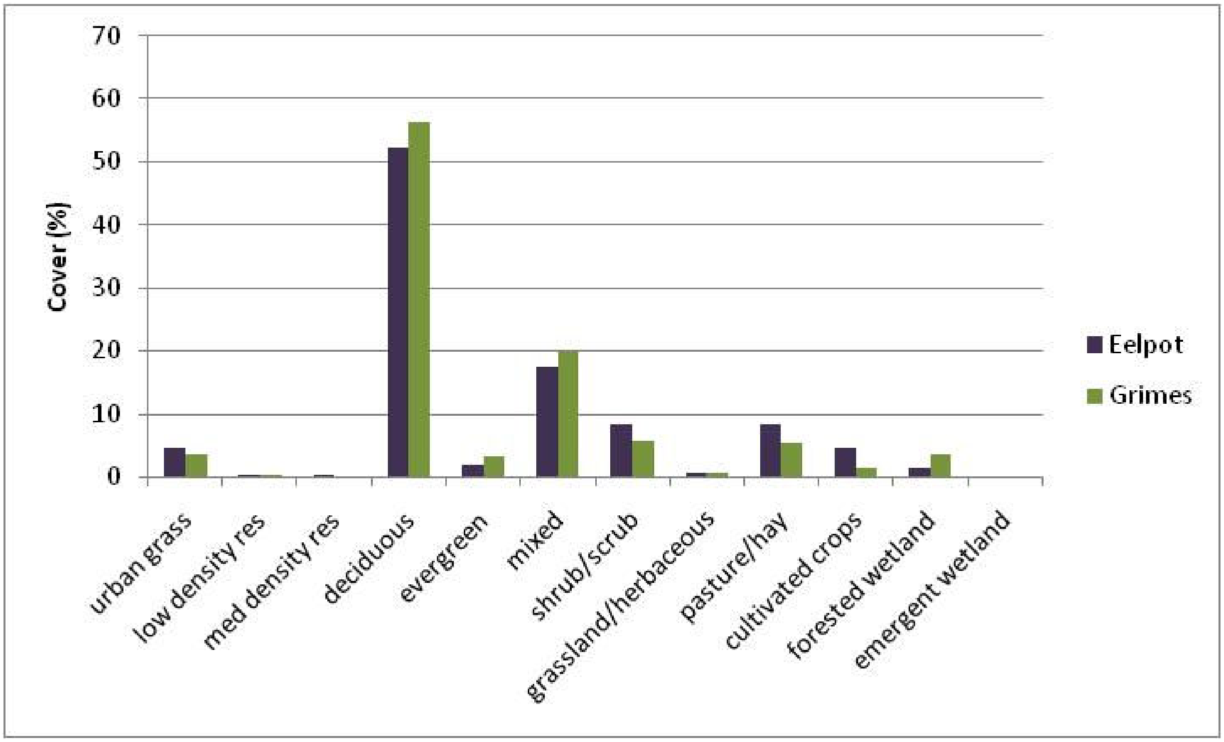


Figure 17 – Percent of each cover type within a "buffer". This image quantifies the LULC map to compare the represented cover types within 30 meters of either side of the streams. Both watersheds are primarily forested in this area, but Eelpot does contain more cultivated crops and pastures.

More than half of the area within 30 meters of both creeks is forested, though it is apparent that Grimes has a slightly higher percentage of forest cover in its buffers, while Eelpot has a higher proportion of cultivated land within 30 meters of the stream. The crosstab results in Table 10 quantify this difference, showing the number of pixels of each land use within the 30 m buffer along Eelpot and Grimes Creeks, and within the entire watersheds.

Table 10 – Cross-Tabulation of land use. This table shows the number of pixels for each land use in Grimes and Eelpot. Land use in the entire watershed is shown, as is land use within 30 meters of the stream. One pixel is 900 m^2.

	Pixels in Entire Watershed		Pixels Within 30 meters of Streams	
	Grimes	Eelpot	Grimes	Eelpot
Water	94	16	10	0
Urban Grass	1336	1258	95	137
Low Density Residential	67	77	7	10
Medium Density Residential	0	32	0	10
High Density Residential	0	0	0	0
Bare Ground	0	0	0	0
Deciduous Forest	26287	11982	1520	1587
Evergreen Forest	1906	1189	89	57
Mixed Forest	4882	3859	539	529
Shrub/Scrub	3359	2734	152	257
Grassland	301	241	18	18
Pasture/Hay	5384	4468	143	251
Cultivated Crops	1498	5447	37	143
Forested Wetland	689	245	94	42
Emergent Wetland	42	80	1	3

Lastly, land cover was divided into two categories : “Anthropogenic” nutrient sources (urban grasses, residential, and cultivated crops) and “Natural” nutrient sources (forests, shrubland, grassland, pastures/hay and wetlands). Figure 18 represents anthropogenic nutrient sources in both watersheds.

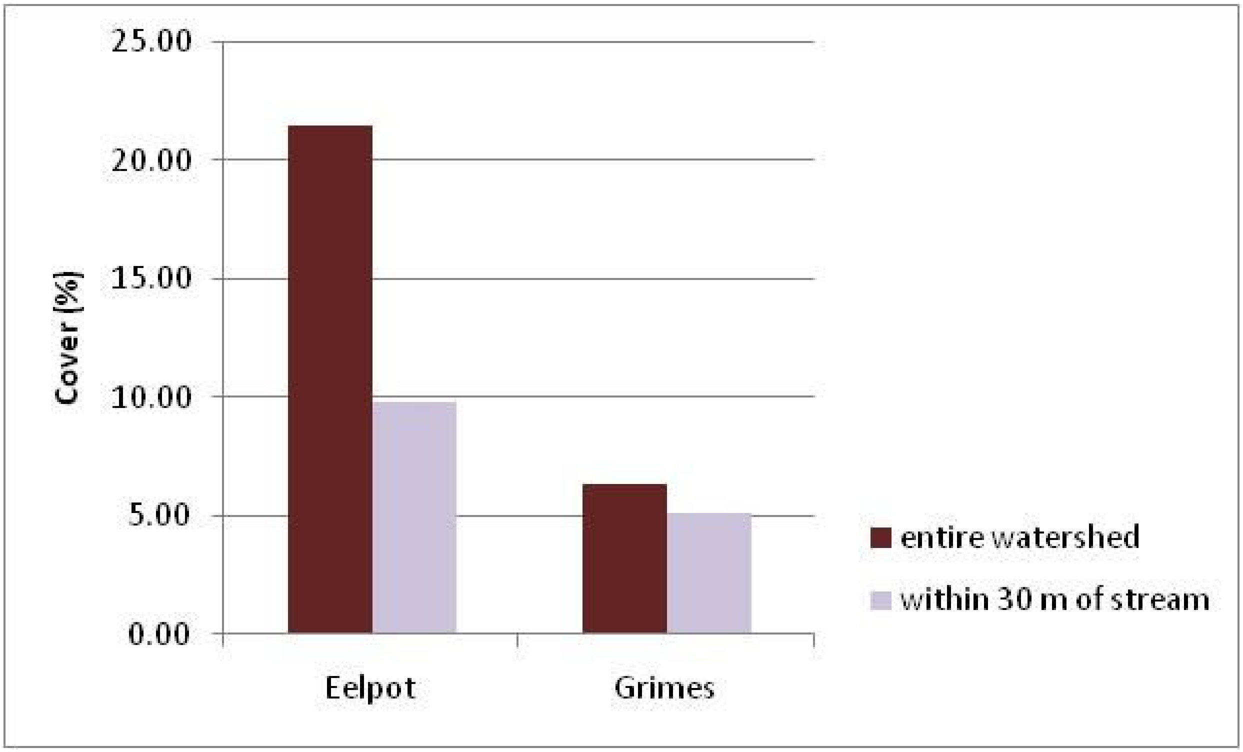


Figure 18 – Anthropogenic sources in the two subwatersheds. Land use in the two subwatersheds was categorized into "anthropogenic" and "natural" nutrient sources. Urban grasses, residential cover and cultivation are considered here to be "anthropogenic" sources. Forests, shrublands, grasslands, and pasture/hay were all considered "natural" sources. The idea was that best management practices could be used to decrease pollutants flowing off of the "anthropogenic" sources. "Natural" sources would however be difficult to control, aside from stabilizing erosion hotspots.

This breakdown of land uses supports the argument that anthropogenic sources are far more prevalent by percent area in Eelpot than in Grimes, even within 30 meters of the stream. Assuming best management practices can be used to decrease pollutants flowing off of the "anthropogenic" sources then, it is logical that much of the TSS and TP in Eelpot can be controlled. "Natural" sources would however be difficult to control, aside from stabilizing stream banks.

RUSLE

Figure 19 illustrates the estimated amount of erosion in each watershed. RUSLE results were classified into erosion categories: 0-1, 1-2, 2-3, 3-4, 4-5, 5-50, 50-150, 150-200 tons/acre/year.

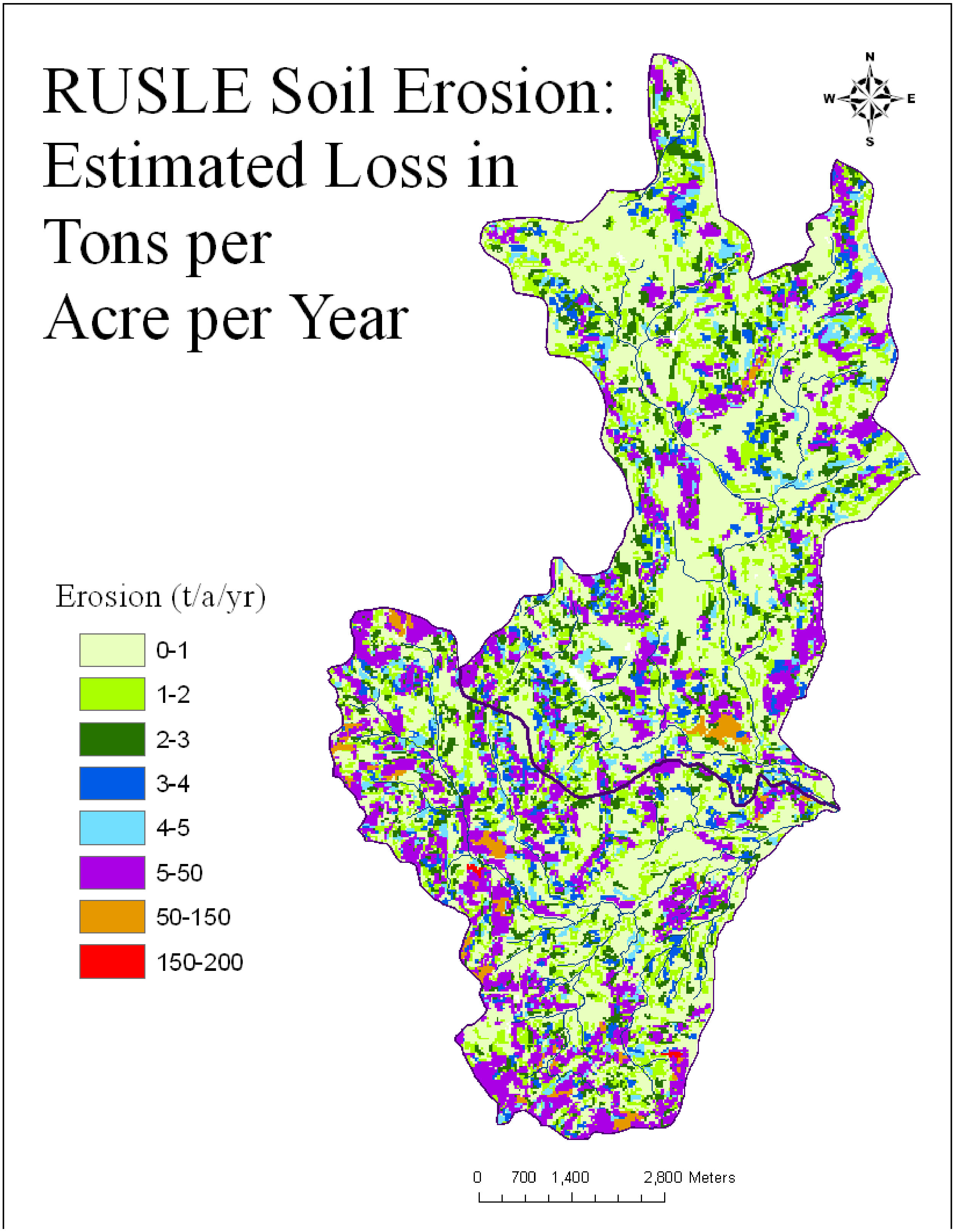


Figure 19 – RUSLE soil erosion model results. This image depicts erosion estimates in tons per acre per year. Up

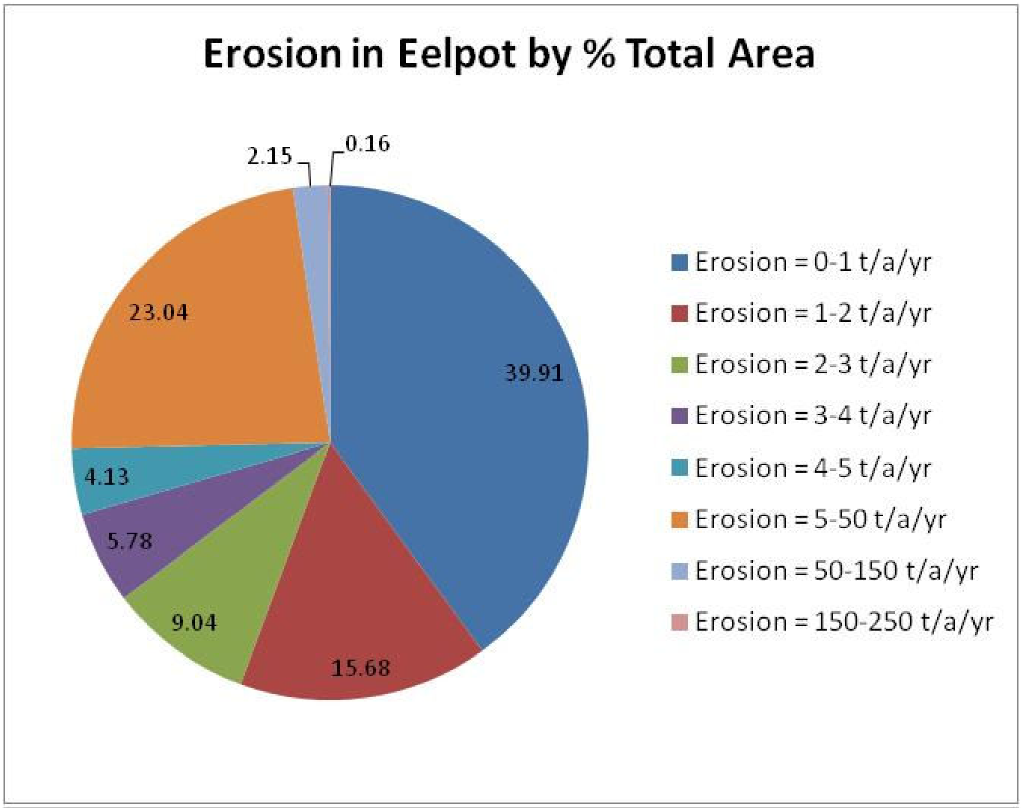
to 5 tons/acre/year is considered to be “sustainable” in this region. It is estimated that about 5 tons/acre/year is *generated* from the bedrock, meaning this amount of erosion would not result in a net loss.

The image reveals that both watersheds have some areas of moderate erosion. More importantly Eelpot appears to have about twice as much land susceptible to 5-50 tons per acre per year of erosion than Grimes. Eelpot also appears to have more patches with a potential risk of seeing 150-200 tons per acre per year of erosion.

IDRISI CrossTab was used to determine the total number of pixels for each erosion category in the watersheds (Table 11). Figure 20 represents percent total area of each erosion class within the two watersheds.

Table 11 – Cross-Tabulation of erosion. This table shows the number of pixels for erosion category in Grimes and Eelpot. Total pixels in the watershed is shown, as is the number of pixels of each category within 30 meters of the stream. One pixel is 900 m^2.

	Pixels in Entire Watershed		Pixels Within 30 meters of Streams	
	Grimes	Eelpot	Grimes	Eelpot
0-1 tons/acre/year	22053	12624	1904	1889
1-2 tons/acre/year	7837	4960	347	473
2-3 tons/acre/year	4792	2860	176	208
3-4 tons/acre/year	2675	1827	70	98
4-5 tons/acre/year	2122	1305	60	76
5-50 tons/acre/year	5946	7288	137	283
50-150 tons/acre/year	278	680	0	7
150-200 tons/acre/year	0	50	0	0



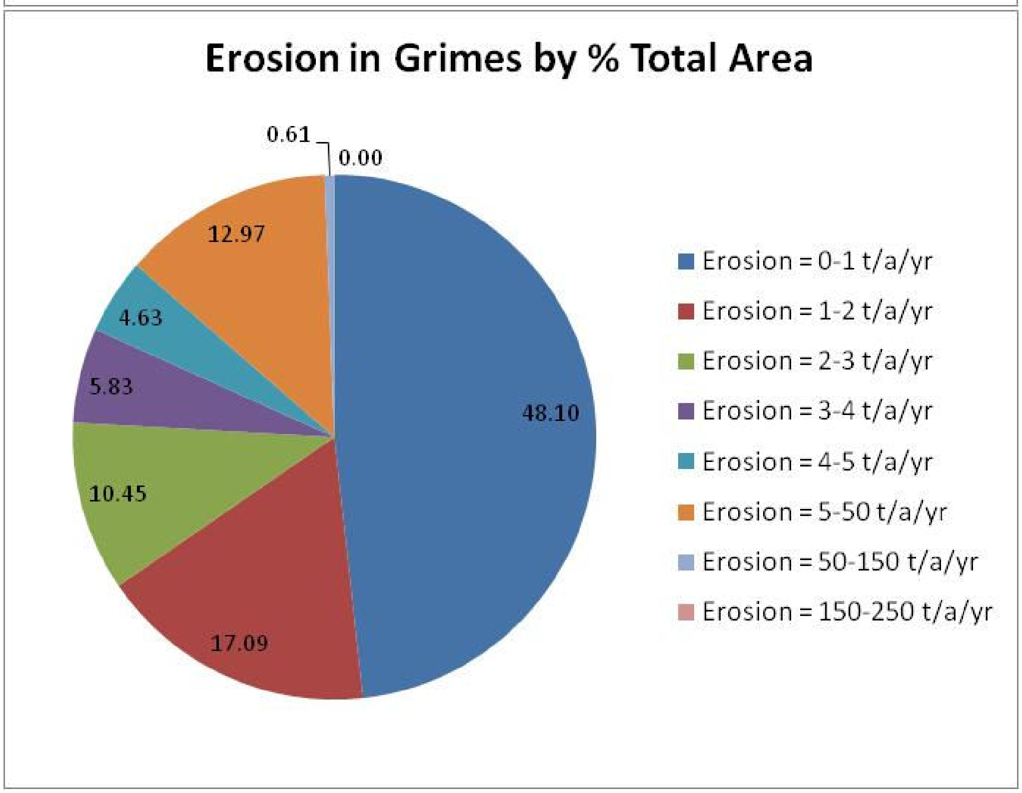


Figure 20 – Percent of erosion by area in Grimes and Eelpot subwatersheds. The top pie chart represents erosion in the Eelpot watershed; the bottom pie chart depicts erosion in Grimes. It can be seen that Eelpot has almost twice as much erosion estimated at 5 – 50 tons/acre/yr than Grimes.

Although slope and runoff are very similar in the two subwatersheds, the RUSLE model estimates that Eelpot has twice as much land by percent area eroding 5-50 t/a/yr than Grimes. Likewise, it was estimated that Eelpot has twice as much erosion by area within the buffer than Grimes. For simplicity, erosion categories within the 30 meter buffer were broken down into only two categories: > 5 t/a/yr and ≤ 5 t/a/yr (Figure 21).

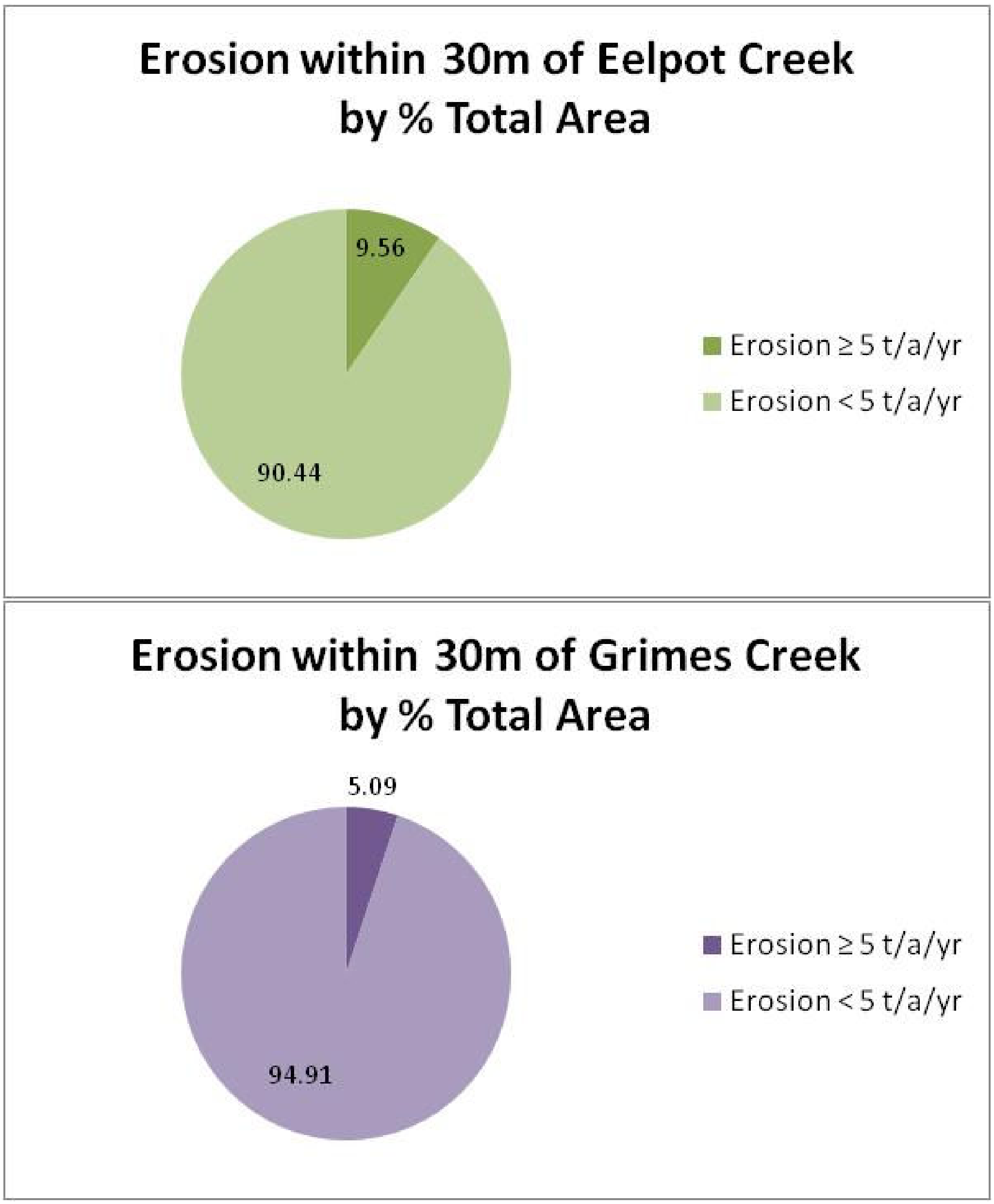


Figure 21 – Percent of erosion within 30 meters of Grimes and Eelpot Creeks. The top pie chart represents erosion in the Eelpot buffer; the bottom pie chart depicts erosion in Grimes. Eelpot has almost twice as much "unsustainable" erosion adjacent to the streams than Grimes.

Chemical Analysis

Storm event samples were collected in Eelpot Creek six times throughout the course of the study and analyzed for total phosphorus (TP), total suspended solids (TSS) and nitrate/nitrite (N). There were a total of 11 sites along Eelpot Creek, including the 5 macroinvertebrate kick-sampling sites (Figure 22). No samples were collected along Grimes Creek because this watershed has historically low TSS, TP and N levels (Gilman and Olvany, 2006).

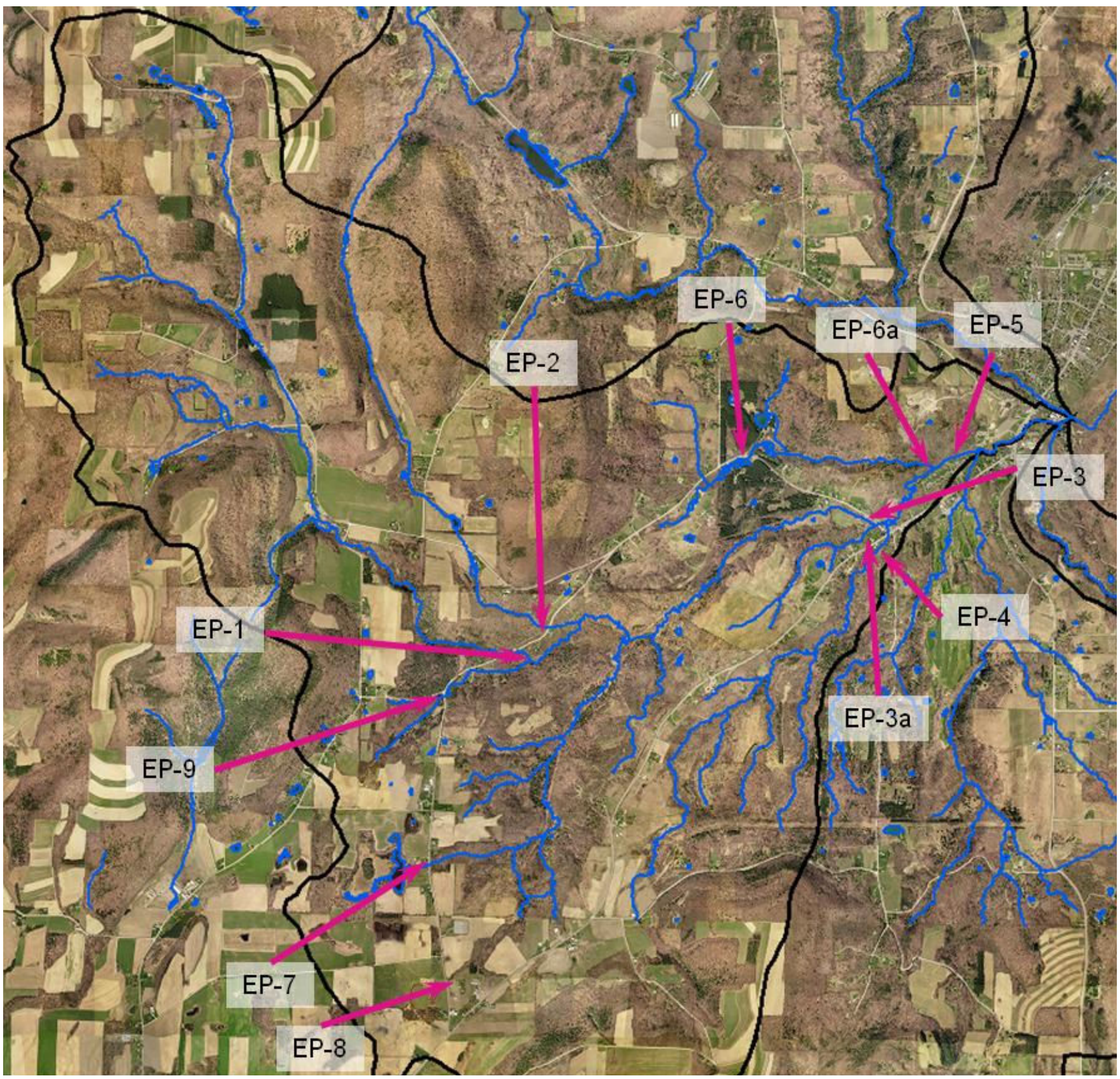


Figure 22 – Chemical sampling locations along Eelpot Creek. Locations were selected to help identify potential pollutant sources. Areas of concern such as those with steep slopes and narrow buffers were targeted.

No site was sampled during every event due to limited accessibility or low flow. Sites EP-3a and EP-7 – EP-9 were added late in the study as potential hotspots after ground-truthing and closer examination of the GIS results. Because of small sample size, chemical results could not be statistically analyzed. Instead, these results were used in conjunction with the macroinvertebrate and GIS data as a rough indication of possible storm event trends. Mean concentrations are summarized in Table 12.

Table 12 – Chemical analysis results.

Sample ID	9/2/06 mg/L	10/20/06 mg/L	10/23/07 mg/L	12/12/07 mg/L	2/5/08 mg/L	10/16/08 Mg/L	2/12/2009 mg/L	Mean	Rank
Total Phosphorus									
EP-1	0.19	0.16	0.022		0.017	0.01	0.042	0.074	6
EP-2	0.09	0.088	0.0015		0.0015		0.036	0.043	1
EP-3	0.65	0.073	0.079	0.028	0.22	0.038	0.34	0.204	8
EP-3a							0.2	0.200	7
EP-4		0.48	0.069	0.012	0.13		0.41	0.220	9
EP-5		0.33	0.093		0.16		0.32	0.226	10
EP-6	0.069	0.029	0.086		0.0051			0.047	2
EP-6a		0.34						0.340	11
EP-7					0.018		0.12	0.069	5
EP-8							0.057	0.057	3
EP-9							0.057	0.057	3
Total Suspended Solids									
EP-1	130	100	34		14	2	66	58	5
EP-2	42	450	2		2	6.7	22	87	6
EP-3	640	150	110	34	370	10	530	263.4	10
EP-3a						2	300	151	7
EP-4		240	56	17	250	30	760	226	9
EP-5		210	68		340	33	800	290	11
EP-6	44	6.5	31		27			27	2
EP-6a		190						190	8
EP-7					33	2	48	28	3
EP-8						2	28	15	1
EP-9						6.7	100	53	4
Nitrate/Nitrite									
EP-1	0.32	1.1	0.57		1.1	1	1.2	0.882	9
EP-2	0.53	0.2	0.0015		1.6	0.93	0.85	0.685	7
EP-3	0.3	0.48	0.39	0.85	1.3	0.48	1	0.69	8
EP-3a						0.071	0.8	0.436	5
EP-4		0.17	0.12	0.22	0.57	0.036	0.67	0.298	3
EP-5		0.4	0.36		1.1	0.42	0.83	0.622	6
EP-6	0.02	0.02	0.11		0.26			0.103	1
EP-6a		0.16						0.160	2
EP-7					0.81	0.088	2.3	1.066	10
EP-8						0.13	3	1.565	11
EP-9						0.4	0.4	0.400	4

To more easily compare pollutant concentrations in the watershed on a single scale, concentrations were calculated as a percentile of the range of measured values, adjusted to 0 (Figure 23). Thus, sites that show 0% had the lowest mean concentrations, while sites at 100% had the maximum value in the range. TP and N results falling below instrument sensitivity

(0.030 mg/L) were assigned a value of 0.015 mg/L. Instrument sensitivity for TSS is 4 mg/L, so a value of 2 mg/L was assigned to results falling below this level.

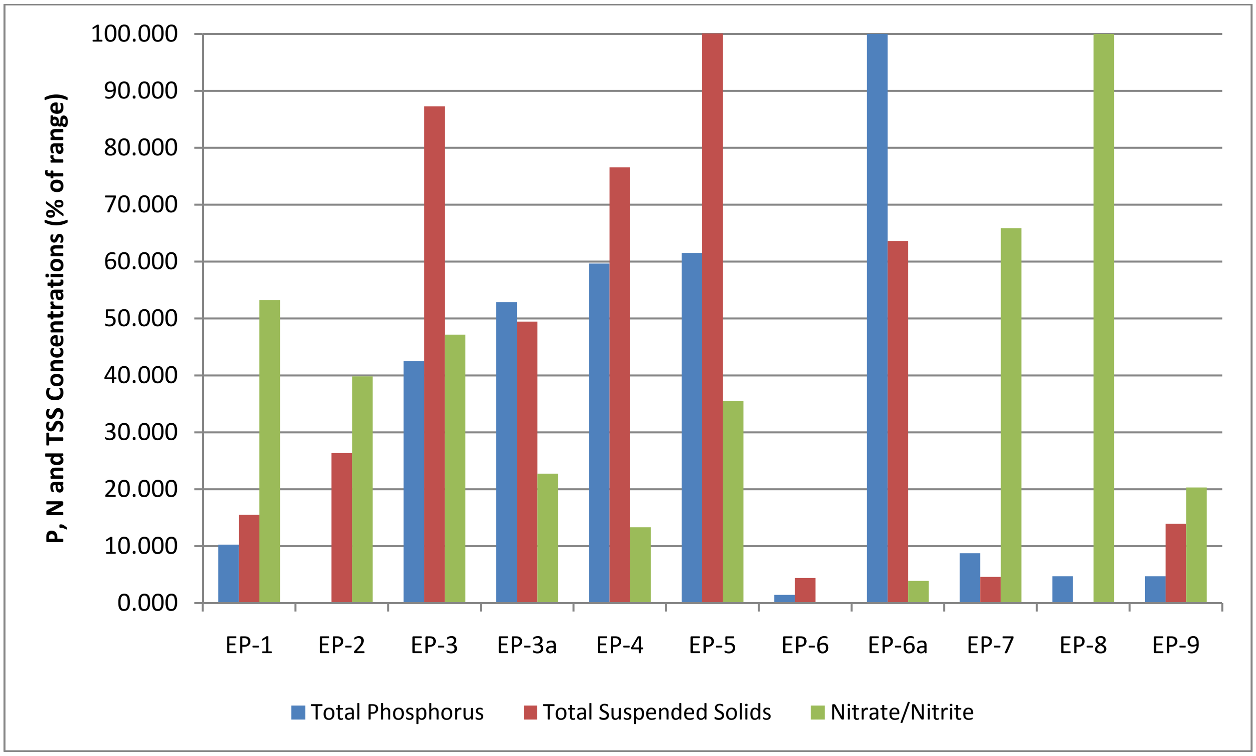


Figure 23 – Chart of chemical results.

TP is highest at sites EP-6a, EP-5, EP-4 and EP-3a. TSS is highest at sites EP-5, EP-3 and EP-4. It is also relatively high at EP-6a. Nitrate/Nitrate is highest at sites EP-7, EP-8 and EP-1. Managers should also consider that concentrations alone do not fully account for the threat of contaminants. For the purpose of this study (identifying pollutant sources), concentration alone was adequate, but it is important to take stream flow into account as well, particularly when estimating total contaminant runoff. Recall that sites EP-3 and EP-5 have the highest rates of flow in both Grimes and Eelpot Creeks. A larger volume of water carrying higher concentrations of contaminants is of greater concern than the same contaminant concentrations in a slow-moving stream.

Discussion

Canandaigua Lake is characterized as having high water quality, and is used for drinking water by about 60,000 people. Thousands more utilize this resource for fishing, boating and swimming each year. The Canandaigua Lake Watershed Council (CLWC) monitors the lake and its tributaries to protect this valuable resource. While water quality overall remains fairly high, some tributaries leading to the lake (such as Eelpot Creek) have relatively high concentrations of total phosphorus (TP) and total suspended solids (TSS). To ensure the integrity of Canandaigua Lake as a clean water source, it is important to pinpoint and reduce pollutant contributions throughout the watershed.

The Eelpot Creek subwatershed is adjacent to the Grimes Creek subwatershed, which has consistently lower concentrations of TSS and TP than most other creeks leading to the lake. At a glance, however, Grimes and Eelpot Creeks appear to have very similar watersheds in terms of land use and other factors. It was believed, therefore, that if Grimes contained a similar composition of potential contaminant sources, then perhaps riparian forested buffers (RFBs) were protecting the streams. Ground-truthing and macroinvertebrate, chemical and GIS analyses were used to locate and assess potential pollution sources in the Grimes and Eelpot watersheds. The potential sources were compared to determine why pollutant concentrations in Eelpot are consistently higher than in Grimes and to suggest strategies that may help reduce contaminant loads. The strategies focused on reducing contaminants in runoff through the use of RFBs.

CLWC lists impervious surfaces, construction, road bank erosion, steep slopes and agriculture as factors that cause erosion in the Canandaigua Lake watershed, leading to high TSS measurements. There is little construction in either the Grimes or Eelpot watersheds, so construction was excluded in this study as a significant contributor to sedimentation in Eelpot. L-THIA evaluates impervious cover to estimate annual runoff. Results show an estimate in

Grimes and Eelpot of 0.03 and 0.04 feet of runoff per year, respectively. One hundredth of a foot indicates no difference in impervious cover as it pertains to runoff, indicating alternate factors for high sedimentation in Eelpot. Similarly, there is very little difference between slopes in the two subwatersheds (apart from approximately 10% more slopes by area with a 15% grade or steeper in Eelpot than in Grimes).

Despite these similarities, the RUSLE model run in this analysis estimated higher amounts of erosion in Eelpot (Figure 20). This result supports the idea that land use and cover is likely playing a factor in Eelpot's erosion. Areas of highest concern (150-200 tons/acre/year) seem to coincide with cultivated patches (Figure 19), but constitute a very small portion of the watershed (0.16%). Almost a quarter of the land in Eelpot, however, is estimated to lose 5 – 150 tons/acre/year of sediment versus about 13% of Grimes (Figure 20). Likewise these erosion "hotspots" occur throughout the watershed on both cultivated and uncultivated land, indicating that cultivated areas are not the sole contributors to pollution in Eelpot. Other factors such as stream bank erosion do contribute to sedimentation in the stream. Consider that Eelpot's buffer contains approximately 5% cultivated cover, yet almost twice as much land within the buffer demonstrated probable high erosion in the GIS models. This study relied heavily on the RUSLE model since most of the stream channel in Eelpot is difficult to access. If precise areas of concern are to be identified, managers should use high resolution maps. Likewise, the streams should be hiked along areas of concern to effectively assess primary sources of erosion and determine manageability based on accessibility. In 2007, interns with the CLWC did hike a portion of the main branch of Eelpot Creek (from EP-1 to EP-3) to search for evidence of erosion. Several locations were noted and documented with photographs. Another potential source of suspended solids in runoff is dirt roads and gravel driveways. The presence of these features was not quantified in the GIS analysis as much more detailed data is required. It was found during ground-truthing that these were present in both watersheds. Another factor that was indirectly addressed in this study is the erodibility of soils. While this factor is included in the RUSLE model, soils were not directly assessed as a possible cause for the difference in TSS concentrations.

Regardless, cultivation cannot be discounted as a potential source of TSS. Likewise, these areas are of slightly higher concern because they are more likely to also be sources of TP. Recall that Eelpot has significantly more agriculture than Grimes (20% to 3% respectively, Table 12), the majority of which can be found in the headwaters of three out of four branches. The most runoff (and therefore pollution) will enter a stream in the headwaters causing these particular locations to be of higher concern (Correll, 2005).

One strategy for reducing pollutants is the use of buffers. While there are many different buffer types that can reduce TSS and TP to varying degrees, riparian forested buffers (RFBs) offer a number of additional biological and ecosystem benefits (Anbumozhi *et al.,* 2005; Correll, 2005; Lovell and Sullivan, 2005; Sweeney *et al.*, 2004; Quinn *et al.*, 2004). For this reason it is recommended that, where possible, RFBs be used to reduce runoff. This study was the first step in determining the most appropriate locations for RFBs in the Eelpot Creek subwatershed.

Understandably, erosion and runoff models are only estimates and rely heavily on assumptions, but this still allows us to compare Grimes and Eelpot to identify key differences in land use and locate potential hotspots. Considering the risks of environmental impact associated with slope and land use in the study subwatersheds, RFBs should play an important role in protecting water quality in areas of concern. For instance, Figures 16 and 18 reveal a paucity of riparian forested buffers within the Eelpot subwatershed. There is about twice as much land by area with anthropogenic nutrient sources within 30m of the stream than in Grimes (for this study, cultivated land, residential areas and urban grasses are considered to be anthropogenic nutrient sources). When considering the implications of this, the complexity of Eelpot Creek must be factored in. Although Grimes is a larger watershed, Eelpot has over 300,000 m^2 more land within 30m of the stream. Runoff in Eelpot will therefore have less contact with the ground before flowing into the stream, allowing less permeation into the ground. This also means that nutrients in runoff are less likely to be captured on land.

While GIS and ground-truthing helped select potential hotspots for runoff, macroinvertebrate and chemical analyses were used to determine which of these areas of concern were most impacted and where the most contaminants likely originate.

There was insufficient macroinvertebrate data to suggest a significant difference in stream quality between the two subwatersheds. Further, there was no significant difference between sample locations within each watershed, with the exception of EPT richness between EP-2 and EP-5. That there are no sites with impacted communities is not surprising since all sample locations used in this study are ideal macroinvertebrate habitats in relatively high quality streams. As previously mentioned, the Canandaigua Lake watershed is well known for its high quality overall and the point of close monitoring of the watershed is to maintain the current level of quality.

Some factors of this study may have weakened the analysis. For instance, several semi-aquatic and terrestrial organisms (such as millipedes and some *Diptera*) were excluded from the samples because they could not be applied to the indices. Many of the organisms removed were from Eelpot Creek. A study of whether these organisms indicate low water quality would be a valuable supplement to macroinvertebrate studies. Pupae were also excluded due to the level of difficulty in accurate identification. Because of these exclusions, many sites had fewer than 100 organisms (the number of individuals that the indices are based on). Counts were therefore adjusted to represent a 100-organism sample, which may have affected index results. More kick samples would reduce these limitations and make distinct differences between sites more apparent. Future studies should also be more selective in the sample collection to avoid such exclusions.

Visual assessment of embeddedness at the sample locations indicated that there is relatively high sedimentation in EP-1, EP-2, EP-4 and G-3. G-3 was expected to have heavy sedimentation due to the high amount of erosion witnessed along the banks during the course of this study. EP-4 is located along a branch of Eelpot that contains a high percentage of cultivated land in the headwaters and so was also expected to show heavy sedimentation.

The Mean Assessment Profile Value, which summarizes the results of the five indices used to assess macroinvertebrate communities, demonstrated slight impact at EP-3 (Figure 11). Slight impact indicates that this site is affected by organic or other pollutants to cause slight differences from an ideal macroinvertebrate community. While this may indicate that the documented erosion between EP-1 and EP-3 affects water quality in the stream, the headwaters north of EP-1 contain large areas of cultivated land along steep slopes. It is presumed that this likely also contributes, particularly considering that EP-1 is slightly impacted according to the Mean Assessment Profile Value (Figure 11).

Because EP-3 is situated downstream of the confluence of two major branches and represents a large portion of the watershed, this site was expected to have some of the highest pollutant concentrations in the watershed. Interestingly, the chemical results show little difference in N concentration between sites EP-1, EP-2 and EP-3. Both EP-1 and EP-2 have lower concentrations of P than EP-3, but while EP-2 has the lowest P concentrations in the watershed, EP-1 ranks sixth (5^{th} highest concentrations) for P. This suggests P and N sources along the stream branch leading to EP-1, and N sources along the branch leading to EP-2. TSS appears to be much higher at EP-3 than at EP-1 and EP-2, suggesting that the stream bank erosion does contribute to sediments in the lake. Parts of the watershed upstream of EP-1 were canvassed and large corn fields and streambank erosion along the stream's headwaters were found. EP-2 scored higher in general on macroinvertebrate indices than the rest of the sites tested in Eelpot, which makes it unclear whether nitrogen leads to any problems in this branch.

The EP-5 macroinvertebrate community was also found to be slightly impacted, but as with EP-3 this was fully expected – EP-5 is located downstream of the confluence of all branches in the subwatershed. EP-4 macroinvertebrate indices were borderline between slight and no impact, but EP-4 is ranked number 9 (3rd highest concentration) for both TSS and P. This site was expected to have higher concentrations and show some impact since the headwaters are characterized by cultivation along steep slopes. Investigation upstream of the sample site would help clarify the sediment sources, but this branch is inaccessible by roads or public property and so was not investigated during this study. If watershed managers choose to continue monitoring this region to determine ways of controlling TSS and TP, focus should be placed on sites EP-1 and EP-4, and continued monitoring should be used to identify trends in community composition and any possible pollutant increases.

EP-3a was added late in the study, after ground-truthing revealed unbuffered cornfields along a steep glacial moraine, which are typically characterized by loose, highly erodible soils (Gilman and Olvany, 2006). The field was currently fallow but in rotation for corn production. Chemical samples taken at this site indicate that this site should also be continuously monitored for agricultural pollutants to see whether high P is a trend. EP-6a on the other hand was selected early on because of an open gravel pit north of the branch downstream of EP-6. The suspicion that this would be a source of solids downstream appears to be supported by the sample result. Only one sample was taken from EP-6 and EP-6a during the study because the rate of storm event flow made them dangerous to access.

That the G-3 macroinvertebrate community also appears to be slightly impacted was no surprise due to the high erosion seen at this site throughout the course of the study (several feet of the stream bank at the sample site were eroded throughout the year). Sites G-1 and G-2, like EP-2, demonstrated high quality overall and minimal impact. Likewise investigators found no reasons while ground-truthing to be concerned with respect to land uses upstream.

A high percentage of unbuffered cultivated land and heavy stream bank erosion are believed to be the causes of relatively high pollutant concentrations in Eelpot Creek. Agriculture is a central component in this region's success, and it is not the intention of this study to limit land use in the Canandaigua Lake watershed. Thus, it is important to encourage creative land use and appropriate use of best management practices to protect both the agricultural industry in the region and the lake itself, which is often referred to as the "lifeblood" of the region.

Recommendations

Cultivated land produces fine sediment as bare soil is eroded by heavy rainfall and carried to streams in large volumes of runoff. Bioavailable P (available for use by organisms) can bind readily to soil particles and be carried into streams with the sediment or be carried as dissolved P. Other forms of P can also be carried in runoff (Zemenchik *et al.*, 2002).

It is recommended that a riparian forested buffer program be established to improve water quality in Eelpot Creek. While there are alternative methods of pollution control, RFBs in many cases are more effective and contain more ecosystem benefits than other strategies. If funding or other factors prove to be limiting, the stream should at a minimum be protected by a grassed or other buffer.

Locations along the headwaters of the southern (west of EP-4) and northern (north of EP-1) branches of Eelpot Creek should be considered first. Efforts should also be made to monitor and protect the small branch leading to EP-3a. Especially in the Finger Lakes region, steep slopes significantly contribute to runoff and erosion. When these slopes surround cultivated land, the risk of sending large volumes of water over the surface of the fields, removing topsoil and sending it into the streams, greatly increases. The models used in this study were based on the assumption that BMPs are not used in agricultural portions of Eelpot and Grimes, and that the condition of vegetative cover provides poor erosion control. While this may affect the actual runoff estimate (which was not addressed in this study), the results still indicate that erosion is higher in Eelpot, and runoff is approximately the same as in Grimes. Further, agriculture in Eelpot occurs mostly in the headwaters. This is concerning because the largest volume by area and therefore the most runoff is likely to reach the stream. Likewise, pollutants entering in the headwaters are able to impact the entire stream under the right conditions. Similarities between the two subwatersheds in the L-THIA and slope results suggest that slope and volume are not the only factors influencing water quality and erosion. Land use must therefore play an important role in Eelpot's high TSS and TP concentrations. Sections of the RUSLE image that particularly stand out are along the southwest edge of Eelpot, where there are relatively large patches of high erosion (Figure 19). Because the size of the patch influences erosion, these large areas are of high concern and should therefore be targeted first.

P and TSS concentrations, at any given time, depend on a number of factors. For instance, runoff during storm events carries sediment to a stream from throughout the watershed. Barros and Gordon (2002) note that runoff and erosion rates vary over time, but the majority of sediment moves into a water body during rainstorm and other flooding events. High amounts of erosion are of increasing concern as you move closer to a water body, because there is less of a chance for sediments to settle on land. Thus, it is important to also focus first on areas of concern that are closest to waterbodies.

Best management practices (BMPs) can help reduce these pollutants. Cornell

Cooperative Extension of Ontario County and the Soil and Water Conservation District have been working closely with farmers in the Grimes and Eelpot watersheds for many years to help implement BMPs and develop sound agricultural management plans to protect the integrity of agriculture around Canandaigua Lake (CCE and OCPD, 2000).

Many assumptions are made in this study regarding land use and BMPs. For instance, the difference between cultivated plots with BMPs and those without is difficult to distinguish in the available LULC images. It is known that many farmers use BMPs throughout the watershed, yet how many farmers use them or how effectively is unknown. Thus, it was assumed in the RUSLE analysis that BMPs are used in all cultivated areas, but that they are in "poor" condition. Using a "poor" BMP value was intended to balance the quality and quantity of BMP use in the area.

Likewise, because this analysis was run primarily to compare watersheds and not calculate a specific erosion amount, a generic agricultural practice factor (P) of 1 was assigned. The P factor indicates the quality of erosion control (0 being no erosion; 1 being maximum erosion). Therefore the amount of erosion predicted in this model may be high. A more detailed analysis should be conducted to develop land cover images that take best management practices into consideration and appropriately assign P factors to different agricultural plots.

Some literature on BMPs indicates a disconnect between landowner and land manager perceptions on BMPs. This means that well-intentioned landowners sometimes establish practices at their own expense that do little to amelliorate pollution issues. Based on the literature, it was assumed at the outset of this study that this might be the case in the Candandaigua Lake Watershed. However, conversations with the Soil and Water Conservation District (SWCD) and some local landowners have highlighted the many successes that have been made in this region in applying BMPs to limit agricultural pollution. These efforts make it less likely that such issues are a problem in this watershed, but it is important to note the possible undervaluation of BMPs in this analysis. Regardless, the results of this study indicate that agriculture and stream bank erosion play an important role in TSS and TP loading in Eelpot Creek. This relationship between SWCD, CLWC, and landowners should be an important part of future efforts to improve riparian barriers and thereby enhance water quality. Appendix 1 includes a proposal designed to assess local knowledge and use of BMPs, and to include landowners in the process of the potential addition of RFBs to help insure maximum benefit at little cost.

Since many agricultural landowners in the Eelpot watershed already utilize best management practices (Ontario County Cornell Cooperative Extension, personal communiction), the conversion of streamside land to undisturbed buffers in Eelpot Creek is the next important step toward improving water quality in this watershed. It is recommended that this be strongly considered in Eelpot and other parts of the Canandaigua Lake watershed where runoff and nutrient pollution are of concern. The analyses in this study, coupled with ground-truthing, revealed specific areas of concern in certain parts of this study. With respect to potential agricultural hotspots, the branches leading to EP-1, EP-3a, and EP-4 should be monitored and looked at more closely. Stream bank erosion between EP-2 and EP-3 should also be addressed.

It is understood that the reallocation of agricultural property to include a buffer can be costly, so it is important to consider the various options for managing cost. Several state and federal programs subsidize stream restoration projects that include forested buffers as a BMP (Sweeney *et al*., 2004). Projects to implement riparian forested buffers in New Jersey and Missouri included significant investment of federal, state and private funds (Qui *et al.,* 2004). They discuss their analysis of landowners' willingness to pay (WTP) with respect to a contingent valuation model (CVM) that estimates the value of natural resources. These authors focused on the natural values of RFBs, such as increases in property value, as factors that influence landowners' WTP. Where natural value fails as an incentive, it may be helpful to include economic value as well. Buffer zones recommended by the USFS include an 18 m harvestable zone (Figure 1). Such a zone might allow farmers to receive economic benefit from the buffer itself, if the loss of land has a significant impact on crop revenue.

Most importantly, landowners should not be legally required to develop buffers. There are already a number of environmental regulations in place that economically strain landowners. Requiring landowners to be responsible for buffers would be a highly controversial policy that might ultimately delay protection of the watershed. Instead, landowners should be encouraged to work with watershed managers to come to a mutually beneficial solution. The CLWC has been notified of the TSS and P "hotspots" throughout Eelpot for management purposes. To encourage the most effective change with minimal impact on agriculture in the region, the close relationships between managers and landowners need to be maintained.

One solution commonly used is offering economic incentives for landowners to set aside areas along the streams to allow the natural progression of forests or wetland. This incentive program is used across much of the U.S. Other incentives such as payment for public use of the buffer as a natural recreational area, or allowing the harvesting of low-impact vegetation as previously mentioned might also encourage farmers to participate. Although the NRCS (2006) notes that buffer vegetation should be native, non-invasive tree and shrub plants, it is also noted that "substitution with approved and locally accepted cultivars or purpose-specific species is allowed." For instance, the use of fast-growing willow species, which have a number of economic uses including use as biofuels (Kuzovkina and Volk, 2009), may provide enough economic incentive for adequate buffer protection.

These are things to consider in the economically creative use of RFBs. Some researchers shed a hopeful light on the future of buffers:

> Demonstrating the increased value of riparian forest ''services'' relative to forest ''products'' could significantly change economic analyses and lead to a reduction of riparian deforestation for profit, an increase in landowner perceptions of the value of riparian forests, and a corresponding decrease in the need for external incentives for landowner cooperation. (Sweeney, *et al*., 2004)

This philosphy of natural value can in many ways be more beneficial than cash incentives. While cash incentive may provide immediate compensation to landowners, they require substantial upkeep (continued payment). Likewise, increased value of a landowners' property can in some cases produce greater reward than cash paid out by the government.

Buffer effectiveness largely depends on the location and streamside length of the buffer itself. Typically it is best to establish buffers in the headwaters and work downstream. Correll (2005) argues that long, thin buffers are often more effective than wide buffers along only a small section of the stream because they protect the full length of the stream. Otherwise, pollutants can be introduced to the stream in large concentrations where there are breaks in the buffer. Space and funding for the implementation of RFBs are limited however, and in many cases it is impractical to buffer the entire stream. Buffer locations must therefore be carefully chosen to maximize benefit at minimal cost. For instance, ground-truthing in Eelpot revealed several unbuffered cultivated areas with steep slopes. One particular location consisted of corn fields along a glacial moraine, sloping directly into a branch of Eelpot Creek. Such areas should be Strongly considered for the implementation of buffers.

It may appear simple to determine the most likely contributors to sedimentation within a watershed, but it has been found in some watersheds that relative sediment contributions of stream branches can vary seasonally and decadally. Likewise suspended solids also occur in streams when substrate is carried into the water column by increased currents during storm events. Barros and Gordon (2002) noted changes in sedimentation likely due to changes in rainfall and erosivity on a decadal time scale, but also noted changes likely due to land use on a centennial time scale. Their study highlighted several barriers to accurate identification of particular sources of sedimentation.

For example, although cultivated fields in many areas appeared to be separated from streams by forested areas or wetlands, field visits through the watersheds occurred in fair weather when drainage patterns could not be determined. The effectiveness of these "buffers" depends on the drainage pattern of water passing through them. Some studies have demonstrated that because steep areas tend to channel water, sediment may ultimately travel about three times farther than in shallower areas with over-land "sheets" of runoff (Belt et al, 1992; NRCS, 2006). Thus, existing buffers should be checked during storm events in areas with high pollution potential to ensure water is passing across the buffer, rather than in a channel running through or around it. If channels are found, it may be possible to fill and level them out to control the flow of water. This strategy could reduce pollution without costly management programs .

The USFS recommends a general buffer width of 30m on either side of the stream (Correll, 2005). However, this size is an estimate that encapsulates multiple landscapes. Flat or gently sloping plots with pervious surfaces generally require smaller buffers to manage runoff than large plots with steep slopes. This means there's a possibility that 1) reserving a smaller patch of land for buffers could significantly improve water quality, or 2) installation of a 30m wide buffer would be inadequate to protect the streams from runoff over large, steep plots of land. The latter of these two is an undesirable situation for both landowners and watershed managers. The literature is quite varied with respect to appropriate buffer width. Fischer and Fischenich (2000) summarize many of the various schools of thought on recommended buffer widths by function and vegetation type. Taking all of this literature into account, the authors generalize that the recommended width for water quality and protection is 5 to 30 m. Such a remarkably wide range makes deciding on buffer width a daunting task, but there are a number of situations that can help narrow the range. The authors do caution that "for low to moderate slopes, most filtering occurs within the first 10 m, but greater widths are necessary for steeper slopes, buffers comprised of mainly shrubs and trees, where soils have low permeability, or where [nonpoint source pollution] loads are particularly high." The report also notes that for stream bank stabilization, a buffer of 10 to 20 m is recommended. Multiple buffer types (e.g., grassed strips, forested buffers, mixed vegetation buffers) are summarized in this report. One paper reviewed by Fischer and Fischenich estimates that a forested buffer at least 19 m wide can remove as much as 80% of excess P. Another study reported 85% sediment removal by a grass strip at least 9 m wide in a region with 7 and 12 percent slopes (Fischer and Fischenich, 2000). These summaries demonstrate the potential variability in effectiveness of management techniques.

There are models available that consider factors such as slope, plot size, impervious surfaces and soil type in determining adequate buffer width, and it is highly recommended such a model be run once buffer locations are selected in the watershed. ArcGIS has these models built-in. Some organizations use standardized protocols relating to factors such as slope when designing buffers. For example, the Superior Watersheds Partnership (Michigan) has developed a Model Riparian Buffer Implementation Plan, adapted from the Environmental Protection Agency's Model Buffer Ordinance. This ordinance suggests a base buffer width of about 15 m, but recommends adding between 3 and 21 m to this depending on the steepness of the slope (SWP, 2003). The Stormwater Manager's Resource Center (Maryland) has developed a similar ordinance based on EPA guidelines, which has a base buffer width of 100 feet, increasing width based on slope and watershed characteristics (SMRC, year unknown). Such models should be carefully studied and chosen by applicability to the region. Recalling that Eelpot Creek has a large percentage by area of slopes steeper than 15%, it is probable that this watershed requires buffer width to be a minimum of 30 m, if not more.

Other considerations with RFBs include their potential impact on the ecosystem. Parkyn *et al.* (2005) discuss a model for the conversion of an entire watershed from cultivated crops to pine plantation. While their scenario is dissimilar to this study, many ecologically-relevant observations are made with respect to altering the landscape along streams. For instance, the researchers address the possibility that shaded streams may experience a temporary decrease in nutrient uptake before the riparian ecosystem is established, since light required for the photosynthetic process by aquatic macrophytes would be diminished. It is important to understand that the benefits of major habitat changes are not always immediate, but could in fact take several years to present. Despite these drawbacks, RFBs in Eelpot Creek have the potential to decrease TSS and P concentrations, thus helping to maintain the integrity of Canandaigua Lake. The results of this study indicate some locations, particularly cultivated areas, within the Eelpot subwatershed that are likely contributing high levels of TSS and TP. The combined chemical and ecosystem benefits of RFBs make them a stronger candidate as a means of protecting the water quality of Canandaigua Lake than other pollutant reduction strategies.

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Appendix 1
Research Proposal

Understanding the Role of Farmers in Environmental Conservation

Abstract

The Canandaigua Lake Watershed feeds a clean lake that's used by thousands of residents and tourists every year. Concerns regarding pollution from agricultural runoff have led to my thesis, which argues that installing riparian forested buffers (RFBs) along the streamside will help prevent diminished water quality in the lake. This proposal is a recommendation for a future master's thesis project to qualitatively assess farmers' perceptions on RFBs and other conservation practices. The available literature has led me to believe that there may be a chasm between the perceptions of farmers and the actualities or predictions made by environmental control models. The proposed research would collect data through focus groups and one-on-one interviews to help clarify how farmers view conservation practices and what limitations prevent them from doing more. A better understanding of the farmers' perspective would greatly contribute to the success of future environmental conservation efforts in the agricultural sector.

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Introduction

The city of Canandaigua reports that approximately 60,000 residents rely on the water of Canandaigua Lake for their drinking supply, and thousands more utilize this resource for fishing, boating and swimming each year. The lake's watershed covers 174 square miles and is shared between thirteen towns, two villages and one city (Canandaigua Lake Watershed Council (CLWC), 2005). The CLWC was formed to unite the various municipalities throughout the watershed with the goal of "[maintaining and enhancing] the high water quality of the Canandaigua Lake Watershed through education, research, restoration and if necessary regulation (CLWC)." Although Canandaigua Lake has been monitored periodically for thirteen years, the most extensive monitoring program began in the spring of 2003, and has been repeated annually. Through this program, the CLWC and its partners have revealed that the lake has remained in very good condition. However, the results do demonstrate an overall increase in total phosphorus and total suspended solids (the concentration of solid particles in the water column) over the sampling period (Gilman and Olvany, 2006), which causes concern for the lake's future. Agricultural runoff carries with it nutrients and pesticides, causing environmental degradation that lowers biodiversity and makes the water less useful for humans (Duda, 1985).

Because the region is primarily agricultural and characterized by steep slopes, my current research focuses on assessing the possibility of lowering the threat of these increasing pollutants through the creation and restoration of riparian forested buffers (RFBs), or 30 meter zones of natural forest and other vegetation along a stream (Correll, 2005), to help reduce agricultural runoff. The positive effects of RFBs makes them a strong candidate for pollution control (Anbumozhi, *et al*., 2005; Correll, 2005; Lovell and Sullivan, 2005).

Unfortunately, when land is set aside for one use it is no longer available for other uses. The study proposed here would use interviews with local farmers to address the perceived and actual impacts of riparian forested buffers on agriculture. It would consist of two main parts: (1)

farmers' perceptions on their contribution to pollution contrasted with models and pollution data, and (2) farmers' perceptions on economic and social losses as a result of losing land to buffers compared to the actual price tags and losses associated with buffer installation. The primary interest of this study is to determine how perceptions and calculations compare.

This study is recommended as a master's thesis in sociology or environmental science, and is designed to be carried out for one to two years at low budget (estimated cost is US $1388.42). The results of the study would provide insight into one community's perspective on agricultural environmental regulations, and provide a different point of view for understanding farmers' choices regarding voluntarily conservation techniques. If the results reveal that perception and reality are indeed different in some way, these results can (1) help farmers understand the benefits of conservation, or (2) encourage the development of more economically feasible options.

Much of the literature available is from the 1970s and 1980s, indicating that little attention has been paid to the agricultural sector recently, despite it being one of the major causes of pollution. This study would help open the door for continued research, while including the farmer as an equal. Further, participation in this study would connect farmers to research projects that can directly benefit them while helping the environment. The use of RFBs is not easily generalized – different vegetation responds to different soil types and typographies that can severely alter the effectiveness of a buffer (Schultz *et al.*, 2004). The expertise of farmers can help tailor site-specific solutions to such issues. Such a relationship can also reduce animosity toward environmental regulation, or even open up new ideas for making RFBs economically useful.

Background

The environmental movement took a strong hold in the US in the early 1960s. In this time of prosperity, many Americans had the opportunity to explore the world beyond them, trying to understand the environment and their connection to it. Naturally, this heightened level of awareness opened the public's eye to many pollution issues associated with health and the environment that have stemmed from anthropogenic activities. Many committees have since been formed to discuss sustainability, the cost of "going green," and the overall impacts of humanity on the environment. The Kyoto Accord, adopted in 1997 (UNFCCC, year unknown) and the sustainable development concept, first adopted by the World Commission on Environment and Development (Clark, 1995), are examples of how changes in opinion and perspective have spurred cultures and communities to organize global initiatives aimed at environmental protection.

Given that sociology revolves around the study of human interactions with their surroundings, it is no surprise that many sociological organizations elected committees to study the environmental movement shortly following its inception (Dunlap and Catton, 1979). Some examples include the "Sociological Aspects of Forestry Research Committee/Research Committee on Sociological Aspects of Natural Resource Development," later renamed the "Natural Resources Research Group," which formed from the Rural Sociological Society in 1964, the "Environmental Problems Division" of the Society for the Study of Social Problems (1973), and the "Ad Hoc Committee on Environmental Sociology" of the Council of the American Sociological Association (ASA) in 1974 (Dunlap and Catton, 1979). In 1975, the latter was succeeded by the ASA "Section on Environmental Sociology," which "appears to represent the full range of interests currently pursued by environmental sociologists (Dunlap and Catton, 1979)."

Continual shifts in our perception of interactions with the natural environment are mirrored in the constantly changing goals and names of these sociological committees. As a result, much of the sociological research has targeted one of the more prominent aspects of the environment – the human social aspect of utilizing the environment for recreational purposes (Dunlap and Catton, 1979). On the other hand, interactions between the environment and agriculture or business have been more closely studied using political and economic theory and quantitative modeling. Very little qualitative research has aimed to illuminate the impacts that protective environmental regulations have on people. This study is therefore unique in that it explores one of the more often neglected aspects of environmental sociology.

Among the multitude of environmental concerns, water quality has held the spotlight for many years as an important target for environmental regulation. Point and nonpoint source pollution were identified in the Federal Water Pollution Control Act Amendment as the two main types of sources of water pollution in 1972 (Kerns and Kramer, 1985). The US Geological Survey defines point sources as pollution that stems from a single, identified source (NWRC, 2007). Common examples are pipes, wells and ditches. These types of pollution were targeted first, primarily due to the ease of source identification. Economic consequences that have resulted from strict regulation of these sources have been thoroughly discussed. For example, Portney (1981) estimated that the total incremental cost of pollution abatement from 1979 to 1988 would total 518.5 billion 1979 US dollars for all forms of abatement. This estimate provides a general idea of the cost associated with initializing and maintaining environmental pollution abatement techniques.

Due to the effectiveness of reducing the negative impact of point sources through regulation, more attention has focused on nonpoint pollution sources (Bouraoui and Grizzetti, 2008). In 1983 six of the EPA's ten regions reported that nonpoint pollution is the greatest perpetrator of water pollution within the region (Duda, 1985). Nonpoint pollution is defined by the USGS as "indirect or scattered sources of pollution," primarily in runoff and airborne particles (NWRC, 2007). The Canandaigua Lake watershed is largely agricultural, and eight of the ten EPA regions also reported in 1983 that agriculture contributed most to polluting runoff (Duda, 1985). Therefore, agriculture is targeted as a primary source of pollution in this study.

Runoff control might seem less costly than retrofitting factories, but it still comes with a price, and there are many unperceived social impacts. It comes as no surprise, then, that the decision-makers in environmental policy are largely economists and politicians. These actors rely heavily on maintaining "business as usual" standards, while supposedly improving the environment (Clark, 1995). Typically this means little regulation or responsibility at the federal level, and great responsibility at local and individual levels. The federal government did make an effort to introduce cost-sharing programs – the most popular option for pollution control. Unfortunately, funding for such programs is tight and options for program improvement are limited (Kerns and Kramer, 1985).

The brunt of conservation costs therefore lies on local government and individual farmers. For this reason the environment often sits on the back burner in the face of economic needs. This highlights concerns proposed by many that perhaps protecting the environment does involve an increase in spending and production cutbacks (Clark, 1995). The cost to farmers of carrying out pollution control is largely ignored. Very little discussion on pollution control costs in the agricultural sector, while many economists have focused on costs to industry (see Ridker and Watson, 1981 and Portney, 1981).

However, it is not simply cost that guides a farmers' willingness to participate in conservation programs. Clearfield and Osgood (1986) remind us that soil conservation practices have likely always been used in agriculture. They use the example of the "dust bowl days" of the

1930s, when controlling soil erosion was more profitable than allowing the rich topsoil to literally be thrown to the wind. These authors further argue that since fertilizers and pesticides have reduced the need for erosion control, the cultural significance of conservation now stems from a social obligation to protect the greater community (perhaps even to a global scale), rather than from economic necessity (Clearfield and Osgood, 1986). Other studies have shown that conservation practices are dependent on factors such as age, type of farm, whether the land is owned or leased, as well as many other factors (Kerns and Kramer, 1985; Clearfield and Osgood, 1986). This implies that farmers are aware of their choices and weigh costs and benefits in the decision-making process. But what factors are they taking into consideration, and are they able to clearly perform such an analysis from their own perspective? More importantly, since farmers have multiple reasons for practicing conservation strategies, it is difficult to apply an all-encompassing model to estimate who will employ which practices (Clearfield and Osgood, 1986). One question that arises is whether we can generalize within a region, or if conservation truly needs to be on an individual case basis. Likewise, would it be possible to create a matrix that encompasses all of the various reasons for choosing to participate in conservation? These are additional questions I recommend the researcher keep in mind.

Proposed Research

At the 2007 National Water Conference, Dr. Jonathan Winsten proposed the idea that perhaps nonpoint source pollution could be addressed in a way that gave farmers more "flexibility," "induce[d] innovation" to help with pollution control, and improved government spending (Winsten, 2007). Such an angle on the issue could greatly improve pollution control in the agricultural sector – if it is done correctly. As it stands, many factors inhibit the success of conservation programs. One of these factors is the issue of defining pollution and measuring individual contributions to it. Another is a difference in perceptions that limits action. It seems that farmers currently feel that there is no significant issue, or that they are unable to contribute to the solution. If farmers do not feel empowered to make these changes, we will never succeed.

Before change is possible, it is essential to understand the intricacies of where farmers stand on pollution control measures today. What is the difference between farmers' perceptions and calculated or predicted values? In spite of the cost issues and lack of focus on the agricultural sector, differences between perception and actuality may distort individual perspectives and hinder conservation efforts. The goal of this research is to define the farmer's understanding of the pollution problem and his contribution to it, as well as to determine the difference between individual perceptions and actual price of abatement, if such a difference exists. For instance, it is possible that farmers believe they are contributing less to pollution than their neighbors, or believe they are practicing conservation strategies when they are in fact not (Clearfield and Osgood, 1986). Likewise, the perceived cost might also be lower than actual cost or vice versa (Clearfield and Osgood, 1986). Lastly, the study should address factors other than cost and stewardship principles that govern a farmer's decision to practice conservation.

Methods

Data Collection

This study would begin with two focus group discussions to gather general information about conservation practices already used in the watershed. Participants should be representatives from the local farms. Since the watershed is relatively small, landowners from all non-subsistence farms should be invited to share their input; I am estimating that 30 farmers will agree to participate in the focus group. Tax parcel data in GIS will provide names and addresses for all farmers in the area, and this information should be confirmed by the CLWC to ensure all names are accurate and that no farmers have been excluded from the participant list. It is suggested that topics covered during this session include:

- Is nonpoint pollution an issue in the watershed?
- Why or why not?
- What or who is the largest contributor?
- Which agricultural best management practice (ABMP) strategies are practiced in the watershed?
- What percentage of farmers employs each of these strategies?
- Is there a standardized definition and procedure for each ABMP strategy?
- Do any of the municipalities assist with conservation practices?
- In what way?
- Does the watershed council assist with conservation practices?
- In what way?
- Do the needs of farmers differ based on location in the watershed?
- Do local government benefits differ based on location in the watershed?

Focus group discussion will allow the researcher to quickly learn the terms for BMPs common to the region, understand runoff and management as the farmers perceive it, and lastly gain an understanding of the relationship between agriculture and local municipalities/organizations. The research also has the opportunity to observe interpersonal dynamics – is there agreement on local issues? If there is disagreement, where does it seem to start? Understanding these dynamics will help the researcher sort out individual responses from an objective point of view during personal interviews.

Individual interviews following the focus group session will be carried out to address these issues on a more personal level. The researcher may at this point choose to interview all focus group participants, or randomly select a portion of them. I am assuming in this proposal that the researcher will select half of the focus group participants for personal interviews (15 farmers).

In addition to a review of the focus group questions, farmers should be asked to comment on their personal contributions to pollution, and their attempts if any at reducing their impact. Those who claim to have practiced conservation strategies should be asked to elaborate on which strategies are believed by the landowner to be most effective, which strategies were employed and how, why these strategies were selected over others, and at what cost. These discussions should revolve around the categories of:

- The perceived problem
- The perceived ideal solution
- The perceived or estimated cost
- Other limiting factors

After compiling and analyzing the interview and focus group information, the researcher should compare group responses to individual responses, and compare perceived best practices and costs to a quantitative study of actual best practices and costs in their region (this study may be performed by the student, or may be another project entirely). The qualitative results would produce valuable information regardless of whether a quantitative study is available for comparison. The analysis should focus on cost to farmers who practiced ABMPs as compared to the perceived costs of those who did not practice ABMPs, and estimated costs reported. A quantitative analysis of the landscape would also be useful in comparing the perceived problem of pollution to the actual problem. Detailed observation of the landscape and ground estimates might also be useful.

All participants shall receive a small gift for their contributions to the study.

A microcassette recorder and transcriber should be borrowed from the liberal arts or technology department. If one is unavailable, this should be added to the budget.

Participant Protection

The researcher should do his or her best to protect the identity of the participants in this study. As part of this process, the study must be submitted for institutional review board (IRB) or equivalent review. Although it is likely that focus group participants will know each other, individual interview responses should be maintained confidentially. Focus group consent forms must be signed before the focus groups, and interview consent forms should be signed shortly following the focus groups, upon selection of participants. Each participant should be assigned a unique identification number and be referred to by that number throughout the researcher's notes, tape recordings and report.

The nature of this subject is rather sensitive as it asks participants to point out problems in their own business, or their neighbor's businesses. The researcher should take care in emphasizing that the study is not to point blame at the farmers, but to better understand their thinking on what limits them. Care should be taken to avoid accusations and indications of blame, particularly in focus groups, while still targeting the main issues.

Timetable

Because I have designed this study as a master's thesis, the proposed timetable is extended to accommodate a student's schedule. It begins in September at the beginning of the academic year. Personal interviews are scheduled for the spring so the researcher may observe the effectiveness of BMPs during the rainiest season if he or she chooses to do so.

September – October

Selection of focus group participants

Review of literature

Borrowing of equipment

November – December

IRB approval form submitted and edited where necessary

Consent forms signed and stored

Organization of participants/Assignment of numerical identifiers

Purchase and setup of equipment

Focus group accommodations organized

January

First focus group

Detailed notes following focus group

Transcription and compilation of responses

Patterns of responses

February

Second focus group

Detailed notes following focus group

Transcription and compilation of responses

Patterns of responses

March

Analysis of focus group responses

Gaps in data and need for clarifications identified

Adjustment of interview questions where necessary

Selection of interviewees

April – May

Personal Interviews

Time taking detailed notes will follow each interview

Visits to watershed and farms

Transcription of interview responses

June – August

Final analysis of results

Comparison to other studies

Final report generated

Report delivered to participants and municipalities

Budget

Transportation = $811.50

$0.541 per mile (AAA, 2008)

x 15 trips at 100 mi roundtrip

Equipment = $72.45

5 notebooks x $1.98 + 8.25% tax

100 pens = $1.19 + 8.25% tax

3 packs Maxell 60 Minute Micro-cassettes, 9/Pack at $8.99 + 8.25% tax

Food for Focus Groups and Presentations/Meetings = $150

Gifts for Participants = $500

Printing* and final report = $4.47

*Printing will be done on campus, free of charge to the student. If this service is unavailable, printing will cost $0.10 to $0.15 per page, depending on quality and location.

Thermal Report Bind $1.49/book x3

Total Estimated Budget: US $1538.42

The student should consider applying for a research grant to cover the costs associated with travel and gifts to participants. The school will likely provide the remainder of the equipment.

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