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## A river continuum analysis of relationships between bioassessment, land use, and macroinvertebrate assemblages

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**A RIVER CONTINUUM ANALYSIS OF RELATIONSHIPS  
BETWEEN BIOASSESSMENT, LAND USE, AND  
MACROINVERTEBRATE ASSEMBLAGES**

**Thesis**

**Submitted to**

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**in Partial Fulfillment of the Requirements for**

**The Degree**

**Master of Science in Biology**

**by**

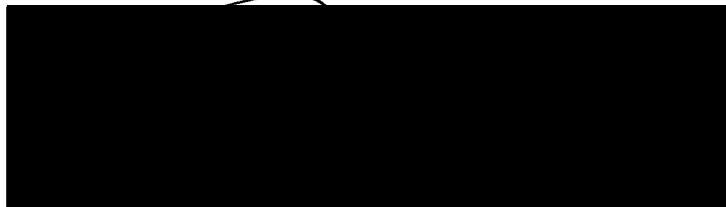
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**April, 2008**

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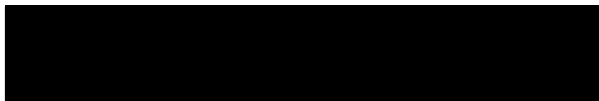
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## ABSTRACT

### A RIVER CONTINUUM ANALYSIS OF RELATIONSHIPS BETWEEN BIOASSESSMENT, LAND USE, AND MACROINVERTEBRATE ASSEMBLAGES

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Sustainable management of stream systems and the development of bioassessment standards are important for the preservation of natural habitats. Maintaining biodiversity in the face of encroaching human disturbance has received much attention in recent years. Bioassessment of habitats is becoming commonplace for many state and federal agencies. This research attempts to answer two questions based on this observation. First, there are currently numerous bioassessment protocols available for use. Recent research has shown no significant difference in aquatic assessment results based on expensive, labor-intensive, quantitative sampling versus more cost-efficient, less defined, qualitative methods. This verifies these findings on a linear river continuum using a macroinvertebrate functional feeding group (FFG) approach. Second, this research utilizes GIS software to account for the effect anthropogenic land uses within the surrounding landscape have on in-stream habitat conditions and their ability to predict macroinvertebrate assemblages

depending on spatial scale. Macroinvertebrates and water quality data representing thirteen sites along the 106-mile Little Miami River in southwestern Ohio were evaluated by collecting six quantitative (Hess sampler) and six qualitative macroinvertebrate samples from riffle/run habitats in June/July 2006 and 2007. Four ecosystem attributes were calculated based on FFG quantities: autotrophy/heterotrophy, fine particulate organic matter/coarse particulate organic matter, suspended fine particulate organic matter/benthic fine particulate organic matter, and substrate stability. Functional feeding group ratios confirmed the quality of the selected reference site. All four FFG ratios verified similar trends between collection methods within each year. Ratios also showed similar trends between years, with the exception of the autotrophy/heterotrophy ratio. This suggests rapid, qualitative methods are equally proficient in characterizing macroinvertebrate assemblage as quantitative methods. Five spatial scales were used, ranging from entire catchment to immediate riparian corridor, to compare macroinvertebrate indices to land use practices. In most cases, indices were related to percent forested land use and in all cases, the local spatial scale showed the strongest correlation. This suggests even small scale efforts to improve riparian zones can benefit impact recovery and mitigation efforts of waterways.

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## LIST OF SYMBOLS/ABBREVIATIONS

DEM – digital elevation model

EPA – environmental protection agency

EPT – ephemeroptera plecoptera tricoptera

EROS – Earth Resources Observation and Science

FFG – functional feeding group

LMR – Little Miami River

MRLC – Multi-Resolution Land Characteristics

NLCD – National Land Cover Database

QHEI – Qualitative Habitat Evaluation Index

RBA – rapid bioassessment

RBP – rapid bioassessment protocols

RM – river mile

WWTP – wastewater treatment plant

## INTRODUCTION

### *Stream bioassessment*

Sustainable management of stream systems and the development of bioassessment standards are important for the preservation of natural habitats. Maintaining biodiversity against encroaching human disturbance has received much attention in recent years (Allan and Flecker 1993, Harding et al. 1998, Sponseller et al 2001, Nerbonne and Vondracek 2001, Allan 2004). As techniques become more refined, bioassessment is becoming a standard and accepted approach of monitoring the quality of lotic systems. The primary purpose for bioassessment is to determine how well a water body supports life. The development of these techniques came as a direct response to the Clean Water Act, set out in 1998 by the Environmental Protection Agency's (EPA) Office of Science and Technology. The act calls for the restoration and maintenance of the physical, chemical, and biological integrity of the nation's waters. Section 305(b) outlines a process for assessing and reporting on the quality of the nation's waters. The goals of this section can be broken into four parts.

Foremost, the status of the water resource must be determined. The EPA has developed a categorical list of defined aquatic life uses with which to designate a water body's quality and potential utilization. Therefore, the obvious first step is to assess the status of the water body under current conditions and, if impaired, try to predict its potential for use in the future. Potential use can be predicted by

determining the source of the water body's impairment and setting realistic goals for rectification. Once the causes of degraded water have been evaluated and the relative contributions of the pollution sources identified, a reasonable plan of action is designed to bring the system quality up to the projected attainable aquatic use level. Implementing this plan, reporting on the measures being taken, and determining the effectiveness of the mitigation programs encompass the third step. At this stage, clean-up efforts can be modified and goals reset to ensure maximum efficiency is attained and the highest possible quality can be reached. Once the projected aquatic life use has been achieved, it becomes necessary to continue monitoring the system to make sure regression to the previous polluted state does not occur (Barbour et al. 1999). The first and final steps in this process are where bioassessment can play an integral role.

Bioassessment has the ability to adequately assess impact within aquatic systems and has some specific advantages over somewhat dated chemical tests. While chemical tests can provide single, instantaneous glimpses of water quality at one point in time, they are often restricted by the methodology available and the detection limits that apply. They are good indicators of specific chemical levels, but are therefore not well suited to detection of any nonpoint source pollution. Characterization of ambient water chemistry may be the most difficult element to assess in river systems because of the many factors that can affect it and the innate temporary nature of the local environment (Barbour et al. 1999). Bioassessment, on the other hand, provides a more user friendly,

environmentally sound method that generates data of a holistic nature. It is the most effective way to detect impact from nonpoint source pollution events (CWA section 319, Barbour et al 1999). Monitoring biological assemblages provides information on how organisms deal with the aggregate impact of potential stressors, such as nutrient enrichment, temperature increase, sedimentation, and toxic chemicals (Rinella, Bogan, and Major 2003). Living, dynamic communities, which move toward equilibrium within their habitat, integrate the effects of these stressors over time and are able to provide information on fluctuating environmental conditions.

There are both quantitative and qualitative protocols in bioassessment research. Studies have shown both methods to be effective and efficient when used with macroinvertebrates. However, qualitative rapid bioassessment protocols (RBPs), are thought to be more efficient (Davies et al 2000, Resh et al 1995). The general methodology is faster, easier, and cheaper than the traditional quantitative method. It has been argued that because rapid methods do not provide accurate data on species abundance or density, they can only detect gross impact and are less sensitive than quantitative methods (Taylor 1997). Small and cryptic taxa may be overlooked, which could leave out important information (Humphrey et al. 2000). Also, issues of inter-operator variability have been brought up regarding the level of experience the person identifying and quantifying all organisms has received (Hannaford & Resh 1995). However, recent studies have also shown that these rapid methods generally give the

same results as quantitative methods and any differences that were found were not a direct result of operator error (Metzeling et al. 2003). This research utilizes a macroinvertebrate functional feeding group (FFG) approach (Merritt and Cummins 1996a, 1996b) to expand upon this proposed disparity, while generating quantitative data for verification of published indices and recent research.

#### *Macroinvertebrate functional feeding group approach*

In aquatic habitats, algae, fish, and amphibians have been used in bioassessment studies to describe the condition of their environment. This research focuses solely on macroinvertebrate populations. Macroinvertebrates play a fundamental role in the ecosystems of rivers and streams, and are therefore useful in bioassessment surveys of riverine habitats. They are excellent biological indicators (Patrick and Palavage 1994) and are the primary organisms used by water quality agencies in both the USA (Barbour et al. 1999, Southerland and Stribling 1995) and worldwide (Metzeling et al. 2003, Chessman 1995, Cummins et al. 2004). First, they provide a link between two trophic levels: the primary producers and the secondary consumers (Bright 1982, Evans and Norris 1997, Merritt and Cummins 1996a, Merritt and Cummins 1996b, Rosenberg and Resh 1993). They feed on the algal producers and/or on each other and are in turn fed upon by fish consumers. This provides information regarding direct pollution effects on their own populations and potentially shows indirect pollution effects on other trophic levels. Second, macroinvertebrates are



naturally ubiquitous. Many small order headwater streams, which support large macroinvertebrate communities, are only able to sustain small populations of fish. Therefore, macroinvertebrates provide a better representation of stream compared to using fish populations. Macroinvertebrates are also taxonomically diverse and therefore express a wide range of tolerance to a variety of impairments. Monitoring changes in the presence and, perhaps more importantly, the absence of certain species can assess potential impacts. As individuals, macroinvertebrates are relatively stationary, which allows for good indication of local conditions. Many of the aquatic invertebrates consist of larval insects maturing to adulthood. This generally involves complex development, which can extend one year or greater. Larvae respond quickly to environmental stressors, which can provide evidence of short-term environmental changes. Most importantly, macroinvertebrates are relatively easy to collect and identify with few people and inexpensive gear and require much less of the tedious lab work that is involved in microorganism sampling (Rosenberg and Resh 1993; Barbour et al. 1999).

For bioassessment studies, two methods of grouping invertebrates have been employed: taxonomic and/or functional. Taxonomic studies ask the question "what is it?" and are employed when some measure of richness, density, or taxonomic metric is warranted. These studies usually require identification to the genus or species level, or sometimes family, which limits its use to those with expert taxonomic experience. While these types of studies can be useful when

determining the exact sensitivity of an organism to a specific chemical contaminant, they are neither practical nor necessary for studies assessing overall habitat quality and ecosystem condition (Cummins et al. 2005). An alternative technique is the functional approach, developed and refined over the past 30 years (Cummins 1973, 1974; Cummins and Klug 1979; Cummins and Wilzbach 1985, Merritt and Cummins 1996a, 1996b). The functional approach categorizes invertebrates into five functional feeding groups (FFGs) based on easily recognizable morphological and behavioral characteristics related to their functional morphology and manner of food acquisition (Table 1). It asks the question "what does it do?" Indeed, Wallace, Vogel, and Cuffney (1986) found that recovery of trophic structure and restoration of function after a disturbance event in lotic habitats seemed to occur in a manner not recognizable solely by taxonomic criteria. The FFG approach does not require the fine level taxonomy necessary for quantitative tests. In most cases, it is only necessary to identify organisms to the family level, and sometimes higher, in order to categorize them, making the identification process much more efficient.

A second advantage of this approach, as described by Merritt and Cummins (1996), is the application of certain ratios to numerically categorize specific lotic ecosystem attributes (Table 2). Values from these ratios are used to describe the trophic status of the system, spatial characteristics of the organic matter within the stream, and estimates of overall substrate stability. These ratios can be used as stand-alone categorization of a single site over time or as relative

values comparing multiple sites, affording the differentiation of sites and monitoring of trends across both spatial and temporal scales.

A final advantage of the functional method is its ability to describe more than just the internal aquatic environment. Rivers are not isolated ecosystems. They are directly linked to the terrestrial realm through their riparian vegetation. The functional approach is sensitive to changes in land use characteristics within the river basin and particularly within the riparian corridor, because it is based on the process by which organisms obtain their food and the main component responsible for contribution of organic material in river systems is the riparian zone (Naiman and Decamps 1997).

#### *Land use effect on stream macroinvertebrate communities*

In-stream conditions that directly affect habitat quality are often mediated by the surrounding landscape. Depending on location within the watershed, land use practices show variable influence on stream conditions (Allan and Johnson 1997). For example, the relative abundance of inorganic nutrients and the general catchment hydrology is often related to land use practices across the entire watershed (Omernik 1977; Swank, Swift and Douglas 1988; Hunsaker and Levine 1995), while availability of organic materials and light intensity is directly effected by nearby streamside vegetation (Gregory et al 1991). Increased inorganic nutrients combined with increased light intensity and higher temperatures affect overall trophic structure of benthic communities (Gurtz and

Wallace 1984) through increased primary production (Webster et al. 1983, Roy et al 2005). Thus, cause and effect relationships of in-stream conditions can be as immediate as direct riparian input and as distant as overall basin geomorphology.

It has been shown that riparian zones have a greater impact on the structure and function of streams than more distant areas of the catchment (Naiman and Decamps 1997; Pusey and Arthington 2003). They often act as buffers that filter pollutants from water that would otherwise enter the stream (Lowrance 1998). Vegetation within the zone provides shade, which regulates water temperature and light input that can influence stream metabolism (Mosisch et al. 1999; Rutherford et al. 2004). Riparian zones also provide organic matter in the form of leafy and woody debris (Cummins et al. 1989) and terrestrial invertebrates (Nakano and Murakami 2001; Ballinger and Lake 2006), affecting stream food webs. They increase the amount of usable habitat within the stream through bank stabilization (Beeson and Doyle 1995) and input of large woody debris (Benke et al. 1985). The amount of large woody debris has been directly correlated to macroinvertebrate assemblages in several studies of non-urban streams (Ormerod et al. 1993; Wooster and DeBano 2006). Obviously, riparian zones play an integral role in the development and maintenance of aquatic systems. The transformation of healthy, forested riparian corridors into more structured and modern landscape can have detrimental effects in-stream habitats.

Despite all the effects the local riparian can have on stream conditions, there is disagreement in the literature over which spatial scale shows the greatest ability to predict macroinvertebrate assemblages based on land use distribution. A study performed by Richards, Johnson, and Host (1996) characterized catchments based on basin geology and amount of land being used for agriculture. They found these features best correlated with channel morphology and stream hydrology at the catchment scale, and that larger regional scales were the best predictors of macroinvertebrate assemblages. However, they did note that local riparian characteristics influenced stream bank erosion and in-stream sediment related variables. A subsequent study done by Richards et al (1997) found that while all of the above may be true, macroinvertebrate species traits were best correlated with local riparian land-cover patterns. Sponseller et al (2001) further confirmed this by reporting catchment-scale land use practices were the best predictors of stream water chemistry, but temperature and other physical stream characteristics were better correlated with smaller scale attributes. Also, macroinvertebrates indices were most closely related to local land use patterns, specifically those found within a riparian reach extending 200 m above the sample site.

In addition to comparing the results of two methodologies, this research attempts to verify the relationship between riparian corridor use and in-stream habitat quality, analyze these correlations at multiple spatial scales, and define possible ameliorative effects and mitigation benefits these zones may have. This study

expands on Sponseller's research by using an entire river watershed with sampling occurring in the 4<sup>th</sup> - 6<sup>th</sup> order midreaches of the main river channel. Data from this 70 mile river continuum (Vannote et. al. 1980), can be used to determine the possibility of riparian zones providing recovery from pollution events that occur farther upstream.

## MATERIALS AND METHODS

### *Sampling area and site selection*

All sampling for this project took place on the Little Miami River (LMR). Named Ohio's first scenic river in 1969, the Little Miami River draws general interest on all levels: from kayaking and fishing, to the associated bike paths, to the basic aesthetic appeal that draws people to riverine environments. It also supports abundant aquatic life including 87 fish and 36 mussel species, numerous species of birds and a multitude of insects and plant life (<http://www.dnr.state.oh.us/dnap/sr/lmiami/tabid/1862/Default.aspx>). Thus, preservation of this natural resource is important for both biodiversity conservation and recreational and practical human utilization.

The Little Miami River (LMR) runs southwest from its headwaters in Clark County, Ohio, approximately 106 miles to its mouth in the Ohio River, passing to the east of Dayton and Cincinnati (Fig. 1). The river drains an area of approximately 1757 square miles, which is predominantly comprised of limestone and dolomite bedrock. The channel form of the river is low gradient and meandering, dropping from 1137 ft. to 448 ft. with an average gradient of 6.5 ft./mile. However, there are channelized portions of the river and it does flow through a variety of land use categories. A total of thirteen sites were selected, which were distributed along the entire length of the LMR from RM 99 to RM 28 and corresponded to OhioEPA assessed sites, as published in *Biological and Water Quality Study of the Little Miami River Basin, 1998* (Table 3). Sites were

selected to represent the broad spectrum of impacts, including agricultural, urban, wastewater treatment effluent, and the more "pristine" forested areas, associated with the LMR continuum, with the goal of adequately assessing the ability of the sampling methods utilized to differentiate between reference and more disturbed environments (Fig. 2). Most sites were situated near a practical public access point from a road or bridge. Site 7 incorporated two sampling areas situated upstream and downstream of the Sugar Creek Wastewater Treatment Plant (WWTP) outfall to include data from point-source as well as non-point source impacts. Site 3, located within John Bryan State Park and the natural Clifton Gorge area, served as the reference site. It represents old growth forest conditions similar to pre-white settlement.

#### *Macroinvertebrate sampling and identification*

Macroinvertebrate sampling was done in June-July 2005 and 2006. All samples were collected from riffle habitats with a cobble substrate, when available, as these give the best example of overall macroinvertebrate diversity (Hynes 1970). However, sites 1, 5, and 7 had sandy substrates and site 5 was especially depositional with silt/sand substrate. Six quantitative and six qualitative samples were collected within a 50 meter reach at each site. In all cases, both methods were performed on the same day for each site and sampled the same type of stream habitat and substrate composition.



Quantitative samples were collected using a Hess sampler (0.086 m<sup>2</sup>) with attached net (500 µm) where substrate was rigorously disturbed and scrubbed for 30 seconds. Qualitative sampling was performed using a modified rapid bioassessment (RBA) protocol. Samples were collected using a standard D-frame dip net (500 µm) and the area scrubbed was defined by the bottom edge of the D-net, 12 inches wide, and about 1 meter upstream of D-net placement; substrate was disturbed and scrubbed for 30s. All larger rocks caught in the net were scrubbed before depositing back in the river. Subsequently, all benthic invertebrate samples were differentiated through a 500 µm sieve, preserved in ~70% ethanol, and returned to the lab for processing. Macroinvertebrates were counted and identified to the appropriate taxonomic resolution (usually to family) for assigning tolerance values and functional feeding group (FFG) categories (Bouchard 2004, Merritt and Cummins 1996a).

#### *Macroinvertebrate indices*

Four ecosystem attribute ratios (Table 2) were calculated from FFG numbers for each RBA and Hess sample. All data were normalized with an arcsine transformation and the six values for each sampling method were compared for significant difference within each site.

A suite of five macroinvertebrate metrics was calculated for each RBA and quantitative sample, including density, Shannon diversity, EPT index, Biotic index, and abundance. Metrics were chosen to represent density, taxa richness,

diversity, evenness, and pollution tolerance (based on Hilsenhoff 1988 and Barbour et al 1999), and the abundance and richness of various taxonomic groups, such as the EPT index which focuses on three intolerant taxa (ephemeroptera, plecoptera, tricoptera).

#### *Physicochemical water parameters*

A qualitative habitat evaluation index (QHEI) was conducted in 2005. The QHEI is a method developed by the Ohio EPA for assessing overall aquatic habitat quality (see Appendix C). Scores are based on a 100 point scale and account for physical large-scale stream attributes, substrate type and quality, both in-stream and riparian cover, stream bank quality, and type and abundance of in-stream habitats. Our QHEI values were compared to EPA assessments for the same sites. In 2005 and 2006, physicochemical parameters (pH, alkalinity, acidity, turbidity, nitrates, temperature, DO, conductivity, and discharge) were collected *in situ* at each site. In 2006, water samples were collected and sent to The Ohio State University's STARLab to measure a suite of ions and heavy metals (Table 4).

#### *Catchment delineation and land use correlation*

Catchment delineation and land use analysis was conducted in GIS using ArcMap 6.0. Processing began with a digital elevation model (DEM) of the LMR basin, obtained from the USGS Seamless Data Distribution System, Earth Resources Observation and Science (EROS) website (<http://seamless.usgs.gov>).

Individual site catchments were delineated using the ArcHydro 9 software add-on (<http://support.esri.com/index.cfm?fa=downloads.dataModels.filteredGateway&mid=15>). For each site, the individual catchment was represented in the form of a feature shapefile. In order to assess land use characteristics for multiple spatial scales, four additional shapefiles were created. A 30-meter riparian buffer zone was created along the length of the LMR. This was divided into four sections representing the four additional scales for each site: the area 200 meters upstream from the sampling site, 1,000 meters upstream from the sampling site, 2,000 meters upstream from the sampling site, and the entire catchment riparian buffer (Fig. 3). The three sub-riparian buffers were created using ArcMap's built-in linear referencing tool.

The land use data (National Land Cover Database 2001) for this study was obtained directly from the Multi-Resolution Land Characteristics (MRLC) Consortium's dynamic download tool, located at their website ([www.mrlc.gov](http://www.mrlc.gov)), and incorporated into ArcGIS 6.0. Land cover data layers were derived from three dates of Landsat 7 imagery (30 m resolution) and various ancillary layers, including digital elevation models and derivatives of slope, aspect, and slope position (Homer et al 2004).

Land cover within the LMR watershed was originally classified into 15 categories (Fig. 2). To make analysis simpler, the land cover layer was reclassified to represent three values: forested, agriculture, and urban. Forested represents

deciduous, evergreen and mixed forest. Agriculture represents pasture/hay and cultivated crops. Urban represents the four developed categories (Fig. 4).

### *Statistical analyses*

A paired t-test was used to compare ecosystem attribute values from quantitative and qualitative macroinvertebrate collection methods at each site. Bivariate regression analysis was used to determine which land use spatial scale was the best predictor of macroinvertebrate indices and in-stream conditions. Each index, calculated for the 2006 Hess samples, was used as the dependent variable against the three riparian sub-corridor segments. Because all samples were taken from the same linear river, the catchment and catchment riparian zone segments build on each other from headwaters to mouth. Therefore, the land use values not completely independent. For this reason, they were not used in the bivariate analysis. Site 7 down was also removed from the data prior to analysis. This site was not completely independent from site 7 up. A  $p < 0.05$  was used to determine significance in all analyses.

## RESULTS

### *Qualitative habitat evaluation index*

QHEI characterization for each site ranged from 37.5 to 87 (Table 5). The reference site was scored highest on the index. Substrate consisted of cobble and boulder and canopy cover was almost 100% for the entire reach. This site is also surrounded by the greatest percentage of forested land cover in the immediate riparian zone (Table 6). Site 1, the most upstream site, scored the lowest. This site was the most channelized of all sites and was surrounded entirely by agriculture with almost no canopy cover. Substrate consisted almost entirely of sand and silts. The general trend shows QHEI increasing from upstream to downstream. When compared using bivariate regression to percent forested land use, the only significance is found at the 200 M scale ( $r^2 = .588$ ,  $n = 14$ ,  $p = 0.034$ ). Lower values upstream are associated with channelization and lack of canopy in the riparian corridor due to agriculture.

### *Physicochemical characterization*

Tables 4 and 5 displays the results of all physicochemical data collected for 2006. Several different trends were seen. Temperature and pH were relatively stable from mouth to headwaters. Dissolved oxygen (DO) fluctuated greatly with no correlation found in regression analysis. Site 5 was characterized by the lowest DO level. This site also had very slow flow and no riffles. It was the characterized by wide channel, low velocity run habitat with high canopy cover. Of all the sites, its substrate was the most depositional with a high percentage of

silt and sand. Both alkalinity and acidity were highest at site one and dropped to plateau after Site 5. The most remarkable changes were seen immediately below the WWTP outfall. Several chemical elements showed spikes at this location, Site 7 down, including phosphorous, boron, sodium, potassium, nitrates, phosphates, and sulfates (Table 4). At Site 8, all of these spikes returned to a position consistent with Site 7 up, the site immediately upstream of the WWTP outfall.

Many of the physicochemical elements show patterns with regard to catchment characteristics. Discharge ranged from 0.63 to 6.48 ( $\text{m}^3 \text{s}^{-1}$ ) and was directly related to catchment size ( $r^2 = 0.879$ ,  $n = 14$ ,  $p = 0.000$ ). Stream temperature ranged from 19.9°C to 28°C and was inversely related to elevation ( $r^2 = 0.278$ ,  $n = 14$ ,  $p = 0.05$ ). Conductivity was also inversely related to elevation ( $r^2 = 0.57$ ,  $n = 14$ ,  $p = 0.002$ ). It ranged from 600 to 889, increasing as elevation decreased. Alkalinity ranged from 214 to 295 ( $\text{mg L}^{-1}$ ) and decreased as discharge increased ( $r^2 = 0.418$ ,  $n = 14$ ,  $p = 0.043$ ), as did acidity ( $r^2 = 0.634$ ,  $n = 14$ ,  $p = 0.006$ ) which ranged from 5.4 to 9.6 ( $\text{mg L}^{-1}$ ). No significant correlations were found when comparing physicochemical variables with land use spatial scales.

#### *Land use characterization*

The LMR watershed's primary land use, particularly the eastern half, is agriculture (Fig. 4). This area represents the upper reaches of the LMR where over half of the catchments used in this study are located. Forested areas are

found in greater percentage further downstream as more tributaries join the main channel. The forested area tends to closely follow the paths of the larger tributaries suggesting a strong wooded correlation with the riparian zone of the downstream sites. There is also a small urban contribution to the system from the city of Dayton, which is located in the northwestern portion of the watershed. Despite this seemingly uniform appearance of the study area, Table 7 shows there is inherent variation between sites and spatial scales. As seen in the Catchment category, agriculture dominates upstream, with gradually decreasing percentages from headwaters to mouth. This clear majority of one land use practice across the entire basin dampens the effect other land-covers can have on any correlations run at this scale. This agriculture majority is again seen in the upstream sites of the Catchment Riparian Zone category, but decreases more dramatically until forested takes position as the majority land use. The three sub-riparian zone categories show much greater variability both in quality and quantity of the majority land use. In many cases, there is no clear majority. Herein lies the variation among independent values that can be used to run regressions.

Forested land use values are shown against all macroinvertebrate indices in Table 6. The overwhelming dominance of agriculture can once again be seen in the Catchment category. The percentage of forested area never rises above 15%, with the exception of Site 11 and 12. This unusual peak is mainly due to the sudden inclusion of a large, well-forested tributary seen in the central portion

of Fig. 4. The Catchment Riparian Zone category shows a similar trend. However, the rate of forested land use percentage rise is more pronounced, starting at 4% for Site 1 and steadily rising to 55% at Site 12.

Again, the three Sub-Riparian Zone categories show the greatest variability among sites. There is no general upstream to downstream trend as seen in the larger areas, but patterns do emerge between spatial scales. Some sites, the most evident being Site 1, show very similar results regardless of size. Others such as Site 3, the chosen reference site, show steadily increasing forested values from the larger to smaller scale. Still some, like Site 6, which travel through more highly developed areas, show steadily decreasing values. In the downstream sites, obvious specific trends are less apparent. This reflects the patchy distribution along waterways.

#### *Biological characterization*

Macroinvertebrate density ranged from 3,849 m<sup>2</sup> at Site 3 to 43,581 m<sup>2</sup> at Site 1. The reference site showed the lowest macroinvertebrate density. Taxa richness ranged from 6 at Site 3 to 21 at Site 11. Macroinvertebrate indices showed strong correlations to land use patterns at different collecting sites over different spatial scales (Table 8). Density, EPT, biotic index, and taxon richness all showed significant correlation against percent forested land use at the 1,000 m and 200 m scale, with the greatest correlation at the 200 m scale. EPT and Biotic index values both increased in quality as % forested area increased.



Density and taxa richness both decreased as % forested area increased.

Obviously, the three land use values are not completely independent of one another as in each case they represent percentages of the same area. However, regressions were run between macroinvertebrate indices and the agriculture and urban land use as well to discover which practice, if any, was the significant driving force in the opposite direction. Not surprisingly for this watershed, agriculture proved to be significant in all four of the cases. Density, in particular, showed the greatest level of significance and highest correlation coefficients. Again, all correlations were most significant at the 1,000 m or 200 m scales.

#### *Ecosystem attributes*

At all fourteen sites, gathering collectors represented the clear majority of all five FFG's (Table 9). Over 50% of the organisms collected at any site were gathering collectors. In many cases, this was due to an extreme abundance of organisms within the Chironomidae. Gathering collectors are in the denominator of all four ecosystem attribute ratios and therefore drove all the values down. This kept all ratio values below 1 (Fig. 5). P/R values remained below the critical value of 0.75 for all samples collected, characterizing every site as heterotrophic and driven by respiration versus production. Site 2 showed the highest value and only peak in the P/R values. Organic matter characterizing ratios showed contradictory responses. The particulate organic size ratio showed little variation across the board. All sites were characterized as having a greater abundance of FPOM than CPOM, with values remaining under 0.1, well below the 0.25 critical

value, and many never climbing above zero. The attribute representing location of organic matter showed much greater variation than its cousin. Three of the sites climbed above the critical value of 0.5, signifying greater organic matter abundance in transport than in the benthic regions. These three sites, 3, 9, and 10, also showed peaks in the channel stability index. (Fig. 5)

### *Comparison of methodologies*

T-tests performed between the two methodologies, for both years of macroinvertebrate collection, showed about 94% of the comparisons being statistically insignificant (Table 10). Only one site, Site 5 in 2006, showed all of the calculated indices to be significantly different. Physical characteristics at this site included relatively full canopy cover, but the unstable substrate of mostly fine silts and sands, which is not ideal habitat for macroinvertebrate survival.

## DISCUSSION

### *Site differentiation*

QHEI results show the 13 sites represent a wide qualitative range of stream habitats. When compared with the corresponding EPA obtained QHEI values (*Biological and Water Quality Study of the Little Miami River Basin, 1998*), scores only deviated around 5 index units suggesting general consistency in this index's ability to show similar differentiation patterns between sites regardless of the user.

### *Rapid and quantitative sampling methods*

As seen in Table 10, overall comparison of RBA and Hess methods show no significant difference across both time and space (Fig. 6). The rapid method, using the D-net, is able to sample a wider spatial area because there is no boundary to the device. This inherently allows for a greater chance of collecting macroinvertebrates in greater quantity and diversity. The larger sampling area provides a larger window on macroinvertebrate dynamics. The only place the ability to produce the same results breaks down, was at the site with the least optimal substrate for macroinvertebrate habitat. The lack of stable habitat contributed to the relatively low densities seen at this site (Table 6) and the absence of organisms belonging to certain functional feeding groups. This absence of entire functional feeding groups, yielded ecosystem attribute values of zero for a few or all of the six RBA samples collected at this site, which could have skewed t-test results in the favor of significant difference. The payoff for

these rapid bioassessment practices is the reduction in the amount of time and money required to obtain similar results as quantitative sampling (Metzeling et al 2003). RBA protocols have been formed that are even simpler and cruder than the methods used for this study (Barbour et al 1999). These methods utilize field picking of macroinvertebrates without the use of microscopes. Some studies have shown that these methods are even more efficient and cost-effective (Gowns et al 1997). Identification of organisms to higher taxonomic groups allowed for much faster processing of samples (Resh and Jackson 1993). Further testing and refinement of these methods could develop techniques into accurate sampling procedures which could be performed by non-experts with limited experience and training. Metzeling et al (2003) found this to be true in the streams of Australia. Methods like these could allow the stewardship of our nation's waters to be placed in the hands of volunteer programs or school projects. This would foster a sense of duty and responsibility toward the preservation of the earth's natural habitats and also cheaply and efficiently build a large bank of data to be used in both monitoring and restoration projects across the country.

#### *Vannote et al. differences*

One remarkable difference from the river continuum theory, as outlined by Vannote et al (1980), is the value of the P/R ratio. Vannote et al. suggests that headwater streams are strongly influenced by riparian vegetation and canopy cover. Because of their small width, autotrophic production is reduced by

shading and allochthonous input is high. As stream size increases, the importance of allochthonous input decreases and trophic cascade is driven by autochthonous organic leakage from upstream and increased solar input. By this theory, as the river widens the P/R ratio should shift from a heterotrophic system to a predominantly autotrophic system. Vannote et al. suggests that this transition should occur at stream order 3 and from 4-6. All sites assessed in this study were of stream order 4-6 and all sites were categorized as heterotrophic. This is inconsistent with predictions made by Vannote et al., but can be explained by way of a headwaters shift. The model described by Vannote et al. was in reference to natural, pristine stream systems, but he recognizes that not all streams are pristine. The LMR system seems to have undergone what Vannote et al. call a reset, which can be caused by non-natural processes occurring in the terrestrial landscape. The most common of these practices alter the degree of autotrophy to heterotrophy. Anthropogenic practices cause the stream to revert to headwaters or mouth conditions, depending on the position of the impact along the river. In this case the stream never makes the shift from the headwaters classification. This could, in part, be caused by the lack of forested riparian due to clear-cutting or grazing. As seen in Table 7, the percent of forested riparian at the catchment scale only reaches a maximum of 55%. The first three sites are especially lacking in forested riparian. These sites, though classified as stream order 4, are physically close to the headwaters of the entire system. This lack of forested land would significantly reduce the amount of allochthonous organic carbon introduced and would deprive the mid-reach

segments of the organic leakage on which they rely. This lack of transition may also be seen in the depositional properties. With forested area lacking, the remaining area is filled with a higher percentage of agriculture and urban. These land uses, especially agriculture, have been shown to increase sedimentation from runoff and flood events (Lenat and Crawford 1994). Lack of a stable substrate would decrease the amount of algal growth possible in fast flowing environments, thereby reducing the primary producers' ability to thrive and inhibiting the establishment of an autotrophic system.

#### *Non-point source impacts*

In this watershed, agriculture seems to be the cause of the reduced quality seen at some sites. It is the cause of most of the clear cut areas and adds nutrients to the system in the form of fertilizers. Density and richness both increase with the increase of agricultural land use, but the upswing is mostly an increase in the more tolerant taxa. Both EPT and the biotic index decrease in quality as percent agriculture increases. Both of them show the same effect when run against  $\text{NO}_3$  levels in the stream, one of the key ingredients in most fertilizers. Because percent forested land correlates in the exact opposite manner, a well forested riparian buffer can block the effects of human impact.

#### *Point source impacts*

As stated above, all data from Site 7 down was removed before any regressions were run. This site is located directly below the wastewater outfall of the Sugar

Creek Water Reclamation Facility. This site was removed because the sub-riparian zones overlap those of site 7 up and therefore the areas are not entirely independent values. However, there was another significant reason the downstream site was removed and not its upstream counterpart.

Macroinvertebrate indices for Site 7 down showed important variations between the two sites that were not present in the landscape. As seen in Table 6, the lowest EPT and Shannon diversity values and the highest Biotic index values occur at this site. This reflects the general lack of quality found here relative to the other thirteen sites. Even more remarkable is the change in the EPT and Shannon diversity values once they pass the outfall. EPT dropped almost fivefold and Shannon diversity almost threefold over the few hundred feet that separate these two sampling reaches. This dramatic drop in quality is not seen in the landscape. Percent forested land use at the smallest scale tested, 200 m sub-riparian zone, increases only 5 percent, from 53% to 58%. This disparity between index results and land use patterns can be attributed to the resolution of land use data available and the point source nature of the impact. Land use patterns were taken from a grid of 30 x 30 m cells which, though it is the smallest resolution available, is too great for one outfall to affect the cell classification process. The outfall also embodies the characteristics of many point-source impacts. They represent effects from urban development that occur mostly outside the riparian buffer zone and do not show up in correlations run against the riparian scale proposed here. Outfalls travel underground taking a direct route to the river, thus bypassing the ameliorative effects a well forested riparian

zone can provide (O'Laughlin and Belt 1995). The deletion of this site removed any possibility regression analysis would be skewed, which was seen when the majority of correlation coefficients became stronger after this site was removed from the model. While this land use model can act as a sufficient predictor of in-stream conditions and seems to be able to adequately differentiate sites across an entire watershed incorporating non-point source pollution effects, it may not be an accurate indicator of impacts from certain point source pollution events.

### *Restoration effects*

Despite this small drawback in the model, a closer look at the in stream habitat conditions and the riparian land use patterns shows that detrimental effects from point source inputs can be rectified by a well established, forested buffer. As seen in Table 6, after the drop in EPT and Shannon diversity values caused by the WWTP outfall, there is a general increase again as the river flows through more highly forested areas farther downstream. The fact that significant correlations show up in this model, run against samples from a linear river system, upholds O'Laughlin and Belt's (1995) conclusion that forested riparian zones do have ameliorative effects on in-stream conditions. These results can be interpreted in two ways. First, that the strongest correlations are seen at the smallest spatial scale shows that local streamside conditions are a greater predictor of macroinvertebrate indices and therefore have a greater impact on in-stream habitat quality, even in opposition to slightly larger scales. On the other hand, it can be stated that the weaker correlations at the larger scales may



represent the increasing mosaic of land use practices included as the physical scale increases. Obviously, an entirely forested, river-length riparian would be optimal and both of these statements reiterate what is already known about the effects of point source impacts on lotic systems and reinforce the argument that forested riparian zones can have ameliorative effects on in-stream conditions and act as a buffer to terrestrial anthropogenic influence. In the face of today's record breaking rate of human growth, when expansion and transformation of natural habitats is often essential but must be balanced against preservation of resources if we are to thrive, small scale riparian restoration may be satisfactory in maintaining the health of our freshwater systems.

## FUTURE WORK

There are several areas of this study in which further questions could be answered and hypotheses tested. First, as noted above, when comparing the two bioassessment methodologies, the area where there was a breakdown in their ability to return similar results occurred at one of the sites with the lowest habitat quality. As these are the types of sites this data is most useful and can be most influential, further testing should be done in this area. Because the disparity was mostly due to the lack of certain FFG's at this site, repeat sampling should be done at this location and other similar locations. It is possible a greater number of samples would resolve this issue.

There is ample room for development of statistical analyses to clarify relationships between both the various in-stream and terrestrial factors and the physical, chemical, and biological factors. With a dataset of this magnitude and site selection of such variability there are a multitude of possible direct and indirect cause and effect relationships whose presence, magnitude, and relationship to overall habitat quality could be quantified. Multiple multivariate analyses could be run using this data to better describe these relationships.

Along the same line, many other factors could be tested for significance against the various land use spatial scales. More specific tests could be designed to relate individual riparian characteristics to in-stream macroinvertebrate assemblages. Work has also been done in this area to determine which width of

riparian buffer would be most optimal and efficient when applying restoration techniques. This work focused solely on a 30 m riparian buffer regardless of stream width. However, work has been done using buffers of a size relative to stream width and thus increasing the area from upstream to downstream.

This research and its dataset could foster many future projects.

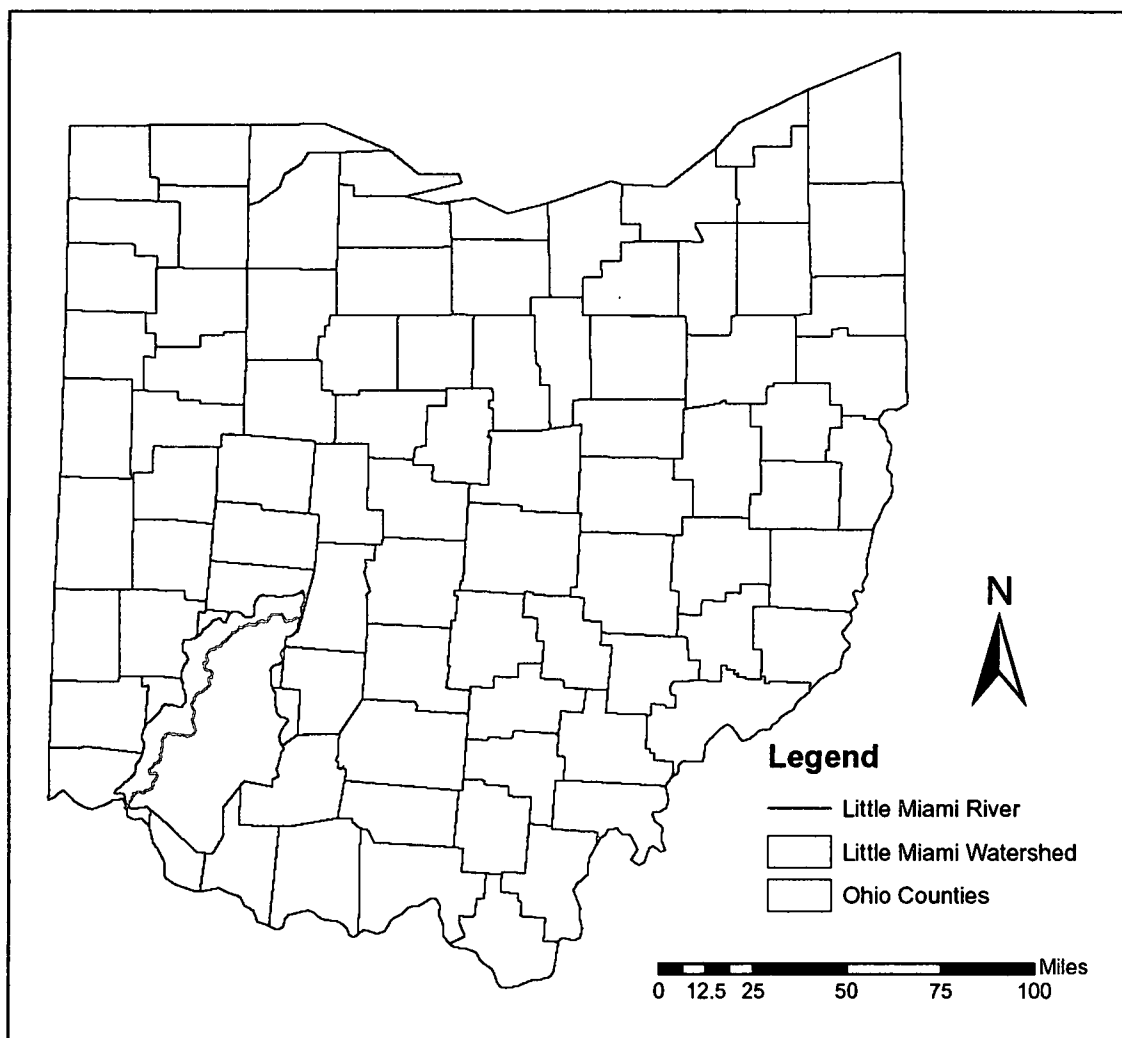


Figure 1: Little Miami River watershed within the context of the state of Ohio.

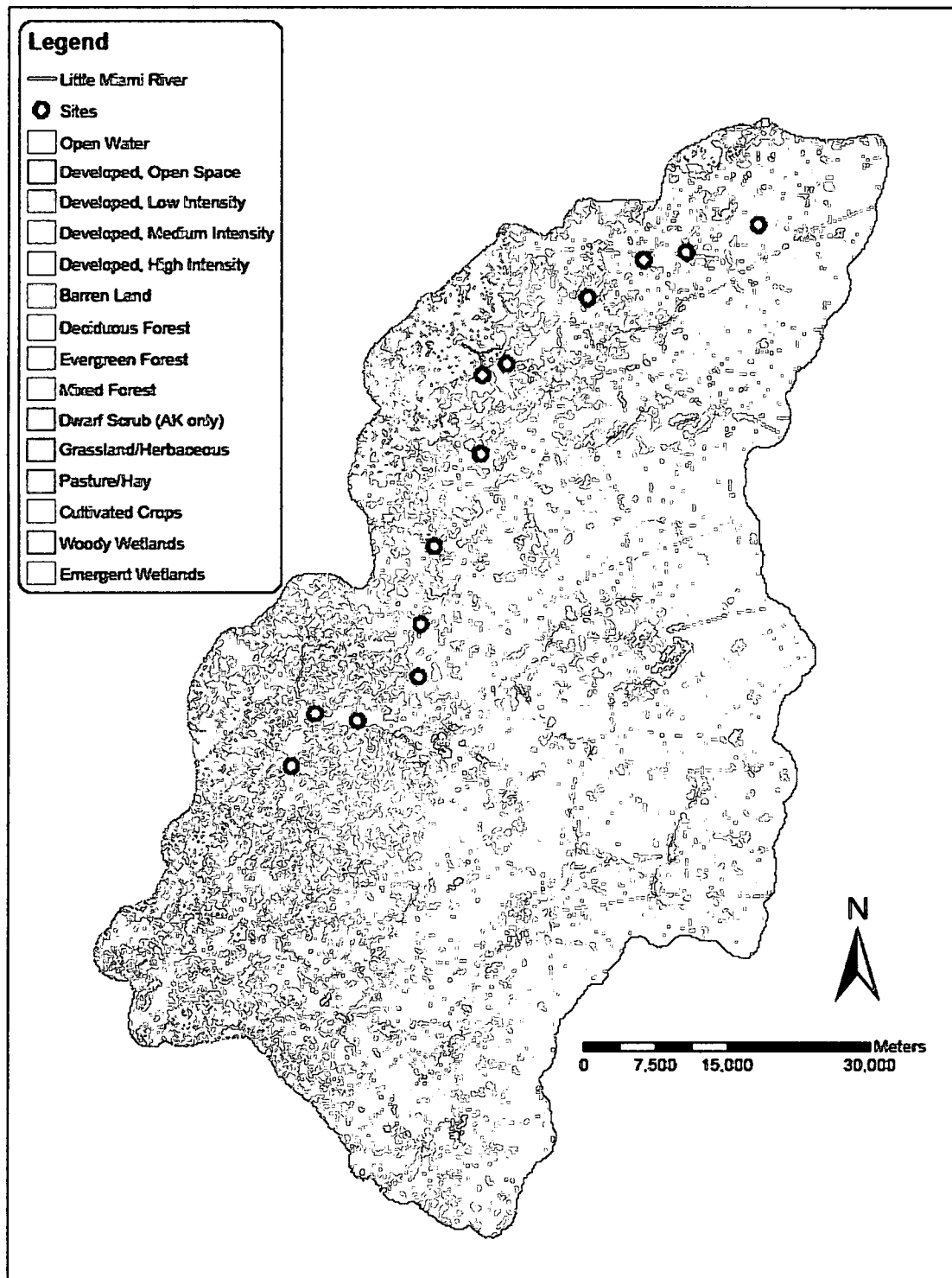


Figure 2: Pattern of land use across the Little Miami River watershed.

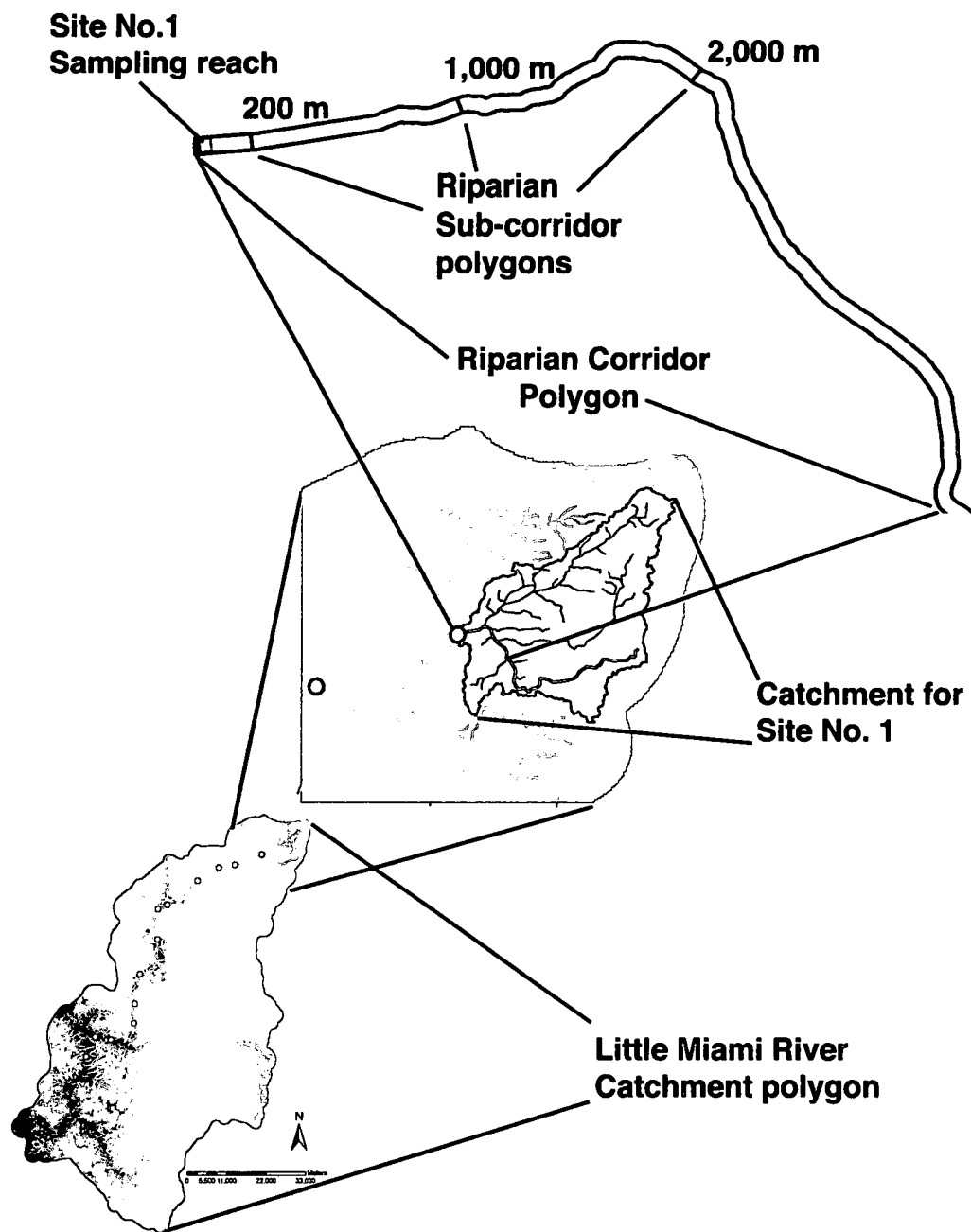


Figure 3: Delineation of five spatial scales used in land use and macroinvertebrate correlations. Figure shows Site 1 as an example.

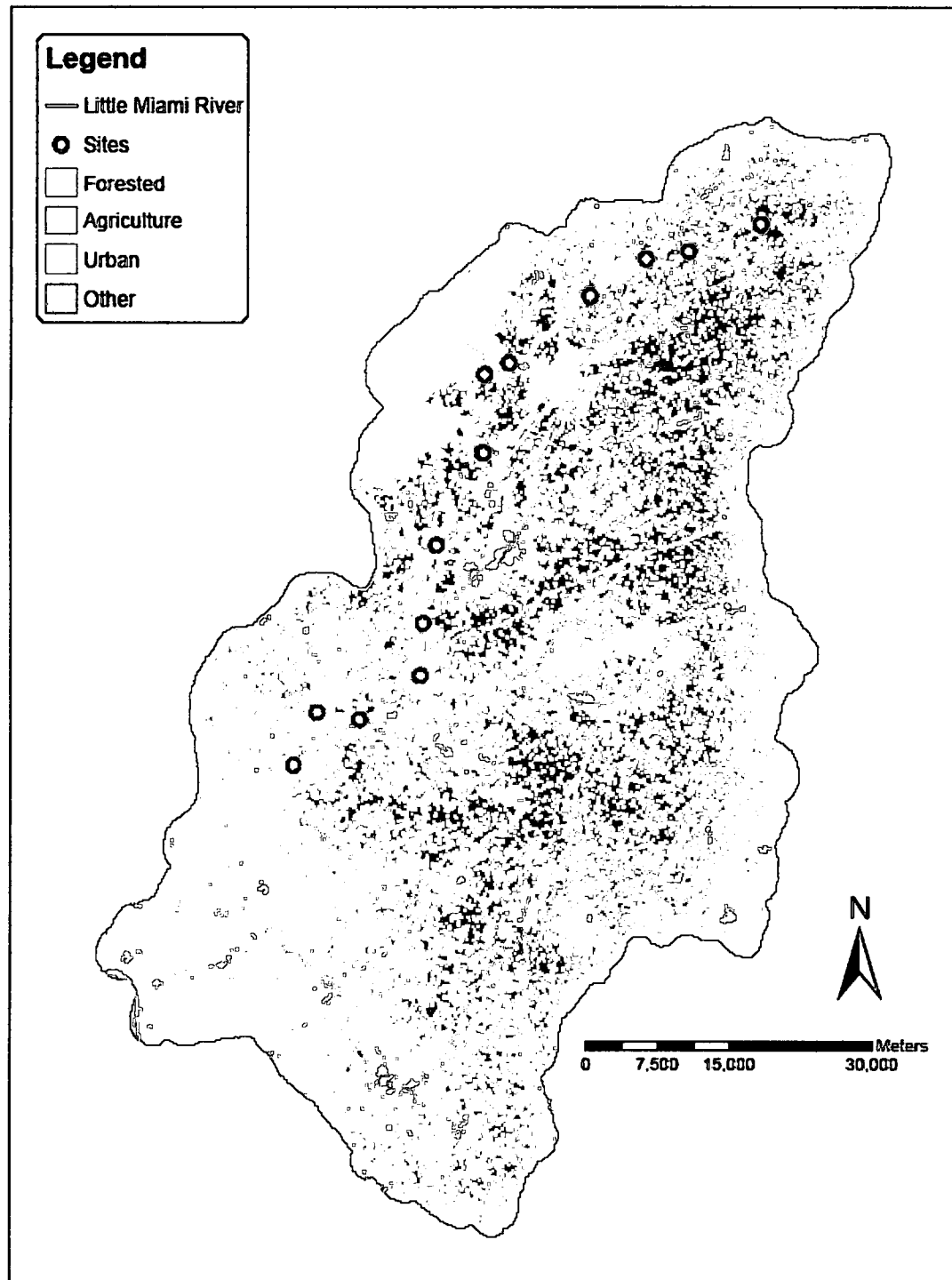


Figure 4: Pattern of land use across the Little Miami River watershed after reclassification into four general categories.

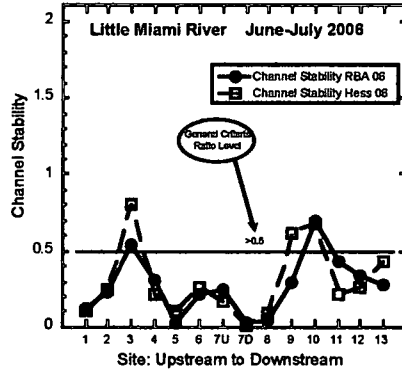
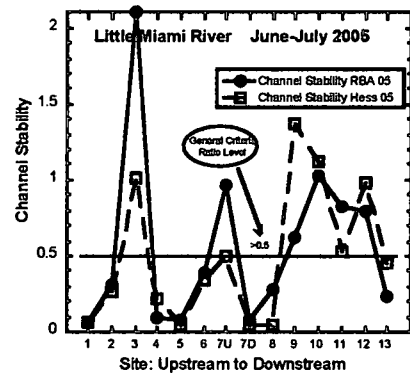
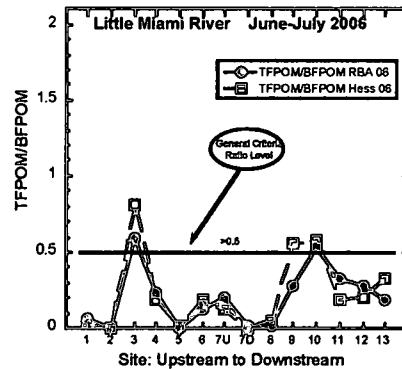
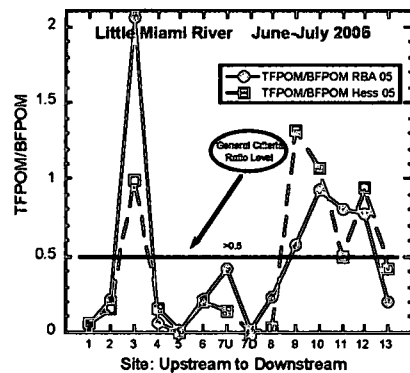
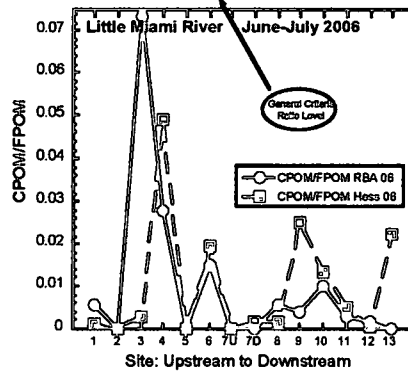
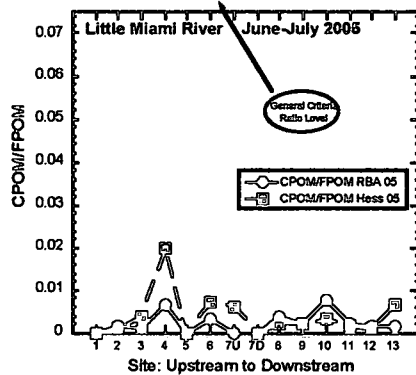
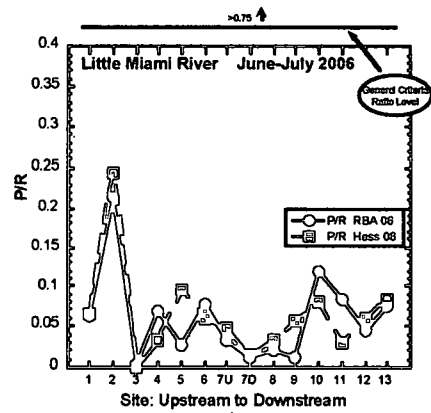
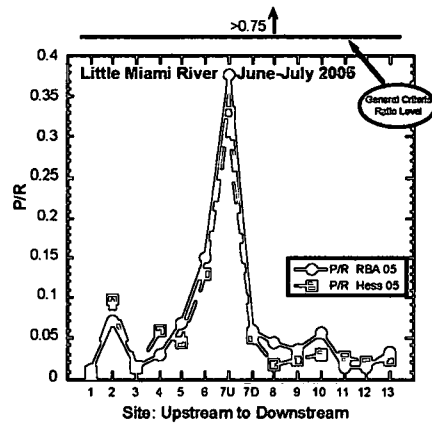




Figure 5: Ecosystem attributes calculated from macroinvertebrate FFG counts for both sampling methods and both sampling years

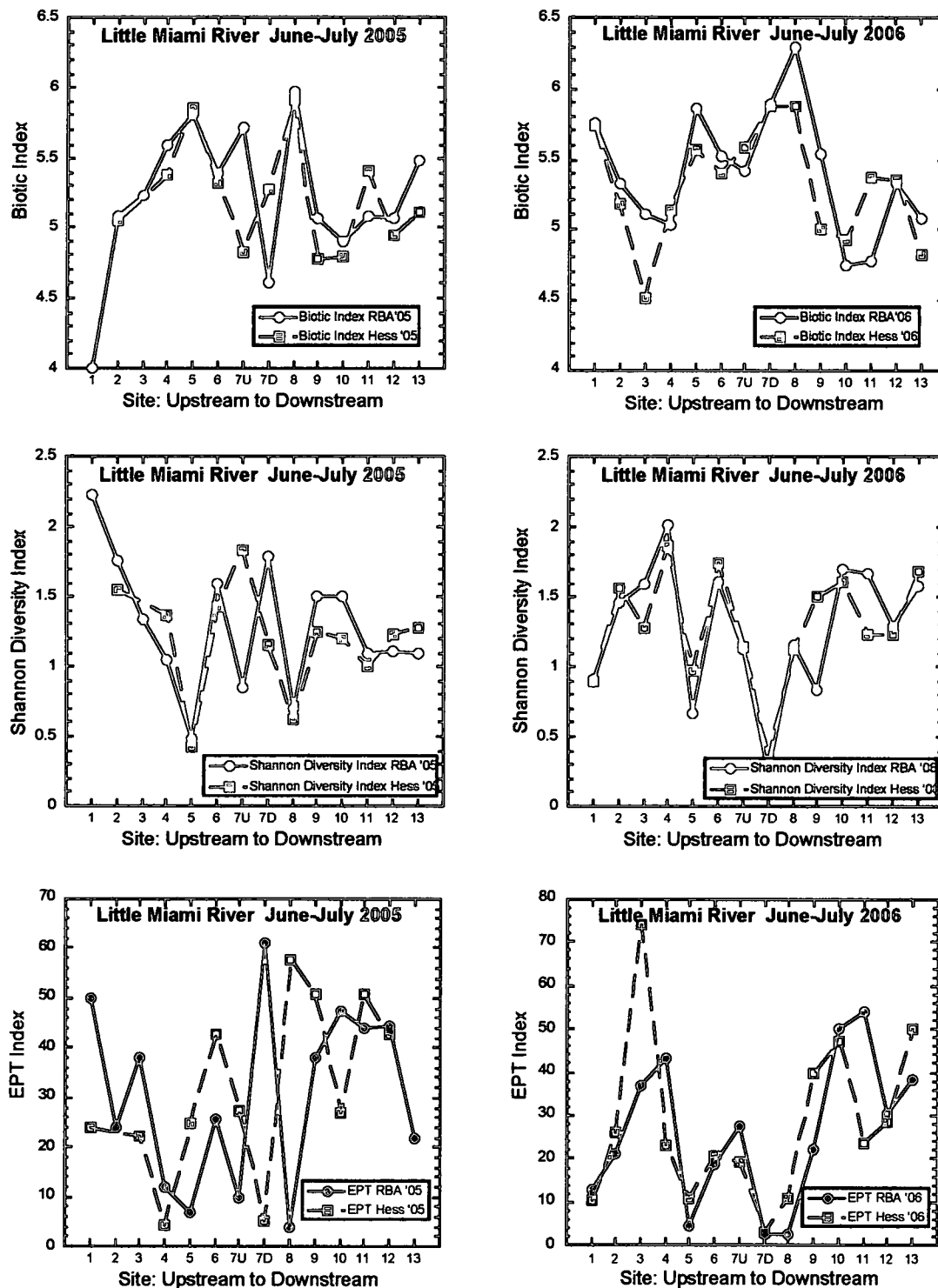


Figure 6: Various diversity indices calculated for both sampling methods and both sampling years

Table 1: Functional group categorization based on food resources (modified from Merritt & Cummins, 1996a). CPOM = Coarse Particulate Organic Matter; FPOM = Fine Particulate Organic Matter

Functional groups	Feeding Mechanisms	Dominant Food Resources	Particle size range of food (mm)
Shredders	Chew conditioned litter or live vascular plant tissue; gouge wood	CPOM - decomposing vascular plants (or living hydrophyte)	> 1.0
Filtering collectors	Suspension feeders - filter particles from the water column	FPOM - decomposing particles of detritus; algae, bacteria, and feces	0.01-1.0
Gathering collectors	Deposit feeders - ingest sediment or gather loose particles in depositional areas	FPOM - decomposing particles of detritus; algae, bacteria, and feces	0.05-1.0
Scrapers	Graze rock and wood surfaces or stems of rooted aquatic plants	Periphyton, attached non-filamentous algae, and associated detritus, microflora and fauna, and feces	0.01-1.0
Predators	Capture and engulf prey or tissue, ingest body fluids	Prey - live animals	> 0.5

Table 2: Functional feeding group ratios as indicators of stream ecosystem attributes. General ratio of ranges given are for numerical or biomass taken when most taxa are in mid- to late larval instars or are in the adult stage (modified from Cummins et. al. 2005)

Ecosystem attributes	Symbols for ecosystem attributes	Functional feeding group ratios for attributes	General criteria ratio levels
Autotrophy to heterotrophy index	P/R	Scrapers : shredders + total collectors	Autotrophic > 0.75
Coarse particulate organic matter to fine particulate organic matter	CPOM/FPOM	Shredders : total collectors	Normal shredder association linked to functioning riparian zone > 0.25
FPOM in transport (suspended) to FPOM storage in sediments (deposited in benthos)	TFPOM/BFPOM	Filtering collectors : gathering collectors	TFPOM greater than normal particulate loading in suspension > 0.05
Substrate (channel) stability	Stable Channel	Scrapers + filtering collectors : shredders + gathering collectors	Stable substrates (e.g., cobbles, boulders, large woody debris, rooted vascular plants) plentiful > 0.05

Table 3: Location of all sites sampled on the Little Miami River

Site Number	Descriptive Location	Latitude	Longitude	River Mile	USGS Quad Map
1	Dolly Varden Rd.	39° 49' 58.68"	83° 41' 39.97"	98.8	S. Charleston
2	Pitchin Rd.	39° 48' 22.95"	83° 46' 54.38"	92.1	Clifton
3	Clifton Gorge	39° 47' 54.66"	83° 50' 05.04"	88	Clifton
4	Jacoby Rd.	39° 45' 50.62"	83° 54' 06.64"	83.1	Yellow Springs
5	US 35	39° 42' 07.95"	83° 59' 57.39"	74.6	Xenia
6	Indian Ripple Rd.	39° 41' 26.77"	84° 01' 43.25"	72.3	Xenia
7 up	OH 725; WWTP	39° 36' 57.48"	84° 01' 47.90"	64.43	Waynesville
7 dwn	OH 725; WWTP	39° 36' 56.67"	84° 01' 44.26"	64.4	Waynesville
8	Oregonia Rd.	39° 31' 44.95"	84° 05' 01.91"	54.3	Waynesville
9	Corwin Ave.	39° 27' 15.09"	84° 05' 52.09"	47.5	Oregonia
10	Morgan's Boat Livery	39° 24' 19.33"	84° 05' 58.95"	43.9	Oregonia
11	Stubbs Mill Rd.	39° 21' 47.09"	84° 10' 22.66"	36	Oregonia
12	OH 48	39° 22' 08.62"	84° 13' 27.40"	32.9	S. Lebanon
13	OH 22 and Old 3C	39° 19' 09.07"	84° 15' 06.41"	28	Mason

Table 4: Chemical ion data collected for each site in 2006.

Site #	P	K	Ca	Mg	S	Al	B	Fe	Mn	Mo	Na	Zn	NO <sub>3</sub>	PO <sub>4</sub>	SO <sub>4</sub>	NH <sub>3</sub>
1	0.05	2.01	84.59	38.44	19.32	0	0.05	0.06	0.01	0.01	12.92	0.01	4.42	0.2	16.82	0.3
2	0.05	1.91	87.06	35.91	18.69	0	0.03	0.09	0.02	0.01	9.21	0.01	3.99	0	16.73	0
3	0.05	0	81.12	33.88	18.01	0	0.03	0.19	0.04	0	9.7	0.02	3	0	16.14	0
4	0.06	2.06	79.53	34.83	16.96	0	0.03	0.09	0.02	0	12.24	0.01	3.27	0	14.89	0
5	0.05	2.24	78.34	33.75	16.26	0	0.04	0.08	0.02	0	16.6	0.01	3.14	0	14.56	0
6	0.14	3.89	77.39	32.42	16.46	0	0.06	0.11	0.03	0	40.67	0.01	4.04	0	14.93	0
7 up	0.11	3.09	80.5	33.53	16.16	0	0.05	0.1	0.02	0	36.25	0.01	3.35	0	14.4	0
7 dwn	0.71	5.59	75.43	32.27	17.49	0	0.1	0.11	0.03	0	62.69	0.02	4.71	0.8	15.38	0
8	0.16	3.15	79.17	32	15.62	0	0.05	0.15	0.04	0	35.55	0.01	3.24	0.17	14.09	0
9	0.13	3.02	72.37	29.39	14.24	0.03	0.04	0.14	0.04	0	29.11	0	3.08	0	12.59	0
10	0.13	3.14	71.46	29.15	14.24	0	0.05	0.14	0.04	0	28.94	0.01	3.02	0	12.56	0
11	0.16	4.19	57.11	21.14	11.69	0.15	0.04	0.31	0.08	0	19.77	0.02	2.55	0	10.51	0
12	0.18	4.59	53.71	18.87	11.24	0.28	0.04	0.41	0.1	0	18.14	0.02	2.57	0	10.11	0
13	0.32	5.94	53.53	17.53	14.04	0.53	0.06	0.5	0.13	0	51.49	0.02	2.32	0.27	12.33	0

Table 5: Physicochemical data collected for all sites in 2006

Site #	pH	DO	Temp (°C)	Cond (µS)	Alkalinity (mg L <sup>-1</sup> )	Acidity (mg L <sup>-1</sup> )	Turbidity	Nitrates	Elevation (ft)	Discharge (m <sup>3</sup> s <sup>-1</sup> )	QHEI	Basin Size (m <sup>3</sup> )
1	8.03	9.5	21.5	695	295	9.6	1.79	1.7	1100	0.629	37.5	79706947
2	8.1	5.6	22.6	688	260	9.2	2.92	0	1010	--	67	133628019
3	8.36	8.41	21.3	600	248	7.6	4.27	0	995	1.888	89	263293582
4	8.28	7.03	21.7	629	242	7	4.42	0.17	988	2.010	86	308557286
5	8.37	2.7	23.9	723	255	6.1	4.91	0.13	785	2.408	57.5	628418355
6	8.2	3.61	19.9	765	218	5.8	11.67	0	775	3.641	73	767547848
7 up	8.3	9.26	20.9	778	238	6.8	10.67	0	749	--	65.75	894677859
7 dwn	8.3	8.96	21.4	800	236	5.8	12	0.1	749	--	--	894698412
8	8.39	10.48	22.3	802	250	6.9	9.42	0	720	1.661	64.5	1025475110
9	8.2	4.4	22.1	758	214	6.2	8.75	0.17	680	5.591	78.25	1727848543
10	--	5.95	22.9	781	247	6	5.83	1.05	658	4.391	80	1749664485
11	6.95	6.02	27.5	717	237	5.4	3.77	0.17	618	6.323	78.5	2485178822
12	--	9.8	23.8	770	239	5.5	4.3	0	608	6.486	76	2637975124
13	8.16	3.89	28	889	240	6	7.03	0	599	--	87	2727523467

Table 6: Percent forested land for each sampling reach at all five spatial scales. Metric values were calculated from the 2006 macroinvertebrate samples. Yellow cells represent lowest site value; green cell represents highest site value.

Site #	1	2	3	4	5	6	7 up	7 down	8	9	10	11	12	13
Catchment	2	4	5	7	8	8	9	9	12	13	14	43	18	15
Catchment Riparian Zone	4	25	25	33	35	37	35	35	39	44	44	55	55	54
Sub-Riparian Zones														
2000 M	0	45	52	34	37	27	41	28	78	69	52	60	41	31
1000 M	0	66	79	40	46	17	46	33	62	62	50	56	12	21
200 M	0	17	83	64	46	0	53	58	29	46	57	45	18	33
Density	43581	4267	3849	5698	4942	12267	10372	8372	15512	13686	11558	18570	10988	5709
Shannon	0.89	1.57	1.27	1.86	0.98	1.74	1.13	0.33	1.12	1.51	1.61	1.23	1.22	1.69
EPT	10.49	25.89	74.02	23.27	11.06	20.85	19.39	3.19	10.72	40.02	46.98	23.86	28.36	50.31
Biotic Index	5.73	5.18	4.51	5.13	5.57	5.41	5.59	5.88	5.87	4.99	4.92	5.38	5.36	4.82
Richness	17	14	6	19	10	18	11	11	15	19	17	21	14	12



Table 7: Percentage of the majority land-use found within each site at all five spatial scales.  
 Sites without a clear majority show the top land-uses for that area. 1 = Forested (green), 2 = Agriculture (yellow), 3 = Urban (red), 4 = Other (blue)

Site #	Catchment	Riparian Zone	2000 M	1000 M	200 M
1	2 - 89%	2 - 90%	2 - 98%	2 - 96%	2 - 83%
2	2 - 87%	2 - 67%	1 - 45%	1 - 66%	2 - 50%
3	2 - 84%	2 - 65%	1 - 52%	1 - 79%	1 - 83%
4	2 - 80%	2 - 49%	4 - 63%	4 - 56%	1 - 64%
5	2 - 79%	2 - 42%	2 - 37%	1 - 46%	4/1 - 54%/46%
6	2 - 68%	1/2 - 37%	4 - 46%	3 - 46%	3 - 100%
7 up	2 - 68%	1/2 - 35%/34%	4 - 53%	4/1 - 50%/46%	1 - 53%
7 down	2 - 63%	1/2 - 35%/33%	4 - 63%	4 - 59%	1 - 58%
8	2 - 63%	1/2 - 39%/31%	1 - 78%	1 - 62%	1/2/3 - 29%
9	2 - 68%	1 - 43%	1 - 69%	1 - 62%	1 - 46%
10	2 - 67%	1 - 44%	1 - 52%	1/4 - 50%/45%	1 - 57%
11	2 - 66%	1 - 55%	1 - 60%	1 - 56%	1 - 45%
12	2 - 65%	1 - 55%	4/1 - 43%/41%	4 - 60%	4 - 71%
13	2 - 53%	1 - 54%	4 - 54%	4 - 61%	3/1 - 39%/33%

Table 8: Correlation coefficients (*r*) for bivariate regressions between macroinvertebrate indices and percent non-forested land use at three spatial scales (*n* = 75, *p* < 0.05). ns = not significant

% forested	Density		H'		EPT		Biotic		Taxa richness	
	<i>r</i>		<i>r</i>		<i>r</i>		<i>r</i>		<i>r</i>	
2000 M Sub-Riparian Zone	ns		ns		ns		ns		ns	
1000 M Sub-Riparian Zone	0.376		ns		0.303		0.265		0.23	
200 M Sub-Riparian Zone	0.395		ns		0.434		0.35		0.323	
% agriculture										
2000 M Sub-Riparian Zone	0.439		ns		ns		ns		ns	
1000 M Sub-Riparian Zone	0.519		0.271		0.278		0.305		0.23	
200 M Sub-Riparian Zone	0.432		ns		0.273		0.293		0.323	
% urban										
2000 M Sub-Riparian Zone	ns		ns		ns		ns		ns	
1000 M Sub-Riparian Zone	ns		ns		ns		ns		ns	
200 M Sub-Riparian Zone	ns		0.383		ns		ns		0.267	

Table 9: Percent organisms found in 2006 Hess sample in each FFG for each site

Site #	PR	SC	SH	GC	FC
1	0.30	6.25	0.11	90.37	2.97
2	1.46	19.30	0.00	78.65	0.58
3	0.30	0.00	0.30	54.98	44.41
4	1.27	3.18	4.45	76.27	14.83
5	0.24	8.56	0.00	90.22	0.98
6	0.00	5.51	1.80	77.84	14.85
7 up	0.12	4.47	0.00	85.19	10.22
7 down	0.00	1.51	0.17	97.66	0.67
8	0.32	3.15	0.16	91.73	4.65
9	0.00	5.27	2.33	59.41	32.99
10	0.00	7.32	1.24	58.25	33.20
11	0.25	2.77	0.50	81.65	14.82
12	0.08	5.51	0.08	78.68	15.64
13	0.00	7.69	2.01	67.93	22.37

Table 10: p-values of t-tests comparing RBA and Hess collection methods. All  $p < 0.05$  blocks are highlighted.

2005	1	2	3	4	5	6	7 up	7 dwn	8	9	10	11	12	13
t-test (RBA:HES)														
P/R	0.819	0.4663	0.332	0.2048	0.2756	0.7212	0.3901	0.774	0.469	0.5319	0.0413*	0.674	0.691	0.428
CPOM/FPOM	--	0.391	0.3739	0.2108	--	0.8357	0.3739	--	0.935	0.7101	0.5348	0.556	0.578	0.369
TFPOM/BFPOM	0.9047	0.8875	0.9996	0.3003	0.6855	0.4022	0.4537	--	0.344	0.2504	0.9718	0.518	0.467	0.756
Channel Stability	0.9252	0.4521	0.8366	0.0509	0.2429	0.2052	0.7166	0.774	0.342	0.199	0.9008	0.542	0.455	0.805

2006	1	2	3	4	5	6	7 up	7 dwn	8	9	10	11	12	13
t-test (RBA:HES)														
P/R	0.9421	0.7249	0.3632	0.3642	0.0037*	0.2007	0.5233	0.383	0.426	0.1202	0.5166	0.339	0.994	0.805
CPOM/FPOM	0.6526	--	0.3085	0.5536	--	0.1542	--	0.374	0.849	0.2732	0.3484	0.358	0.377	0.174
TFPOM/BFPOM	0.1066	0.4723	0.2155	0.6975	0.0176*	0.063	0.4405	0.724	0.389	0.0073*	0.6899	0.483	0.682	0.832
Channel Stability	0.3945	0.7553	0.2083	0.4836	0.0026*	0.3449	0.3882	0.904	0.41	0.0015*	0.6305	0.886	0.646	0.817

## APPENDIX A

## Macroinvertebrate Collection

---

Collection Date: 6.7.05      Collection Type: Qualitative      RM: 98.8

Site Number: 1

---

<i>Baetidae</i>	28	<i>Ryacophilidae</i>	4
<i>Chironomidae</i>	4	<i>Simuliidae</i>	2
<i>Corydalidae</i>	1	<i>Tricorythidae</i>	1
<i>Dytiscidae</i>	2		
<i>Elmidae</i>	29		
<i>Gammaridae</i>	2		
<i>Gerridae</i>	2		
<i>Hydropsychidae</i>	1		
<i>Hydroptilidae</i>	10		
<i>Leptophlebiidae</i>	4		
<i>Naucoridae</i>	6		
<i>Naucoridae</i>	6		
<i>Perlidae</i>	4		
<i>Philopotamidae</i>	1		
<i>Psephenidae</i>	4		
<i>Pyralidae</i>	1		

Total Taxa: 18

Total Organisms: 106

## Macroinvertebrate Collection

---

Collection Date: 6.7.05      Collection Type: Qualitative      RM: 92.1

Site Number: 2

---

<i>Aeshnidae</i>	2	<i>Psephenidae</i>	13
<i>Baetidae</i>	49	<i>Simuliidae</i>	1
<i>Bivalvia</i>	33	<i>Tipulidae</i>	3
<i>Ceratopogonidae</i>	3	<i>Unknown - Caddis</i>	3
<i>Chironomidae</i>	110		
<i>Decapoda</i>	1		
<i>Elmidae</i>	351		
<i>Empididae</i>	5		
<i>Gastropoda</i>	70		
<i>Gomphidae</i>	1		
<i>Helicopsychidae</i>	3		
<i>Heptageniidae</i>	8		
<i>Hydropsychidae</i>	124		
<i>Oligochaeta</i>	2		
<i>Perlidae</i>	5		

Total Taxa: 19

Total Organisms: 787

## Macroinvertebrate Collection

---

Collection Date: 6.7.05      Collection Type: Quantitative      RM: 92.1

Site Number: 2

---

<i>Baetidae</i>	92
<i>Ceratopogonidae</i>	11
<i>Chironomidae</i>	356
<i>Elmidae</i>	427
<i>Empididae</i>	1
<i>Heptageniidae</i>	27
<i>Hydropsychidae</i>	142
<i>Hydroptilidae</i>	2
<i>Odontoceridae</i>	2
<i>Oligochaeta</i>	1
<i>Psephenidae</i>	37
<i>Simuliidae</i>	7
<i>Tipulidae</i>	2
<i>Tricorythidae</i>	1
<i>Unknown - Caddis</i>	1

Total Taxa: 15

Total Organisms: 1109



## Macroinvertebrate Collection

---

Collection Date: 6.22.05      Collection Type: Qualitative      RM: 88

Site Number: 3

---

*Baetidae*                      239

*Chironomidae*              143

*Corydalidae*                1

*Elmidae*                     4

*Hydropsychidae*          57

*Hydroptilidae*            12

*Planaria*                    2

*Simuliidae*                355

*Tipulidae*                  1

Total Taxa:                      9

Total Organisms:              814

## Macroinvertebrate Collection

---

Collection Date: 6.10.05      Collection Type: Qualitative      RM: 83.1

Site Number: 4

---

<i>Baetidae</i>	13
<i>Ceratopogonidae</i>	2
<i>Chironomidae</i>	358
<i>Chloroperlidae</i>	2
<i>Elmidae</i>	64
<i>Heptageniidae</i>	13
<i>Hydropsychidae</i>	22
<i>Potamanthidae</i>	1
<i>Psephenidae</i>	1
<i>Simuliidae</i>	6
<i>Tipulidae</i>	3
<i>Tricorythidae</i>	8

Total Taxa: 12

Total Organisms: 493

## Macroinvertebrate Collection

---

Collection Date: 6.10.05      Collection Type: Quantitative      RM: 83.1

Site Number: 4

---

<i>Baetidae</i>	33	<i>Tipulidae</i>	9
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<i>Caenidae</i>	1	<i>Tricorythidae</i>	5
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<i>Ceratopogonidae</i>	1		
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<i>Chironomidae</i>	375		
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<i>Chloroperlidae</i>	3		
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<i>Crustacean</i>	1		
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<i>Elmidae</i>	58		
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<i>Ephemeridae</i>	1		
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<i>Gammaridae</i>	2		
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<i>Heptageniidae</i>	26		
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<i>Hydracarina</i>	1		
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<i>Hydropsychidae</i>	63		
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<i>Isopoda</i>	2		
----------------	---	--	--

<i>Oligochaeta</i>	1		
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<i>Perlidae</i>	1		
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<i>Simuliidae</i>	11		
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Total Taxa:	18		
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Total Organisms:	594		
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## Macroinvertebrate Collection

---

Collection Date: 6.10.05      Collection Type: Qualitative      RM: 74.6

Site Number: 5

---

<i>Bivalvia</i>	2
<i>Chironomidae</i>	478
<i>Elmidae</i>	9
<i>Gastropoda</i>	2
<i>Helicopsychidae</i>	1
<i>Heptageniidae</i>	34
<i>Hydropsychidae</i>	1
<i>Oligochaeta</i>	3
<i>Simuliidae</i>	1
<i>Tricorythidae</i>	2
<i>Unknown - Predator</i>	1

Total Taxa: 11

Total Organisms: 534

## Macroinvertebrate Collection

---

Collection Date: 6.10.05      Collection Type: Quantitative      RM: 74.6

Site Number: 5

---

<i>Ceratopogonidae</i>	2
<i>Chironomidae</i>	497
<i>Elmidae</i>	11
<i>Empididae</i>	1
<i>Ephydriidae</i>	1
<i>Gastropoda</i>	4
<i>Heptageniidae</i>	22
<i>Hydropsychidae</i>	1
<i>Oligochaeta</i>	5

Total Taxa: 9

Total Organisms: 544

## Macroinvertebrate Collection

---

Collection Date: 6.14.05      Collection Type: Qualitative      RM: 72.3

Site Number: 6

---

<i>Asellidae</i>	1
<i>Baetidae</i>	14
<i>Bivalvia</i>	2
<i>Ceratopogonidae</i>	8
<i>Chironomidae</i>	625
<i>Elmidae</i>	151
<i>Gastropoda</i>	87
<i>Heptageniidae</i>	117
<i>Hydropsychidae</i>	167
<i>Hydroptilidae</i>	9
<i>Isopoda</i>	21
<i>Oligochaeta</i>	12
<i>Philopotamidae</i>	2
<i>Simuliidae</i>	4
<i>Tipulidae</i>	3
<i>Tricorythidae</i>	4

Total Taxa: 16

Total Organisms: 1227

## Macroinvertebrate Collection

---

Collection Date: 6.14.05      Collection Type: Quantitative      RM: 72.3

Site Number: 6

---

<i>Baetidae</i>	16	<i>Tipulidae</i>	13
<i>Ceratopogonidae</i>	1	<i>Tricorythidae</i>	3
<i>Chironomidae</i>	1159		
<i>Decapoda</i>	2		
<i>Elmidae</i>	306		
<i>Ephemeridae</i>	1		
<i>Gammaridae</i>	1		
<i>Gastropoda</i>	51		
<i>Heptageniidae</i>	174		
<i>Hydropsychidae</i>	281		
<i>Hydroptilidae</i>	36		
<i>Isopoda</i>	2		
<i>Oligochaeta</i>	15		
<i>Polycentropodidae</i>	2		
<i>Sialidae</i>	4		
<i>Simuliidae</i>	5		

Total Taxa: 18

Total Organisms: 2072

## Macroinvertebrate Collection

---

Collection Date: 7.26.05      Collection Type: Qualitative      RM: 64.43

Site Number: 7 up

---

<i>Baetidae</i>	1
<i>Chironomidae</i>	77
<i>Elmidae</i>	2
<i>Gammaridae</i>	3
<i>Heptageniidae</i>	2
<i>Hydracarina</i>	1
<i>Hydropsychidae</i>	1
<i>Hydroptilidae</i>	2
<i>Isopoda</i>	1
<i>Leptophlebiidae</i>	1
<i>Ryacophilidae</i>	1
<i>Tricorythidae</i>	1

Total Taxa: 12

Total Organisms: 93



## Macroinvertebrate Collection

---

Collection Date: 7.26.05      Collection Type: Quantitative      RM: 64.43

Site Number: 7 up

---

<i>Baetidae</i>	5
<i>Capniidae</i>	1
<i>Ceratopogonidae</i>	2
<i>Chironomidae</i>	82
<i>Elmidae</i>	7
<i>Ephemeridae</i>	6
<i>Heptageniidae</i>	46
<i>Hydracarina</i>	18
<i>Hydropsychidae</i>	17
<i>Hydroptilidae</i>	5
<i>Naucoridae</i>	1
<i>Perlidae</i>	1
<i>Polymitarcyidae</i>	3
<i>Sialidae</i>	1
<i>Tipulidae</i>	2
<i>Tricorythidae</i>	1

Total Taxa: 16

Total Organisms: 198

## Macroinvertebrate Collection

---

Collection Date: 7.26.05      Collection Type: Qualitative      RM: 64.4

Site Number: 7 down

---

<i>Baetidae</i>	23
<i>Caenidae</i>	1
<i>Chironomidae</i>	64
<i>Elmidae</i>	19
<i>Heptageniidae</i>	54
<i>Hydracarina</i>	4
<i>Hydropsychidae</i>	48
<i>Polymitarcyidae</i>	7
<i>Sciomyzidae</i>	1
<i>Tricorythidae</i>	6

Total Taxa: 10

Total Organisms: 227

## Macroinvertebrate Collection

Collection Date:	7.26.05	Collection Type:	Quantitative	RM:	64.4
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**Site Number:** 7 down

**Baetidae** 1

**Chironomidae** 7

*Heptageniidae* 1

Hydracarina 1

*Hydroptilidae* 1

**Total Taxa: 5**

**Total Organisms: 11**

## Macroinvertebrate Collection

---

Collection Date: 6.17.05      Collection Type: Qualitative      RM: 54.3

Site Number: 8

---

<i>Baetidae</i>	16
<i>Bivalvia</i>	77
<i>Chironomidae</i>	911
<i>Elmidae</i>	21
<i>Gastropoda</i>	15
<i>Heptageniidae</i>	8
<i>Hydropsychidae</i>	17
<i>Hydroptilidae</i>	1
<i>Isopoda</i>	7
<i>Oligochaeta</i>	5
<i>Tipulidae</i>	1

Total Taxa: 11

Total Organisms: 1079

## Macroinvertebrate Collection

---

Collection Date: 6.17.05      Collection Type: Quantitative      RM: 54.3

Site Number: 8

---

<i>Baetidae</i>	13
<i>Bivalvia</i>	34
<i>Chironomidae</i>	960
<i>Elmidae</i>	17
<i>Gastropoda</i>	5
<i>Heptageniidae</i>	13
<i>Hydropsychidae</i>	23
<i>Hydroptilidae</i>	1
<i>Isopoda</i>	11
<i>Oligochaeta</i>	4
<i>Tipulidae</i>	2
<i>Tricorythidae</i>	8

Total Taxa: 12

Total Organisms: 1091

## Macroinvertebrate Collection

Collection Date:	6.21.05	Collection Type: Qualitative	RM: 47.5
Site Number:	9		
<i>Baetidae</i>	11	<i>Oligochaeta</i>	16
<i>Bivalvia</i>	7	<i>Perlidae</i>	4
<i>Chironomidae</i>	672	<i>Polycentropodidae</i>	2
<i>Coenagrionidae</i>	1	<i>Polymitarcyidae</i>	3
<i>Collembola</i>	1	<i>Psephenidae</i>	2
<i>Dixidae</i>	1	<i>Simuliidae</i>	9
<i>Elmidae</i>	233	<i>Tipulidae</i>	3
<i>Ephemeridae</i>	5	<i>Tricorythidae</i>	28
<i>Ephydriidae</i>	5	<i>Unknown Caddis</i>	3
<i>Fish</i>	1	<i>Veliidae</i>	1
<i>Gastropoda</i>	1		
<i>Heptageniidae</i>	3		
<i>Hydropsychidae</i>	542		
<i>Hydroptilidae</i>	14		
<i>Isopoda</i>	46		
<i>Philopotamidae</i>	2		
Total Taxa:	26		
Total Organisms:	1616		

## Macroinvertebrate Collection

---

Collection Date: 6.21.05      Collection Type: Quantitative      RM: 47.5

Site Number: 9

---

<i>Baetidae</i>	9	<i>Psephenidae</i>	5
<i>Bivalvia</i>	10	<i>Psychomyiidae</i>	3
<i>Chironomidae</i>	812	<i>Saldidae</i>	1
<i>Decapoda</i>	1	<i>Simuliidae</i>	15
<i>Elmidae</i>	149	<i>Tipulidae</i>	5
<i>Hebridae</i>	1	<i>Tricorythidae</i>	26
<i>Heptageniidae</i>	13	<i>Unknown Caddis</i>	2
<i>Hydropsychidae</i>	1350	<i>Zygoptera</i>	2
<i>Hydroptilidae</i>	18		
<i>Isopoda</i>	51		
<i>Oligochaeta</i>	12		
<i>Perlidae</i>	1		
<i>Philopotamidae</i>	1		
<i>Planaria</i>	2		
<i>Polycentropodidae</i>	2		
<i>Polymitarcyidae</i>	5		

Total Taxa: 24

Total Organisms: 2496

## Macroinvertebrate Collection

---

Collection Date: 6.17.05      Collection Type: Qualitative      RM: 43.9

Site Number: 10

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<i>Baetidae</i>	15	<i>Psephenidae</i>	2
<i>Baetiscidae</i>	1	<i>Simuliidae</i>	14
<i>Bivalvia</i>	5	<i>Tipulidae</i>	17
<i>Chironomidae</i>	890	<i>Tricorythidae</i>	7
<i>Elmidae</i>	196		
<i>Ephemeridae</i>	19		
<i>Gastropoda</i>	75		
<i>Heptageniidae</i>	2		
<i>Hydropsychidae</i>	967		
<i>Hydroptilidae</i>	34		
<i>Isopoda</i>	5		
<i>Oligochaeta</i>	36		
<i>Perlidae</i>	2		
<i>Philopotamidae</i>	38		
<i>Polycentropodidae</i>	34		
<i>Polymitarcyidae</i>	1		

Total Taxa: 20

Total Organisms: 2360



## Macroinvertebrate Collection

---

Collection Date: 6.17.05      Collection Type: Quantitative      RM: 43.9

Site Number: 10

---

<i>Asellidae</i>	1	<i>Psephenidae</i>	1
<i>Baetidae</i>	10	<i>Simuliidae</i>	3
<i>Bivalvia</i>	3	<i>Tipulidae</i>	13
<i>Chironomidae</i>	1073	<i>Tricorythidae</i>	17
<i>Elmidae</i>	131		
<i>Ephemeridae</i>	11		
<i>Gastropoda</i>	22		
<i>Heptageniidae</i>	2		
<i>Hydropsychidae</i>	1302		
<i>Hydroptilidae</i>	19		
<i>Isopoda</i>	10		
<i>Oligochaeta</i>	62		
<i>Perlidae</i>	4		
<i>Philopotamidae</i>	2		
<i>Polycentropodidae</i>	3		
<i>Polymitarcyidae</i>	3		

Total Taxa: 20

Total Organisms: 2692

## Macroinvertebrate Collection

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Collection Date: 6.17.05      Collection Type: Qualitative      RM: 36

Site Number: 11

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<i>Baetidae</i>	11	<i>Tricorythidae</i>	13
<i>Chironomidae</i>	1114	<i>Unknown Caddis</i>	3
<i>Elmidae</i>	68		
<i>Ephemeridae</i>	2		
<i>Ephydriidae</i>	4		
<i>Gastropoda</i>	3		
<i>Heptageniidae</i>	15		
<i>Hydropsychidae</i>	898		
<i>Hydroptilidae</i>	5		
<i>Libellulidae</i>	1		
<i>Perlidae</i>	2		
<i>Philopotamidae</i>	8		
<i>Polycentropodidae</i>	5		
<i>Psephenidae</i>	3		
<i>Simuliidae</i>	34		
<i>Tipulidae</i>	4		

Total Taxa: 18

Total Organisms: 2193

## Macroinvertebrate Collection

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Collection Date: 6.17.05      Collection Type: Quantitative      RM: 36

Site Number: 11

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<i>Baetidae</i>	12	<i>Tricorythidae</i>	29
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<i>Chironomidae</i>	1472
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<i>Elmidae</i>	80
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<i>Ephemeridae</i>	6
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<i>Ephydriidae</i>	6
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<i>Gastropoda</i>	2
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<i>Heptageniidae</i>	13
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<i>Hydracarina</i>	1
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<i>Hydropsychidae</i>	496
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<i>Hydroptilidae</i>	14
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<i>Perlidae</i>	1
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<i>Philopotamidae</i>	3
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<i>Psephenidae</i>	2
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<i>Psychomyiidae</i>	9
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<i>Simuliidae</i>	20
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<i>Tipulidae</i>	3
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Total Taxa:	17
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Total Organisms:	2169
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## Macroinvertebrate Collection

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Collection Date: 6.28.05      Collection Type: Qualitative      RM: 32.9

Site Number: 12

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<i>Baetidae</i>	81	<i>Tricorythidae</i>	3
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<i>Chironomidae</i>	1298
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<i>Coenagriidae</i>	1
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<i>Elmidae</i>	104
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<i>Ephemeridae</i>	1
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<i>Gastropoda</i>	3
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<i>Glossosomatidae</i>	1
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<i>Heptageniidae</i>	2
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<i>Hydropsychidae</i>	1072
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<i>Hydroptilidae</i>	12
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<i>Isopoda</i>	1
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<i>Philopotamidae</i>	6
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<i>Psephenidae</i>	1
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<i>Pyralidae</i>	2
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<i>Simuliidae</i>	54
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<i>Tipulidae</i>	2
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Total Taxa:	17
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Total Organisms:	2644
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## Macroinvertebrate Collection

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Collection Date: 6.28.05      Collection Type: Quantitative      RM: 32.9

Site Number: 12

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<i>Baetidae</i>	93	<i>Psychomyiidae</i>	1
<i>Bivalvia</i>	1	<i>Pyralidae</i>	2
<i>Ceratopogonidae</i>	1	<i>Simuliidae</i>	46
<i>Chironomidae</i>	837		
<i>Elmidae</i>	102		
<i>Ephemeridae</i>	5		
<i>Gastropoda</i>	12		
<i>Heptageniidae</i>	5		
<i>Hydropsychidae</i>	914		
<i>Hydroptilidae</i>	6		
<i>Isopoda</i>	1		
<i>Muscidae</i>	1		
<i>Oligochaeta</i>	1		
<i>Philopotamidae</i>	5		
<i>Polycentropodidae</i>	1		
<i>Psephenidae</i>	1		

Total Taxa: 19

Total Organisms: 2035

## Macroinvertebrate Collection

---

Collection Date: 6.28.05      Collection Type: Qualitative      RM: 28

Site Number: 13

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<i>Baetidae</i>	98
<i>Chironomidae</i>	1332
<i>Elmidae</i>	141
<i>Heptageniidae</i>	1
<i>Hydracarina</i>	1
<i>Hydropsychidae</i>	276
<i>Hydroptilidae</i>	37
<i>Polycentropodidae</i>	1
<i>Psephenidae</i>	2
<i>Pyalidae</i>	1
<i>Simuliidae</i>	38
<i>Tipulidae</i>	2
<i>Tricorythidae</i>	12

Total Taxa: 13

Total Organisms: 1942

## Macroinvertebrate Collection

---

Collection Date: 6.28.05      Collection Type: Quantitative      RM: 28

Site Number: 13

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<i>Baetidae</i>	227
<i>Baetiscidae</i>	12
<i>Chironomidae</i>	1041
<i>Elmidae</i>	59
<i>Heptageniidae</i>	3
<i>Hydropsychidae</i>	560
<i>Hydroptilidae</i>	23
<i>Pyralidae</i>	5
<i>Philopotamidae</i>	2
<i>Psephenidae</i>	1
<i>Pyralidae</i>	3
<i>Simuliidae</i>	24
<i>Tipulidae</i>	3
<i>Tricorythidae</i>	15

Total Taxa: 14

Total Organisms: 1978

## Macroinvertebrate Collection

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Collection Date: 6.19.06      Collection Type: Qualitative      RM: 98.8

Site Number: 1

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<i>Baetidae</i>	37
<i>Ceratopogonidae</i>	1
<i>Chironomidae</i>	1308
<i>Elmidae</i>	59
<i>Gastropoda</i>	53
<i>Glossosomatidae</i>	1
<i>Haliplidae</i>	8
<i>Hirudinea</i>	3
<i>Hydropsychidae</i>	81
<i>Hydroptilidae</i>	71
<i>Oligochaeta</i>	1
<i>Polycentropodidae</i>	1
<i>Simuliidae</i>	10
<i>Tricorythidae</i>	18

Total Taxa: 14

Total Organisms: 1652



## Macroinvertebrate Collection

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Collection Date: 6.19.06      Collection Type: Quantitative      RM: 98.9

Site Number: 1

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<i>Baetidae</i>	58	<i>Tricorythidae</i>	70
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<i>Bivalvia</i>	1		
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<i>Caenidae</i>	2		
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<i>Ceratopogonidae</i>	10		
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<i>Chironomidae</i>	2998		
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<i>Corydalidae</i>	1		
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<i>Elmidae</i>	216		
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<i>Gastropoda</i>	65		
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<i>Haliplidae</i>	4		
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<i>Hirudinea</i>	1		
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<i>Hydropsychidae</i>	68		
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<i>Hydroptilidae</i>	195		
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<i>Oligochaeta</i>	9		
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<i>Planaria</i>	7		
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<i>Psephenidae</i>	2		
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<i>Simuliidae</i>	41		
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Total Taxa:	17		
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Total Organisms:	3748		
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## Macroinvertebrate Collection

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Collection Date: 6.20.06      Collection Type: Qualitative      RM: 92.1

Site Number: 2

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<i>Baetidae</i>	30
<i>Bivalvia</i>	2
<i>Chironomidae</i>	172
<i>Corydalidae</i>	1
<i>Elmidae</i>	56
<i>Empididae</i>	1
<i>Gastropoda</i>	8
<i>Gomphidae</i>	1
<i>Heptageniidae</i>	28
<i>Hydropsychidae</i>	2
<i>Oligochaeta</i>	2
<i>Psephenidae</i>	5
<i>Tricorythidae</i>	6

Total Taxa: 13

Total Organisms: 314

## Macroinvertebrate Collection

---

Collection Date: 6.20.06      Collection Type: Quantitative      RM: 92.1

Site Number: 2

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<i>Baetidae</i>	39
<i>Chironomidae</i>	181
<i>Corydalidae</i>	3
<i>Elmidae</i>	71
<i>Gastropoda</i>	10
<i>Gomphidae</i>	1
<i>Hemiptera</i>	1
<i>Heptageniidae</i>	30
<i>Hydropsychidae</i>	2
<i>Isopoda</i>	1
<i>Oligochaeta</i>	3
<i>Perlidae</i>	1
<i>Psephenidae</i>	1
<i>Tricorythidae</i>	23

Total Taxa: 14

Total Organisms: 367

## Macroinvertebrate Collection

---

Collection Date: 6.23.06      Collection Type: Qualitative      RM: 88

Site Number: 3

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<i>Baetidae</i>	74
<i>Chironomidae</i>	111
<i>Elmidae</i>	4
<i>Empididae</i>	3
<i>Hydropsychidae</i>	46
<i>Oligochaeta</i>	1
<i>Simuliidae</i>	66
<i>Tipuliidae</i>	22

Total Taxa: 8

Total Organisms: 327

## Macroinvertebrate Collection

---

Collection Date: 6.23.06      Collection Type: Quantitative      RM: 88

Site Number: 3

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*Baetidae*                      149

*Chironomidae*                33

*Empididae*                    1

*Hydropsychidae*            96

*Simuliidae*                   51

*Tipulidae*                    1

Total Taxa:                    6

Total Organisms:            331

## Macroinvertebrate Collection

---

Collection Date: 6.23.06      Collection Type: Qualitative      RM: 83.1

Site Number: 4

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<i>Baetidae</i>	15	<i>Tipulidae</i>	8
<i>Bivalvia</i>	4	<i>Tricorythidae</i>	55
<i>Ceratopogonidae</i>	1		
<i>Chironomidae</i>	86		
<i>Corydalidae</i>	3		
<i>Decapoda</i>	2		
<i>Elmidae</i>	80		
<i>Ephemeridae</i>	1		
<i>Fish</i>	1		
<i>Gastropoda</i>	16		
<i>Heptageniidae</i>	16		
<i>Hydropsychidae</i>	55		
<i>Hydroptilidae</i>	1		
<i>Oligochaeta</i>	2		
<i>Perlidae</i>	1		
<i>Psephenidae</i>	1		

Total Taxa: 18

Total Organisms: 333

## Macroinvertebrate Collection

---

Collection Date: 6.23.06      Collection Type: Quantitative      RM: 83.1

Site Number: 4

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<i>Baetidae</i>	20	<i>Simuliidae</i>	2
<i>Bivalvia</i>	4	<i>Tipulidae</i>	21
<i>Caenidae</i>	23	<i>Tricorythidae</i>	13
<i>Ceratopogonidae</i>	3		
<i>Chironomidae</i>	186		
<i>Corydalidae</i>	2		
<i>Decapoda</i>	1		
<i>Elmidae</i>	122		
<i>Ephemeridae</i>	4		
<i>Gastropoda</i>	7		
<i>Glossosomatidae</i>	2		
<i>Heptageniidae</i>	5		
<i>Hydropsychidae</i>	68		
<i>Hydroptilidae</i>	1		
<i>Oligochaeta</i>	5		
<i>Perlidae</i>	1		

Total Taxa: 19

Total Organisms: 490

## Macroinvertebrate Collection

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Collection Date: 6.23.06      Collection Type: Qualitative      RM: 74.6

Site Number: 5

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<i>Bivalvia</i>	6
<i>Chironomidae</i>	255
<i>Elmidae</i>	28
<i>Gastropoda</i>	1
<i>Heptageniidae</i>	7
<i>Isopoda</i>	2
<i>Tricorythidae</i>	7

Total Taxa: 7

Total Organisms: 306



## Macroinvertebrate Collection

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Collection Date: 6.23.06      Collection Type: Quantitative      RM: 74.6

Site Number: 5

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<i>Bivalvia</i>	7
<i>Caenidae</i>	1
<i>Chironomidae</i>	314
<i>Corydalidae</i>	1
<i>Elmidae</i>	46
<i>Heptageniidae</i>	35
<i>Hydropsychidae</i>	4
<i>Gastropoda</i>	2
<i>Tricorythidae</i>	7
<i>Oligochaeta</i>	8

Total Taxa: 10

Total Organisms: 425

## Macroinvertebrate Collection

---

Collection Date: 6.27.06      Collection Type: Qualitative      RM: 72.3

Site Number: 6

---

<i>Baetidae</i>	17
<i>Bivalvia</i>	2
<i>Caenidae</i>	1
<i>Chironomidae</i>	238
<i>Corydalidae</i>	1
<i>Elmidae</i>	93
<i>Heptageniidae</i>	24
<i>Hydropsychidae</i>	45
<i>Isopoda</i>	1
<i>Gastropoda</i>	70
<i>Tipulidae</i>	6
<i>Tricorythidae</i>	7
<i>Veliidae</i>	1
<i>Oligochaeta</i>	2

Total Taxa: 14

Total Organisms: 508

## Macroinvertebrate Collection

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Collection Date: 6.27.06      Collection Type: Quantitative      RM: 72.3

Site Number: 6

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<i>Baetidae</i>	8	<i>Tipulidae</i>	16
<i>Bivalvia</i>	7	<i>Tricorythidae</i>	12
<i>Caenidae</i>	2		
<i>Chironomidae</i>	433		
<i>Decapoda</i>	1		
<i>Elmidae</i>	218		
<i>Ephemeridae</i>	29		
<i>Gastropoda</i>	142		
<i>Heptageniidae</i>	34		
<i>Hydropsychidae</i>	131		
<i>Hydroptilidae</i>	4		
<i>Isopoda</i>	2		
<i>Isopoda</i>	1		
<i>Oligochaeta</i>	13		
<i>Psephenidae</i>	1		
<i>Simuliidae</i>	1		

Total Taxa: 18

Total Organisms: 1055

## Macroinvertebrate Collection

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Collection Date: 6.27.06      Collection Type: Qualitative      RM: 64.43

Site Number: 7 up

---

<i>Baetidae</i>	103	<i>Psephenidae</i>	1
<i>Bivalvia</i>	4	<i>Simuliidae</i>	2
<i>Chironomidae</i>	778	<i>Tricorythidae</i>	6
<i>Corixidae</i>	1		
<i>Decapoda</i>	1		
<i>Elmidae</i>	36		
<i>Empididae</i>	1		
<i>Fish</i>	1		
<i>Gammaridae</i>	1		
<i>Gastropoda</i>	3		
<i>Glossosomatidae</i>	1		
<i>Heptageniidae</i>	21		
<i>Hydropsychidae</i>	180		
<i>Isopoda</i>	1		
<i>Oligochaeta</i>	8		
<i>Polycentropodidae</i>	3		

Total Taxa: 19

Total Organisms: 1144

## Macroinvertebrate Collection

---

Collection Date: 6.27.06      Collection Type: Quantitative      RM: 64.43

Site Number: 7 up

---

<i>Baetidae</i>	47
<i>Bivalvia</i>	3
<i>Chironomidae</i>	627
<i>Elmidae</i>	50
<i>Gastropoda</i>	27
<i>Heptageniidae</i>	36
<i>Hydracarina</i>	1
<i>Hydropsychidae</i>	87
<i>Isopoda</i>	8
<i>Oligochaeta</i>	3
<i>Tricorythidae</i>	3

Total Taxa: 11

Total Organisms: 892

## Macroinvertebrate Collection

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Collection Date: 6.27.06      Collection Type: Qualitative      RM: 64.4

Site Number: 7 down

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*Chironomidae*                      240

*Elmidae*                              2

*Heptageniidae*                      3

*Hydracarina*                      1

*Hydropsychidae*                      3

*Oligochaeta*                      2

Total Taxa:                      6

Total Organisms:                      251

## Macroinvertebrate Collection

---

Collection Date: 6.27.06      Collection Type: Quantitative      RM: 64.4

Site Number: 7 down

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<i>Baetidae</i>	2
<i>Chironomidae</i>	679
<i>Elmidae</i>	8
<i>Haliplidae</i>	1
<i>Heptageniidae</i>	9
<i>Hydropsychidae</i>	9
<i>Isopoda</i>	1
<i>Oligochaeta</i>	5
<i>Planaria</i>	1
<i>Tipulidae</i>	2
<i>Tricorythidae</i>	3

Total Taxa: 11

Total Organisms: 720

## Macroinvertebrate Collection

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Collection Date: 6.29.06      Collection Type: Qualitative      RM: 54.3

Site Number: 8

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<i>Baetidae</i>	3
<i>Bivalvia</i>	326
<i>Caenidae</i>	1
<i>Chironomidae</i>	343
<i>Elmidae</i>	17
<i>Gastropoda</i>	25
<i>Heptageniidae</i>	7
<i>Hydropsychidae</i>	6
<i>Isopoda</i>	1
<i>Oligochaeta</i>	10
<i>Planaria</i>	1
<i>Tipulidae</i>	4
<i>Tricorythidae</i>	3

Total Taxa: 13

Total Organisms: 747



## Macroinvertebrate Collection

---

Collection Date: 6.29.06      Collection Type: Quantitative      RM: 54.3

Site Number: 8

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<i>Baetidae</i>	30
<i>Bivalvia</i>	176
<i>Chironomidae</i>	946
<i>Decapoda</i>	1
<i>Elmidae</i>	36
<i>Empididae</i>	3
<i>Gastropoda</i>	16
<i>Heptageniidae</i>	36
<i>Hydracarina</i>	1
<i>Hydropsychidae</i>	59
<i>Hydroptilidae</i>	1
<i>Isopoda</i>	3
<i>Oligochaeta</i>	7
<i>Tipulidae</i>	2
<i>Tricorythidae</i>	17

Total Taxa: 15

Total Organisms: 1334

## Macroinvertebrate Collection

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Collection Date: 7.7.06      Collection Type: Qualitative      RM: 47.5

Site Number: 9

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<i>Baetidae</i>	24
<i>Bivalvia</i>	6
<i>Chironomidae</i>	1087
<i>Decapoda</i>	1
<i>Elmidae</i>	19
<i>Glossosomatidae</i>	1
<i>Heptageniidae</i>	4
<i>Hydractinea</i>	1
<i>Hydropsychidae</i>	285
<i>Hydroptilidae</i>	5
<i>Polycentropodidae</i>	2
<i>Pyralidae</i>	1
<i>Simuliidae</i>	22
<i>Tipulidae</i>	4
<i>Tricorythidae</i>	3

Total Taxa: 15

Total Organisms: 1465

## Macroinvertebrate Collection

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Collection Date: 7.7.06      Collection Type: Quantitative      RM: 47.5

Site Number: 9

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<i>Baetidae</i>	26	<i>Simuliidae</i>	3
<i>Bivalvia</i>	7	<i>Tipulidae</i>	26
<i>Chironomidae</i>	533	<i>Tricorythidae</i>	12
<i>Elmidae</i>	120		
<i>Ephemeridae</i>	2		
<i>Glossosomatidae</i>	6		
<i>Heptageniidae</i>	16		
<i>Hydropsychidae</i>	378		
<i>Hydroptilidae</i>	25		
<i>Isopoda</i>	6		
<i>Oligochaeta</i>	4		
<i>Planaria</i>	2		
<i>Polycentropodidae</i>	1		
<i>Psephenidae</i>	4		
<i>Psychomyiidae</i>	5		
<i>Pyralidae</i>	1		

Total Taxa: 19

Total Organisms: 1177

## Macroinvertebrate Collection

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Collection Date: 7.12.06      Collection Type: Qualitative      RM: 43.9

Site Number: 10

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<i>Baetidae</i>	135	<i>Tricorythidae</i>	28
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<i>Bivalvia</i>	3		
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<i>Chironomidae</i>	529		
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<i>Decapoda</i>	1		
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<i>Elmidae</i>	114		
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<i>Ephemeridae</i>	3		
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<i>Gastropoda</i>	12		
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<i>Glossosomatidae</i>	52		
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<i>Gomphidae</i>	1		
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<i>Hebridae</i>	1		
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<i>Heptageniidae</i>	41		
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<i>Hydropsychidae</i>	412		
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<i>Hydroptilidae</i>	19		
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<i>Isopoda</i>	6		
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<i>Simuliidae</i>	3		
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<i>Tipulidae</i>	12		
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Total Taxa:	17		
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Total Organisms:	1372		
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## Macroinvertebrate Collection

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Collection Date: 7.12.06      Collection Type: Quantitative      RM: 43.9

Site Number: 10

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<i>Baetidae</i>	55	<i>Trycorythidae</i>	34
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<i>Bivalvia</i>	3		
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<i>Chironomidae</i>	422		
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<i>Elmidae</i>	72		
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<i>Ephemeridae</i>	1		
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<i>Gastropoda</i>	9		
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<i>Glossosomatidae</i>	11		
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<i>Heptageniidae</i>	36		
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<i>Hydropsychidae</i>	313		
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<i>Hydroptilidae</i>	13		
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<i>Isopoda</i>	1		
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<i>Planaria</i>	1		
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<i>Polycentropodidae</i>	2		
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<i>Psycomyiidae</i>	2		
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<i>Simuliidae</i>	7		
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<i>Tipulidae</i>	12		
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Total Taxa:	17		
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Total Organisms:	994		
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## Macroinvertebrate Collection

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Collection Date: 7.21.06      Collection Type: Qualitative      RM: 36

Site Number: 11

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<i>Baetidae</i>	495	<i>Tipulidae</i>	2
<i>Chironomidae</i>	555	<i>Tricorythidae</i>	96
<i>Elmidae</i>	251		
<i>Gastropoda</i>	4		
<i>Glossosomatidae</i>	1		
<i>Heptageniidae</i>	30		
<i>Hydracarina</i>	1		
<i>Hydropsychidae</i>	321		
<i>Hydroptilidae</i>	19		
<i>Isopoda</i>	1		
<i>Perlidae</i>	3		
<i>Philopotamidae</i>	2		
<i>Polycentropodidae</i>	1		
<i>Psephenidae</i>	1		
<i>Pyralidae</i>	2		
<i>Simuliidae</i>	11		

Total Taxa: 18

Total Organisms: 1796

## Macroinvertebrate Collection

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Collection Date: 7.21.06      Collection Type: Quantitative      RM: 36

Site Number: 11

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<i>Baetidae</i>	52	<i>Psephenidae</i>	2
<i>Chironomidae</i>	1028	<i>Pyralidae</i>	1
<i>Decapoda</i>	1	<i>Simuliidae</i>	1
<i>Elmidae</i>	166	<i>Tipulidae</i>	1
<i>Empididae</i>	1	<i>Tricorythidae</i>	64
<i>Fish</i>	1		
<i>Glossosomatidae</i>	1		
<i>Haliplidae</i>	4		
<i>Heptageniidae</i>	13		
<i>Hydropsychidae</i>	232		
<i>Hydroptilidae</i>	13		
<i>Hyrudinea</i>	1		
<i>Oligochaeta</i>	8		
<i>Perlidae</i>	3		
<i>Planaria</i>	1		
<i>Polycentropodidae</i>	3		

Total Taxa: 21

Total Organisms: 1597

## Macroinvertebrate Collection

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Collection Date: 7.21.06      Collection Type: Qualitative      RM: 32.9

Site Number: 12

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<i>Baetidae</i>	119
<i>Chironomidae</i>	1510
<i>Elmidae</i>	106
<i>Empididae</i>	1
<i>Ephemeridae</i>	54
<i>Glossosomatidae</i>	6
<i>Heptageniidae</i>	18
<i>Hydropsychidae</i>	430
<i>Hydroptilidae</i>	52
<i>Isopoda</i>	1
<i>Philopotamidae</i>	1
<i>Pyrallidae</i>	3
<i>Simuliidae</i>	46
<i>Tricorythidae</i>	52

Total Taxa: 14

Total Organisms: 2399



## Macroinvertebrate Collection

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Collection Date: 7.21.06      Collection Type: Quantitative      RM: 32.9

Site Number: 12

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<i>Baetidae</i>	59
<i>Chironomidae</i>	622
<i>Elmidae</i>	37
<i>Ephemeridae</i>	1
<i>Glossosomatidae</i>	1
<i>Heptageniidae</i>	4
<i>Hydropsychidae</i>	133
<i>Hydroptilidae</i>	48
<i>Oligochaeta</i>	3
<i>Philopotamidae</i>	1
<i>Pyrilidae</i>	1
<i>Simuliidae</i>	13
<i>Tricorythidae</i>	21
<i>Veliidae</i>	1

Total Taxa: 14

Total Organisms: 945

## Macroinvertebrate Collection

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Collection Date: 7.21.06      Collection Type: Qualitative      RM: 28

Site Number: 13

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*Baetidae*                      154

*Bivalvia*                      4

*Chironomidae*                552

*Elmidae*                      189

*Fish*                          1

*Heptageniidae*               28

*Hydropsychidae*            195

*Hydroptilidae*              16

*Oligochaeta*                2

*Perlidae*                    1

*Polycentropodidae*        1

*Simuliidae*                 5

*Tricorythidae*              69

Total Taxa:                  13

Total Organisms:            1217

## Macroinvertebrate Collection

---

Collection Date: 7.21.06      Collection Type: Quantitative      RM: 28

Site Number: 13

---

<i>Baetidae</i>	81
<i>Bivalvia</i>	1
<i>Chironomidae</i>	159
<i>Elmidae</i>	80
<i>Ephemeridae</i>	1
<i>Heptageniidae</i>	12
<i>Hydropsychidae</i>	116
<i>Hydroptilidae</i>	5
<i>Planaria</i>	2
<i>Simuliidae</i>	1
<i>Tipulidae</i>	1
<i>Tricorythidae</i>	32

Total Taxa: 12

Total Organisms: 491

## Macroinvertebrate Collection

---

Collection Date: 7.21.06      Collection Type: Quantitative      RM: 28

Site Number: 13

---

<i>Baetidae</i>	81
<i>Bivalvia</i>	1
<i>Chironomidae</i>	159
<i>Elmidae</i>	80
<i>Ephemeridae</i>	1
<i>Heptageniidae</i>	12
<i>Hydropsychidae</i>	116
<i>Hydroptilidae</i>	5
<i>Planaria</i>	2
<i>Simuliidae</i>	1
<i>Tipulidae</i>	1
<i>Tricorythidae</i>	32

Total Taxa: 12

Total Organisms: 491

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## APPENDIX B

Table 11: Total individuals and total percent of individuals within each FFG for the RBA samples collected in 2005

Site #	Total Individuals						Total Percent					
	PR	SC	SH	GC	FC		PR	SC	SH	GC	FC	
1	13	55	0	4339	191		0.283	1.196	0.000	94.367	4.154	
2	18	48	1	556	122		2.287	6.099	0.127	70.648	15.502	
3	1	13	1	279	574		0.115	1.498	0.115	32.143	66.129	
4	4	14	3	443	29		0.811	2.840	0.609	89.858	5.882	
5	1	33	0	489	2		0.190	6.286	0.000	93.143	0.381	
6	8	150	3	812	173		0.698	13.089	0.262	70.855	15.096	
7 up	5	61	0	113	48		2.203	26.872	0.000	49.780	21.145	
7 down	2	5	0	84	1		2.174	5.435	0.000	91.304	1.087	
8	1	47	4	897	202		0.043	2.043	0.174	38.983	8.779	
9	7	53	3	965	554		0.266	4.625	0.262	84.206	48.342	
10	2	122	17	1116	1044		0.087	5.302	0.739	48.501	45.372	
11	2	27	4	1126	906		0.076	2.356	0.349	98.255	79.058	
12	1	38	4	1459	1132		0.038	3.316	0.349	127.312	98.778	
13	4	60	3	1573	314		0.205	3.071	0.154	80.502	16.070	

Table 12: Total individuals and total percent of individuals within each FFG for the Hess samples collected in 2005

Site #	Total Individuals						Percent					
	PR	SC	SH	GC	FC		PR	SC	SH	GC	FC	
1	18	42	0	4508	246		0.374	0.872	0.000	93.644	5.110	
2	15	108	1	973	150		1.203	8.661	0.080	78.027	12.029	
3	0	4	1	133	132		0.000	1.481	0.370	49.259	48.889	
4	6	33	11	472	74		1.007	5.537	1.846	79.195	12.416	
5	3	22	0	509	1		0.561	4.112	0.000	95.140	0.187	
6	5	230	13	1486	288		0.247	11.375	0.643	73.492	14.243	
7 up	44	54	1	144	19		16.794	20.611	0.382	54.962	7.252	
7 dwn	1	2	0	41	0		2.273	4.545	0.000	93.182	0.000	
8	0	19	2	1012	23		0.000	0.725	0.076	38.626	0.878	
9	5	55	5	1038	1368		0.246	2.720	0.247	51.335	67.656	
10	4	73	9	1224	1310		0.153	2.786	0.344	46.718	50.000	
11	2	57	3	1410	698		0.098	2.819	0.148	69.733	34.520	
12	3	42	2	1021	966		0.147	2.077	0.099	50.495	47.774	
13	0	42	11	1223	513		0.000	2.348	0.615	68.362	28.675	

Table 13: Total individuals and total percent of individuals within each FFG for the RBA samples collected in 2006

Site #	Total Individuals						Percent					
	PR	SC	SH	GC	FC		PR	SC	SH	GC	FC	
1	3	93	8	1413	91		0.187	5.784	0.498	87.873	5.659	
2	3	53	0	246	2		0.987	17.434	0.000	80.921	0.658	
3	3	1	22	188	112		0.920	0.307	6.748	57.669	34.356	
4	5	20	8	235	55		1.548	6.192	2.477	72.755	17.028	
5	0	9	0	323	0		0.000	2.711	0.000	97.289	0.000	
6	2	31	6	355	45		0.456	7.062	1.367	80.866	10.251	
7 up	1	36	0	914	189		0.088	3.158	0.000	80.175	16.579	
7 down	1	3	0	242	3		0.402	1.205	0.000	97.189	1.205	
8	0	8	2	366	8		0.000	2.083	0.521	95.313	2.083	
9	1	16	6	1126	309		0.069	1.097	0.412	77.229	21.193	
10	2	143	12	778	413		0.148	10.608	0.890	57.715	30.638	
11	4	115	4	1033	335		0.268	7.713	0.268	69.282	22.468	
12	2	76	3	1338	386		0.111	4.211	0.166	74.127	21.385	
13	1	60	0	665	126		0.117	7.042	0.000	78.052	14.789	



Table 14: Total individuals and total percent of individuals within each FFG for the Hess samples collected in 2006

Site #	Total Individuals					Percent				
	PR	SC	SH	GC	FC	PR	SC	SH	GC	FC
1	11	229	4	3312	109	0.300	6.248	0.109	90.368	2.974
2	5	66	0	269	2	1.462	19.298	0.000	78.655	0.585
3	1	0	1	182	147	0.302	0.000	0.302	54.985	44.411
4	6	15	21	360	70	1.271	3.178	4.449	76.271	14.831
5	1	35	0	369	4	0.244	8.557	0.000	90.220	0.978
6	0	49	16	692	132	0.000	5.512	1.800	77.840	14.848
7 up	1	38	0	725	87	0.118	4.465	0.000	85.194	10.223
7 down	0	9	1	584	4	0.000	1.505	0.167	97.659	0.669
8	4	40	2	1164	59	0.315	3.152	0.158	91.726	4.649
9	0	61	27	688	382	0.000	5.268	2.332	59.413	32.988
10	0	71	12	565	322	0.000	7.320	1.237	58.247	33.196
11	4	44	8	1295	235	0.252	2.774	0.504	81.652	14.817
12	1	67	1	956	190	0.082	5.514	0.082	78.683	15.638
13	0	65	17	574	189	0.000	7.692	2.012	67.929	22.367

## APPENDIX C

Qualitative Habitat Evaluation Index Field Sheet QHEI Score:  

River Code: \_\_\_\_\_ RM: \_\_\_\_\_ Stream: \_\_\_\_\_

Date: \_\_\_\_\_ Location: \_\_\_\_\_

Scorer's Full Name: \_\_\_\_\_ Affiliation: \_\_\_\_\_

1) SUBSTRATE (Check ONLY Two Substrate TYPE BOXES; Estimate % present)

TYPE		POOL RIFFLE	POOL RIFFLE	SUBSTRATE ORIGIN	SUBSTRATE QUALITY	
<input type="checkbox"/> BUDR SUBSTR [10]	<input type="checkbox"/> GRAVEL [7]	Check ONE (OR 2 & AVERAGE)		Check ONE (OR 2 & AVERAGE)		Substrate <div style="border: 1px solid black; width: 40px; height: 40px; margin: 5px auto;"></div> Max 20
<input type="checkbox"/> BOULDER [8]	<input type="checkbox"/> SAND [6]	<input type="checkbox"/> LIMESTONE [1]	SILT:	<input type="checkbox"/> SILT HEAVY [-2]		
<input type="checkbox"/> COBBLE [8]	<input type="checkbox"/> BEDROCK [5]	<input type="checkbox"/> TILLS [1]	<input type="checkbox"/> WETLANDS [0]	<input type="checkbox"/> SILT MODERATE [-1]		
<input type="checkbox"/> HARDPAN [4]	<input type="checkbox"/> DETRITUS [3]	<input type="checkbox"/> HARDPAN [0]	<input type="checkbox"/> SANDSTONE [0] EMBEDDED	<input type="checkbox"/> SILT NORMAL [0]		
<input type="checkbox"/> MUCK [2]	<input type="checkbox"/> ARTIFICIAL [0]	<input type="checkbox"/> REP/RAP [0]	NESS:	<input type="checkbox"/> SILT FREE [1]		
<input type="checkbox"/> SILT [2]	NOTE: Types Change Originating From Each Category		<input type="checkbox"/> LACUSTRIENE [0]	<input type="checkbox"/> EXTENSIVE [-2]		
NUMBER OF SUBSTRATE TYPES: <input type="checkbox"/> 4 or More [2]		<input type="checkbox"/> 3 or Less [0]	<input type="checkbox"/> SHALE [-1]	<input type="checkbox"/> MODERATE [-1]		
COMMENTS:		<input type="checkbox"/> COAL FINES [-2]	<input type="checkbox"/> NORMAL [0]	<input type="checkbox"/> NONE [1]		

2) DISTREAM COVER (Give each cover type a score of 0 to 3; see back for instructions)

STRUCTURE		TYPE: Score All That Occur	AMOUNT (Check ONLY One or check 2 and AVERAGE)	Cover
<input type="checkbox"/> UNDERCUT BANKS [1]	<input type="checkbox"/> POOLS > 70 cm [2]	<input type="checkbox"/> OWBOWS, BACKWATERS [1]	<input type="checkbox"/> EXTENSIVE > 75% [11]	<div style="border: 1px solid black; width: 40px; height: 40px; margin: 5px auto;"></div> Max 20
<input type="checkbox"/> OVERHANGING VEGETATION [1]	<input type="checkbox"/> ROOTWADS [1]	<input type="checkbox"/> AQUATIC MACROPHYTES [1]	<input type="checkbox"/> MODERATE 25-75% [7]	
<input type="checkbox"/> SHALLOWS (IN SLOW WATER) [1]	<input type="checkbox"/> BOULDERS [1]	<input type="checkbox"/> LOGS OR WOODY DEBRIS [1]	<input type="checkbox"/> SPARSE 5-25% [3]	
<input type="checkbox"/> ROOTMATS [1]	COMMENTS:		<input type="checkbox"/> NEARLY ABSENT < 5% [1]	

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

SIMILITUDY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATIONS/OTHER	Channel
<input type="checkbox"/> HIGH [4]	<input type="checkbox"/> EXCELLENT [7]	<input type="checkbox"/> NONE [6]	<input type="checkbox"/> HIGH [3]	<input type="checkbox"/> SNAGGING	<div style="border: 1px solid black; width: 40px; height: 40px; margin: 5px auto;"></div> Max 20
<input type="checkbox"/> MODERATE [3]	<input type="checkbox"/> GOOD [5]	<input type="checkbox"/> RECOVERED [4]	<input type="checkbox"/> MODERATE [2]	<input type="checkbox"/> RELOCATION	
<input type="checkbox"/> LOW [2]	<input type="checkbox"/> FAIR [3]	<input type="checkbox"/> RECOVERING [3]	<input type="checkbox"/> LOW [1]	<input type="checkbox"/> CANOPY REMOVAL	
<input type="checkbox"/> NONE [1]	<input type="checkbox"/> POOR [1]	<input type="checkbox"/> RECENT OR NO RECOVERY [1]	<input type="checkbox"/> URGING	<input type="checkbox"/> BANK SHAPING	
				<input type="checkbox"/> ONE SIDE CHANNEL MODIFICATIONS	

COMMENTS:

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

RIPARIAN WIDTH		FLOOD PLAIN QUALITY (PAST 100 METERS RIPARIAN)		BANK EROSION		Riparian
L R (Per Bank)	L R (Most Predominant Per Bank)	L R	L R (Per Bank)			<div style="border: 1px solid black; width: 40px; height: 40px; margin: 5px auto;"></div> Max 10
<input type="checkbox"/> WIDE > 50m [4]	<input type="checkbox"/> FOREST, SWAMP [3]	<input type="checkbox"/> CONSERVATION TILLAGE [1]	<input type="checkbox"/> NONE/LITTLE [3]			
<input type="checkbox"/> MODERATE 10-50m [3]	<input type="checkbox"/> SHRUB OR OLD FIELD [2]	<input type="checkbox"/> URBAN OR INDUSTRIAL [0]	<input type="checkbox"/> MODERATE [2]			
<input type="checkbox"/> NARROW 5-10 m [2]	<input type="checkbox"/> RESIDENTIAL, PARK, NEW FIELD [1]	<input type="checkbox"/> OPEN PASTURE, ROWCROP [0]	<input type="checkbox"/> HEAVY/SEVERE [1]			
<input type="checkbox"/> VERY NARROW < 5 m [1]	<input type="checkbox"/> FENCED PASTURE [1]	<input type="checkbox"/> HIGH/CONSTRUCTION [0]				

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

MAX. DEPTH	MORPHOLOGY	CURRENT VELOCITY (POOLS & RIFFLES)	Pool/Current
(Check 1 ONLY!)	(Check 1 or 2 & AVERAGE)	(Check All That Apply)	<div style="border: 1px solid black; width: 40px; height: 40px; margin: 5px auto;"></div> Max 12
<input type="checkbox"/> > 1m [5]	<input type="checkbox"/> POOL WIDTH > RIFFLE WIDTH [2]	<input type="checkbox"/> EDDIES [1]	
<input type="checkbox"/> 0.7-1m [4]	<input type="checkbox"/> POOL WIDTH = RIFFLE WIDTH [1]	<input type="checkbox"/> FAST [1]	
<input type="checkbox"/> 0.4-0.7m [2]	<input type="checkbox"/> POOL WIDTH < RIFFLE W. [0]	<input type="checkbox"/> MODERATE [1]	
<input type="checkbox"/> 0.2-0.4m [1]		<input type="checkbox"/> SLOW [1]	
<input type="checkbox"/> < 0.2m [POOL=0]	COMMENTS:	<input type="checkbox"/> TORRENTIAL [-1]	
			<input type="checkbox"/> INTERMITTENT [-2]
			<input type="checkbox"/> VERY FAST [1]

CHECK ONE OR CHECK 2 AND AVERAGE				Riffle/Run
RIFFLE DEPTH	RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS	<div style="border: 1px solid black; width: 40px; height: 40px; margin: 5px auto;"></div> Max 8
<input type="checkbox"/> Best Areas > 10 cm [2]	<input type="checkbox"/> MAX > 50 [2]	<input type="checkbox"/> STABLE (e.g., Cobble, Boulder) [2]	<input type="checkbox"/> NONE [2]	
<input type="checkbox"/> Best Areas 5-10 cm [1]	<input type="checkbox"/> MAX < 50 [1]	<input type="checkbox"/> MOD. STABLE (e.g., Large Gravel) [1]	<input type="checkbox"/> LOW [1]	
<input type="checkbox"/> Best Areas < 5 cm [RIFFLE=0]		<input type="checkbox"/> UNSTABLE (Fine Gravel, Sand) [0]	<input type="checkbox"/> MODERATE [0]	<div style="border: 1px solid black; width: 40px; height: 40px; margin: 5px auto;"></div> Max 10
COMMENTS:	<input type="checkbox"/> NO RIFFLE (Metric=0)		<input type="checkbox"/> EXTENSIVE [-1]	

6) GRADIENT (ft/mi): \_\_\_\_\_ DRAINAGE AREA (sq.mi.): \_\_\_\_\_ %POOL:   %GLIDE:  %RIFFLE:   %RUN:  

\* Best areas used to large enough to support a population of fish or aquatic species

EPA 4520

08/24/01

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