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A Stormwater History of Grand Valley State University and an Assessment of the Stream Quality of the Little Mac Ravine

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Introduction

As Grand Valley State University (GVSU) was built and expanded in Allendale, Michigan, the negative impacts of the campus stormwater discharge on the ravines also grew. It was not until the early 2000's that GVSU began to understand the impacts stormwater had on the ravines. In 2011, 32 acres of stormwater drainage from the west side of campus was diverted to a series of constructed wetlands. Prior to this change, a biological baseline was determined by Snyder et al (2008) by sampling the macroinvertebrates in the Little Mac stream (Snyder et al 2008). The purpose of this project was to examine the series of campus events that resulted in the degradation of the ravine streams and to compare new macroinvertebrate data to the set collected in 2008 for signs of change since the reduction flow in stormwater to the ravines.

Chapter One of this report discusses the major changes to the GVSU Allendale campus that impacted stormwater. The Allendale campus was constructed on farm fields near the Grand River in 1960. The first buildings were completed in 1964 and GVSU continued building and expanding since then. The area of impervious surface went from zero acres in 1960 to over 170 acres now, and the university continues to add new buildings to accommodate the growing student population. The stormwater management practices shifted from subsurface pipes draining directly to the ravines in the beginning to the implementation of practices, such as rain gardens, green roofs, and wetlands, to reduce stormwater runoff and utilize it for irrigation on campus beginning in 2007.

In Chapter Two, I discuss the results of macroinvertebrate samples collected in the Little Mac stream and the control stream in 2013. The results for the Little Mac stream were compared to samples collected by Snyder et al (2008). The comparison of the macroinvertebrates sampled

in 2013 and 2008 showed that overall the changes were insignificant. However, some of the changes indicated the stream was beginning to stabilize and allow areas of soft sediment accumulation, which were not previously present. The comparison with the control stream samples revealed that the Little Mac stream is more degraded than the stream without urban impairments. This supports the idea that GVSU needs more restoration efforts to improve the water and habitat quality of the Little Mac stream.

Chapter Three presents the project conclusions, management implications of the results, and recommended restoration activities. Additional research priorities also are presented. Since GVSU controls the entire watershed of the ravines, it will be easier for the University to continue working at the watershed scale to manage stormwater. Additional practices that should be explored include stream bed restoration, use of plants for stream bank stabilization wherever possible, and construction of wetlands within the ravine to aid with flow control and contaminant filtration.

Chapter One

A brief history of the Grand Valley State University ravines and stormwater management

The formation of the ravines on and around Grand Valley State University's Allendale campus (GVSU) was the result of glacial activity in the area (Figure 1.1). As the glaciers receded, they carved out the ravine formations (Colgan 2009). Evidence indicates that when the ravines were initially carved out, they were deeper than present depths. As the water levels in Lake Michigan rose, the Grand River level also rose and sediment was deposited in the bottom ravines. For the last 10,000 years, the ravines were heavily wooded and the vegetation held the sediment in place and maintained a steady state. In 1800, before settlers were in the area, the vegetation for the area was mixed hardwood swamp and white pine-white oak forest (Comer and

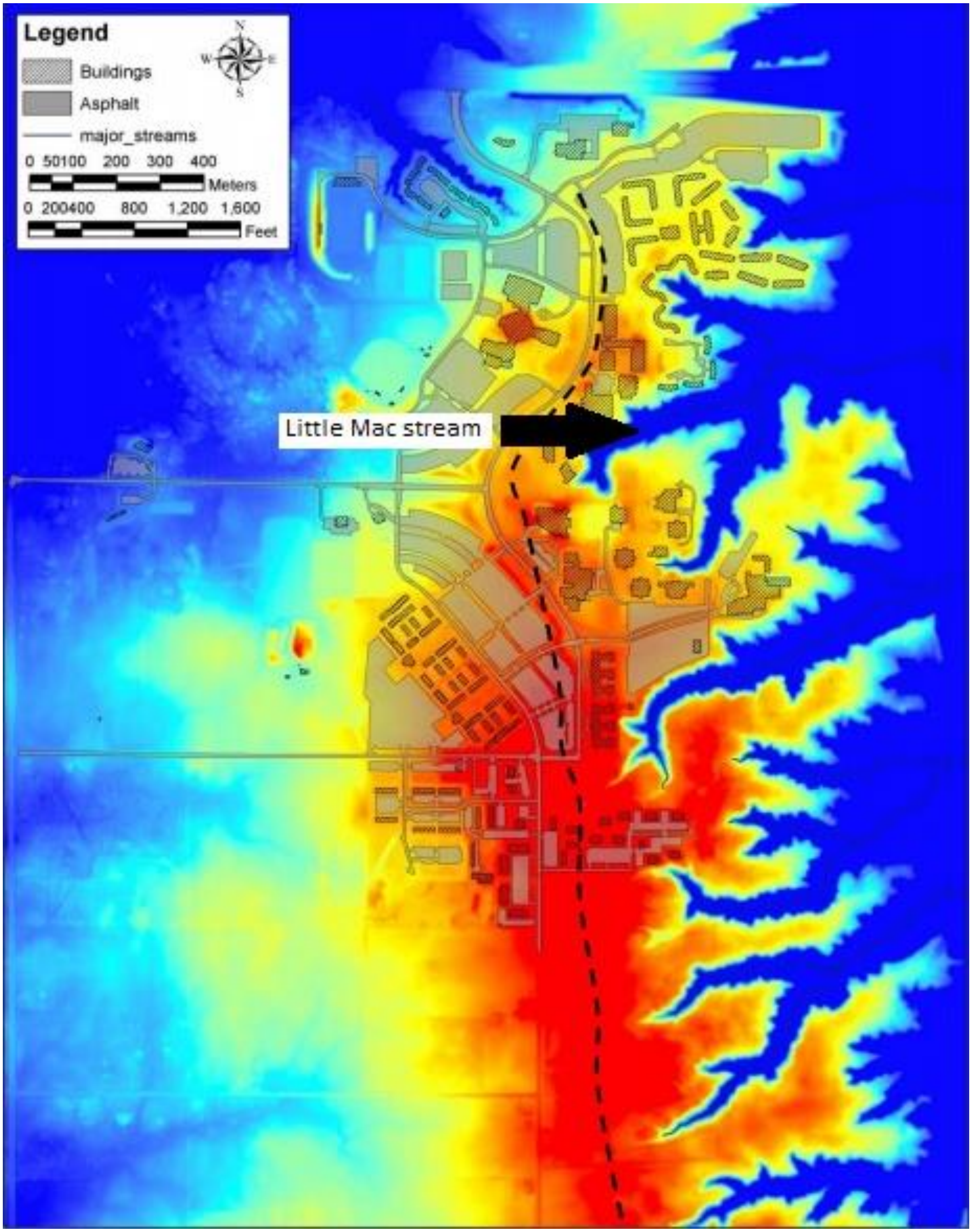

Figure 1.1 A digital elevation model for Grand Valley State University and ravines (Womble 2006). Dark red indicates higher elevation and dark blue indicates lower elevation.

Albert 1997; Figure 1.2). When settlers came to the area, they cleared the forested land surrounding the top of the ravines and began to farm the area (Colgan 2009). This activity started a dramatic increase in sedimentation in the ravines. It is believed that the additional sedimentation buried many trees on the bottom of the ravines beyond their tolerance and resulted in their death.

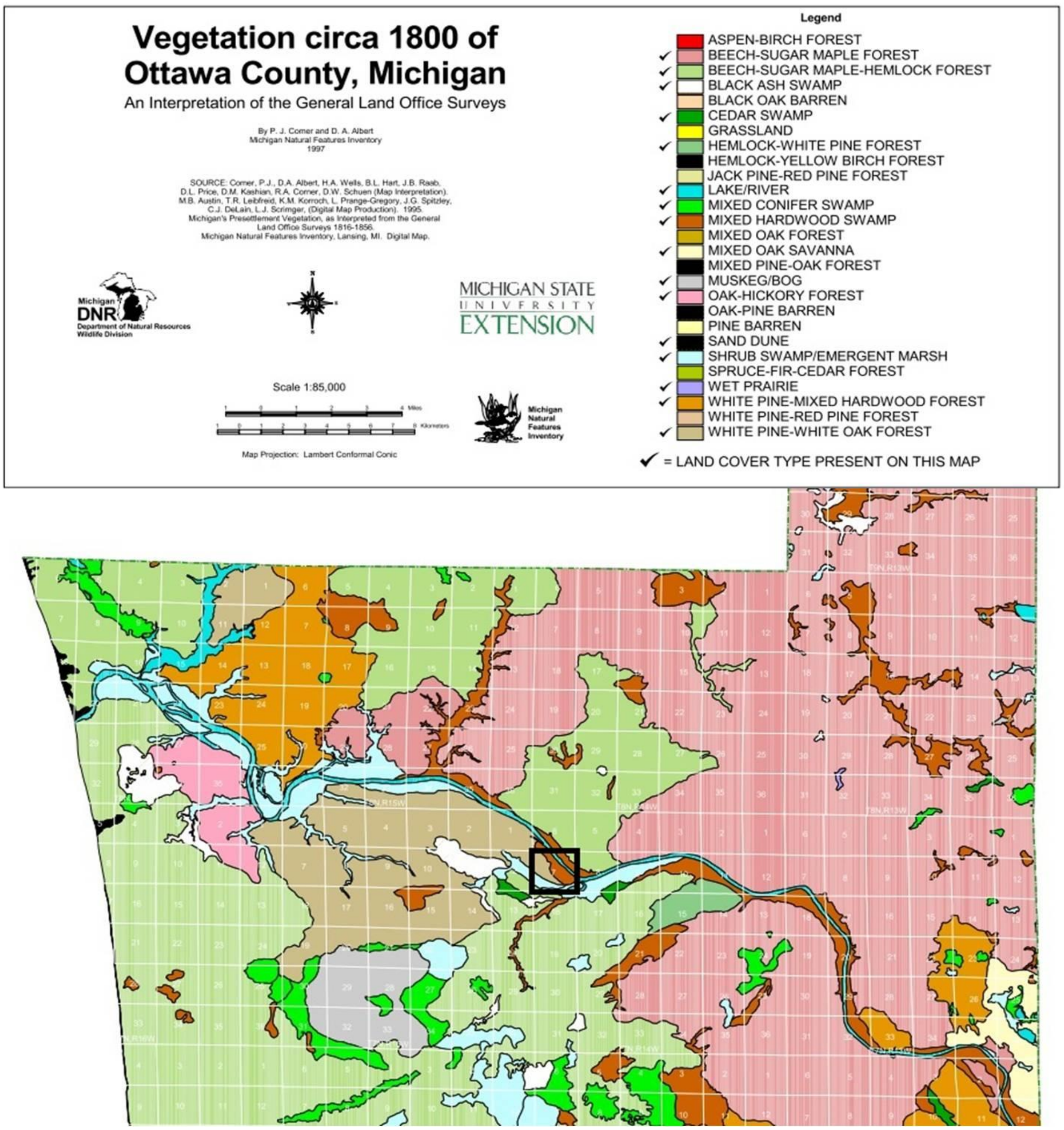

Figure 1.2 Located within the black box, the pre-settlement vegetation for the Allendale campus of Grand Valley State University was mixed hardwood swamp and white pine-white oak forest (Comer and Albert 1997).

The agricultural history of the GVSU Allendale campus influenced the stormwater management practices implemented by the university. Farmers wanted to get the water off their fields as quickly as possible and usually used ditches or pipes to accomplish this goal (James Moyer, personal communication). When GVSU was founded in 1960, the practice of direct discharge of stormwater to the ravines continued. In 1963, the first campus buildings, Lake Michigan Hall and Lake Superior Hall, were completed (Stivers 2010). These buildings, and the parking lots that accompanied them, were the first impervious surfaces on the farm fields and marked the beginning of the expansion of impervious surface around the ravines.

The first academic buildings were centralized on the same peninsula that extends along the south side of the Little Mac ravine. In 1966, the Loutit Hall of Science and the James M. Copeland Living Center were completed (Stivers 2010). These building were on the peninsula along the north side of the Little Mac ravine and started the expanding influence of GVSU on the ravines. By 1969, more academic buildings (Mackinac Hall, Manitou Hall, and the James H. Zumberge Library), the Commons Dining facility, the fieldhouse, and another dormitory (Kenneth W. Robinson Living Center) were all completed. At this time a development plan for GVSU was developed to prepare for the expanding university. In addition to planning the expansion of campus buildings and infrastructure, GVSU continued to utilize sub-surface drainage systems to capture stormwater and release it in the ravines (JJ&R 1969). By 1973 GVSU accumulated 58.5 acres of impermeable surface, making up 5% of the total campus area (Womble 2006). Throughout the rest of the 20th century several more buildings for academics, student housing, and athletics, as well as parking lots and sidewalks, were constructed (Stivers 2010). Each new addition increased the impervious surface within the watershed draining into the Little Mac ravine and further degraded the stream. In 1998 GVSU built a total of 152.2 acres

of impermeable surfaces, so that 13% of the campus was impervious (Womble 2006). Eventually, the addition of buildings and parking lots on the west side of campus altered the hydrology of the campus watershed so that a larger surface area drained stormwater into the ravines (Figure 1.3). By 2004 168.9 acres of the campus were impermeable and only 25% of the discharge into the Little Mac stream could be attributed to natural runoff (Womble 2006). It was around this time that GVSU realized the implications of the stormwater management practices that were in place.

Figure 1.3 Aerial view of Grand Valley State University Allendale campus showing the original drainage before the university (green), how the drainage area changed by 2004 (dark blue), and how it changed again after the construction and utilization of wetlands (light blue; Kerri Miller, personal communication).

The massive increase in runoff resulted in major erosion problems in the ravine based streams, which also caused slope failures along the ravine walls due to the steep nature of the topography (Figure 1.1). When the Seidman House was originally constructed in 1964, it had

patios that overlooked the ravines (Figure 1.4; James Moyer, personal communication). Slope failures in that area caused the patios to start leaning away from the building and resulted in their removal in 2005 (Nancy Richard, personal communication). On the north end of campus, a road for the Ravine Apartments was eighteen inches away from being lost due to slope failures. Other buildings, like the Seymour & Esther Padnos Hall of Science and Lake Ontario Hall, were threatened by slope failures. In response to the increasing problems associated with stormwater runoff, the Stormwater Advisory Group (SWAG), consisting of faculty and staff members, was founded in 2005 and a more environmentally friendly stormwater management strategy for GVSU was developed (Kerri Miller, personal communication; Womble 2006).

Figure 1.4 Student using the Seidman House outdoor study area, circa 1972 (Courtesy of GVSU University Archives). Due to slope failures the area became unstable and was removed in 2005.

The initiation of these new steps marked a shift in the focus of stormwater management at GVSU. The new focus for stormwater management was collection and reuse of stormwater or directing the flow of stormwater west of campus (James Moyer, personal communication). Stormwater became viewed as an asset: it could be stored for irrigation on campus or be utilized for rain gardens. The biggest contributor to the structural complications in the ravines was the volume of water racing through the streams during a rain event, so a plan was developed to reroute some stormwater away from the ravines (FTC&H 2007). The concerns about the ravines drew the attention of professors at GVSU. Several studies were completed to investigate the impacts of the changing stormwater management practices. In 2008 macroinvertebrates were sampled in the Little Mac ravine to set a biological baseline for reference after the stormwater diversion to the wetland complex (Snyder et al 2008). This project completed a second biological assessment for comparison with the original baseline.

In 2011, a series of wetlands was constructed to accept stormwater from 32 acres of impervious surface the previously flowed to the ravines (Simonson et al 2011; Figure 1.5). It was expected that the wetlands would reduce the volume of stormwater entering the stream and allow a reduction of erosion in the streams and stabilization of the ravine slopes. Other discharge reduction practices implemented included rain gardens, porous asphalt parking lots, and green roofs (Table 1.1; Kerri Miller, personal communication). Stormwater management is also included in the planning of new buildings. Implementing stormwater management practices during building construction is much more cost effective than attempting to remedy damages and conduct retrofits after the building is completed.

Even with these improvements to stormwater management, there are still problems associated with the structural integrity of the ravine slopes. In 2013 it was discovered that small

slope failures around the Little Mac bridge compromised the foundations of the bridge. This discovery motivated additional planning to stabilize the ravine streams and slopes. Engineers from Fishbeck, Thomson, Carr & Huber Inc., professors and faculty at GVSU, and interested GVSU students met during a series of meetings to discuss the current stormwater issues: options for reducing stormwater runoff, ravine slope stabilization, stream bank restoration, vegetation in the ravines, and research and educational opportunities. The meetings developed a couple of plans for stabilizing the stream and ravine slopes. One option involves anchoring the slope near the base with long pins. Another plan included filling the streambed to historical levels and stabilizing it with rocks to prevent further erosion.

Figure 1.5 Aerial view of the constructed wetland complex (brown) and areas draining into the constructed wetlands (blue, green, yellow, and orange) post-diversion (Wampler and Kneeshaw 2013).

Table 1.1 Stormwater best management practices present on GVSU Allendale Campus, as of October 2010 (Wampler 2011).

Stormwater Best Management Practice	Location
Rain Gardens	Kelly Family Sports Center Mark A. Murray Living Center Ronald F. Vansteeland Living Center South Apartments Glenn A. Niemeyer Living Centers
Detention Ponds	Parking Lots D, H, and K Alexander Calder Fine Arts Building
Green Roof	Kelly Family Sports Center Mackinac Hall Glenn A. Niemeyer Honors Hall
Permeable Concrete	Kelly Family Sports Center Mackinac Hall South Apartment E
Permeable Asphalt	Parking Lots C and R
Bioswales	Mackinac Hall Seidman House

Chapter Two

A biological assessment of the Little Mac stream

Introduction

As Grand Valley State University (GVSU) developed and expanded the Allendale campus (Chapter One), the watershed draining into the ravines became urbanized. Water systems in urban environments are influenced by three main elements: water supply, waste water, and stormwater (Walsh et al 2012). Stormwater in any system has the largest effect on the stream flow regime. The runoff from urban surfaces degrades streams by altering the volume, patterns, and quality of water. Subsurface drain systems, such as GVSU utilizes, allow large areas to drain into the stream much more quickly and exacerbate the impacts of the stormwater in

the stream. Urbanization can also increase the concentration of nutrients and contaminants in the stream (Walsh et al 2005). Nonpoint source (NPS) pollution is predominantly transferred to streams by runoff from impervious surfaces (Johnson et al 2013). NPS pollution is the most common stressor in urban streams – decreasing richness, abundance and pollution intolerant taxa (Walsh et al 2005). In the Little Mac stream, suspended solids, turbidity, and total phosphate were the contaminants found to be above the typical range for west Michigan streams (Wampler and Kneeshaw 2013). Urbanization of the watershed may also impact the flow regime of the stream (Walsh et al 2005).

The increased impervious surface that defines urbanization decreases the amount of rain water that infiltrates into the soil and results in a greater quantity of stormwater runoff (Doyle et al 2000). Due to the lack of infiltration and increased runoff, urban streams exhibit lower base flows than rural streams and peak flows that can exceed those in rural streams by an order of magnitude or more (Novotny and Witte 1997). Connecting impervious surface to the stream with pipes increases the frequency, magnitude, and volume of storm flow (Burns et al 2012). Stream "flashiness," or rapid rise of stream levels during storm events, tends to be more common in smaller streams (such as the stream in the Little Mac ravine) than in larger streams (Konrad and Booth 2005). Urbanization can also contribute to a flashy hydrograph (Walsh et al 2005). The combination of impervious surface and small size of the Little Mac stream increases the flashiness of the stream (Figure 2.1).

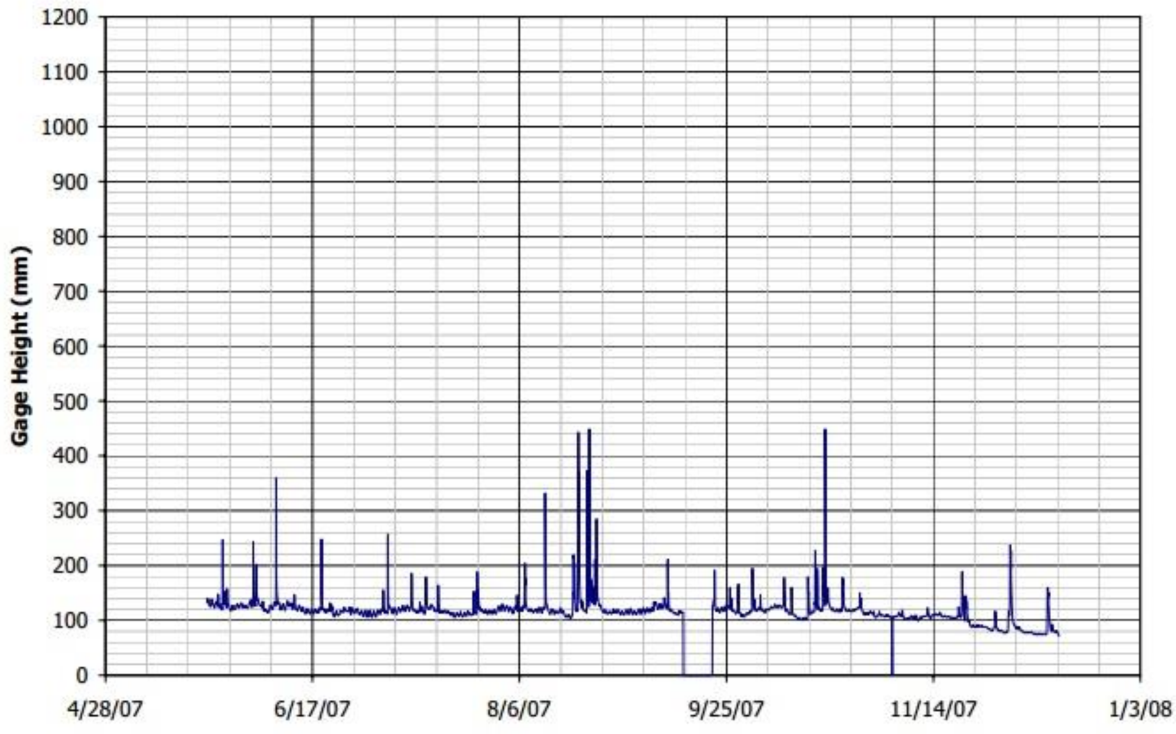

Figure 2.1 Hydrograph from the Little Mac stream in 2007, before stormwater was diverted to wetlands (Wampler 2009). The quick rise and fall of the stream flow indicates a flashy stream.

Stream flow is a major factor in determining the physical habitat of the stream (Bunn and Arthington 2002). Stormwater pulses from urbanized catchments can degrade habitat for the fauna living in and around the stream (Novotny and Witte 1997). Urbanization can also result in an imbalance between the capacity to transport sediment and the supply of sediment. Every stream has a sediment transport capacity that depends on the discharge of the stream (Harvey and Watson 1986). Water running off from an urban setting usually carries less sediment due to the pavement and traveling through a pipe (Booth 1990). When this is the case, a sediment imbalance is produced in the stream and, to compensate, the stream picks up more sediment and erodes the banks (Harvey and Watson 1986). Other factors that influence the capacity of a stream to carry sediment include velocity of flow, volume of stream flow, size of the sediment

particles, availability of the particles for movement, and channel roughness (Schwab et al 1966). The Little Mac stream is surrounded by tall steep slopes (Figure 1.1) causing the stormwater from the campus to travel down the steep slope through pipes and enter the stream at an increased velocity. The combination of the high velocity, increased volume, and the relatively sediment-free stormwater, results in accelerated erosion of the Little Mac stream. In 2014 the Little Mac stream was found, on average, to be 10 inches more cut-in on the landscape than the control stream, indicating accelerated erosion rates (Hamilton 2014). Erosion is detrimental to the stability of the stream, which in turn may result in a decline of macroinvertebrate species numbers (Death and Winterburn 1995).

The high storm event flows associated with urban streams are capable of modifying the trophic structure within the stream by carrying dissolved nutrients and organic matter, or selecting for certain benthic organisms (Konrad and Booth 2005). High flow events can scour the stream beds and kill organisms or transport organisms downstream. Macroinvertebrates are vulnerable to rapid changes in stream flow (Bunn and Arthington 2002). Individual or occasional high flow events are not detrimental, but frequent events may result in simpler trophic structure, low taxonomic diversity, and high dominance of a few taxa because the stream is not allowed enough time to recover from each high flow event (Konrad and Booth 2005). A problem in urban streams is that small rain events are capable of producing large flow responses, especially in watersheds with efficient drainage, like the subsurface system utilized by GVSU (Burns et al 2012).

In attempt to reduce the impacts of the campus on the ravines, GVSU installed check dams and riprap in 2002 and 2003 to reduce the impact of storm flows and erosion (Wampler 2009). By 2008, it was evident these structures were failing: the riprap was washed downstream

and the check dams were falling over. To help reduce the amount of stormwater entering the ravines, GVSU built a series of wetlands in 2011. Drainage from 32 acres of impervious surface was rerouted to these wetlands, diverting stormwater away from the ravines. This study examined macroinvertebrate data collected in 2008 (Snyder et al 2008) and in 2013 to determine changes that occurred after the stormwater entering the ravines was reduced. Macroinvertebrate samples from the Little Mac stream also were compared to a nearby ravine stream exhibiting a low degree of urban impairment. This control stream provides an example of what the Little Mac stream would be like without urbanization.

Methods

Site Description

Macroinvertebrates were sampled from the Little Mac stream and a control stream (Figure 2.2). The sample site in the Little Mac stream (Figure 2.3) was the same site used by Snyder et al (2008). The stream flows under the Little Mac bridge on the GVSU Allendale campus and drains into the Grand River. It is a small stream with widths varying from approximately 2-5 feet and depth ranging from a couple inches to a couple of feet. The sample location (N42.96532° W085.88363°) was chosen in 2008 for the presence of rocky substrate, as it is good habitat for macroinvertebrates. The watershed of the Little Mac stream is largely urbanized from development of the GVSU Allendale campus.

The control stream is located in a ravine south of the GVSU Allendale campus. The stream was chosen as the control due to the similar size to the Little Mac stream and the lack of urban based impairments. The area surrounding the control stream is mostly agricultural and forested land, with a small road and a house being the only impervious surfaces. There are no pipes carrying stormwater to the stream, like there are in the Little Mac stream, and the stream

appears to be much less eroded than the Little Mac stream. The sample site of the control stream (N42.95128° W085.87582°) was chosen for its similar flow to the Little Mac stream sample location. Unfortunately, the site did not have a rocky substrate like the Little Mac stream, but rather more soft sediment and leafy material (Figure 2.3).

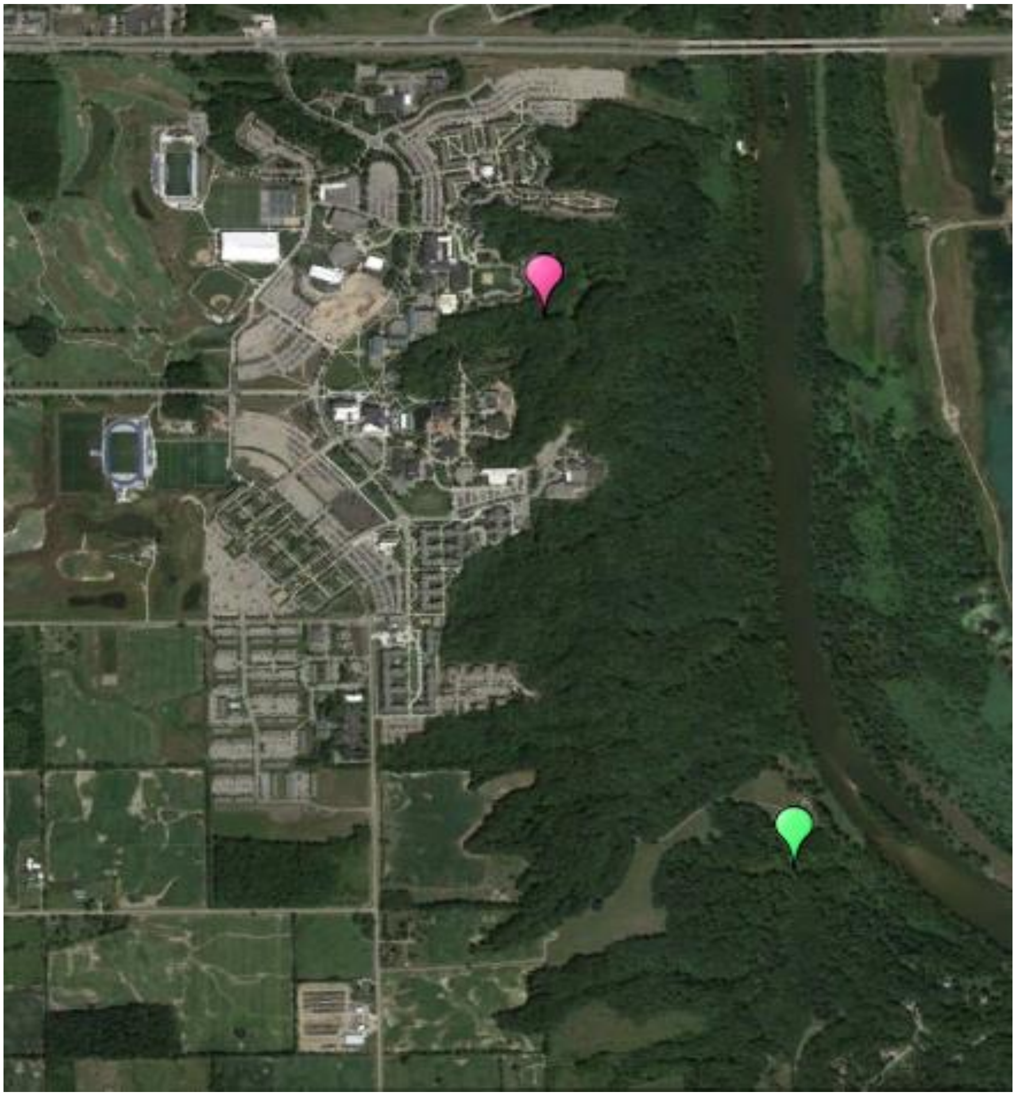

Figure 2.2 Macroinvertebrate sampling locations in the Little Mac stream (pink) and the control stream (green).

Figure 2.3 Sample location for the Little Mac stream in 2013 (left) was the same location sampled in 2008, and the control stream in 2013 (right).

Macroinvertebrates

Following the procedures used by Snyder et al (2008), macroinvertebrate samples were collected in triplicate with a Surber sampler, moving from downstream to upstream. The samples collected in 2013 were collected in October, while the samples collected by Snyder et al (2008) were taken in June. Each sample was stored in a buffered 10% formalin solution with Rose Bengal. The invertebrates were separated from the substrate and stored in an 80% ethanol solution. Trichoptera were keyed to genus using Merritt and Cummins (1996). All other insects were keyed to family using Merritt and Cummins (1996). The non-insects were keyed to class, order, or family.

Similarities and differences between ecological data sets were examined using statistical methods. Analysis of Similarities (ANOSIM) tests, run using the software R, were performed to

examine similarities between years and sites based on the presence/absence and quantity of taxa. The t-tests were run using SPSS to evaluate differences in ecological metrics.

Results and Discussion

Macroinvertebrates were sample in 2008 (Figure 2.4, Snyder et al 2008) and in 2013 from the Little Mac stream (Figure 2.5) and from a control stream (Figure 2.6). From these samples, a series of ecological metric were calculated (Table 2.1). The family biotic index was calculated using values from Hilsenhoff (1988).

Table 2.1 Summary of metric calculated for macroinvertebrate sampling (adapted from Snyder et al 2008).

				Abundance (#/m^2)								
Site	Mean Richness	Shannon's Diversity	Simpson's Dominance	EPT	E	P	T	Chironomidae	Total Abund.	% Chironomidae	%EPT	Family Biotic Index
Little Mac 2008	3	0.79	0.52	3.7	0.0	0.0	3.7	477*	759	62.95*	0.49	5.35
Little Mac 2013	4*	0.90	0.46	0.0	0.0	0.0	0.0*	3.7*	552	0.67*	0.00*	5.36*
Control 2013	7*	1.10	0.47	29.6	0.0	0.0	29.6*	0.0	730	0.00	4.06*	4.32*

*= Significant difference (t-test; $p < 0.05$)

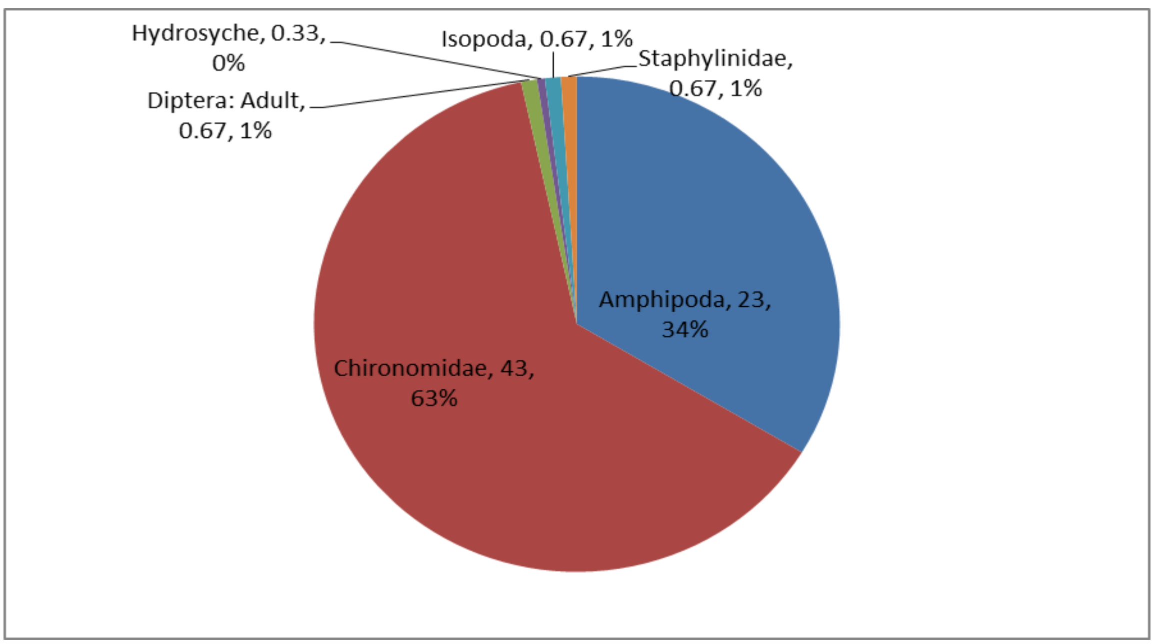

Figure 2.4 Mean number of macroinvertebrates sampled from the Little Mac stream in 2008 (Snyder et al 2008).

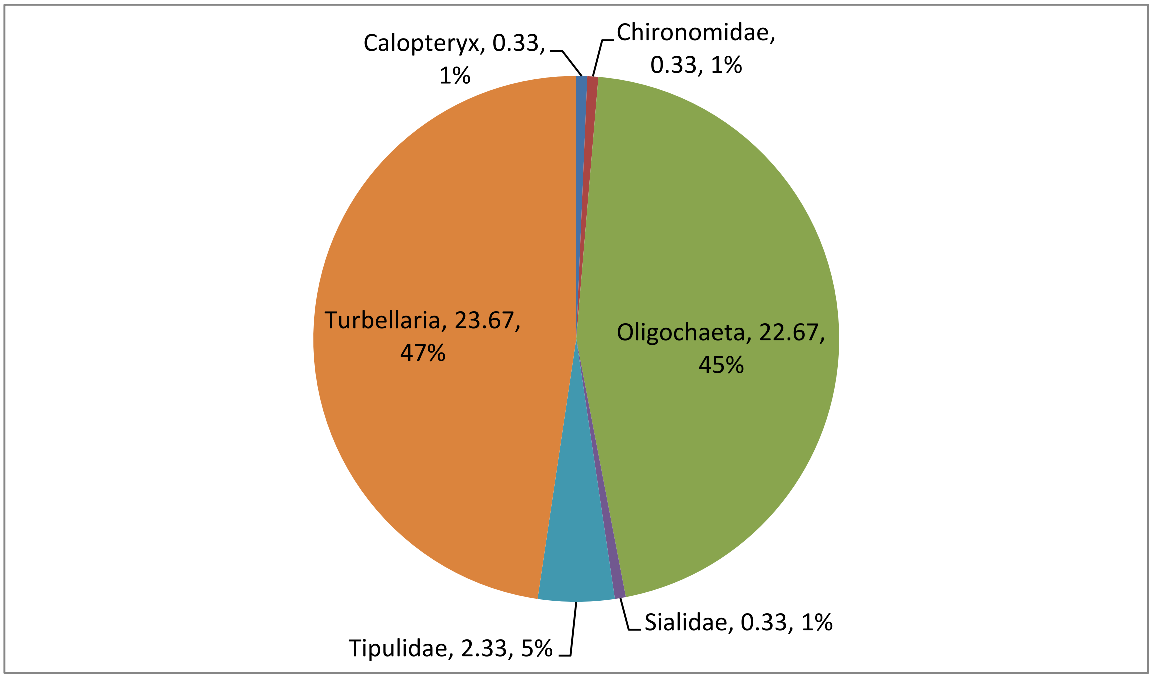

Figure 2.5 Mean number of macroinvertebrates sampled from the Little Mac stream in 2013.

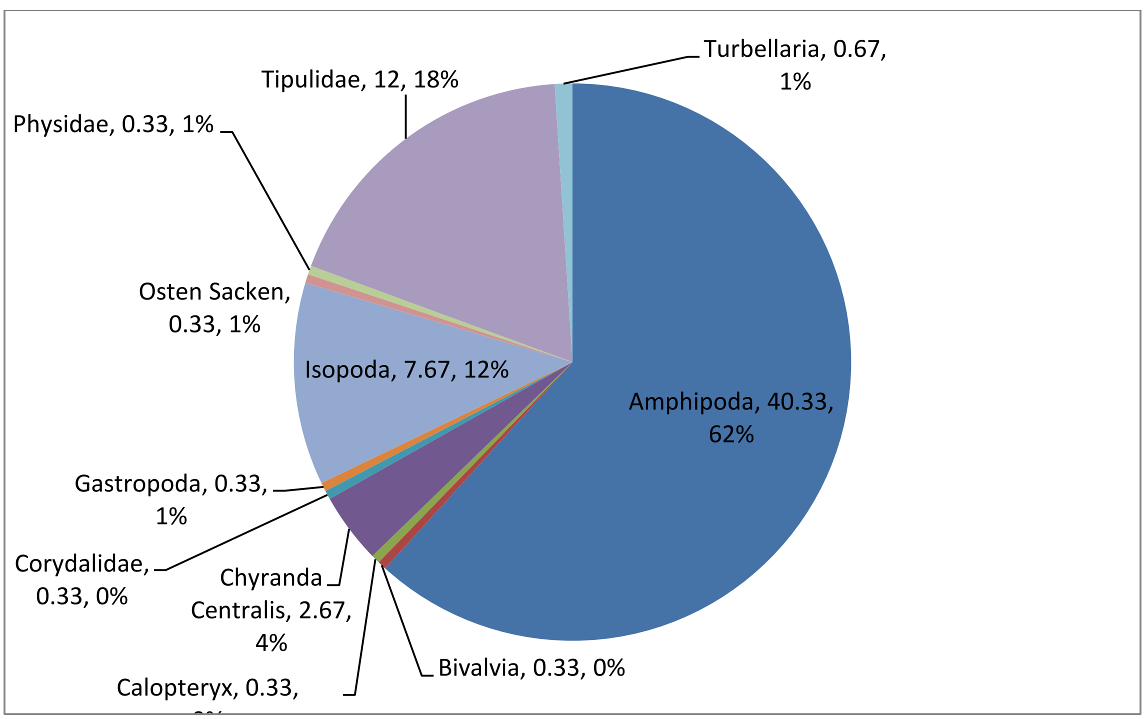

Figure 2.6 Mean number of macroinvertebrates sampled from the control stream in 2013.

Historical Stream Comparison

From 2008 to 2013 the only metric that showed significant change was the abundance of Chironomidae (p=.037). Due to the wide range of habitat conditions that chironomids can inhabit, it would be difficult to determine the cause for this change without keying the chironomids to lower taxa (Pinder 1986). An Analysis of Similarities (ANOSIM) was conducted on the assemblages and found that the differences between the two sites were insignificant (p=.108; Figure 2.7). This may be due to the lack of tight grouping, or similarity, of all three samples within each set.

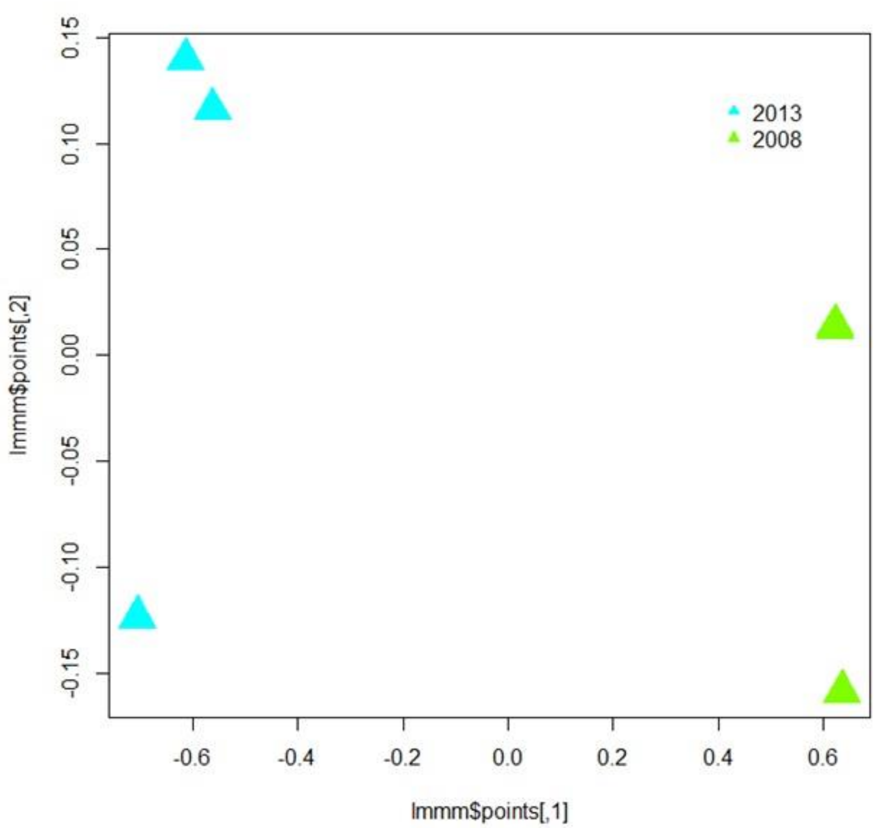

Figure 2.7 Comparison of Little Mac stream macroinvertebrate assemblages from 2008 (Snyder et al 2008) and 2013 using ANOSIM. (Two of the 2008 samples were similar and were overlapped in the figure.)

The macroinvertebrate samples showed a shift from amphipods and chironomids to turbellaria, oligochaetes, and tipulids (Figure 2.8). Turbellaria feed on oligochaetes, so their increase in abundance was likely due to the increase in oligochaetes (Voshell 2002). Oligochaetes and tipulids live in soft sediment (Voshell 2002). Their increased presence in 2013 may indicate soft sediment has been able to accumulate since 2008. The presence of soft sediment was evident at the sampling site (Figure 2.3) among the rocks. This suggests that the post-diversion stormwater inputs were less intense than the pre-diversion stormwater inputs and scouring was not as frequent. Further improvement to the benthic community may be noticed if stream flashiness was reduced.

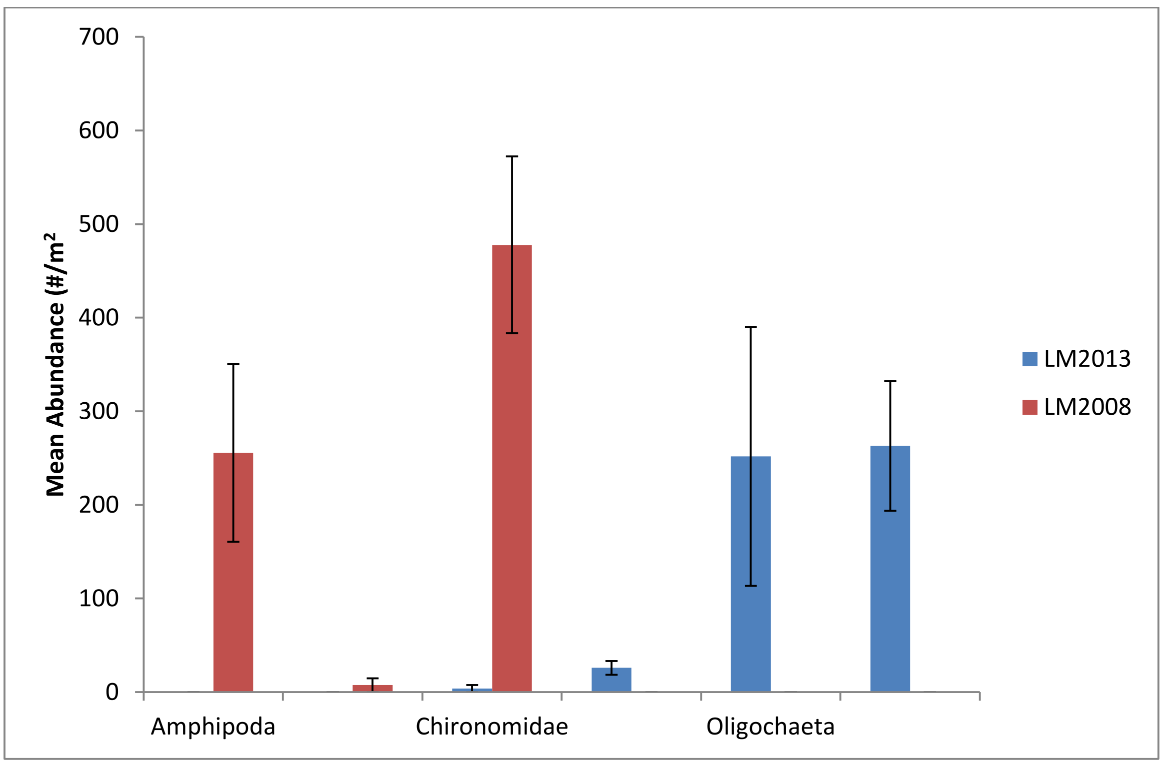

Figure 2.8 Most abundant taxa in samples from the Little Mac stream in 2008 (Snyder et al 2008) and 2013.

Control Stream Comparison

The ANOSIM of the Little Mac stream and the control stream also found the differences in macroinvertebrate assemblages insignificant (p=.109; Figure 2.9). This may be due to the lack of tight grouping, or similarity, of all three samples within the Little Mac stream set. However, the t-tests of the metrics in Table 2.1 revealed significant changes in the family biotic index and richness (p= .033 and .021, respectively). The family biotic index indicates water quality (Hilsenhoff 1988, Table 2.2). Based on the family biotic indices, the water quality in the Little Mac stream is fair and the control stream has good water quality. The lower water quality in the Little Mac stream is likely due to the urban runoff from GVSU's campus. Urban runoff tends to carry contaminants that can lower water quality (EPA 2012). The increased richness could be the result of better water quality. Better water quality can provide habitat for more pollution intolerant species. The richness could also be attributed to different substrate. The Little Mac stream sample site was rockier with little organic matter, while the control stream sample site contained few rocks and an abundance of organic matter. Another possibility for forces driving this variation is the stability and quality of the habitat. Due to the large area of impervious surface draining into the Little Mac stream, it experiences large stormwater inputs during rain events. This flashiness decreases the stability of the habitat and decreases the quality of habitat present. The watershed above the control stream is mostly composed of agricultural and forested land. There are a couple of buildings and a small paved road, but the watershed does not have as much impervious surface around it as the Little Mac stream. The significantly shorter bank heights indicate the control stream experienced less erosion in the past and likely has a less flashy hydrograph (p=.005, Hamilton 2014). Therefore, the habitat in the control stream will be more stable and of better quality than the Little Mac stream.

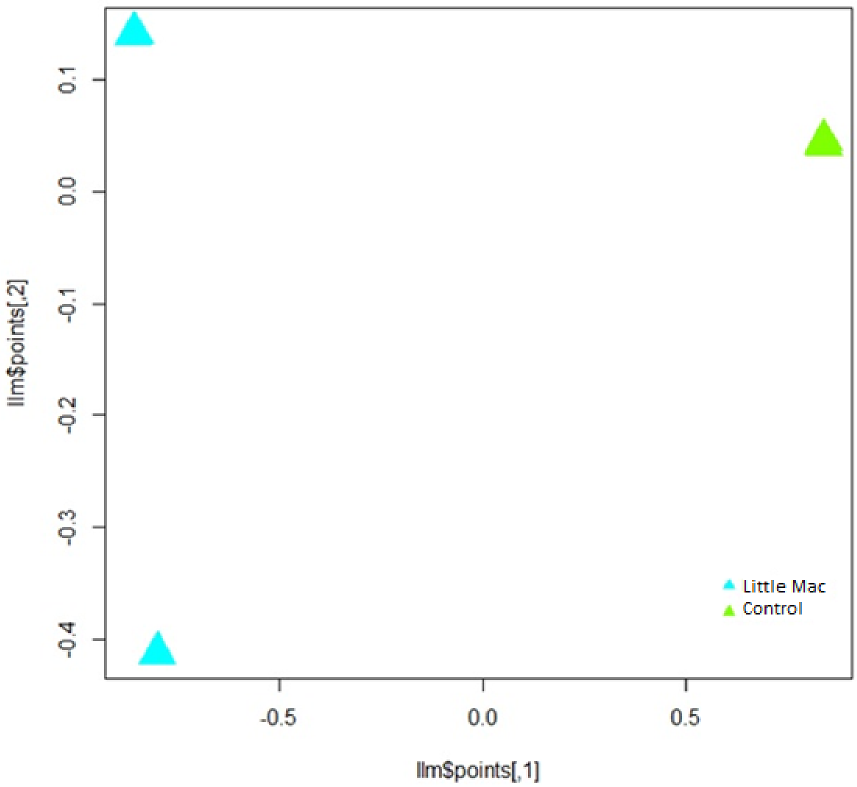

Figure 2.9 Comparison of macroinvertebrate assemblages from Little Mac stream and control stream using ANOSIM. (The three control samples and two of the Little Mac samples were very similar and were overlapped on the figure.)

Table 2.2 Water quality based on family biotic index values (Hilsenhoff 1988).

Family Biotic Index Value	Water Quality Rating
0.00-3.75	Excellent
3.76-4.25	Very good
4.26-5.00	Good
5.01-5.75	Fair
5.76-6.50	Fairly poor
6.51-7.25	Poor
7.26-10.00	Very poor

The variation in substrate explains some of the differences seen in macroinvertebrate compositions (Figure 2.10). Amphipods, tipulids, and isopods are all shredders – they eat organic matter (like leaves) and depend on a stable source of organic matter (Voshell 2002). The

control stream had a large build up of leaf matter in the bottom. Due to the thickness of the leaf pack, it was evident that this was present year round, not just on a seasonal basis. The Little Mac stream did contain some leaf matter; however, it was not nearly as thick or prevalent as in the control stream. The Little Mac stream is also flashier. This would reduce the stability of the leaf litter presence. Turbellaria were most abundant in the Little Mac stream. They mostly consume other soft-bodied invertebrates (Voshell 2002). Since the one of the more common taxa was oligochaetes, the abundance of turbellaria may be linked to a food source.

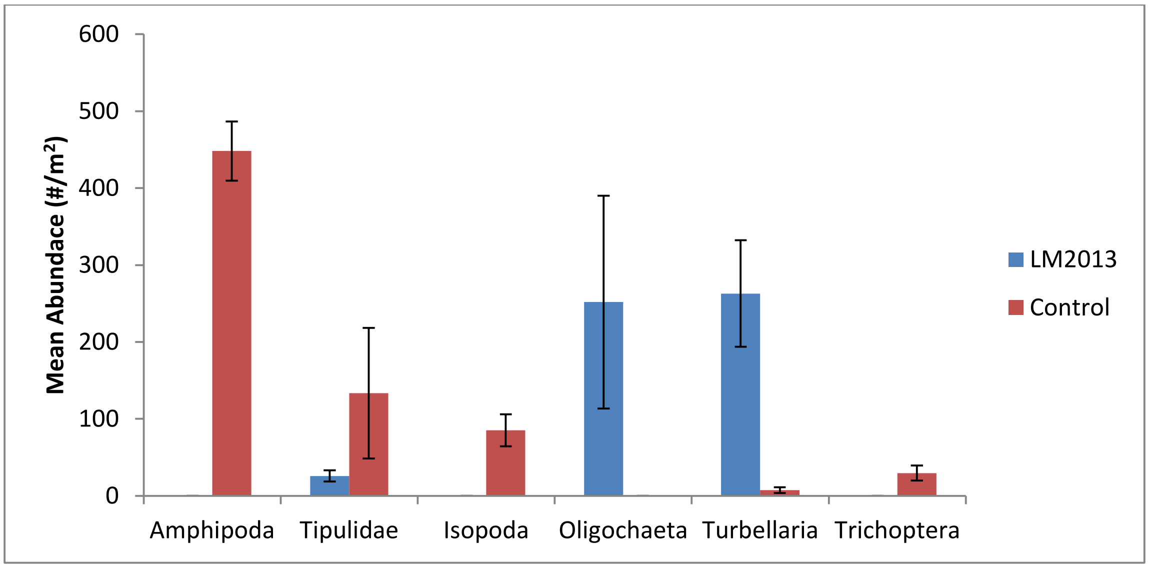

Figure 2.10 Most abundance taxa in samples from the Little Mac stream and the control stream.

The timing of the sampling in 2008 and 2013 could also account for some of the differences present in the samples. The sampling by Snyder et al (2008) was done in June, while the sampling for this report was completed in October. This can result in some inconsistency simply due to seasonal changes in the macroinvertebrate community related to life cycle and size. Sampling during the same time of year will allow for more consistent results, and more

frequent sampling (e.g. annually, quarterly, monthly) will provide a clearer picture of the changes in the benthic community.

Conclusions

Although the ANOSIM found no significant difference in macroinvertebrate assemblages between the control samples and the Little Mac samples, there was a significant difference in family biotic indices. This may indicate a difference in water and habitat quality. It is known that contaminants, like suspended solids and phosphate, are present in the Little Mac stream (Wampler and Kneeshaw 2013). The control stream also contains different substrate than the Little Mac stream – more soft sediment and organic matter. Both of these factors influence the difference in biotic indices. The runoff from impervious surface into the Little Mac stream creates two problems: it carries contaminants from the impervious surfaces that decrease water quality, and it increases the volume and velocity of water in the stream, making the stream more flashy and erosive. Both of these problems degrade the quality of the water and habitat in the stream, and are reflected by the macroinvertebrate samples. No significant changes were found between the 2008 samples and the 2013 samples in the ecological metrics. This indicates that the biotic community had insufficient time to recover from the decrease in stormwater runoff or the stream was still to flashy. More runoff may need to be diverted, or other restoration efforts may need to take place.

Chapter Three

Conclusions and Recommendations

In the past 10 years, GVSU recognized the historical adverse effects of stormwater discharges on the ravines and worked to restore and mitigate current and future impacts. The construction of over 170 acres of impervious surface, in the form of buildings, parking lots, and sidewalks, increased the amount of stormwater flowing through pipes into the ravines. The study done by Snyder et al (2008) demonstrated the impact to the Little Mac stream via macroinvertebrates. This report reveals that the diversion of stormwater to constructed wetlands may not be enough to provide stability within the stream as the benthic community showed insignificant changes since 2008.

Recommendations

Restoration efforts for the stream could include modifying stream substrate to reduce the gradient (the stream is currently very cut in), improving riffle/pool sequences, stabilizing banks with rocks, and planting herbaceous cover in canopy gaps. Stranko et al (2011) examined several urban streams where attempts at restoration were made. In the streams studied, the restoration efforts included planting trees, reconstructing the stream channels, building or modifying stormwater ponds, and creating wetlands. Wetlands at the end of a catchment are able to assist in lowering the contaminant loading and peak flows, though the ability is limited (Burns et al 2012). These practices were found to be ineffective in restoring biodiversity in the streams studied (Stranko et al 2011). The authors, however, hypothesized that restoration may be more effective in less severely impacted streams and at a more comprehensive, watershed scale. This encourages the idea that restoration of biological diversity in the Little Mac stream is feasible: the stream is not severely impacted, and GVSU controls of the entire watershed and works to

make improvements at a watershed scale. Since the Little Mac stream is small, it may be beneficial to explore the possibility of constructing wetlands within the ravines to help moderate flow in the stream and filter out contaminants. The plan of GVSU to reconstruct the stream channel to more closely resemble historical levels may also help improve biodiversity in the stream. Inclusion of riffles and pools will likely assist with that goal.

A monitoring program, including hydrology, water quality, and macroinvertebrates, should be conducted to document the effectiveness of the current stormwater management practices and determine if additional improvements are necessary. Macroinvertebrate samples should be collected the same month to minimize life cycle influences on the populations. The information provided by regular macroinvertebrate sampling would be beneficial to help decision makers understand the impact of changes they made, or need to make, in the watershed.

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