Analysis of Sediment and Possible Effects on Macroinvertibrate Population on the Maple River and Lake Kathleen in Cheboygan, MI

Theresa Regan

University of Michigan Biological Station
EEB 381 – General Ecology
8/17/2015
Dr. Shannon Pelini

Abstract

The Maple River Dam in Cheboygan, MI, is scheduled for removal within the next few years. All studies on dam removal up to this point have begun after the dam has been removed. They usually use sediment samples and macroinvertibrate populations far upstream of the dam location as references to approximate the original conditions of the river downstream of the dam. We took sediment samples on the Maple River downstream of the dam as well as in Lake Kathleen, the reservoir above the dam. We found that sediment in Lake Kathleen is mostly fine-grained organic material, while the dominant substrates in the Maple River are a combination of pebble and cobble. Additionally, there are significantly higher concentrations of PO_4, C, and N in lake sediment than in the river.

It is likely that once the dam is removed, the fine-grained sediment from the lake will wash downstream, carrying nutrients with it. Change in dominant substrate in the Maple River could directly affect macroinvertibrate populations by removing habitat and altering water flow and dissolved oxygen. The influx of nutrients could cause rapid growth of algae or aquatic plants, which would indirectly affect macroinvertibrate populations by altering food and habitat availability. Regardless of the final results, the completion of this study will provide a more accurate understanding of how sediment is transported and deposited after dam, and how this spread of sediment affects macroinvertibrate populations.

I grant the Regents of the University of Michigan the non-exclusive right to retain, reproduce, and distribute my paper, titled in electronic formats and at no cost throughout the world.

The University of Michigan may make and keep more than one copy of the Paper for purposes of security, backup, preservation and access, and may migrate the Paper to any medium or format for the purpose of preservation and access in the future.

Signed,

August 17, 2015

Theresa Regan
August 2, 2015

Analysis of Sediment and Possible Effects on Macroinvertibrate Population on the Maple River and Lake Kathleen in Cheboygan, Michigan

Abstract

The Maple River Dam in Cheboygan, MI, is scheduled for removal within the next few years. All studies on dam removal up to this point have begun after the dam has been removed. They usually use sediment samples and macroinvertibrate populations far upstream of the dam location as references to approximate the original conditions of the river downstream of the dam. We took sediment samples on the Maple River downstream of the dam as well as in Lake Kathleen, the reservoir above the dam. We found that sediment in Lake Kathleen is mostly fine-grained organic material, while the dominant substrates in the Maple River are a combination of pebble and cobble. Additionally, there are significantly higher concentrations of PO_4, C, and N in lake sediment than in the river.

It is likely that once the dam is removed, the fine-grained sediment from the lake will wash downstream, carrying nutrients with it. Change in dominant substrate in the Maple River could directly affect macroinvertibrate populations by removing habitat and altering water flow and dissolved oxygen. The influx of nutrients could cause rapid growth of algae or aquatic plants, which would indirectly affect macroinvertibrate populations by altering food and habitat availability. Regardless of the final results, the completion of this study will provide a more accurate understanding of how sediment is transported and deposited after dam, and how this spread of sediment affects macroinvertibrate populations.

Introduction

Biogeomorphology is the study of linkages between biological and geological processes, namely how geomorphological changes affect biota in the surrounding area (Naylor *et al.*, 2002). This concept can be applied to environmental restoration efforts, including environmental engineering on streams through dam removal.

Streams and small rivers have habitats with moderately moving currents and unbroken water that can be described as “runs,” and habitats with swift currents and turbulent water that can be described as "riffles" (Hicks and Watson, 1985). While runs may flow over a variety of sediment substrates, riffles tend to occur over cobbles (Hicks and Watson). These riffle habitats house many aquatic macroinvertibrate populations, particularly immature stoneflies and caddisflies, because of the large concentration of dissolved oxygen and the shelter provided by the cobblestones (Wallace and Anderson, 1996).

When dams are removed from streams, there is initially an increase in water flow through the river that was once downstream of the dam. This increase in water flow will change the existing channels in the river (Hart *et al.*, 2002). However, it is difficult to predict how flow rates and channel geomorphology will change, as flow rate in particular is greatly determined by the size and friction given by sediment in the streambed (Hart *et al.*; Newbury, 1984).

After dam removal, a channel forms in the reservoir and fine sediment immediately begins to flow downstream (Doyle *et al.*, 2005). When sediment is deposited, it greatly changes the shape of the riverbed and flow of water. The location of runs and riffles in a stream may change. This may affect macroinvertibrate recovery time, as populations in runs can take years longer to recover than those in riffles (Hansen and Hays, 2012).

Sediment from the reservoir also holds nutrients, particularly nitrates and phosphates, which have come from fertilizer used for agricultural and urban land (Stanley and Doyle, 2002). This influx of nutrients affects vegetation recovery after the dam removal. This also may affect aquatic macroinvertibrate populations, as their recovery is very dependent on habitat recovery and food availability (Doyle *et al.*)

Generally after a dam is removed, a deep channel begins to form in the former impoundment, then widens and decreases in depths as new sediment accumulates, and eventually reaches quasi-equilibrium (Stanley and Doyle, 2002). This process may take years, but macroinvertibrate populations in former impoundments tend to reach very similar levels to populations upstream within one year of dam removal (Doyle *et al.*; Hart *et al.*).

The West and East branches of the Maple River in Northern Michigan flow into Lake Kathleen, in Emmet County, MI. The lake was created by the Maple River Dam, which was reconstructed in 1967 to replace a previous dam that had been destroyed in 1952 (Godby, 2014). Since its construction, the dam has prevented much of the sediment from upstream from being carried into the main branch of the Maple River. Since 2013, the Conservation Resource Alliance in Michigan has advocated for the dam's removal (Godby, 2014). If the dam were to be removed, much of the sediment in Lake Kathleen would be washed downstream. Additionally, the increased volume of water in the Maple River would greatly alter its topography, which would in turn affect the amount and type of sediment that would collect in different sites along the river.

We hypothesized that sediment collected from Lake Kathleen would be comprised of smaller particles than those in the combined branch of the Maple River. When the Maple River Dam is removed, the fine sediment from the lake will likely wash into the river and be deposited most heavily at river bends. In sites where this sediment is deposited, the biogeomorphology and nutrient densities of the local habitats will change, affecting both the size of macroinvertibrate populations and the time it takes them to recover to their original numbers. In order to establish a database of pre-dam removal conditions, we collected and analyzed sediment from Lake Kathleen—where sediment composition is largely unknown—and the Maple River. The data that we collected can be used as a reference in the future to compare conditions of the Maple River before and after the removal of the dam. This will provide a more complete analysis of the effects of the removal of the Maple River Dam, and hopefully can contribute to a broader understanding of dam removal and biogeomorphology.

Materials and Methods

Collection Sites

We had five collection sites in the combined branch of the Maple River (sites 7, 14, 18, 22, and 31), which we chose from a preexisting set (Appendix A). We chose these sites based on their proximity to bends in the river, which are likely to accumulate sediment washed downstream from the reservoir once the dam is removed.

We had ten collection sites in Lake Kathleen (Appendix B). We attempted to spread these sites out such that we would collect samples near where the East Branch flows into the lake, near where the West Branch flows into the lake, near the dam, and then evenly spaced throughout the lake. We used a GPS unit to record our location at each sampling site.

Sediment Collection

At each site on Lake Kathleen, we used an Ekman grab to collect one sediment sample, which we stored in separate plastic containers kept on ice. We also used a Dissolved Oxygen meter to measure temperature and dissolved oxygen in mg/mL at 0.5m below the surface. These data were added to the arcGIS database. Once we returned to Lakeside Lab, we separated the sample from each site into three 50mL centrifuge tubes and one 500mL Nalgene bottle.

We had five sampling locations in the combined branch of the Maple River. At each site, we measured the width of the riverbed. We divided this transect into $1m^2$ sections using a $1m^2$ PVC quadrat, and in each section we used a metal hand spade to remove the top 2cm of soil along the diagonal of the square. This soil was placed in a plastic container, with the sample from each quadrat layered on top of the previous samples. We transported the plastic containers in a cooler to Lakeside Lab.

At each site in the Maple River, we identified the dominant microhabitats. In each of these, we placed a $0.25m^2$ PVC quadrat and collected the top 2cm of substrate from within that square, which we placed in a 500mL Nalgene bottle. These were also transported back to Lakeside Lab in a cooler.

Chemical Analysis

We prepared samples from all five sites on the Maple River and all 10 sites on Lake Kathleen for analysis on Nitrate (NO_3), Ammonium (NH_4), and Phosphate (PO_4) concentrations (ug/L), percent Carbon (C) and Nitrogen (N), and the Carbon to Nitrogen ratio (C:N). After samples were prepared, they were stored in a freezer and then analyzed by Timothy Veverica at Lakeside Lab at the University of Michigan Biological Station.

To prepare samples for NO_3 and NO_4 analysis, we measured a wet 2g of sediment and 40mL of 2M KCl into an acid-washed 50mL centrifuge tube. These tubes were mechanically shaken for 60 minutes. We then filtered the solution through a syringe into another acid-washed 50mL centrifuge tube.

To prepare samples for PO_4 analysis, we measured a wet 0.2g of sediment and 400mL of Troug's solution into a 500mL acid-washed centrifuge tube. These tubes were mechanically shaken for 60 minutes, before we filtered the liquid solution through a syringe into another acid-washed 50mL centrifuge tube.

To prepare samples for C, N, and C:N analysis, we filled a small metal drying tin with sediment from each site. We dried these samples at 100C for 48 hours. We then put the dry samples through a ball mill for 5 minutes, and put the milled sediment into acid-washed 50mL centrifuge tubes.

Physical Analysis

We used a sediment corer to select a smaller sample from our large plastic container of layered sediment from the river. We dried these samples at 100C for 48 hours, along with the 500mL of sediment from lake sites B, C, D, G, and J.

After the samples had dried, we separated pebble and cobble sized substrates out of the river samples by sifting all of the sediment through a grate with 4mm holes. We weighed the pebbles and cobbles that did not pass through the grate, then used digital calipers to measure the individual pieces at each site and further classify them according to the Wentworth scale (Wentworth, 1922) (Table 1). The sediment from Lake Kathleen, which had originally been very fine, had dried into very hard clumps. To return the sediment to its original state, we milled it in a ball mill for five minutes.

THE GRADE TERMS

The Pieces	The Aggregate	The Indurated Rock
Bowlder	Bowlder gravel	Bowlder conglomerate
256 mm.		
Cobble	Cobble gravel	Cobble conglomerate
64 mm.		
Pebble	Pebble gravel	Pebble conglomerate
4 mm.		
Granule	Granule gravel	Granule conglomerate
2 mm.		
Very coarse sand grain	Very coarse sand	Very coarse sandstone
1 mm.		
Coarse sand grain	Coarse sand	Coarse sandstone
1/2 mm.		
Medium sand grain	Medium sand	Medium sandstone
1/4 mm.		
Fine sand grain	Fine sand	Fine sandstone
1/8 mm.		
Very fine sand grain	Very fine sand	Very fine sandstone
1/16 mm.		
Silt particle	Silt	Siltstone
1/256 mm.		
Clay particle	Clay	Claystone

Table 1. Classifications of substrate types based on diameter of particles, known as the Wentworth Scale.

After the larger pebbles and cobbles were removed, we mechanically shook each sediment sample for 60 seconds through a series of sieves with openings of 2mm, 1/2mm, 1/8mm, and 1/16mm. We weighed the amount of sediment in each of the six size classes that were separated by the sieves (including >2mm and <1/16mm), then calculated the percent of the total sample mass that was in each category, counting all pebbles and cobbles with diameter >4mm as one category.

Statistical Analysis

We used a student's t-test to analyze differences in the presence of NO_3, NO_4, PO_4, C, N, and C:N above and below the dam. We also used a chi-squared test to evaluate the evenness of of Wentworth sediment classes present both in Lake Kathleen and the Maple River.

Results

Chemical Analysis

There were no significant differences in NO_3 (t=0.689, p=0.497, df=13) and NH_4 (t=1.413, p=0.181, df=13) concentrations in sediment in Lake Kathleen and the combined branch of the Maple River (Fig. 1). There were also no significant differences in the C:N ratio (t=0.231, p=0.829, df=4.083) in the lake and the river (Fig. 3).

There was a significant difference in PO_4 concentrations (t=6.243, p<0.001, df=13) in the lake and the river (Fig. 1). There were also significant differences in C (t=6.054, p<0.001, df=13) and N (t=5.452, p<0.001, df=13) levels in the lake and the river (Fig.2).

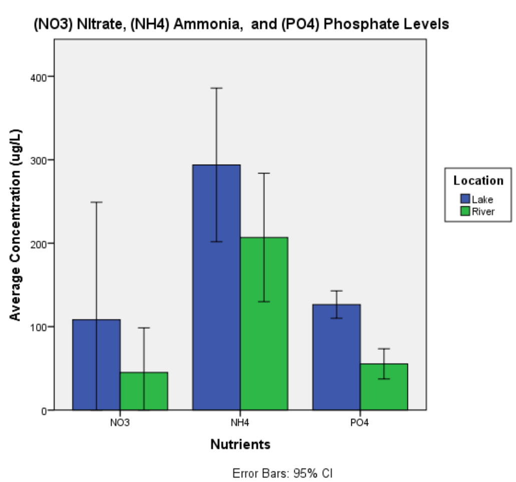


Fig. 1: A comparison of nitrate, ammonium, and phosphate concentrations in both bodies of water. Only PO_4 had a statistically significant difference in the lake and the river.

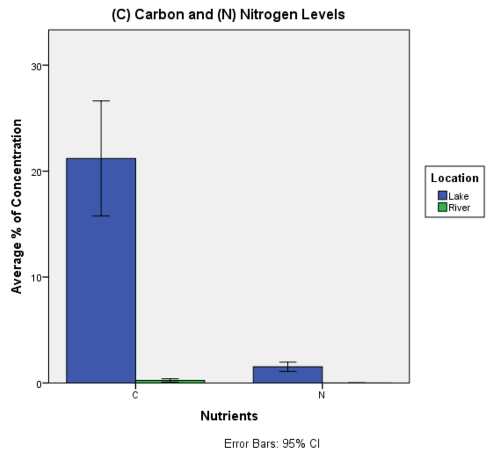


Fig. 2: C and N percentage in both locations. Sediment in Lake Kathleen is comprised of a lot of organic material.

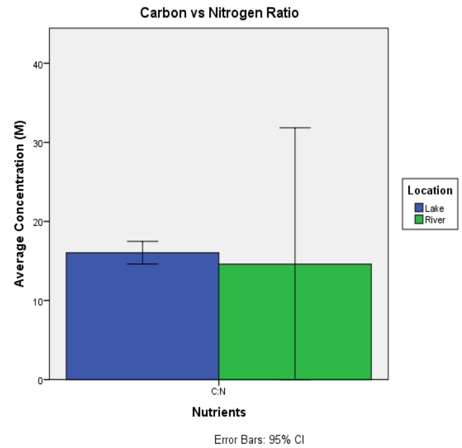


Fig. 3: Carbon to Nitrogen ratio in both locations. There was no significant difference between the two.

Physical Analysis

Chi-square analyses revealed uneven distributions of substrate size type in both Lake Kathleen (X^2=1589.896, p<0.001, df=4) and the combined branch (X^2=15123.597, p<0.001, df=5). In Lake Kathleen, most of the sediment was medium-fine sand, which comprised 81.5% of all sediment (Fig. 4). In the combined branch of the Maple River, pebble and cobble made up 71.2% of the substrates (Fig. 5). Specific breakdown of pebble/cobble sizes varied between the sites (Fig. 3).

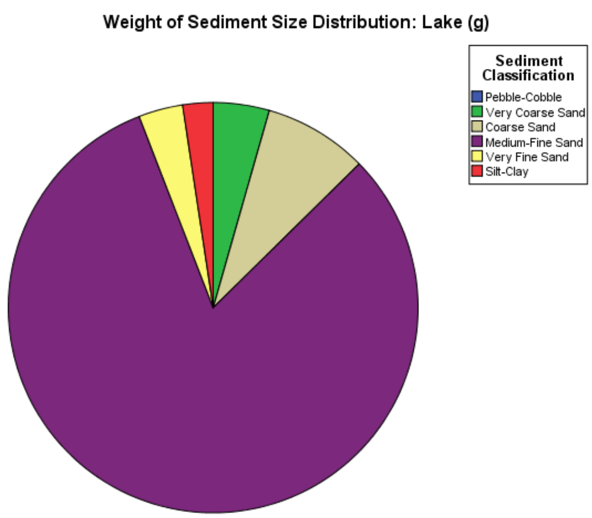


Fig. 4: Composition of substrate types in Lake Kathleen. Pebble-cobble=0.00%; Very coarse sand=4.42%; Coarse sand=8.21%; Medium-fine sand=81.48%; Very fine sand=3.49%; Silt-clay=2.39%.

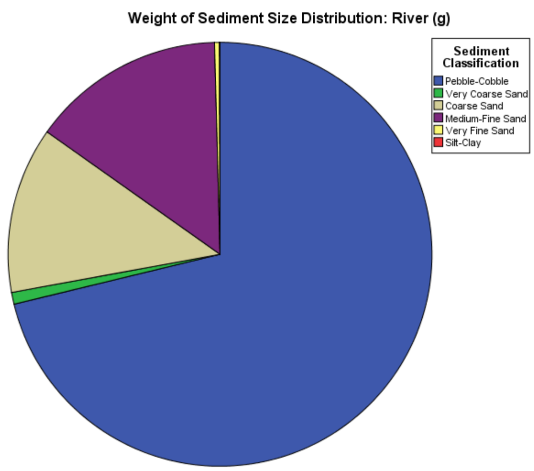


Fig. 5: Composition of substrate types in the Maple River. Pebble-cobble=71.22%; Very coarse sand=0.90%; Coarse sand=12.68%; Medium-fine sand=14.78%; Very fine sand<0.01%; Silt-clay<0.01%.

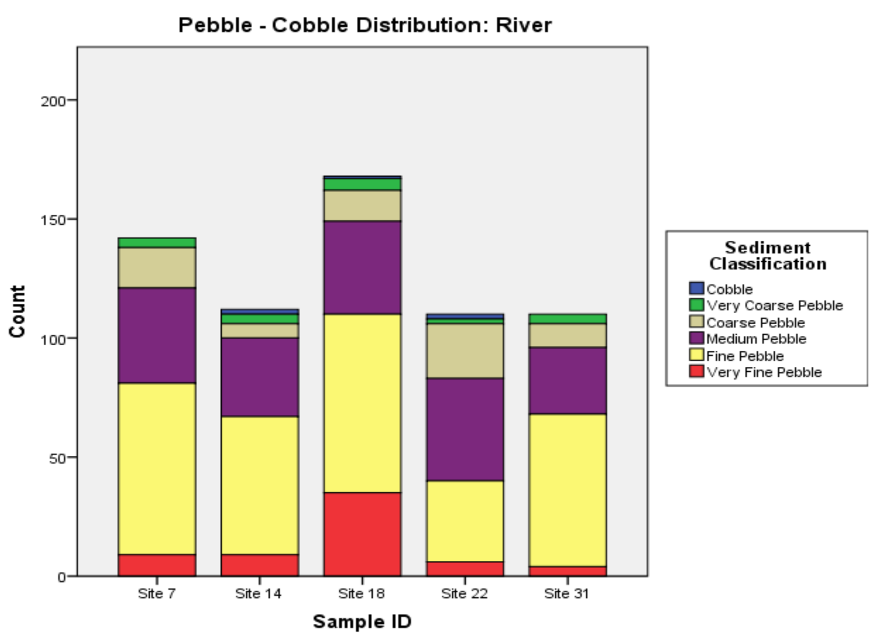


Fig. 6: Variance in pebble and cobble classification at each river site. All sites were comprised mostly of fine and medium pebble. Site 18 in particular had a lot of clay.

Discussion

The size of sediment substrates in Lake Kathleen was drastically smaller than the average size of substrates in the combined branch of the Maple River. The medium-fine sand in the lake will begin to flow downstream immediately after the dam is removed. When sediment from the lake flows into the river, it will take nutrients with it. As PO_4, C, and N were the nutrients that were significantly more abundant in the lake than the river, the influx of these nutrients into the river will have a strong affect. These nutrients, particularly PO_4, bond easily to small sediment particles (Stanley and Doyle, 2002). So while we cannot predict where sediment will be deposited, we can assume that deposition sites will show increased PO_4, C, and N levels even if they are located far downstream from the dam.

The Maple River currently has pebbles and cobbles as its dominant substrate. They are a habitat for many aquatic macroinvertibrates such as caddis flies and stoneflies (Wallace and Anderson, 1996). If fine-grained sediment from Lake Kathleen is deposited over these sites, the cobble will no longer provide shelter to these organisms, and their populations will either diminish or migrate. Furthermore, replacing cobble with sand will affect the friction that the "boundary layer" of the dominant substrate applies to the water, and in turn will affect the water flow (Wallace and Anderson). This will be problematic for filter-feeding insects that are dependent on a specific velocity of moving water.

Additionally, replacing cobble with sand could decrease water turbulence over riffles, which would result in diminished dissolved oxygen levels. This effect may be compounded if the PO_4, C, and N carried in the fine sediment spawn algae blooms that resulted in eutrification. Macroinvertibrate populations in areas of decreased dissolved oxygen would also diminish or migrate.

While fine sediment deposition over cobbles in riffles would certainly decrease available habitat for the macroinvertibrate populations that rely on riffle habitats, sediment deposition elsewhere could potentially aid other macroinvertibrate populations in their recovery. The nutrients in the fine-grained sediment could allow growth in aquatic plant populations after the dam removal, which would provide habitat and food to some herbivorous macroinvertibrates.

Previous studies of the effects of dam removal have relied on sediment samples and populations of macroinvertibrates far upstream as a reference to what the ecosystem downstream of the dam was like before its removal. In analyzing sediment size and chemistry before dam removal, both in the reservoir and downstream, we have created a database that can be used as an accurate reference of pre-dam removal conditions. Further study of sediment composition once the dam is removed will complete the first study done on a specific dam removal both before and after said dam is removed. This will provide a more accurate understanding of how sediment from a reservoir moves and gets deposited, and how this spread of sediment through the downstream habitats affects macroinvertibrate populations.

Works Cited

Doyle, M. W., E. H. Stanley, C. H. Orr, A. R. Selle, S. A. Sethi, and J. M. Harbor. 2005. Stream ecosystem response to small dam removal: lessons from the heartland. Geomorphology. 71:227-244.

Godby, N. 2014. Status of the fisheries report. Michigan Dept. of Natural Resources.

Hansen, J. F., and D. B. Hays. 2012. Long-term implications of dam removal for macroinvertebrate communities in Michigan and Wisconsin rivers, United States. River Res. Applic. 28: 1540-1550.

Hart, D. D., T. E. Johnson, K. L. Bushaw-Newton, R. J. Horwitz, A. T. Bednarek, D. F. Charles, D. A. Kreeger, and D. J. Velinsky. 2002. Dam removal: challenges and opportunities for ecological research and river restoration. Bioscience. 52: 669-681.

Hicks, B. J., and N. R. N. Watson. 1985. Seasonal changes in abundance of brown trout (*Salmo trutta*) and rainbow trout (*S. gairdnerii*) assessed by drift diving in the Rangitikei River, New Zealand. New Zealand Journal of Marine and Freshwater Research. 19:1-9.

Naylor L.A., H. A. Viles, N. E. A. Carter. 2002. Biomorphology revisited: looking towards the future. Geomorphology. 47:3-14.

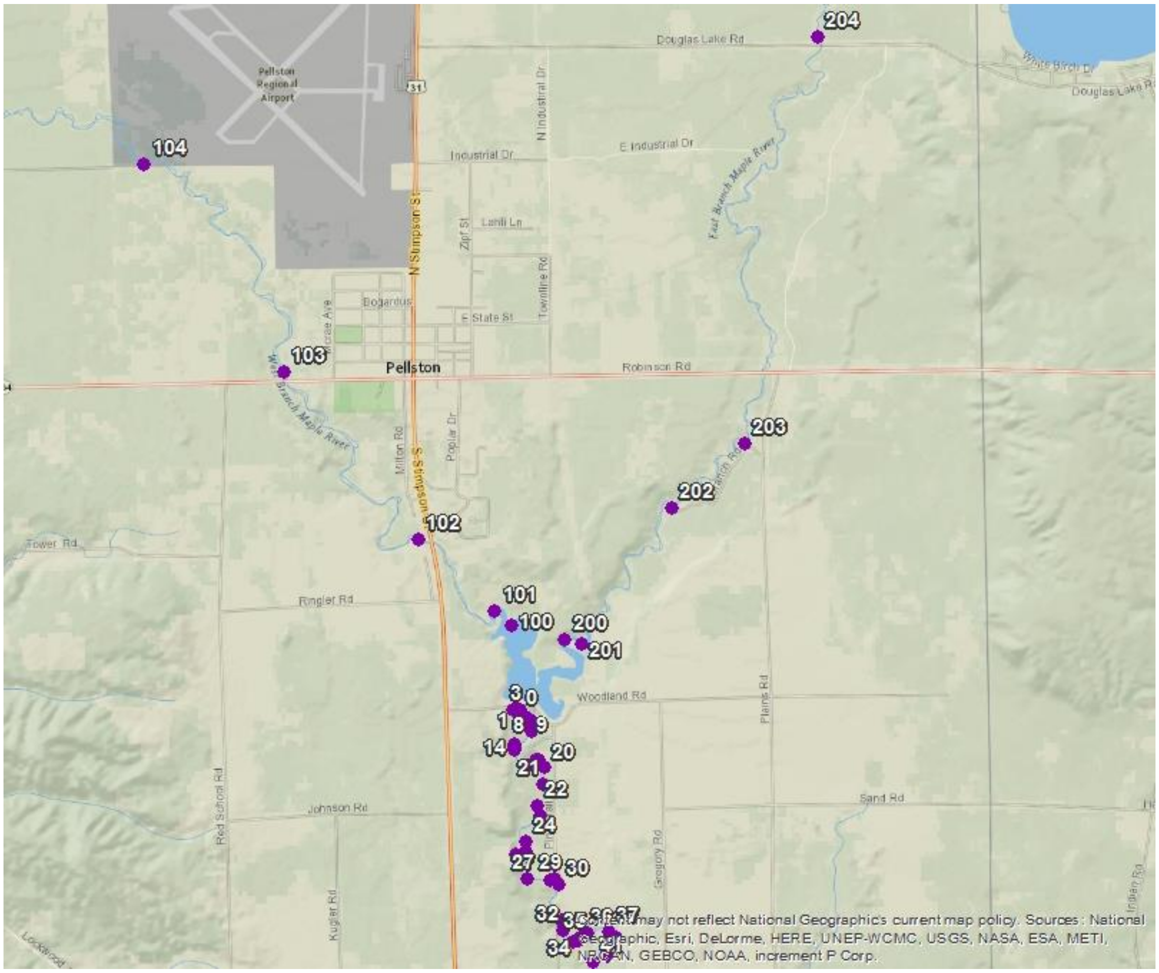
Newbury, R. W. 1984. Hydrologic determinants of aquatic insect habitats, pp. 323-357. *In* V. H. Resh and D. M. Rosenberg (eds.), The ecology of aquatic insects. Prager Publishers, New York, NY.

Stanley, E. H., and M. W. Doyle. 2002. A geomorphic perspective on nutrient retention following dam removal. Bioscience. 52:693-701.

Wallace, J. B., and N. H. Anderson. 1996. Habitat, life history, and behavioral adaptations of aquatic insects, pp. 41-73. *In* R. W. Merritt and K. W. Cummins (eds.), Aquatic insects of North America. Kendall/Hunt Publishing Company, Dubuque, Iowa.

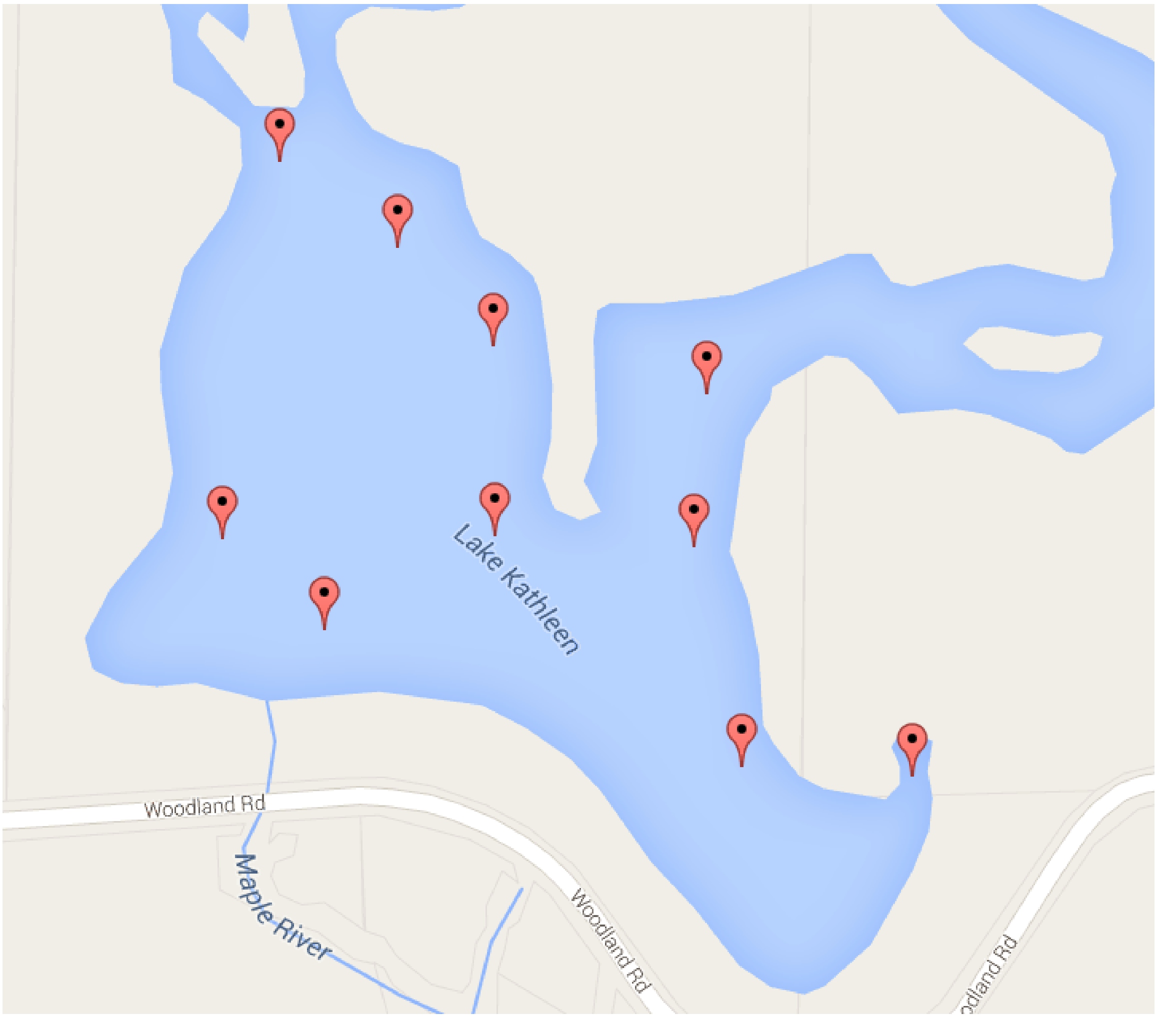
Wentworth, C.K. 1922. A scale of grade and class terms for clastic sediments. The Journal of Geology. 30:377-392.

Appendix A



A map of sample sites along the maple river. Our samples came from sites 7, 14, 18, 22, and 31.

Appendix B



A map of sample sites in Lake Kathleen.