Quantitative Suspended Sediment Analysis within the Macatawa Watershed

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Abstract:

Our study intended to analyze the relationship between riparian buffer width and concentrations of suspended sediments found in the immediately adjacent watershed through the development of a cheap and effective method of suspended sediment capture. Suspended sediment loads within the Macatawa Watershed are massive and known to carry pollutants from the land into the watershed. Chemicals such as phosphorous are low in solubility and are effectively carried into the watershed by forming complexes with soil particles that are then washed into the watershed by precipitation events. We designed and constructed out of Tupperware containers a cheaper alternative to extremely expensive methods of analyzing suspended sediment concentrations. We tested the percent efficiency of our traps in the lab using a constructed stream simulator. We also tested our method in the field. Although our design was not perfect, the results of our study are that cheaper while still effective methods of suspended sediment analysis are possible, and our research shows insights into how this could be accomplished and used in a wide variety of applications, including analyzing the relationship between riparian buffer widths and suspended sediment concentrations.

Introduction:

Experiments such as our study are capable of applying to broad conservation projects. In seeking to identify a relation between riparian buffer zone width and suspended sediment levels within streams, guidelines may be constructed in determining safe land development for the Macatawa Watershed. The Izaak Walton League of America identified that the preservation of watersheds depends on many things; widespread scientific, local, government, and citizen education and support. They identify components of stream ecology that are influenced by land use practices. Indications of degradation due to manipulation and development of riparian zones are seen in the hydrology streams, the increased levels of nutrients used in fertilizer application in the watershed, habitat degradation for fish and macro-invertebrates, riparian and floodplain vegetation, and water quality and its channel dimensions (Middleton 2001). Characterization of the site is important to the study for

Fig. 1. The Macatawa Watershed

applicable programs, where it is found that "the most successful restoration projects develop solutions for specific areas (Middleton 2001)."

Riparian buffer zones, the vegetated regions immediately adjacent to streams and wetlands, are thought to be extremely effective at reducing harmful products in agricultural and urban non-point source runoff (Mayer et al. 2007). Riparian buffer width is thought to be positively correlated to nitrogen removal and retention (Mayer et al. 2007). The wider a riparian buffer is, the greater the health of the aquatic system in a variety of ways. However, in a developing world, defining suitable widths of riparian buffer zones that will allow maximal land use as well as aquatic system health becomes a key concern (Gorsevski et al. 2008). The assessment of riparian buffers is vital to watershed management (Liu et al. 2007). Basically, riparian buffers play important ecological roles in erosion prevention and bio-filtration of pollutants.

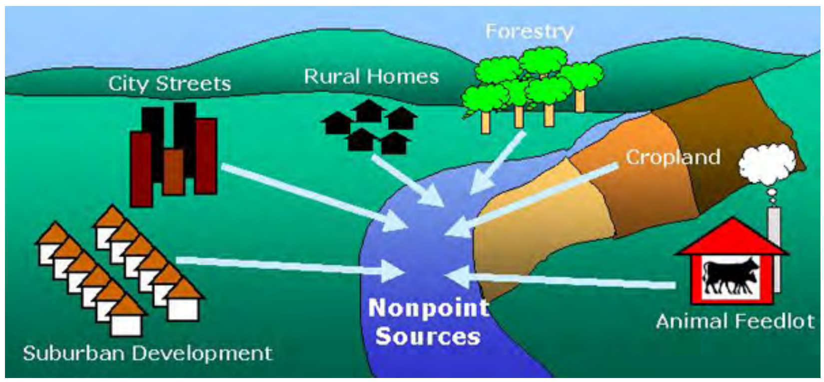


Fig. 2. Diagram of how pollutants enter the watershed as a result of runoff. Buffer zones intercept this runoff and act as filters or sponges. http://www.magazine.noaa.gov/stories/mag112.htm

In addition to the width of a buffer zone; vegetation type, soil type, subsurface hydrology, and subsurface biogeochemistry are also important factors governing the removal and retention of runoff contaminants (Mayer et al. 2007**)**. The slope of the buffer zone can also play a role as it affects the retention time of the runoff water and therefore has a reduced capacity to moderate water quality (Hazlett et al. 2008). Species composition is also positively correlated with high levels of runoff contaminants in stream water (Hazlett et al. 2008). One study showed a significant difference between entirely herbaceous buffers and buffers that also had woody plants in their ability to trap sediments and sediment bound nutrients (Lee et al. 2000). Species indices are used to characterize specific species compositions to project the riparian buffer zone's efficiency and effectiveness. Riparian buffer zones have also been shown to play a significant role in temperature regulation and moderation of the stream habitat they buffer (Wilkerson et al. 2006).

Fig. 3. Example of a riparian buffer in agricultural land
pubs.usgs.gov/circ/circ1209/major_findings.html

Suspended sediments are soil particles suspended within water as a result of erosion, runoff, and stream bed disturbance. They are a natural part of stream ecology. One of the most important runoff pollutants found within the Macatawa watershed is phosphorous. This phosphorous is hard to measure since the vast majority found in the water is complexed with sediment particles. When it rains, these complexes of sediments and phosphorous found in fields and urban lawns erode and eventually find their way into a stream or watershed. Riparian buffer zones are important for their filtration and capture of these sediments before they reach the water and cause aquatic environmental damage. High phosphorous loads results in the eutrophication of the watershed. A clear positive relationship between suspended sediment levels in the water and the level of sediment-bound pollutants exists. One study showed that a near 30% abatement in sediment resulted in a 40% reduction in total phosphorous in the watershed (Liu et al. 2007).

In light of all of this known information, suspended sediment measurements do take place within watersheds across the globe. The only problem is that present methods require extremely complicated and expensive pieces of equipment. Prices for these pieces of equipment are usually in the thousands of dollars, which limits the capabilities of studies on suspended sediment measurement.

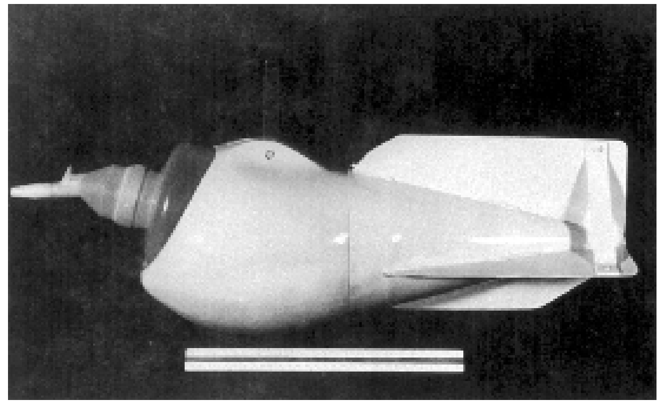


Fig. 4. Depth-Integrating Suspended Type- US D-77- an example of a suspended sediment measuring device. This particular model costs $2,130 dollars. http://www.rickly.com/ss/depth-integrating-samplers.htm

Our study aims at developing a cheaper yet still effective method of suspended sediment capture and analysis. We developed a plan for constructing sediment traps out of Tupperware containers. We tested the percent efficiency of these traps and tested them in the field. We concentrated on a particular site and method in the hopes that it can be perfected and used to characterize the buffer system within the entire Macatawa Watershed.

We expect to observe an inverse relationship between riparian buffer width and the level of suspended sediment concentration within the watershed. As the riparian buffer width is decreased the amount of suspended sediments will increase. At some point we expect to reach an optimal buffer width at which an increase in riparian buffer width would result in minimal reduction in suspended sediment concentration within the watershed.

Materials and Methods:

We are looking to perfect a cheap and effective suspended sediment capture technique to analyze the effect of riparian buffer zone width on sediment runoff retention after precipitation. This project will be centered on the collection of suspended sediments flowing in the waters of various small streams within the Macatawa watershed. In order to collect suspended sediments we will construct a suspended sediment trap. The design for the sediment trap we will make and use was inspired by the work of McDowell and Wilcock 2006, but will be significantly modified using cheaper material.

The trap was made from ordinary Tupperware available at any grocery store. We then cut out one square inch holes on each end of the trap. This design allows the water to enter through the first hole and then slow down inside our trap enough to allow suspended sediments to drop out before the water leaves through the other hole. We also covered the hole with a mesh that would allow water and sediments through but not organic matter such as leaves for our field trials.

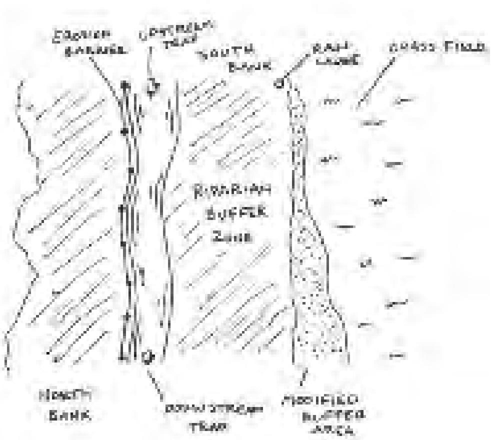
Fig. 5. Suspended Sediment Trap design.

According to McDowell and Wilcock 2006 this cavity between the two smaller holes has a cross sectional area much greater than the inlet and outlet holes and drastically decreases water flow velocity relative to ambient flow, thereby enhancing sedimentation. Samplers can capture as much as 70 to 80% of the sediment that passes through them, thus obtaining a sample representative of SS (suspended sediments) over a defined time period for small streams.

In order to determine the percent efficiency of our trap design we created a simulated stream in a lab to then find a function that would extrapolate to our field data. We used a large aquatic tank to build the structure in and used plastic sheeting to create the reservoir and streambed. The plastic sheeting was held up by duct tape and was also used to secure our trap during trial runs. We took a high powered pump and placed it in the left end of the tank before creating the reservoir above it. The reservoir was held up on the other end by a wood plank that would also serve as the start of the streambed. Therefore when water was pumped from underneath the system it would fill the reservoir and then flow into the streambed at a constant rate. The streambed was on a small angle and ended before the end of the tank to allow the water to recycle underneath to our pump. Directly before the end of the streambed we placed a fish filter to catch the sediment we introduced to the streambed. In order for us to calculate the concentration of the water we needed to know how much water flowed through the system and the amount of sediment added. If the sediment from previous runs was allowed to move freely in the system more sediment would be entering the streambed than accounted for. Finally we cut a hole in the plastic making up the streambed about half way down for our trap to fit into. In the stream water would flow all around the trap but in our design it would only run about half way up the trap so we needed to sink it in order for water to enter the trap successfully. Also important to the design was a small slit we cut for ventilation between runs. When we needed to remove the trap to weigh the captured suspended sediments we needed to empty some water and refill it. This created an air bubble that did not allow our streambed to lay flat.

Fig.6. In-lab stream simulator

The constructed stream simulator was used to determine a percent efficiency of our sediment trap design. A trap was placed and secured in the flow of the stream simulator. The amount of time it took to fill the trap up to various amounts was recorded. From this data a logistic curve was developed from which the time it took for the stream simulator to completely fill the trap with water was calculated. Then 50 grams of dried sediment, collected from the field site of this study, was slowly and constantly sprinkled into the water upstream from the trap. The time over which this addition occurred was also recorded. The amount of sediment trapped was carefully removed, filtered out using a Buchner funnel and filter paper, dried, and then weighed and recorded. The logistic curve was used to calculate the time period for which 600 mL (full trap capacity) was cycled through. The length of each run was then used to determine the amount of water cycled through the trap. A measurement of the pump rate of our stream simulator pump was taken to determine the total amount of water being pumped. The known amount of sediment was divided by this to get a concentration of the water. Then end result was a computation of a percent efficiency of our trap design by laboratory testing.



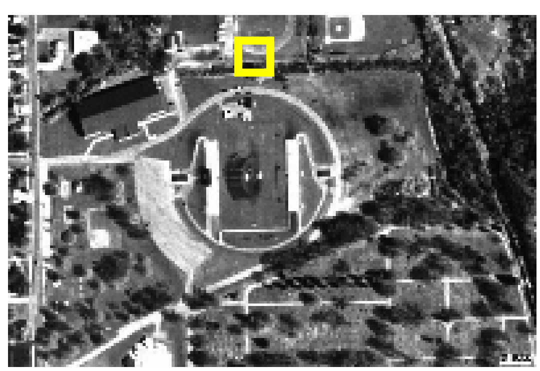


Fig. 7. Aerial view of Holland Municipal Stadium. Field study site is highlighted in yellow.

To test our proposed method in the field, a site was chosen in a creek just north of the Holland Municipal Stadium. The creek ran east to west between Hope College property and the City of Holland's property. A 10 meter long section of nearly straight creek was chosen. The riparian buffer was highly herbaceous with a few woody plants. The buffer was artificially straightened using cutting tools so that it was a uniform 6 meters wide all the way along the 10 meter long section. Along the north bank, an erosion barrier made out of stakes and plastic tarping was installed to isolate the effects of the riparian buffer zone on the south bank. A rain gauge was installed in the buffer region so that the amount of rain that fell on it during a trial could be recorded. Two traps were used, an upstream and a downstream trap, so that the upstream trap could measure the amount of suspended sediments entering the system and the downstream trap would measure the addition of suspended sediments over the study area, determined by the difference between the two trapped sediment amounts. Traps were left out over a known time period so that the approximate amount of water cycling through them could be determined. Sediment was carefully removed, filtered out by Buchner funnel and filter paper gravity filtration and then dried in an oven and weighed. The amount of precipitation that fell over the trial was also recorded.

To determine the relationship between buffer width and suspended sediment concentrations we proposed a method of roto-tilling away strips of the herbaceous buffer and observing any subsequent effect on the level of suspended sediment concentration within the water.

Results:

Due to our limited man power we collected two field samples during this experiment. Both of these were collected when the buffer width was 6m so it was never manipulated in our experiment. We were also concerned about the suction created by the mesh pulling leaves and other organic matter up against the front of the trap. We therefore decided instead to cut it out of our design and just let the organic matter in. (One time we even caught a small creek chub!) In lab we also had to make some adjustments. We saw that as water flowed down to our trap it all was directed toward the front of our trap due to the weight of the water on the plastic stream bed. This was a flaw in the design and could be corrected in future studies. We also observed that since the design had a flat wall where the water entered, water that normally would not enter was obstructed by the design and therefore hitting against the front and flowing toward the trap again. Both of these were design issues and allowed more opportunity for sediment to flow into the trap. We were not therefore able to calculate a percent efficiency from these methods.

From the time trials projecting the water flow through the in lab stream traps we could create a function of how much water was flowing through the trap over time. From this equation we then calculated the point where the function intersects 600mls (Fig 8).

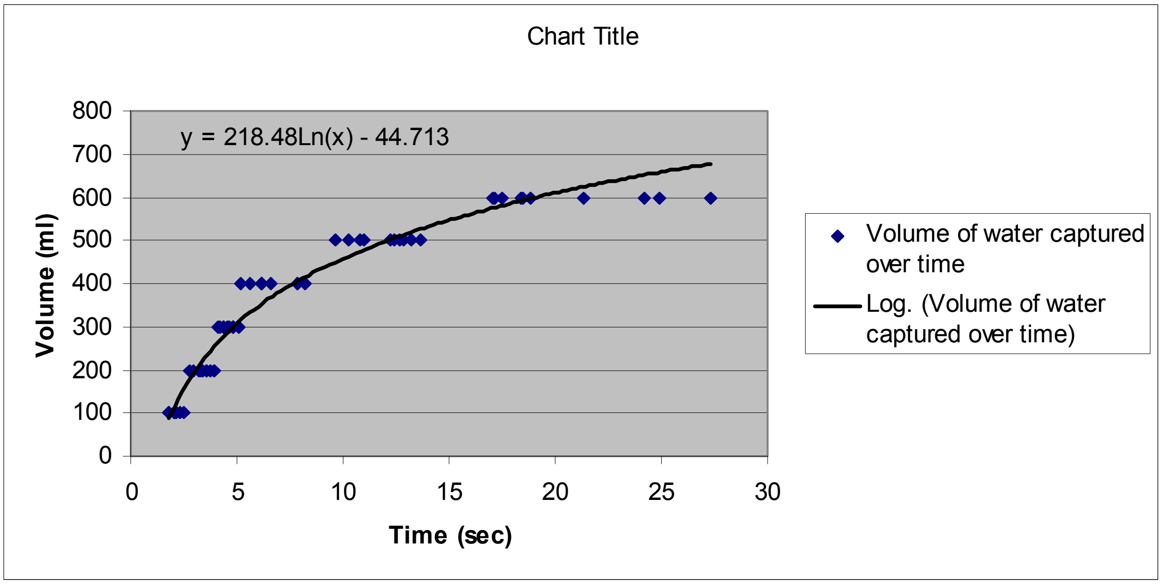


Fig. 8. In-lab volume of water entering trap over time

This was done since the traps both in the field and in the lab sediment simulations were running at full capacity. This determined that every 19.117 seconds 600ml of water had flowed through. We observed that the flow rate affected the percent of sediment captured. When the sediment was introduced to slow or too fast into the stream the traps caught less. After calculating the concentration of sediment in the water and amount of water that flowed through the traps we found percent efficiencies of between 100 and 200%. We attributed these to the problems with the design. Therefore we took a rudimentary percentage, dividing the amount captured by the amount of sediment loaded (50g). This produced a wide range from between 9 and 30%. Since these we considered not accurate. We chose an arbitrary 10% efficiency of our traps to analyze our field data. We also estimated the area of our stream bed with a width of 3ft and a depth of 2ft. We then would know that the amount we caught was only 1 square in of the entire area. The two runs we sampled consisted of one dry and one wet. Since we did not manipulate the riparian buffer width it was unnecessary to distinguish between the upstream and downstream traps so we averaged their capture for our calculations. The dry run occurred when no rainfall had occurred prior and .1 in was observed during our run. From this we captured .3g which if the trap was 10% efficient would correlate to 3g that should have been captured. Therefore, during a 24 hr period with no accumulation of rain we could expect 1.05 kg of suspended sediment to enter the water system. Our wet run was done after .5 in of rain and during the run .1 in was observed. We captured 2.65g so when extrapolated we would estimate 4.10 kg would pass into the water stream during 24 hours of a rain event of this size. Though they may seem high we underestimated the area of the stream, the percent efficiency of the traps and how much time it took to recycle 600ml of water. These large amounts are characteristic of the Macatawa

Watershed and are why there is a concern as to ways we can reduce the amount of sediment loading into the water system.

Conclusions:

Although the basic design of our sediment traps was not perfect, we have shown that with a little fine tuning our idea for a cheaper yet still effective way of trapping suspended sediments for analysis is not a remote possibility. In one semester's worth of work were were not able to put the $2,000 dollar machines out of business with our $1 Tupperware containers, but it is easy to see that we are not far from that result. Our lab tests showed a correctable flaw in our design, but the field tests proved that the traps did collect sediment. We have proven our method in the field, and proven that further research into cheaper alternative sampling methods is viable. Due to the set up of our lab test and design of our trap, a true percent efficiency was not found for our design, but since we have proven that the design does collect sediments in the field we propose a calibration method of study. If a more expensive model of suspended sediment sampling could be obtained, through purchase or even borrowing, then this design could be calibrated and then for the same price as one sampler you could have over 2000 samplers potentially covering an entire watershed and resulting in valuable information regarding sediment loads.

These methods have wide applications and could be used in any study that wanted to correlate suspended sediment loads with any other variable. This could include our original intentions of examining the relationship between riparian buffer width and suspended sediment load. Potential other investigations include vegetative state, soil composition, stream bed profiling, and a look into the land use in immediate area.

One of the bigger conclusions we had was how to improve upon our design while still keeping costs down. From conclusions about the water flow at the front of the trap, we suggest that an extension be added on to the front so that water flow around the opening is not impeded by the bulk of the trap until later, away from the opening. We feel this will eliminate the problems we observed and still keep the trap design cheap.

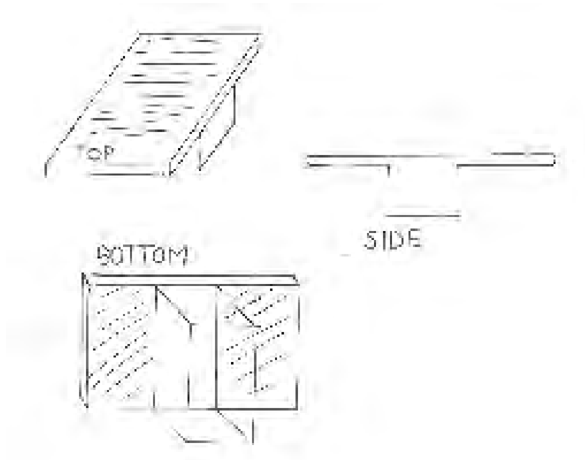


Fig. 8. Proposed future modifications to our basic sediment trap design. The extension will allow water to freely flow around the entrance to the trap

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