Decoding the sediment to understand ravine processes at Seven Mile Creek Park, Nicollet County, Minnesota

By Zach Severson

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Under Supervision of Laura Triplett and Julie Bartley

Abstract:

Seven Mile Creek Watershed is located in Nicollet County, Minnesota, and is a direct tributary to the Minnesota River. Seven Mile Creek is fed by a network of terraces and ravines as it enters the Minnesota River. The Minnesota River, is draining sediment from most of southern Minnesota, sediment loads have increased over the past 150 years. The behavior of the landscape that feeds the tributaries of the Minnesota River, is potentially adding increased sediment transport to ravines. Ravines are formed by running water-eroding deeply into the soil and sediment, typically on a hillside or valley wall. Decoding sediment in ravines is important because it allows for us to understand the processes that occurred during the formation of the ravine and that are responsible for moving sediment into the Minnesota River. Decoding sediment allows for us to understand the general particular process. For example, you'll be able to distinguish between sediment deposited in an alluvial fan and sediment deposited by continuously running water

My hypothesis is that different geological processes occurred while depositing these sediments in various manners. With decoding sediment we are able to examine the textural properties of grain size and shape, particle surface texture, and grain fabric. The sediments in the ravine reveal grain size patterns throughout the ravine. Near the head of the ravine, sediment was mud-dominated and poorly-sorted. The middle stretch of the ravine sediment had well-sorted, with a median grain size around 350µm. The mouth of the ravine contained both well-sorted and poorly-sorted sediments. The poorly-sorted sediment had an excess amount of mud from erosion near the head of the ravine. The well-sorted sediment had a median grain size around 280µm. Spatial differences in median grain size, sand distribution, and sorting suggest that both glacial and fluvial processes are responsible for sediment deposition in the ravine at Seven Mile Creek Park.

Acknowledgements:

There are many people who have helped me throughout this project and I would like to give thanks to all of them. First I would like to thank Dr. Laura Triplett for being my advisor and keeping me on track in time of need. I would also like to thank Dr. Julie Bartley for helping my thesis drastically is spring semester when I need help and guidance. I would like to thanks Dr. James Welsh for giving feedback and providing resources needed to understand my site. I would like to thank fellow Gustavus geology students Grant Noennig and Russ Krueger. Grant helped collect samples and getting measurements throughout the ravine. Russ taught me how to use the Microtrac Laser Diffractometer particle size analyzer. Lastly I would like to thank my parents for giving me the opportunity to further my education at Gustavus Adolphus College.

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Introduction:

Ravines are tributary streams that feed water into creeks or rivers. Ravines are formed from running water, eroding strongly into the soil and sediment, typically on a hillside or valley wall. When ravine formation is in process, the flowing rate of water can substantially cut deep into the sediment (Colgan, 2009). Ravine erosion is the process by which ravines are formed, and erosion keeps the ravines actively widening (Christensen, 2003). A ravine has the potential to transport large amounts of sediment by a variety of mechanisms. Besides eroding sediment, ravines can also hold sediment. This occurs when sediment is deposited in the middle of the ravine when there is a decrease in water discharge through the ravine. Decoding of the ravine is important because it lets us analyze the sediment in the ravine to understand the transport and storage within the ravine. With decoding the ravine, I believe that we will be able to understand that glacial processes put the sediment in Seven Mile Creek Park before the fluvial downcutting of the ravine began.

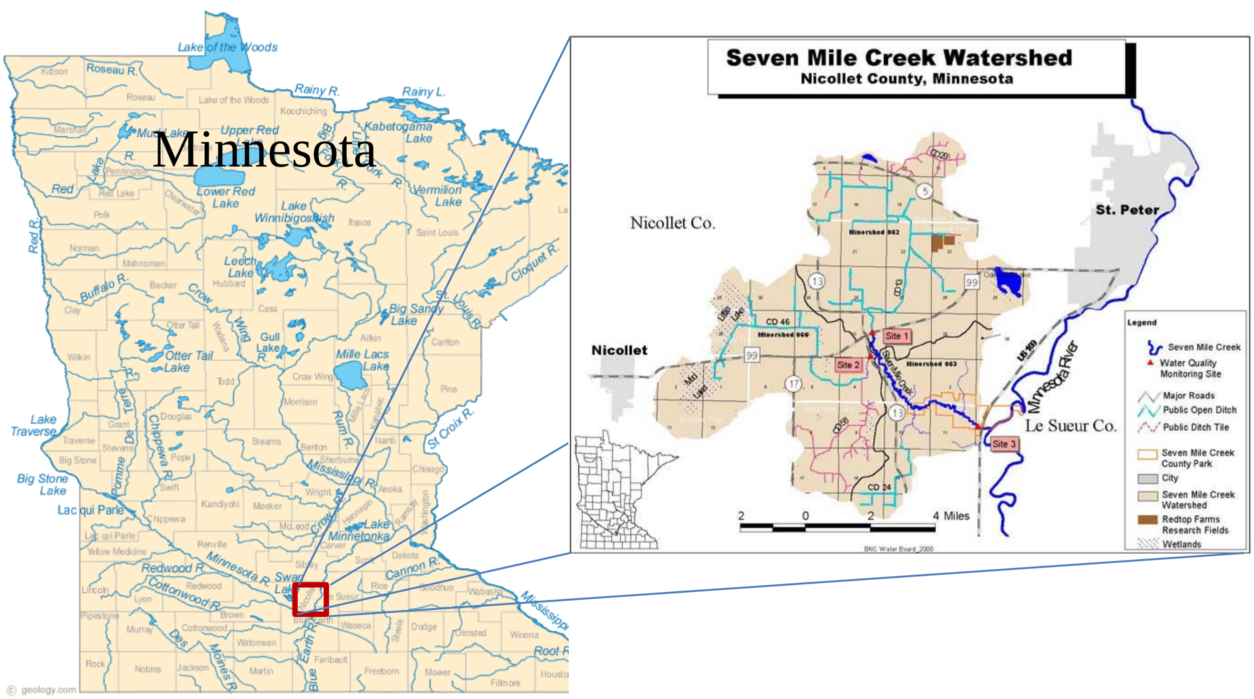
In addition to understanding the processes of ravine formation, decoding sediment allows for us to understand the general geologic setting of an area. With decoding sediment we are able to examine the textural properties of grain size and shape, particle surface texture, and grain fabric. An intensive understanding of the nature and significance of sedimentary rocks is fundamental to interpretations of transport conditions (Boggs, 2009). These grain particles can range in size from clay particles where you need a microscope to view them to pebbles centimeters thick. The sizes of particles in an area reflect weathering and erosional processes, which develop sediment particles of varying sizes (Boggs, 2009). Measurement of grain size data generates large quantities of data that can be put into tables and graphs showing the diameter and size of a given sediment. These graphs and tables simplify the sediment data to understand the average grain size and sorting of the sediment. Graphical plots help provide a promptly comprehensible visual representation of grain-size distributions.

The primary focus of this study is to decode sediment in a ravine in Seven Mile Creek Park. Seven Mile Creek Watershed is located in Nicollet County, Minnesota, and is a direct tributary to the Minnesota River. The Minnesota River, is draining sediment from most of southern Minnesota, and has been transporting large sediment loads during the past 150 years. This is presumably caused by sediment erosions in watershed linked to water, land-use changes like agriculture development also alters the properties (Jennings, 2010). Agriculture development like drainage tiles on agriculture fields rapidly transports the water from the crop soil directly into the ravines, which will eventually drain into the stream and river. Tile drainage and the corresponding changes to the landscape, draining wetlands, wet soils, and channelizing streams, have contributed to more erosive rivers (Schottler, 2013). The water increase in the ravine causes head-ward erosion; this can mobilize extensive amounts of parent material and topsoil. The built up water that feeds these streams, is potentially adding increased sediment transport to Ravines.

To explain the depositional processes, we need to understand the sorting of the sediment. The sorting of a grain population is a measure of the range in grain sizes present and the magnitude of the spread of these sediment sizes around the mean sediment size (Boggs, 2009). Sorting describes the degree of uniformity of a grain size. Particles become sorted on the basis of density, because of the energy of the transporting medium (Nelson, 2012). We classify the size sorting on a basis of well-sorted to poorly-sorted. Well-sorted sediments have similar grain size, and are a result of sediment transport. Sediments with relatively close sized grains will be deposited in the same area. Well sorted coarse grains will be nearest to the source of the sediment, and well sorted very-fine grains will be furthest away from the source sediment. Fluvial processes and beach deposits generally show a good example of well-sorted sediments because the energy of transportation is usually constant. Poorly-sorted sediments have grains of varying sizes. They are evidence that the sediment was deposited close to the source sediment, and have not gone through much transport. Glacial till, which contains a mixture of course angular rock fragments, sand, silt, and mud is a good example of poorly-sorted sediment.

Fluvial processes include the motion of sediment and erosion or deposition of a sediment. Fluvial processes can have well-sorted and poorly-sorted sediment. Well sorted fluvial sediment can be found in beach deposits where the energy of transporting medium is constant (Nelson, 2012). This allows for similar sediment particle sizes to be deposited in a common area. Well-sorted fluvial processes also form in association with river processes. Depending on the amount of energy for sediment to travel. In a high energy state river we can find well sorted regions from boulders being deposited closest to the head and finest sediments closest to the mouth. River deposits are generally dependent on two stratigraphic relationships. Sand bars which tend to have better sorted deposits of sand which form in the inside of meanders, where the water velocity is lowest. Floodplains are characterized by fine-grained deposits of mud that often have a high percentage of organics (Harms, 1982). Transport by stream flow would be expected to produce a better sorted and probably coarser sediment.

Glacial movement occurs very slowly, as the glacier move it plucks, plucking is the erosion and transport of large chunks of rocks. As the glacier moves over the land, water melts below the glacier and seeps into bedrock cracks below the glacier. This water continuously freezes and melts, weakening the bonds holding the rock (Eyles, 2006). This allows for the glacier to pluck up the large chunks of rock. Plucking contributes to glacial erosion, known as abrasion. Abrasion is the erosion that occurs when particles scrape against one another. Very fine material, called rock flour, is produced by the scraping and grinding or rock surfaces (Eyles, 2006). Deposits of debris directly by the glacier, such as intra-glacial material deposited by retreating ice sheets, is till. Glacial till was deposited by the very slow plowing action of a glacial ice sheet over the land (Stephenson, Flemming, Mickelson, 1998). Glacial processes put the sediment here before the downcutting of the ravine began. The ravine is holding unmodified material put in the ravine, most likely from mass wasting, like a slump. I predict that that the ravine widening by mass wasting would retain a grain size distribution that looks very much like the original transport process.



Map 1: This shows the regional area of study. Seven Mile Creek Park is the tan colored area and Seven Mile Creek is the blue river connecting to the Minnesota River.

Geologic Setting:

Seven Mile Creek watershed rests within the Minnesota watershed and is a tributary the leads directly to the Minnesota River, seen in Map 1. The entirety of the Minnesota River watershed is broad glacial lowland created by repeated advances of confluent ice streams that formed the Des Moines lobe (Jennings, 2010). The landscape of south central Minnesota is fairly young, having been sculpted by the most recent post-glacial fluvial system with the initial draining of glacial Lake Agassiz (Mann, 1999). Seven Mile Creek is located in South Central Minnesota. In south-central Minnesota, Early Paleozoic sedimentary bedrock underlies Cretaceous and Pleistocene strata. In this area, exposed Paleozoic bedrock includes the Cambrian Jordan Sandstone and the overlying Oneota Dolomite, the older formation in the Ordovician Prairie Du Chien Group (Runkel, 1994).

The Oneota Dolomite which overlies the Jordan Sandstone does not crop out in Seven Mile Creek Park. The Oneota is absent most likely due to landscape erosion in this region prior to the great Ice Age. The great ice age began roughly 2,000,000 years ago and ended around 10,000 years ago. There are four tills present in the area of the Minnesota River Valley (Matsch, 1972). This is a result of many glacial advances which covered this watershed. The most recent glacial advance was the Des Moines Lobe, which laid the New Ulm Till. This is a calcareous clay loam till, which contains shale, limestone, dolomite, and granitic rock (Jennings, 2010). This glacier was present in Canada, North and South Dakota, Minnesota, and Upper Central Iowa. Around 12,000 years ago the Des Moines Lobe started to melt back and retreat. This melting and retreat led to the creation of pro glacial lakes which include Lake Agassiz, the largest glacial lake, expanding more than 200,000 square miles. The size and position of Lake Agassiz was highly variable at times but roughly covered parts of present day Saskatchewan, Manitoba, Ontario, Quebec, Minnesota, North Dakota, and South Dakota (Michalek, 2014).

Glacier River Warren is a hypothesis on how the Minnesota River watershed was formed. When the glaciers melted and formed glacial Lake Agassiz, that melt water was released from Lake Agassiz and created the glacial River Warren channel (Jennings, 2010). The discharge carved through till and bedrock, creating an engraved 45 to 70 meter deep channel from South Dakota to Blue Earth River, MN. Terraces comprised of sand and gravel is the remnants of former floodplains; they geomorphically act as step-like features to the river's edge. Since base level dropped as the river engraved the valley, high terraces are typically older and lower elevation terraces are typically younger. As the valley formed, new tributaries formed by incising the valley walls at points of low relief. As the amounts of water increased, the flow increased, the headword erosion lengthened the ravines upstream, eventually developing new tributaries and ravines. As local base levels created from River Warren dropped, the tributaries similarly cut downward, leaving terraces at the edge of their channels. Seven Mile Creek, which enters the Minnesota River, is such a tributary stream. Seven Mile Creek has steep-walled stream valleys and tributary ravines suggesting that it has linking geologic features with the Minnesota River Valley.

Recently, human alteration of the landscape has changed how water and sediment move off the land surface and into the stream of Seven Mile Creek. Many of the wetlands around Seven Mile Creek have been filled in to make land for agricultural use. This wetland removal causes runoff to flow more directly into the river, increasing the amount of water going into the river drastically. These land use changes from wetland to agriculture is causing an increase in erosion through Seven Mile Creek and the Minnesota Watershed. The land use changes such as these cause accelerated ravine development and down cutting in tributary streams (Bock, 2010). Forcing more sediment to be brought into Seven Mile Creek and eventually in to the Minnesota River.

The ravine I chose to study is a smaller ravine in Seven Mile Creek Park. As seen in Map 2, there are many larger ravines in the park. The ravine mouth is around 50ft. from the creek, and the head is located 850ft. from the creek. This specific ravine was very steep at points, with very high ravine walls. It cut deep in to the edge of the ravine valley and continuously steepened towards the head of the ravine and flattened near the mouth.

Map 2: On the left is Seven Mile Creek Park. The right shows the area of the studied ravine. Orange spots mark out the sites where samples were taken. Site 6 is the head of the Ravine and site 1 is near the mouth of the ravine.

Methods:

Field Methods:

The majority of my work came from field work and data gathered from outcrop in a ravine in Seven Mile Creek Park. The ravine was visited three times between the months of February and April during the 2015 calendar year. The head of this ravine was located 801.5ft from the walking path and around 850ft from the creek. To gather data from outcrop, I walked the Ravine to find six sites where we could record data. The six sites are located from the head of the ravine down to the mouth, seen in Map 2. The sites were chosen based outcrop that looked sufficient or had layers of bedding where sediment could be collected. The bedding layers were important; it allowed me to take multiple samples at the site with different elevation. At each individual site samples were collected; the samples were collected based on color of the sediment and location. Data and field description of outcrop were recorded in a field notebook.

In the field notebook, the distance from the path, the height from the base of the ravine, the sample number, and the description of the outcrop were recorded. With a small trowel I was able to knock sediment loose; sterile specimen cups and lids were used to keep each sample isolated until it could be processed in the lab. The site number and sample number were recorded on each specimen cup. The distance from the path and the base of ravine were recorded with a Kesson 165 feet measuring tape. There is potential error in measuring the ravine. It is difficult to get the horizontal tape measure to be perfectly flat, so there typically a curve in the tape, decreasing accuracy. After recording the data, pictures were taken of the outcrop. Pictures were taken from a zoomed out angle of the outcrop and then a zoomed in angle with an indicator, a standard claw hammer with a wooden handle. After data was collected at one site, I moved to the next site. To obtain the distance to the next site my field assistant held the tape measure from the previous site as I walked to the next site. We continued this process at every site until we reached the head of the Ravine. By the time we reached the head of the Ravine I had collected thirteen samples from the six different sites.

Lab Methods:

In the lab the majority of the work was spent on running the samples through a Particle size analyzer. The Microtrac Laser Diffractometer is the particle size analyzer used to interpret the sediment. To run the sample, each sample needed to be weighed to a specific weight. The Mettler Toledo scale was used to measure the weight each sample. For a silt dominated sample, 0.07-0.2 1 grams of sediment were used. When the sample was mostly sand dominated, the weight of the sediment was around 0.35 grams. The difference in mass between the categorizations is necessary due to the amount of grains compared to weight, for example the coarser samples would need more weight due to the number of composing larger grain sizes (Horiba). Once the samples were weighed, each was placed in a clean 50mL centrifuge tube. After the samples were placed in the tube, 5mL of hexametaphosphate (HMP) is added to the centrifuge tube using a pipette. After adding the HMP, the tube the cap was placed back on it was shaken for a minute to ensure that the grains came in contact with the HMP. The HMP is important because it breaks up the sediment and prevents clumping. After a minute of shaking, the sediment was ready to be put into the Microtrac particle size analyzer. The Microtrac particle analyzer, recorded the size of each individual grain in the sample tube. The sizes of the grains are recorded in microns (μm) (1.0×10^{-6}m). The data attained allowed me plot the grain size distribution as both channel percentage and retained percentage, and to determine the median grain size, the upper 95th percentile of the grains, and the lower 5th percentile of the grains.

The particle size is measured as the median (d50); the size for which half the grains in the sample are larger and the other half smaller. The particle size of the upper 95% (d95) gives the grain size that is larger than 95% of the grain population, with only 5% of the grains larger. For the lower 5% (d5), 95% of the grains are larger and 5% smaller. By knowing the average (d50) and the upper 95% (d95) we can calculate the sorting in the sediment. Dividing d95 by d50 gives us a number, the closer that number is to one, the more sorted the sediment is. This can also be done by dividing d50 by d5 but the results may vary from the amount of extremely fine grains (Horiba). These averages give detail on how sorted the sediment is and the grain size distribution. Once all thirteen samples were analyzed, the data were recorded and exported into Excel. Once in Excel, I was able to make graphs and tables that display the sediment data. The graphs were displayed showing the grain size compared to the retain percentage and the channel percentage. The retained percentage shows the percent of each individual grain in the sample, and the percent of grains that are larger than that individual grain. The channel percentage distribution is a histogram of grain size frequency across the observed grain sizes.

Results:

The head of the ravine in Seven Mile Creek, roughly 850 ft. from the creek is closest to site six, where sample 13 was taken. Sample 13 is six feet and seven inches downstream from the head of the ravine. It was collected one foot and three inches above the ravine floor. This sediment was very fine, it was very dark brown and is poorly consolidated. The particle size (d50) is 7.11 µm, it has the smallest average particle size. The particle size of the upper 5% (d95) is 79.6 µm and the particle size of the lower 5% is 0.9 µm. In this sample the d95/d50 is 12 µm. This particle size for sample 13 is the smallest out of all of the sites.

Site five is located 156 ft. downstream of the head of the ravine. It contains two samples, sample 12 and sample 11. Sample 12 is located 23ft 2in above the ravine floor. It is located on a steep ravine wall where erosion and mass wasting has taken place; tree roots are exposed here. The sediment has a tan, light brown color. It was moist, very fine sediments, with possible clay and till. There was large junks of sediment in the area but was too large to test. The particle size (d50) was 12.7 µm. The particle size for (d95) is 144.5 µm and the (d5) is 1.19 um. In this sample the d95/d50 is 11 µm. Sample #11 is 14ft 11in above the floor of the ravine. It is located on the ravine wall under a dark till layer, it is light tan in color. It was very dry and had what looked like bedding layers in it. The particle size (d50) was 17.9 µm. The particle size for (d95) is 219 µm and the (d5) is 1.3 µm. In this sample the d95/d50 is 12 µm.

The location of site four is 263.7ft downstream of the ravine head. Site number four contains three samples sample 10, 9, and 8. It is located on a less steep wall of the ravine, slumping and mass wasting is occurring. Sample 10 is located 8ft 7in above the ravine floor. It is located under a slumping tree. It is a tan to light brown sediment, as a whole, the unit was not well sorted. There were many large pebbles located throughout the area. The particle size (d50) is 20.8 µm. The particle size (d95) is 223.6 µm and the (d5) is 1.486 µm. In this sample the d95/d50 is 10 µm. Sample 9 is 6ft 3in above the ravine floor. It is a dryer, poorly consolidated sediment, it is light brown to tan in color. It is located 2ft 4in below sample 10, the particle size (d50) is 22.6 µm. The (d95) is 253.6 µm and the (d5) is 1.527 µm. In this sample the d95/d50 is 11 µm. Sample 8 is located 4ft 6in above the ravine floor. It is located in a layer of sediment below sample 9, it has very light tan and brown color. The particle size (d50) is 27.33 µm. The particle size (d95) is 218.6 µm and the (d5) is 2.2 µm. In this sample the d95/d50 is 8 µm.

Site three has a location that is 354.3ft downstream of the ravine head. At this site two sample were collected sample 7 and 6. This site is located next to a large fallen tree, there is mass wasting and erosion, causing roots to show and trees to fall. Sample 7 is located at a distance of 7ft 8in above the ravine floor. It is a medium brown color and contains many coarse to very coarse grains, while being surrounded by fine to very fine grains. In sample 7 the particle size (d50) is 98.7 um. It has an (d95) of 313.1 µm and a (d5) of 6.2 µm. The d95/d50 in this sample is 3 µm. Sample 6 is located 4ft 3in above the ravine floor. It is located under a small tree, the colors range from dark to medium brown. The particle size (d50) is 22.3 µm. The (d95) is 232.2 µm and the (d5) is 1.5 µm. The d95/d50 in this sample is 10.

Site two is located 460.8ft downstream of the ravine head. This location had distinct layers, the bottom layer was light brown with some dark gray, the middle layer was a dark brown and the top layer was a tannish orange. Samples 5, 4, and 3 were each taken from a different layer of sediment. Sample 5 was the top tannish orange layer it is 4ft 11in above the ravine floor. It had a particle size (d50) of 64.8 µm. The (d95) is 268.2 µm and the (d5) is 3.5 µm. The d95/d5 for this sample is 4 µm. Sample 4 is the dark brown middle layer, it is located 3ft 6in above the ravine floor. It has a particle size (d50) of 189.5 µm. The (d95) is 1.36 µm and the (d5) is 11.3 µm. The d95/d5 in this sample is 11 µm. Sample 3 is the light brown with dark gray bottom layer, its located 2ft 11in above the ravine floor. The particle size (d50) is 23.2 µm. The (d95) is 235.8 µm and the average (d5) is1.5 µm. The d95/d50 in this sample is 10 µm.

The site farthest downstream of the ravine is site one; it is located 496ft downstream of the ravine head. It is located directly next to a boulder and a dead tree that had fallen over the ravine. Both samples 1 and 2 are located here. Sample 2 is 5ft 11in above the ravine floor. It is a dark gray to black sediment, and has a particle size (d50) of 18.9 µm. The (d95) is 154.6 µm and the (d5) is 1.5 µm. The d95/d50 is 8 µm. Sample 1 is 3ft 11in above the ravine floor, it is located directly next to the boulder. The color is dark gray to black, it has a particle size (d50) of 23.91 µm. The (d95) is 196.6 and the (d5) is 1.7 µm. The d95/d50 is 8 um.

Site Number	Sample Number	Avergae Particle Size (um) at 50% (d50)	Average Particle Size (um) of Upper 5% (d95)	Average Particle Size (um) of lower 5% (d5)	d95/d50 (um)
6	13	7.11	79.57	0.888	11.19
5	12	12.76	144.5	1.191	11.32
	11	17.97	219.7	1.339	12.23
4	10	20.84	223.6	1.486	10.73
	9	22.67	253.6	1.527	11.18
	8	27.33	218.6	2.128	7.99
3	7	98.71	313.1	6.201	3.17
	6	22.31	232.2	1.473	10.39
2	5	64.85	268.2	3.491	4.14
	4	16.76	189.5	1.361	11.31
	3	23.21	235.8	1.515	10.16
1	2	18.98	154.6	1.511	8.14
	1	23.91	196.6	1.673	8.22

Table 1: This table shows the average particle size (d50) compared with the average particle size of the upper 5% (d95) and the lower 5% (d5) of each sample collected. The (d95/d50) of each sample gives the sorting number of each sample, the closer to 1, the more well sorted it is.

Site Number	Sample Number	Distance From Ravine Head (ft)	Height from Ravine Base (ft)	d95/d50 (um)
6	13	6.7	1' 3"	11.19
5	12	156	23' 2"	11.32
	11	156	14' 1"	12.23
4	10	263.7	8' 7"	10.73
	9	263.7	6' 3"	11.18
	8	263.7	4' 6"	7.99
3	7	354.3	7' 8"	3.17
	6	354.3	4' 3"	10.39
2	5	460.8	4' 11"	4.14
	4	460.8	3' 6"	11.31
	3	460.8	2' 11"	10.16
1	2	496	5' 11"	8.14
	1	496	3' 11"	8.22

Table 2: This table shows the distance from the head in feet of where each sample was collected. The height from the ravine basin where each sample was collected is also shown. The (d95/d50) of each sample gives the sorting number of each sample, the closer to 1, the more well sorted it is.

Discussion:

The variation in grain size, sand distribution, and sorting suggests that multiple processes have occurred during the deposition of sediments in the ravine at Seven Mile Creek Park. The d50 of the upstream sediment towards the head of the ravine does not correlate sufficiently with the d50 of the downstream sediment within the middle of the ravine, seen in Figure 1 and Table 1.

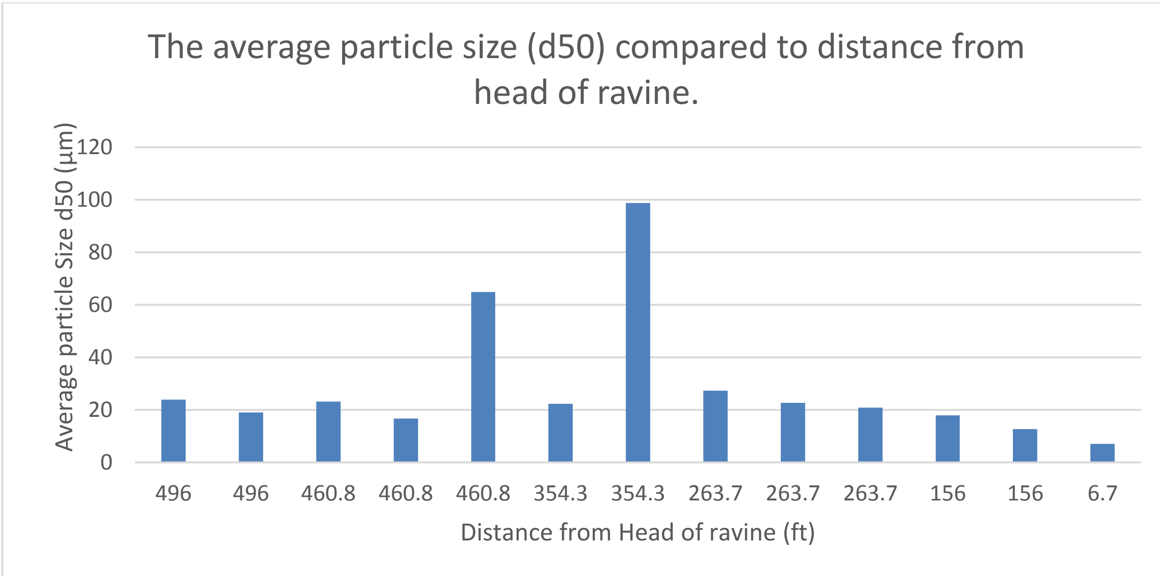


Figure 1: The graph shows the spatial difference of d50 compared to the distance from the ravine head. It can be seen that the average increases in the middle of the ravine. The head of the ravine is on the right and the mouth is on the left.

The d50 of the sediment closest to the mouth of the ravine resembles more accurately with the d50 nearest to the head of the Ravine. However the sorting (d95/d50) of the sediments near the head of the ravine and mouth of the ravine do not correspond as seen in Figure 2.

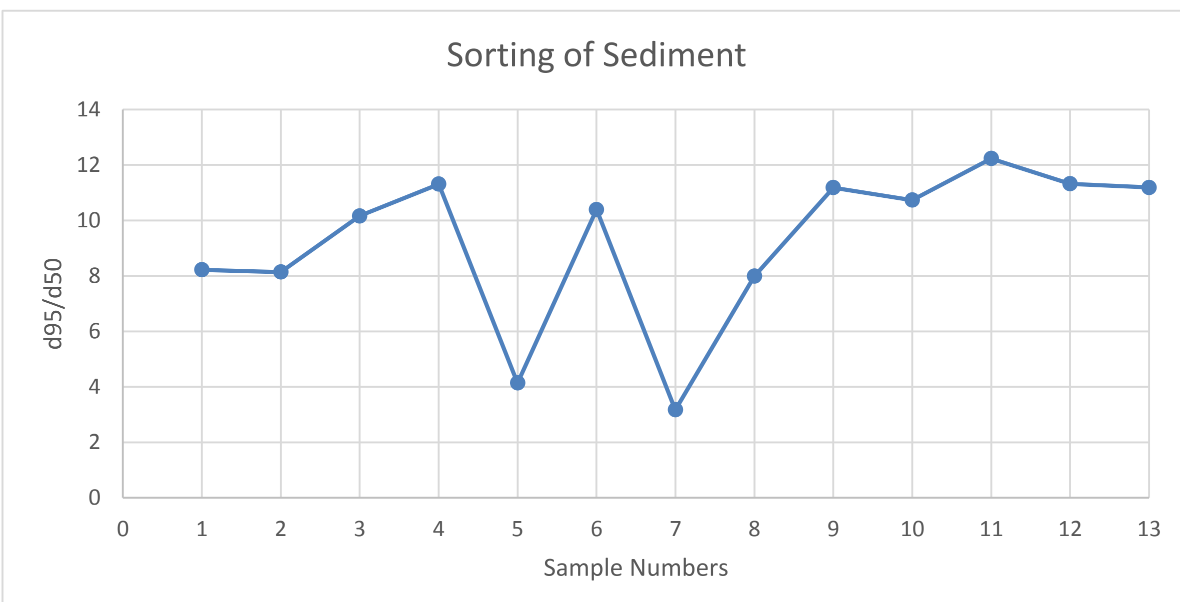
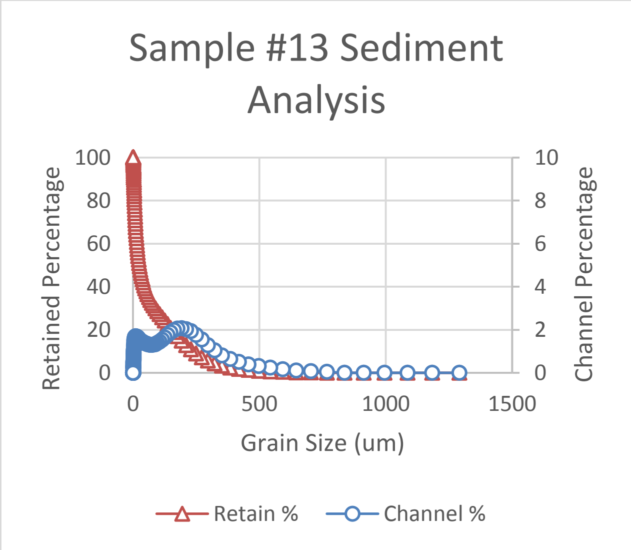


Figure 2: The graph shows the sorting of the sediment d95/d50 at each sample collected. The lower numbers show a well-sorted particle sample. The head of the ravine is the right at sample 13 and the mouth is left at sample 1.

These factors may be due to different geological processes that occurred while depositing these sediment in various manners. I believe glacial and fluvial processes took place in deposition of the sediment.

At the head of the Ravine (Sites 5 and 6) there is very muddy sediment. This sediment consisted of varying sized sediments with the majority being muddy clay. The sediment is poorly sorted do to the majority of the sediment being mud particles; the small amounts of coarser sediments in the mud drastically affects the sorting percent. In this region within 200ft from the ravine head we find very muddy, poorly sorted sediments. The sediment deposition was probably from glacial processes. When glacial ice sheets retreat they deposit clay mixtures of clay, sand and gravel. Since the sediment contained a clay mixture of mostly mud and sand we can conclude that this sediment is till being deposited from the last glaciation event as seen in Figure 3. The other mud and clay sized particles are likely being deposited from water runoff from agricultural land above the ravine.



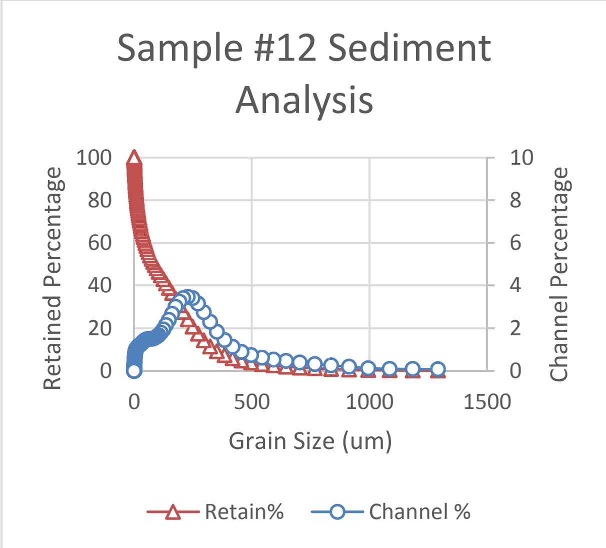
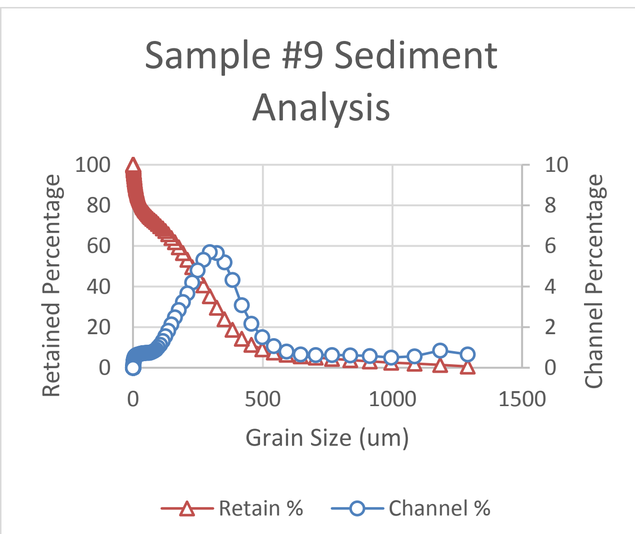


Figure 3: The left graph shows the grain size distribution at sample #13, the sample closest to the head of the ravine. The right graph shows the grain size distribution at sample #12, the second closest sample to the head of the ravine. Sample #13 shows how muddy and fine the sediment was closest to the head of the ravine, where sample #12 shows the grain size starting to spread out in size.

In the middle of the Ravine (Sites 3 and 4) we have some samples containing mud, fine grains, and medium grains. The sample closest to the ravine basin in site 4 was comprised of some mud and upper fine grains as seen in Table 2. The sample was well-sorted and comprised mostly of fine lower grains. The two samples taken at a farther distance from the ravine basin at site 4 were comprised mostly of lower fine grained sediment to medium grained sediment. They were poorly sorted from the influx of fine grained sediments and medium grained sediments as seen in Figure 4.



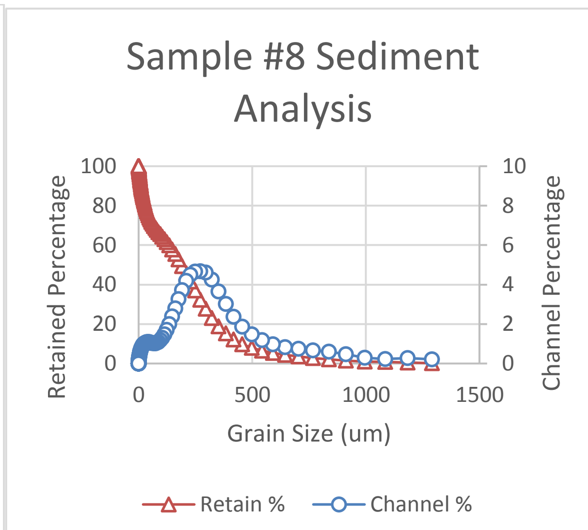
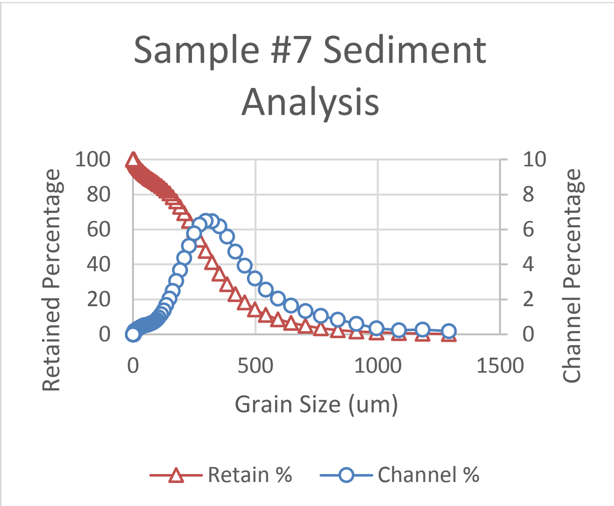


Figure 4: The left graph shows the grain size distribution at sample #9, the high arch shows the mode and distribution widths of the sample. The right shows the grain distribution at sample #8, sample #8 is more sorted then #9, we can see this because the mode is closer to the median grain size. These samples were both taken at site 4.

At site 3 the sample closest to the ravine basin was comprised mostly of mud and fine grained particles and was poorly-sorted. The sample taken farther away from the ravine basin was well-sorted and comprised of mostly lower fine to upper fine grained sediments, it contained little mud seen in Figure 5.



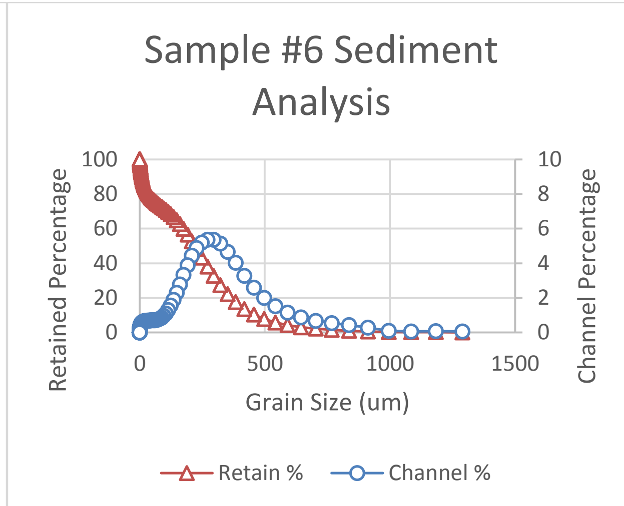
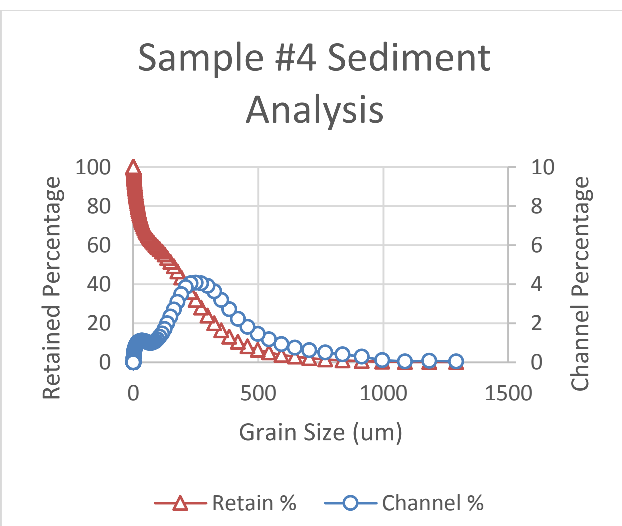


Figure 5: The left graph shows the grain size distribution at sample #7. This is an example of very well-sorted sediment. The mode and median are very close together, we know this from the high curve in the graph, and grains are mostly distributed around 400 µm. The right graph shows distribution in sample #6, this sample is poorly sorted, the curve near 0 µm peaks before the main curve, showing pore sorting and distribution (Horiba).

In this middle region of the ravine, the samples varied in sorting. At site 4 the two samples farthest from the ravine basin were most likely deposited by glacial processes. The samples could be considered till from how high up on the ravine wall they were. It was most likely till that had not been eroded and stayed where it was deposited during the last glaciation. The sample closest to the ravine was well sorted and deposited by fluvial processes. This sample was likely to be deposited in a high energy water state where it could have been deposited in a sand bar or flood plain (Harms, 1982 and Weiland). At site 3 the sample closest to the ravine was likely deposited by a glacial process, it is poorly sorted, containing large quantities of mud. It is close to the ravine basin from mass wasting. The sediment was over saturated and mass wasting occurred, causing the glacial till to slump into the ravine (Mitchell, 2012). The sample farthest from the ravine at site 3 was very well sorted and likely to be deposited by a high energy fluvial process.

Near the mouth of the ravine (Sites 2 and 1) we have sorted sediments but not all are well sorted as seen in Figure 6. The samples at site 2 contain a well-sorted sample which is farthest from the ravine basin, it consists of almost all fine lower grains, with a little mud. The other two sample are closer to the ravine, they are poorly sorted and contain mostly mud particle with some lower fine grained sediments. The samples closest to the mouth of the ravine at site 1 are well sorted, containing mostly mud particles to lower fine and fine grains. The two samples at site 2 which are poorly sorted are thought to be glacial processes. They are comprised almost entirely of all mud particles. They are likely deposited from mass wasting forming a slump, and then getting eroded and transported down the ravine. The sorted samples in the region closest to the ravine can be thought to be deposited by fluvial processes. Being deposited by a stream deposit where low energy fluvial processes is transporting the sediment. Mud size particles and fine grained particles are being deposited together in this region from the low energy (velocity) of movement.



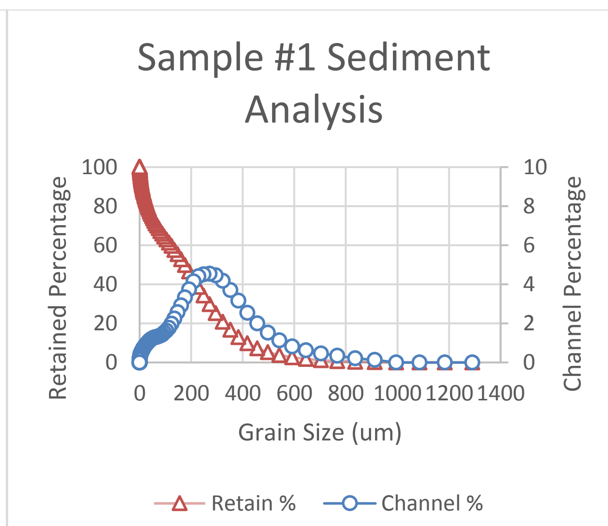


Figure 6: The left graph shows grain size distribution at sample #4, it is poorly sorted, the curve near 0 (μm) peaks before the large curve. The average grain size is smaller than those in sample

#1, the graph on the right. Sample #1 is well-sorted, there is no minor curve before the large curve, making the sample sorted. Sample #1 shows the extent of strong fluvial processes near the mouth of the ravine, and sample #4 shows stream run off, where the finer sediments do not get sorted and come to steady rest further from the mouth of the ravine.

Conclusion:

The decoding of the sediment in the ravine permits me to believe that both fluvial and glacial processes occurred in the depositions of sediments in the ravine. At the head of the Ravine there is very muddy sediment. This sediment consisted of varying sized sediments with the majority being muddy clay. The sediment is poorly-sorted do to the majority of the sediment being mud particles; the small amounts of coarser sediments in the mud drastically affects the sorting percent. The poor sorting and grain size variation allow for an understanding that glacial processes deposited this sediment. This occurred during the last glaciation around ten thousand years ago. The middle of the ravine, the samples varied in sorting. There was well-sorted and poorly-sorted sediment samples. The poorly-sorted sediment in this region was till. Till is in this region from mass wasting. The sediment was over saturated and mass wasting occurred, causing the glacial till to slump into the ravine. The well-sorted sediment in the region was deposited by fluvial processes. This samples were likely to be deposited in a high energy water state where it could have been deposited in a sand bar or flood plain. The mouth of the ravine we have sorted to well-sorted sediment samples. The well-sorted samples are comprised of mostly mud particles to lower fine and fine grains. They were deposited during a fluvial process. It was thought to be deposited by a stream bed where low energy fluvial processes is transporting the sediment where the finest particles are furthest from the source. The poor-sorted sediment are thought to be brought by glacial processes. Mass wasting occurs bringing the slumps into the ravine, erosion occurs transporting the sediment down the ravine where it is deposited with larger size grains. Glacial and fluvial processes both occurred in the deposition of sediments. Glacial processes happened prior to the ravine formation, but fluvial processes continue to form and shape the ravine.

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