

**RAVINE DEVELOPMENT AND BANK RECESSION OF RAVINE Z  
IN SEVEN MILE CREEK PARK**

by  
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under the supervision of Dr. Laura Triplett

## **ABSTRACT**

The Minnesota River is faced with increasing sediment loads, which are a result of sediment erosion in watersheds linked to the river. Ravine Z is active compared to surrounding ravines, but it is unknown if it is caused by stratigraphy, land-use change, or drain tile. The other ravines in the park contain rock outcrops, some contain drain tile, but the neighboring ravines do not have such distinct nick points as Ravine Z. Benchmark pins were installed and width and depth measurements were taken to monitor change over time of the wall and head recession, and nick point migration. Also, modeling through ArcGIS using LiDAR data was performed in order to construct cross sections and a slope profile of Ravine Z. Along with modeling, numerous photographs of the important sites were taken and will be important in finding changes in the ravine.

## **ACKNOWLEDGEMENTS**

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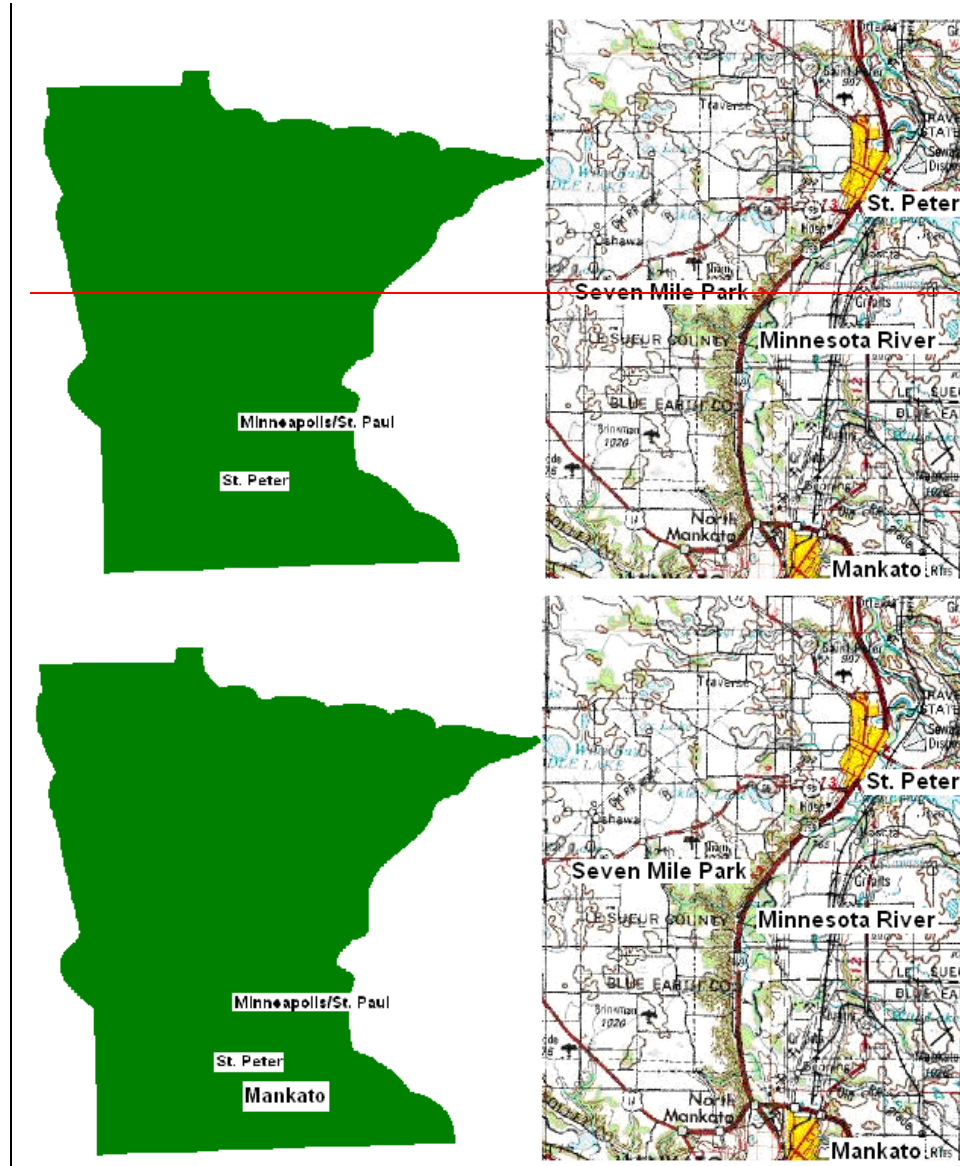
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## INTRODUCTION

Understanding erosion processes in a stream is very important in an agricultural area like southern Minnesota. The Minnesota River, a large river draining most of the southern part of the state, has been transporting unnaturally large sediment loads during the past 150 years, presumably caused by sediment erosion in watersheds linked to the river (Kelley and Nater, 1997; Engstrom et al., 2009). Land-use changes like farming and development alter the properties and behavior of the landscape that feeds these streams, potentially causing increased sediment transport from ravines and gullies. For instance, drainage tile on upland agricultural fields rapidly transports water from the soil to streams and ravines, which may increase erosion rates. Also, headward erosion of ravines can mobilize large amounts of the parent material and/or topsoil. However, ravine development has not been thoroughly studied, so any new knowledge of the controls of the erosional or depositional process will be essential in preserving important lands and in beginning to improve the quality of downstream water bodies like the Minnesota River.

The purpose of this study was to examine ravine development in the Seven Mile Creek watershed. Seven Mile is a small stream located west of Highway 169, about four miles south of St. Peter (Figure 1). Ravine Z, the studied ravine, is located across the foot bridge at the end of the road leading into the park. A system for monitoring the headward creep and the recession of the walls was established in Ravine Z. Factors like land-use change around the ravine and geologic stratigraphy were also examined to determine potential causes of erosion.



**Figure 1.** St. Peter is located about 60 miles south of Minneapolis. Seven Mile Park is just west of the Minnesota River. Map taken from [www.terraser-ver-usa.com](http://www.terraser-ver-usa.com)

Previous work in the Seven Mile watershed dealing with erosion is minimal, but similar watersheds of large rivers have been studied to a large extent in adjacent geographic regions. Van Nest and Bettis (1990) studied erosion along the Skunk River, a Mississippi tributary in Iowa, by using 17 cut bank exposures, and 28 auger borings. The headward expansion and net erosion that formed the basin occurred during a late-glacial climate episode. Headward extension was caused by increased seepage erosion, a result of a rise in the water table, directly related to more precipitation (Van Nest and Bettis, 1990). Trimble (1981) performed a long-term study on sediment storage in the Coon Creek Basin, in Wisconsin. It is an agricultural basin that is 360 square kilometers. A sediment budget was constructed during two periods: 1853-1938, and 1938-1975. The Coon Creek data show that sediment yield per area might actually increase as basin size increases, and in other basins with similar characteristics like agricultural disturbances and climatic profiles (Trimble 1981).

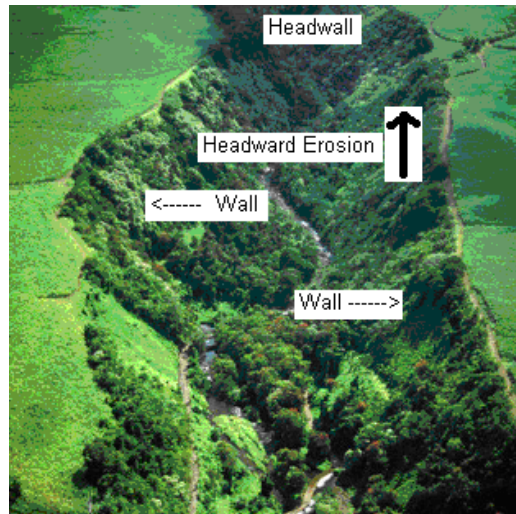
The Blue Earth River, a tributary of the Minnesota River in southern Minnesota, carries a sediment load somewhere around 100,000 metric tons each year, which is large compared to most rivers its size. Bauer et al. (1988) used aerial photographs, in order to measure and observe the sediment load from bank erosion. The photographs were used to find areas where large changes from erosion have occurred with 136 sites identified as erosion sites along the stream bank. In addition, slumping was also measured annually, but significant change did not exist. During the study, one landslide was discovered to have contributed approximately 5% of the annual sediment load of the entire Blue Earth River. While it was commonly believed that agricultural fields contribute to the majority of the sediment load, this study's findings showed that streambed erosion contributed to

sediment load as much as upland erosion occurring in agricultural fields (Bauer et al, 1998).

Overall, most short-term studies have used aerial photographs and ground-based techniques to measure and study the erosion of streambeds. In cropland environments, the volume of soil eroded by ephemeral gullying has been measured in short-term studies. However, longer term studies are required in order to identify significant changes and patterns. Gully wall retreat has also been monitored by placing benchmarks and measuring the distance of retreat between the gully head and wall (Poesen, 2003).



**Figure 2.** The cement pipe above is the outlet at the head of Ravine Z, and about 8 inches of cement is visible to the left of the pipe which is only visible after headward erosion.



**Figure 3.** This is an aerial photograph of a typical ravine. The walls are located along the sides, and headward erosion is upstream, toward the head. The head is located at the source of water, and is always at the highest elevation. Photo taken from <http://pro.corbis.com>.

## GEOLOGIC HISTORY

Glaciers spread over southwestern Minnesota during the Wisconsin glaciation and previous glaciations, leaving large deposits of sand, gravel, and clay. The Wisconsin glaciation ended about 12,000 years ago, just 1,000 years before the formation of Lake Agassiz in the northwest of Minnesota. Lake Agassiz was a massive glacial lake located in the center of North America, large than all of the Great Lakes, and containing more water than every lake in the world combined. The lake existed around 30,000 to 10,000 years ago, and drained catastrophically, creating the Glacial River Warren which carved out most of the Minnesota River valley. The result of that deepened valley was that the base level for area streams that drain into the Minnesota River was lowered by 100-200

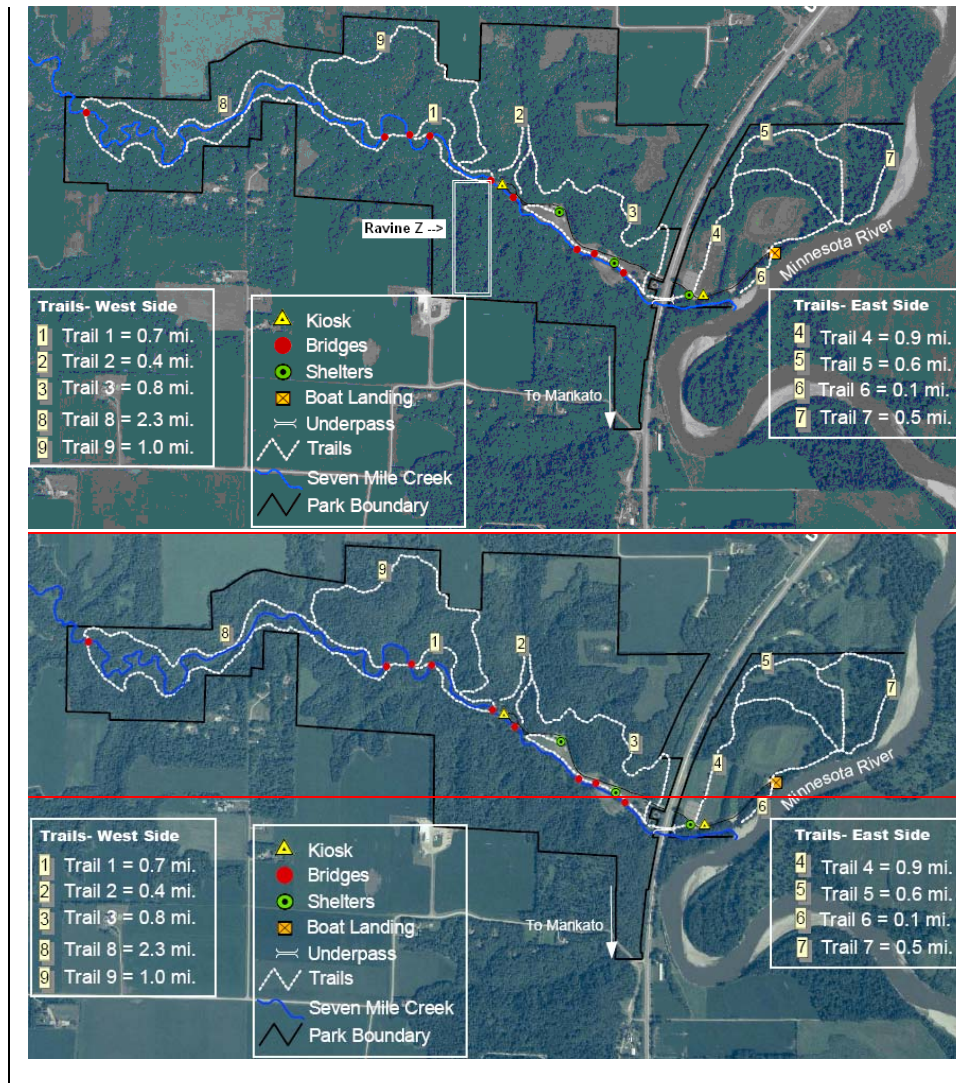
feet ([Bauer, 1998](#))([Britannica.com](#)).

At Seven Mile Creek, the oldest bedrock present is the Jordan Sandstone, which is exposed in a number of places. The sandstone is Upper Cambrian, and is the base rock layer underlying the creek. Missing in the Seven Mile Creek area is the Oneota Dolomite, which normally overlies the Jordan Sandstone, presumably from pre-glacial erosion. The next youngest layer is the Oneota Dolomite from the Ordovician Period, which is found in Kasota, but appears to have eroded away in many of Seven Mile's watershed boundaries. Many tills exist from the large amount of glaciations which occurred up to the latest, which left the loamy till from the Des Moines Lobe glacier.

#### **SEVEN MILE CREEK**

The watershed is located in south-central Minnesota, about four miles south of St. Peter ([Figure 4](#)). The watershed is a tributary of the Minnesota River, and it is therefore important to understand whether erosion in the park could be contributing to high sediment loads in the river. While the sediment inputs from Seven Mile alone may not be significant, understanding this system will make it possible to apply it to similar watersheds spanning the entire river.

The Seven Mile Creek Park watershed is filled with eroding ravines, as seen in the park map. Land-use change in the upland, mostly from agriculture, and more specifically from corn and soy bean farming, has affected the watershed. The addition of drain tile in the farms draws in the water to the pipe system, and releases it in a localized manner which is very erosive as the rate of flow on the topography increases.



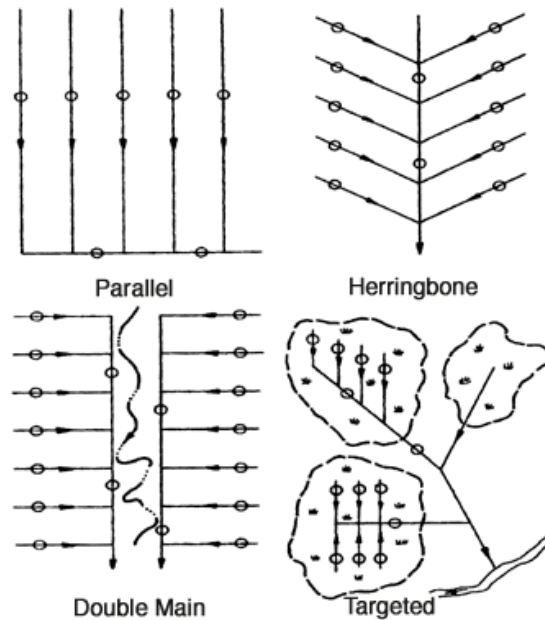
**Figure 4.** Following the water from SE to NE, the ravine is located just south of the first bridge (red circle) after the last kiosk (yellow triangle).

Water clarity is important, and depending on the time of year, the clarity changes based on how the climate and any other activity affect the Minnesota River. Seven Mile Creek is a natural habitat for brown trout, and a construction project took place in 2003 to make the water suitable for trout life year round. The project's focus was to create and

make sustainable pockets which would remain unfrozen even in the coldest months of the Minnesota winter. In order to stay fluid, the water in these pockets must remain at about 36 inches, and provide shelter for the brown trout. Therefore, the presence of increased sediment in the watershed is beginning to raise concern about clarity in Seven Mile.

Erosion in the Watershed occurs at different scales, and the magnitude likely depends on multiple different variables. Gully erosion is a process where the runoff water removes soil from a small area, and creates deep channels. A gully is classified as permanent when the eroded channel is too deep for normal farm equipment to repair it, usually somewhere between 1-30 meters deep. Previous studies indicate that worldwide gully erosion is responsible for 10-94 percent of all sediment yield caused by water erosion (Poesen et al, 2003). A gully is simply a smaller version of a ravine, but both follow the same processes, only under different timescales and magnitudes. The watershed contains a number of gullies, and some larger ravines, which experience significant down cutting during some seasons.

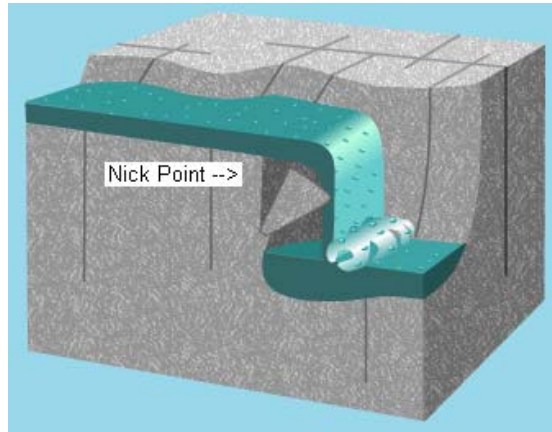
An increase in groundwater is likely the reason for increased activity in most ravines, and artificial drainage like drain tile may potentially be the main contributor. Drainage tiles are used to lower the water table, and drain soils which are seasonally wet, as most are in the Midwest. Drain tile allows farmers to begin the planting season earlier, along with keeping the overall conditions of the soil more stable than farms with natural drainage. The different patterns of drain tile shown in Figure 5 are used depending on the topography, and parallel is the type used in southern Minnesota. There are many variables associated with variations in soil behavior but the two most relevant are soil type, and rainfall infiltration (Schilling and Helmers, 2008).



**Figure 5.** The four patterns above are all ways of implanting drain tile on agriculture. Parallel is the most common, and is the tile used in most Southern Minnesota farms. The arrows shows the direction of flow, and all systems but the Double Main have only one outlet pipe.

## RESEARCH APPROACH

Seven Mile Creek is in a geologically young area. This study is designed to show changes in sediment storage at significant spots, and also to show how quickly the gully head and walls of one gully are receding. Determining nick points is crucial for finding where the majority of the down cutting occurs, and finding patterns for how the landscape is eroding. The water falls over the nick point, like in Figure 6, and erodes away the bottom, until finally the wall falls. This is the process of nick point migration against the direction of water flow.

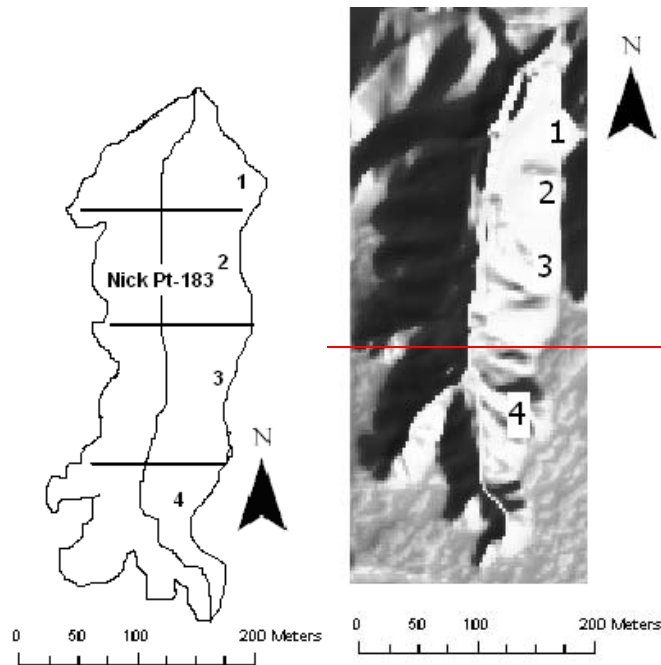


**Figure 6.** The water falls over the nick point, and erodes the underlying land. It moves in the headward direction. Image taken from <http://www.classzone.com>.

While it is easy to observe that erosion is currently taking place in the young landscape of Seven Mile Creek, quantifying the amount of drawback in the sides of the ravine is essential for understanding how much sediment the ravines are contributing to Seven Mile Creek and the Minnesota River. Once the amount of drawback in different parts along the stream is known, simple observations of the vegetation, type of till or fill, and overall land patterns may provide insight as to what is generally controlling the stream behavior. As mentioned previously though, referring to erosion and creep as fast-moving is relative, and a five year study may be considered to be short term in a watershed like Seven Mile Creek Park. While Seven Mile Creek, and Ravine Z, are active landscapes, the amount of water flowing through them is not enough to allow for the drawing of significant conclusions in the short-term timescale. So, this study is intended to provide short term observations, while setting up pins to assist in ongoing measurements for longer term studies.

## **METHODS**

All field work was conducted in Ravine Z in areas that were reached by foot. Qualitative observation of the neighboring ravines made it clear that Ravine Z has faced increased erosion. These neighboring ravines are located to the north and south of Ravine Z, on the same side of the path, and only the ravine to the south is drain tile-fed. From August to November, four visits were made to the ravine simply to take photographs, write down observations, and take note of any significant changes. Samples of sediment in the walls, floor, and head were taken at different intervals, in order to determine if the sediment changed at different elevations. Benchmark pins were placed at 4 sites, and all were buried to the third notch of five. They were placed at the point where the top of the wall meets the topography above it, as best as the eye could determine.



**Figure 7.** Shows the sites of the 4 pin locations.

Photographs of every pin were taken at the first placement, for future reference and to aid in viewing any changes. Measurements were made from the top of each pin to the bottom of the ravine, as determined by the location of flowing water. . Four foot soil borings were taken at a number of random spots, and just below and above the large nick point to determine if there was any layering in the soil, rather than the dark sediment that is exposed in most places.

| Site | Wall Height | Wall Width |
|------|-------------|------------|
| 1    | 26 ft 6 in  | 32 ft 3 in |
| 2    | 15 ft 10 in | 11 ft 9 in |
| 3    | 8 ft 4 in   | 14 ft 1 in |
| 4    | 13 ft 10 in | 10 ft 7 in |

**Figure 8.** These are the measurements taken at the four pin sites.

ArcGIS was used to help model the ravine and its corresponding elevations. The LiDAR data is from 2008, and was collected for the Brown-Nicollet County Water Board, and provided a clear image of the ravine and the differing elevations throughout. ArcGIS also made it possible to determine the slope along the bottom of Ravine Z, and provided cross sections of the ravine at several sites. Using the 'interpolate line' function, points were plotted along the low point of the ravine, starting at the head. Then, points were plotted as close together as possible, in order to make a detailed slope profile.

## RESULTS

Numerous qualitative and quantitative measurements were made throughout the nine months of the study, in Ravine Z and the surrounding area. The head of the ravine is

currently at approximately 310 meters above Seven Mile Creek. At the head, a concrete pipe with a 5 inch diameter protrudes 9 inches from the eroding earth. The walls for the next 200 meters, which is referred to as the Upper Ravine Profile in Figure 9, are generally U-shaped. The vegetation is abundant, with trees of diameter between 3-12 inches, and the walls are parallel enough to the ground that trees are still stable on the slope.



**Figure 9.** A typical portion of the Upper ravine. Note gradual slope, and abundant vegetation. The next two hundred meters are steep walls ranging from 10-35 feet, with small plants, many fallen trees, and trees of 2-6 inches in diameter just above the walls. This begins at the Mid Ravine Profile, and ends just after the highest nick point at 345 meters from the bottom. At this point, the topography above the walls gets steeper, and there are

large fallen trees on the hill slopes, with about two inches of fallen leaves. One highlight of this stretch is that there is one nick point, but it is not as easy to distinguish from the landscape as the lower nick point. The vegetation at the bottom of the nick point helps it blend in, and disguises the abrupt change in slope.



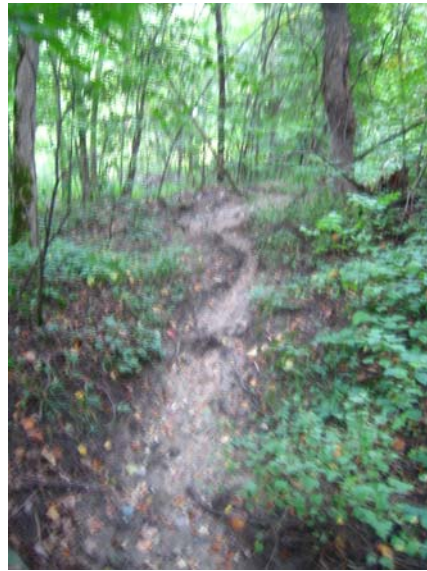
**Figure 10.** Picture taken just below 345 meter nick point. Walls become steeper at this section, and roots become exposed as root systems fail.

The last 230 meters are very active, and at the main nick point, there are large roots sticking out and holding in the sediment. There is a large tree with a diameter of about 30 inches at the top of the nick point that likely is restricting the nick point from eroding as fast as it would without the tree at that location. There is massive vegetation all around this point, and down to the bottom. The walls have more of a layered

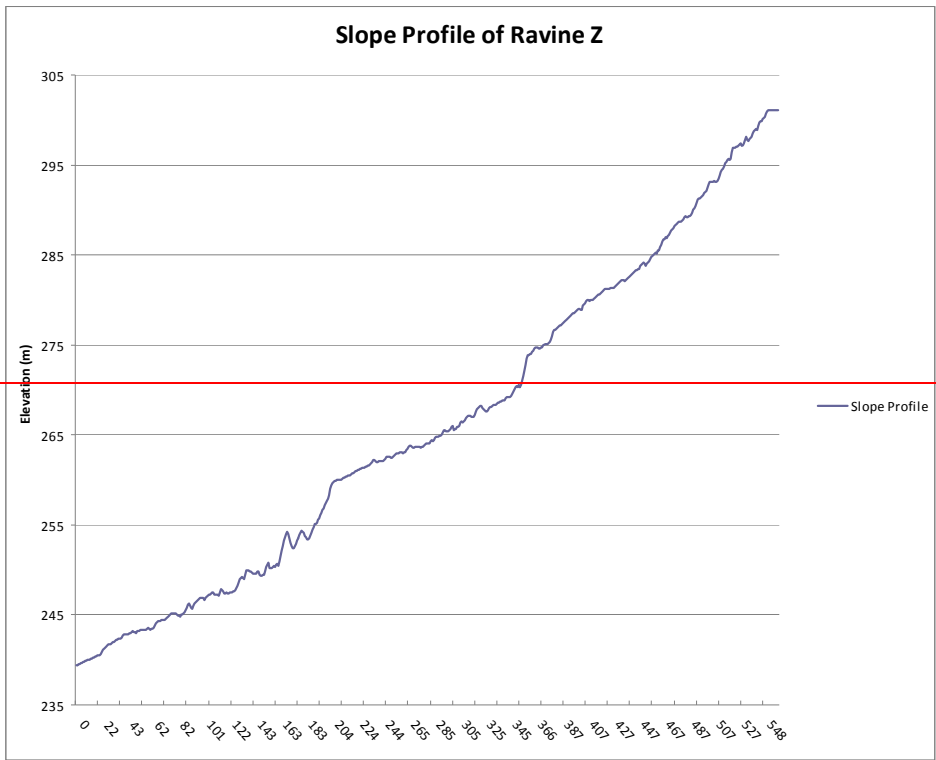
appearance with fill on the walls just below the nick point from the damming event mentioned later. The bottom has large amounts of sand that becomes finer grained as it stretches to the lowest elevations. There are also rocks on the bottom in the size range of 1-3 inches in diameter. The walls just below the nick point are about 18 feet tall, and very steep, and the walls lower by about 5 feet every 75 meters. The body of the ravine ends about 10 meters short of the path, and the land between is filled with sediment that water of heavy flow has carried out of the ravine.

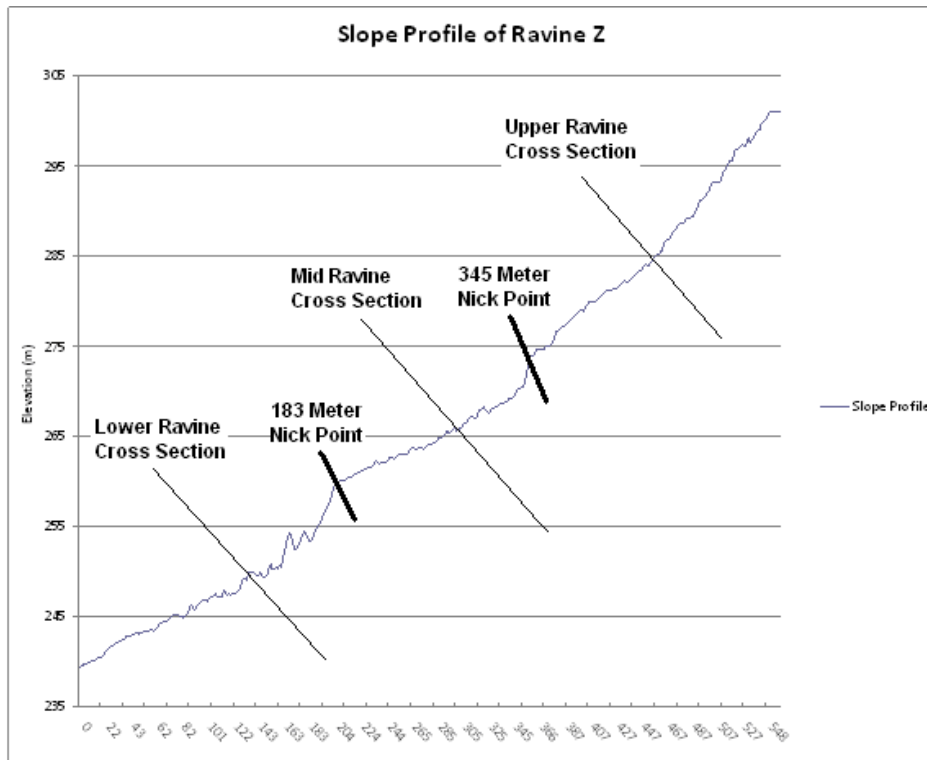


**Figure 11.** Just below the 183 meter nick point. Large fallen trees, steep walls, and vegetation.



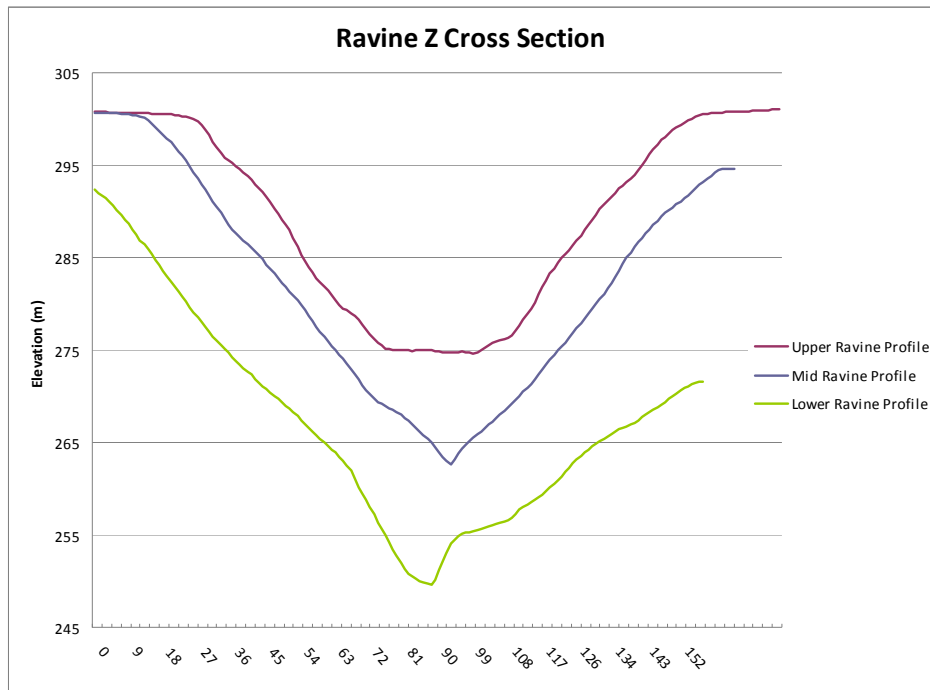
**Figure 12.** Note the sandy bottom. This is Forty feet from the end of the ravine.





**Figure 13.** Slope profile of Ravine Z, highlighting the two nick points, and the location of each cross section.

Using ArcGIS, a slope profile was constructed from the bottom of Ravine Z, following the lowest point of the ravine all the way to the top at the flat land just above the drainage pipe. The average slope of the profile is .11. The location of nick points is shown in Figure 13 above.



**Figure 14.** Cross section of Ravine Z. Note the differences in the shape of the bottom of the three profiles.

Again with ArcGIS, a cross-sectional slope profile was constructed to create the Upper, Mid, and Lower ravine profiles. Each cross section is 200 meters apart, dividing the ravine into 3 equal parts. Placing all three cross-sections in the same figure not only shows the difference in elevation as one travels toward the head, but also the change in shape of the walls and bottom. In the lower profile, the ravine makes a fairly rounded V shape, and the left side is much taller and steeper. The middle third is a sharp V, and the shape of the bottom is the same as travels up the walls. This part of Ravine Z is very steep, with tall walls. The upper portion of the ravine is more of a broad shape like a U, with walls that are not as high as walls in the lower parts of the ravine.

*You're still going to mark some of the important locations, like profile locations and the extent of each ravine 'segment' (upper, mid, lower) on a map or image, right?*

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## **DISCUSSION**

The bedrock and till stratigraphy do not appear to control the rate of erosion in Ravine Z. After searching for outcrops of bedrock throughout the length of the entire ravine, no discoveries were made. If the bedrock were a large contributor to the erosion rate, the bedrock likely would be exposed around the two nick points, and possible in other locations inside Ravine Z. Also, the material comprising most of the ravine walls is not till, but is just a mixture of dark soil, very small pebbles, and some grains of sand from past flooding episodes where water transported sand and sediment. Below the nick point at 183 meters, the walls appear to be made of "fill". The fill differs from the soil part of other ravine walls because the fill is layered. The fill wall is dark at the bottom, and then there are horizons of lighter colored, brown fill, which were likely the result of a damming episode of some sort. The layers are about 3 inches high, and continue upward to about 8 feet up on the wall, for a total of three layers. The fill is finer sediment, and has fewer rocks and pebbles mixed in, compared to the dark sediment found throughout the ravine.

Fill around the nick point was probably the result of some kind of constriction in flow occurring somewhere just below the nick point. In Figure 9, note that the bottom of the upper ravine cross-section is rounded, and appears to be filled with sediment, while the other two have eroded more into a V-shape. Similarly, below the nick point at 183 meters, sediment built up, leaving a layering of fill along the walls. The two nick points

in Ravine Z indicate that changes are recent, and that the ravine is still working to reach equilibrium. So, further migration of the nick points toward the head is expected in the future. Also, erosion and recession of the walls is occurring at a much higher rate toward the bottom of the ravine, as is demonstrated by the steeper walls in Figure 9. Walls with steeper angles are much less stable in times of major water flow through the ravine, so more change is expected in the lower ravine.

Vegetation, dead and alive, also appears to control the erosion of the ravine at numerous parts. When large trees fall, sometimes because the slope becomes unstable, and roots are not strong enough to hold it into the earth, they eventually tumble toward the ravine. It is possible that in the past, a few logs dammed a portion of the ravine, restricting water and sediment flow. The sediment built up against the logs, forming layers, which would eventually look similar to the layered fill found below the first nick point. Eventually the logs could have moved or decomposed, leaving very little evidence of the event. Trees are abundant in the ravine, and just above the walls of the ravine, and the roots systems which anchor them to the ground and are also responsible for nutrition are essential to ravine. The roots hold sediment in, and restrict erosion around those areas for the most part. The trees prevent erosion, until they are undercut enough that the roots fail, and the tree falls. Slumping, where a mass of unconsolidated material drops along a concave slip surface, takes place in Ravine Z, but the presence of trees also helps to prevent major slumping events. However, all ravines in Seven Mile park are heavily wooded, so the current vegetation cannot alone explain why Ravine Z is so active.

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Another possibility is that increased drain tile flow has affected the development and erosion of Ravine Z. The drain tile was installed in 1961, but addition of more acreage to the drainage pipe, or increased density of drain tile per acre could have significant consequences. The problem is that finding out specific information is difficult because there is no specific organization responsible for recording this information. So, the drainage rate to the ravine is obviously increased with the addition of agricultural drainage. Funneling the drainage to one cement pipe will cause increased erosion at that site compared to surrounding ravines which are fed more gradually and by several different sources flowing in at different locations. Also, the addition over the years of more tile to one drainage system could be the reason that erosion is occurring at a faster pace in Ravine Z. Again, though, other ravines in the park receive drain tile discharge, and further research should be done to determine whether drain tile discharge can explain driving the rapid erosion in Ravine Z.

~~How about starting a new section here called "Future Research in Ravine Z" FUTURE RESEARCH IN RAVINE Z:~~

The lack of change in the measurements between August and April is not surprising, but changes in the coming years will inevitably occur (see figure 8). Change could happen at small scales from creep and small slumps, or it could happen in rapid discrete events following a flood or sudden snowmelt, for example. Slumping occurs all over the ravine, and above the ravine where the large trees are beginning to lean. The land has slumped down, leaving an irregular topography in the more active areas. A large storm or period of flooding could feasibly trigger down cutting substantial enough to measure change.

As continual monitoring and measuring of Ravine Z occurs, the patterns of creep, down cutting, and headward erosion will become more evident. Through the last nine months of observations and findings, it appears that there will be no correlation with the behavior of Ravine Z, and the underlying bedrock of Seven Mile. To determine if differences in flow from drain tile are significant, future researchers could record the flow from the drainage pipes at several ravines in the park, eventually comparing them to Ravine Z. Also, future research could include monitoring the highly vegetated areas of Ravine Z, in an attempt to determine if these portions are more or less stable than the barren portions. An in depth study of soil properties could be essential in finding what exactly the layered pattern below the 183 meter nick point is, and possibly providing further insight to the circumstances under which the soil was deposited.

Also, you should end the paper with a summary of your findings; that is, you need a quick, concise restatement of which factors you think could be controlling erosion in Z, and which aren't. It could be a paragraph at the very end, in which case you should frame your findings in terms of what they mean for future research (something like, 'further research could seek to confirm the fill hypothesis and determine whether draitile flow into Z differs from flow into other ravines'). Or, you could have a separate Conclusions section.

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