The Restoration of a Historical Sediment Study and the use of LiDAR in the Determination of Elevations in the Whitewater River Valley.

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Abstract

Monuments of a 73-year-old sediment study were recovered to document their location and elevation to modern standards. The location data then was used with new LiDAR datasets to replicate previous studies.

The original floodplain sediment study of the Whitewater River was established by Dr. Stafford Happ, head of the Stream and Valley Section, Sedimentation Division, USDA Soil Conservation Service. The original 1939 study consisted of 72 cross-section ranges. The ranges were spaced in the valley at approximately 0.9 mile intervals and to mark the end of the range lines permanent monuments were established. In 1964 the study was expanded to a total of 94 cross-section ranges and again surveyed by Dr. Happ and his staff. The study was again repeated in 1994 by staff of the USDA Natural Resources Conservation Service (NRCS).

Beginning in 2009, field work has recovered approximately 84 percent of the of the survey endpoint monuments. Coordinates of those monuments have been established using mapping grade GPS's. Of the recovered monuments 41 percent have been surveyed to modern standards and coordinates and elevations have been established. A total of 7 endpoint monuments are known to been lost to natural or human activities. To date 26 endpoints have yet to be located.

The acquisition of LiDAR data in the watershed in 2008 offered the opportunity to use modern elevation data sets to complement the existing data from previous studies. The Lidar data with a vertical RMSE <=18 cm; a horizontal RMSE <=1 meter, and mean point spacing of 2 meters, was used for comparison to the historic survey data. The valley has experienced significant sedimentation as a result of flooding and upland erosion due to historically poor farming practices during the early settlement period. Data from the historical surveys along with the addition of the LiDAR data indicates that the floodplain continues to build and rise in elevation.

A comparison of historic profiles and Lidar derived profiles shows that the rate of deposition for the period between the 1994 and 2008 periods continues at an increasing rate. It is estimated that a minimum of 52 million cubic yards of soil had been transported and deposited to the valley floor during since 1939. Because of gaps in the recovery of range monuments a complete estimate of deposition in the valley cannot be made at this time.

Future work will continue and will focus on locating all of the remaining monuments, completing the survey of the monuments to modern standards and continuation of measurement of floodplain buildup with LiDAR. Additional needs are the completion of locating the cross-section ranges and gather ground truth survey measurements along those ranges to validate the LiDAR data.

Acknowledgements

I would like to thank my advisor Dr. Jay Parrish P.G., Professor of Practice, Penn State University for his insight and guidance. And also want to thank him for his gentle reminders to pay attention to the academic side of this project. It was far too easy to get involved in the fun part of working outside in the watershed and Dr. Parrish helped keep me focused.

I would also like to thank and acknowledge Doug Christianson, Construction Inspector, USDA, Natural Resources Conservation Service, Rochester, Minnesota. Doug is the only remaining person who worked on the 1994 survey and who is still working for NRCS. Without Doug's efforts much of the recovery of monuments would not have happened. His experience and knowledge of the project, the Whitewater watershed, past surveys, and his skill with modern survey equipment was an important contribution to this project.

I would like to also thank Robert Bird AE-Retired USDA SCS for his assistance in interpreting and archiving materials from the 1994 survey. He helped fill in a lot of blanks when a specific monument proved to be difficult to find. I would also like to acknowledge the contribution of two members of the 1994 survey team who have since passed away, John Micheel SCT and Bill Lorenzen Biologist.

And last but not least I would like to acknowledge Dr. Stafford Happ whose vision and foresight in establishing this study in 1939 made everything possible. This study is truly a rare and valuable resource for anyone wishing to study valley floodplain sedimentation. As I studied old records and hiked to the more remote study locations I gained more and more respect and appreciation for the efforts of Dr. Happ and his crew. Just the physical effort of hauling steel, concrete, and all the survey equipment to the sites would have been challenging. And to accomplish all they did without the infrastructure and equipment of today is remarkable. I hope to have contributed in a small part to the effort of others.

Contents

1. Introduction

The purpose of this project is twofold. It is to locate and document a previous sediment study established in 1939 and to use elevation data extracted from a LiDAR data set along the set of pre-defined valley cross sections. This project will be a preliminary effort to determine if LiDAR-derived elevations can be used in conjunction with established and previously surveyed valley cross-sections in the Whitewater River Valley. In addition this paper will serve as the first effort to document and publish the original survey markers for future studies.

To replicate the surveys of the past is a time consuming and physically demanding task. For example the 1994 survey which required limited re-establishment of the range cross section monuments and using modern electronic survey equipment took 4-5 people more than 5 months to complete. And because the X-sections cross the river and backwaters of the Whitewater much of the survey has to be done in the winter. A demanding time for field work in Minnesota.

2. The Geographic Area of Study

The study area is in the Whitewater River basin. The Whitewater River is located in SE Minnesota and drains an area of 321 square miles (Hydrologic Unit Maps, 2009).

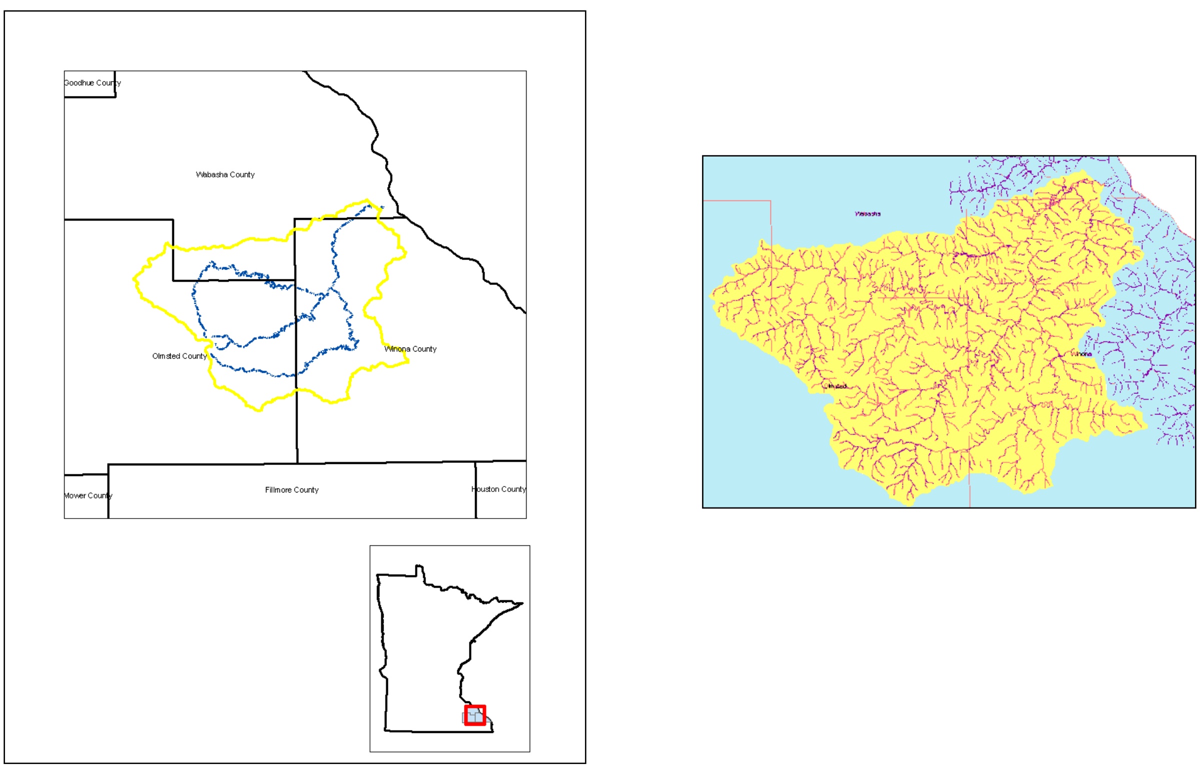


Figure 1 Location of Whitewater River watershed in SE MN.

The topography in the area is part of a rolling plain at an elevation near 1250 feet above sea level. There are remnant bedrock ridges which rise above this surface and have approximately equal elevations. This Whitewater River dissects this region and the upper reaches have narrow, steep-walled valleys that are more than 500 feet below the upland plains. The hillsides are very steep with 45 degree slopes or greater common. All along the valley are steep to vertical bluffs of exposed limestone and sandstone.

Bedrock in the region is a combination of layers sedimentary rock of limestone, dolomite limestone, shale and sandstone. This area resides in the SE MN karst region and the typical layer of glacial debris is not as present as areas to the west (Natural History - Minnesota's geology). The uplands are comprised mostly of loess soils covering the rolling uplands. Loess soils by their physical nature are very erosive and are transported easily leading to the problems experienced by local residents.

The upper reaches of the valley floor are narrow and composed of alluvial materials. In the lower portions of the valley the bottomland soils are now buried by several feet of modern sediment. Dr. Happ's soil boring logs indicated that in 1939 sediment layers varied in depth from 5 feet to more than 20 feet.

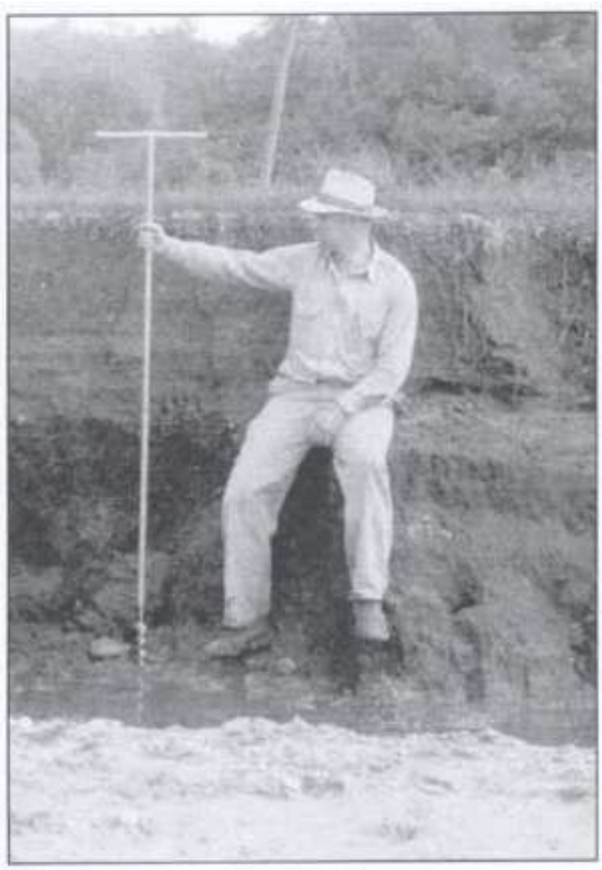


Figure 2 "Stafford C. Happ in a tributary of the Whitewater River, in the Driftless Area near Beaver, Winona County, Minnesota, 29 August 1940. The cut bank exposes the old, black, pre-settlement soil overlain by 60-90 cm of historic, brown sediment. Happ sits on a ledge formed by the more resistant old soil and subsoil." Caption from US Department of Agriculture Technical Bulletin 695, 1940: Some Principles of Accelerated Stream and Valley Sedimentation.

Vegetation in the valley is predominantly upland oak, elm, and ash hardwoods (Ecological Classification System, Paleozoic Plateau Section, 2012). They occur mostly on the side hills and in the upper reaches of the watershed. The valley floor is predominated by herbaceous material and willow. The largest herbaceous component is Reed canarygrass (*Phalaris arundinacea L*) which is a tall, dense, fast growing, aggressive grass (Conservation Plant Characteristics for Phalaris arundinacea, ND). It dominates the lower floodplain areas with occasional stands of willow (*salix sp.).*

3. Project Area History

The Whitewater River is located in the karst region of SE Minnesota. It drains directly into the Mississippi River and was one of the initial areas settled in Minnesota during the mid-1800's (Folwell, 1921). Below the confluence of the three branches of the river the town site of Beaver was established in 1854. (Minnesota Place Names, Townships and Villages, 2009) Because of its close proximity to the Mississippi River, steamboat traffic, and the easy access to the western plains it quickly became a terminus for people traveling westward to the western plains (Folwell, 1921). At its heyday it was the eastern end of a stagecoach line and later a narrow gauge railroad (Society, 1883).

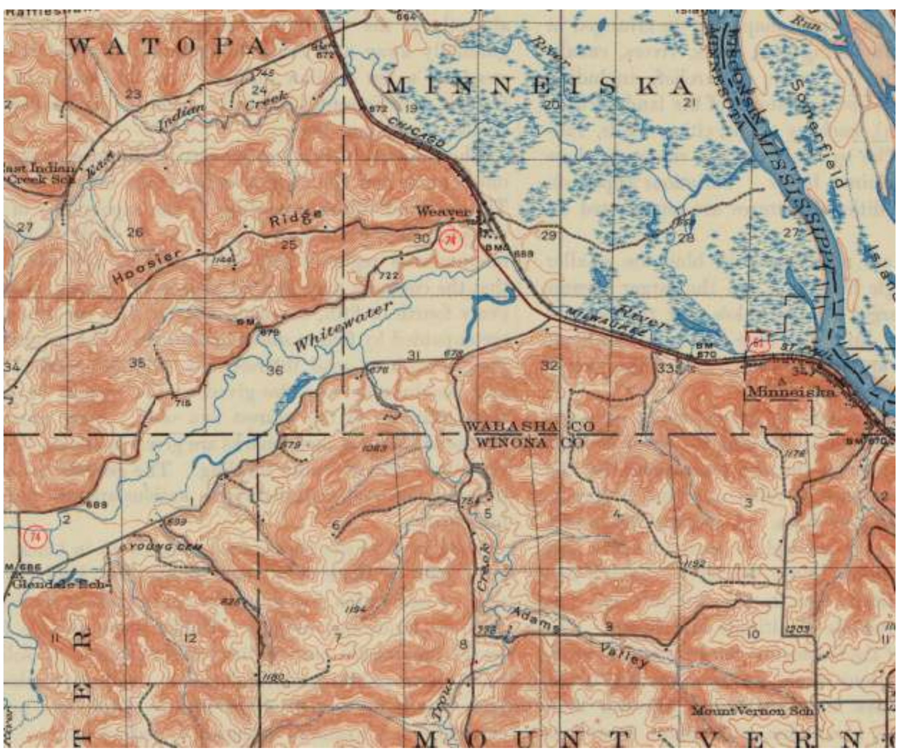


Figure 3 **Topo**graphic map **of the lower main branch Whitewater River.** USGS Cochrane Quadrangle 1937

The valley floor and related uplands quickly became settled and cleared for agriculture. The steep hillsides that were unsuitable for row crop farming were cleared and grazed with livestock, predominantly cattle. At its peak the town of Beaver had a population of more than 1,000 people and supported 3 hotels (Fig. 4) (The Beaver Story, We Remember, 1962)

Figure 4 Beaver Town Site Late 1800's Photo courtesy of the Winona County Historical Society

In the 1920's and 1930's because of increasingly intensive farming practices, the lack of conservation measures, and permanent cover on critical slopes the town of Beaver and the Whitewater River flood plain began to experience increasing levels of flooding and inundation. Historical records relate how in 1938 the town and valley area were flooded 28 times. (The Beaver Story, We Remember, 1962) The upland erosion associated with the flooding also deposited tremendous amounts of sediment in the valley floodplain damaging cropland, infrastructure, and buildings (Fig. 5).

Figure 5 Typical damage to the cropland in the Whitewater flood plain after a flood event. Notice the lack of trees and permanent cover on the hillsides in the background. Also notice the height of the fence posts in the foreground. Fences usually are 4 feet or more above ground level. Photo Courtesy of the USDA Soil Conservation Service

Figure 6 Damage to a dwelling in the Whitewater valley due to sedimentation. Photo Courtesy of the Winona County Historical Society.

Due to the almost continuous flooding damage and sedimentation people began to leave the valley and the State of Minnesota began to purchase the land for establishment of a Wildlife Management Area (WMA). The purchasing of the land was completed in the 1960's and much valley floor is now WMA, State Forest, or State Park land. When some of the older buildings were salvaged or torn down it was discovered that what was assumed to be the first floor was actually the second floor. The owners had just built onto the existing building upward after the first story had become filled with sediment (Fig. 6).

Figure 7 Road Damage due to flooding and sedimentation in the Whitewater Valley. Photo courtesy of USDA Soil Conservation Service.

Since the State of Minnesota has taken ownership of the valley and over the following years the Whitewater Valley has become one of the premier outdoor recreation and hunting and fishing areas in the state.

Figure 8 Beaver Town site 1949 Photo Courtesy of the Winona County Historical Society.

Figure 9 Beaver town site 1980. Photo by author

Figure 10 Topographic map of the lower main branch Whitewater River**,** USGS Weaver Quadrangle 7.5 minute series, 1972. Notice the increasing amount of water and wetlands symbols in the valley floodplain as compared to the 1937 topographic map (figure 3)

In the late 1930's Dr. Stafford Happ a geologist and the leader of the Stream and Valley Section of the Sedimentation Division of the USDA Soil Conservation Service established and surveyed 94 cross sections in the valley to document the level of sedimentation and its movement. The cross sections were established in all major tributaries of the river and crossed the valleys and ended on each foot slope. They were meticulously documented and had permanent concrete and steel monuments established on each end. These cross sections were surveyed and soil profiles logged. The study was again repeated in the 1960's by Dr. Happ. Many of the records (survey books, log sheets, maps, and notes) exist as scanned files and photocopies of the original survey notes. Beginning in the early 1990's the Winona Soil and Water Conservation District (SWCD) applied for a PL-566 Small Watershed Project. Part of the application process was to again locate and survey those same X-sections to document the sediment budget and erosion estimates. This work was carried out by USDA Natural Resources Conservation Service personnel, SWCD staff, and volunteers.

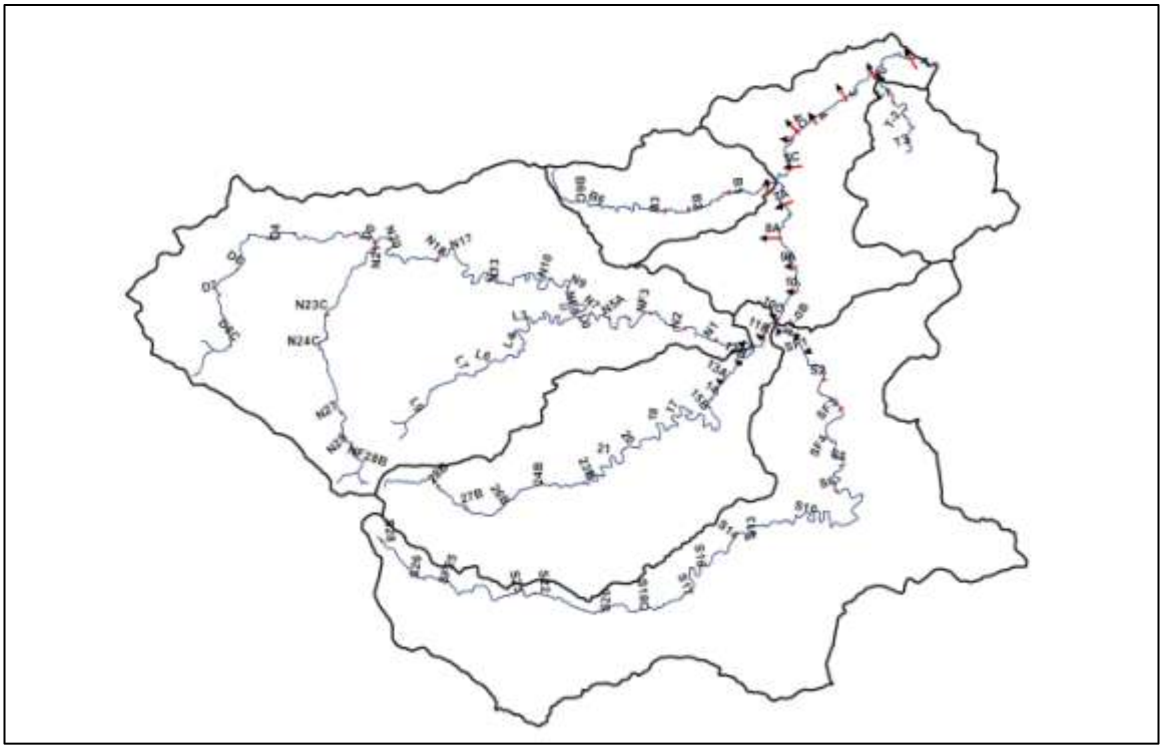


Figure 11. Location of Happ Sediment Study ranges. Also pictured are sub-watershed boundaries

In 2008 the MN Pollution Control Agency in response to the Clean Water Act began to investigate designating the Whitewater River TMDL for turbidity. Again there was interest in surveying the Happ X-sections to document the changes that have again occurred in the watershed.

Figure 12 Road Damaged in 2007 Flood Event in the Whitewater River Photo courtesy Wikipedia.

In recent history the Whitewater watershed has experienced 2 15+ inches rain storm events. They occurred in July1978 and again in August 2007 (Whitewater State Park, 2011). Both events caused millions of dollars of property damage and the unfortunate the loss of life (Fig. 6). On a personal note, two of the deaths in the 2007 flood were my Soil Conservation Technician and his wife who were swept off a road by floodwaters as they traveled from Wisconsin back to their home in the valley. These two storm events changed the valley in many ways. Moving of the channel, scouring the channel bottom, and deposition in the valley floodplain are just some of the long term impacts. Because of the damage caused by the 2007 storm and the need for flood recovery and flood mitigation the State of Minnesota directed state funds for the acquisition of LIDAR data for the entire 10 county SE MN area. In addition the data was to be publicly available (Loesch, 2009).

4. Data Sources and Specifications

In the spring of 2008 a contract was awarded to Aerometric, Sheboygan, WI to collect LiDAR data for the 10 county area of SE Minnesota (Loesch, 2009). The deliverable products included 1 meter resolution DEMs, 3 meter resolution DEMs, 2 foot contours, edge of water breaklines, and classified LAS point files. Specified vertical accuracy was 18 cm. using NSSDA accuracy methodologies. (Loesch, 2009). the type of sensor used by Aerometric for this survey appears to be missing. The actual LIDAR data was collected leaf-off in November of 2008 with the first deliverables recieved in the spring of 2009.

The Whitewater River lies in the counties of Olmsted, Winona, and Wabasha. This study concentrated on an area in Winona and part of Wabasha Counties. The delivered RMSE for Winona was 0.161 meters and Wabasha was 0.117 meters. Data was delivered in tiles that covered $1/16^{th}$ of a 1:24,000 scale quadrangle. The data is comprised of classified las files, personal geodatabases which include 1 and 3 meter DEMs, 2 foot contour maps, breaklines, validation points, and shaded relief raster images for each tile.

All data is in NAD 83 UTM Zone 15 projection.

During the 1994 survey many of the located monuments were also recorded with GPS equipment. The state of GPS at the time was considered to be operational beginning in 1993 (Observatory). The Soil Conservation Service (SCS) acquired Rockwell Portable Lightweight GPS Receivers (PLGR) (Navigation, ND) a year later. These units were single channel receivers and while they did use the more accurate encrypted Y band signals they were somewhat slow and had difficulty locking onto satellites and giving an accurate position fix in tree canopy.

Much of the surveys conducted in the 1994 period were during the winter of 94-95. Conditions were cold for Minnesota winters (Daily Temperature Departures from Average in 1994, ND), the people doing the surveys were often volunteers working on their weekends, and little time was spent collecting GPS data. It was related to the author by one of the survey party members that if the GPS did not provide a quick lock on satellites or if it had difficulty because of overhead cover the user just moved away from the monument location until a good fix was taken. In addition the location data was collected in decimal degrees, minutes, and seconds. After the data was downloaded by the GIS person at the time rounded the values to the nearest whole second. So depending on the location of the monument and the extent of rounding that occurred many of the PLGR locations are only accurate to approximatly 200 meters of the actual point.

Considering that more than ½ of the monuments are currently on private lands it was surprising that so many have survived 70 years and that many have been found. Landowners varied in their knowledge regarding the monuments, their purpose, and their locations. Some were very well versed in what they were and what they represent while others had no idea what they were. There are two sites where monuments existed in the middle of the landowners lawns, The owners had been mowing and trimming around them for 25+ years, never knowing what they were or why they existed.

Figure 13 An example of the original survey notes from the Happ survey in 1939

Beginning in the early spring of 2009 an effort by Doug Christianson, NRCS and the author was started to locate the monuments from the previous surveys. Previous surveys had located a majority of them but 18 years had elapsed since the last time they were located. During the 1994 survey additional notes as to the location were made and approximate locations were hand drawn on hard copy USGS maps. Off and on during the next 2 years endpoint monuments were located on approximately 85% of the ranges.

A typical effort would be to read and print out the old surveys which have been scanned into Adobe pdf format files, transfer the hand drawn end point locations from the USGS maps to digital maps in ARCMap. Those points were loaded into a consumer grade GPS which was used to navigate to the general area. Once in the general area it was like a modern treasure hunt. The old survey notes from all three epochs provided clues based on descriptions of bearing trees that may or may not still be living, fence lines that may or may not still exist or in their past locations, and roads that also may or may not still be in the same location. Often times the old x section survey themselves provided excellent clues as to the location of the monument in the topography. Usually if one endpoint monument was located it was relatively easy to locate the other since the original notes included an azimuth and distance to the other end

Figure 14 Examples of the monuments that marked the endpoints of the x-section lines

once the monuments were located they were marked with flagging and paint. After the monuments were located either concurrently or during later visits the location was recorded using GPS. Originally the initial effort was using a NDGPS differentially corrected Garmin GPS in the USDA configuration 1 (Configuration I, ND). Later the NRCS upgraded to the Trimble GEOXT 2008 (GeoExplorer 2008 Series Documentation, ND)which provided additional precision and the ability to edit shapefiles directly in the field. After the end points had been located where possible the location and elevation was further refined by use of a survey grade Trimble R8 GNSS reciver.

The Whitewater Valley is a very difficult environment for using GPS to locate positions. The steep sideslopes of the valley mask the valley floor and point locations are often 300 - 500 feet below the upland plains. Often heavy tree canopy limits the usefullness of the Trimble R8 in more than half of the located monuments. In addition much of the Whitewater Valley has limited or no cell phone coverage which also reduced the usefulness of the Trimble R8 that required cell phone coverage for VRS correction. These points in the future will need to be surveyed in a more traditional manner.

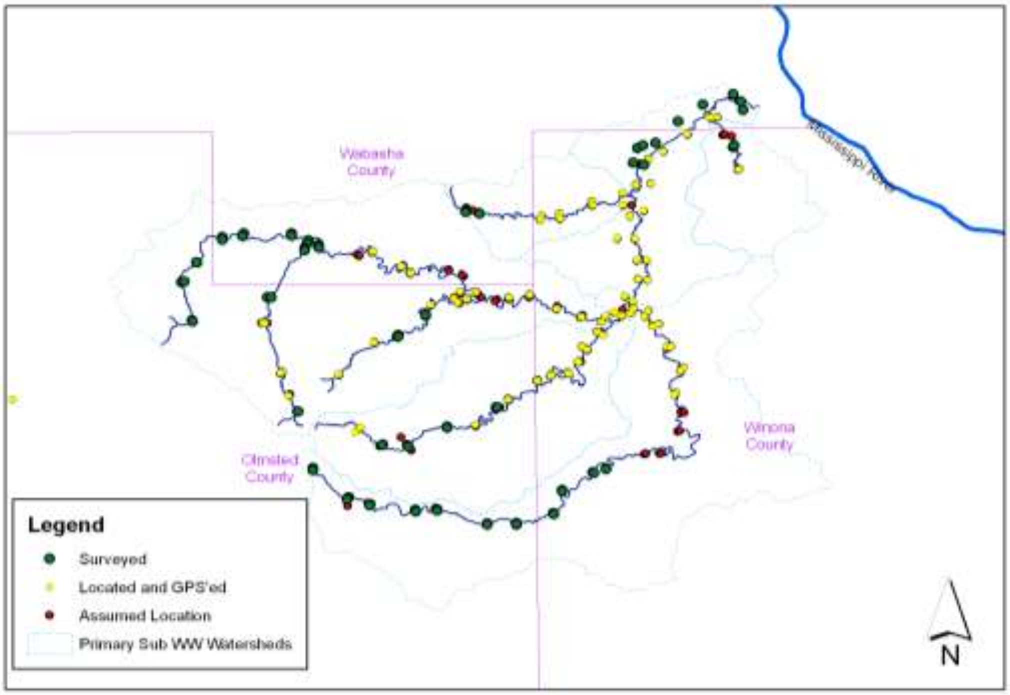


Figure 15 Status of locating range endpoint monuments 12/2011

Approximatly 26 monuments of the 196 origional endpoints remain to be found. Almost all of the endpoints missing during the 1994 survey have been accounted for, either found, found as disturbed and/or distroyed, or determined to be missing. The monuments are relativly easy to see in the early spring and to some extent very late fall before snow cover. Once vegetative green up begins in the spring conditions rapidly deterorate to the point where the monuments become almost invisable Some X section ranges and their endpoints are relativly easy to access due to proxcimity to roads, trails, and managed agricultural lands. Other ranges are very difficult to access because they are miles away from road access and require traveling through lands with heavy understory that has not been managed for 60 years. Most of the remaining monuments fall into the second category and will take many lenghtly field sessions to locate and survey. Because of the remote locations it is expected that they still exist in un-distrubed condition

5. Processing and Analyzing the Data

A general project file was prepared in ESRI ArcMap with the projection set to NAD 83 UTM Zone 15.

Included in the project were:

- The points file of the GPS derived survey in 2009
- Watershed boundary maps from the 12 Digit Hydrologic Unit Code for the Whitewater River from the USDA Data Gateway.
- A stream centerline polyline file from the MN Data Deli (for orientation purposes only)

- A 3 meter DEM derived from the 2008 LiDAR data
- A polygon file of county boundaries from the USDA Data Gateway
- An index polygon of LIDAR tiles for the county.
- 2010 NAIP color orthophoto for Winona, Olmsted, and Wabasha Counties from the USDA Data Gateway.

A polyline shapefile was created and polyline features of the x-sections were created by snapping the endpoints to the surveyed endpoints of the ranges. Line direction was established to match the stationing of the original surveys.

A comma delimited file was imported into ArcMap and a graph was made of the 4 datasets using the ArcMap graphing function. The charts with each range in the appendix were derived from this process.

Using EZ Profiler (Huang, 2009) available through the ESRI downloads site a points file was created along each X section range polyline. EZ Profiler creates an attribute table for that includes the XY coordinates, Z values, and distance along the line from the origin. The tool has the capabilities to place points at specified distances along the line or a set number of points along the line spaced equally. I chose to have 200 points which after trial and error seemed to provide good resolution of the DEM. The 3 meter DEM was used as the elevation source.

Since the output of EZ Profiler derived from the 3 meter DEM was metric units the data was exported to MS Excel where elevation and distances were converted to feet. This was necessary because all measurements from previous epochs were in feet units of measurement. Z values and distance where summarized with the other epochs x-sectional survey data elevation and distance.

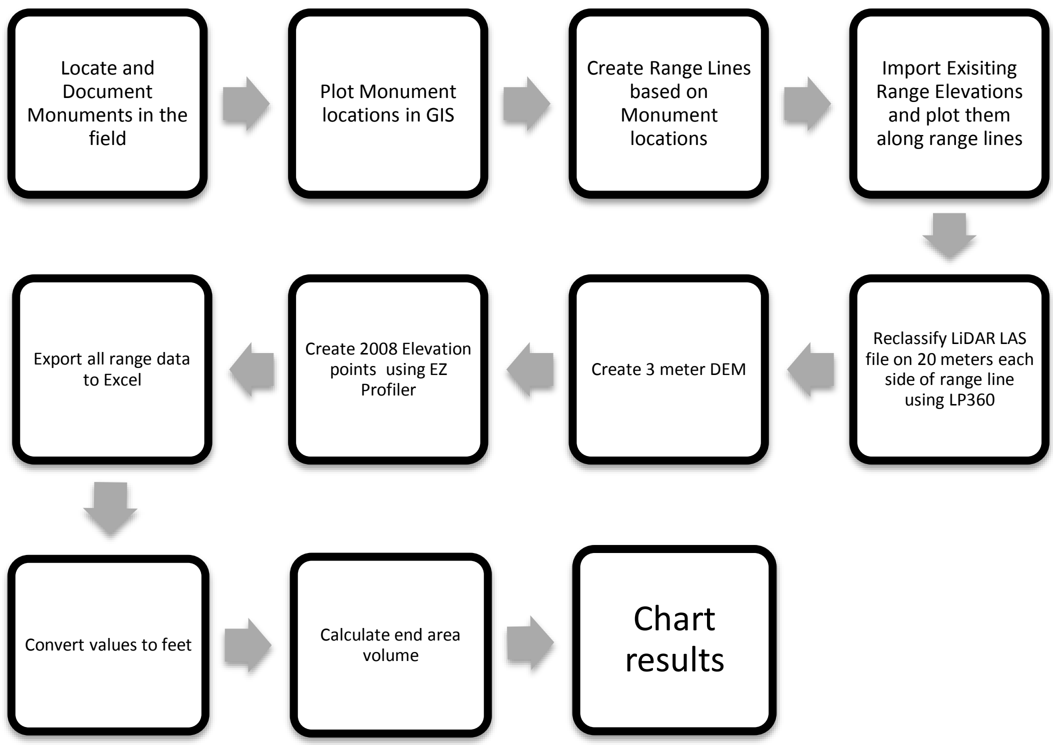


Figure 16 Processing Flow Chart

6. Results

Volumetric differences were calculated using the end area method (Fundamentals of Transportation/Earthwork, 2011). The end area method of calculating volumes is common in earthwork computations and typically used where x-sectional data exists. The XY coordinates are typically plotted and the area under the curves is measured. In this example the area was determined mathematically using the elevation values for the Y value and the distance along the x-section lines for the X. The X values were determined as the distance between two survey point and the Y values were the average elevation value for each of the two points. These values were used to calculate the square foot area of the x-section. To calculate cubic volumes ½ the distance to the next upstream range and ½ the distance from the next downstream range were combined and multiplied times the square foot area for that x-section and epoch. For locations of the individual range locations refer to figure 11

All surveys previous to the 2008 LiDAR collection were converted to sea level elevations and UTM coordinates. The cubic volumes were calculated for each epoch (1939, 1964, 1994, and 2008) on each range line. Comparison between epochs was made using the differences between the charted range elevations. The differences are expressed as a percent of the total volume of the range as measured in 1939. Since there has not been established a true pre-European settlement baseline elevation, 1939 was used as the baseline. It is known by the history of the area that significant amounts of sediment had already been deposited prior to 1939, it is beyond the scope of this study to establish that baseline

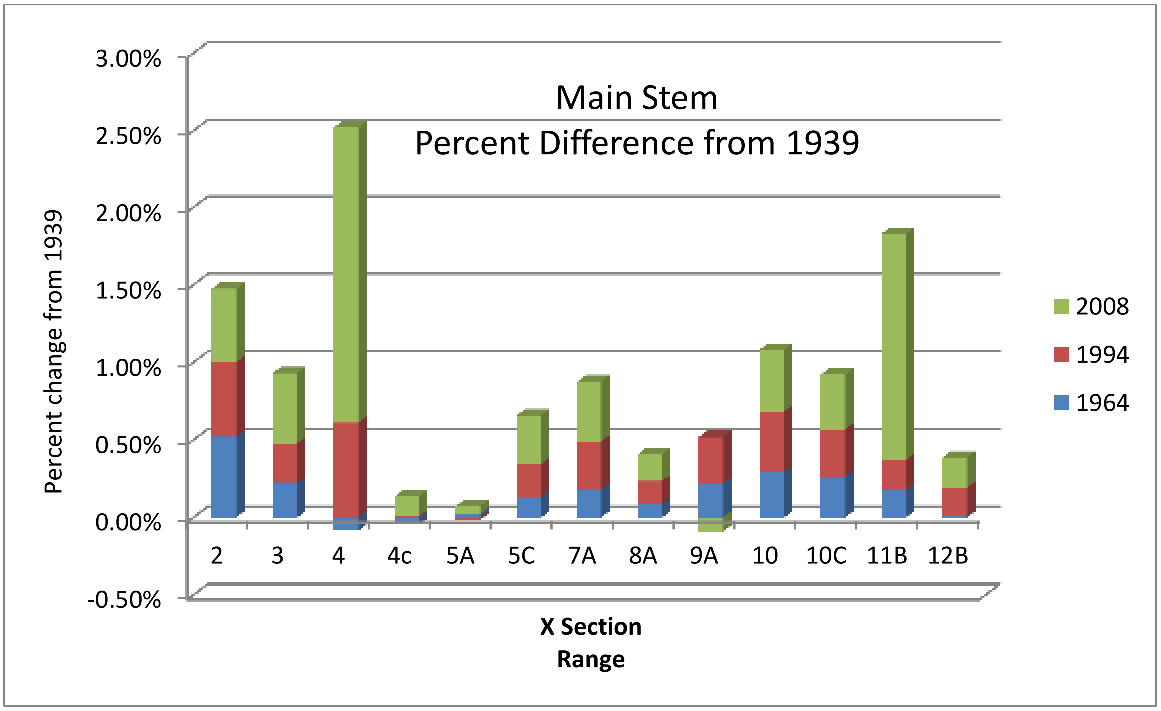


Chart 1 Percent change Main Stem for each epoch using 1939 as the baseline

Main Stem Percent Difference from 1939

Range	1964	1994	2008
2	0.5199%	0.4806%	0.4736%
3	0.2226%	0.2558%	0.4524%
4	-0.0847%	0.6104%	1.9106%
4c	-0.0453%	0.0070%	0.1292%
5A	0.0194%	-0.0148%	0.0530%
5C	0.1301%	0.2148%	0.3141%
7A	0.1801%	0.3113%	0.3862%
8A	0.0823%	0.1537%	0.1717%
9A	0.2185%	0.3000%	-0.0894%
10	0.2896%	0.3940%	0.3981%
10C	0.2597%	0.3077%	0.3531%
11B	0.1752%	0.1954%	1.4588%
12B	0.0094%	0.0018255	0.001954
Average	0.15%	0.26%	0.48%
Standard deviation	0.0016	0.0017	0.0055

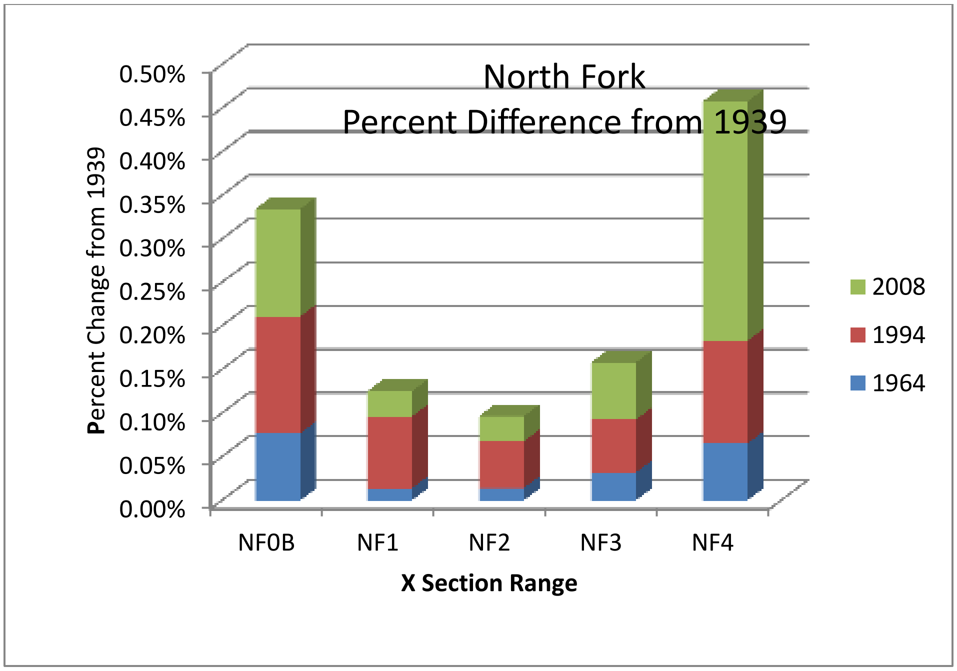


Chart 2 Percent change North Fork for each epoch using 1939 as the baseline

North Fork Percent Difference from 1939

	1964	1994	2008
NF0B	0.0769%	0.1340%	0.1237%
NF1	0.0138%	0.0822%	0.0288%
NF2	0.0141%	0.0536%	0.0288%
NF3	0.0319%	0.0606%	0.0655%
NF4	0.0650%	0.1178%	0.2748%
Average	0.04%	0.09%	0.10%
Standard deviation	0.0003	0.0003	0.0009

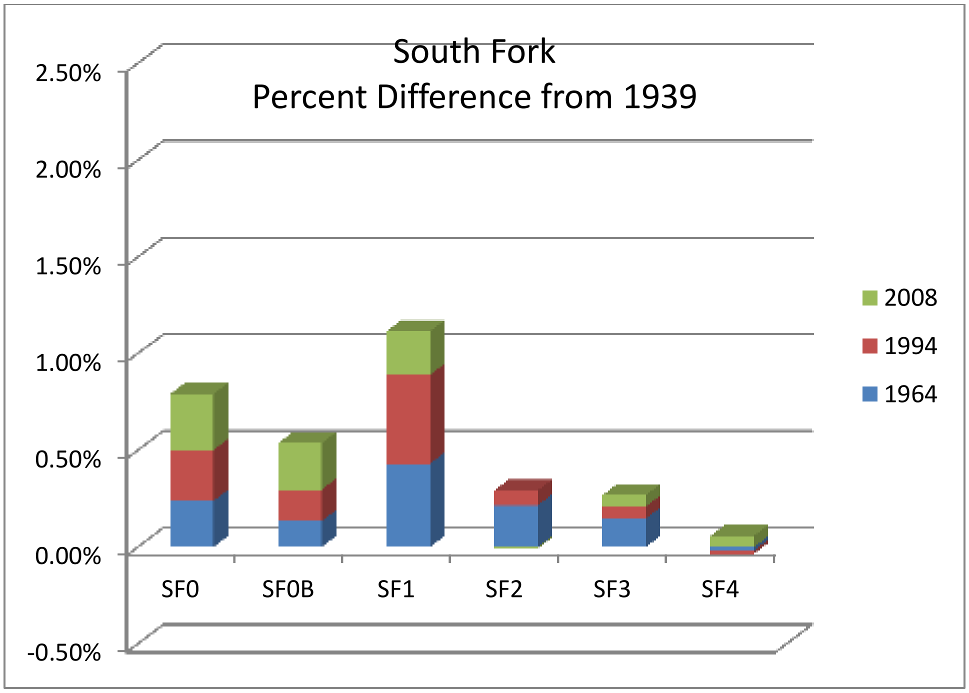


Chart 3 Percent change South Fork for each epoch using 1939 as the baseline

South Fork Percent Difference from 1939

	1964	1994	2008
SF0	0.23895%	0.26220%	0.28987%
SF0B	0.13464%	0.16211%	0.24075%
SF1	0.43075%	0.45833%	0.22790%
SF2	0.21533%	0.07710%	-0.00662%
SF3	0.14802%	0.06162%	0.05843%
SF4	-0.01736%	-0.01649%	0.05843%
Average	0.19%	0.17%	0.14%
Standard deviation	0.0013	0.0016	0.0011

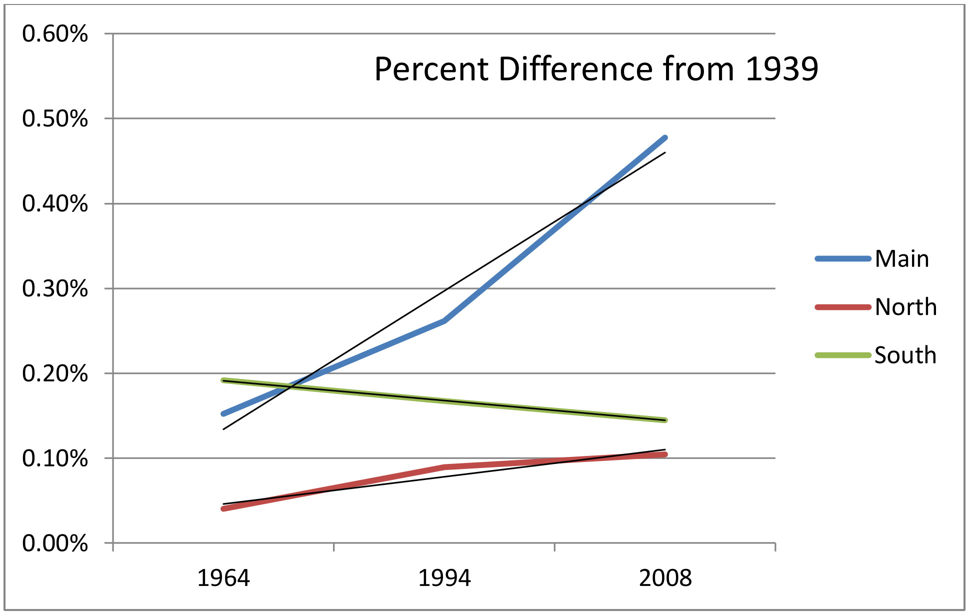


Chart 4 Rate and trends of floodplain elevations as compared to 1939

The data shows there is a increasing rate of deposition between epochs. In the main stem of the Whitewater the rate almost doubles from each epoch. There continues to be increasing sedimentation along the North and South Forks but the rates are slightly decreasing and increasing respectively. There are only a few negative values on isolated ranges. A negative value in percent difference indicates that sediment was removed from that range during that time period. Almost all ranges from all epochs showed a positive value indicating continuing sedimentation is occurring and the floodplain continues to build.

The flood of 2007 has severely impacted the area around Range 12B. This area had significant flood damage and as a result also significant reconstruction activities. In addition because of all the changes to the endpoint monuments Range 1 was considered to be an outlier and not included in this analysis.

7. Conclusions.

A review of the individual cross-section graphs indicates the history of the area. For almost every range the valley flood plain continues to increase from each preceding survey period.

In addition the rate of sedimentation between the epochs is accelerating. Anecdotally the watershed has been increasingly moving toward more row crop intensive agricultural rotations. There has been a significant reduction in the number of dairy and beef operations in the watershed (USDA, NASS, 2011). What dairy farms are left are being consolidated into large and very large operations leading to a reduction in forage crops planted. Forage crops are significantly more effective in holding soil in place during heavy rainfall events. And with the increasing size of farm equipment and the impact of underutilization on profit margins many traditional conservation practices are being removed for the sake of efficiency

The rate of deposition in the upper reaches of the North and South Forks is less than the main stem of the Whitewater. This may lead to hypothesize that sediment is being removed from the water earlier and upstream of the study area and there is less sediment to make the dramatic changes as have been seen historically in the lower section. The lower section may continue to be impacted by active bank erosion and sediment may be deposited, eroded, and re-deposited again as it moves through the river system. A survey of the river banks in 1991 and 1994 indicated that almost ½ of the length of the river had the potential to erode on either one or both sides (Rippley, 1991). Much of this length was in the lower sections of the river. This is consistent with other studies performed in the region. (Trimble, 2009)

When viewing the graphed data extracted from the LIDAR dataset the lines are very irregular. I believe it to be the influence of the heavy reed canarygrass cover in the valley on the LiDAR return. Because the area is not managed for agriculture and there is no active burning in the valley, the whole valley floor has been taken over and reed canarygrass and scattered willow stands dominate.

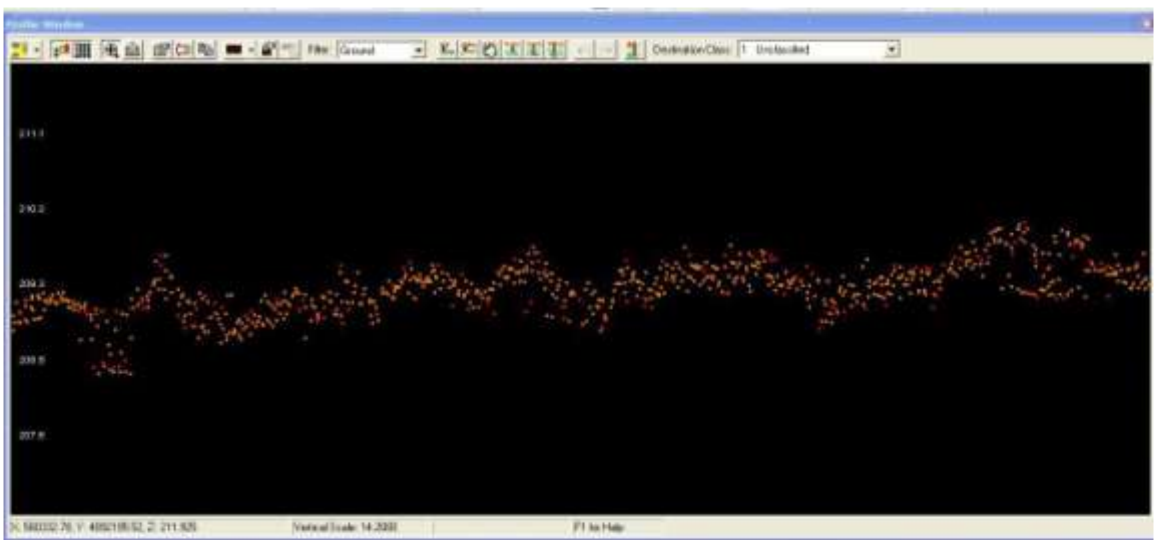


Figure 17 Profile of las points displayed in LP360

Figure 17 displays the classified las points as delivered by the vendor along the range 4C. In many places the depth of the points is about 1 foot or more. Only points classified as ground (class 2) and model key points (class 8) are displayed. The model key points are red and points classified as ground are orange. So when the 1 meter and 3 meter DEM were developed the cell values appear to have an equal chance of being a value at the upper part of the range or the lower part of the range.

Figure 18 The area displayed in Figure 15 is along the range line between the road SE to the river

While perhaps the LIDAR derived elevation data may not be as exact as the previously surveyed data I believe that with the corrections discussed earlier to be accurate enough in the macro sense to be used to calculate sediment accumulation or reduction in the valley floor.

A gap in the study that cannot be modeled using airborne LIDAR is the active bank erosion. With the exception of breaklines and elevation differences the dataset cannot model the amount of bank erosion. Studies in other watersheds suggests that bank erosion is a large part of the sediment load in watersheds in agricultural areas. A walking survey performed in 1991 and 1994 indicate that over half the length of streambanks in the watershed have the potential to contribute sediment to the river. A study by Nasermoaddili and Pasche Application of Terrestrial 3D Laser Scanner in Quantification of the Riverbank Erosion and Deposition, indicates that terrestrial LIDAR could be a valuable resource in determining the additional sediment loading contribution of bank erosion.

At this point the goal was met to produce cross section plots of the various cross sections and to compare the data from the 1930's 1960's 1990's and the results from the LIDAR data. See appendix 1 for individual plots and photos of the ranges.

One purpose of this study was to determine if the accuracy level of the LIDAR will allow future floodplain evaluation using LIDAR only products. Graphing elevations of individual cross sections was useful in making comparisons as to the rate of floodplain accumulation. The end area method of calculating volume gave a good estimate of total volumes and the amount and rate of change. But given the distance between each range and the variability of the terrain between the ranges, calculation of actual cubic feet or tons of sediment deposited would be more misleading than useful.

Each range has its own story. An example would be Range 1 at the mouth of the valley. The north endpoint was established in 1939 but was lost before the next survey in 1964.

The endpoint was then moved to a higher elevation further north but was again lost before the 1994 survey. Again the end point was moved to another higher elevation and again it was further north. The south end point monument was thought to have been lost between the 1964 and 1994 surveys but was found this past summer by Doug Christenson and the author. A fence was used to reference the location of the monument. The monument was recorded in distance and direction of the fence line in the survey notes. The fence was moved right before the 1994 survey and the survey party was unaware of the change and therefore were looking in the wrong location. It happened to be found because one day during a search the landowner drove by and inquired what was going on. In the following conversation it was discovered the fence had been moved further off the road and probably more in accordance with the county legal right-of-way. Once the additional distance was accounted for a quick scan with a metal detector located the monument, bent over and buried about 10 inches below ground on the road shoulder. Being that the monument was bent, probably by equipment resurfacing the road, we can only estimate the probable location and elevation of the original end point.

Future Works Needed

The study focused only on the lower ranges on all three branches and the main stem of the Whitewater. Looking at the completion map figure 15 shows which monuments that have not been located yet. These monuments need to be located, surveyed, and documented to expand the study to the whole watershed. The monuments in the middle of the branches are the most difficult to access and survey. In order to expand the study through the whole watershed these monuments must be located and documented.

In addition future study will be needed to validate the elevations along the range lines. While there appeared to be good correlation of elevations determined by LiDAR at proximate points such as roads or near the endpoint monuments further validation in areas of heavy reed canary grass cover or tree cover will be needed. This can be accomplished with relative ease once the endpoint monuments have been surveyed and documented to sea level elevations.

A logical expansion of my study would be to investigate further the smoothing of the LiDAR based 2008 lines with a possible reclassification of the las files and then building new DEMs to be used in the study.

Additional study could investigate land use and farming trends and determine if there is a relationship between upland land use and floodplain deposition.

In this study 1939 was used as the baseline for all comparisons. But based on the history of the area it's known that large amounts of sediment had already been deposed by 1939. Dr. Happ made numerous and detailed soils boring logs along each of the ranges. It would be possible based on the historical survey data to assign a elevation to the line where he noted the original soil and the beginning of the sediment cap. That line would be the historical baseline and a more accurate estimate of sedimentation since European settlement could be made. Some of the soils logs from Dr. Happ's study are not in the materials stored locally.

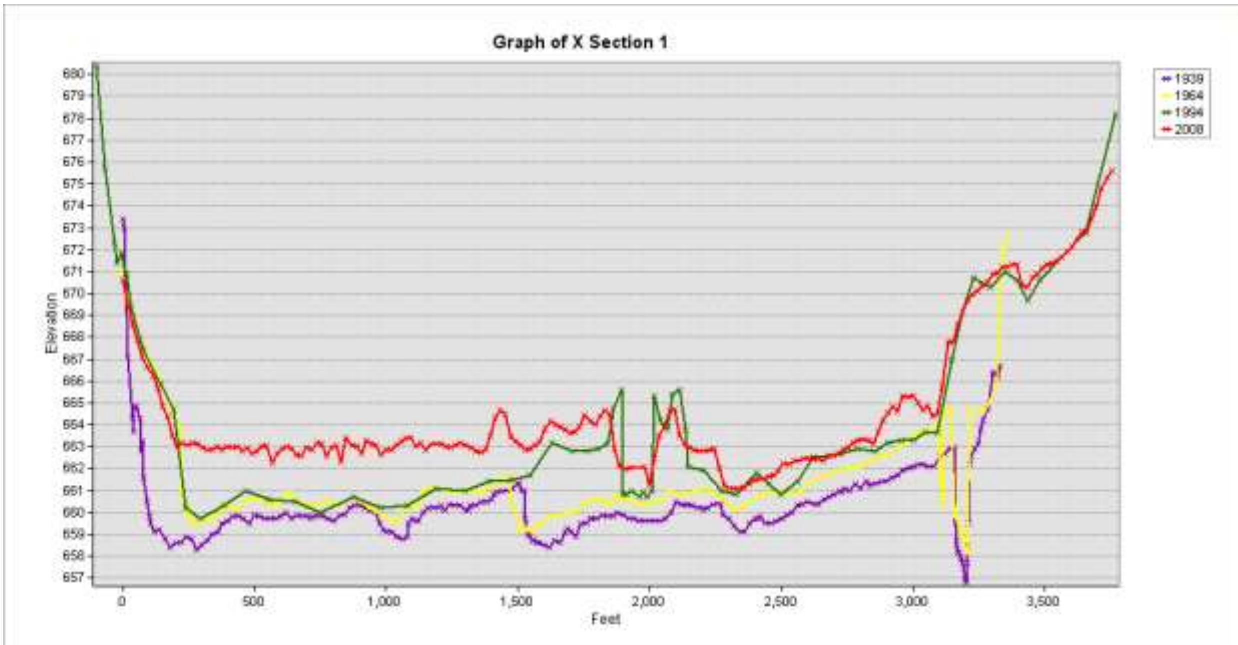
If they could be located it would provide additional data for estimating total sedimentation in the valley and establishing the baseline elevations prior to settlement.

Additional items to be completed

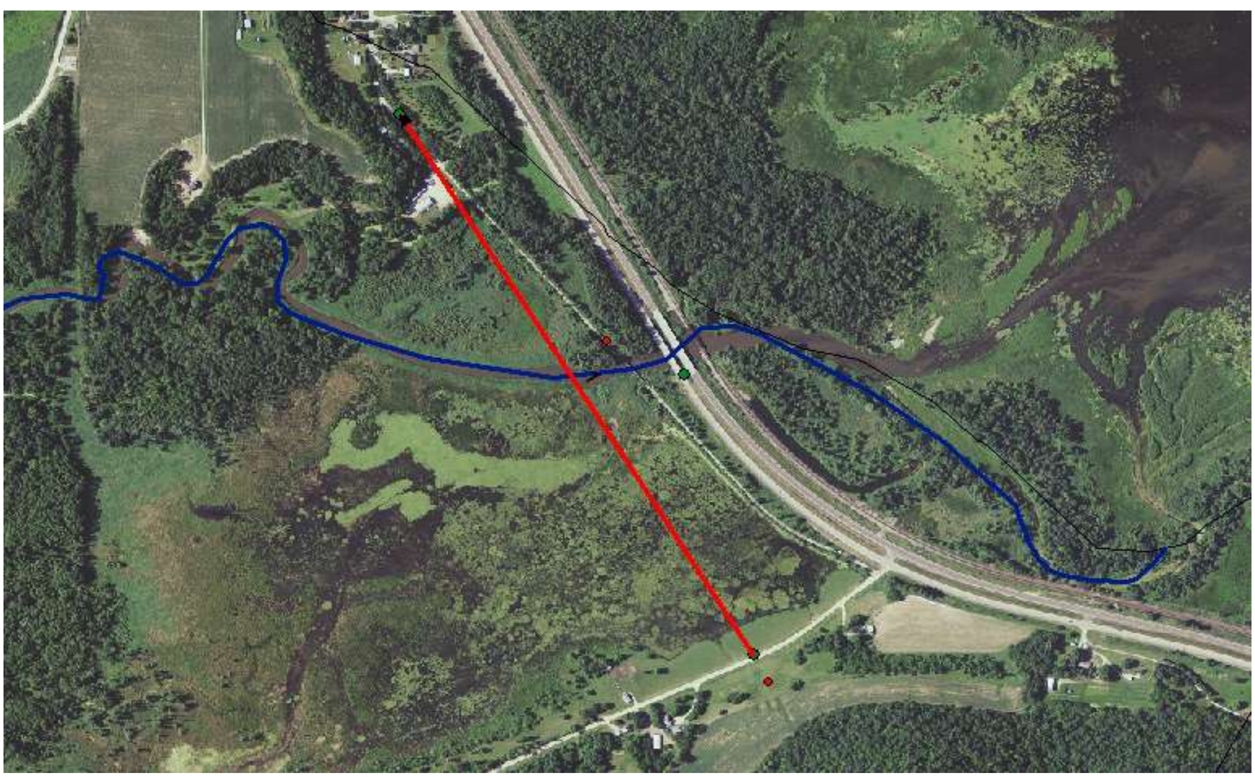
- Complete locating remaining monuments
- Survey the remaining monuments to modern accuracy standards
- Validate LiDAR data along ranges

Appendix 1

Range 1



Plot of elivations of the various surveys.

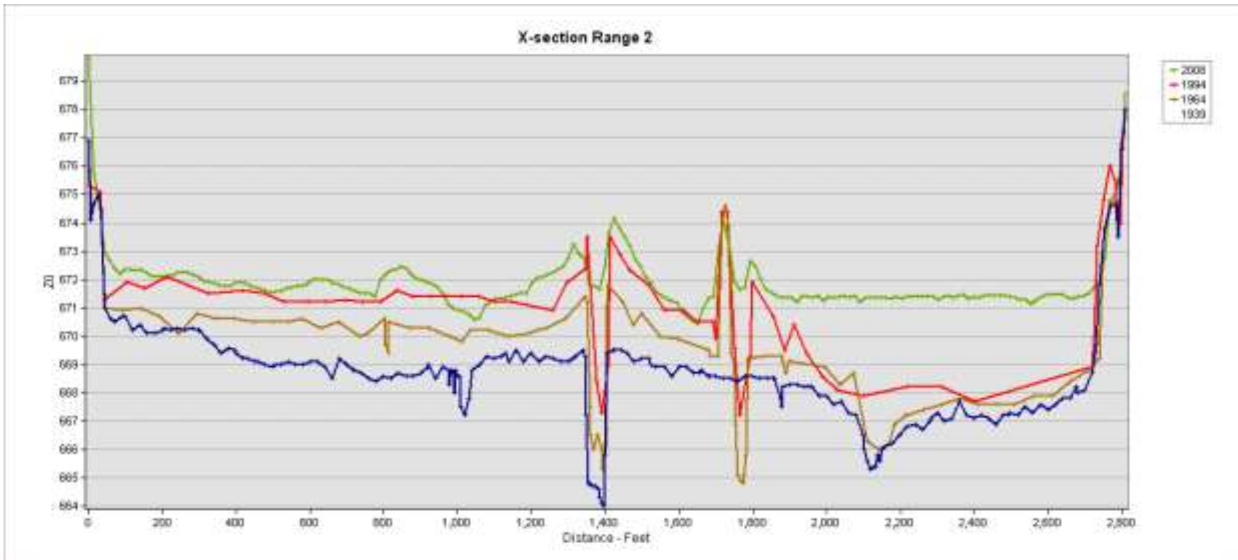


X Section Range 1 Whitewater Main branch. This is the outlet of the Whitewater at its confluence with the Mississippi River. Station 0+00 is located right down stream and goes from south east to northwest. Significant manipulation of the area due to the installation of the railroad and twice relocating US Hwy 61 has caused the manipulation of the river channel and restriction of flow due to the two bridges installed. While the south endpoint established in 1939 has been relocated in 2011 the north endpoint monument has been lost and reset repeatedly during each survey making the northern data somewhat suspect.

Monument 1-N This monument has been repeatedly moved during the life of the survey. It was originally established during the 1939 establishment period but lost and re-established both in the 1964 and 1994 surveys. Photo by Doug Christianson

Monument 1-S. This monument was located on 4/22/11 after repeated attempts over a numbr of years to locate. It was during one of the attempts while looking for it with a metal detector that the owner of the property came by. Through a conversation it was discovered that the fence referenced in the 1994 survey was moved 1 month after the survey. The road was widened and the fence was moved. It is now only 2 feet off the shoulder of the current road and most likely was bent during construction activities. Photo by author.

Range 2

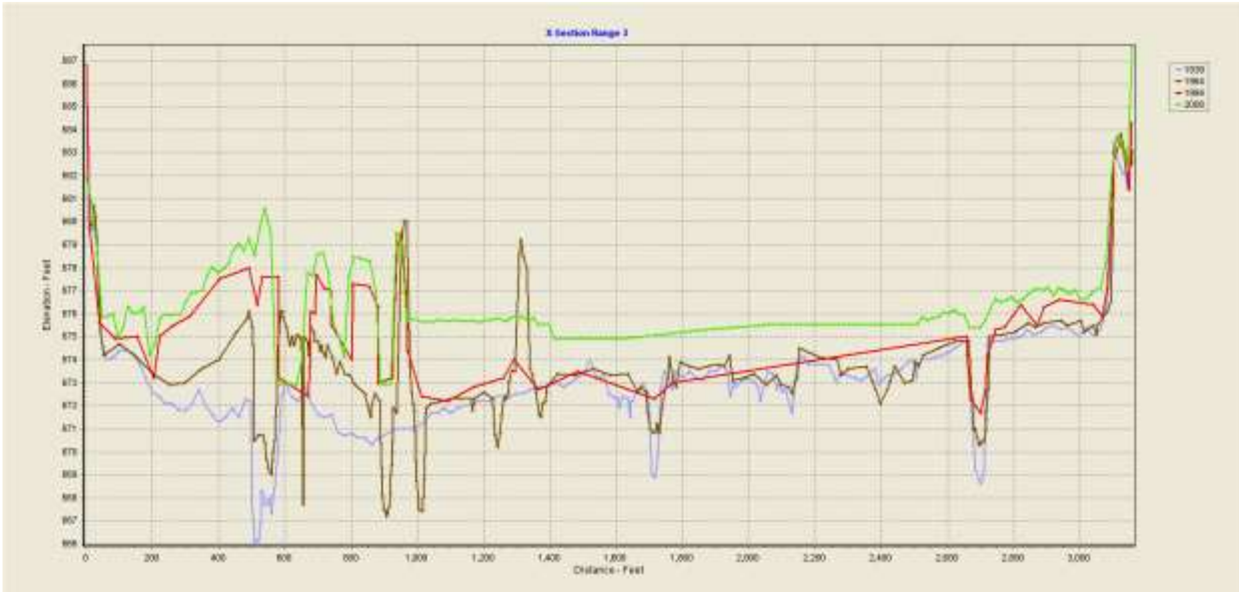


X Section Range 2 Whitewater Main branch. Station 0+00 is located right down stream and goes from southeast to northwest.

Monument 2-N. Located 2/06/09. End point of Range 2. The pipe within a pipe and filled with concrete was typical of the early monument established by Dr. Happ. Later monuments where a 2” diameter pipe with a stamped threaded cap. Photo by Doug Christianson.

Monument 2-S. Located 5/26/11 Beginning point 0+00 of Range 2 Looking in approximate direction (NNW) of X-section. Even by the end of May the heavy vegetation would make any type of survey during the summer months almost impossible. Photo by author

Range 3

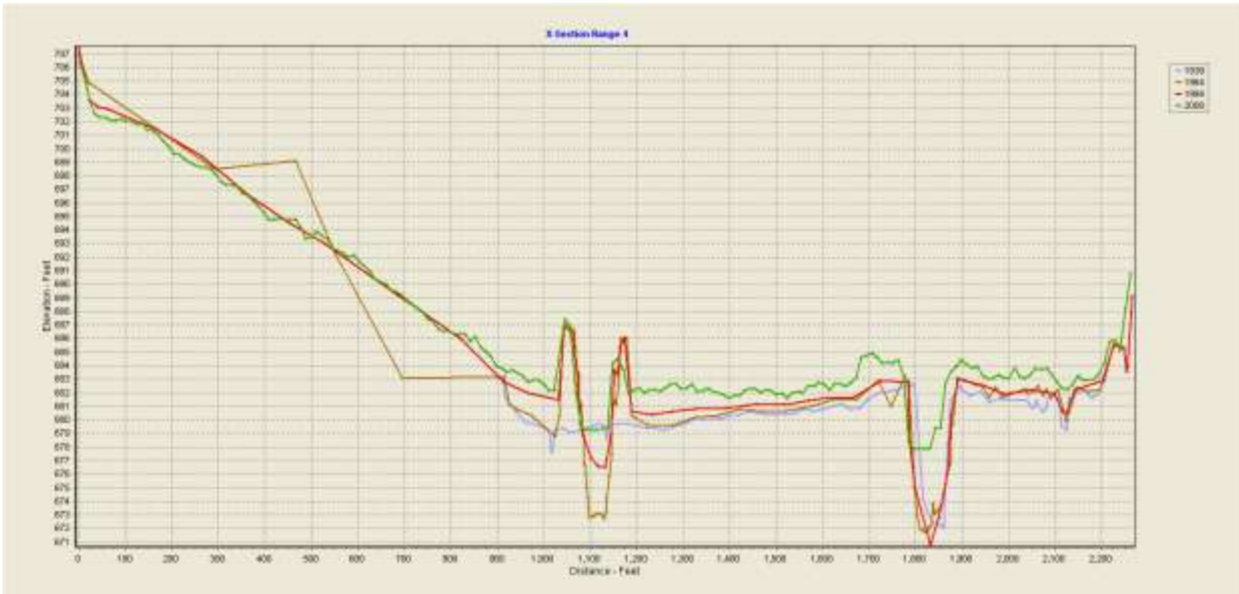


X Section Range 3 Whitewater Main branch. 0+00 is located right down stream and goes from southeast to northwest.

Monument 3-N Located 2/06/09 End point of Range 3 Photo by Doug Christianson

Monument 3-S Located 2/18/09 Beginning point 0+00 of Range 3 Photo by Doug Christianson

Range 4

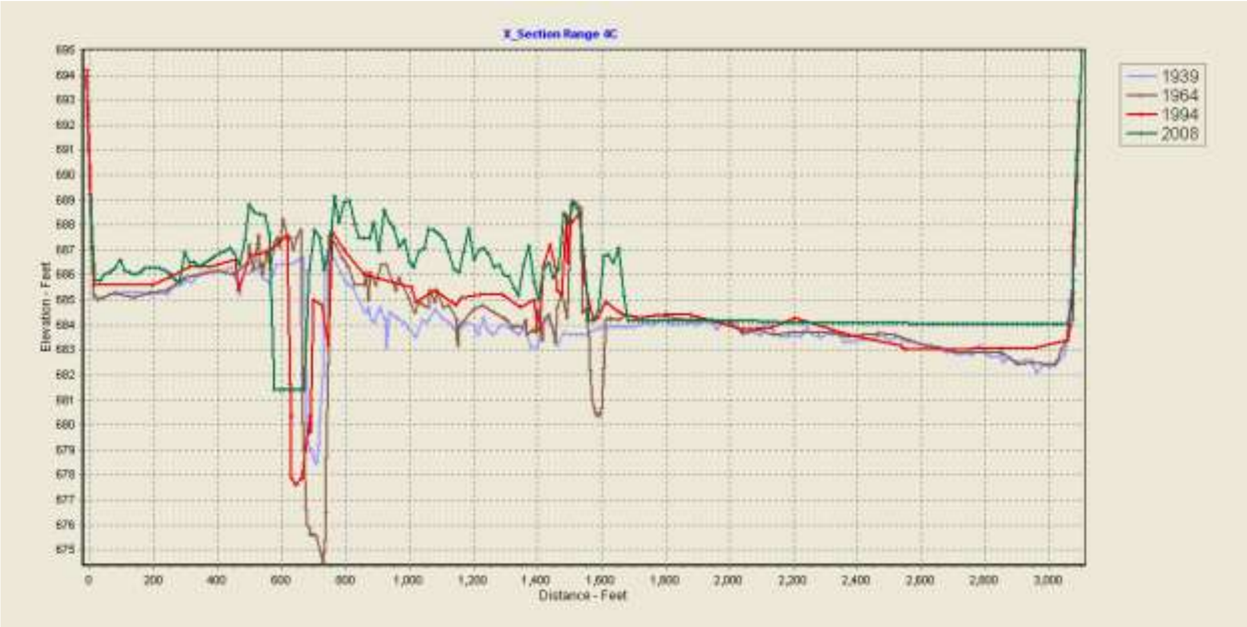


X Section Range 4 Whitewater Main branch. 0+00 is located right down stream and goes from southeast to northwest.

Monument 4-S. Located 3/09/09. WAE employee Steve Erickson in photo. Beginning point 0+00 for Range 4. Photo by Doug Christianson.

Monument 4-N Located 2/6/09. WAE employee Steve Erickson in photo. End point of Range 4. Photo by Doug Christianson.

Range 4C

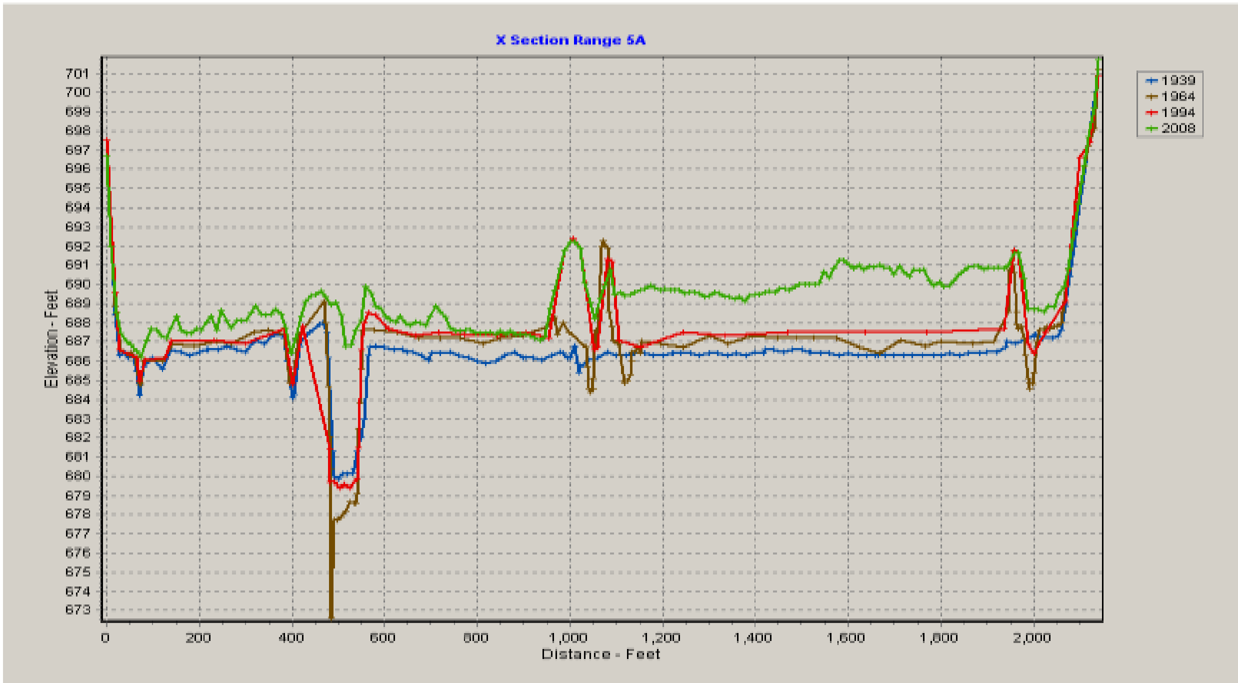


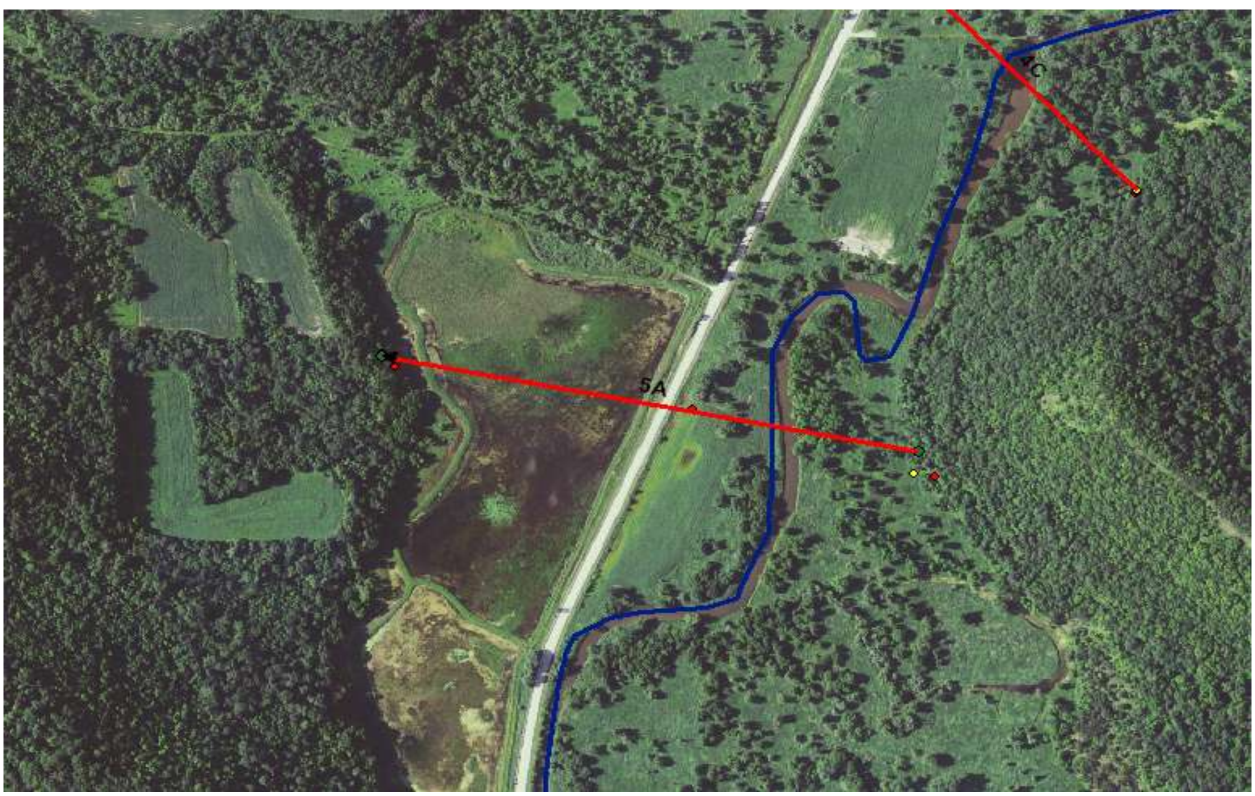
X Section Range 4C Whitewater Main branch. 0+00 is located right down stream and goes from south east to northwest.

Monument 4C-N. Located 3/5/09. End point of Range 4C. Photo by Doug Christianson.

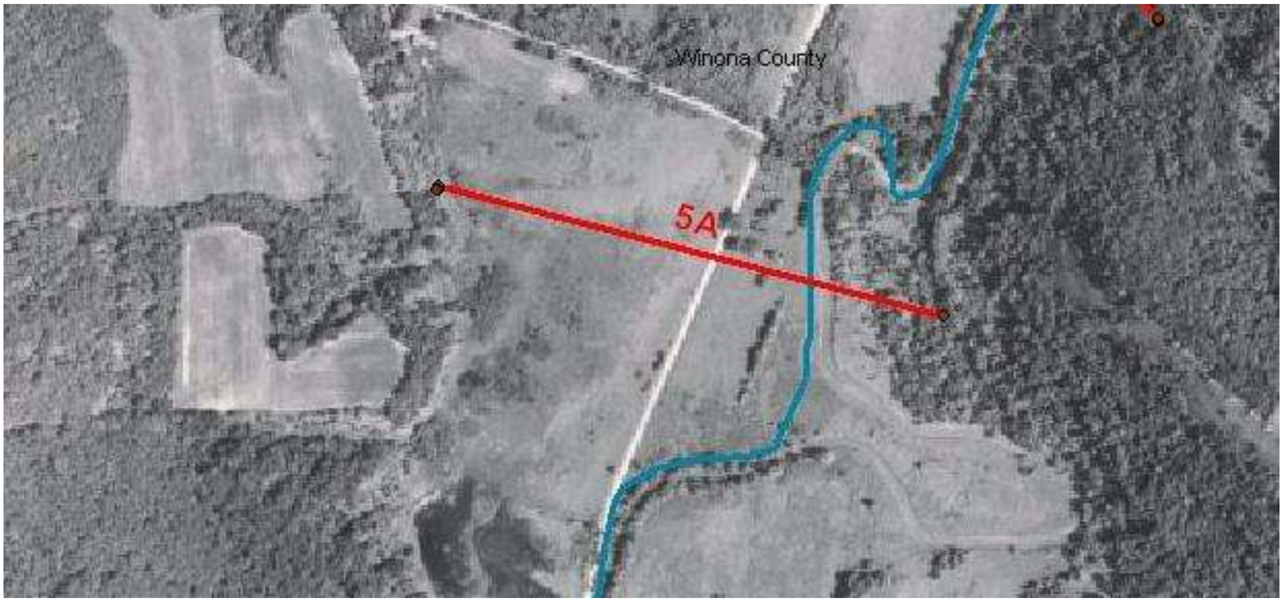
Monument 4C-S. Located 2/12/09. Beginning point 0+00 for Range 4C. WAE Steve Erickson in photo. Photo by Doug Christianson.

Range 5A





X Section Range 5A Whitewater Main branch. 0+00 is located right down stream and goes from east to west.

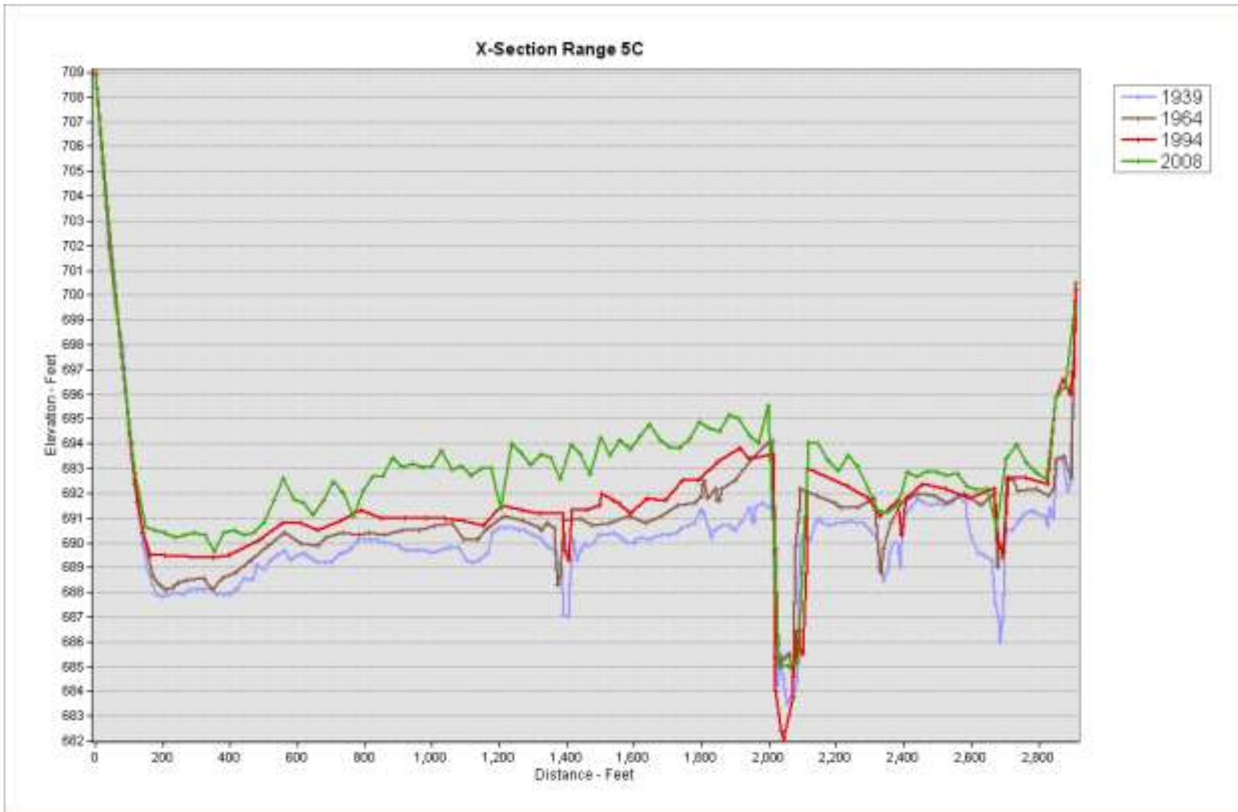


Range 5A with 1954 Photo Observe the meander in the SE corner is cut off in Figure . Rectification of the photo had a RMS error of 30.1 meters.

Monument 5A-N. Located 2/06/09. NRCS employee Mark Kanable in photo. End point for Range 5A.

Monument 5A-S was located with GPS to Survey grade standards but no photo has been taken to date.

Range 5C



X Section Range 5C Whitewater Main branch. 0 is located right down stream and goes from east to west.

Monument 5C-N. Located 2/06/09. NRCS employee Mark Kanable in photo. End point for Range 5C. Photo by Doug Christianson

Monument 5C-S. Located 2/12/09. WAE Steve Erickson in photo. Beginning point 0+00 for Range 5C. Photo by Doug Christianson.

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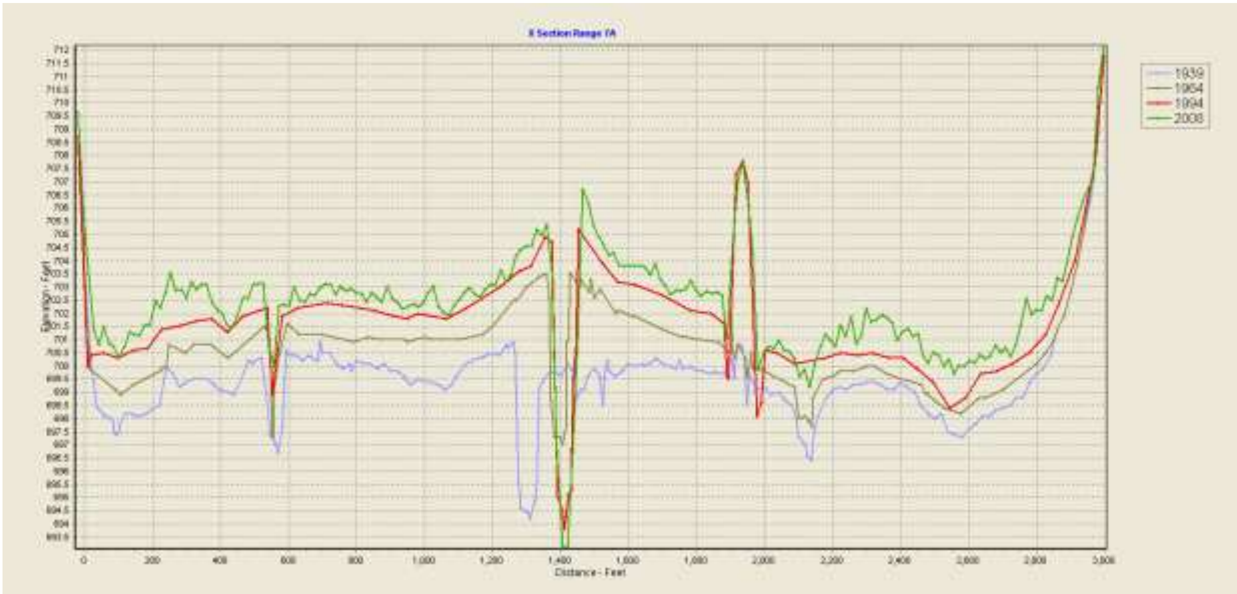
Range 7A

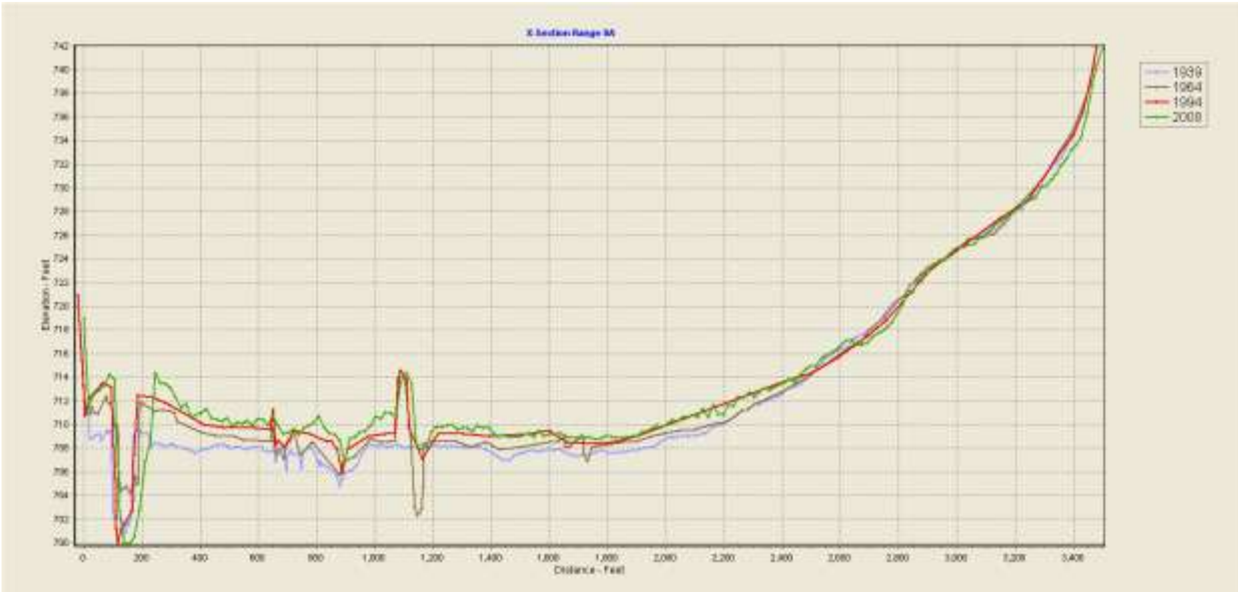


X Section Range 7A Whitewater Main branch. 0+00 is located right down stream and goes from northeast to southwest.

Monument 7A-N. Located 2/10/09. WAE Steve Erickson in photo. End point for Range 7A. Photo by Doug Christianson.

Monument 7A-S. Located 2/10/09. WAE Steve Erickson in photo. Beginning point 0+00 for Range 7A. Photo by Doug Christianson.

Range 8A

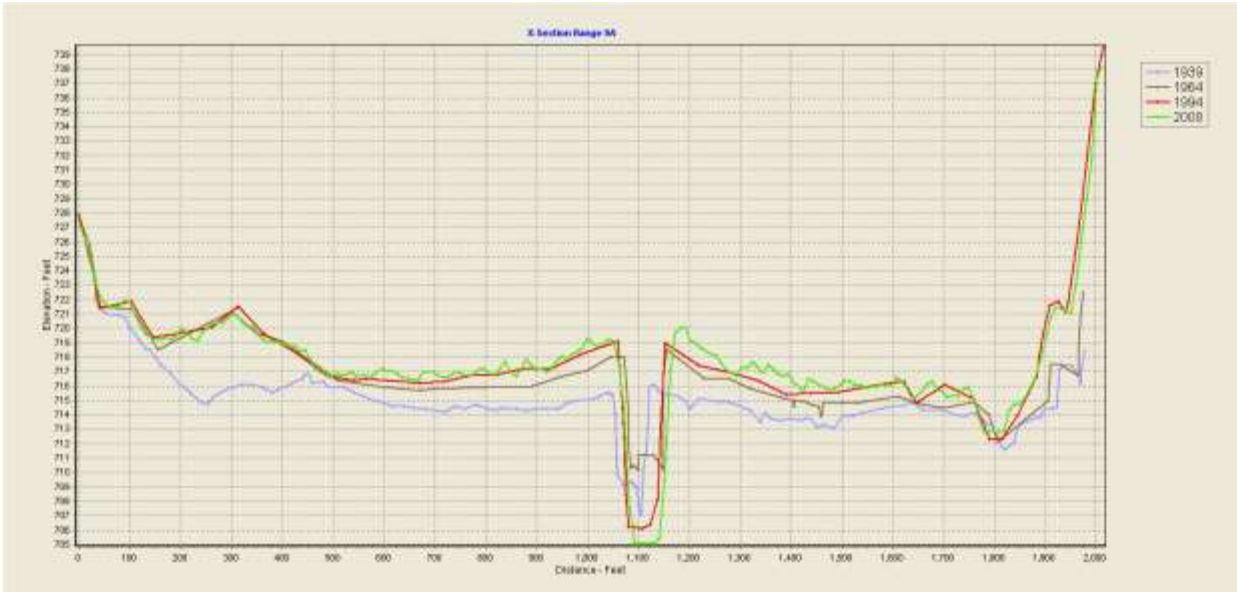


X Section Range 8A Whitewater Main branch. 0+00 is located right down stream and goes from east to west.

Monument 8A-N. Located 2/09/09. WAE Steve Erickson in photo. End point for Range 8A. Photo by Doug Christianson

Monument 8A-S. Located 2/12/09. WAE Steve Erickson in photo. Beginning point 0+00 for Range 8A. Photo by Doug Christianson

Range 9A



X Section Range 9A Whitewater Main branch. 0+00 is located right down stream and goes from east to west. Endpoint 9A-S at the 0+00 end remains in place and was located the last time on 2/12/2009.

Monument 9A-N on the west end of the range was lost between the 1964 and 1994 surveys. The original endpoint was located approximately in the road and was probably lost due to construction. During the 1994 survey the endpoint was extended to be away from the road and construction influence. A 4 foot re-bar was placed on the hillside. The line was extended approximately 37 feet further depending on what range distance is used. NRCS employee Doug Christianson in photo. Photo by Doug Christianson.

Monument 9A-S. Located 2/12/09. WAE Steve Erickson in photo. Beginning point 0+00 for Range 9A. Photo by Doug Christianson.

Range 10

X Section Range 10 Whitewater Main branch. 0+00 is located right down stream and goes from east to west.

Monument 10-N. Located 2/09/09. Photo by Doug Christianson.

Monument 10-S. Located 2/11/09 Beginning point 0+00 for Range 10. Photo by Doug Christianson.

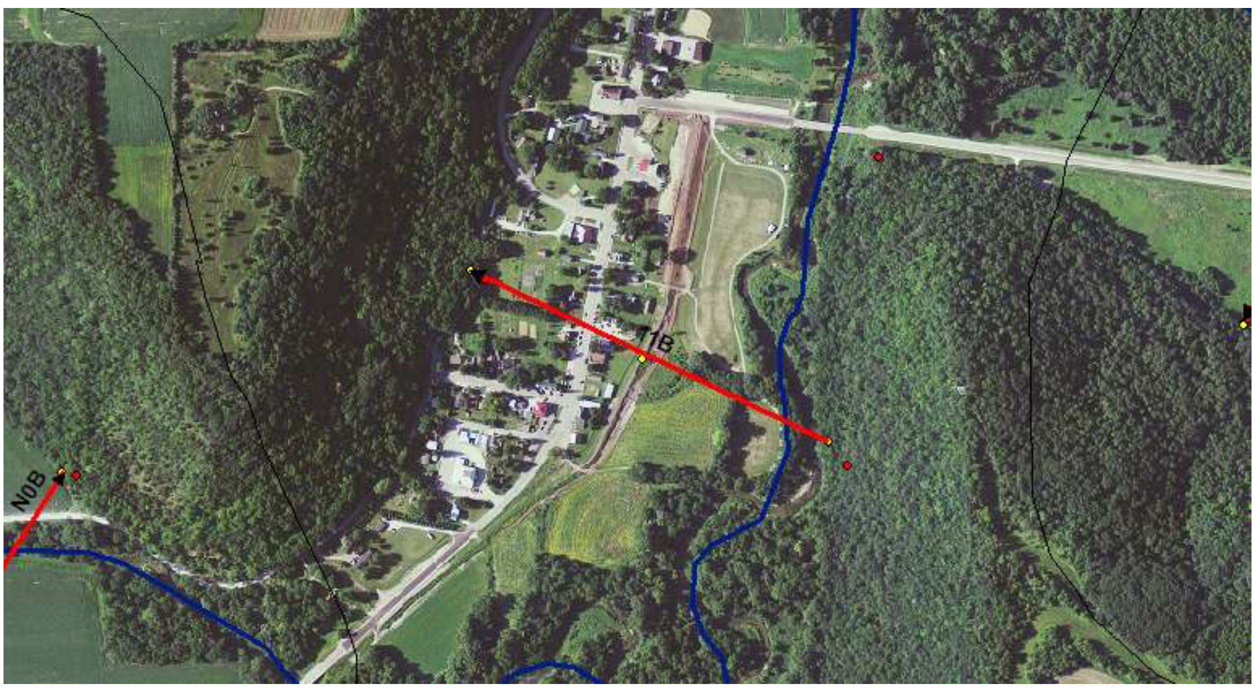
Range 10C

X Section Range 10C Whitewater Main branch. 0+00 is located right down stream on the SE end of the line and goes to the NW

Monument 10C-N. Located 2/09/09. WAE Steve Erickson in photo. Only approximately 2 feet off of private driveway. Landowner knew the pipe existited but was not aware what its purpose was. Photo by Doug Christianson.

Monument 10C-S. Located 2/11/09. Monument was buried approximately 4 inches below the surface. Beginning point 0+00 for Range 10C. Photo by Doug Christianson.

Range 11B



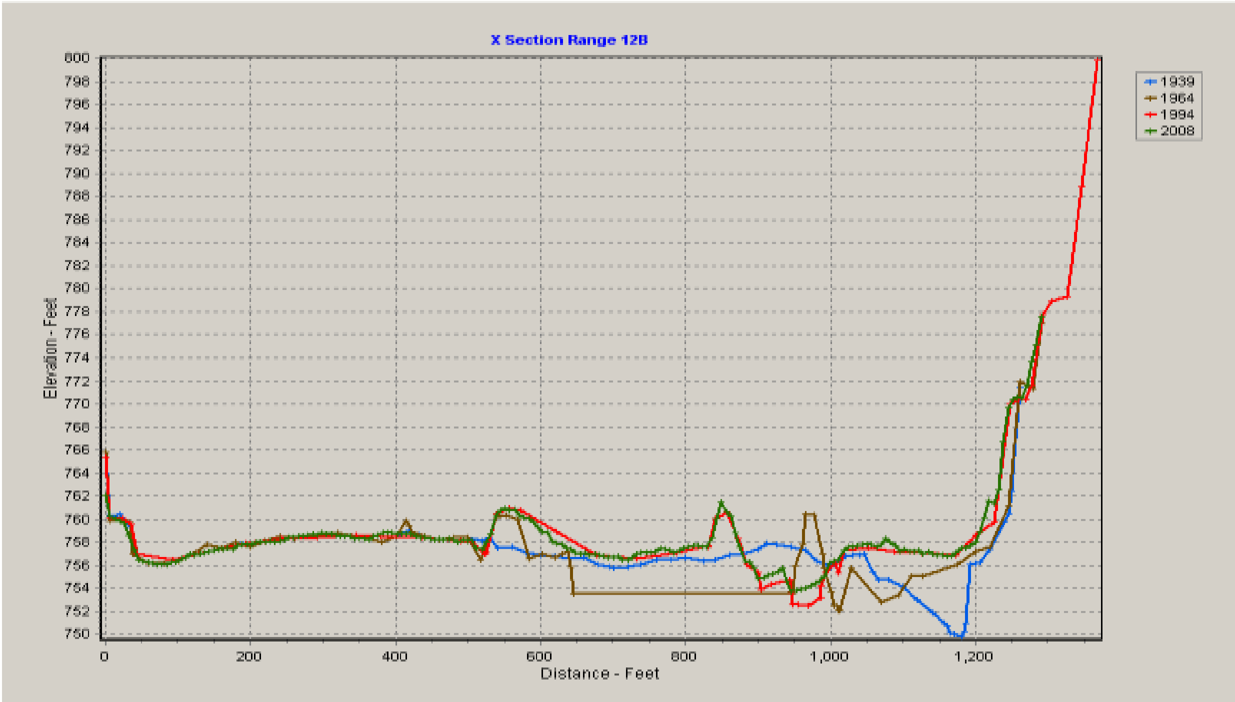
X Section Range 11B Whitewater Main branch. 0+00 is located right down stream at monument 11B-S, and is at the SE end of the line moving to the NW. The North Branch of the Whitewater enters the main channel near the lower SW corner of the photo and the South Branch of the Whitewater enters approximately ½ mile to the north. The town of Elba is located in the center of the photo.

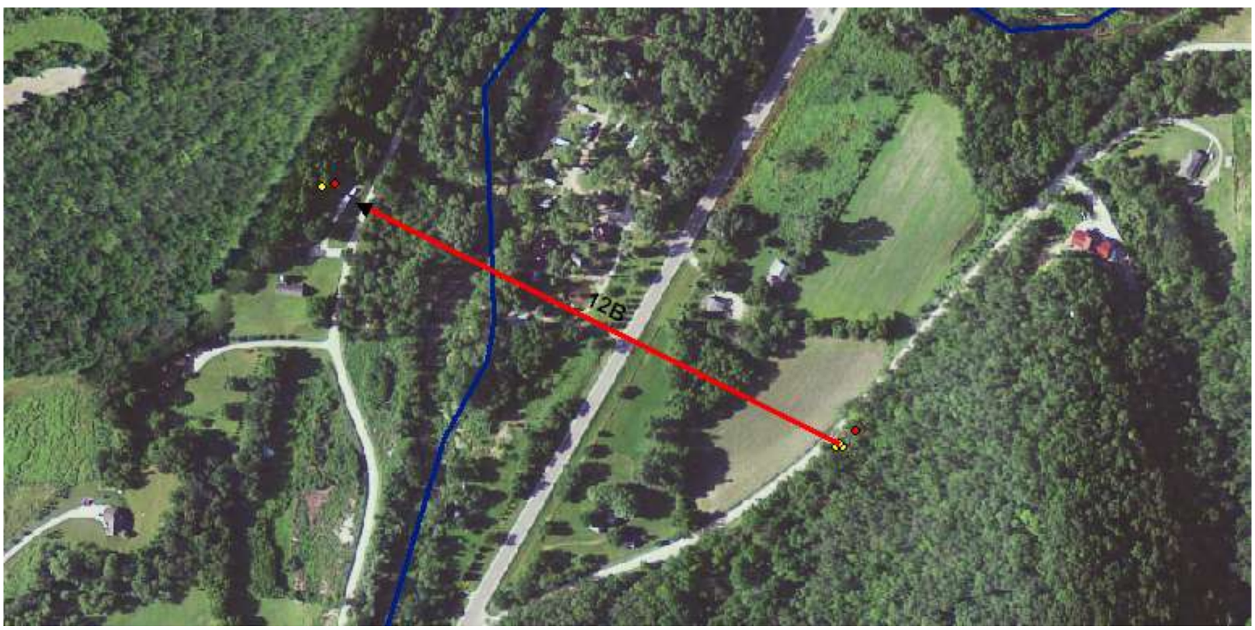
Monument 11B-N. Located 11/30/11. Photo by author

Monument 11B-S. Located 5/12/11. 11B-S is the only endpoint monument which is marked with a brass cap set in concrete. 11B-S could not be located during the 64 and 94 surveys and was considered lost until located by this study in the summer of 2011. Because the cap is brass the normal use of a metal detector did not work. The red point on the photo above was the assumed located location for many years. It was finally locate by running a line from 11B-N through a stake that was still in place on the earthen dike from the 94 survey. Measuring the surveyed distance from the notes and using the azimuth we got to within 5 feet of this location. A 4 foot steel rebar was driven into the ground next to the brass cap to aid in future locating. The beginning point 0+00 of Range 11B. Photo by author

The town of Elba 1940. This photo was taken 1 year after the establishment of the Range 11B. The location of 11B-N would be approximately on the far right edge of the photo near the base of the hill. Also notice the lack of trees and vegetation on the hillsides. This condition of the hillsides was widespread and contributed greatly to the flooding problems of the watershed. Photo courtesy of the Whitewater River Watershed Project

Range 12B



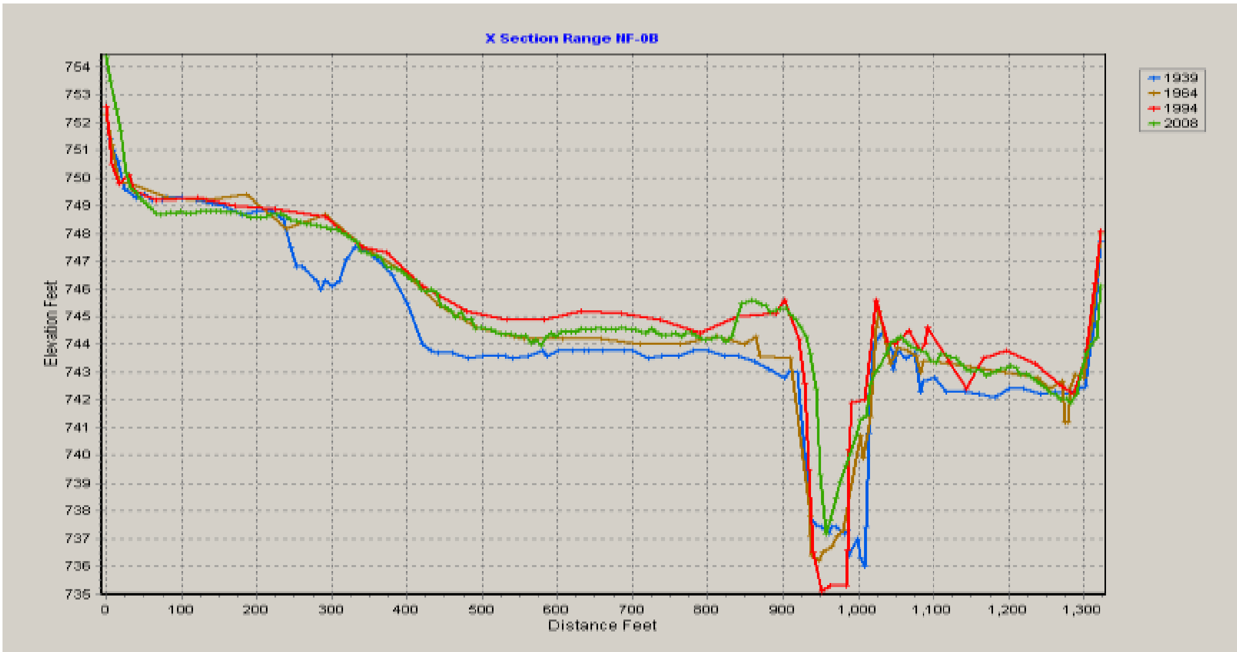


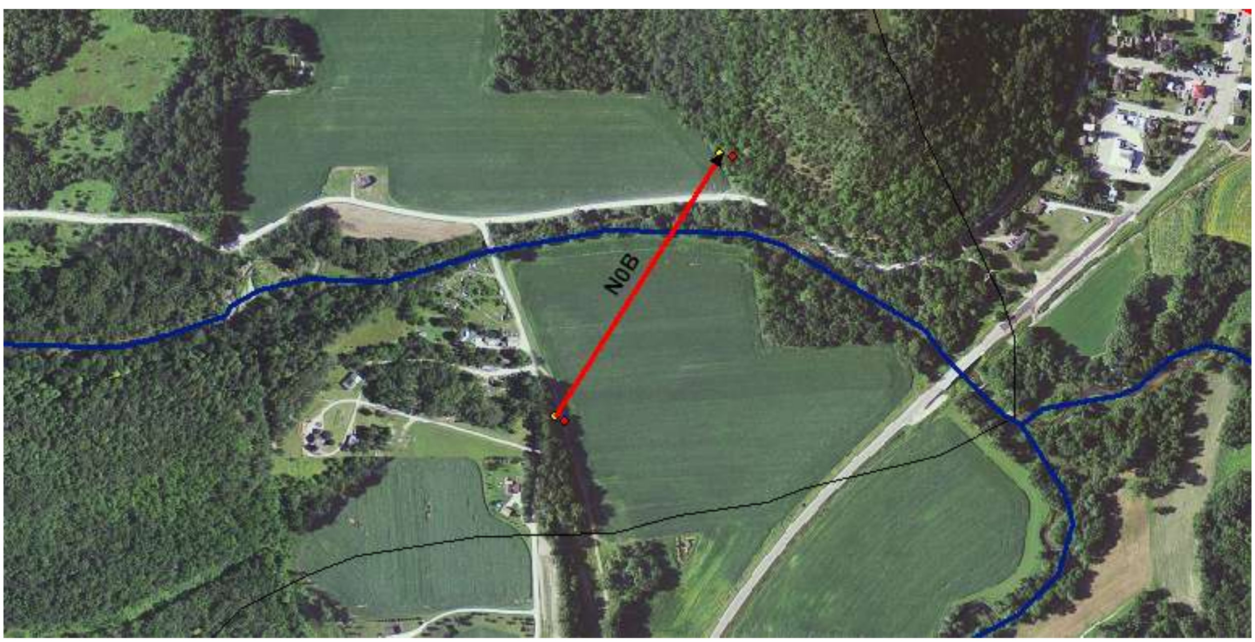
X Section 12B Middle Branch of the Whitewater. 0+00 is located right down stream and is located on the SE end of the line moving to the NW. Monument 12B-L was lost due to construction activities in the area and had been replaced with a 4 foot rebar in a higher elevation during the 94 survey. Also the area west of the highway was highly disturbed and damaged during the flood event of 1978.

Monument 12B-L Located 3/09/09. This monument was lost due to construction activities around the building site and was re-established during the 94 survey. Monument is now a 4 foot rebar driven into the ground. Photo by Doug Christianson.

Monument 12B-R. Located 5/23/11. Photo by author

Range NF-0

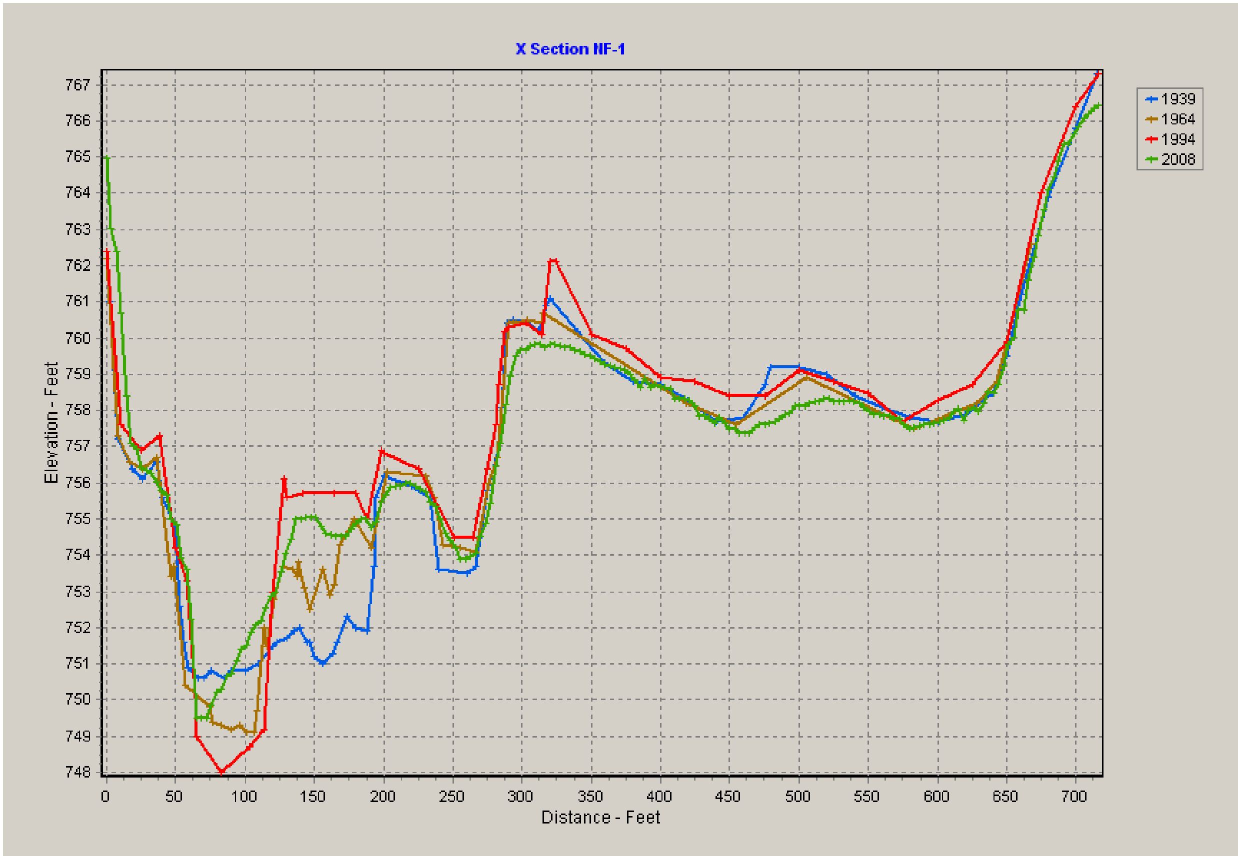


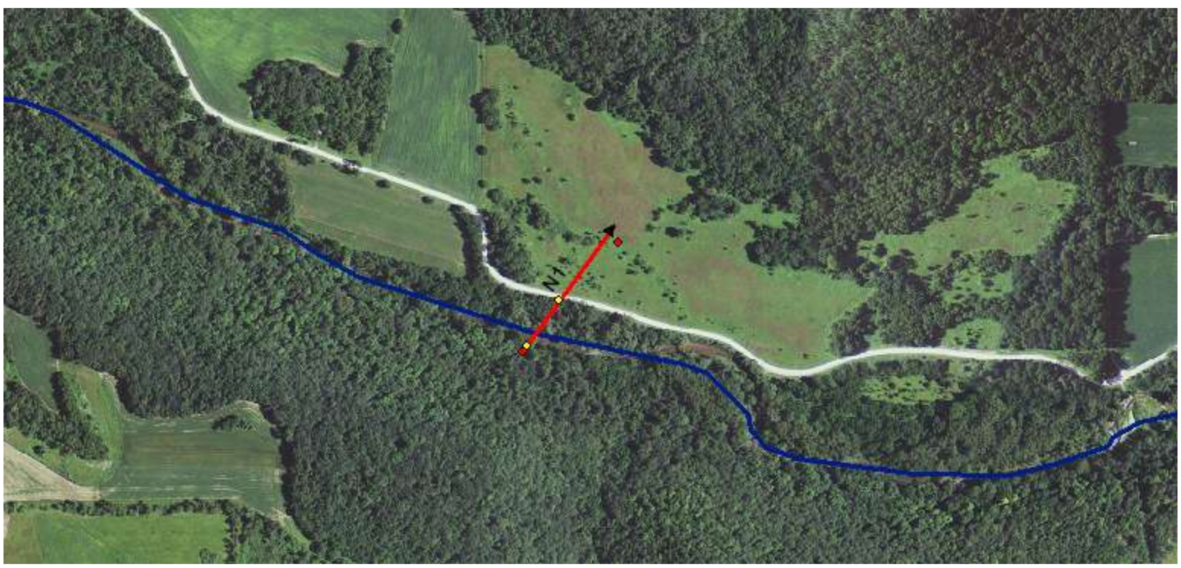


X Section NF-0B near the confluence of the North Fork and the Middle Fork of the Whitewater River. 0+00 is located right down stream and is located on the southwest end of the line moving to the northeast. .

Monument NF-0B. Neither monument could be located involving a number of visits. Located 6/27/11. NF-OB-W was discovered after a visit at the site of a recent excavation. Approximately 3 feet of the monument was exposed and partially damaged. Absolute elevation and latitude-longitude is suspect due to the damage. Photo by author.

Monument NF-0B-E. Located 6/27/11 Photo by author.





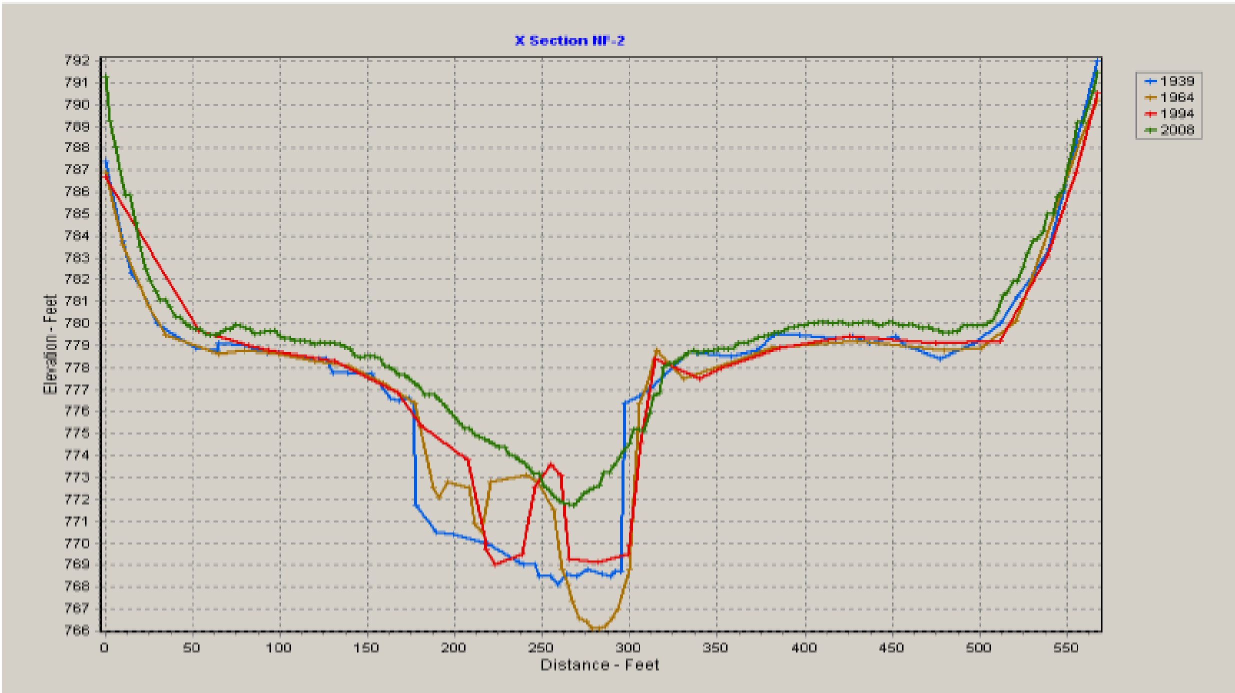
X Section Range N1 on the North Fork of the Whitewater. 0+00 is located right downstream and is the SW end of the line. NF-1-S south of the river was located but NF-1-N was lost in the 1964 survey and relocated to a point in the south road ditch. The line was extended by bearing and distance based on original survey.

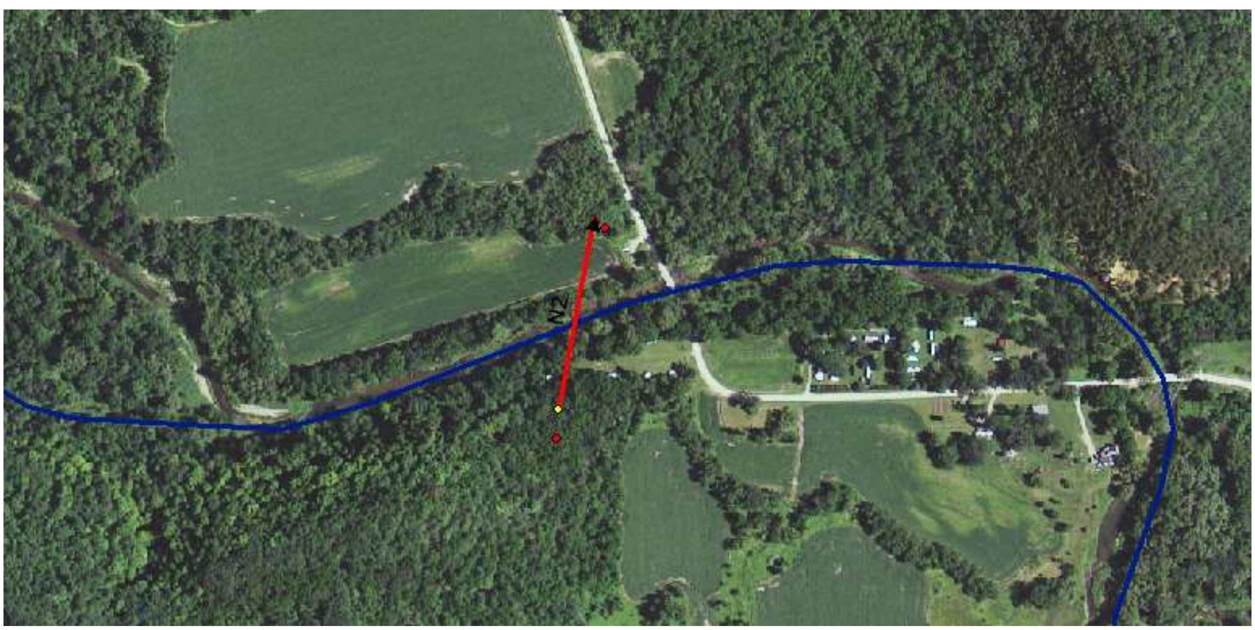
Monument NF-1-S. Located 5/10/11. Photo by author.

Monument NF-1-N. Located 5/10/11. Established in 1939 and lost between the 1939 and 1964 surveys it was re-established in 1964 by Dr. Happ. Instead of being the end point of the range the monument now is a reference point for establishing the line. The end of the line extends 435 feet north (to the left in the photo). Photo by author.

1954 Photo of same area in X Section N1 for comparison purposes. Much of the area north of the road is being farmed at the time of this photo.   Photo courtesy of the USDA Natural Resources Conservation Service.

Range NF-2





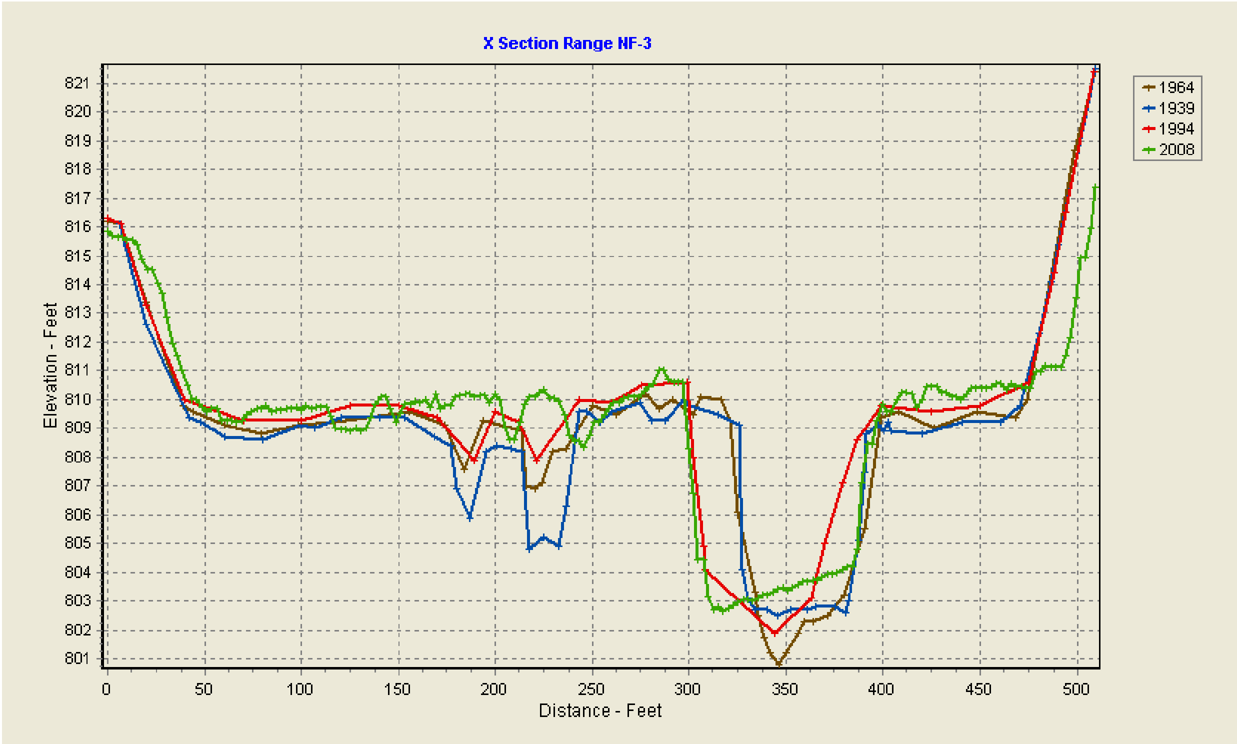
X Section Range N2 on the North Fork of Whitewater. 0+00 is located right down stream and is the south end of the line. NF-2-N has been damaged by excavation on the site and is lying on the ground. Location was determined by bearing and distance from original survey.

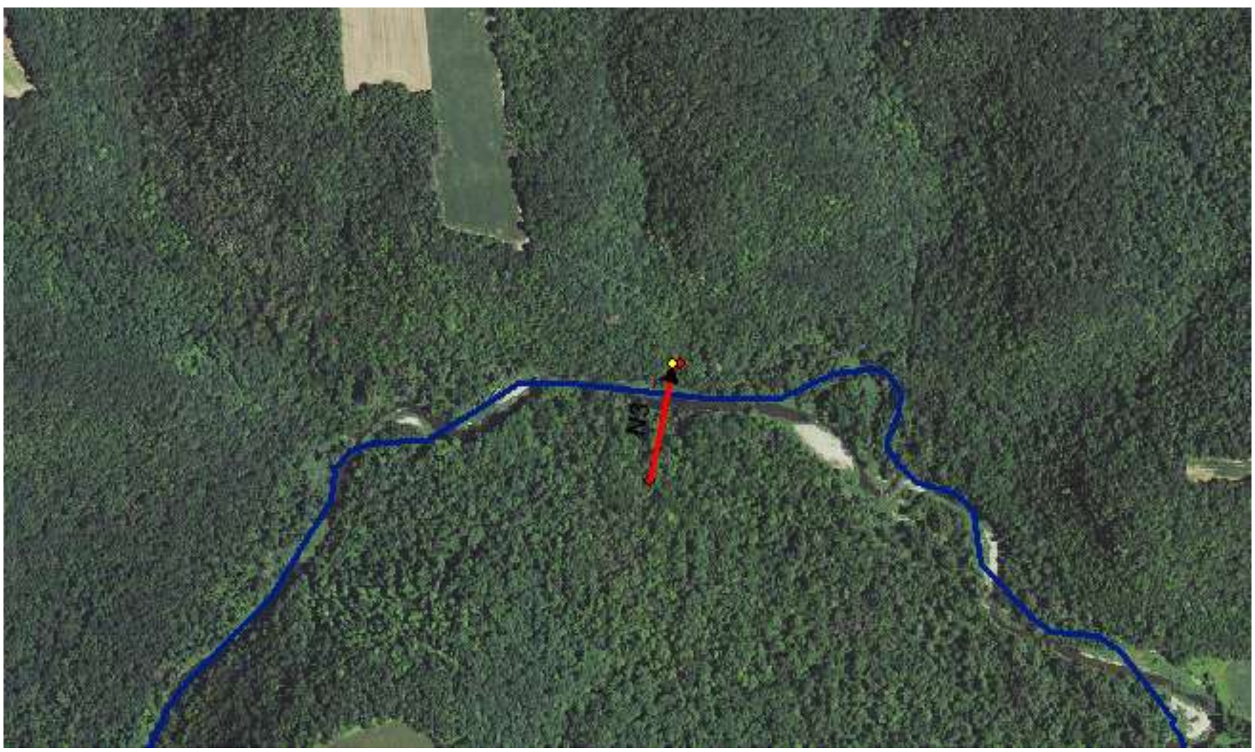
Monument N2-N has been destroyed and was lying on the ground. Located 5/6/11. You can also see remnants of the stone foundation of the house that was in the area. Its position assumed based on location of monument N-2-S, length of x-section range and azimuth from original survey. Photo by author.

Fairwater Crossing cir. 1940. This is the location of Range NF-2. The photo was taken 1 year after the establishment of the range. Monument NF-2-N was located very near the center of the photo. According to the original notes it was close to the foundation of the house located on the back side of the road. Monument NF-2-S is located out of the photo to the left. Photo courtesy of the Whitewater River Watershed Project.

Monument N-2-S. Located 5/6/11. Also refered to in the survey notes as N-2-S. Notice the height of original ground based on concrete level. Unsure if the monument is pushing up or the land is eroding down around the monument. It is near a private campground and there is potential of disturbance based on the fate of other monuments near similar campgrounds. Photo by author.

Range NF-3



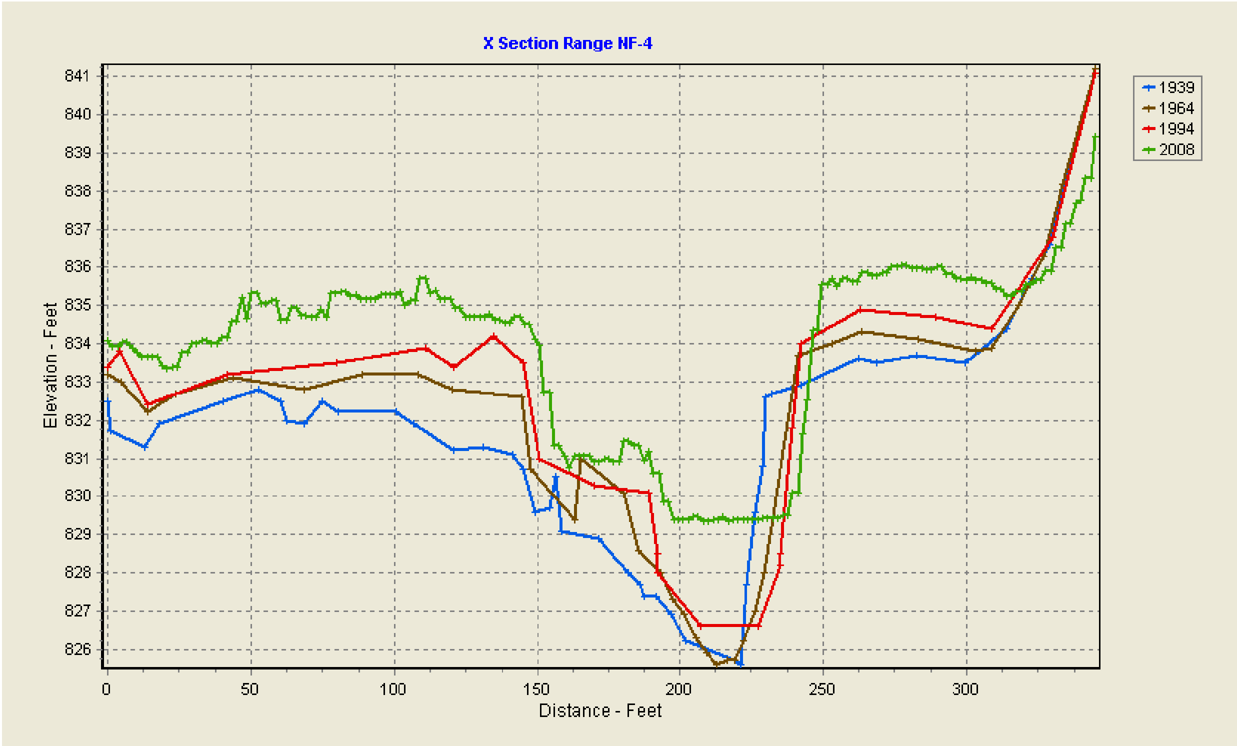


X Section Range N3 North Fork Whitewater. 0+00 is located right down stream and is located on the south end of the line.

Monument N-3-L Located 5/6/11. Photo by author

Monument N-3-R has not been located yet.

Range NF-4

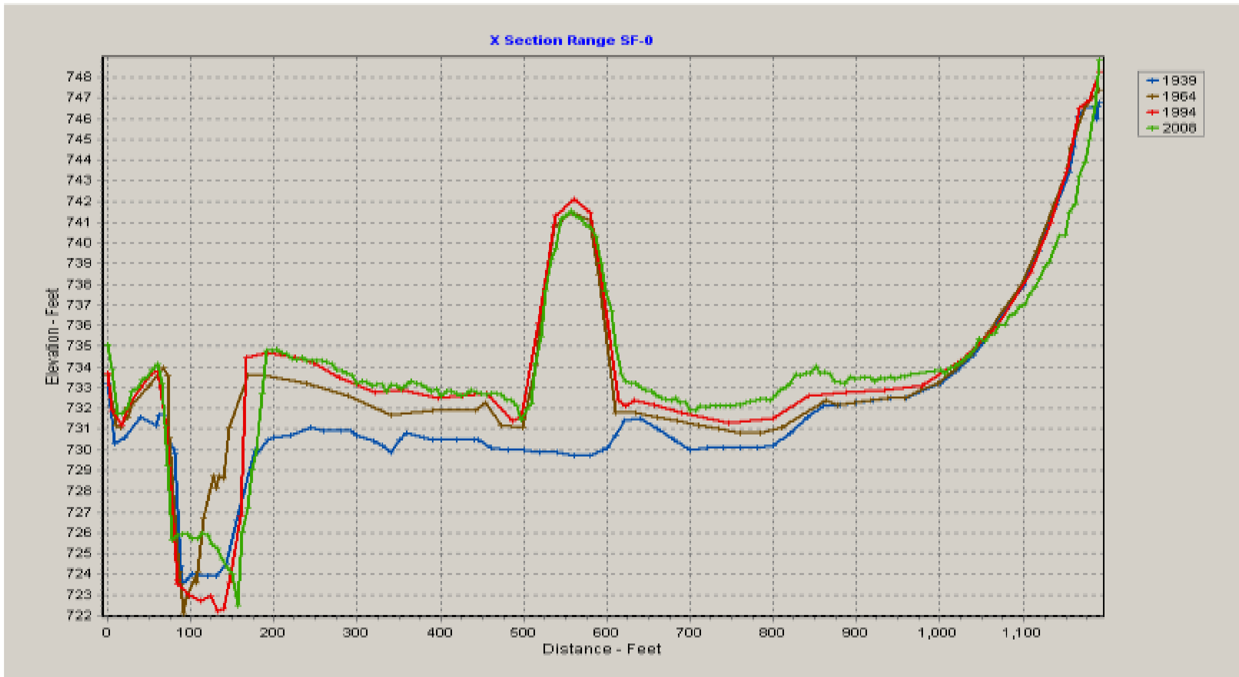


X Section Range NF-4 North Fork of the Whitewater. 0+00 is located right down stream and is on the south end of the line.

Monument N-4-L. Located 5/6/11. Photo by author

Monument N-4-R has not been located yet.

Range SF-0

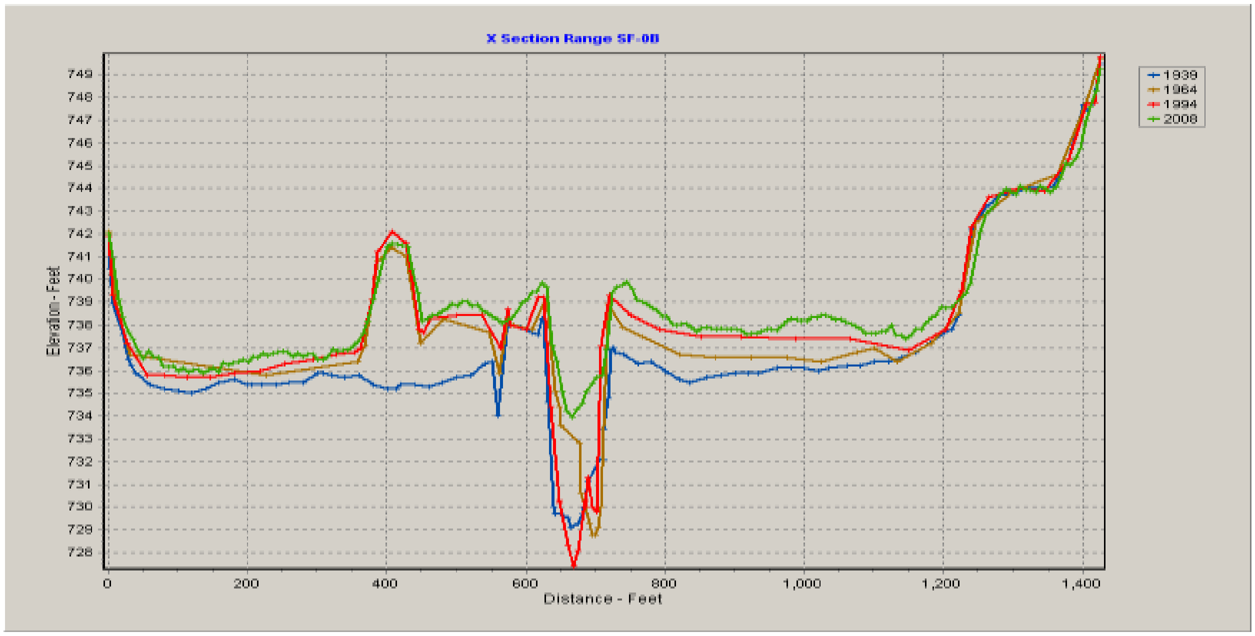


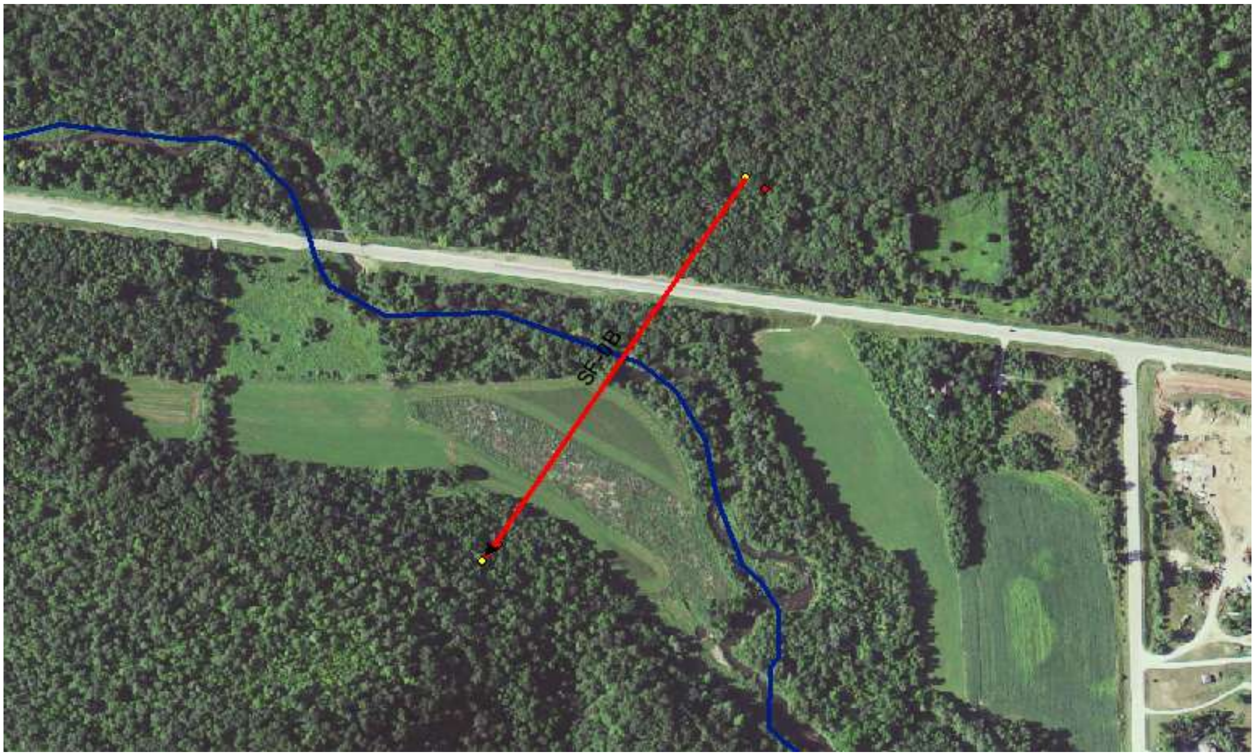
X Section Range SF-0 South Fork of the Whitewater River. 0+00 is located right down stream and is on the northeast end of the line.

Monument SF-0-W. Located 2/10/09. Monument is slightly buried approximately 2 inches below the surface of the ground. Photo by Doug Christianson.

Monument SF-0-E. Located 2/11/09. Photo by Doug Christianson.

Range SF-0B



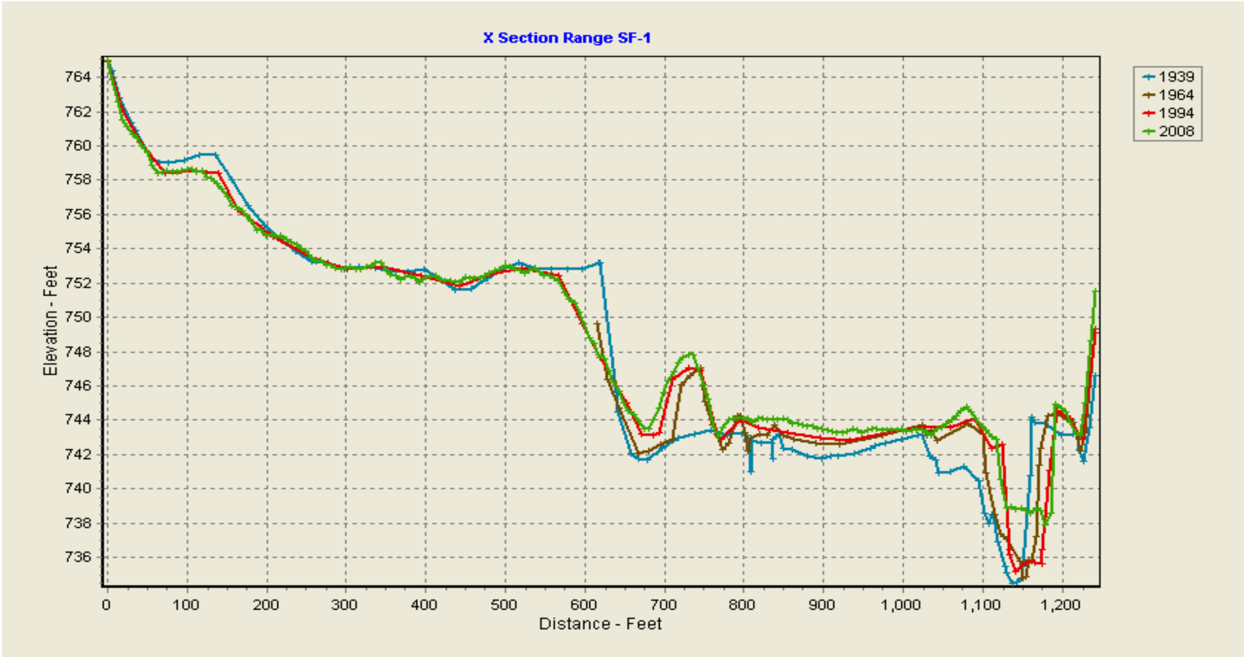


X Section Range SF-0B South Fork of the Whitewater River. 0+00 is located right down stream and is on the northeast end of the line.

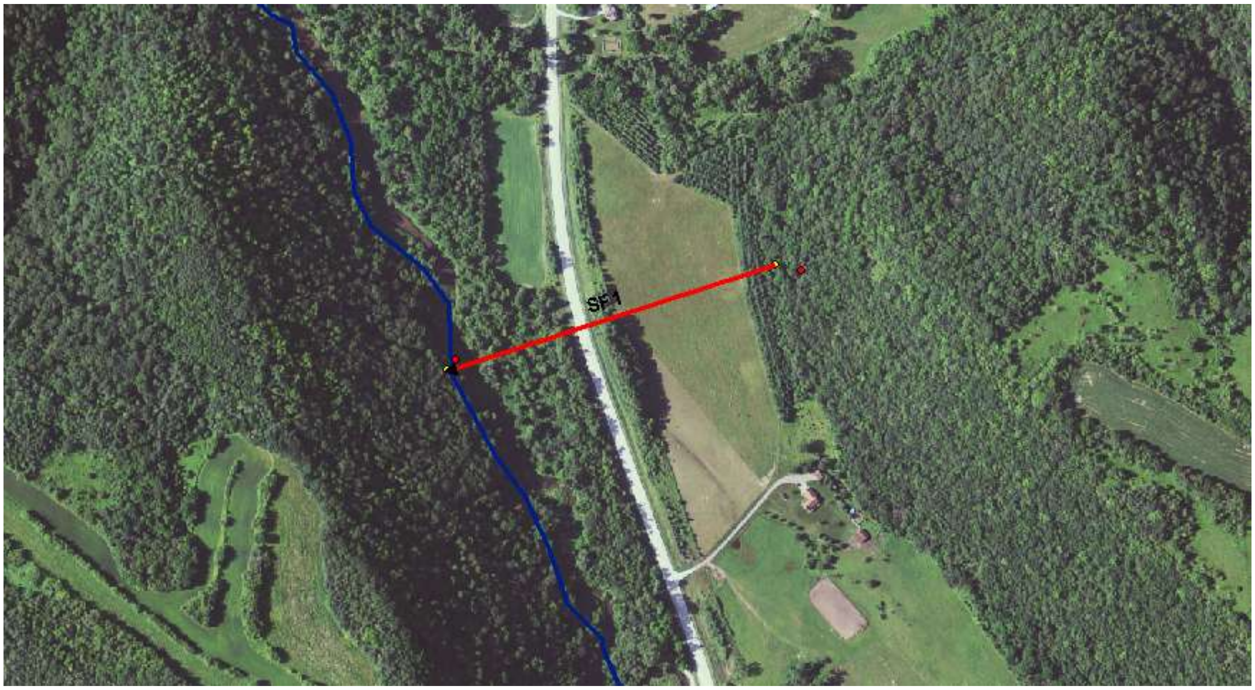
Monument SF-0B-E. Located 3/6/09. This is the 0+00 beginning point of the range. Photo by Doug Christianson

Monument SF-0B-W. Located 5/18/11. Photo by author.

Range SF-1



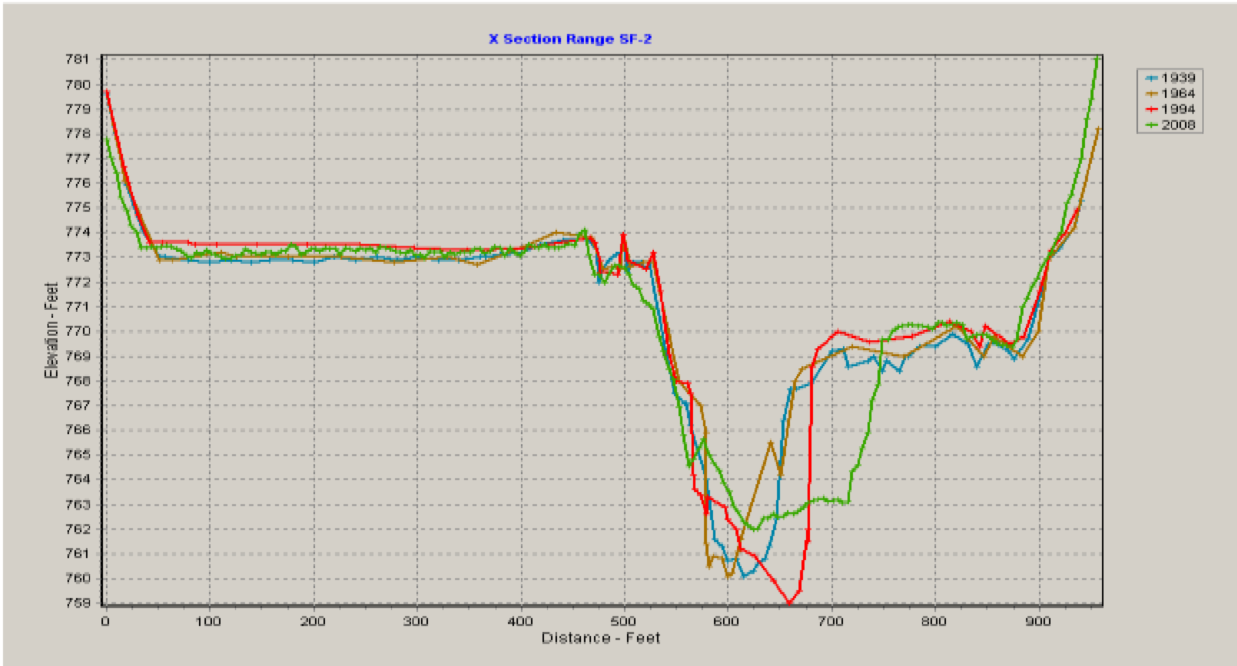
This section shows the installation of the road and the extension of the range between the 1939 and 1964 surveys

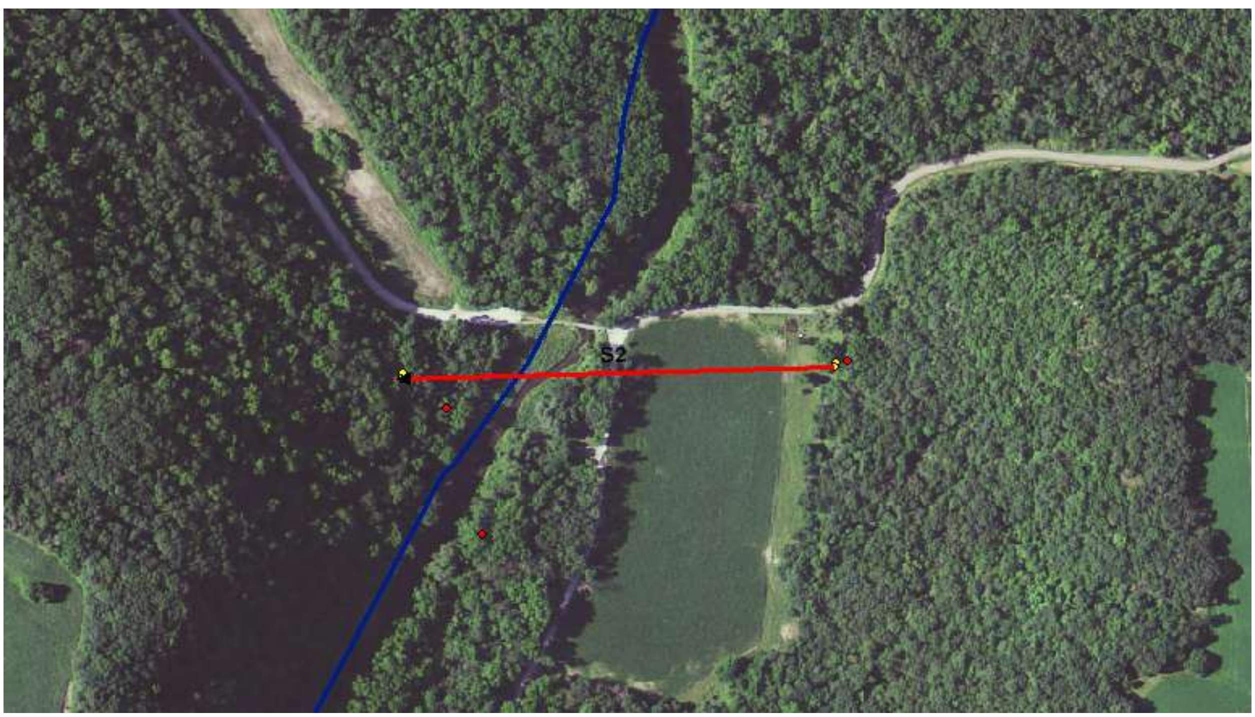


X Section Range SF-1 South Fork of the Whitewater River. 0+00 is located right down stream and is on the east end of the line.

Monument S-1-E. Located 5/18/11. This view is along the x-section line toward S-1-W. This is the 0+00 beginning point of the range. The landowner was aware of what the monument was about and what it was used for. He was enthusiastic about maintaining the monument. Photo by author

Range SF-2





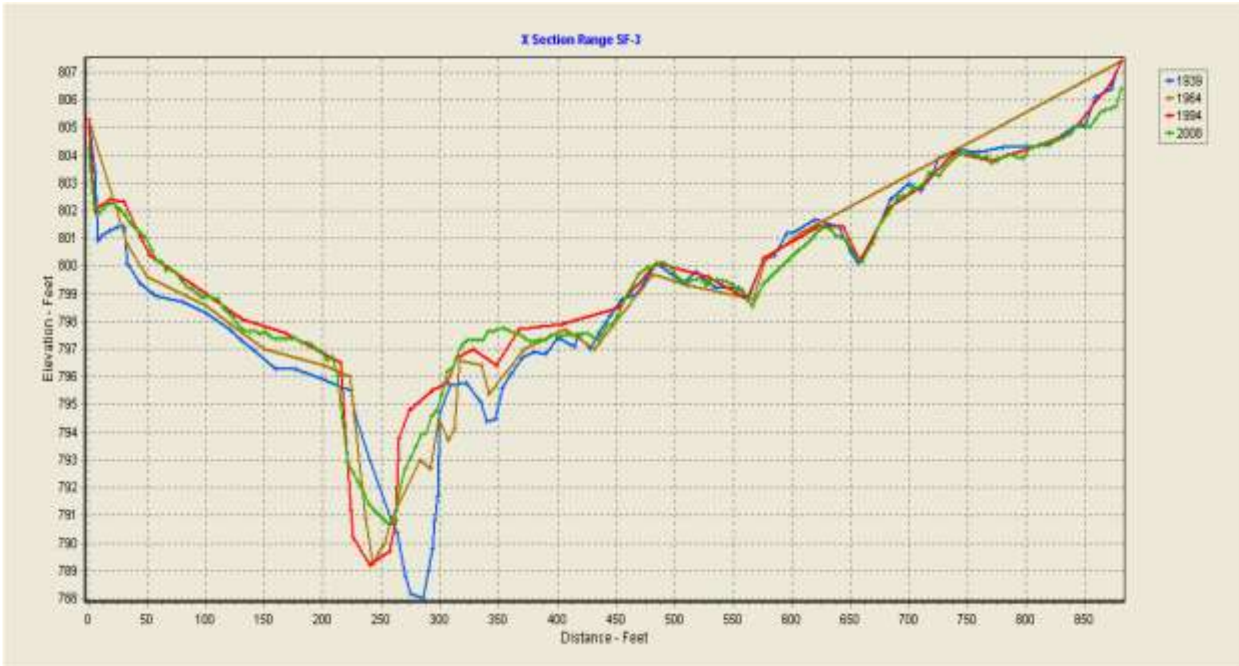
Section Range SF-2 South Fork of the Whitewater River. 0+00 is located right down stream and is on the east end of the line. Site along channel is very disturbed. Bridge below line is washed out and only suitable for foot traffic. Approximately 500 feet upstream of the S-2-W monument is a USGS stream gauging station.

Monument S-2-E. Located 5/20/11. Located in the middle of a private campground. It is about 1-2 inches below ground. It would appear the cap has been torn off and the monument damaged. Based on appearances the elevation may be suspect but the XY is probably accurate. Photo by author.

Monument S-2-W. Located 5/20/11 Photo by author

Lawrence Svien

Range SF-3

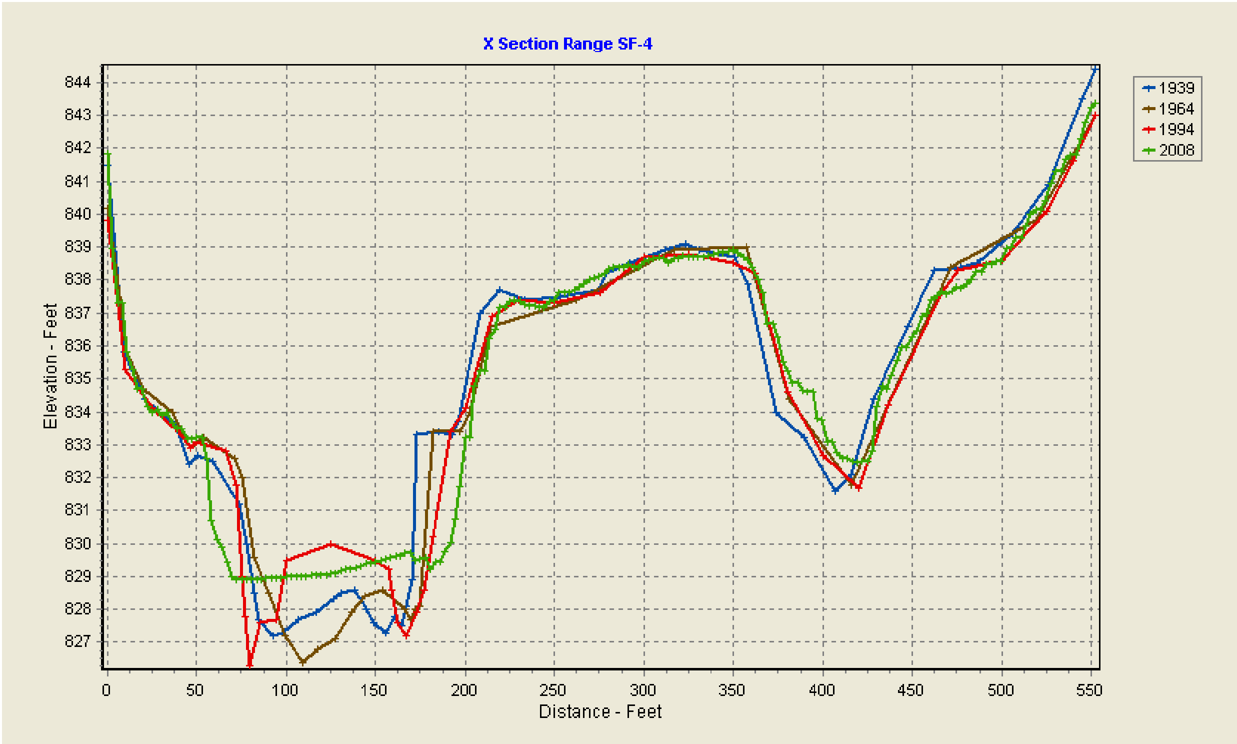


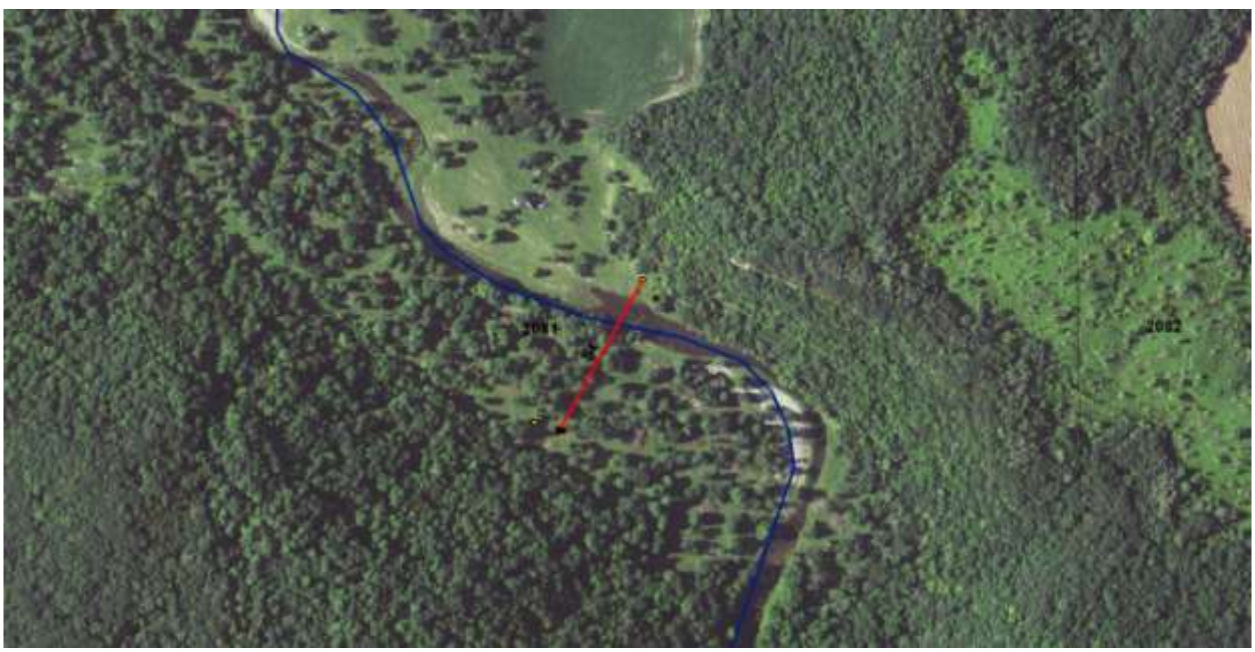
X Section Range SF-3 South Fork of the Whitewater River. 0+00 is located right down stream and is on the northeast end of the line.

Monument S-3-R. Located 6/2/11. Right adjacent to a township road and just across the road from a private campground area. While it would appear to be well hidden in this photo it does visibly stand out when the vegetation is down or dead. Somewhat surprising that the monument has not been disturbed. Photo by author.

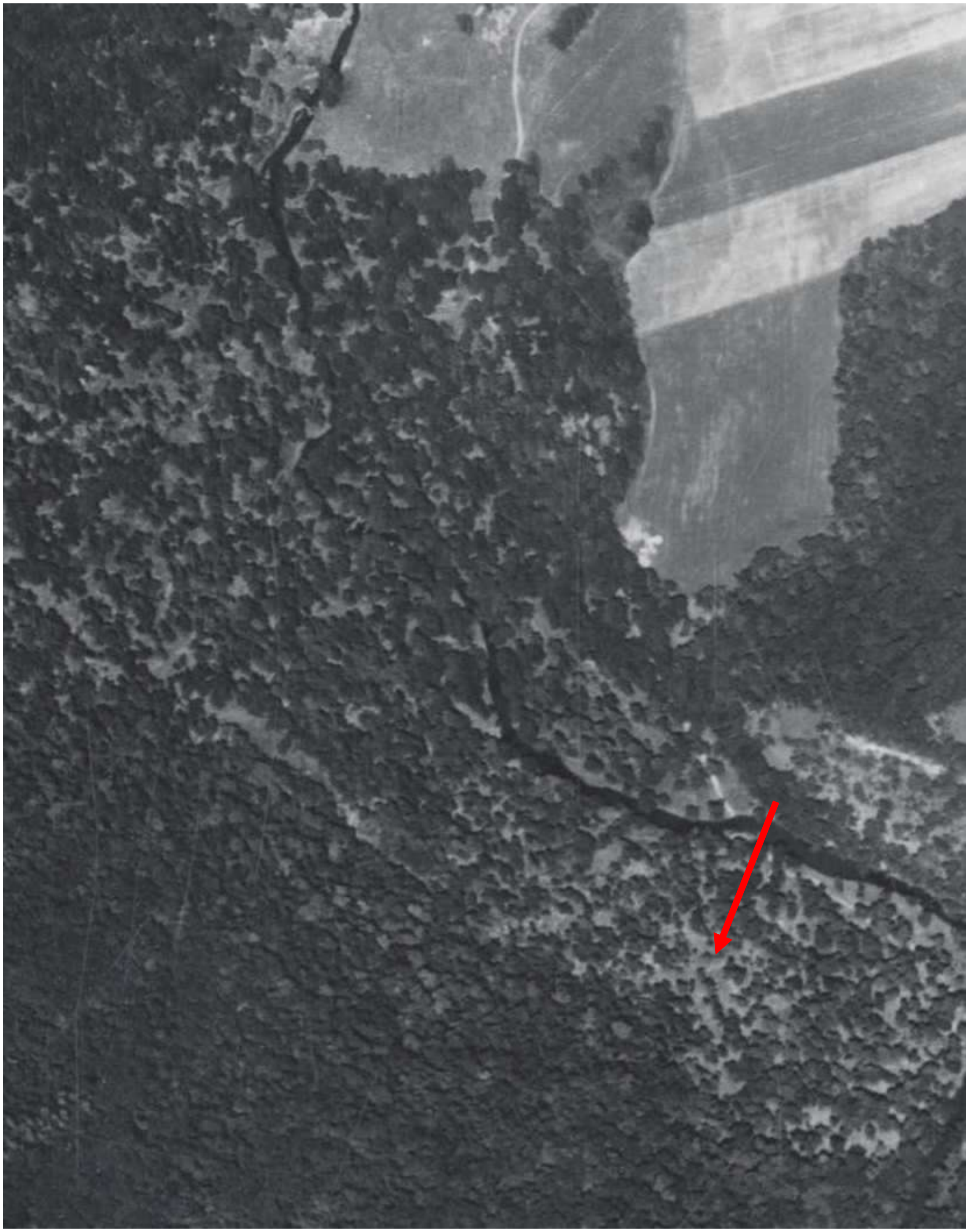
Monument S-3-L. Located 6/2/11. Located in a pasture area with scattered trees. This is also an example of how most of the caps are stamped. In this example it is a close up photo of the cap stamped with USGS and SF R 3 L. Photo by author

Range SF-4





X Section Range SF-4 South Fork of the Whitewater River. 0+00 is located right down stream and is on the northeast end of the line.



X Section Range SF-4 1954 photo of area around SF-4. Location of x section range is approximate. Note that stream is much narrower and heavier woodland cover than the 2010 photo above. Landowner is actively removing trees at the time of this study. Background photo courtesy of USDA NRCS.

Monument SF-4-L. This area is near a private campsite with 80 – 100 sites, the area is highly disturbed with lots of human presence throughout the year. It would appear that monument was pulled out with a chain and bent in the process. Monument pipe was laying on surface of the ground and it appears to have lain there for quite a while. Monument was located and recorded during the 1994 survey. Its present location was noted and recorded but more for posterity than any scientific reason. Lying approximately 45 feet from expected location based on the location of SF-4-R, distance of x section, and azimuth recorded in previous surveys. Photo by author

Monument SF-4-R. Located 6/2/11. Notice campground in background. This is one of approximately 80 in the area. Much long term human disturbance in the area. Photo by author.

Apendix 2

Table 1. Monuments located and surveyed to modern accuracy standards

Point	Y - Meters	X - Meters	Z - Feet	Comment
1	4895577.265	586106.173	677.401	Brass Cap
2	4896045.87	585624.283	679.55	1-N
3	4896045.813	585624.3156	679.309	1-N Grd
4	4895072.641	586224.1074	669.368	1-S
5	4895376.547	583822.373	678.427	2-N
6	4895376.463	583822.3968	677.992	2-N Grd
7	4894600.103	584189.9368	684.644	2-S
8	4894600.275	584189.8649	683.737	2-S Grd
9	4894349.425	582346.0733	684.598	3-N
10	4894349.404	582346.123	684.473	3-N Grd
11	4892977.001	580999.7574	689.967	4-N
12	4892976.922	580999.8147	689.639	4-N Grd
13	4892426.475	581416.3626	707.193	4-S
14	4892426.522	581416.2922	706.944	4-S Grd
15	4892647.558	579912.313	693.592	4C-N
16	4892823.067	580231.9366	690.911	8DRL Brass Cap
17	4891744.809	579658.7069	701.74	5a-N
18	4891618.273	580298.7031	697.647	5a-S
19	4876881.39	572144.2427	1000.008	MF-20-L
20	4876881.335	572144.2408	998.594	MF-20-L Grd
21	4876833.206	572180.0125	1001.812	MF-20-R
22	4876833.272	572179.999	1001.133	MF-20-R Grd
23	4876390.279	571452.5911	1021.521	MF-21-L
24	4876390.296	571452.6432	1020.605	MF-21-L Grd
25	4875156.135	568513.3166	1078.945	MF-24B-L
26	4875156.061	568513.3145	1078.478	MF-24B-L Grd
27	4875087.58	568512.1008	1078.694	MF-24B-R
28	4875087.624	568512.0788	1078.467	MF-24B-R Grd
29	4873985.569	566143.9572	1106.779	MF-26B-L GONE
30	4873913.318	566195.9807	1106.247	MF-26B-R GONE
31	4874039.432	564682.724	1136.764	MF-27-L
32	4874039.395	564682.6728	1135.773	MF-27-L Grd
33	4874023.238	564632.1964	1134.84	MF-27-R
34	4874023.263	564632.254	1134.002	MF-27-R Grd
35	4875113.35	563315.7859	1203.188	MF-28B-L
36	4875113.292	563315.7951	1201.493	MF-28B-L Grd

37	4874986.233	563191.3074	1195.688	MF-28B-R
38	4874986.266	563191.3419	1193.094	MF-28B-R Grd
39	4873487.113	581229.2212	1039.192	SF-10-L
40	4873487.116	581229.2846	1038.45	SF-10-L GRD
41	4873466.865	581312.1749	1030.454	SF-10-R BRONZE CAP
42	4873466.941	581311.9555	1030.416	SF-10-R ROCK
43	4873460.343	580319.8385	1052.583	SF-11-L GRD GONE
44	4873453.56	580380.4227	1049.017	SF-11-R
45	4873453.588	580380.3971	1047.814	SF-11-R Grd
46	4872513.137	578016.0418	1070.85	SF-13-L
47	4872490.588	578016.1583	1070.128	SF-13-R
48	4872309.897	577243.311	1079.653	SF-14-L
49	4872258.535	577304.1485	1084.706	SF-14-R
50	4871195.118	575393.4356	1097.11	SF-16C-L
51	4871121.823	575400.5896	1097.476	SF-16C-R
52	4869737.321	574858.9478	1104.357	SF-17-L Grd GONE
53	4869652.263	574892.2493	1107.44	SF-17-R
54	4869652.282	574892.2478	1105.985	SF-17-R Grd
55	4869705.121	574931.1763	1109.615	BRASS CAP BRIDGE By 17-R
56	4869022.66	572668.2384	1119.139	TBM CHISLED SQUARE
57	4869006.337	572663.4256	1119.283	BRASS CAP
58	4869104.528	572673.1581	1115.403	SF-18-L-GRD GONE
59	4869029.524	572678.0084	1116.762	SF-18-R
60	4869029.49	572678.0413	1116.059	SF-18-R Grd
61	4869065.584	570917.0447	1126.806	SF-20-L GONE
62	4869019.333	570917.1291	1132.538	SF-20-R GONE
63	4869011.477	570845.9666	1141.145	BRASS CAP By bridge 20
64	4869982.253	567856.7116	1154.72	chiseld X Cattle Xing
65	4869977.122	567932.088	1151.308	SF-22-L
66	4869977.059	567932.1261	1151.121	SF-22-L Grd
67	4869884.98	567940.8044	1158.547	SF-22-R
68	4869884.856	567940.7437	1157.59	SF-22-R Grd
69	4869920.172	566618.3668	1170.561	TBM NAIL Tel pole By 23-L
70	4869916.517	566619.8679	1169.991	SF-23-L
71	4869916.487	566619.8844	1169.754	SF-23-L Grd
72	4869833.983	566636.9779	1186.612	SF 23-R GRD BENT
73	4869833.367	566637.2077	1185.508	SF-23-R Grd
74	4870306.867	563912.0186	1205.848	SF-25-L
75	4870306.828	563911.9693	1205.511	SF-25-L Grd
76	4870219.605	563878.7384	1207.095	SF-25-R
77	4870219.635	563878.7412	1206.917	SF-25-R Grd

78	4870721.84	562626.5947	1222.895	TBM BRASS CAP BRIDGE HWY 14 BY 26
79	4870721.845	562626.6322	1222.925	CHISELD SQUARE SW CORNER BOX Culvert
80	4870698.674	562567.0646	1221.525	SF-26-L
81	4870698.592	562567.0615	1220.487	SF-26-L Grd
82	4870587.931	562549.7577	1227.84	SF-26-R
83	4870588.022	562549.7498	1226.89	SF-26-R Grd
84	4872548.473	560494.8223	1269.754	SF-28-L
85	4872546.125	560499.9122	1269.209	SF-28-L Grd
86	4872548.679	560500.897	1269.857	SF-28-L Grd 20'@ East
87	4872438.98	560496.5856	1267.673	SF-28-R
88	4872439.519	560502.5194	1267.418	SF-28-R Grd
89	4872438.868	560502.6264	1267.38	SF-28-R Grd 20'@
90	4882117.232	567228.1899	1027.748	L-4-L BENT
91	4882117.464	567228.1933	1028.513	L-4-L GS
92	4882176.102	567255.4024	1027.756	L-4-R BENT
93	4882175.911	567255.4469	1028.503	L-4-R GS
94	4880900.219	565608.9521	1060.24	TBM-Headwall L-6
95	4880816.737	565539.3882	1057.276	L-6-L GONE GRD
96	4880801.195	565590.0115	1060.847	L-6-R BENT
97	4880801.149	565590.3651	1061.082	L-6-R GRD
98	4886856.594	560240.1698	1060.995	D-0-L Cemetery Elgin
99	4886856.538	560240.1409	1060.237	D-0-L Grd
100	4886667.685	560149.9658	1053.232	D-0-R
101	4886667.739	560150.0094	1053.072	D-0-R Grd
102	4887294.221	559219.7473	1067.895	D-1-L CL CO.RD.25 GONE
103	4887158.725	559222.1375	1063.812	D-1-R GRD GONE
104	4887282.557	556364.522	1079.621	D-3-L BENT
105	4887282.54	556364.423	1079.37	D-3-L Grd
106	4887141.713	556296.0706	1076.645	D-3-R GONE GRD
107	4887071.212	555062.4954	1078.57	D-4-L GONE GRD
108	4886900.644	555062.4862	1077.801	D-4-R GONE GRD
109	4885478.619	553522.6403	1103.616	D-6-L
110	4885478.633	553522.6345	1102.035	D-6-L Grd
111	4885428.775	553624.9568	1103.002	D-6-R
112	4885428.769	553624.9086	1102.223	D-6-R GRD
113	4884248.646	552646.2296	1121.903	D-7-L
114	4884248.65	552646.2589	1121.874	D-7-L Grd
115	4884285.196	552799.6778	1152.611	D-7-R
116	4884285.102	552799.5641	1150.351	D-7-R Grd
117	4881834.93	553252.1873	1176.899	D-8C-L

118	4881834.968	553252.2117	1174.503	D-8C-L GRD
119	4881779.502	553303.3178	1188.965	D-8C-R
120	4881779.626	553303.2422	1186.152	D-8C-R GRD
121	4888570.928	570447.5058	1088.592	B-6-L
122	4888570.968	570447.5094	1087.847	B-6-L Grd
123	4888556.547	570475.3273	1088.854	B-6-R
124	4888556.618	570475.3252	1087.888	B-6-R Grd
125	4888736.469	569648.1818	1112.701	B-6C-L
126	4888736.871	569645.1667	1113.669	B-6C-L 10'US-L
127	4888656.615	569650.2563	1113.046	B-6C-R
128	4888656.29	569647.2622	1114.685	B-6C-R 10'US-R
129	4888710.629	569649.1349	1115.985	Corner STEEL POST
130	4888767.813	570036.7814	1110.108	NAIL 1/4 MILE LINE
131	4888920.345	569647.2799	1139.75	NAIL 1/2 MILE LINE
132	4885219.911	565768.4326	1010.914	NF-14-L
133	4885219.923	565768.4472	1010.409	NF-14-L Grd
134	4885225.157	565838.536	1012.199	NF-14-R
135	4885225.245	565838.7521	1009.285	NF-14-R Grd
136	4886191.591	564079.615	1037.435	NF-17-L
137	4886191.525	564079.5885	1037.41	NF-17-L ROCK
138	4886157.251	564007.09	1033.841	NF-17-R
139	4886157.246	564007.1342	1033.351	NF-17-R GRD
140	4885889.988	563257.3668	1059.355	NF-18-R
141	4885908.316	563257.3226	1057.575	NF-18-R GRD
142	4886509.735	560802.9513	1046.64	NF-20-R BORKEN OFF
143	4886396.987	560849.3087	1049.582	NF-20-L GRD GONE
144	4886384.469	559988.5593	1066.429	NF-21 GRD-L GONE
145	4886247.704	559989.6809	1054.174	NF-21 GRD-R GONE
146	4883300.492	557759.1173	1077.772	NF-23C-L
147	4883300.537	557759.0844	1076.274	NF-23C-L Grd
148	4883300.995	557990.9677	1073.678	NF-23C-R GONE
149	4881676.449	557478.3533	1090.921	NF-24-L
150	4881676.475	557478.1658	1090.365	NF-24-L GRD
151	4881676.57	557605.7508	1090.736	NF-24-R
152	4881676.549	557605.7164	1089.383	NF-24-R GRD
153	4878538.101	558517.706	1139.174	NF-27-L
154	4878538.249	558517.9215	1140.15	NF-27-L GRD
155	4878615.515	558639.0286	1136.11	NF-27-R
156	4878615.155	558638.9893	1136.478	NF-27-R GRD
157	4876110.65	559578.214	1237.477	NF-28B-A BENT
158	4876110.881	559578.3146	1236.538	NF-28B-A GRD

159	4876099.018	559612.0496	1233.726	NF-28B-BB
160	4876098.955	559612.0599	1232.307	NF-28B-BB GRD
161	4894550.588	584296.9149	685.925	T-0-W
162	4894550.703	584296.9558	685.885	T-0-W Grd
163	4894610.165	584651.7923	685.98	T-0-E
164	4894610.223	584651.4571	685.322	T-0-E Grd
165	4892730.117	585645.273	734.225	T-2-L- GRD GONE
166	4892820.843	585696.3048	732.122	T-2-R

Coordinates were established with a Trimble R8 GPS with VRS correction and a Trimble S3 Total Station.

Coordinates are Projected Coordinate System: NAD_1983_UTM_Zone_15N
Projection: Transverse_Mercator. Z values are recorded in International Feet.

Table 2. Monuments located and recorded.

	Y - meters	X - meters	Z - feet	Comment
1	4890348.68	579814.0264	0	
2	4891747.736	579658.6676	0	
3	4885609.413	579858.2995	0	
4	4892977.606	580999.2148	0	
5	4892648.577	579910.2072	0	
6	4889835.657	579000.3954	0	
7	4886984.626	578668.1602	0	
8	4886985.282	578667.8918	0	
9	4884422.539	579927.6313	0	
10	4880929.255	577832.2623	0	
11	4879291.894	576287.4021	0	
12	4888391.146	579424.779	0	
13	4888742.894	580274.1712	0	
14	4882281.244	579480.0924	0	
15	4884372.315	580490.6456	0	
16	4886959.591	579733.9921	0	
17	4885621.37	580471.1888	0	
18	4890434.371	580696.6075	0	
19	4891960.154	580560.7268	0	
20	4893550.277	582879.3324	0	
21	4878479.01	575785.7693	0	
22	4878572.427	575714.0279	0	
23	4876882.535	542517.5159	0	
24	4876882.729	542516.6143	0	

25	4888506.676	575228.0385	0	
26	4888406.225	574113.7245	0	
27	4888558.977	570474.3808	0	
28	4888570.479	570447.1921	0	
29	4896046.737	585622.2551	0	
30	4895376.481	583822.1723	0	
31	4894351.486	582346.6333	0	
32	4892648.629	579912.2981	0	
33	4892825.364	580232.071	0	
34	4891747.787	579658.5248	0	
35	4888391.661	579430.2142	0	
36	4890345.146	579819.0459	0	
37	4892975.548	581000.2078	0	
38	4888741.433	580275.2141	0	
39	4886958.856	579733.6658	0	
40	4885619.156	580471.5985	0	
41	4886959.301	579735.0487	0	
42	4890434.605	580695.7729	0	
43	4891961.672	580560.0585	0	
44	4886986.633	578668.6405	0	
45	4885610.11	579858.6516	0	
46	4884424.18	579926.3529	0	
47	4883338.968	579118.615	0	
48	4882348.953	578477.4955	0	
49	4882277.466	579481.1628	0	
50	4883047.324	579605.3328	0	
51	4884373.664	580490.4227	0	
52	4882434.851	580546.872	0	
53	4880178.507	581607.8073	0	
54	4880185.315	581895.865	0	
55	4880928.436	577830.7221	0	
56	4880202.49	576577.2407	0	
57	4879290.691	576289.0344	0	
58	4892427.861	581415.5572	0	
59	4893547.584	582879.5411	0	
60	4879212.461	576399.9366	0	
61	4879995.546	576894.6479	0	
62	4881118.814	577456.0317	0	
63	4882233.428	578700.2983	0	
64	4878478.87	575783.9342	0	
65	4878570.891	575714.0665	0	

66	4889836.179	579001.6028	0	
67	4894608.84	584651.2045	0	
68	4878069.268	573934.5568	0	
69	4876833.57	572179.5842	0	
70	4876881.545	572143.7908	0	
71	4876389.627	571453.0265	0	
72	4878471.209	574777.1063	0	
73	4878470.196	574776.7145	0	
74	4878361.69	574718.2854	0	
75	4874985.283	563187.8746	0	
76	4875113.869	563314.3164	0	
77	4874790.752	562994.3673	0	
78	4891589.831	580292.483	0	
79	4876100.345	559611.3329	0	
80	4876111.038	559577.0811	0	
81	4881678.121	557477.5599	0	
82	4881679.402	557605.4424	0	
83	4883301.715	557758.1133	0	
84	4883301.382	557758.439	0	
85	4881836.254	553251.7398	0	
86	4881781.177	553302.4222	0	
87	4885479.655	553522.3989	0	
88	4885429.126	553625.471	0	
89	4889065.415	579024.2168	0	B0_S
90	4881675.11	557480.5851	1102.4	N-24-L
91	4882348.356	578479.9812	662	11b-L
92	4882127.286	578941.8342	0	11B-R
93	4880930.617	577833.0786	668	12B-L
94	4880928.935	577835.2668	774	12S
95	4880201.497	576577.4604	832	13A-LL
96	4880000.821	576893.1115	815	13A-STBM
97	4879211.948	576401.2644	824	14-S
98	4878476.657	575789.7558	779	15-b-s
99	4878110.302	573949.2471	948.2	18-L
100	4878066.864	573939.0836	974.4	18-R
101	4895071.918	586224.4014	682.4	1-R
102	4876878.437	572145.8147	997.4	20-L
103	4876834.29	572182.1151	1000.7	20-R
104	4895377.098	583822.0406	0	2-N
105	4894351.084	582345.5139	0	2-S
106	4894600.51	584187.9821	559	2-S

107	4892649.442	579911.5993	705	4C-N
108	4886987.882	578671.1502	755	8A-N
109	4889068.033	579014.603	608	B-0-S
110	4889314.538	577170.8279	633	B-1-N
111	4889068.804	577191.6968	656	B-1-R
112	4888240.837	575260.8178	720	B-2-L
113	4888398.577	574111.5238	764	B-3-L
114	4888163.548	574088.951	732	B-3-R
115	4882960.729	569157.4453	915.4	L-0B-L
116	4883201.742	569680.9323	889.1	L-0-L
117	4883142.447	569704.3727	912.1	L-0-R
118	4883216.674	568924.697	918.6	L-1-R
119	4882815.407	567516.1722	1010.5	L-3-L
120	4882821.831	567583.4015	1063.0	L-3-R
121	4880493.791	564119.5027	1053.1	L-7-L
122	4880423.659	564160.9463	1030.2	L-7-R
123	4880418.24	564119.6038	1102.4	L-7-ref
124	4878445.521	561989.9452	1197.5	L-9-L
125	4878408.224	562013.7553	1197.5	L-9-R
126	4876391.142	571451.9924	924	mf-21b-l
127	4875300.971	570195.3294	999	MF-23-L
128	4878571.312	575712.4323	773	middlefork group
129	4882087.288	577948.275	774.27824	N-0B-E
130	4881748.838	577733.6832	748.03152	N-0B-W
131	4884792.915	566307.4616	987.53284	N-13_L
132	4884905.923	566320.7458	1030.18376	N-13-R
133	4885224.352	565764.4316	937	N-14-L
134	4882079.29	576549.1857	0	N-1-L
135	4882017.438	576504.6126	0	N-1-R
136	4881676.879	557607.5539	1102.4	N-24-R
137	4876107.383	559578.657	1243.4	N-28B-L
138	4876072.526	559580.8119	1230.3	N-28B-L_Old
139	4876099.104	559609.3395	1227.0	N-28B-R
140	4882568.647	575069.839	800.5	N-2-R
141	4883452.141	573446.4619	839.9	N-3-l
142	4883282.304	572211.7316	856.3	N-4-L
143	4883599.404	570233.9183	0	N-7-R
144	4883646.571	569275.2012	0	N-8-L
145	4885225.892	565835.6761	894	NF-14-R
146	4886190.384	564080.99	967.8	NF-17-L
147	4886158.632	564006.8129	935	NF-17-R

148	4878539.929	558516.1313	1036	NF-27-L
149	4878617.954	558638.1472	1030	NF-27-R
150	4877109.638	559021.2529	1086	NF-28-L
151	4882065.73	580308.6975	0	S-0B-L
152	4882609.557	579644.8999	0	S-0-R
153	4873489.73	581228.8638	1023.6	S-10-L
154	4873475.578	581306.9634	1066.3	S-10-R
155	4881489.122	580788.5977	0	S-1-L true
156	4880174.311	581607.0735	687	S-2-W
157	4880182.739	581894.9398	692	S-2-W
158	4878888.712	582653.2499	707	S-3-E
159	4878689.473	582471.1403	713	S-3-W
160	4877173.43	582092.1061	742	S-4-L
161	4877308.225	582194.2664	738	S-4-R
162	4881604.483	581146.0099	0	sb-1-r-m
163	4869650.102	574892.4084	1024	SF-17-R
164	4869918.063	566619.6226	1076	SF-23-L
165	4869835.3	566637.3513	1095	SF-23-R
166	4870590.763	562549.0374	1142	SF-26-S
167	4872440.066	560496.4039	1181	SF-28
168	4876077.47	582483.6513	885.8268	SF-5-L
169	4874912.491	582437.6846	912.07352	SF-6-E
170	4874863.606	582294.8911	980.97116	SF-6-L
171	4894555.864	584297.3368	0	T-0-W
172	4892821.067	585696.043	731.62732	T-2-R
173	4891327.891	585936.9375	641	T-3-L
174	4891348.374	585985.1198	642	T-3-R

Coordinates were established with GPS units ranging from commercial grade Garmin GPSMap 76 with NDGPS beacon correction USDA Configuration II, Garmin Oregon with WAAS Correction, Trimble GeoXT 2008 Mapping grade GPS, Trimble GeoXT 6000 Mapping grade GPS. Accuracy is considered to range from 0.5 – 3 meters

Coordinates are Projected Coordinate System: NAD_1983_UTM_Zone_15N Projection: Transverse_Mercator. Z values are recorded in Feet. Note that when data was first collected elevation (Z data) was not collected.

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