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Channel Stabilization, Habitat Restoration, and Realignment Feasibility Study for Class I Trout Stream in Wisconsin

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Abstract

Trout Creek is considered Exceptional Resource Water maintaining a Class I wild brook trout population. Wisconsin Department of Natural Resources (DNR) classifies trout streams as Class I if the high quality trout waters support natural reproduction to sustain populations of wild trout at or near carry capacity. Excessive sediment from the uplands as well as some bank erosion is causing deteriorating conditions that may contribute to losing the brook trout population permanently.

A proposal was made to relocate the stream from its present channel away from a 20-foot high unstable bank. The proposed change would shorten the stream channel by 81 feet. A geomorphologic study was required to determine if the stream would be stable after this change. Lane's stream balance equation was used for this study. Due to the results obtained, we decided to implement a traditional streambank stabilization alternative.

The project was divided in several stages, one of them being the restoration of an eroded streambank in the most downstream section of the stream pertaining to one landowner. Another phase involved a section in the upstream part of the stream within the same property's boundaries with two areas of rock riprap, a rock channel crossing, a rock weir for providing fish habitat, and removal of a washed-down snowmobile bridge, which is believed to be the initial cause of problems in this area of the stream. Both of these stages have already been completed.

There was also work done in uplands pertaining to a different landowner, which affected our stream. This consisted of grade stabilization structures to control massive gully erosion. Later stages of the project will very likely need to involve bioengineering due to the height and steepness of the eroding bank in remaining areas of concern.

Introduction

Wisconsin Fish: Trout Stream Classifications[1]

The Department of Natural Resources (DNR) uses three categories to classify the different types of trout streams throughout the state. These are evident in Wisconsin Trout Streams (PUB-FH-806 2002, PDF, 1,035KB), which provides a comprehensive list of trout streams throughout the state, and in Wisconsin Trout Stream Maps, a set of trout stream maps covering the majority of Wisconsin.

Since 1980, the total number of trout streams has increased by 254, and the miles have increased by 809. The miles of class 1 trout streams have increased by 600 miles, the miles of class 2 have increased by 401 miles, and the miles of class 3 have decreased by 192 miles. The reasons for these changes are numerous, including changing land use patterns, land conservation measures, habitat restoration and protection, and wild trout stocking.

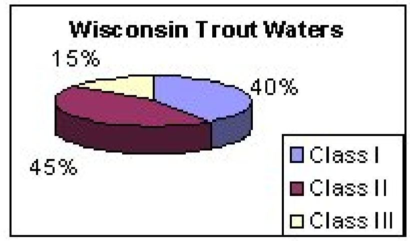

Figure 1. Distribution of Trout fish habitat in Wisconsin waters by class.

The classifications are as follows:

Class 1

High quality trout waters that have sufficient natural reproduction to sustain populations of wild trout, at or near carry capacity. Consequently, streams in this category require no stocking of hatchery trout. These streams or stream sections are often small and may contain small or slow-growing trout, especially in the headwaters.

There are 4,136 miles of Class 1 trout streams in Wisconsin and they comprise 40% of Wisconsin's total trout stream mileage.

Class 2

Streams in this classification may have some natural reproduction, but not enough to utilize available food and space. Therefore, stocking is required to maintain a desirable sport fishery. These streams have good survival and carryover of adult trout, often producing some fish larger than average size.

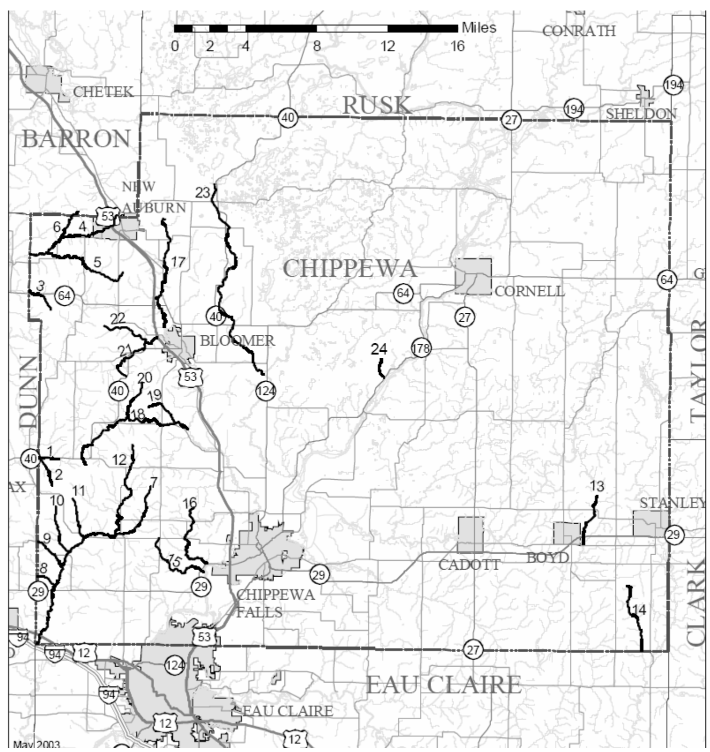

Figure 2. Location of trout streams in Chippewa County, WI.

There are 4,644 miles of Class 2 trout streams in Wisconsin and they comprise 45% of Wisconsin's total trout stream mileage.

Class 3

These waters are marginal trout habitat with no natural reproduction occurring. They require annual stocking of trout to provide trout fishing. Generally, there is no carryover of trout from one year to the next.

There are 1,591 miles of Class 3 trout streams in Wisconsin and they comprise 15% of Wisconsin's total trout stream mileage.

Site Location

The site is located in the township of Wheaton, Chippewa County, in the northwestern part of the state of Wisconsin.

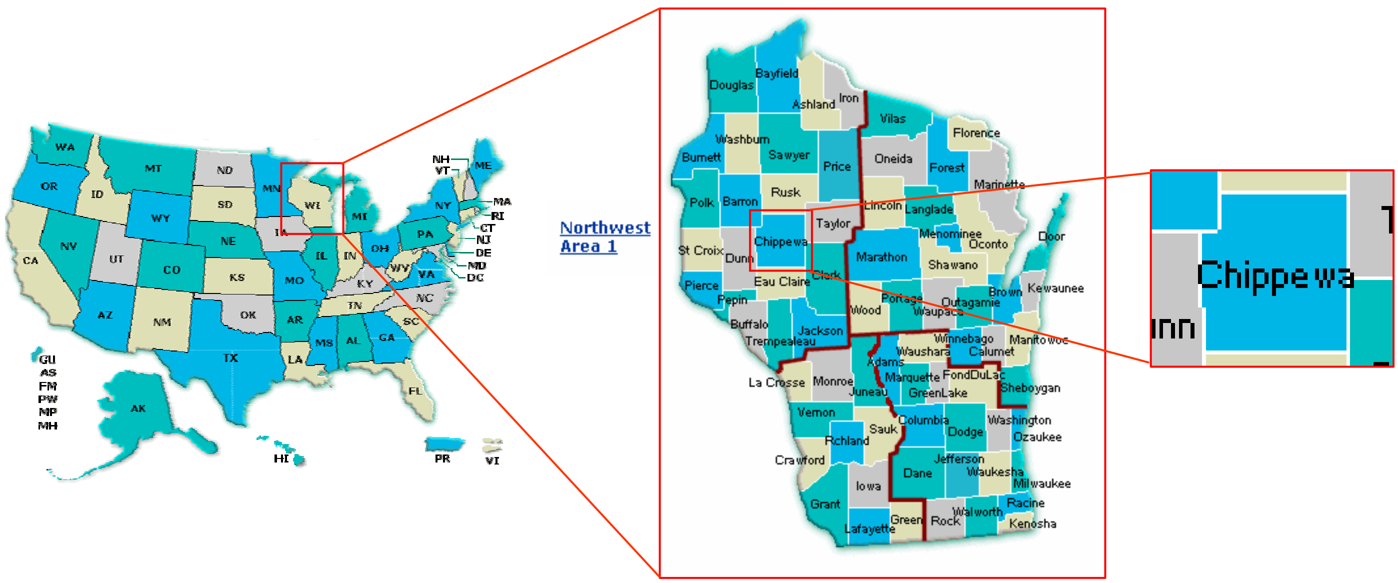

Figure 3. Location of Chippewa County, WI.

Site Description

The watershed that drains to our site has an area of 4,252.3 acres. The watershed length is 30,653 feet, with an average watershed slope of 34.5%. The soils consist of glacial outwash comprised of sand, gravel, and some cobbles and boulders.

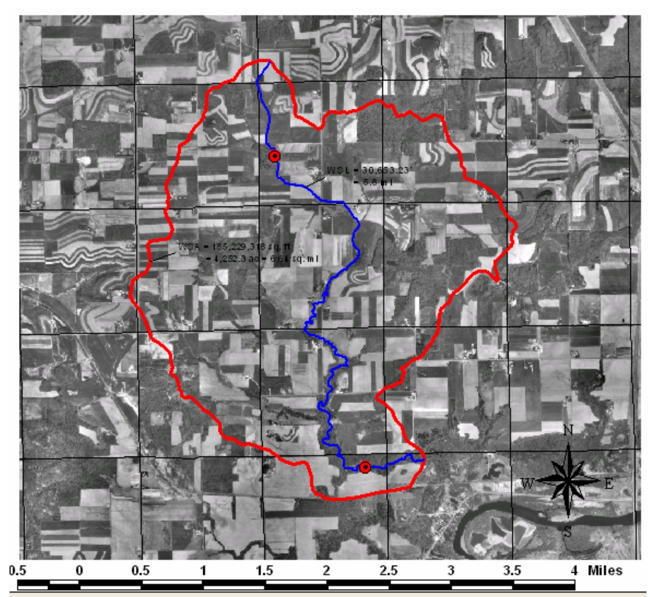

Figure 4. Site Watershed.

Site Assessment

It is believed that a wooden bridge installed by a local snowmobile association aggravated the stream's erosion problems when it washed downstream, got stuck, and blocked water flow. Our restoration work includes the removal of this bridge.

Figure 5. Wooden snowmobile bridge washed down, blocking stream flow downstream of eroding site.

The landowner and Department of Natural Resources proposed re-locating the stream sections along the high eroding banks. Wisconsin NRCS Conservation Standard for design of Streambank and Shoreline protection states that significant alterations to channel alignment or channel geometry shall be made only after an evaluation using current fluvial geomorphologic techniques. We worked together with our State Geologist to complete the geomorphologic study for Trout Creek in order to evaluate the feasibility of this measure and its impact on the stream's stability and trout habitat.

The yellow line in the photo below is the approximate creek location in 1992 whereas the line in blue is from the topographic map which was dated 1972. In 20 years, the increase in sinuosity can be seen. The site where work was initially done is the curve with the radius of curvature of 165 feet. The maximum distance the creek has moved at the site in the 20 years from 1972 to 1992 is 67 feet for an average annual rate of movement of the creek of 3.3 feet. The sinuosity of the creek has changed from 1.3 in 1972 to 1.4 in 1992 with a total increase in length from (the curve labeled R_C = 51 ft. downstream to the railroad tracks) of 300 feet!

Due to the thick sequences of layered sands and gravels in the creek and river valleys in addition to poor land use in the past, there is excess sediment in the system. Excess sediment from the eroding banks is too great to be transported by the stream so the stream drops much of its load and creates multiple channels at the downstream end of the site.

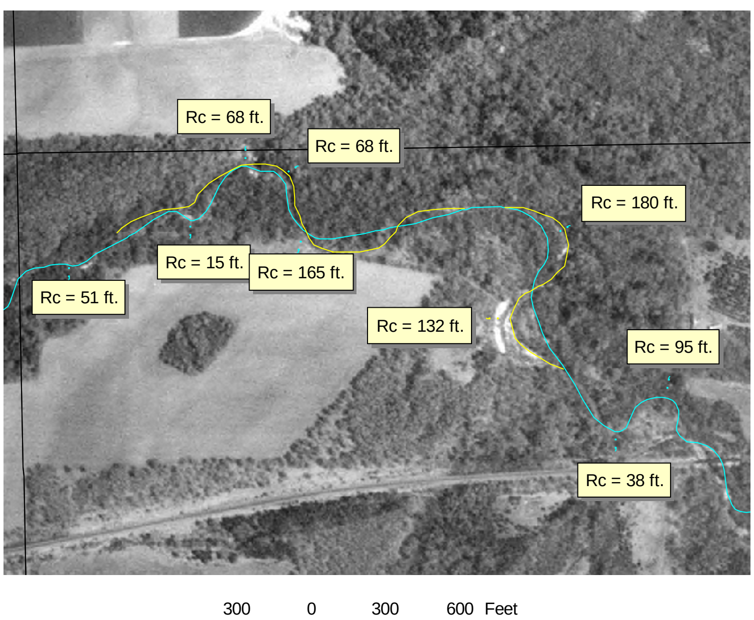

Figure 6. Change in sinuosity of the stream

The air photo to the left shows the range of radius of curvatures (15-180) for the site. The average radius of curvature R_c is 105 feet.

The meander wavelengths recorded for this site using ArcView and the 1972 hydrography from the topographic map are: 346, 165, 1077, 885, 525, 611, 365. The average meander wavelength, L_m = 568 ft.

Using the average meander wavelength of 568 and an equation developed by Langbein and Leopold (1966) the average radius of curvature should be 114. The average radius of curvature should be a little greater than what is present, given the distance between meander bends and the sinuosity.

$$R_c = \frac{L_m K^{1.5}}{13(K-1)^{0.5}}$$

K= sinuosity

The average sinuosity for a C4 stream type is 1.9. This stream may eventually become a C4 stream type. In either a C4 or C5 stream type, the sinuosity for this stream should be higher than the current 1.4.

Stream Cross Section, Valley Type and Regional Curves

The stream has been classified as a C5 channel. C5 stream types are located within many different valley types. The stream reach at the Custer site is located in a type VIII valley. Type VIII valleys are most readily identified by the presence of multiple river terraces positioned laterally along the valley which is often broad with a gentle gradient. The following data, cross section and photos show the riffle cross section used to classify the stream. Two sets of calculations were run based on two possible bankfull surfaces.

Using 94.6 for bankfull elevation (this surface is the terrace identified on the longitudinal profile):

Bankfull Width, W_{bkf} = 65 ft.
Bankfull Cross Sectional Area, A_{bkf} = 139 sq. ft.
Floodprone Area Width, W_{fpa} >137
Entrenchment ratio: >2.2
Sinuosity 1.4
Mean Depth, d_{bkf} = 2.1 ft.
Width/Depth Ratio, W_{bkf}/d_{bkf} = 31
Maximum Depth, d_{mrif} = 5.1 ft.
Slope, S = .0078
Median particle size: .31 mm (medium sand)

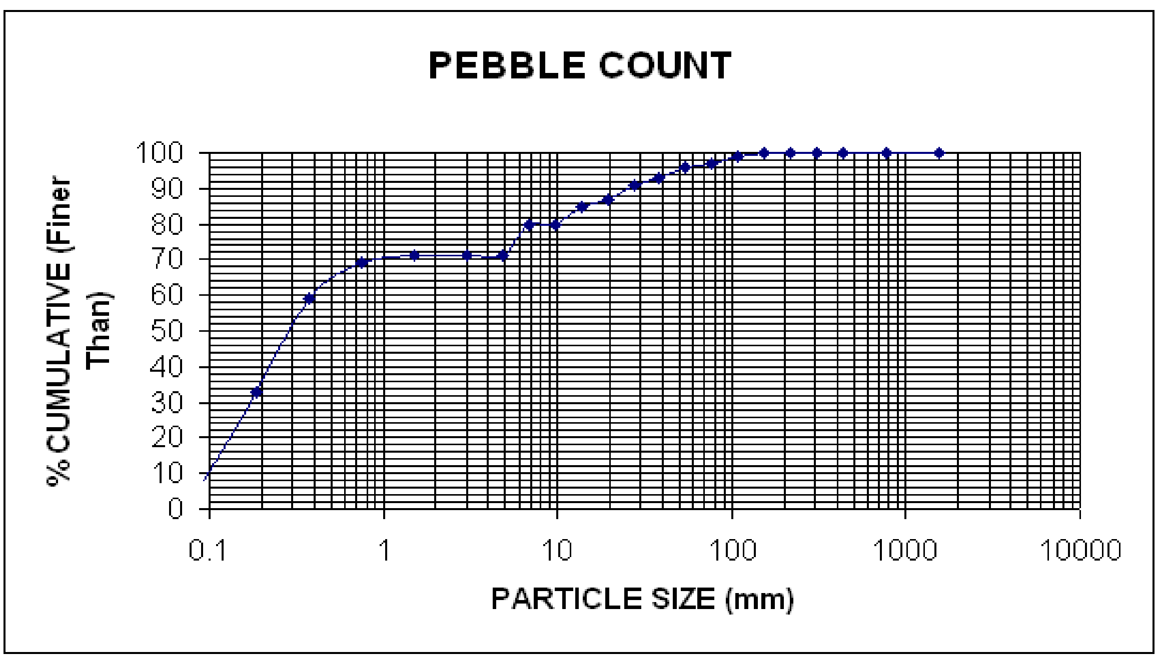

Figure 7. Median Particle size (D_{50}) = 0.31 mm (medium sand)

Because a regional curve has not been developed for this area another curve was used. Comparison of cross section data to several regional curves shows a rough match with the NRCS-North Carolina

State University curve for the rural piedmont area of North Carolina. Using the rural piedmont curve from North Carolina and using the bankfull elevation of 93.8 on the riffle cross section on page 15 and using a velocity of 6 feet/second gives a bankfull discharge of 486 cfs. The Rural Piedmont North Carolina curve was used since it was closest to the dimensions of the channel at the site.

Velocity, Manning's n and Sediment Transport

The USGS Flood-Frequency Characteristics of Wisconsin Streams method (formerly known as the Conger method) of computing bankfull discharge was used for our calculations. Using this data, the bankfull discharge should be 158 cubic feet per second (cfs). Using a bankfull area of 81 square feet gives a velocity of 1.9 feet per second.

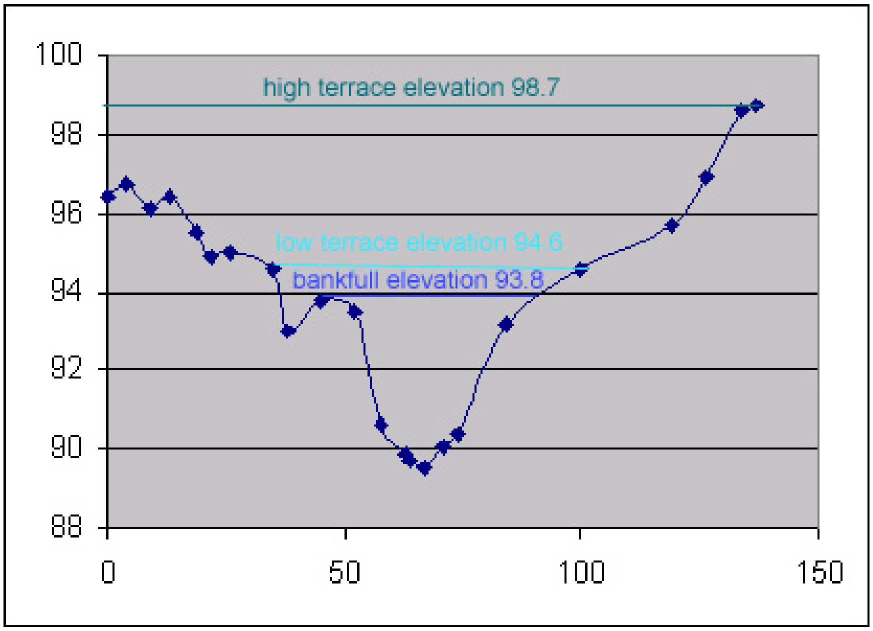

Figure 8. Stream cross-section.

This does not sound reasonable so the velocity was calculated by two different equations that use a friction factor determined from the hydraulic radius and D84 in a riffle. A velocity of 6 is calculated using 93.8 as the bankfull elevation.

Calculating shear stress during bankfull flows shows that particles 60 mm and smaller (very coarse gravel – Wentworth scale) will move. This is roughly the size of some of the largest particles found on the bar across from the site where work will be done.

$$\tau = \gamma\, RS = 0.86$$

τ = Bankfull shear stress, lbs./ft.^{2}

γ = Specific weight of water = 62.4 lbs./cu. ft.

R = Hydraulic radius of riffle cross section, ft.

S = Average water surface slope, ft./ft.

Summary of Facts and Findings

- Trout Creek is a Class I trout stream
- Excess sand is the primary cause of degradation of trout habitat
- Embedded sands prevent successful trout reproduction
- Deep pools are a limiting factor for trout habitat
- The stream bed is aggrading in this reach
- The stream is only slightly entrenched and remains connected to its floodplain
- Particles 60 mm (2.4 inches) and smaller will move during bankfull flows
- The velocity during bankfull flow averages roughly 6 feet/sec.
- The valley through which Trout Creek flows is primarily erodible layered glacial sands and gravels
- The stream has potential to become a gravel bed C4 stream
- The stream bank is eroding an average of 3.3 feet per year laterally
- Seepage is a contributing factor to bank failure on banks perpendicular to the regional groundwater flow (northwest to southeast) on the upgradient side of the creek
- The stream reach has added 300 feet in length over 20 years
- The sinuosity of the stream (stream length/valley length) has increased from 1.3 to 1.4 over 20 years
- The sinuosity of the stream will continue to increase
- Excess sand is being delivered to the stream, likely due to past straightening of the channel and poor land use practices
- Excess sand created multiple channels just downstream of the high eroding bank

Recommendations based on Geomorphologic study:

It is recommended that the guidelines for treating high eroding streambanks in the NRCS Engineering Field Handbook, Wisconsin Supplement on page 16-WI-53 be followed. The guidelines propose the installation of a toe bench for Rosgen[2] "C" channels which are connected to their floodplains. The stream reach should not be shortened.

- Decrease the width depth ratio of the stream by deepening and narrowing the stream where work on the stream is to be done. This will improve sediment transport at the location the work is done.
- Work with the stream which is trying to lengthen its flowpath
- Don't shorten the flowpath
- Find a stable reference reach and copy some of its dimensions, using a reach with the same drainage area or correcting for drainage area size
- Develop regional curves so in the future the correct width and depth of the channel will be known and it will be unnecessary to survey a reference reach
- Do a mechanical analysis on a bar sample to more accurately determine the size material which moves during bankfull flow.
- Maintain existing watershed runoff and sediment loads
- Create more floodplain through excavation, if possible

Design

To improve trout habitat we planned on reducing sedimentation in the stream. In order to accomplish this, we looked at other segments of the stream that appeared to be stable and attempted to narrow the stream in our work area to a width typical to that in the healthier areas of the stream (about 6 feet wide). This would maintain a constantly higher velocity throughout the channel, thus reducing sediment accumulation at the bottom.

There were two main eroding bank areas within the property of one particular landowner. We addressed these two areas first. For location purposes, we named the sites East streambank site and West streambank site. See Figure 10 below for a map with location of each site.

The design for the East streambank involved a traditional streambank protection rock riprap structure and banksloping at 3:1 slopes. This structure was designed for a velocity of 6.3 fps, with an 8-inch spherical D_{50} rock. The DNR had considered installing lunker structures for habitat enhancement, but due to the high sediment load, it was ruled out. They will establish other measures.

The West streambank design consisted of 2 rock riprap protections, a rock channel crossing, and a rock weir and scour hole for habitat enhancement purposes. The stream crossing was originally designed for a 10-yr storm of 4.4 fps with 3.5-in. D_{50} cubical rock. DNR modified our stream crossing and rock weir designs to meet their experience with this type of structures. The upstream riprap was designed for the 50-yr storm with a velocity of 6.7 fps, with a 9-inch D_{50}. The downstream riprap was designed for a velocity of 7.5 fps, with same-size D_{50} rock.

Figure 9. Before construction (top) and narrowing and re-routing of the stream (bottom) in Downstream Riprap location (looking upstream).

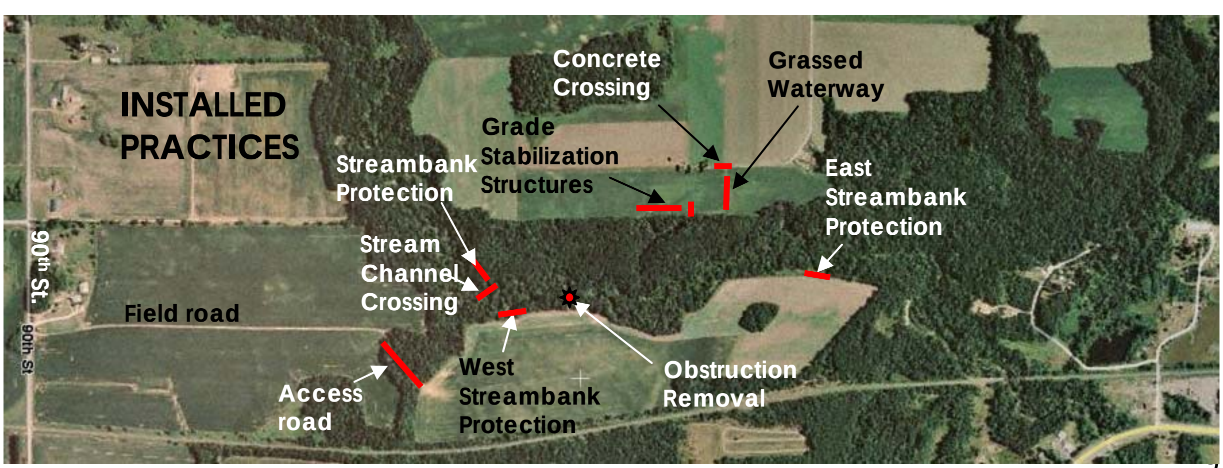

Figure 10. Installed Conservation Practices in Trout Creek Site.

FLOOD FREQUENCY CHARACTERISTICS OF WISCONSIN STREAMS (ver 12.01.04) **Draft Version**

USGS Water Resources Investigations Report 03-4250

Wisconsin Flood Frequency Area 2[Note 1.]

Project:	Ken Custer		
County:	Chippewa		
By:	DMH	Date:	5/25/2005
Checked By:		Date:	

Watershed Area (square miles)			6.64
Watershed length (miles)			5.8
Enter Elevation upstream from point of interest	0.58	miles	850
Enter Elevation upstream from point of interest	4.93	miles	1000
Enter Soil Permeability, (inches/hr) [Note 2.]			1.65

Area	A	6.64	sq miles
Soil Perm	SP	1.65	in/hr
Slope	S	34.5	feet/mile

Peak Flood Discharge with n-year recurrence interval [Note 3.]

Q_2	195	cfs
Q_5	336	cfs
Q_{10}	434	cfs
Q_{25}	572	cfs
Q_{50}	676	cfs
Q_{100}	780	cfs

Note 1. As indicated by map in Figure 3 of above report

Note 2. Soil permeability from Plate 2 of above report

Note 3. Flood frequency equations from Table 2, equations 2-1 to 2-6 of above report.

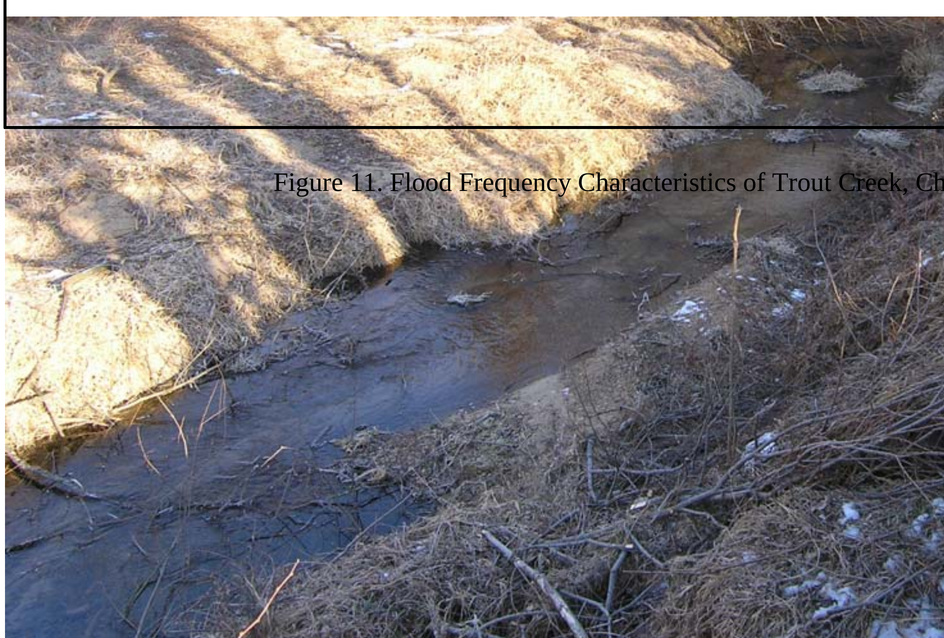

Figure 11. Flood Frequency Characteristics of Trout Creek, Chippewa Co, WI.

Figure 12. Prior to construction, sediment accumulation along the channel bottom was one of the greatest concerns that threatened trout population in this stream.

earthwork is evident along channel bottom.

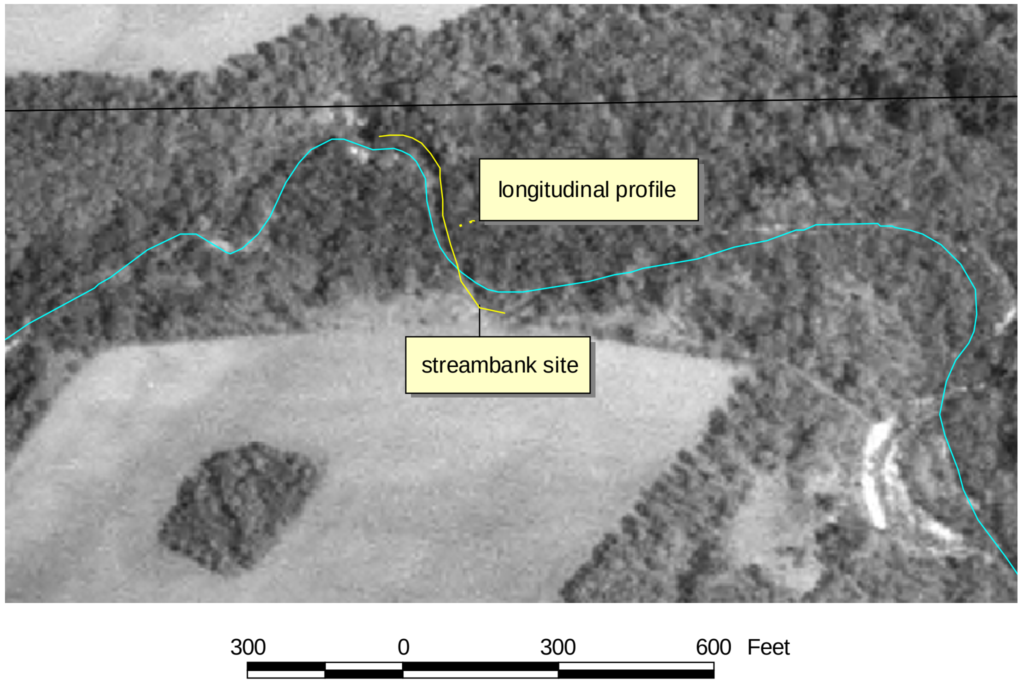

Figure 15. Location of area surveyed for longitudinal profile (indicated by yellow line).

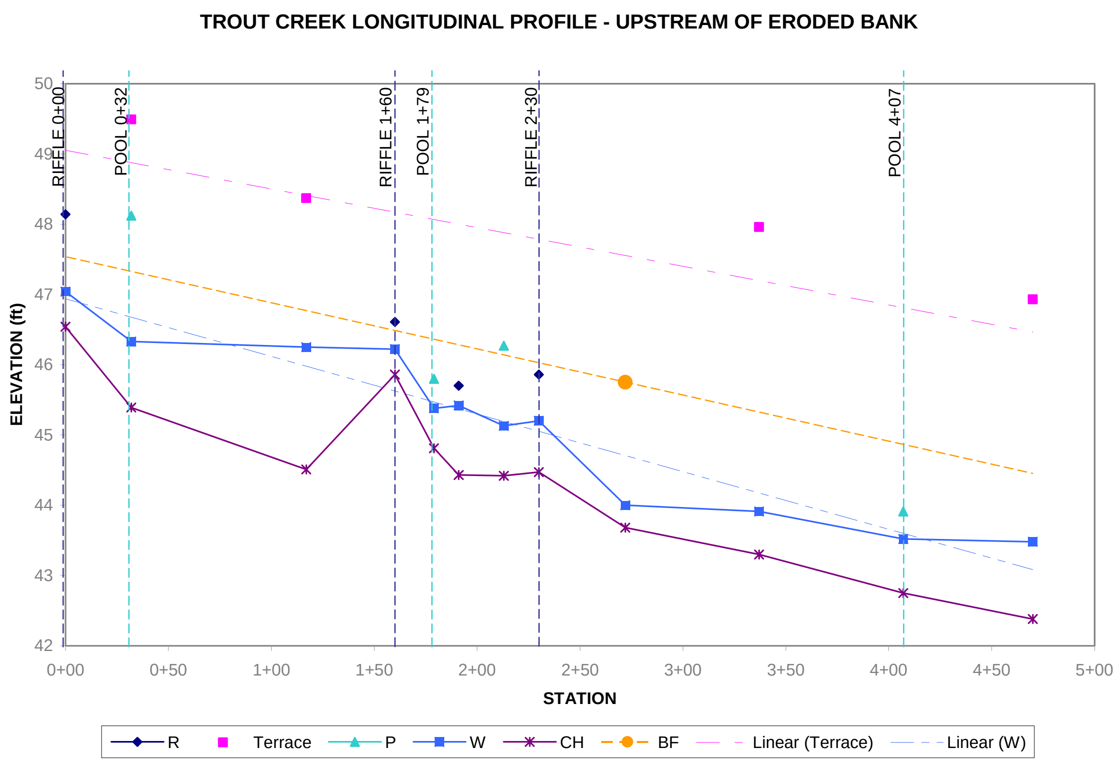

Figure 16. Trout creek longitudinal profile – upstream of eroded bank.

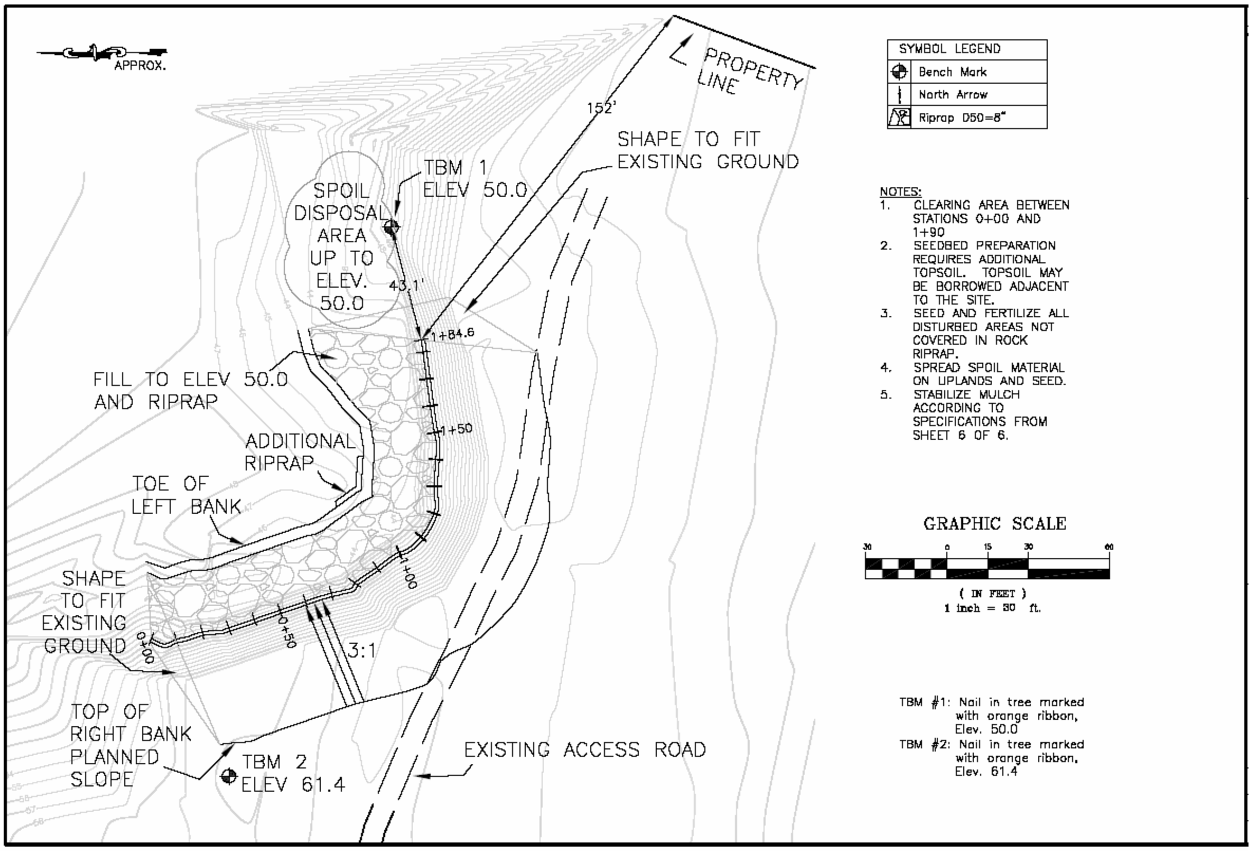

Figure 17. Plan view of proposed design for East streambank site.

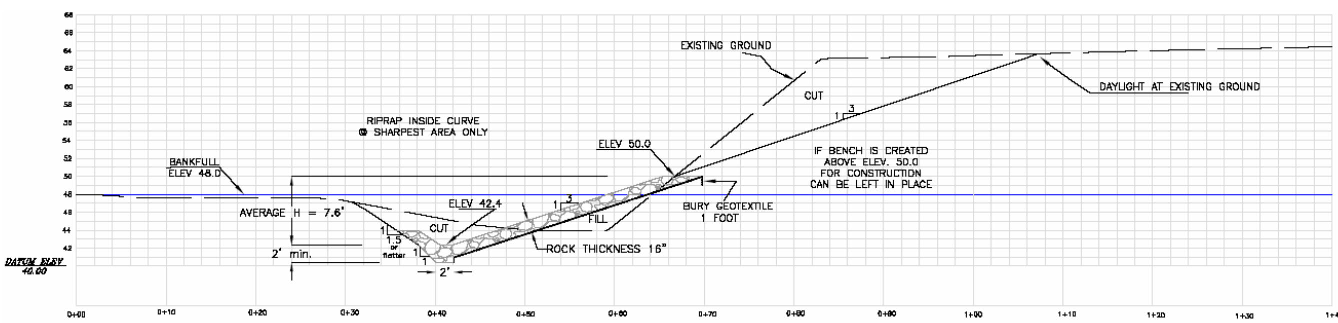

Figure 18. Stream cross-section showing proposed rock riprap and banksloping.

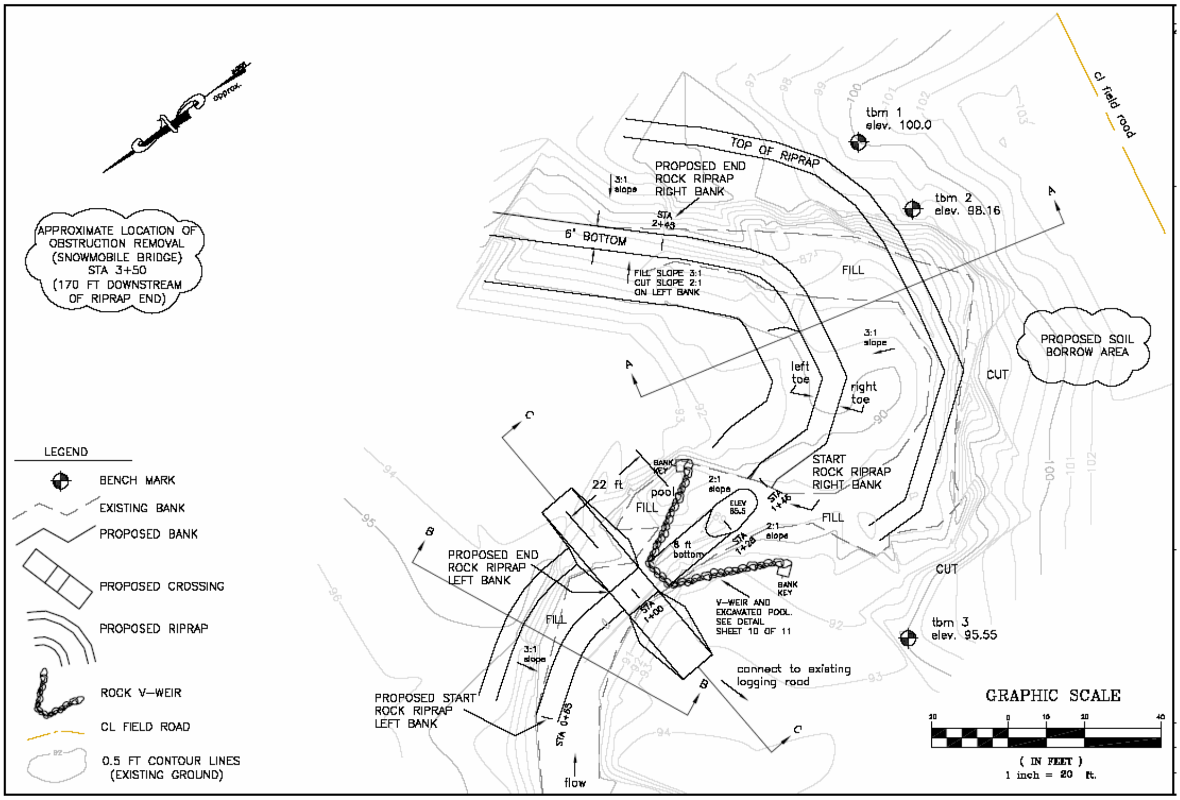

Figure 19. Plan view of proposed design for West streambank site.

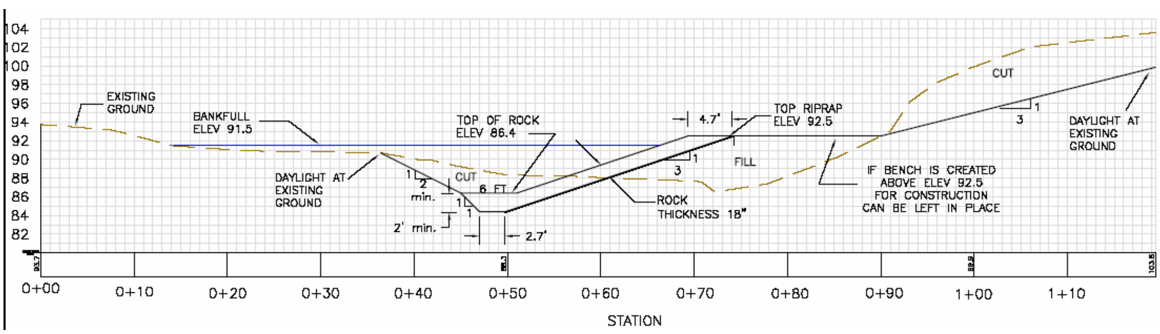

Figure 20. Stream cross-section showing proposed riprap downstream of crossing (looking downstream)

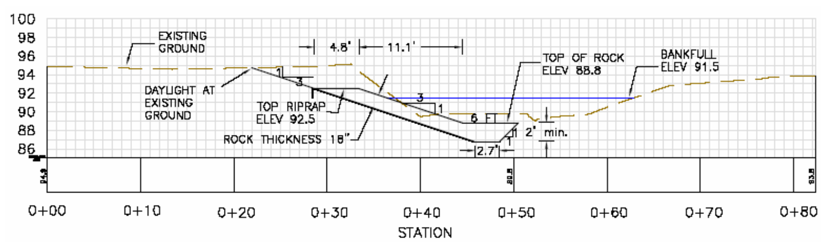

Figure 21. Stream cross-section showing proposed riprap upstream of crossing (looking downstream)

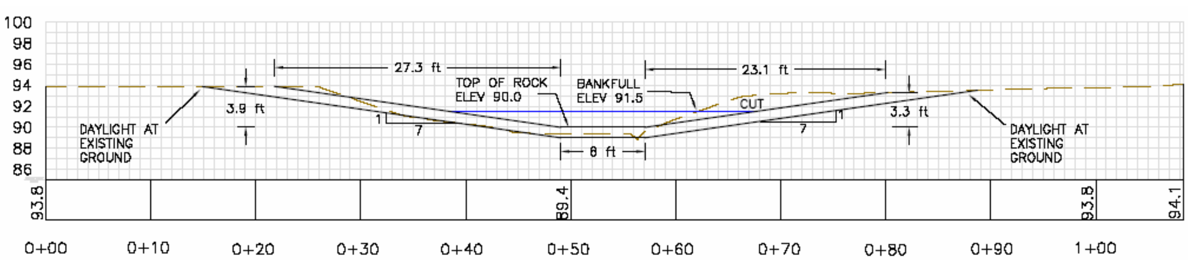

Figure 22. Stream cross-section showing proposed rock stream crossing

Construction

- The East streambank structure was designed with an 8-inch spherical D_{50} rock. The actual D_{50} used in construction was 11 inches.

- For the West streambak design, both the upstream riprap and the downstream riprap were designed with a 9-inch D_{50}. The actual D_{50} used in construction was 13 inches.

- The stream crossing was originally designed with 3.5-in. D_{50} cubical rock. DNR modified our stream crossing and rock weir designs to meet their experience with this type of structures. 3.5-in. was the actual D_{50} used in construction.

Actual total costs for construction of each project:

East streambank rock riprap $15,978.49

Item	Unit	Quantity
Clearing	Job	1
Excavation	Cu. Yd.	1770
8-in. D50 loose rock riprap	Cu. Yd.	190
Geotextile (class I non-woven)	Sq. Yd.	390
Seedbed Preparation	Job	1
Seeding	Acres	0.33

Project was completed in 4 days (approx. 43 hours) with a staff of 6 different workers.

West streambank rock riprap (including stream channel crossing and rock weir) $26,750

Item	Unit	Quantity
Obstruction Removal	Job	1
Clearing & Grubbing	Job	1
Excavation	Cu. Yd.	467
Earthfill	Cu. Yd.	475
3.5-in D50 Rock	Cu. Yd.	32.2
13-in. D50 loose rock riprap	Cu. Yd.	342.4
8-in. dia. Rock weir	Cu. Yd.	24
Geotextile (class I non-woven)	Sq. Yd.	550
Seedbed Preparation	Job	1
Seeding	Acres	1

Project was completed in 4 days.

Equipment

Figure 23. CAT 320C Backhoe

Figure 24. Deere 750C Dozer

Figure 25. Dump truck

Figure 26. CAT 950F and 544E Loaders

Materials

Figure 27. 11’’ and 13” D-50 rock riprap

Figure 28. Class I Geotextile

Figure 29. 3.5” D-50 rock

Figure 30. Earthfill from on-site borrow areas

Figure 31. looking upstream on East streambank site during construction.

Figure 32. looking downstream on East streambank site during construction

Figure 33. Soil stripping and site preparation.

Figure 34. Sloping of bank.

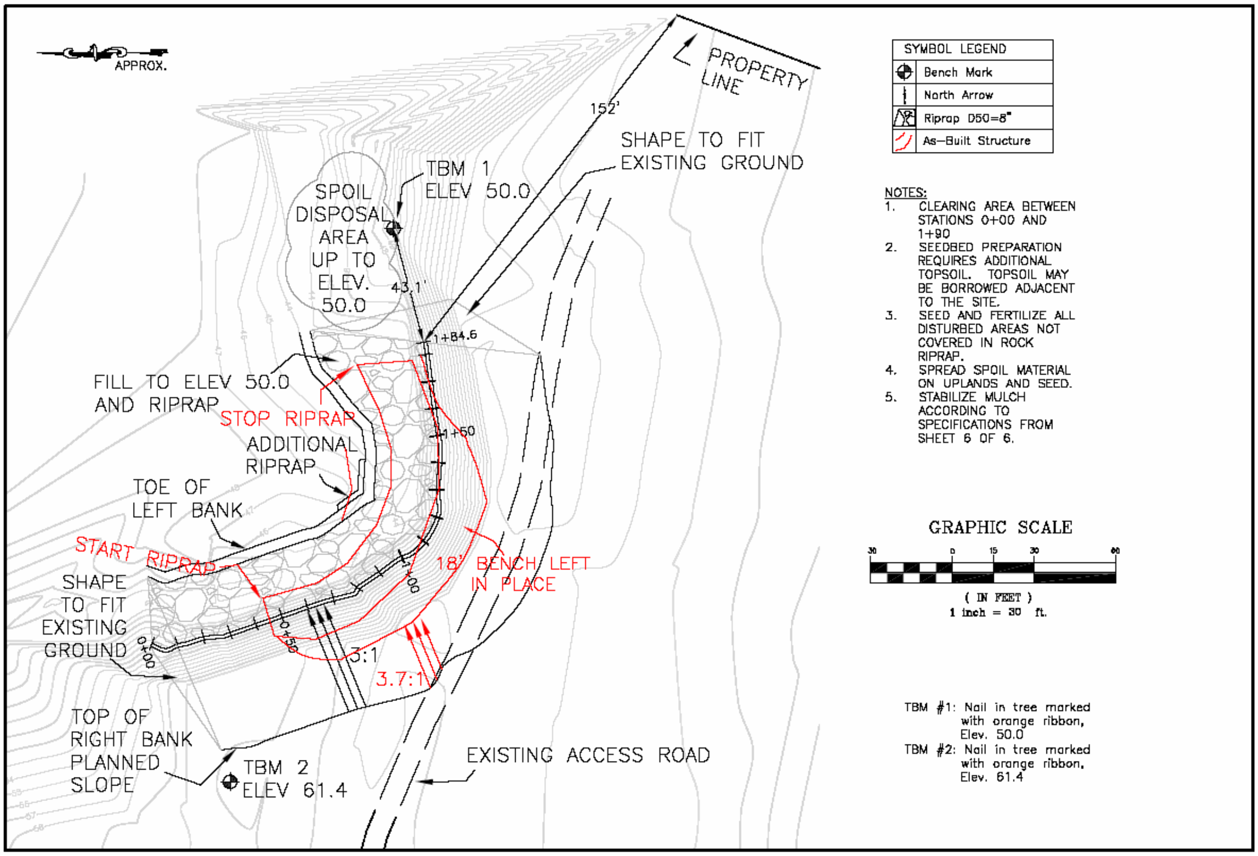

Figure 35. As-built survey of East streambank site.

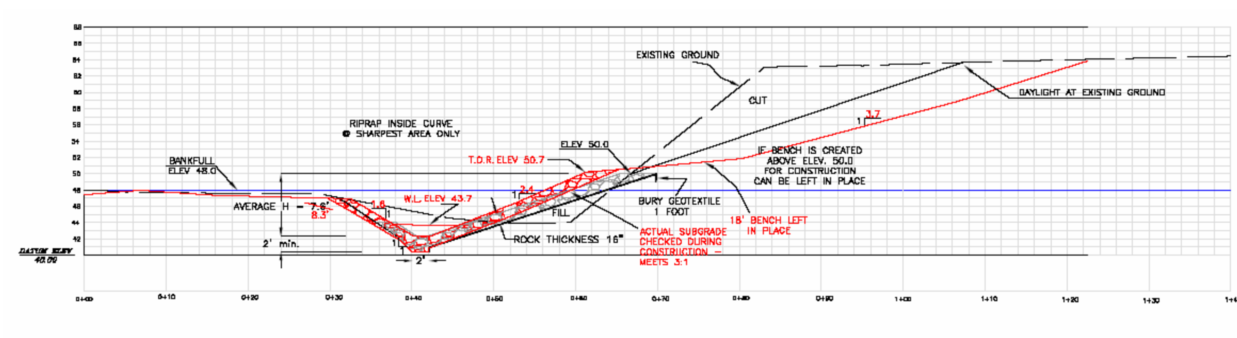

Figure 36. Stream cross-section showing as-built rock riprap and banksloping of East streambank.

West Streambank Protection
Construction pictures

Figure 37. A bench was created for construction.

Figure 38. Bank sloping of rock riprap subgrade.

Figure 39. Placement of geotextile.

Figure 40. Placement of rock riprap.

Figure 41. Cleared access to washed snowmobile bridge.

Figure 42. Bridge removal.

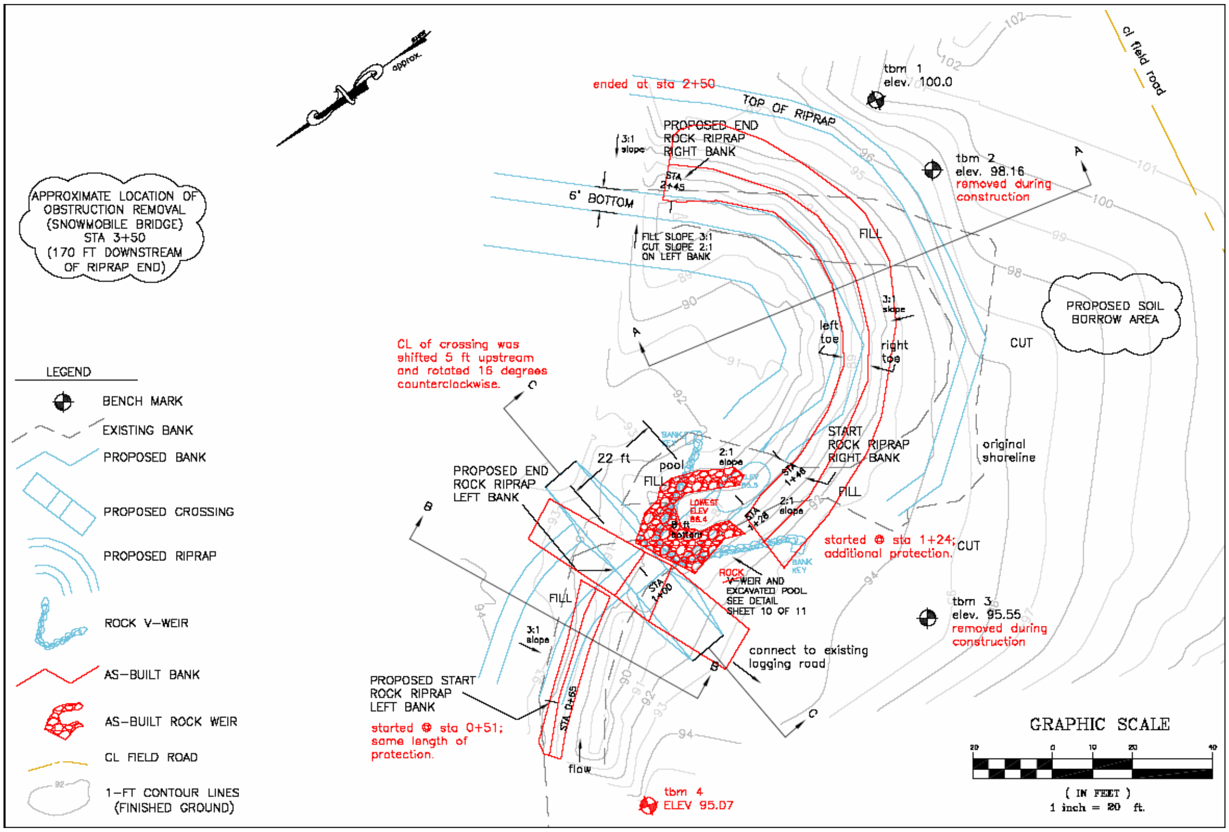

Figure 43. As-built survey of West streambank site.

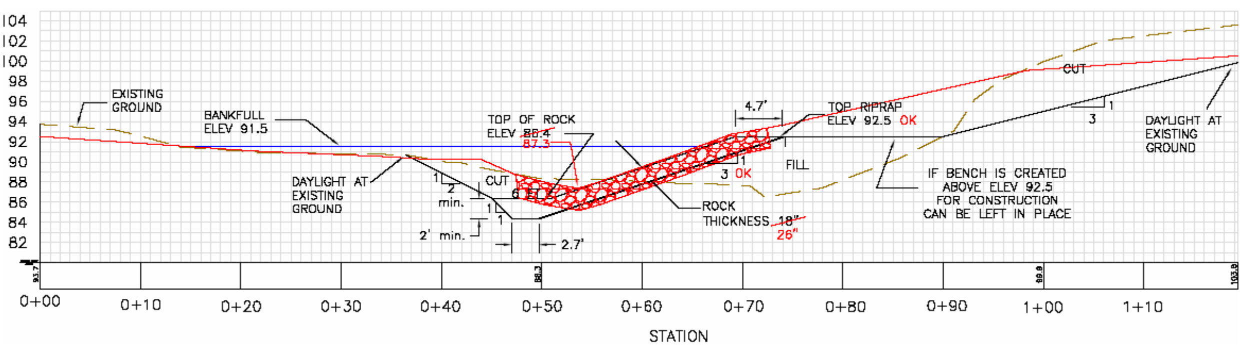

Figure 44. Stream cross-section showing as-built riprap downstream of crossing (looking downstream)

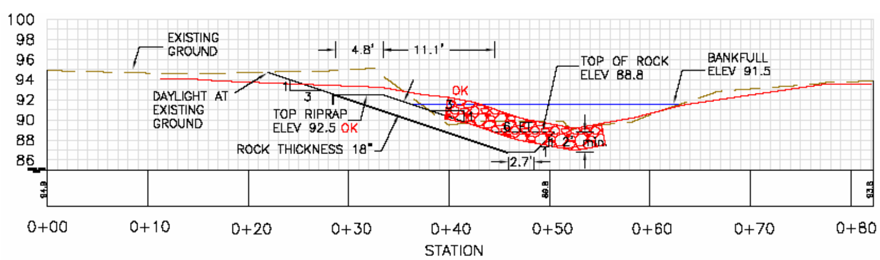

Figure 45. Stream cross-section showing as-built riprap upstream of crossing (looking downstream)

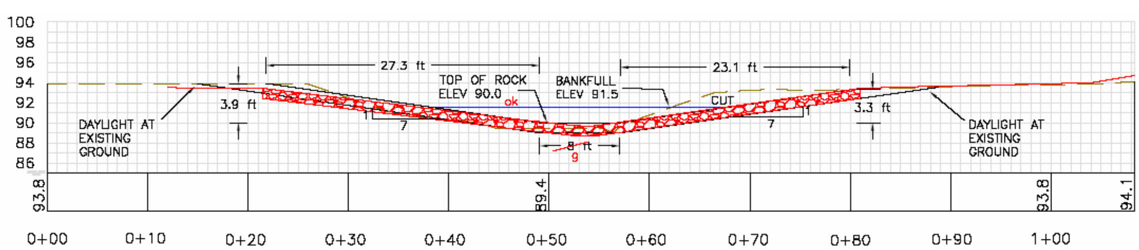

Figure 46. Stream cross-section showing as-built rock stream crossing

Figure 47. West streambank site prior to construction start.

Figure 48. West streambank site after clearing of trees.

Figure 49 West streambank site during construction.

Figure 50. West-streambank site after construction.

Pending Work

The Department of Natural Resources is yet to establish further habitat enhancement measures in addition to the practices we have already established. More streambank work will be completed this year in neighboring lands along Trout Creek downstream of our installed ripraps.

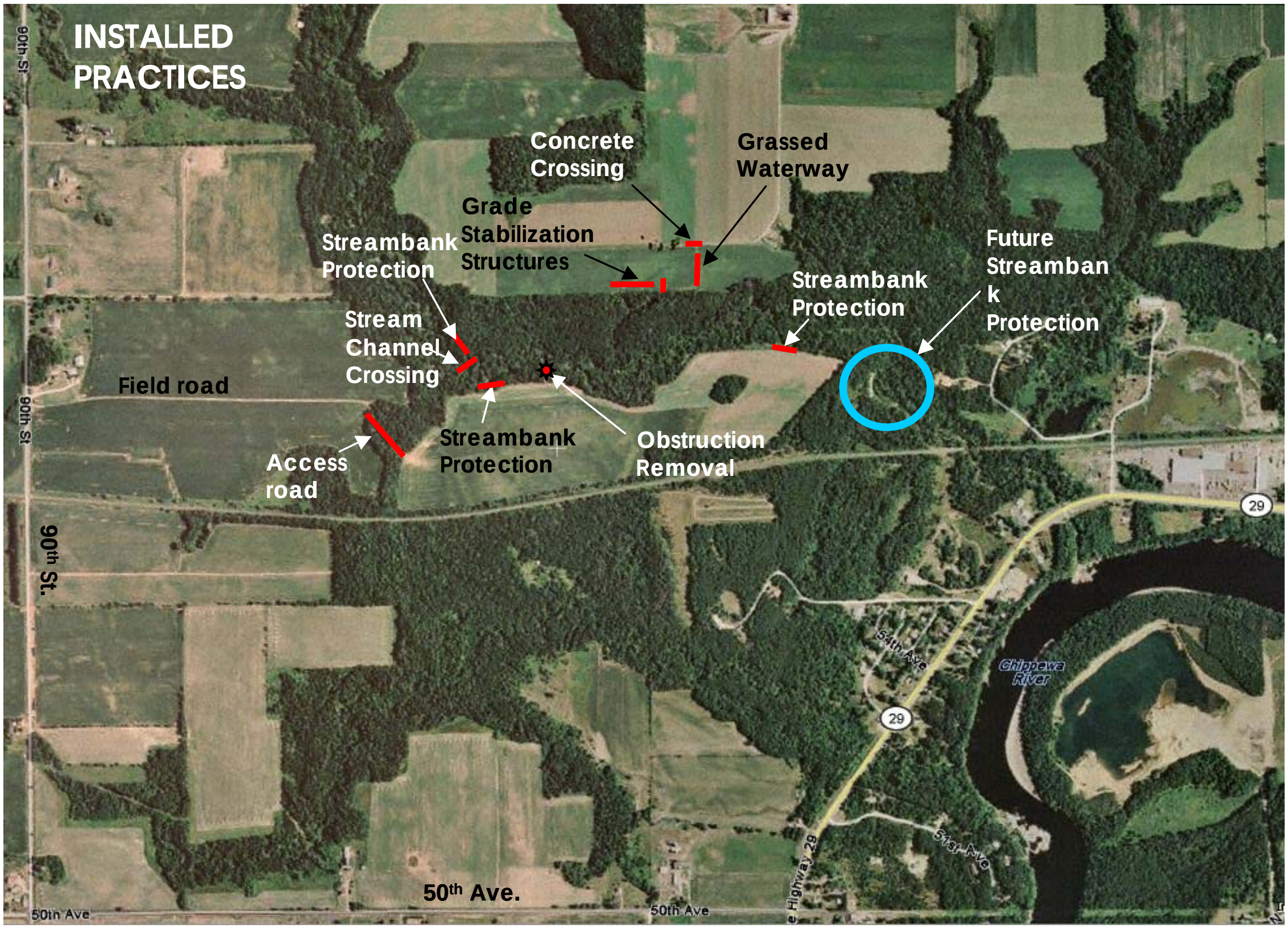

Figure 51. In the photo above, red indicates installed practices and blue indicates future restoration work along the stream.

Conclusions

There are 4,136 miles of Class 1 trout streams in Wisconsin that comprise 40% of Wisconsin's total trout stream mileage. On one such stream, human alterations, such as past straightening of channel and poor land use practices, have caused excess sand to be delivered to the stream. Excess sand is the primary cause of degradation of trout habitat in Trout Creek because it fills in deep pools and becomes a limiting factor for wintering habitat. In addition, embedded sands prevent successful trout reproduction because they smother spawning areas. Stream sinuosity (stream length/valley length) has increased from 1.3 to 1.4 over 20 years and will continue to increase in order to stabilize itself, which is why straightening or relocating a stream typically is not recommended. In extreme cases, this can be considered as an option but it shall be evaluated through a geomorphologic study to determine its feasibility in a case-to-case basis. Site visits to the Trout Creek site following construction have shown immediate improvement to the sedimentation problem in the treated areas. Further treatment should be provided on additional upstream and downstream reaches of Trout Creek in order to achieve long-term results.

Definitons[3]

Bankfull Elevation *(V.B.1.b.)* – In Wisconsin, the bankfull elevation of channels is roughly the water elevation during the 1.2-year discharge. In many channels, this is the point where water begins to flow out onto its floodplain. Note: Since floodplains may be small or inconspicuous in some stream types where floodplains are naturally indistinct or presently being developed, it is important to verify correct identification of the bankfull surface by checking it against the 1.2-year discharge. This can be done using Manning's equation, USGS Flood-Frequency Characteristics of Wisconsin Streams (formerly known as the Conger method), TR20 or TR55, or from gauge data.

Bank Zone (V.D.13.c.) – The area above the toe zone located between the average water level and the bankfull elevation or OHWM. Vegetation may be herbaceous or woody, and is characterized by flexible stems and rhizomatous root systems.

D50 (V.D.15.c.) – The size of material of which 50 percent of the material sample is smaller by weight.

Ordinary High-Water Mark (OHWM) (V.C.3.) – Ordinary high-water mark is the point on the shore up to which the presence and action of the water is so continuous as to leave a distinct mark by one of the following: erosion, destruction of terrestrial vegetation, or other easily recognized characteristics.

Soil Bioengineering (III.) – A system of living plant materials with a specified configuration installed as the primary means of soils stabilization.

Toe Zone (V.D.13.e.) – The portion of the bank that is between the average water level and the bottom of the lakebed or channel, at the toe of the bank.

Structural Treatments (III.) – A system of non-living materials with a specific configuration installed as a means of (bank or shore) stabilization including, but not limited to, riprap, tree revetments, log/rootwad/ boulder, dormant post, jacks, coir logs, bulkheads, and stream barbs.

References

[1] WDNR, Trout Stream Classifications (PUB-FH-806 2002) http://dnr.wi.gov/org/water/fhp/fish/species/trout/streamclassification.shtml.

[2] Rosgen, D. 1996. *Applied River Morphology*. Pagosa Springs, Colorado: Wildland Hydrology

[3] Field Office Technical Guide, Section IV, Code 580 – Streambank and Shoreline Protection, NRCS, WI 12/05.