Appendix A

Total Suspended Solids Data Analysis and Duration Curve Methodology

Data Sources

The data used in this total maximum daily load (TMDL) report were collected in the field by numerous government agencies, their contractors, and helpful citizens. Without the effort of the individuals in these organizations it would not be possible to conduct a rigorous water quality study to determine appropriate loadings for the Cedar River basin.

The load duration curve method described below was used to calculate the TMDL for total suspended solids (TSS). This method depends on three basic parameters: stream flow (i.e. discharge in cubic feet per second), TSS (or surrogate) measurements, and time. Measurements were correlated by date and time, rounded to the nearest fifteen minutes.

Three of the flow gauges used in this study were operated by the Minnesota DNR and daily flow data is available from the Minnesota DNR's HYDSTRA database. For the purposes of this TMDL, FTS DTS-12 turbidimeters were installed at three gauge locations and set to measure average turbidity at intervals of 15 minutes (some intervals were 10 minutes or 30 minutes) to provide a finer view of the variation of turbidity over time. To relate turbidity with flow in the duration curves, 15 minute flow measurements were also recorded. The "continuous" DTS-12 turbidimeters record data in FNU turbidity units, and were reported in the HYDSTRA database as well. Continuous flow and continuous turbidity were typically available for the study period, but datasets were reduced due to reductions in monitoring during the winter, and equipment malfunctions.

One flow gauge used in this study was operated by the USGS. Daily average flow data and 15-minute flow measurements are available through the USGS National Water Information System and the USGS Instantaneous Data Archive, respectively. Continuous flow measurements were typically available for the study period, except where winter conditions prevented accurate measurement.

HSPF modeled daily flow was available for 1996 through 2012. When measured flow was unavailable, HSPF modeled flow was used instead.

Periodic grab samples at all flow levels taken at the gauge sites were sent to the Minnesota Department of Health Laboratory in St Paul to be analyzed. Samples collected by Cedar River Watershed District (CRWD) were analyzed by Minnesota Valley Testing Laboratories in New Ulm. The two laboratory parameters used in this TMDL were TSS (mg/L) and turbidity (NTRU). This data was accessed through MPCA's EQuIS database and an electronic file from CRWD.

At each sampling event a transparency tube or Secchi tube reading was also taken and reported to MPCA's EQuIS database. These tube measurements provide a simple gauge of water clarity similar to a Secchi disc (for lakes), and therefore are a good indicator for turbidity. On some stream reaches, transparency tube measurements were the only turbidity readings taken, generally by citizen volunteers, and reported to MPCA's EQuIS database.

TSS and Surrogates

The process used to compare other data to the 65 mg/L TSS standard requires additional explanation. TSS data were aggregated with available Secchi tube measurements, transparency tube measurements (from both 60 cm and 100 cm tubes), and turbidity measurements (in FNMU, NTRU, NTU, and FNU). These are summarized in the table below.

Table A - 1

Parameter	Type	Analysis Location	Unit	QA
Total Suspended Solids	Grab	Lab	mg/L	Technician Calibration
Secchi Tube	Grab	Field	cm	None
Transparency Tube (100 cm)	Grab	Field	cm	None
Transparency Tube (60 cm)	Grab	Field	cm	None
Turbidity	Continuous	Field	FNU	Technician Calibration
Turbidity	Grab	Field	FNMU	Technician Calibration
Turbidity	Grab	Field	FNU	Technician Calibration
Turbidity	Grab	Lab	NTRU	Technician Calibration
Turbidity	Grab	Field	NTU	Technician Calibration
Turbidity	Grab	Lab	NTU	Technician Calibration

For each surrogate parameter and measurement unit, an equation was used to estimate TSS from the surrogate. MPCA equations were used where available, estimating TSS from Secchi tube cm and Secchi tube cm from transparency tube cm. The relationship between turbidity and TSS was described by a linear regression for each turbidity unit across all aggregated data sources. A summary of the regression parameters and goodness of fit (R^2) for each surrogate unit is shown in Table A-2. Each parameter unit was assigned a numeric priority based on its reliability and the strength of its relationship with TSS.

An estimated TSS result was calculated for each TSS surrogate unit. When multiple stations within a reach had results for the same parameter unit, a simple average was used to compute a composite. For non-flow parameters, negative measurements and measurements of zero were deemed unreliable and ignored. For each reach and measurement time, the remaining data were condensed to a single "TSS Measured or Estimated" result, using the result or estimate with the greatest ordinal priority (lowest Priority number; 1 = first, 2 = second, etc.), based on the strength of the relationship between TSS and turbidity, followed by the Secchi tube-TSS relationship.

Table A - 2

Estimation	Equation	Priority	R^2	Source
TSS mg/L from Turbidity NTU	TSS mg/L = 13.827 + 0.9312 * Turbidity NTU	2.1	0.9363	Barr
TSS mg/L from Turbidity NTRU	TSS mg/L = 6.7864 + 1.1278 * Turbidity NTRU	2.2	0.7658	Barr
TSS mg/L from Turbidity FNU	TSS mg/L = 7.1437 + 0.8189 * Turbidity FNU	2.3	0.746	Barr
TSS mg/L from Turbidity FNMU	TSS mg/L = 6.3095 + 0.437 * Turbidity FNMU	2.4	0.1773 †	Barr
TSS mg/L from Secchi Tube cm	TSS mg/L = $(205.09/\text{Secchi Tube cm})^{1/0.654}$	3	0.8362	MPCA
Secchi Tube cm from Transparency Tube (100) cm	Secchi Tube cm = -2.155 + 1.097 * Ttube100 cm	4		MPCA
Secchi Tube cm from Transparency Tube (60) cm	Secchi Tube cm = 0.689 + 1.135 * TTube60 cm	5		MPCA

† The turbidity (FNMU) dataset available correlated poorly with TSS. The raw data was included in the tables, but no TSS estimations based on the FNMU equation shown above were used in the analysis.

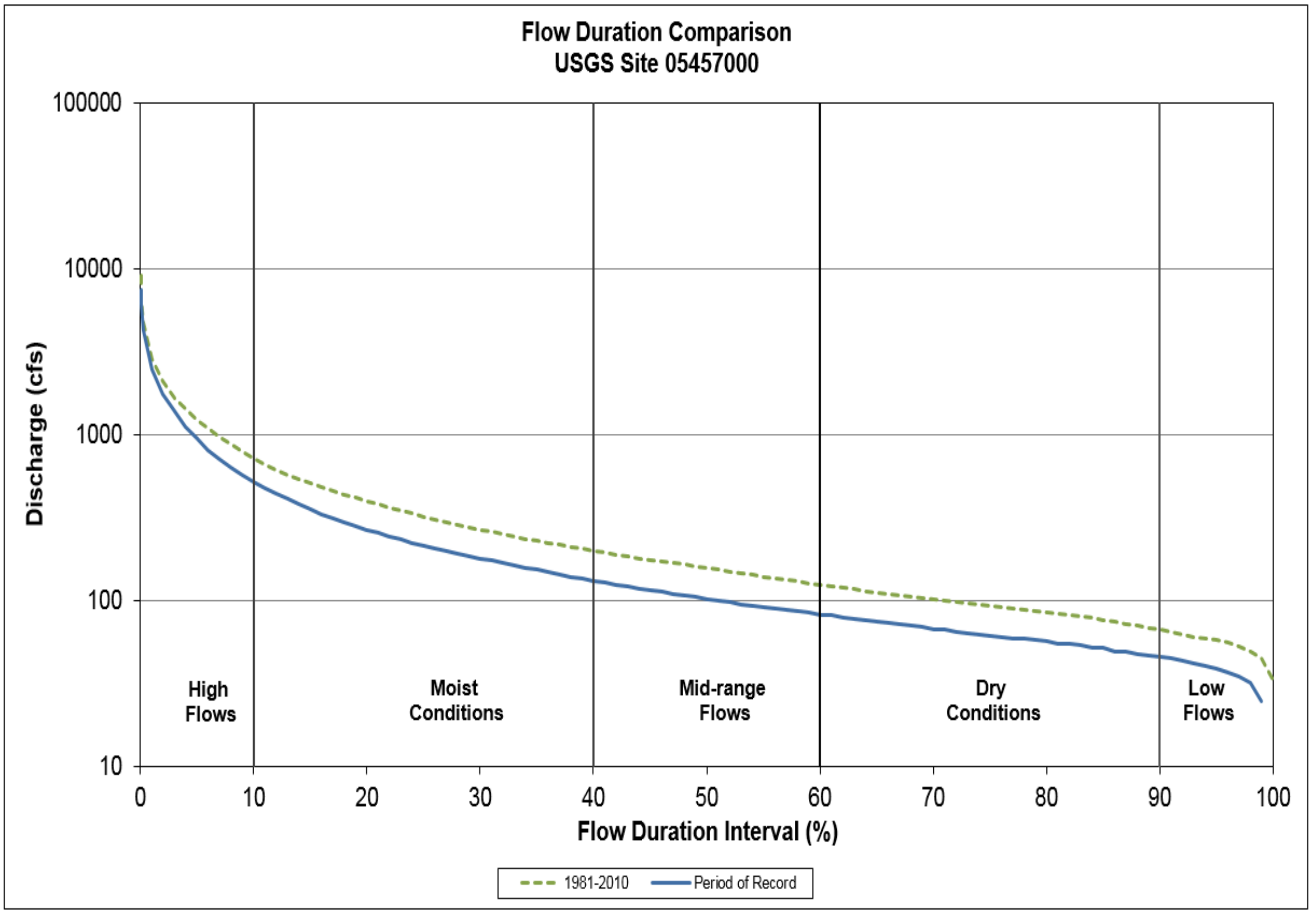
Methodology for TMDL Equations and Load Duration Curves

The loading capacity determination used for this report is based on the process developed for the "Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota" (MPCA, 2006). This process is known as the "Duration Curve" method and is further discussed in MPCA (2009) and Cleland (2003).

The load duration curve approach relies on having a flow record that reasonably represents the range of conditions that would be expected. This is typically accomplished by using a long-term flow record, but for some reaches of this TMDL a long-term record was not available. When examining the flow duration curves for the recent period vs. the long-term record (1909-2010) at the USGS gage 05457000 downstream of Austin, it appears that discharge has increased in every flow regime from low flows to high flows (see Figure A-1, below). This is likely the result of land use/land cover change, hydrologic alteration and climatic changes.

Loading capacities for specific pollutants are related directly to flow volume. As flows increase, the loading capacity of the stream will also increase. Thus, it is necessary to determine loading capacities across the range of flow. To illustrate portions of the flow record it is useful to divide up the record into "flow zones."

Figure A - 1



For this approach, daily flow values for each site are sorted by flow volume, from highest to lowest and a percentile scale is then created (where a flow at the X^{th} percentile means X% of all measured flows equal or exceed that flow). Five flow zones are illustrated in this approach: "very high" (0-10^{th} percentile), "high" (10^{th}- 40^{th} percentile), "mid-range" (40^{th}-60^{th} percentile), "low" (60^{th}-90^{th} percentile) and "very low" (90^{th}-100^{th} percentile). The flows at the mid-points of each of these zones (i.e., 5^{th}, 25^{th}, 50^{th}, 75^{th} and 95^{th} percentiles) can then be multiplied by the water quality standard concentration and a conversion factor to yield the allowable loading capacity or TMDL at those points. Load duration curves shown in the report display the allowable load across the range of flows in the timeframe selected.

For example, applying the 65mg/L TSS standard to the flow zone example above, the TMDL for TSS would be:

100 cubic feet/sec x 65 mg/L TSS x 28.31 L/cubic ft x 86,400 s/day ÷ 907,184,740 mg/ton

= 17.5 tons TSS/day

TMDLs were calculated for all the flow zones for each listed reach of the project. The TMDLs were then divided into a Margin of Safety (MOS), Wasteload Allocations (WLAs) and a Load Allocation (LA).

For this TMDL an explicit ten percent MOS was used. The next step in the process was determining the WLAs for point sources with specific discharge limits.

The permitted wastewater and water treatment facility WLAs were determined based on their permitted discharge design flow rates and their permitted TSS concentration limits or their permitted daily loading rates, whichever were higher. Example calculations for the WLA for a wastewater treatment facility discharging 3,000,000 gallons of effluent per day with a 45 mg/L TSS concentration limit are as follows:

$$3{,}000{,}000 \text{ gallons/day} \times 45 \text{ mg/L TSS} \times 3.785 \text{ L/gallon} \div 907{,}184{,}740 \text{ mg/ton}$$

$$= 0.56 \text{ tons TSS/day}$$

The WLA for a given wastewater treatment facility will be the same under all flow zones since its allocation is based on the volume it is permitted to discharge.

The WLAs for these dischargers with specific discharge limits and the MOS were subtracted from the total available loading capacity. The remaining capacity was then divided up based on land area between the nonpoint sources, i.e., the LA category, and communities subject to Stormwater MS4 permit requirements. For example, if 5% of the watershed is covered by communities subject to MS4 permit requirements, then 5% of the available loading capacity is assigned to those communities and 95% is assigned to the LA. (For TSS, permitted construction stormwater and industrial stormwater were also provided WLAs based on an estimated land area covered (0.05 %)).

E. coli bacteria data analysis and duration curve methodology

General Information on bacteria in surface waters

Appropriate for the general audience is the MPCA's 2008 fact sheet entitled *"Bacteria: Sources, Types, and Impact on Water Quality – A General Overview."* https://www.pca.state.mn.us/sites/default/files/wq-iw3-20.pdf
This fact sheet provides basic information on indicator groups, sources and pathways of bacterial contamination, and WQS. Of note is a good reference list of additional information sources, appropriate for anyone interested in bacterial water quality issues.

The Minnesota Department of Health (MDH) also provides pertinent background information on recreational water illnesses, including causes, symptoms, reporting and prevention.
http://www.health.state.mn.us/divs/idepc/dtopics/waterborne/waterborne.html

Data sources

Surface water sample collection with subsequent laboratory analysis for indicator bacteria has been conducted for many decades in Minnesota. For the Cedar River 1.5 miles south of Austin (Station ID S000-001), water sample collection began around 1952.

Sample collections have been conducted by state of Minnesota personnel, and by local government (city, county) staff. Sampling protocols at the field scale include many factors, including sample location, bottle type, collection method, sample holding times and transportation. Representative stream samples are collected from flowing waters, directly into a sample bottle. Protocols used by the MPCA staff call for the collection of a 125 mL grab sample, and cooling the sample to 4 degrees C. While the strict holding time is eight hours before culturing the sample at a laboratory, the current procedure is to allow data to be used in a qualified manner, for samples held in the 8 to 30 hour range. Data resulting from samples that are held for times exceeding 30 hours are not used. For more information, see the MPCA's Standard Operating Procedures for stream water quality (MPCA 2017). Water quality sampling procedures used in the CRW, are frequently similar to those included in the watershed pollutant load monitoring network program (MPCA 2015).

Laboratory analyses and methods have varied over time, and include Standard Method 9221 E and D, for fecal coliform bacteria, and Standard Method 9223B for *E. coli* bacteria. FMI see the Minnesota Department of Health Environmental Laboratory handbook. (http://www.health.state.mn.us/divs/phl/environmental/handbook.pdf).

This TMDL uses available water quality data, supplementary information, and references some investigative studies – as noted in the TMDL guidance for bacteria (MPCA 2009). Detailed source identification and transport studies were not included in this project. The general approach that was employed for this TMDL can support implementation efforts, and anticipated future work will provide adjustments and refinements.

E. coli and fecal coliform

The fecal coliform stream WQS was used in Minnesota until 2008, when it was replaced with the *E. coli* WQS.

To convert fecal coliform data to *E. coli* concentration equivalents, the following equation was used:

$$E.\ coli \text{ concentration (equivalents)} = 1.80 \times (\text{Fecal Coliform Concentration})^{0.81}$$

For this TMDL, indicator bacteria data have been used in three main ways. First, data from a longer timeframe (2000 through 2016) were used to assess the monthly geometric means. This was feasible only for the months of June, July and August, when a greater number of samples had been collected and analyzed. The minimum threshold of samples was five, which is consistent with the geometric mean WQS, which requires five samples in a calendar month. There were 7 occasions, between the three months and the 14 AUIDS, when only 5 samples were available. Most site/month combinations had about 10 to 15 samples for this analysis.

The second way the data were used was to compare to the maximum WQS of 1260 cfu/100 ml. This analysis was abstracted from the Cedar River Watershed Monitoring and Assessment Report (MPCA 2012).

The third way the data were used was for development of the bacteria LDCs and allocation tables, which is described further in the next section.

Methodology for TMDL Equations, WLA, LA, and load duration curves

Daily *E. coli* loading capacities and allocations were developed using the load duration curve process, with completed tables for each AUID saved to an Excel spreadsheet (data spreadsheets and allocation summary spreadsheets available from the MPCA upon request).

Bacterial loads from the Austin MS4 area were estimated based on the percent of the MS4 area within the contributing watershed for a given AUID, and these data are provided in Table 3-10.

Since construction stormwater is not considered an important source of bacteria, there is no bacterial WLA for CSW (MPCA 2009).

The wasteload allocation for each AUID was the point source daily discharge (mgd) multiplied by the permit limit for fecal coliform (200 cfu/100 ml), and converted to *E. coli* equivalents using the formula included above. For non-continuous discharge NPDES-permitted facilities (i.e. stabilization ponds), flow volumes and discharge periods were calculated in both spring and fall, based upon a maximum drawdown of 6 inches/day. Permits for all wastewater treatment facilities are using fecal coliform for permit limits, thus requiring the conversion to *E.coli* equivalent values (i.e. to match the in-stream WQS, which is *E. coli*).

Straight-pipe septic systems are illegal and un-permitted. They were assigned a WLA of zero. This means that straight-pipe septic systems must be eliminated, through the ongoing work by government and private sector implementation measures.

Livestock facilities that have been issued a NPDES Permit are also assigned a WLA of zero. A permit condition allows no pollutant discharge from the livestock housing facility and associated site. The discharge of bacteria from fields with manure application is part of the load allocation.

The load allocation (LA) in this TMDL includes the nonpoint sources not subject to NPDES Permit requirements, as well as natural background sources. The nonpoint sources included runoff from small cities (i.e. non-MS4 urbanized areas), runoff from agricultural land uses (non-NPDES sites), and under-performing/failing SSTS (but not straight-pipes). Natural background sources include bacteria generated by wildlife (ex. deer, birds), and bacteria that enter a stream by normal hydrologic processes. Because there was no specific source tracking work done for this TMDL, there are no breakdowns for the natural background component of the LA.

References

MPCA, 2009. TMDL Training Modules. Session 9, Analyze water quality data to characterize the watershed and pollutant sources. https://www.pca.state.mn.us/sites/default/files/wq-iw3-50-9.pdf

Cleland, Bruce, TMDL Development From the "Bottom Up" –Part III: Duration Curves and Wet Weather Assessments, America's Clean Water Foundation, 2003, Washington, DC, pp. 1-12.

MPCA 2009. Bacteria TMDL protocols and submittal requirements. Prepared by the Bacteria TMDL Protocol Team in 2007, and revised in March 2009. https://www.pca.state.mn.us/sites/default/files/wq-iw1-08.pdf

MPCA 2015. Watershed pollutant load monitoring network (WPLMN) standard operating procedures and guidance (surface water quality sampling). August 2015 by WPLMN staff.

MPCA 2017. Standard operating procedures – Intensive watershed monitoring, stream water quality component. Authors of the update: Pam Anderson, Kelly O-Hara, Lindsay Egge, and Lee Engel (wq-s1-18).

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Introduction

Rivers, in many cases are in the process of adjusting to current and past events in their watersheds. River stability can be defined as a river's ability to transport the water and sediment supplied by its watershed while maintaining its dimension, pattern, and profile without either aggrading or degrading (Rosgen 1996). An understanding of whether or not a river is stable or unstable and whether or not it is evolving toward stability or instability is necessary to protect or restore stream and watershed health.

Understanding these evolutionary trends and current state, is critical to understanding ties to water quality, biological function, geomorphology, hydrology, and connectivity. For example, a stream evolving from a stable stream type C[1] to an unstable type F will typically see a negative aquatic habitat response. Variables like instream and overhead cover, substrate composition, pool quality, holding cover velocity, temperature, oxygen, macro invertebrates, spawning habitat, habitat diversity, rearing, and IBI scores would all be expected to degrade with a stream type C to F evolution. Whereas, an evolution or restoration from an unstable stream type F to a stable stream type C would result in a reversal of those negative consequences.

River studies often include assessments of parameters suspected of causing impairments. For example, altered hydrology and vegetation in the watershed can be examined directly by studying flow and precipitation records and land use changes, or indirectly, by analyzing changes in channel morphology that result from increased flows or changes in vegetation. Increased frequency and magnitude of high flow events can have adverse and cascading effects. An increase in flows can be caused by changes in vegetative cover, increased agriculture or urban drainage, increased precipitation, or combinations of these. Channel forming flows are the product of the magnitude and frequency of flow events. With increases in high flow events stream channel dimensions oft stream bed degradation are an incised condition that requires a larger magnitude flood to overtop the banks. Incised streams have higher banks that are often associated with increased bank erosion. Consequences of wider streams may be a decreased ability to scour the stream bed and transport sediment and an increase in sediment contribution from stream banks. Healthy riparian vegetation is critical for stabilizing stream banks and reducing bank erosion. Loss of stream vegetative buffers result in a greatly increased potential for stream bank erosion. Even small adjustments in stream morphology away from a stable state can have substantial effects on water quality, biology, and natural function. Also, once disturbed, it can take decades for streams to adjust from an unstable state to a stable state if left alone.

Solutions to these problems may be as simple as installing grade control riffles or stream buffers. However, solutions may be more involved and require slowing runoff and sediment supply from the watershed. Returning streams to a pristine condition is often not possible so a more realistic goal may be to restore natural function, water quality, stability, and biological health. But this goal can only be accomplished with a thorough understanding of the current and evolutionary state and recovery potential of the river.

Study Area – insert map of watershed, recon, and geo stations -
The Cedar River watershed has an area of 7,815 square miles with 586 square miles located in southern Minnesota. The Cedar River is located in the Mississippi River Basin. The Cedar River valley is a gentle sloping u-shaped type VIII glacial valley (Rosgen 1996) . The Cedar River channel can be characterized as having little slope with most less than 0.1%, supporting moderate sinuosity and a higher width to depth ratio than we would expect in C4 to C5 stream types (see Rosgen 1996 for description of stream classification). The stream consists of consolidated and unconsolidated, heterogeneous, non-cohesive, alluvial material which varied from clays, slits, loam, sands, gravel, cobble and occasional random boulders. In areas of unconsolidated bank material the stream banks are susceptible to accelerated stream bank erosion with lateral migration primarily limited through riparian vegetation. Disturbance of the riparian vegetation on this stream type will increase bank erosion and lateral migration rates.

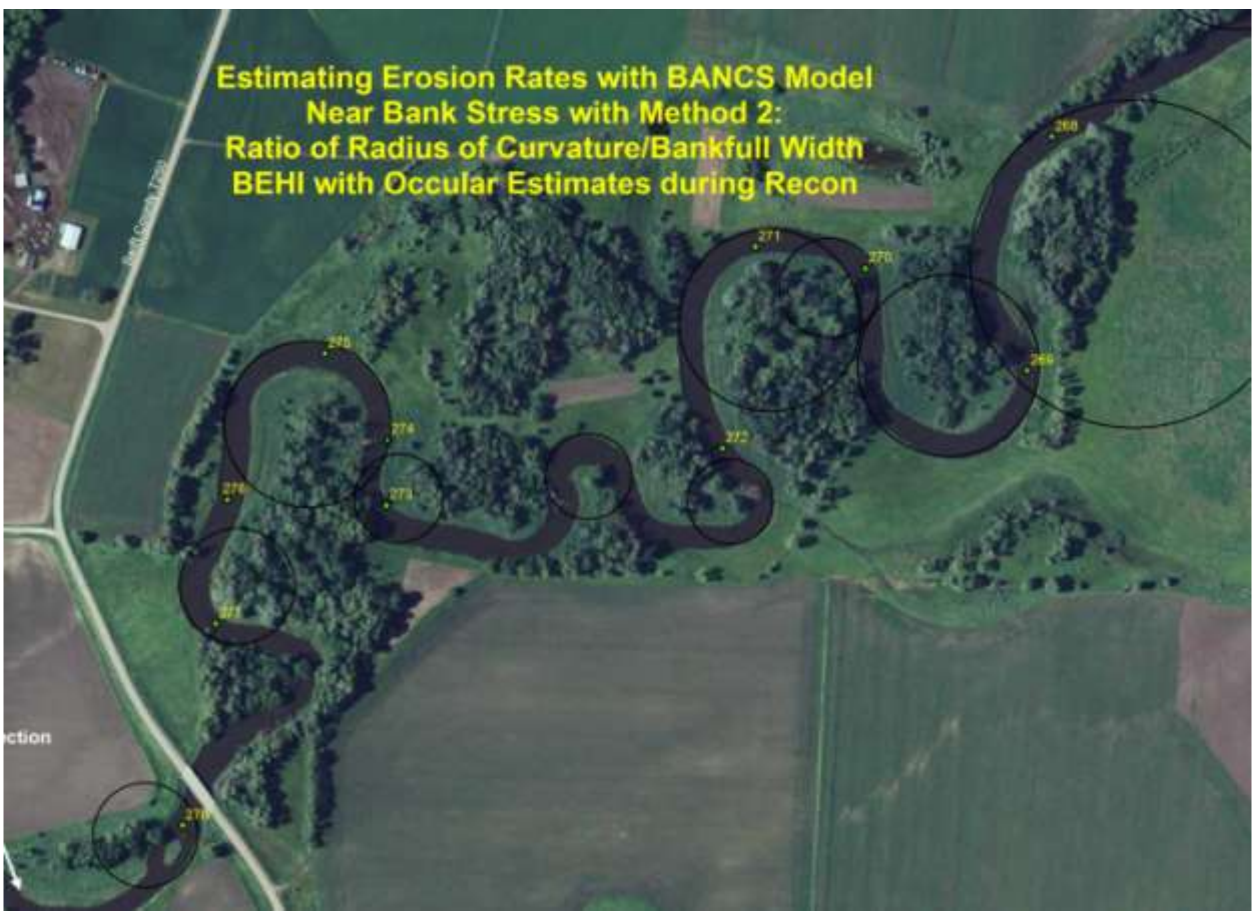
The riparian corridor along the Cedar River consist of reed canary grass, short-tall grass prairie, sedges, cattail and moderate to dense woody vegetation in the mid and upper reaches transitioning to predominate forested floodplain corridor. Woody vegetation is a varied mix of cottonwood, willow, alder, silver maple and box elder. Due to geological factors stream stability for the Cedar River is strongly tied to maintaining a healthy vegetated corridor with an intact floodplain.

The general stream classification of the Cedar River is a C4c-. This classification is characterized by low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains. Tributaries, like Upper Rose Creek, are predominantly stream class E4 channels characterized by low gradient, meandering riffle/pool stream channels with low width to depth ratios and little deposition. E streams usually have a high meander width ratio. Other Stream like Lower Turtle Creek, Blooming Prairie Creek and Roberts Creek are B5c channels. These streams are moderately entrenched channels with gradients < .02%, relatively narrow channels, low sinuosity and relatively stable channels where moderately dense riparian vegetation exist.

Methodology
Geomorphic studies were completed on the Cedar River during the 2009 and 2010 field seasons. The purpose of these studies was to collect baseline data on the dimension, pattern, and profile of the river and its tributaries, to assess river stability and sediment supply, to relate the findings to water quality and biological impairments, and to suggest potential restoration activities in the locations where they would be most effective.

Four reaches of the Cedar River were assessed by MPCA and DNR, staff from kayaks on four dates during the spring of 2010. Locations and dates for these reconnaissance assessments are shown in figure x (**watershed map with recon and goemorph stations and dates**) These assessments roughly covered the area between Blooming Prairie and just north of the Iowa boarder. The goals of the recon surveys included collecting data on stream condition, including stream classification, bank erosion potential, stream habitat condition, riparian condition, indices of stream stability, identification of representative areas for collection of additional data, and identification of potential problem and restoration areas.

The procedure for estimating bank erosion rates and total erosion during the reconnaissance portion of our investigation was a modified version of the "Bank Assessment for Non-point source Consequences of Sediment" (BANCS) model (Rosgen, 1996, 2001b, 2006b). This empirical model uses the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) erosion estimation tools. Visual estimates of the BEHI were made as we traveled downstream for stream banks where erosional processes were observed. Waypoints and photographs were collected along with bank height and length measurements using laser range finders and waypoint information. NBS was estimated through analysis of aerial photos using method 2 in the River Stability Field Guide. This method uses the ratio of the radius of curvature of the meanders to the bankfull width of the channel. This method is a measure of the tightness of the bends in the river and the degree of boundary shear stress acting on those banks. The annual streambank erosion rate can then be estimated using the BEHI and NBS ratings, and known erosion rates using those relationships. We used known erosion rates from North Carolina, Colorado, and Yellowstone National Park data to provide a range of possible erosion rates for our study. As we validate more of these erosion rates with bank studies we will develop local erosion rate relationships with BEHI and NBS estimates, which will greatly strengthen our estimates.

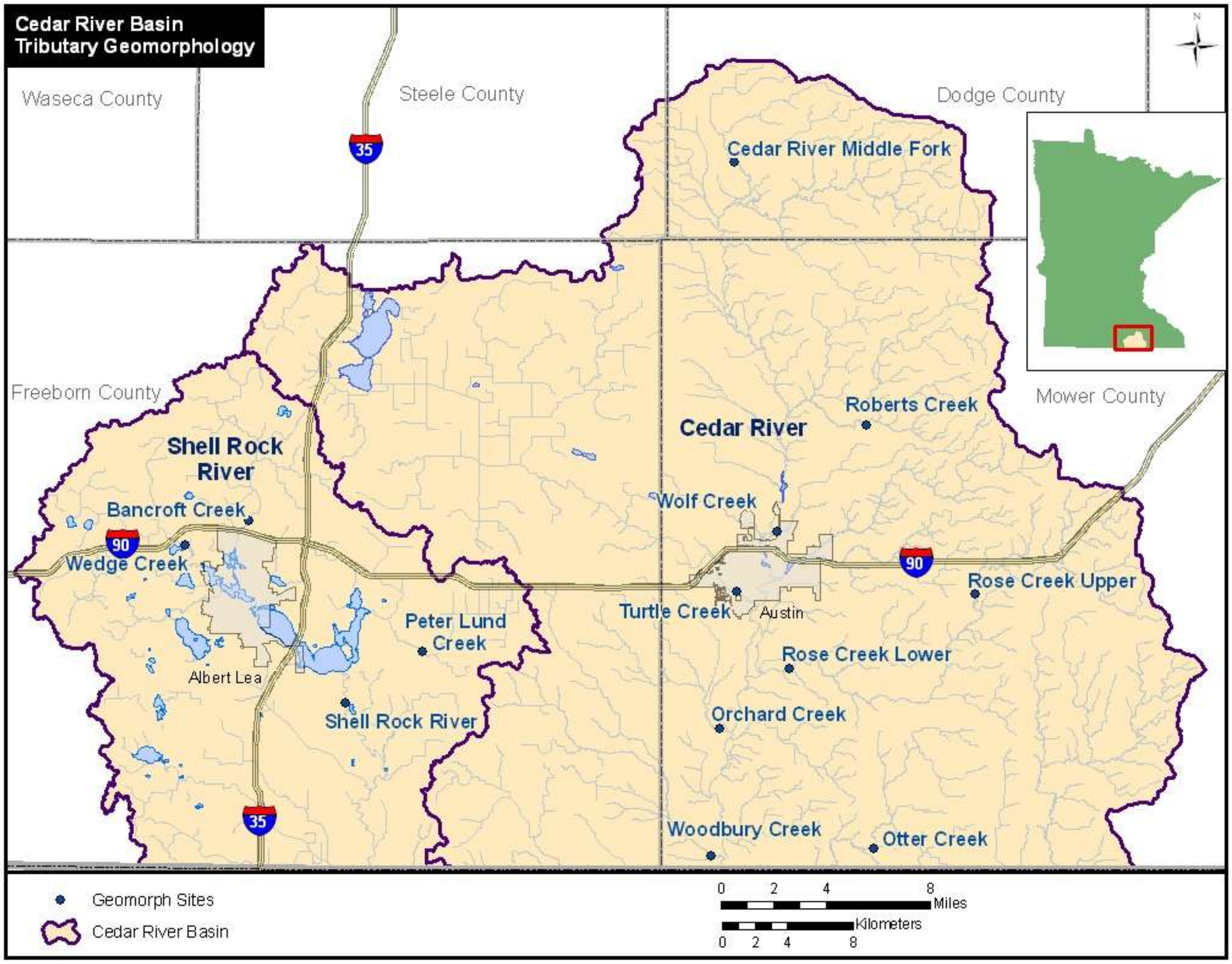


Other reconnaissance tasks included; 1) determining bankfull indicators and relative bankfull elevation, 2) estimating the degree of channel incision by comparing bankfull elevation with low bank elevation, and 3) determining stream classification to describe the reach.
– stability indicies – channel dimensions – stream classification – scoping for more intensive stations and identifying possible problem areas.

Stream reaches were subjected to more intensive geomorphic assessments at 16 locations on the Cedar River and associated tributaries. These assessments followed the procedures outlined in the "River Stability Field Guide" (Rosgen 2008) levels I-IV. Level I assessment procedures were completed during field reconnaissance including broad level stream classification and valley classification. Level II tasks included cross sections, longitudinal profiles, pebble counts, hydraulic relations, level II stream classification, morphological descriptions, and dimensionless ratios. Level III procedures included the prediction of annual streambank erosion rates using the BANCS empirical model (uses the Bank Erosion Hazard Index and Near Bank Stress). Level IV procedures included the validation of streambank erosion rates by setting up study banks with bank and bed pins and measuring actual annual erosion rates to start to develop local bank erosion relationships.

Talk about this being one of the earliest efforts – made some mistakes – recommend some changes to future studies – or in discussion

Results and Discussion
In progress.



Cedar River Basin Study Reaches for 2009-2010

Site	UTM	Description
Station 1	499842, 4816332	IA/MN border, Mower county road 105
Station 2	499659, 4822756	Mower county road 5, upstream from private campground
Station 3	501259, 4828032	Mower county road 4, west of Varco
Station 4	502496, 4834334	Downstream of Austin Mill Pond
Station 7	502231, 4848647	Mower county road 25
Station 8	499763, 4852036	Mower county road 1, one mile east of Hwy 218, Brookside Campground
Station 11	505284, 4858300	740th Street culvert, at gravel pit, may require walking downstream
Station 12	508573, 4858280	740th Street culvert , east of Station 11
Dobbins Creek	505099, 4836028	Hormel Nature Center
Upper Rose Creek	515206, 4833576	Stream assessment site
Lower Rose Creek	503822, 4829025	Stream assessment site
Lower Turtle Creek	500447, 4833771	Stream Assessment reach

Bancroft Creek	470608, 4838143	Stream assessment reach
Blooming Prairie Creek	488908, 4852260	Stream assessment site
Roberts Creek	508538, 4844009	Stream assessment site
Cedar River Middle Fork	500446, 4833771	Stream assessment site
150th Street – CR 2	504343, 4858086	Stream bank study reach 2.5 miles
Cr 2 – Cr 1	499485, 4856664	Stream bank study reach 4.1 miles
540th Av- Mill Pond	502216, 4848620	Stream bank study reach 8.6 miles
Cr 23 to 140th St	501585, 4832969	Stream bank study reach 9.3 miles
Turtle Creek	491998, 4839221	Stream bank study Moscow to CR 23 in Austin, 9.5 miles

Station (Reach)	Rosgen Stream Classification	Field Stage Estimates for 1.5 year event	USGS Stage Estimates for 1.5 year event	Drainage Area mi 2
1	C5c-	3521	1800	586
2	C4c-	3319	1600	523
3	C4/1	3125	1480	475
4	C4/1	1848	1000	243
7	C5c-	1147	802	160
8	C5c-	435	629	113
11	C5c-	274	254	25
12	C5c-	206	249	20
Dobbins Creek	C4	220	220	19
Upper Rose Creek	E4	465	305	26
Lower Rose Ck	C4	674	526	65
Lower Turtle Creek	B4/1c	776	460	152
Bancroft Creek	C5c-	285	249	29
Blooming Prairie	B5c	157	106	8.6
Roberts Creek	B5c	500	300	25
Cedar Mid Fork	C5c-	224	200	19

Station (Reach)	Recovery Potential	Sensitivity to Disturbance	Veg Controlling Influence	Supported (successful) Structures for this Stream Type
1	fair	Very High	Very High	Cross Vanes, W weir, Root Wads, J-Hook
2	good	Very High	Very High	Cross Vanes, Root Wads,

				J-Hook
3	good	Very High	Very High	Cross Vanes, Root Wads, J-Hook
4	good	Very High	Very High	Cross Vanes, Root Wads, J-Hook
7	fair	Very High	Very High	Cross Vanes, Root Wads, J-Hook
8	fair	Very High	Very High	Cross Vanes, V weir, Root Wads, J-Hook
11	fair	Very High	Very High	Cross Vanes, V weir, Root Wads, J-Hook
12	fair	Very High	Very High	Cross Vanes, V weir, Root Wads, J-Hook
Dobbins Creek	good	Very high	Very High	Cross Vanes, Root Wads, J-Hook
Upper Rose Creek	good	Very High	Very High	Cross Vanes, Root Wads, J-Hook
Lower Rose Creek	good	Very High	Very High	Cross Vanes, V- weir, Root Wads, J-Hook
Lower Turtle Creek	excellent	moderate	moderate	Cross Vanes, V weir, Root Wads, J-Hook
Bancroft Creek	fair	Very High	Very High	Cross Vanes, V weir, Root Root Wads, J-Hook, Cross vanes
Blooming Prairie Creek	excellent	moderate	moderate	Root Wads, J-Hooks, Rock Vanes
Roberts Creek	excellent	moderate	moderate	Root Wads, J-Hooks, Rock Vanes
Cedar Mid Fork	fair	Very High	Very High	Cross Vanes, V- weir, Root Wads, J-Hook

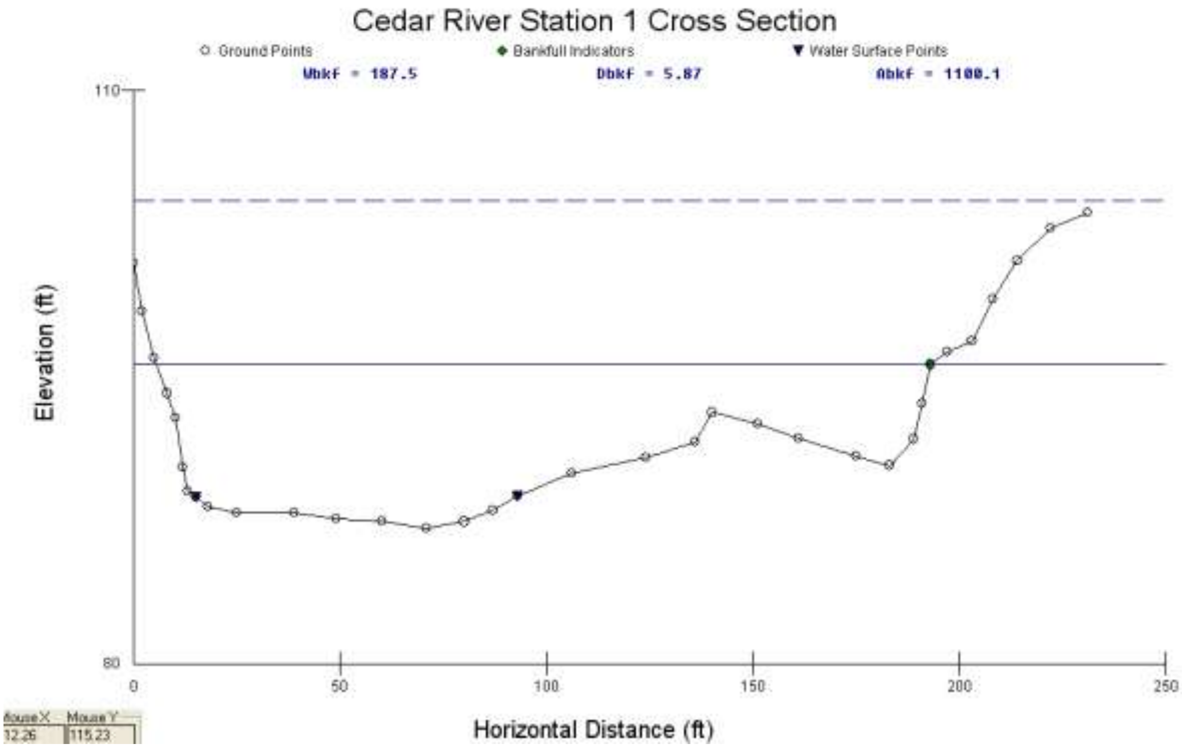


Figure 1. Riffle Cross Section at Station 1 upstream of CR 105.

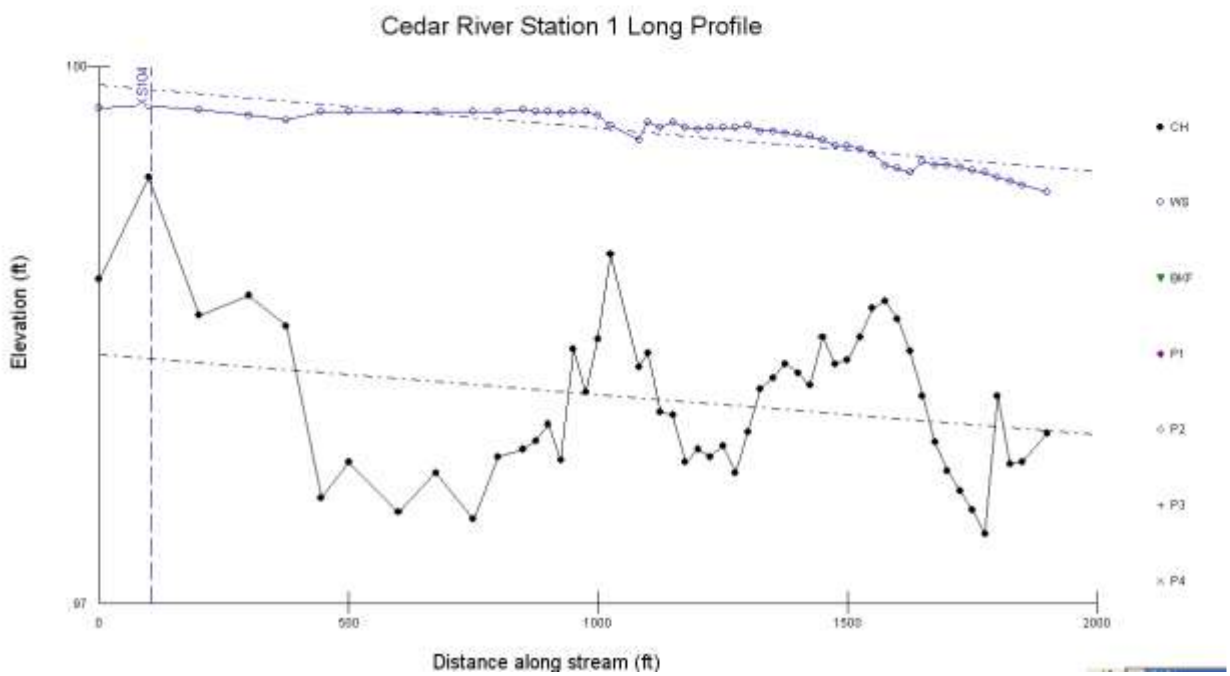


Figure 2. Longitudinal Stream Profile for 1800 feet of Station 1.

WIDTH	HYD RAD	MEAN D	SLOPE	ROUGH	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
184.19	4.6	4.7	0.0002	0.02056	210.83	2.83	16.43	0.12	2448.96
184.45	4.69	4.79	0.0002	0.02057	214.95	2.86	16.48	0.13	2532.75
184.71	4.78	4.89	0.0002	0.02058	219.08	2.9	16.52	0.13	2617.7
184.97	4.87	4.98	0.0002	0.02058	223.2	2.93	16.57	0.13	2703.79
185.23	4.95	5.07	0.0002	0.02059	226.87	2.97	16.61	0.14	2787.39
185.49	5.04	5.17	0.0002	0.0206	231	3	16.65	0.14	2875.74
185.75	5.13	5.26	0.0002	0.0206	235.12	3.04	16.7	0.14	2965.21
186.01	5.22	5.35	0.0002	0.02061	239.24	3.07	16.74	0.15	3055.82
186.27	5.31	5.44	0.0002	0.02062	243.37	3.1	16.78	0.15	3147.54
186.53	5.4	5.54	0.0002	0.02062	247.49	3.14	16.82	0.15	3240.4
186.79	5.49	5.63	0.0002	0.02063	251.62	3.17	16.86	0.16	3334.38
187.05	5.57	5.72	0.0002	0.02064	255.29	3.2	16.9	0.16	3425.49
187.31	5.66	5.81	0.0002	0.02064	259.41	3.23	16.94	0.16	3521.64
187.77	5.74	5.9	0.0002	0.02065	263.08	3.26	16.97	0.17	3614.85
188.54	5.82	5.97	0.0002	0.02066	266.74	3.29	17.01	0.17	3709.19
189.31	5.89	6.05	0.0002	0.02066	269.95	3.32	17.04	0.17	3800.59
190.07	5.96	6.13	0.0002	0.02067	273.16	3.34	17.07	0.17	3893.05
190.8	6.04	6.2	0.0002	0.02067	276.83	3.37	17.1	0.18	3990.82

Velocity Formula Mannings Equation

Roughness coefficient	Limerino's 'n"
Bed material D84	6.65mm
Sediment Transport	Parker (1990) mean diameter bed material 7.05mm
Energy slope	0.0002(water slope)

Figure 3. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Station 1 for the Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red.

USGS Streamstats Site 1 Report

Date: Wed Sep 15 2010 09:41:43 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.5002 (43 30 01)
NAD27 Longitude: -93.0015 (-93 00 06)
NAD83 Latitude: 43.5002 (43 30 01)
NAD83 Longitude: -93.0017 (-93 00 06)
Drainage Area: 586 mi2
Peak Flow Basin Characteristics
100% Region D (586 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	586	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	3.08	1.49	77.2
Percent Lakes and Ponds (percent)	0.50	0	14
Generalized Runoff (inches)	7.43	2.15	7.8

Statistic	Flow (ft3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	**1800**	**64**	**3.1**	**629**	**3910**
PK2	2550	56	3.5	1000	5210
PK5	4970	50	6.3	2220	9440
PK10	7030	51	8.8	3160	13300
PK25	10100	55	11	4380	19600
PK50	12700	60	13	5280	25400
PK100	15800	65	14	6190	32500
PK500	23600	78	15	8000	53100

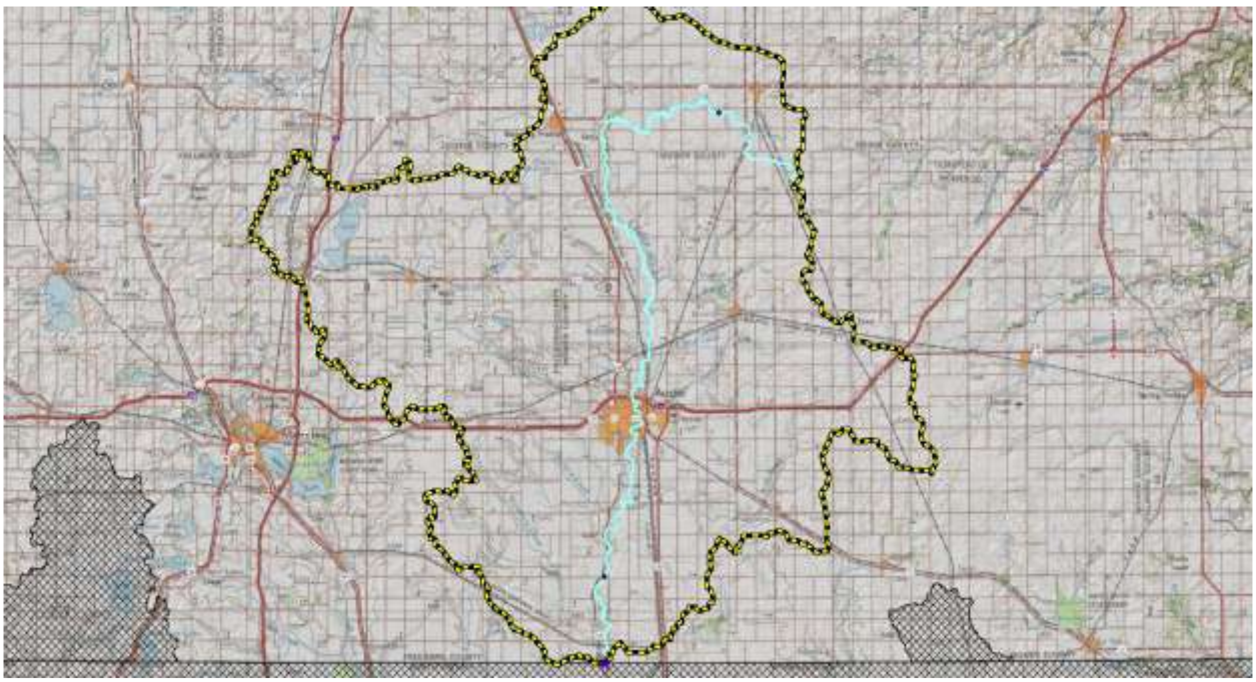


Figure 4. Watershed (586 sueare miles) used in the USGS StreamStat Regession Flow Calaulations.

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Main Branch Cedar River

Reach Name: Stat 1 CR105-IA line <-- This is not a Reference Reach

Drainage Area: 586 sq mi

State: Minnesota
County: Mower
Latitude: 43.5002
Longitude: -93.0017
Survey Date: 09/04/2009

Classification Data

Valley Type:	Type VIII
Valley Slope:	0 ft/ft
Number of Channels:	Single
Width:	191.49 ft
Mean Depth:	6.23 ft
Flood-Prone Width:	800 ft
Channel Materials D50:	0.34 mm
Water Surface Slope:	0.00025 ft/ft
Sinuosity:	1.27
Discharge:	3521 cfs
Velocity:	0 fps
Cross Sectional Area:	1193.79 sq ft
Entrenchment Ratio:	4.18
Width to Depth Ratio:	30.74

Rosgen Stream Classification: C 5c-

Figure 5. Stream Classification for Station 1 on the Cedar River.

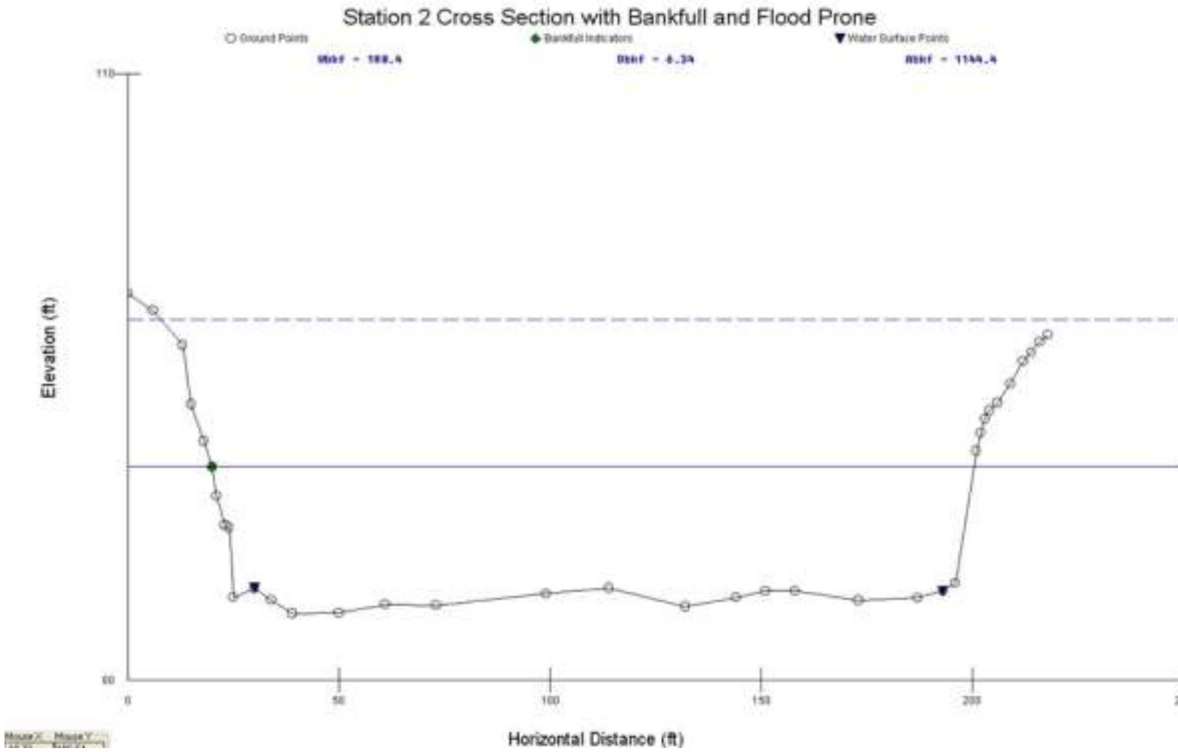


Figure 6. Riffle Cross Section at Station 2 on the Cedar River.

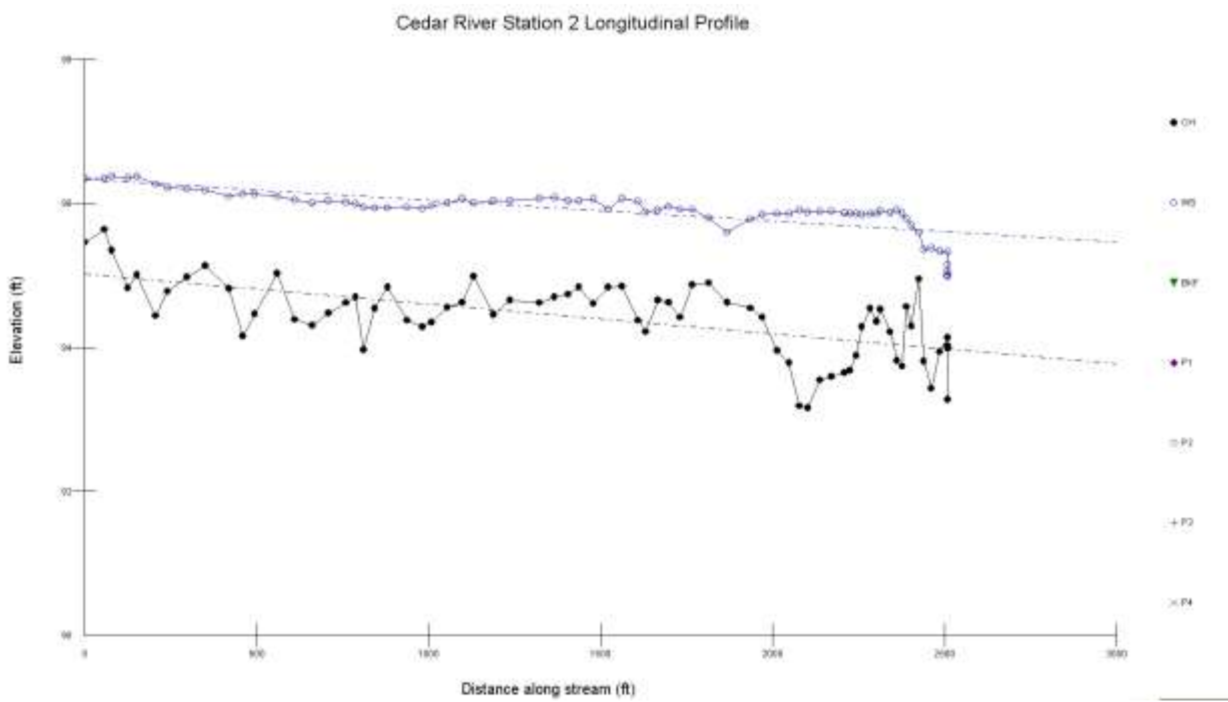


Figure 7. Stream Channel Longitudinal Profile for Station 2 on the Cedar River.

ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	ROUGH	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
89	5.7	864.79	183.33	178.02	4.72	4.86	24.85	2.39	11.18	0.09	2063.72
89.1	5.8	882.6	183.63	178.24	4.81	4.95	25.32	2.42	11.22	0.09	2135.03
89.2	5.9	900.43	183.89	178.41	4.9	5.05	25.79	2.45	11.27	0.09	2207.37
89.3	6	918.28	184.14	178.55	4.99	5.14	26.27	2.48	11.31	0.1	2280.73
89.4	6.1	936.14	184.39	178.7	5.08	5.24	26.74	2.52	11.36	0.1	2355.07
89.5	6.2	954.02	184.63	178.84	5.17	5.33	27.21	2.55	11.4	0.1	2430.42
89.6	6.3	971.91	184.88	178.99	5.26	5.43	27.69	2.58	11.44	0.1	2506.74
89.7	6.4	989.82	185.13	179.14	5.35	5.53	28.16	2.61	11.48	0.11	2584.06
89.8	6.5	1007.74	185.38	179.28	5.44	5.62	28.64	2.64	11.52	0.11	2662.35
89.9	6.6	1025.68	185.63	179.43	5.53	5.72	29.11	2.67	11.56	0.11	2741.63
90	6.7	1043.63	185.87	179.58	5.61	5.81	29.53	2.7	11.6	0.11	2818.29
90.1	6.8	1061.59	186.12	179.72	5.7	5.91	30	2.73	11.64	0.12	2899.43
90.2	6.9	1079.57	186.37	179.87	5.79	6	30.48	2.76	11.68	0.12	2981.56
90.3	7	1097.57	186.62	180.02	5.88	6.1	30.95	2.79	11.72	0.12	3064.65
90.4	7.1	1115.57	186.86	180.16	5.97	6.19	31.43	2.82	11.75	0.12	3148.66
90.5	7.2	1133.6	187.11	180.31	6.06	6.29	31.9	2.85	11.79	0.13	3233.66
90.6	7.3	1151.64	187.39	180.49	6.15	6.38	32.37	2.88	11.83	0.13	3319.59

Velocity Formula	Mannings Equation
Roughness coefficent	Limerino's 'n"
Bed material D84	57.9 mm
Sediment Transport	Parker (1990)
	mean diameter bed material 23 mm
Energy slope	0.0003

Figure 8. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Station 2 for the Stream Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red.

USGS Streamstats Report for Site 2 North of CR 5

Date: Wed Sep 15 2010 09:36:30 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.5579 (43 33 29)
NAD27 Longitude: -93.0041 (-93 00 15)

NAD83 Latitude: 43.5579 (43 33 28)

NAD83 Longitude: -93.0043 (-93 00 16)

Drainage Area: 523 mi2

Peak Flow Basin Characteristics			
100% Region D (523 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	523	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	2.96	1.49	77.2
Percent Lakes and Ponds (percent)	0.56	0	14
Generalized Runoff (inches)	7.41	2.15	7.8

Peak Flow Streamflow Statistics					
Statistic	**Flow (ft^3/s)**	**Prediction Error (percent)**	**Equivalent years of record**	**90-Percent Prediction Interval**	
				Minimum	**Maximum**
PK1_5	1600	64	3.1	559	3470
PK2	2260	56	3.5	890	4600
PK5	4390	50	6.3	1960	8310
PK10	6190	51	8.8	2780	11700
PK25	8890	55	11	3860	17200
PK50	11200	60	13	4650	22300
PK100	13800	65	14	5450	28500
PK500	20700	78	15	7050	46500

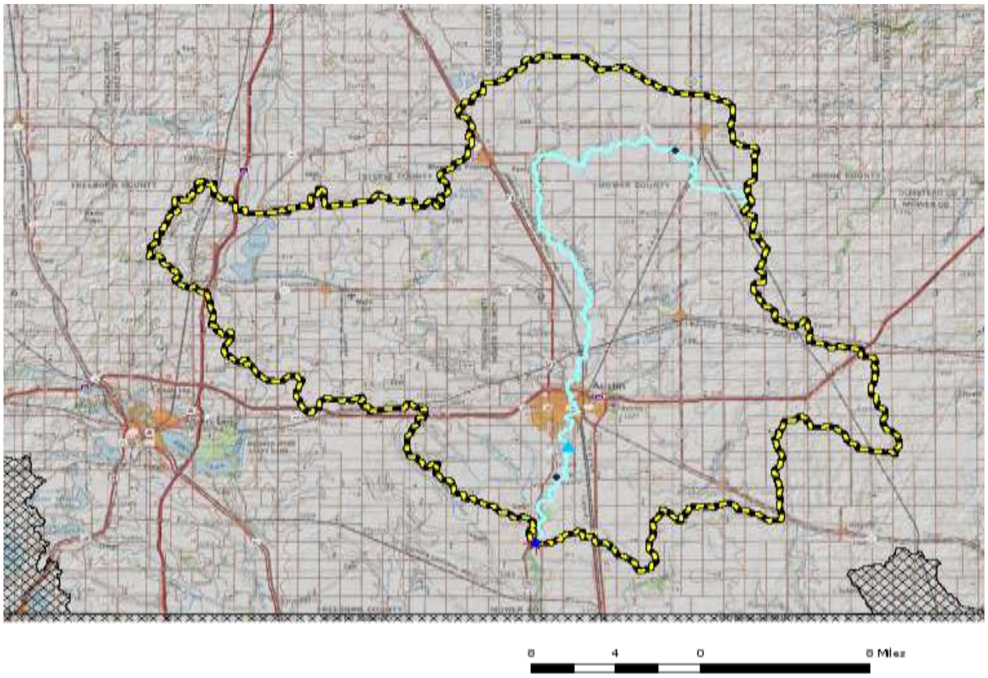


Figure 9. Watershed (532 sueare miles) used in the USGS StreamStat Regession Flow Calaulations

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Main Branch Cedar River
Reach Name: Stat 2 North of CR5
Drainage Area: 523 sq mi
State: Minnesota
County: Mower
Latitude: 43.5579
Longitude: -93.0043
Survey Date: 09/15/2009

Classification Data

Valley Type: Type VIII
Valley Slope: 0.55 ft/ft
Number of Channels Single
Width: 182.36 ft
Mean Depth: 7.1 ft
Flood-Prone Width: 600 ft
Channel Materials D50: 16 mm
Water Surface Slope: 0.0003 ft/ft
Sinuosity: 1.36
Discharge: 3320 cfs
Velocity: 2.8 fps
Cross Sectional Area: 1294.96 sq ft
Entrenchment Ratio: 3.29
Width to Depth Ratio: 25.68

Rosgen Stream Classification: C 4/1c-

Figure 10.. Stream Classification for Station2 on the Cedar River.

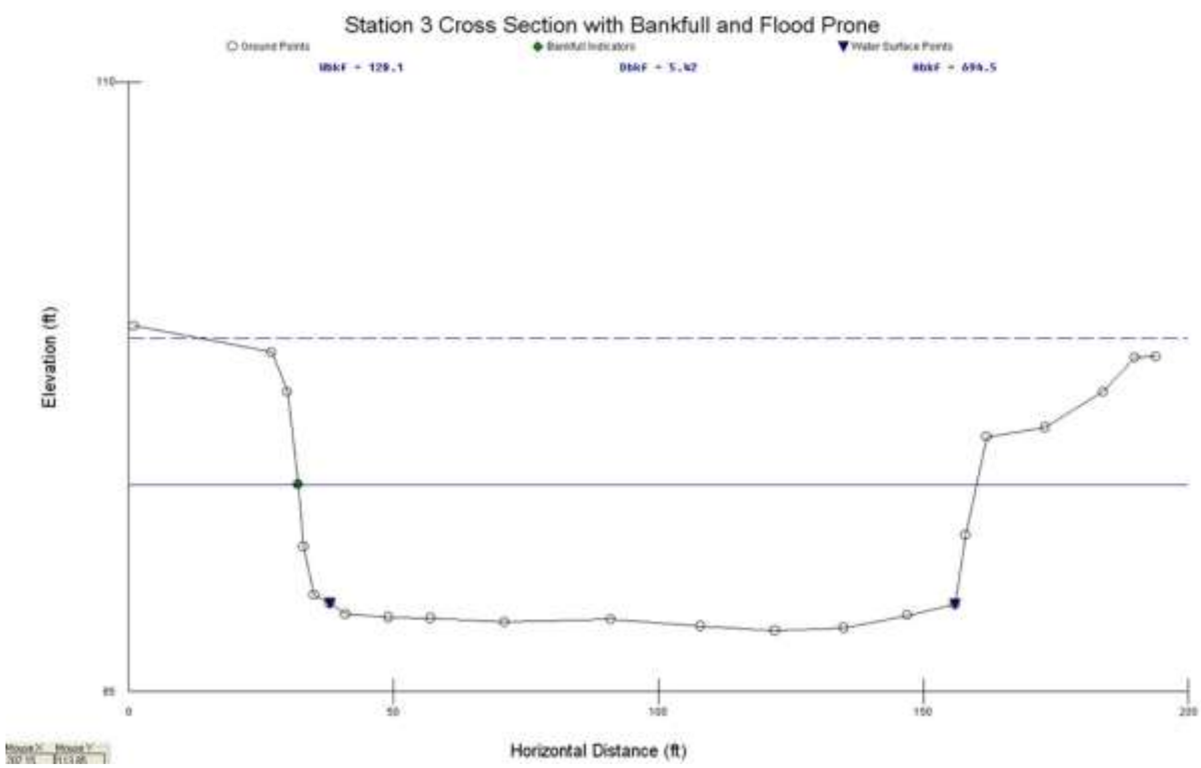


Figure 11. Riffle Cross Section at Station 3 on the Cedar River.

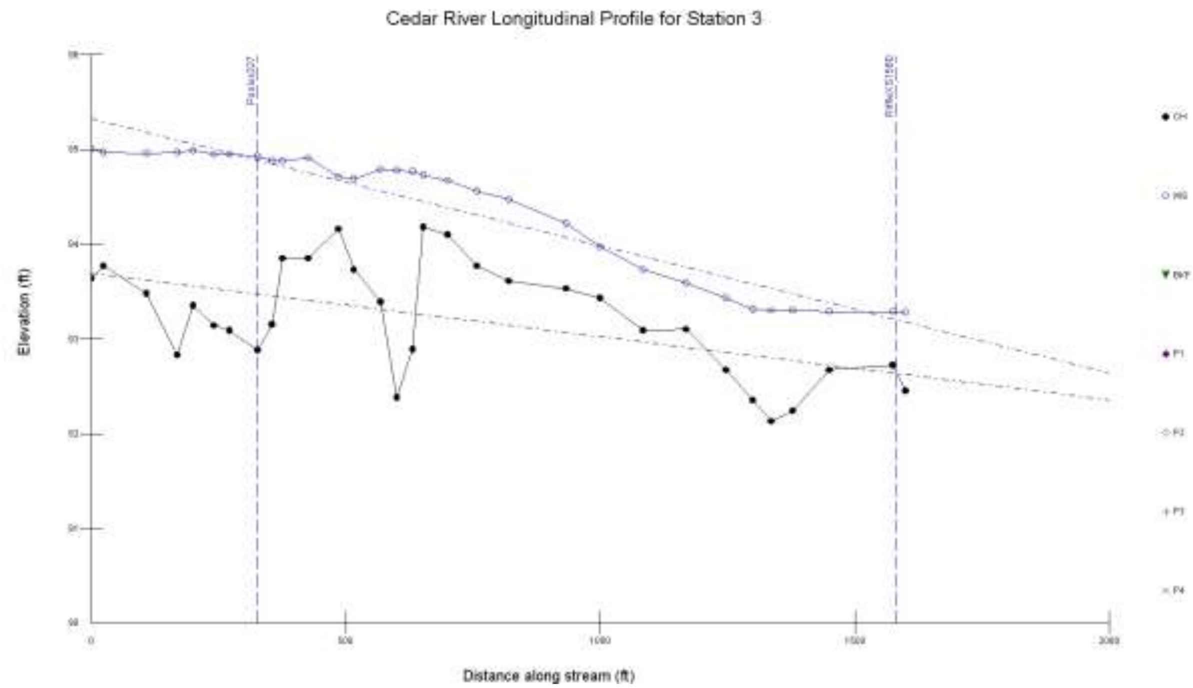


Figure 12. Stream Channel Longitudinal Profile for Station 3 on the Cedar River.

ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	ROUGH	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
91.8	**4.3**	**478.81**	**128.83**	**125.71**	**3.72**	**3.81**	**9.43**	**3.47**	**8.8**	**0.19**	**1661.95**
91.9	**4.4**	**491.39**	**129.08**	**125.85**	**3.81**	**3.9**	**9.66**	**3.54**	**8.85**	**0.19**	**1737.65**
92	**4.5**	**503.98**	**129.33**	**125.99**	**3.9**	**4**	**9.89**	**3.6**	**8.91**	**0.2**	**1814.78**
92.1	**4.6**	**516.59**	**129.58**	**126.13**	**3.99**	**4.1**	**10.12**	**3.67**	**8.97**	**0.21**	**1893.37**
92.2	**4.7**	**529.21**	**129.83**	**126.27**	**4.08**	**4.19**	**10.35**	**3.73**	**9.02**	**0.22**	**1973.36**
92.3	**4.8**	**541.84**	**130.08**	**126.41**	**4.17**	**4.29**	**10.57**	**3.79**	**9.08**	**0.22**	**2054.76**
92.4	**4.9**	**554.49**	**130.32**	**126.55**	**4.25**	**4.38**	**10.78**	**3.85**	**9.12**	**0.23**	**2133.72**
92.5	**5**	**567.15**	**130.57**	**126.68**	**4.34**	**4.48**	**11**	**3.91**	**9.17**	**0.24**	**2217.87**
92.6	**5.1**	**579.83**	**130.82**	**126.82**	**4.43**	**4.57**	**11.23**	**3.97**	**9.23**	**0.25**	**2303.44**
92.7	**5.2**	**592.52**	**131.07**	**126.96**	**4.52**	**4.67**	**11.46**	**4.03**	**9.27**	**0.25**	**2390.38**
92.8	**5.3**	**605.22**	**131.32**	**127.1**	**4.61**	**4.76**	**11.69**	**4.1**	**9.32**	**0.26**	**2478.68**
92.9	**5.4**	**617.94**	**131.57**	**127.24**	**4.7**	**4.86**	**11.92**	**4.16**	**9.37**	**0.27**	**2568.39**
93	**5.5**	**630.67**	**131.81**	**127.38**	**4.78**	**4.95**	**12.12**	**4.21**	**9.41**	**0.28**	**2655.21**
93.1	**5.6**	**643.41**	**132.06**	**127.52**	**4.87**	**5.05**	**12.35**	**4.27**	**9.46**	**0.28**	**2747.55**
93.2	**5.7**	**656.17**	**132.31**	**127.65**	**4.96**	**5.14**	**12.58**	**4.33**	**9.5**	**0.29**	**2841.26**
93.3	**5.8**	**668.94**	**132.56**	**127.79**	**5.05**	**5.23**	**12.81**	**4.39**	**9.55**	**0.3**	**2936.31**
93.4	**5.9**	**681.73**	**132.81**	**127.93**	**5.13**	**5.33**	**13.01**	**4.44**	**9.59**	**0.31**	**3028.26**

93.5	**6**	**694.53**	**133.06**	**128.07**	**5.22**	**5.42**	**13.24**	**4.5**	**9.63**	**0.31**	**3125.94**

Velocity Formula	Mannings Equation
Roughness coefficent	Limerino's 'n"
Bed material D84	120.2 mm
Sediment Transport	Parker (1990)
	mean diameter bed material 55.3 mm
Energy slope	0.0013 (water slope)

Figure 14. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Station 3 for the Stream Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red.

USGS Streamstats Site 3 Report

Date: Wed Sep 15 2010 10:19:05 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.6057 (43 36 21)
NAD27 Longitude: -92.9839 (-92 59 02)
NAD83 Latitude: 43.6057 (43 36 21)
NAD83 Longitude: -92.9841 (-92 59 03)
Drainage Area: 475 mi2

Peak Flow Basin Characteristics

100% Region D (475 mi2)

Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	475	0.15	2640

Stream Slope 10 and 85 Method (feet per mi)	3.02	1.49	77.2
Percent Lakes and Ponds (percent)	0.61	0	14
Generalized Runoff (inches)	7.4	2.15	7.8

Peak Flow Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	1480	64	3.1	518	3210
PK2	2090	56	3.5	824	4250
PK5	4050	50	6.3	1810	7650
PK10	5700	51	8.8	2570	10800
PK25	8180	55	11	3560	15800
PK50	10300	60	13	4280	20500
PK100	12700	65	14	5020	26200
PK500	19100	78	15	6490	42700

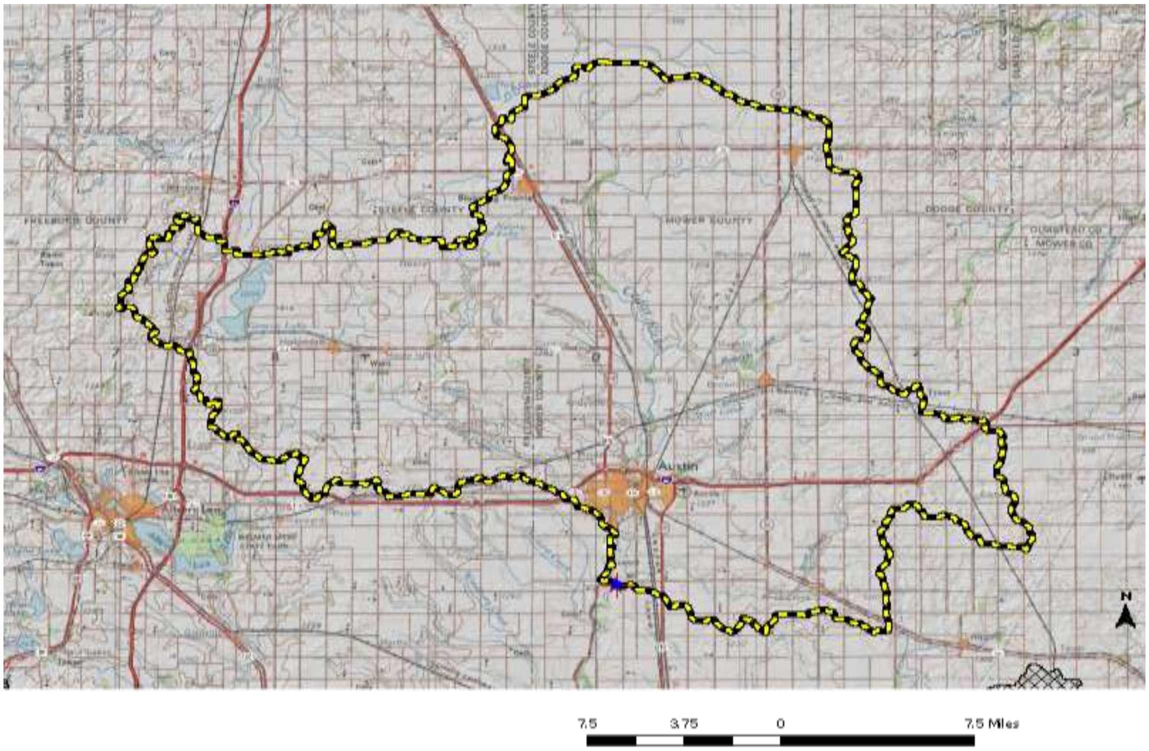


Figure 15. Watershed (475 square miles) used in the USGS StreamStat Regession Flow Calaulations

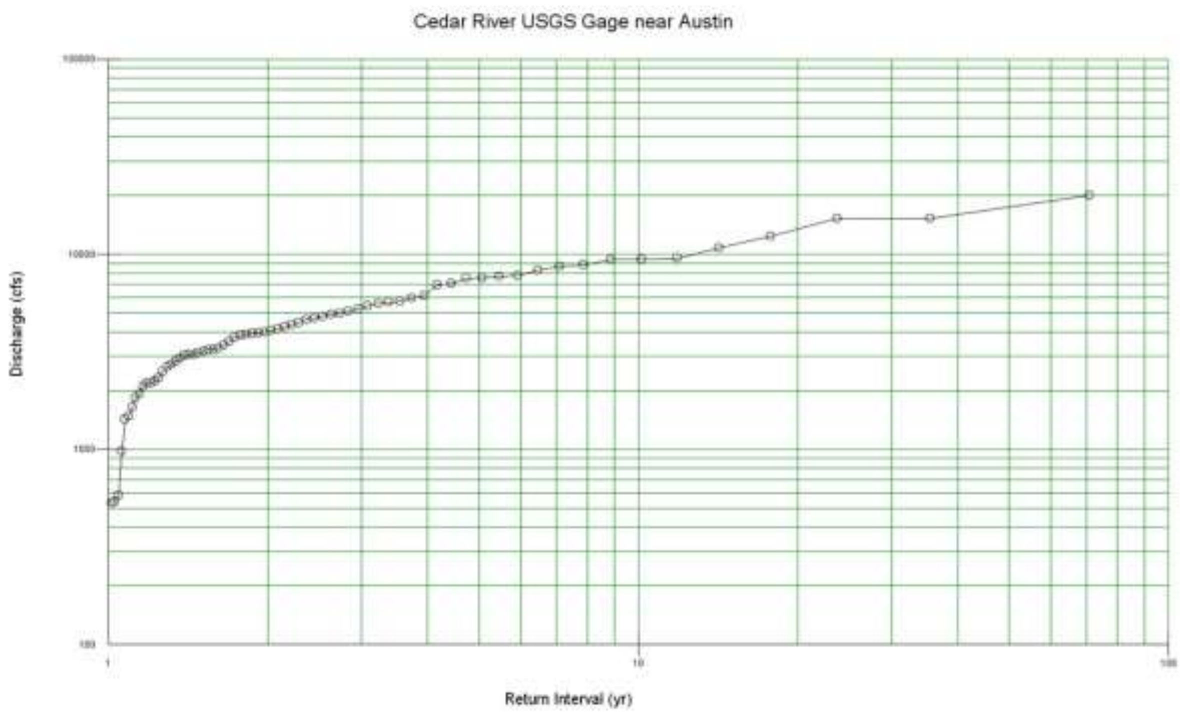


Figure 16.USGS Gage Analysis for the Cedar River below Austin which has a 1.5 year event of 2922 CFS.

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Main Branch Cedar River
Reach Name: Stat 3 CR 4 <-- This is not a Reference Reach
Drainage Area: 475 sq mi
State: Minnesota
County:
Mower
Latitude:
43.6057
Longitude: -92.9841
Survey Date: 09/01/2009

Classification Data

Valley Type:	Type VIII
Valley Slope:	0.55 ft/ft
Number of Channels:	Single
Width:	128.07 ft
Mean Depth:	5.42 ft
Flood-Prone Width:	500 ft
Channel Materials D50:	45 mm
Water Surface Slope:	0.00109 ft/ft
Sinuosity:	1.31
Discharge:	3125 cfs
Velocity:	4.5 fps
Cross Sectional Area:	694.53 sq ft
Entrenchment Ratio:	3.9
Width to Depth Ratio:	23.63

Rosgen Stream Classification: C 4/1

Figure 17. Stream Classification for Station 3 on the Cedar River below Austin

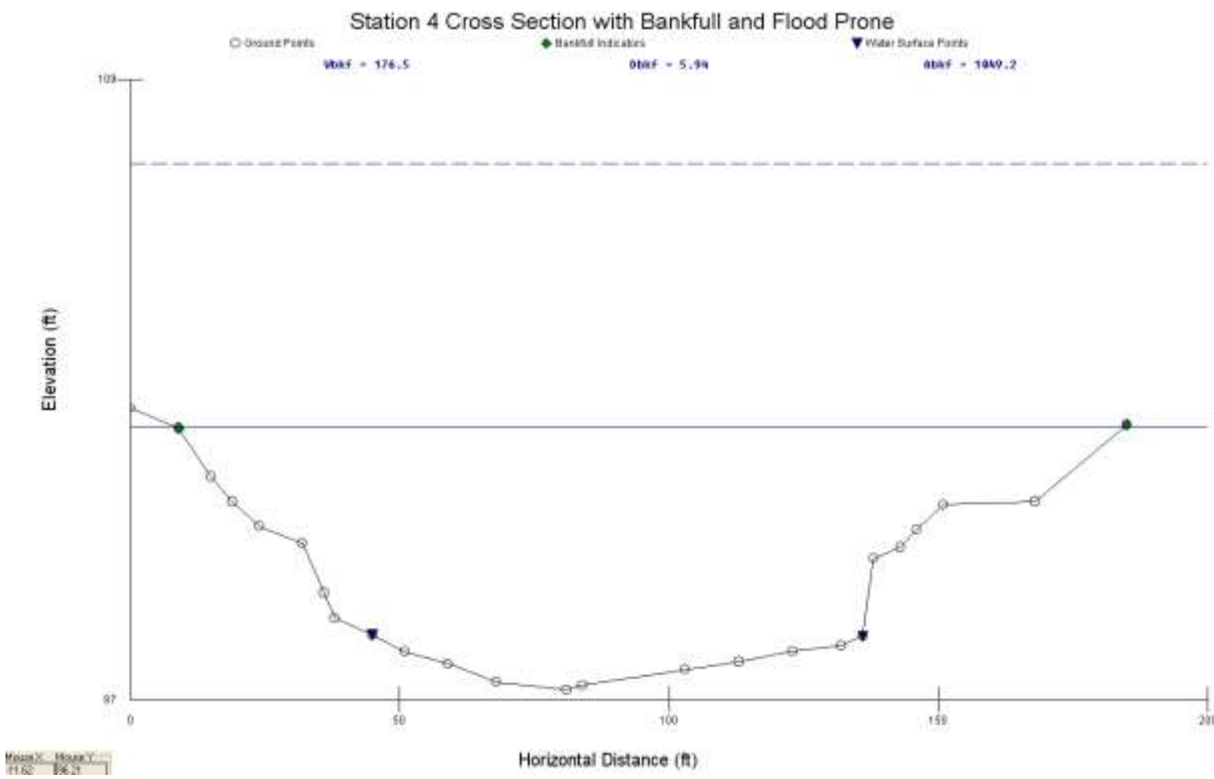


Figure 18. . Riffle Cross Section at Station 4 on the Cedar River.

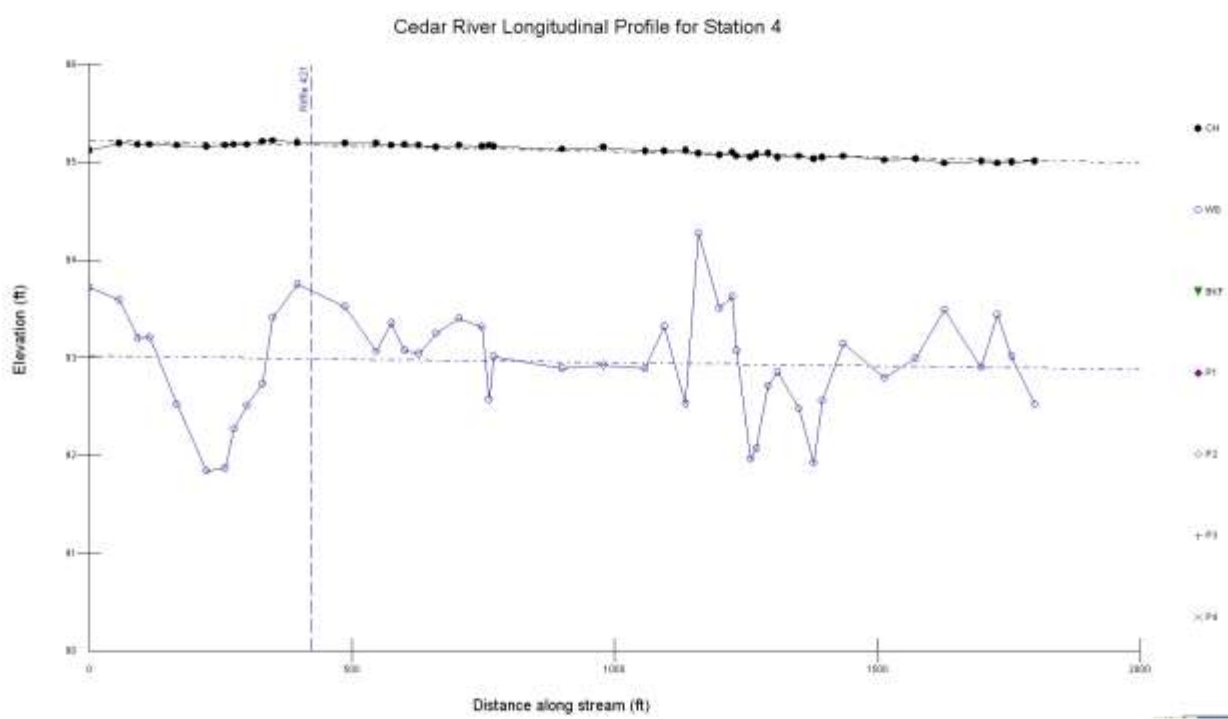


Figure 19. Stream Channel Longitudinal Profile for Station 4 on the Cedar River.

ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	MEAN D	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
95.75	8.4	888.11	169.42	166.72	5.24	5.33	45.96	1.65	12.69	0.04	1463.6
95.85	8.5	904.83	170.42	167.69	5.31	5.4	46.57	1.66	12.72	0.04	1504.94
95.95	8.6	921.65	171.41	168.67	5.38	5.46	47.19	1.68	12.75	0.04	1546.89
96.05	8.7	938.57	172.41	169.64	5.44	5.53	47.71	1.69	12.78	0.04	1587.44
96.15	8.8	955.58	173.41	170.61	5.51	5.6	48.33	1.71	12.81	0.05	1630.57
96.25	8.9	972.69	174.4	171.59	5.58	5.67	48.94	1.72	12.84	0.05	1674.32
96.35	9	989.9	175.4	172.56	5.64	5.74	49.47	1.73	12.87	0.05	1716.59
96.45	9.1	1007.2	176.39	173.54	5.71	5.8	50.08	1.75	12.9	0.05	1761.53
96.55	9.2	1024.6	177.39	174.51	5.78	5.87	50.7	1.76	12.93	0.05	1807.1
96.65	9.3	1042.11	178.64	175.75	5.83	5.93	51.13	1.77	12.95	0.05	1848.94
96.75	9.4	1059.77	180.51	177.6	5.87	5.97	51.48	1.78	12.97	0.05	1889.16
96.85	9.5	1077.6	181.85	178.84	5.93	6.03	52.01	1.8	12.99	0.05	1934.45
96.95	9.6	1095.54	183.19	180.07	5.98	6.08	52.45	1.81	13.01	0.05	1978.07
97.05	9.7	1113.61	184.52	181.3	6.04	6.14	52.98	1.82	13.04	0.05	2024.57
97.15	9.8	1131.8	185.86	182.53	6.09	6.2	53.41	1.83	13.06	0.05	2069.35
97.25	9.9	1150.12	187.2	183.77	6.14	6.26	53.85	1.84	13.08	0.05	2114.71

Velocity Formula		Mannings Equation
Roughness coefficent		Limerino's 'n"
Bed material D84		34.75 mm
Sediment Transport		Parker (1990)
		mean diameter bed material 13.8 mm
Energy slope	0.0013	(water slope)

Figure 20. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Station 4 for the Stream Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red

USGS Streamstats Report for Site 4

Date: Wed Sep 15 2010 09:30:47 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.6625 (43 39 45)
NAD27 Longitude: -92.9659 (-92 57 57)
NAD83 Latitude: 43.6624 (43 39 45)
NAD83 Longitude: -92.9661 (-92 57 58)
Drainage Area: 243 mi2

Peak Flow Basin Characteristics

100% Region D (243 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	243	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	3.19	1.49	77.2
Percent Lakes and Ponds (percent)	0.11	0	14
Generalized Runoff (inches)	7.4	2.15	7.8

Peak Flow Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	1000	64	3.1	350	2170
PK2	1430	56	3.5	562	2910
PK5	2820	50	6.3	1260	5330
PK10	4000	51	8.8	1800	7550
PK25	5780	55	11	2510	11200
PK50	7310	60	13	3040	14500
PK100	9070	65	14	3570	18700
PK500	13700	78	15	4650	30600

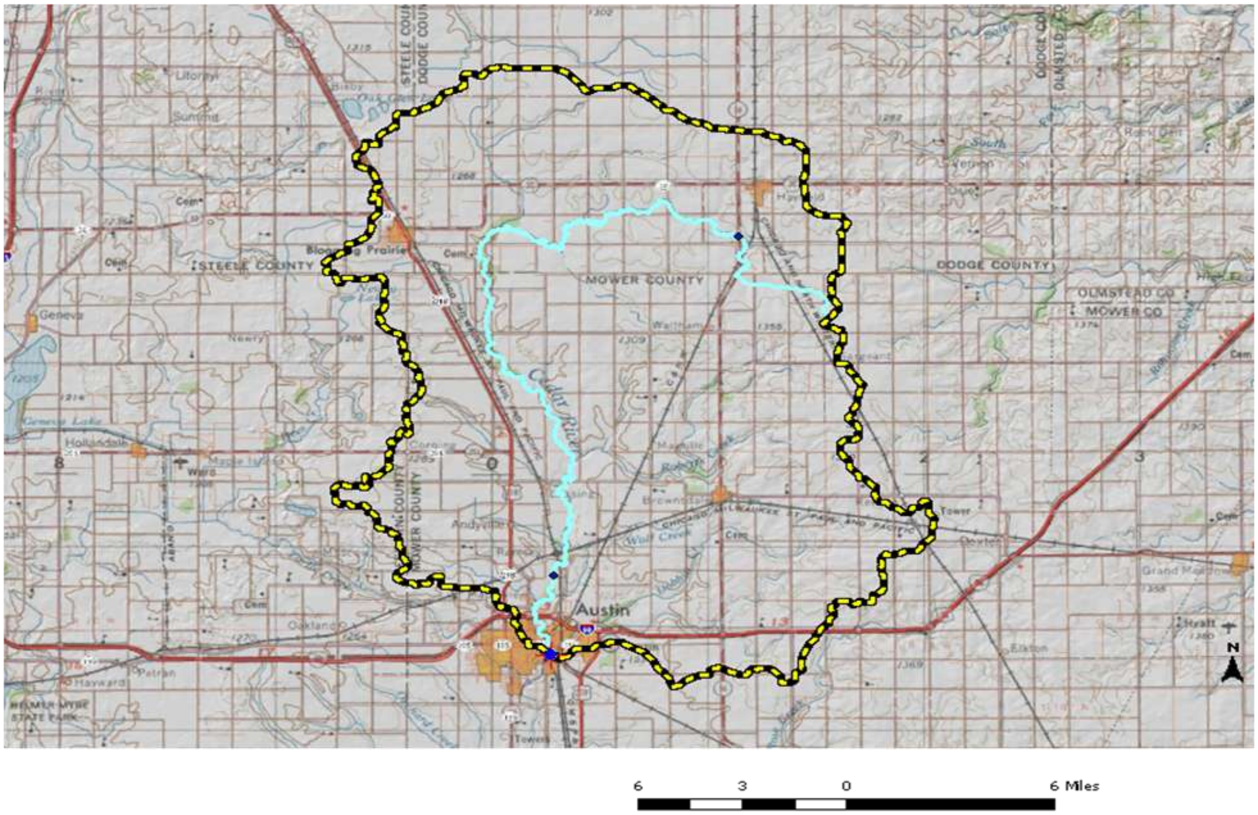


Figure 21. Watershed (243 square miles) used in the USGS StreamStat Regession Flow Calaulations for Sation 4.

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Main Branch Cedar River
Reach Name: Stat 3 CR 4 <-- This is not a Reference Reach
Drainage Area: 475 sq mi
State: Minnesota
County:
Mower
Latitude: 43.6057
Longitude: -92.9841
Survey Date: 09/01/2009

Classification Data

Valley Type: Type VIII
Valley Slope: 0.55 ft/ft
Number of Channels: Single
Width: 128.07 ft
Mean Depth: 5.42 ft
Flood-Prone Width: 500 ft
Channel Materials D50: 45 mm
Water Surface Slope: 0.00109 ft/ft
Sinuosity: 1.31
Discharge: 0 cfs
Velocity: 0 fps
Cross Sectional Area: 694.53 sq ft
Entrenchment Ratio: 3.9
Width to Depth Ratio: 23.63

Rosgen Stream Classification: C 4/1

Figure 22. Stream Classification for Station 4 on the Cedar River in Austin

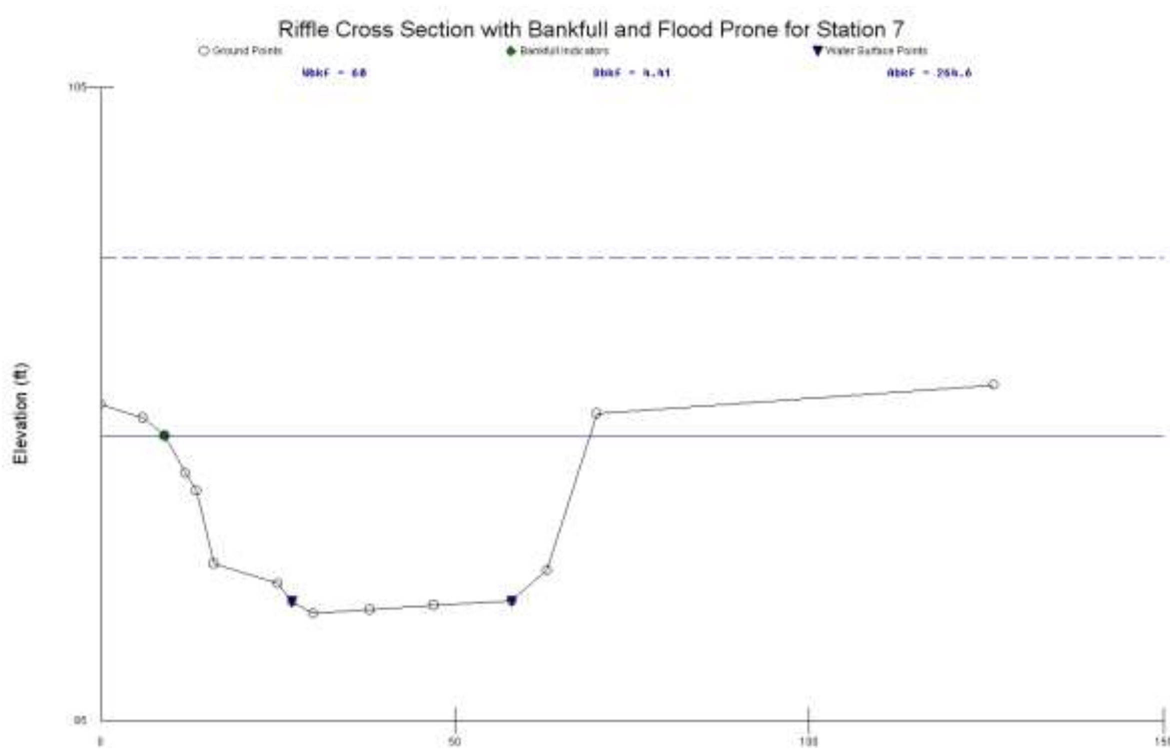


Figure 23. Riffle Cross Section at Station 7 on the Cedar River.

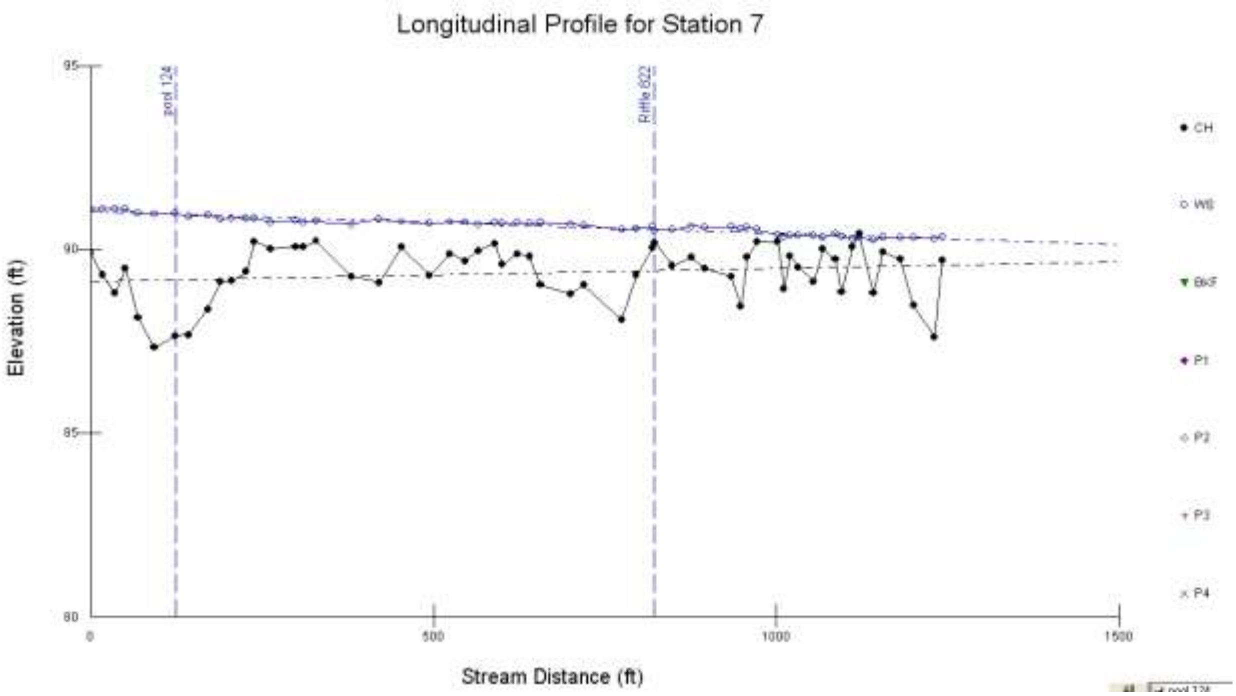


Figure 24. Longitudinal Profile for Station 7 on the Cedar River.

ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	MEAN D	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
92.98	4.6	205.41	58.27	56	3.52	3.67	203.19	3.77	16.34	0.22	774.65
93.08	4.7	211.03	58.72	56.39	3.59	3.74	207.23	3.82	16.39	0.23	806.1
93.18	4.8	216.68	59.16	56.78	3.66	3.82	211.27	3.87	16.44	0.23	838.14
93.28	4.9	222.38	59.61	57.18	3.73	3.89	215.31	3.92	16.48	0.24	870.83
93.38	5	228.12	60.05	57.57	3.8	3.96	219.35	3.96	16.53	0.24	904.15
93.48	5.1	233.9	60.5	57.96	3.87	4.04	223.39	4.01	16.57	0.25	938.1
93.58	5.2	239.71	60.94	58.36	3.93	4.11	226.86	4.05	16.61	0.25	971.03
93.68	5.3	245.57	61.38	58.75	4	4.18	230.9	4.1	16.65	0.26	1006.21
93.78	5.4	251.46	61.83	59.14	4.07	4.25	234.94	4.14	16.7	0.27	1041.98
93.88	5.5	257.4	62.27	59.54	4.13	4.32	238.4	4.18	16.73	0.27	1076.75
93.98	5.6	263.37	62.72	59.93	4.2	4.39	242.44	4.23	16.77	0.28	1113.76
94.08	5.7	269.39	63.38	60.55	4.25	4.45	245.33	4.26	16.8	0.28	1147.96
94.18	5.8	275.48	64.1	61.23	4.3	4.5	248.22	4.29	16.83	0.29	1182.82
94.28	5.9	281.64	64.82	61.91	4.35	4.55	251.1	4.33	16.86	0.29	1218.33
94.38	6	287.86	65.54	62.58	4.39	4.6	253.41	4.35	16.88	0.29	1252.62
94.48	6.1	294.15	66.25	63.26	4.44	4.65	256.3	4.38	16.91	0.3	1289.38

Velocity Formula Mannings Equation

Roughness coefficent Limerino's 'n"

Bed material D84 5.28 mm

Sediment Transport	Parker (1990)	
	mean diameter bed material 10.9 mm	
Energy slope	0.00063	(slope)

Figure 25. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Station 7 for the Stream Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red

USGS Streamstats Report for Site 7

Date: Wed Sep 15 2010 10:12:21 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.7466 (43 44 48)
NAD27 Longitude: -92.9580 (-92 57 29)
NAD83 Latitude: 43.7466 (43 44 48)
NAD83 Longitude: -92.9581 (-92 57 29)
Drainage Area: 160 mi2

Peak Flow Basin Characteristics

100% Region D (160 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	160	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	3.87	1.49	77.2
Percent Lakes and Ponds (percent)	0.00	0	14
Generalized Runoff (inches)	7.35	2.15	7.8

Peak Flow Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error	Equivalent years of	90-Percent Prediction Interval

		(percent)	record	Minimum	Maximum
PK1_5	802	64	3.1	281	1740
PK2	1150	56	3.5	454	2340
PK5	2280	50	6.3	1020	4320
PK10	3250	51	8.8	1470	6130
PK25	4710	55	11	2050	9090
PK50	5960	60	13	2490	11800
PK100	7410	65	14	2930	15200
PK500	11200	78	15	3820	25000

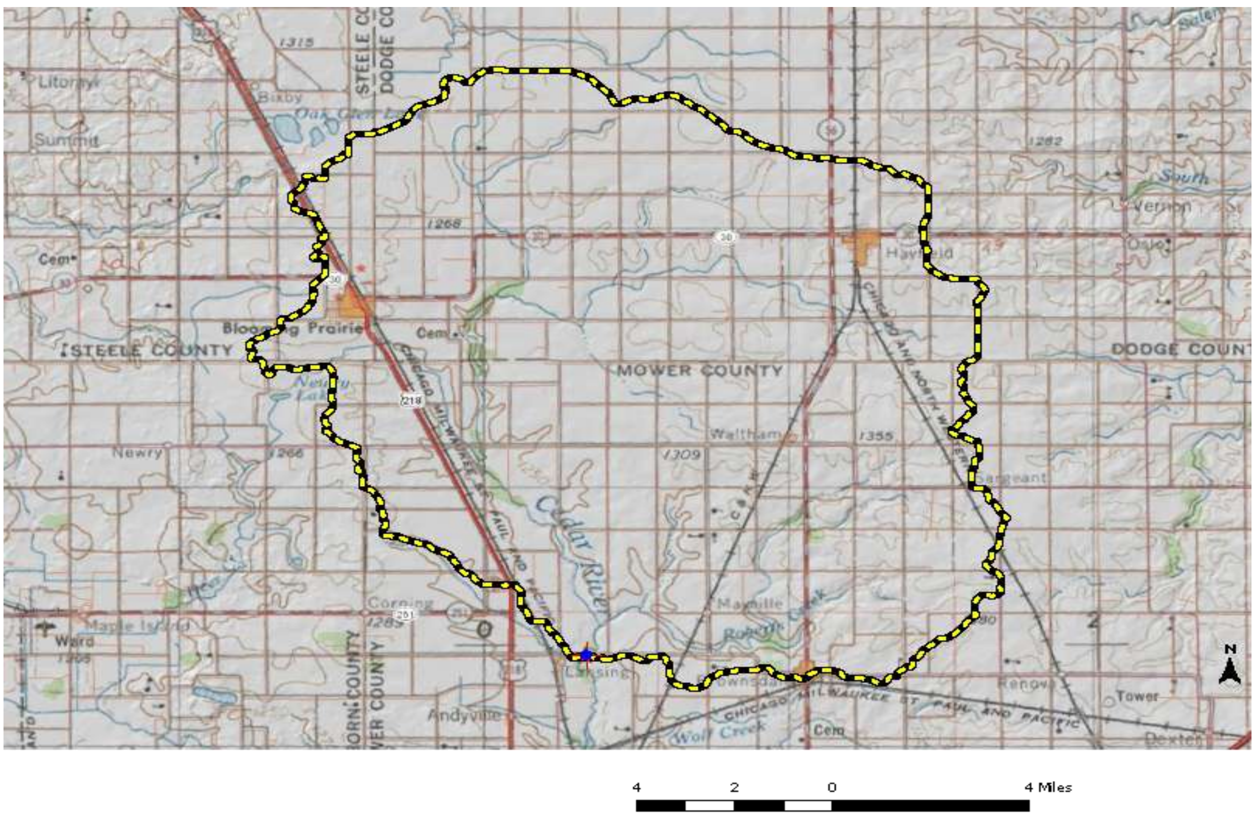


Figure 26. Watershed (160 square miles) used in the USGS StreamStat Regession Flow Calaulations for Sation 7.

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Main Branch Cedar River
Reach Name: Stat 7 CR 25 <-- This is not a Reference Reach
Drainage Area: 160 sq mi
State: Minnesota
County: Mower
Latitude: 43.7466
Longitude: -92.9581
Survey Date: 09/03/2009

Classification Data

Valley Type:	Type VIII
Valley Slope:	0 ft/ft
Number of Channels:	Single
Width:	60.01 ft
Mean Depth:	4.41 ft
Flood-Prone Width:	600 ft
Channel Materials D50	1.12 mm
Water Surface Slope:	0.00063 ft/ft
Sinuosity:	1.48
Discharge:	0 cfs
Velocity:	0 fps
Cross Sectional Area:	264.57 sq ft
Entrenchment Ratio:	10
Width to Depth Ratio:	13.61

Rosgen Stream Classification: C 5c-

Figure 27. Stream Classification for Station 7 on the Cedar River

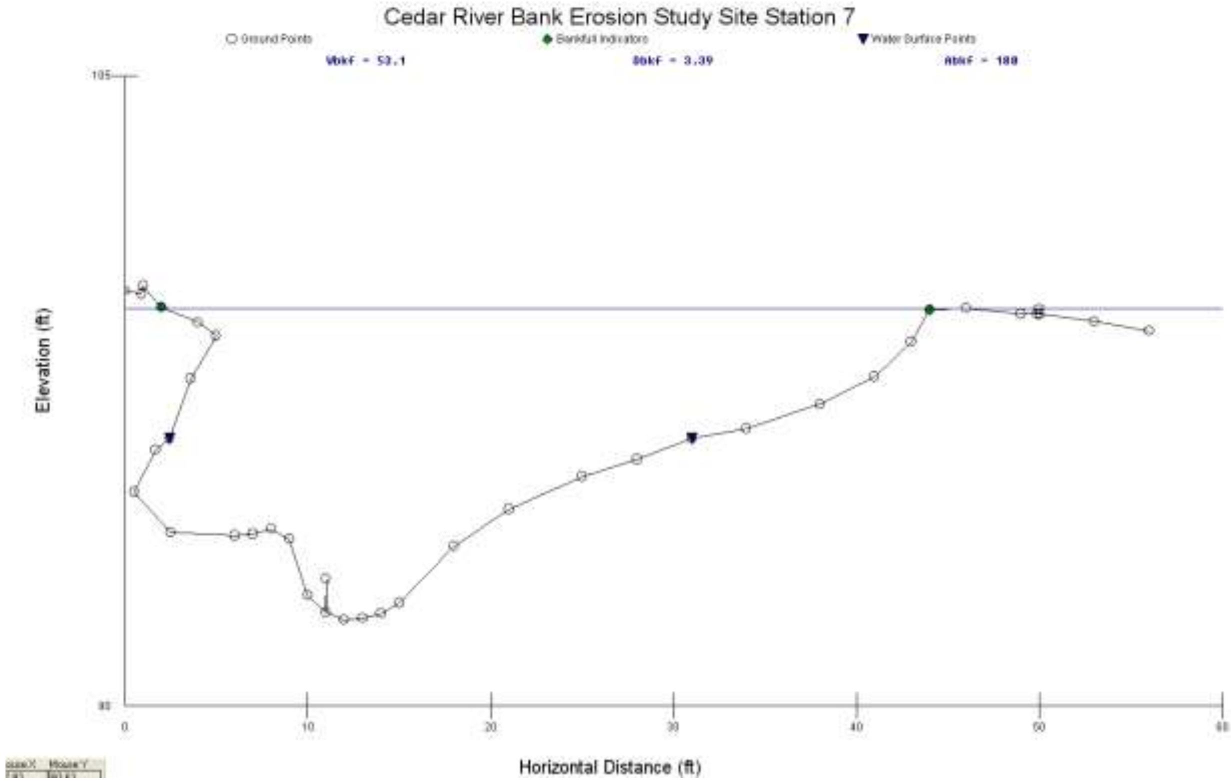


Figure 28. Study Bank Pool Cross Section for Cedar River Study Site 7

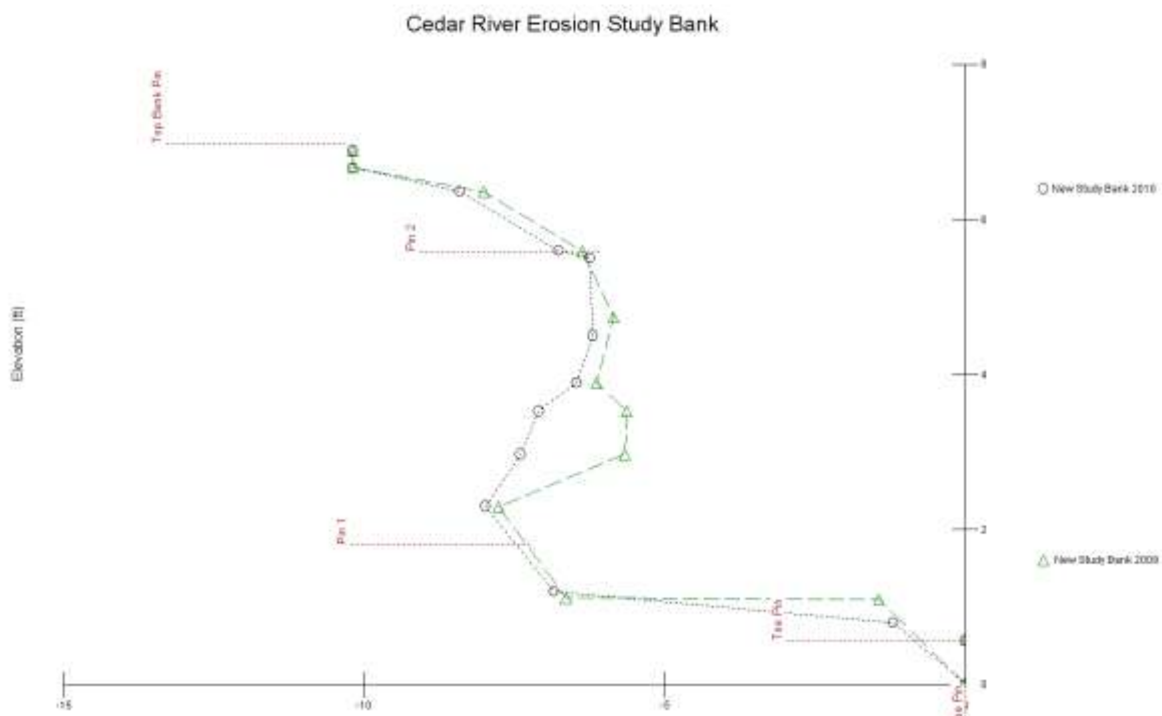


Figure 29. Study Bank Profile for 2009 and 2010 Show Erosion Loss

Toe Pin Area: 43.54 square feet (used for erosion monitoring)
Bank Height: 6.89 feet
Avg. Bank Angle: -29.88 degrees

Overlay #1
Toe Pin Area: 40.05 square feet (used for erosion monitoring)
Bank Height: 6.89 feet
Avg. Bank Angle: 90.00 degrees
Difference in Toe Pin Area: 3.49 square feet
Average Erosion Rate: 0.5065 feet

Figure 30. Erosion Loss and Erosion Rate for Study Bank at Site 7 on the Cedar River

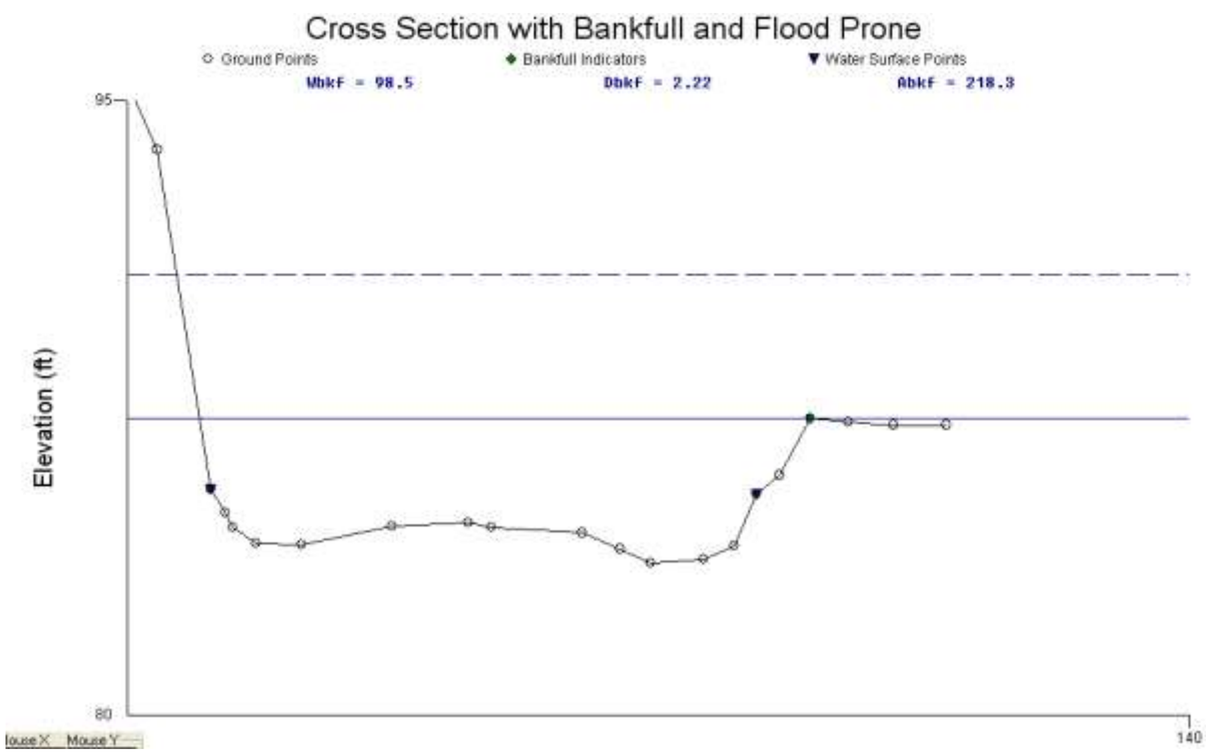


Figure 31. Riffle Cross Section for Station 8 on the Cedar River.

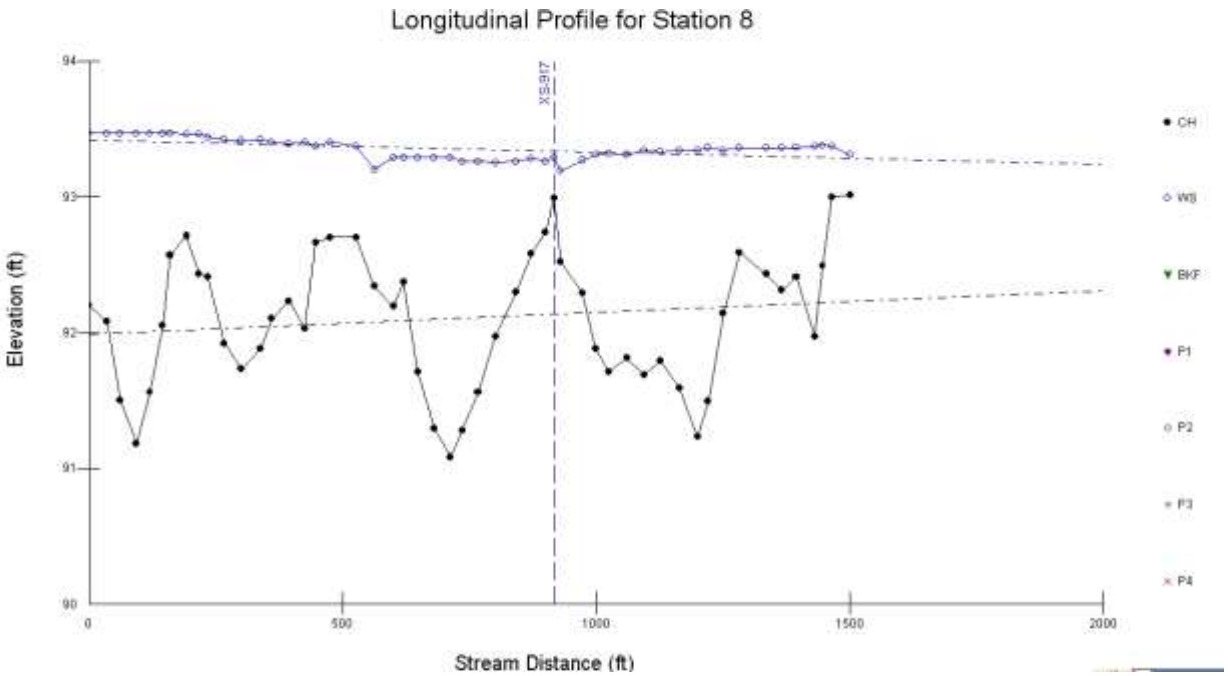


Figure 32. Longitudinal Profile for Station 8 on the Cedar River.

ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	MEAN D	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
86.02	2.3	120.82	76.7	75.93	1.58	1.59	2093.74	1.65	22.07	0.04	199.49
86.12	2.4	128.43	77.14	76.3	1.66	1.68	2199.75	1.7	22.19	0.04	218.55
86.22	2.5	136.08	77.57	76.67	1.75	1.77	2319.02	1.76	22.32	0.05	239.15
86.32	2.6	143.77	78.01	77.04	1.84	1.87	2438.28	1.81	22.45	0.05	260.51
86.42	2.7	151.49	78.44	77.42	1.93	1.96	2557.54	1.87	22.56	0.05	282.6
86.52	2.8	159.25	78.88	77.79	2.02	2.05	2676.81	1.92	22.67	0.06	305.44
86.62	2.9	167.05	79.32	78.16	2.11	2.14	2796.07	1.97	22.78	0.06	329
86.72	3	174.88	79.75	78.53	2.19	2.23	2902.08	2.01	22.87	0.06	352.3
86.82	3.1	182.75	80.19	78.9	2.28	2.32	3021.35	2.06	22.97	0.07	377.27
86.92	3.2	190.66	80.62	79.28	2.36	2.41	3127.36	2.11	23.06	0.07	401.92
87.02	3.3	198.61	81.06	79.65	2.45	2.49	3246.62	2.16	23.15	0.07	428.29
87.12	3.4	206.94	91.96	90.45	2.25	2.29	2981.59	2.05	22.94	0.07	423.79
87.22	3.5	216.36	98.96	97.28	2.19	2.22	2902.08	2.01	22.87	0.06	435.86
87.32	3.6	226.2	100.36	98.53	2.25	2.3	2981.59	2.05	22.94	0.07	463.23
87.42	3.7	236.05	100.59	98.62	2.35	2.39	3114.11	2.1	23.05	0.07	496.33
87.52	3.8	245.92	100.82	98.7	2.44	2.49	3233.37	2.15	23.14	0.07	529

Velocity Formula	Mannings Equation
Roughness coefficent	Limerino's 'n"
Bed material D84	23 mm
Sediment Transport	Parker (1990)
	mean diameter bed material .20 mm
Energy slope	0.00011 (slope)

Figure 33. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Station 8 for the Stream Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red.

USGS Streamstats Report for Site 8

Date: Wed Sep 15 2010 09:24:50 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.7913 (43 47 29)
NAD27 Longitude: -92.9715 (-92 58 17)
NAD83 Latitude: 43.7913 (43 47 29)
NAD83 Longitude: -92.9717 (-92 58 18)
Drainage Area: 113 mi2

Peak Flow Basin Characteristics			
100% Region D (113 mi2)			
	Value	**Regression Equation Valid Range**	
Parameter		**Min**	**Max**
Drainage Area (square miles)	113	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	4.17	1.49	77.2

Percent Lakes and Ponds (percent)	0.00	0	14
Generalized Runoff (inches)	7.32	2.15	7.8

Peak Flow Stream flow Statistics					
Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	629	64	3.1	221	1360
PK2	901	56	3.5	356	1830
PK5	1790	50	6.3	802	3370
PK10	2540	51	8.8	1150	4780
PK25	3680	55	11	1610	7080
PK50	4660	60	13	1950	9210
PK100	5780	65	14	2300	11800
PK500	8740	78	15	3000	19400

Figure 34.. Watershed (113 square miles) used in the USGS StreamStat Regession Flow Calaulations for Station 8.

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Main Branch Cedar River
Reach Name: Stat 8 CR1 <-- This is not a Reference Reach
Drainage Area: 113 sq mi
State: Minnesota
County: Mower
Latitude: 43.7913
Longitude: -92.9717
Survey Date: 09/01/2009

Classification Data

Valley Type:	Type VIII
Valley Slope:	0 ft/ft
Number of Channels:	Single
Width:	98.47 ft
Mean Depth:	2.22 ft
Flood-Prone Width:	230 ft
Channel Materials D50:	0.08 mm
Water Surface Slope:	0.00011 ft/ft
Sinuosity:	1.38
Discharge:	0 cfs
Velocity:	0 fps
Cross Sectional Area:	218.32 sq ft
Entrenchment Ratio:	2.34
Width to Depth Ratio:	44.36

Rosgen Stream Classification: C 5c-

Figure 35. Stream Classification for Station 8 on the Cedar River

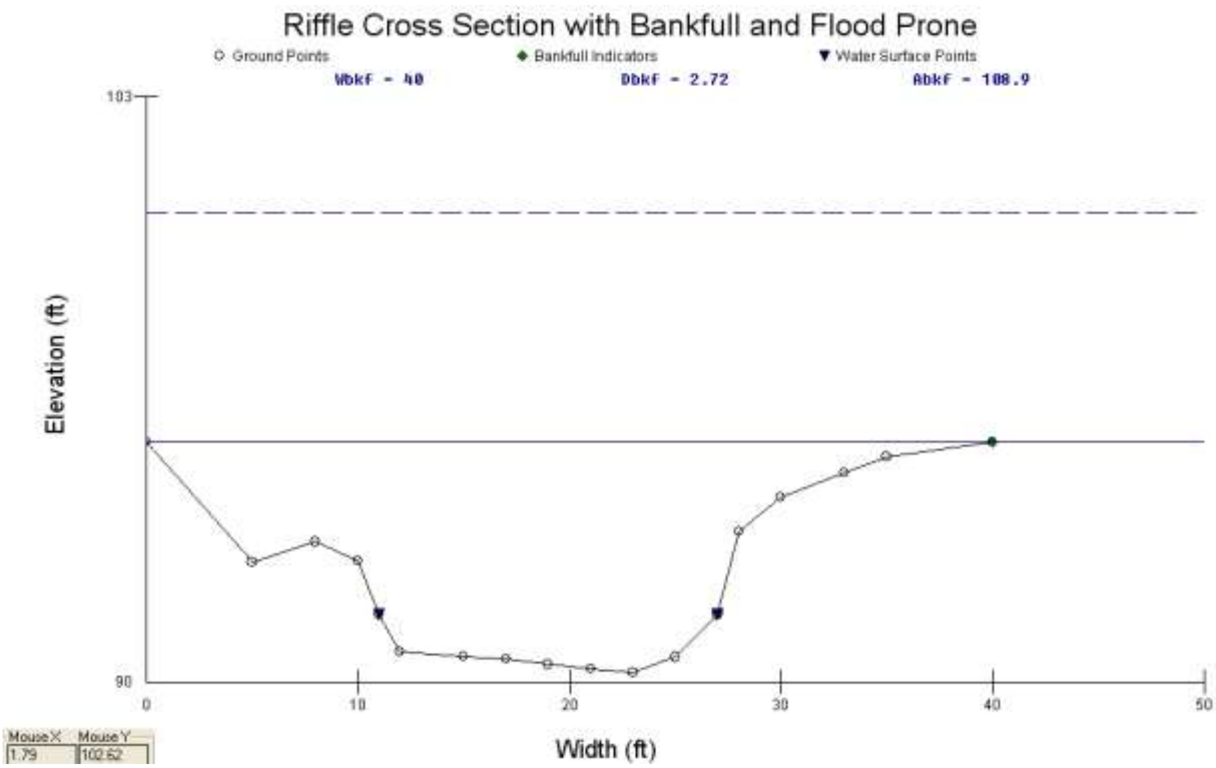


Figure 36. Riffle Cross Section for Station 11 on the Cedar River

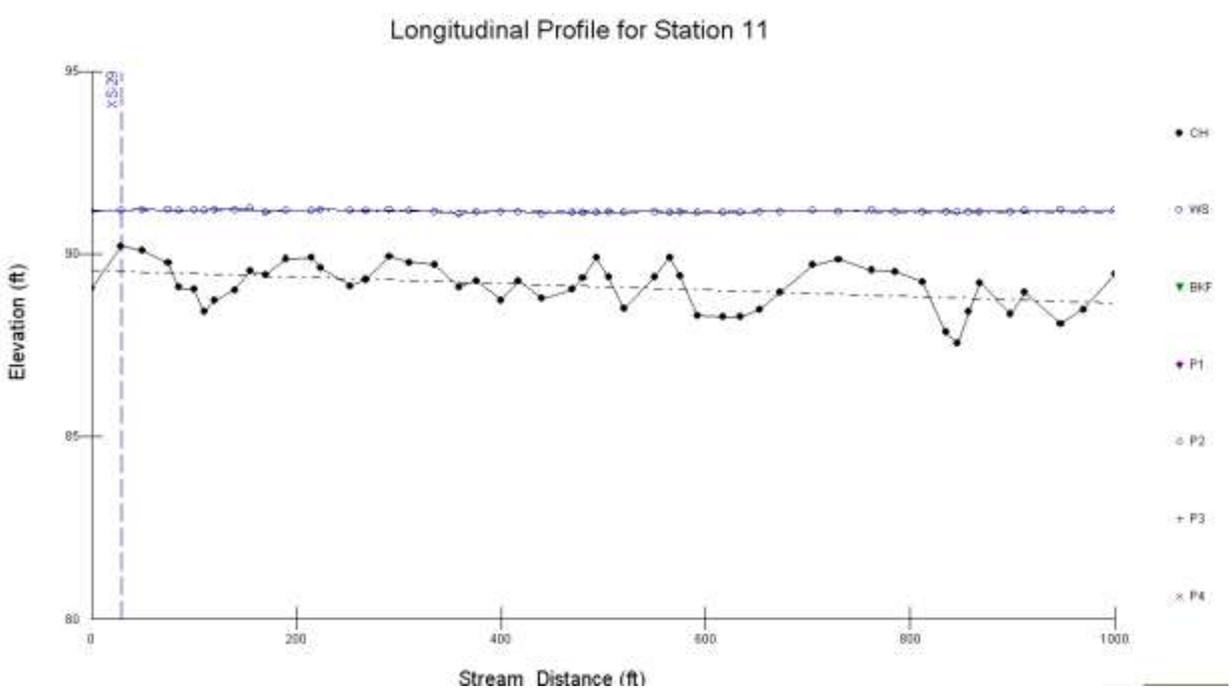


Figure 37. Longitudinal Profile for Station 11 on the Cedar River

ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	MEAN D	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
93.52	3.3	53.84	27.61	25.08	1.95	2.15	178.48	2.2	16.02	0.08	118.38
93.62	3.4	56.37	28.11	25.54	2.01	2.21	183.97	2.24	16.1	0.08	126.43
93.72	3.5	58.94	28.61	25.99	2.06	2.27	188.55	2.28	16.16	0.08	134.33
93.82	3.6	61.57	29.1	26.44	2.12	2.33	194.04	2.32	16.23	0.08	142.97
93.92	3.7	64.23	29.6	26.9	2.17	2.39	198.61	2.36	16.28	0.09	151.43
94.02	3.8	66.95	30.1	27.35	2.22	2.45	203.19	2.39	16.34	0.09	160.2
94.12	3.9	69.7	30.65	27.86	2.27	2.5	207.77	2.43	16.39	0.09	169.21
94.22	4	72.53	31.41	28.59	2.31	2.54	211.43	2.46	16.44	0.09	178.09
94.32	4.1	75.42	32.18	29.33	2.34	2.57	214.17	2.48	16.47	0.1	186.74
94.42	4.2	78.39	32.95	30.06	2.38	2.61	217.83	2.5	16.51	0.1	196.24
94.52	4.3	81.44	33.72	30.79	2.42	2.64	221.5	2.53	16.55	0.1	206.1
94.62	4.4	84.55	34.48	31.53	2.45	2.68	224.24	2.55	16.58	0.1	215.68
94.72	4.5	87.74	35.26	32.27	2.49	2.72	227.9	2.58	16.62	0.1	226.18
94.82	4.6	91	36.03	33.01	2.53	2.76	231.56	2.6	16.66	0.11	237.02
94.92	4.7	94.34	36.81	33.75	2.56	2.8	234.31	2.62	16.69	0.11	247.6
95.02	4.8	97.76	37.69	34.6	2.59	2.83	237.06	2.64	16.72	0.11	258.52
95.12	4.9	101.31	39.52	36.4	2.56	2.78	234.31	2.62	16.69	0.11	265.89
95.22	5	105.04	41.35	38.2	2.54	2.75	232.48	2.61	16.67	0.11	274.29

Velocity Formula	Mannings Equation
Roughness coefficent	Limerino's 'n"
Bed material D84	3.33 mm
Sediment Transport	Parker (1990)
	mean diameter bed material 1.65 mm
Energy slope	0.0003 (water slope)

Figure 38. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Station 8 for the Stream Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red.

Streamstats Site 11 Report

Date: Wed Sep 15 2010 09:06:21 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.8751 (43 52 30)
NAD27 Longitude: -92.9348 (-92 56 05)
NAD83 Latitude: 43.8751 (43 52 30)
NAD83 Longitude: -92.9350 (-92 56 06)
Drainage Area: 25.3 mi2

Peak Flow Basin Characteristics

100% Region D (25.3 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	25.3	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	7.55	1.49	77.2
Percent Lakes and Ponds (percent)	0.00	0	14
Generalized Runoff (inches)	7.36	2.15	7.8

Peak Flow Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	254	63	3.1	89.9	544
PK2	362	56	3.5	144	730
PK5	714	50	6.3	323	1340
PK10	1010	51	8.8	461	1890
PK25	1460	55	11	643	2780
PK50	1840	60	13	778	3600
PK100	2280	65	14	915	4600
PK500	3440	78	15	1200	7530

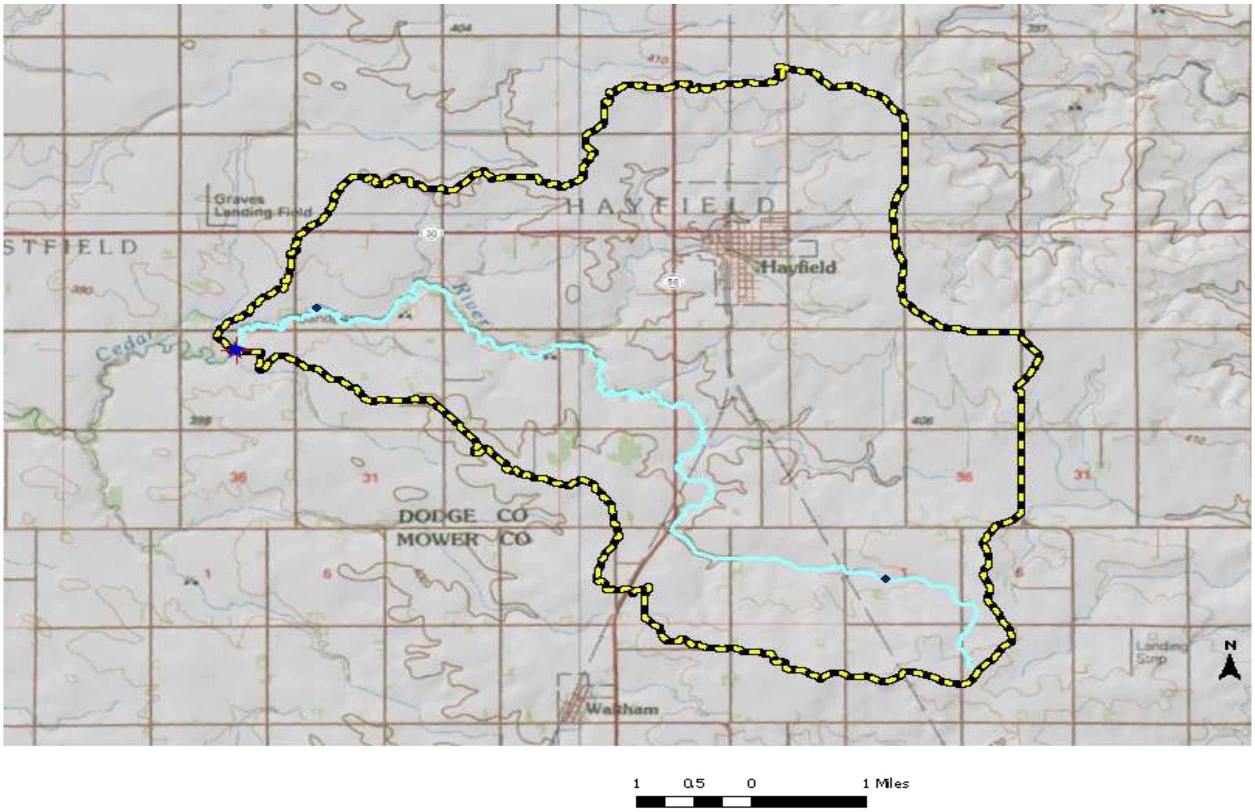


Figure 39.. Watershed (25 square miles) used in the USGS StreamStat Regession Flow Calaulations for Station 11

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RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Main Branch Cedar River
Reach Name: Stat 11 740th street <-- This is not a Reference Reach
Drainage Area: 25.3 sq mi
State: Minnesota
County: Mower
Latitude: 43.8751
Longitude -92.935
Survey Date: 09/10/2009

Classification Data

Valley Type:	Type VIII
Valley Slope:	0 ft/ft
Number of Channels:	Single
Width:	40 ft
Mean Depth:	2.72 ft
Flood-Prone Width:	300 ft
Channel Materials D50:	0.09 mm
Water Surface Slope:	0.0003 ft/ft
Sinuosity:	0
Discharge:	0 cfs
Velocity:	0 fps
Cross Sectional Area:	108.94 sq ft
Entrenchment Ratio:	7.5
Width to Depth Ratio:	14.71

Rosgen Stream Classification: C 5c-

Figure 40. Stream Classification for Station 11 on the Cedar River

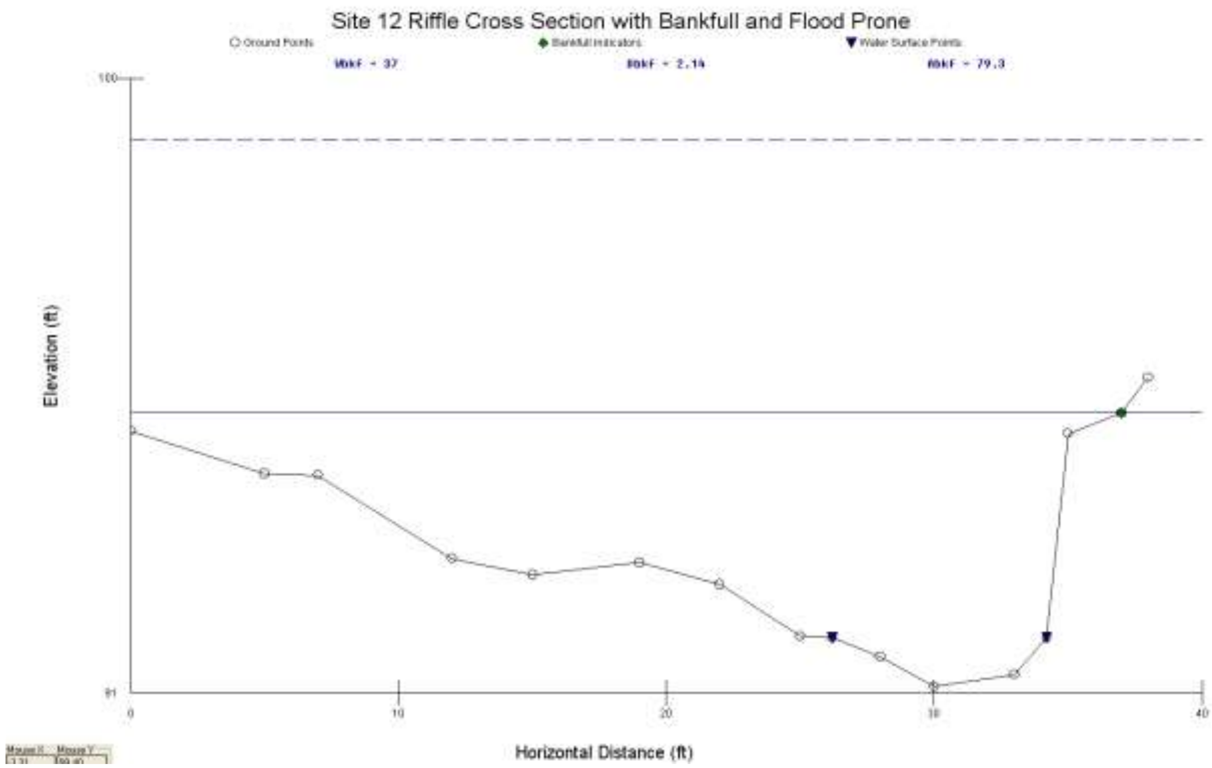


Figure 41. Riffle Cross Section for Station 12 on the Cedar River.

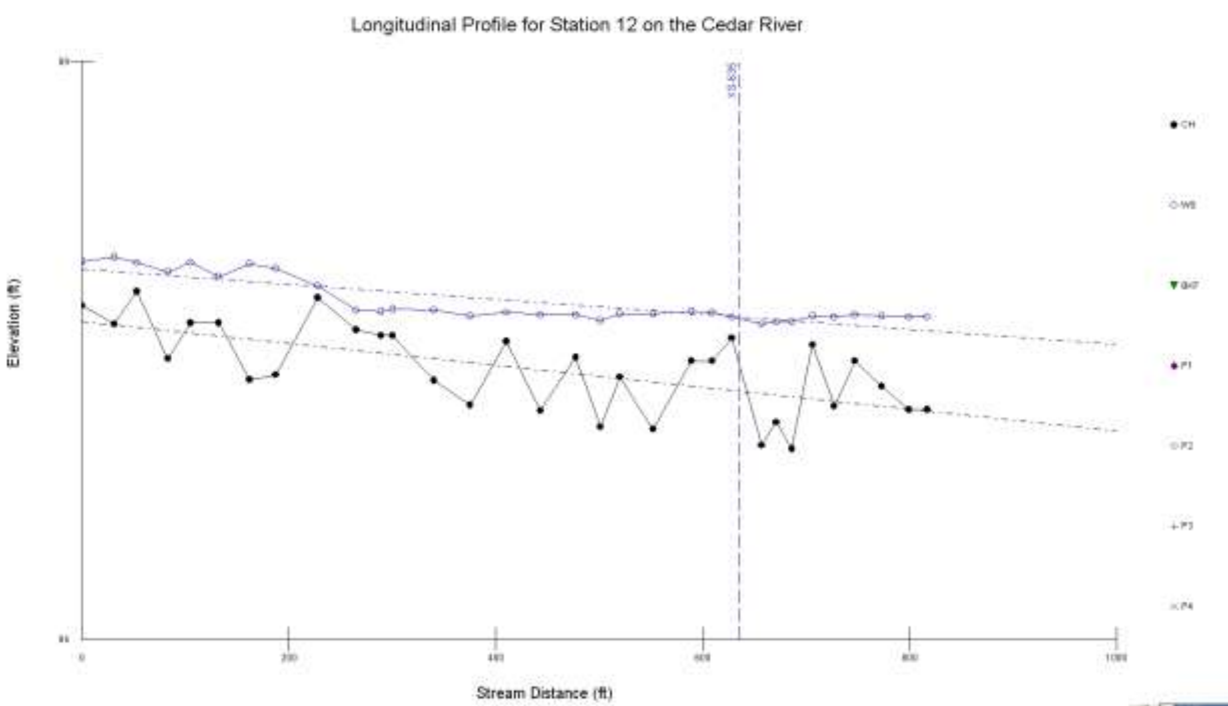


Figure 42. Longitudinal Profile for Station 12 on the Cedar River

ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	MEAN D	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
93.89	2.8	40.76	28.55	26.53	1.43	1.54	36.44	1.93	12.12	0.06	78.6
93.99	2.9	43.44	29.08	26.96	1.49	1.61	37.97	1.98	12.22	0.06	86.22
94.09	3	46.16	29.6	27.4	1.56	1.68	39.75	2.05	12.33	0.07	94.61
94.19	3.1	48.92	30.13	27.84	1.62	1.76	41.28	2.1	12.42	0.07	102.94
94.29	3.2	51.91	32.87	30.5	1.58	1.7	40.26	2.07	12.36	0.07	107.34
94.39	3.3	55	33.77	31.32	1.63	1.76	41.54	2.11	12.44	0.07	116.24
94.49	3.4	58.17	34.68	32.14	1.68	1.81	42.81	2.16	12.51	0.07	125.55
94.59	3.5	61.43	35.58	32.96	1.73	1.86	44.09	2.2	12.58	0.08	135.32
94.69	3.6	64.76	36.48	33.78	1.78	1.92	45.36	2.25	12.65	0.08	145.51
94.79	3.7	68.18	37.39	34.6	1.82	1.97	46.38	2.28	12.71	0.08	155.57
94.89	3.8	71.69	38.19	35.33	1.88	2.03	47.91	2.33	12.79	0.08	167.3
94.99	3.9	75.24	38.67	35.7	1.95	2.11	49.69	2.39	12.88	0.09	180.08
95.09	4	78.83	39.15	36.06	2.01	2.19	51.22	2.44	12.95	0.09	192.66
95.19	4.1	82.45	39.63	36.43	2.08	2.26	53.01	2.5	13.04	0.1	206.32
95.29	4.2	86.11	40.11	36.79	2.15	2.34	54.79	2.56	13.12	0.1	220.44
95.39	4.3	89.81	40.59	37.16	2.21	2.42	56.32	2.61	13.19	0.11	234.3
95.49	4.4	93.54	41.06	37.52	2.28	2.49	58.1	2.67	13.26	0.11	249.3

Velocity Formula	Mannings Equation	
Roughness coefficient	Limerino's 'n"	
Bed material D84	11.96 mm	
Sediment Transport	Parker (1990)	
	mean diameter bed material 4.79 mm	
Energy slope	0.0006	(water slope)

Figure 43. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Station 8 for the Stream Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red.

Streamstats Site 12 Report

Date: Wed Sep 15 2010 09:11:23 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.8777 (43 52 40)
NAD27 Longitude: -92.8930 (-92 53 35)
NAD83 Latitude: 43.8777 (43 52 40)
NAD83 Longitude: -92.8932 (-92 53 36)
Drainage Area: 20.4 mi2

Peak Flow Basin Characteristics

100% Region D (20.4 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	20.4	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	10.7	1.49	77.2
Percent Lakes and Ponds (percent)	0.00	0	14
Generalized Runoff (inches)	7.37	2.15	7.8

Peak Flow Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	249	64	3.1	88.2	534
PK2	357	56	3.5	142	719
PK5	706	50	6.3	319	1320
PK10	1000	51	8.8	456	1860
PK25	1440	55	11	635	2740
PK50	1810	60	13	768	3550
PK100	2250	65	14	903	4530
PK500	3380	78	15	1180	7410

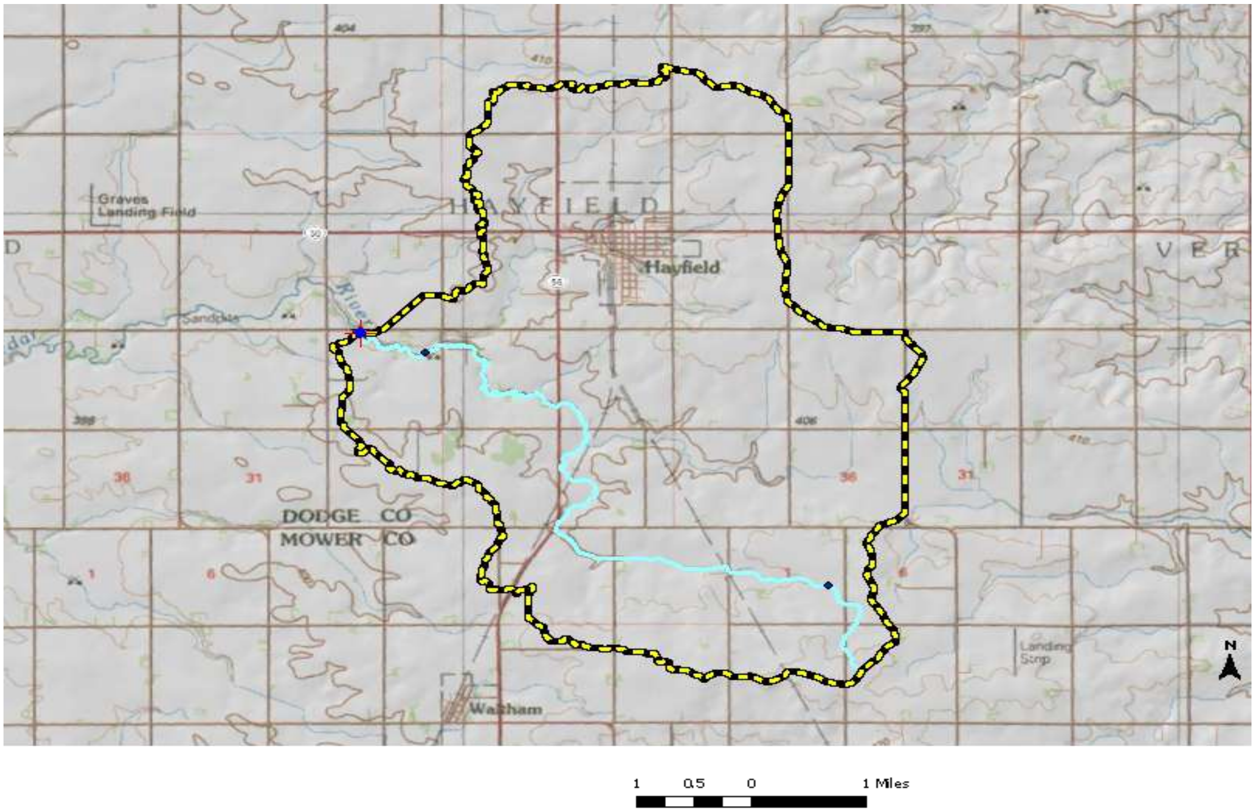


Figure 44.. Watershed (20 square miles) used in the USGS StreamStat Regession Flow Calaulations for Station 12

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Main Branch Cedar River
Reach Name: Stat 12 740th street <-- This is not a Reference Reach
Drainage Area: 20.4 sq mi
State: Minnesota
County: Mower
Latitude: 43.8777
Longitude: -92.8932
Survey Date: 09/11/2009

Classification Data

Valley Type: Type VIII
Valley Slope: 0 ft/ft
Number of Channels: Single
Width:
27.84 ft
Mean Depth: 1.76 ft
Flood-Prone Width: 200 ft
Channel Materials D50: 0.83 mm
Water Surface Slope: 0.0006 ft/ft
Sinuosity: 1.2
Discharge: 0 cfs
Velocity: 0
fps
Cross Sectional Area: 48.92 sq ft
Entrenchment Ratio: 7.18
Width to Depth Ratio: 15.82

Rosgen Stream Classification: C 5c-

Figure 45. Stream Classification for Station 12 on the Cedar River

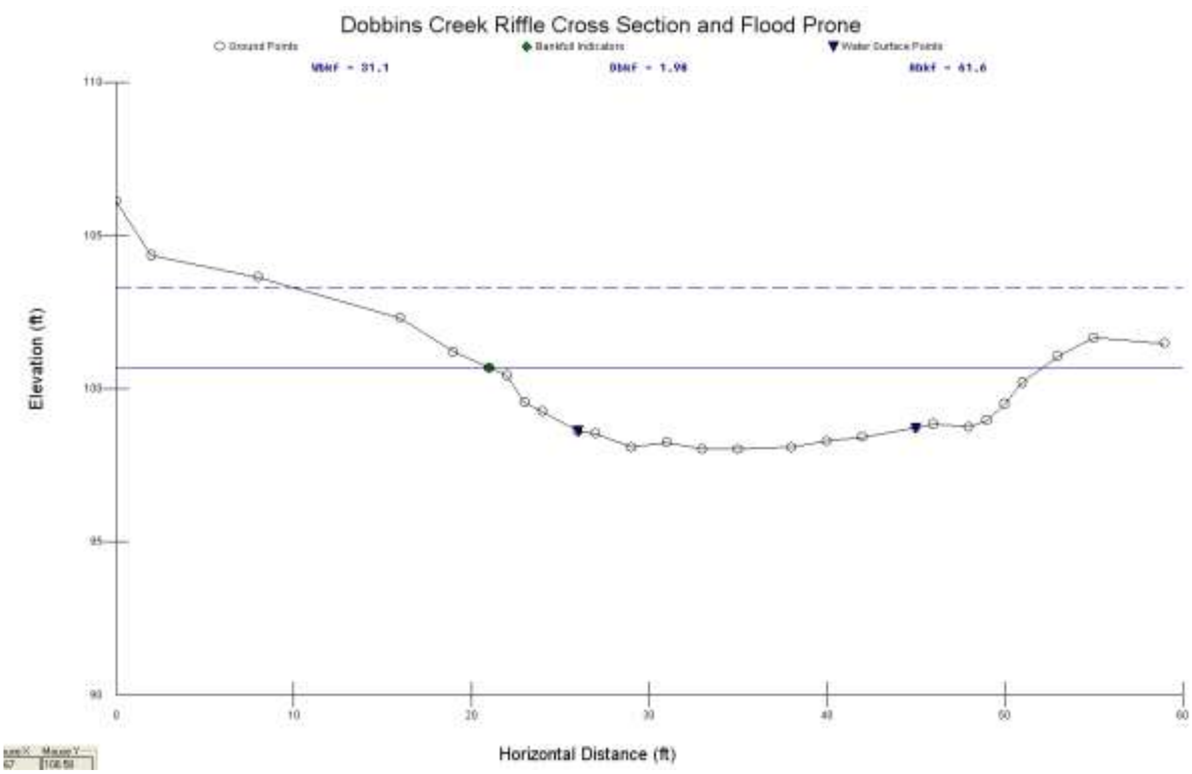


Figure 46. Stream Cross Section for Dobbins Creek in Austin

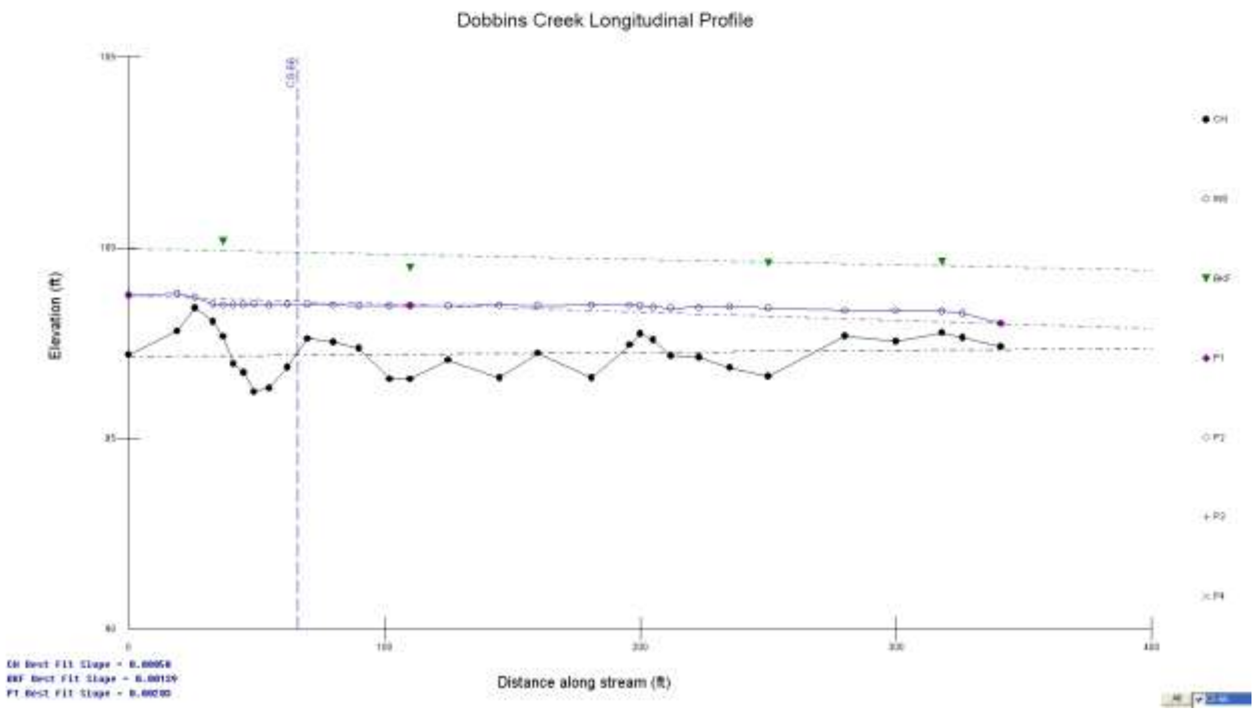


Figure 47. Longitudinal Profile for Dobbins Creek near Austin

ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	MEAN D	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
99.42	1.4	26.02	26.82	26.44	0.97	0.98	7.38	2.19	8.19	0.07	57.01
99.52	1.5	28.69	27.38	26.96	1.05	1.06	7.99	2.33	8.39	0.08	66.96
99.62	1.6	31.4	27.75	27.26	1.13	1.15	8.6	2.47	8.57	0.09	77.66
99.72	1.7	34.14	28.08	27.52	1.22	1.24	9.28	2.63	8.76	0.11	89.66
99.82	1.8	36.9	28.4	27.78	1.3	1.33	9.89	2.76	8.91	0.12	101.82
99.92	1.9	39.69	28.73	28.04	1.38	1.42	10.5	2.89	9.06	0.13	114.7
100.02	2	42.51	29.06	28.3	1.46	1.5	11.11	3.02	9.2	0.14	128.29
100.12	2.1	45.35	29.39	28.56	1.54	1.59	11.72	3.14	9.33	0.15	142.56
100.22	2.2	48.22	29.74	28.84	1.62	1.67	12.33	3.27	9.45	0.17	157.55
100.32	2.3	51.13	30.14	29.19	1.7	1.75	12.93	3.39	9.57	0.18	173.27
100.42	2.4	54.06	30.54	29.53	1.77	1.83	13.47	3.49	9.67	0.19	188.87
100.52	2.5	57.05	31.2	30.16	1.83	1.89	13.92	3.58	9.75	0.2	204.39
100.62	2.6	60.09	31.87	30.79	1.89	1.95	14.38	3.67	9.83	0.21	220.56
100.72	2.7	63.2	32.52	31.41	1.94	2.01	14.76	3.74	9.9	0.22	236.55
100.82	2.8	66.37	33.17	32.03	2	2.07	15.22	3.83	9.97	0.23	254.14
100.92	2.9	69.61	33.82	32.64	2.06	2.13	15.67	3.91	10.04	0.24	272.48

Velocity Formula	Mannings Equation
Roughness coefficient	Limerino's 'n"
Bed material D84	40.6 mm
Sediment Transport	Parker (1990)
	mean diameter bed material 24.5 mm
Energy slope	0.00229 (water slope)

Figure 48. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Dobbins Creek8 for the Stream Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red.

Streamstats Ungaged Site Report for Dobbins Creek

Date: Mon Sep 20 2010 13:04:40 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.6773 (43 40 38)
NAD27 Longitude:-92.9367 (-92 56 12)
NAD83 Latitude: 43.6773 (43 40 38)
NAD83 Longitude:-92.9369 (-92 56 13)
Drainage Area: 19.2 mi2

Peak Flow Basin Characteristics			
100% Region D (19.2 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	19.2	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	8.47	1.49	77.2
Percent Lakes and Ponds (percent)	0.00	0	14

Generalized Runoff (inches)	7.53	2.15	7.8

Peak Stream flow Statistics					
Statistic	**Flow (ft^3/s)**	**Prediction Error (percent)**	**Equivalent years of record**	**90-Percent Prediction Interval**	
				Minimum	**Maximum**
PK1_5	220	64	3.1	78.1	473
PK2	314	56	3.5	125	633
PK5	615	50	6.3	278	1150
PK10	869	51	8.8	396	1620
PK25	1250	55	11	550	2380
PK50	1570	60	13	664	3080
PK100	1940	65	14	780	3930
PK500	2920	78	15	1020	6410

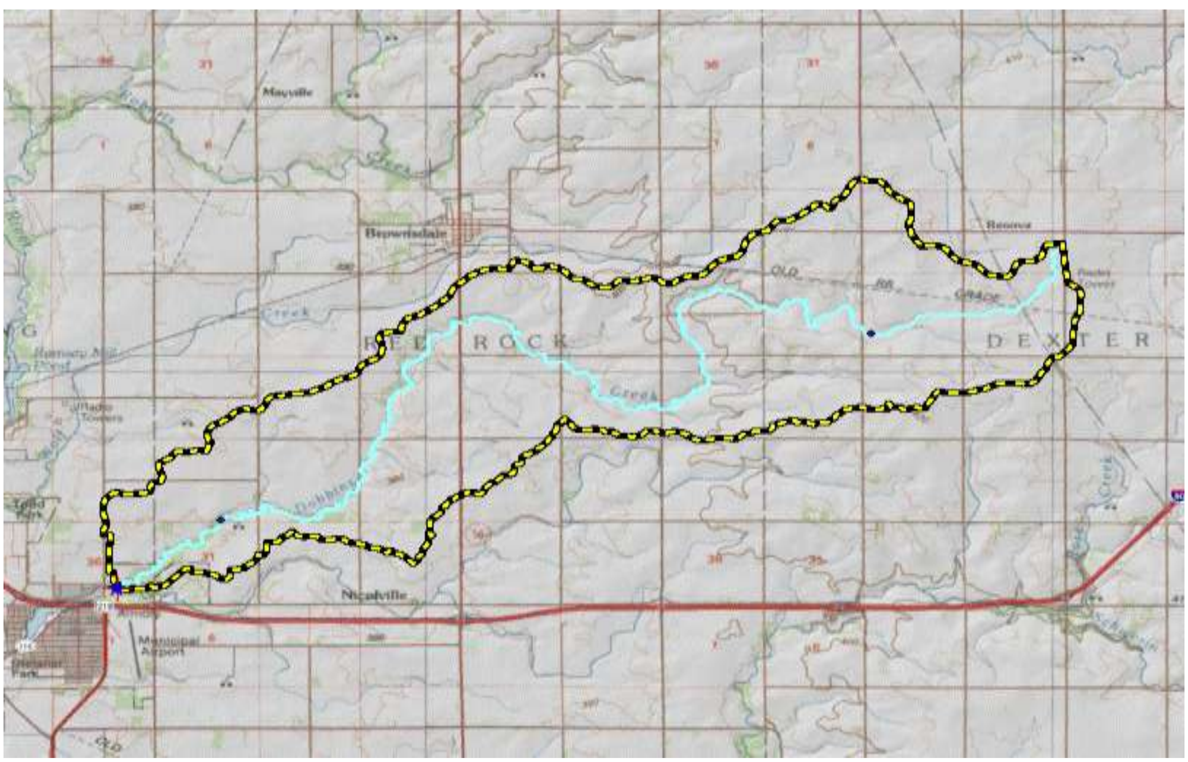


Figure 49.. Watershed (19 square miles) used in the USGS StreamStat Regession Flow Calaulations for Dobbins Creek near Austin.

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Dobbins Creek North
Reach Name: Reach 1 <-- This is not a Reference Reach
Drainage Area: 19.2 sq mi
State: Minnesota
County: Freeborn
Latitude: 43.67724
Longitude: -92.93674
Survey Date: 04/13/2010

Classification Data

Valley Type:	Type VII
Valley Slope:	0 ft/ft
Number of Channels:	Single
Width:	31.1 ft
Mean Depth:	1.98 ft
Flood-Prone Width:	250 ft
Channel Materials D50:	19.03 mm
Water Surface Slope:	0.00229 ft/ft
Sinuosity:	1.66
Discharge:	0 cfs
Velocity:	0 fps
Cross Sectional Area:	61.64 sq ft
Entrenchment Ratio:	8.04
Width to Depth Ratio:	15.71

Rosgen Stream Classification: C 4

Figure 50. Stream Classification for Dobbins Creek near Austin

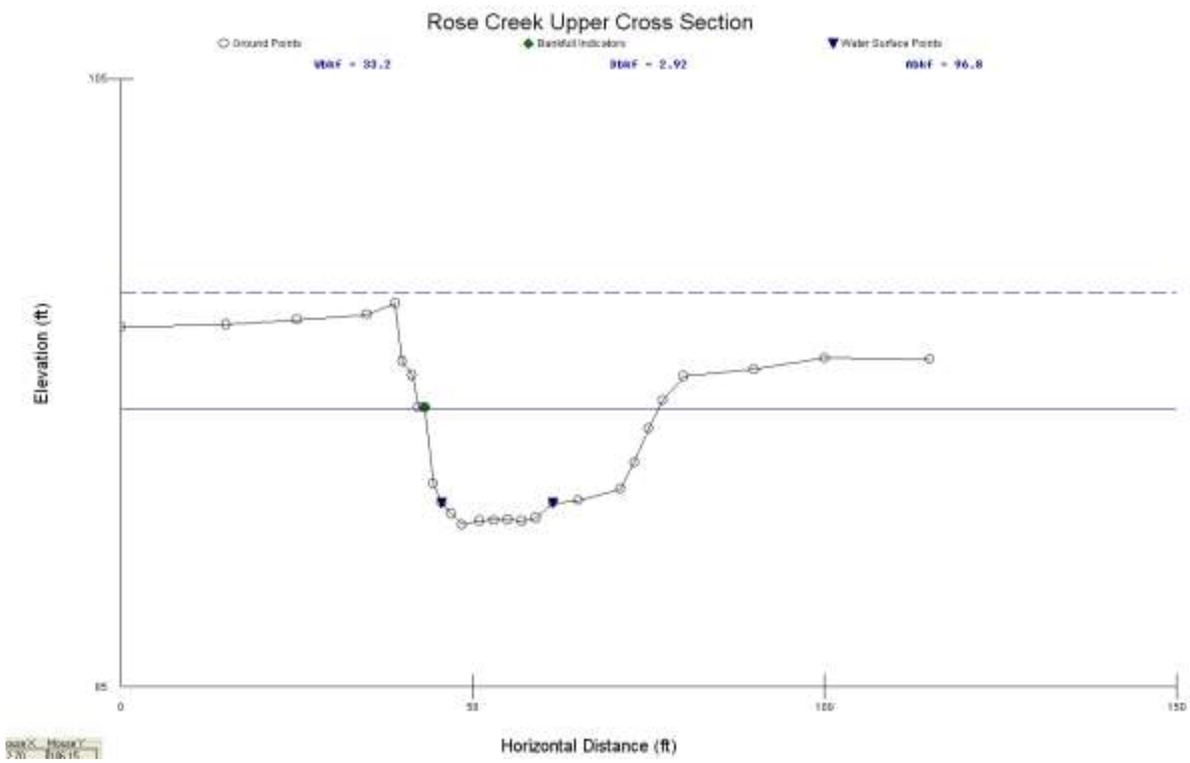


Figure 51. Riffle Cross Section with Bankfull and Flood Prone Area for Upper Rose Creek

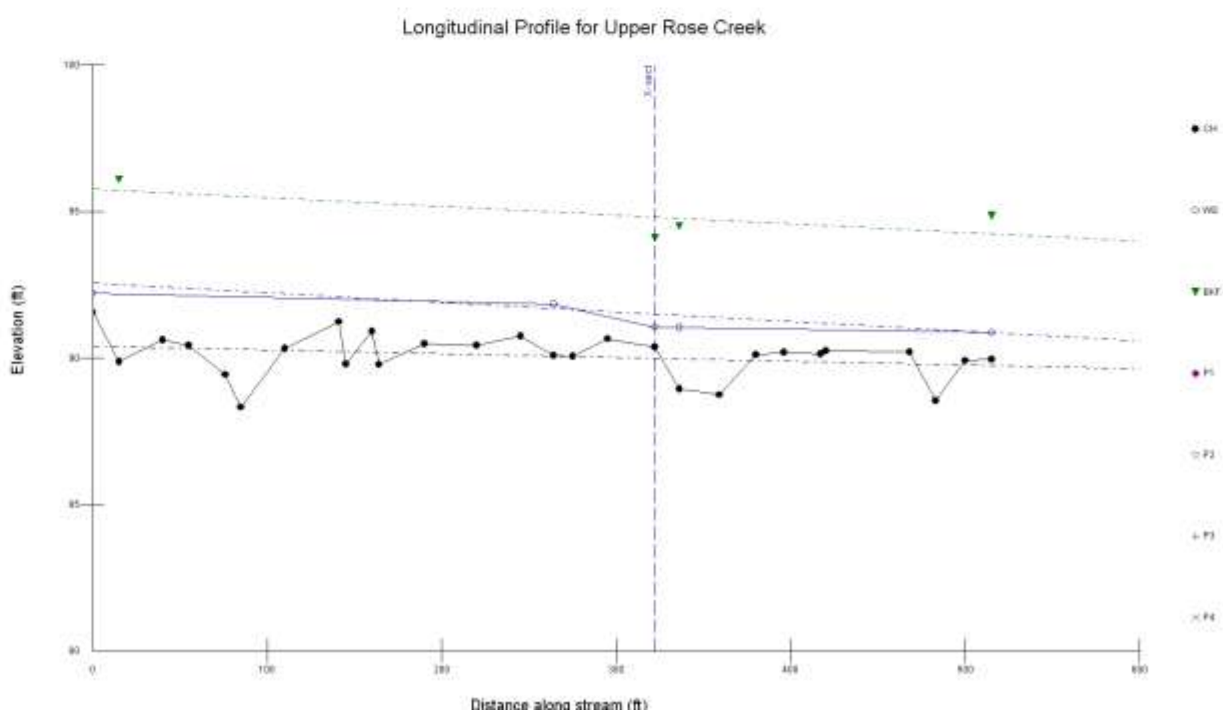


Figure 52. Longitudinal Profile for Upper Rose Creek

ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	MEAN D	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
94.03	3.7	92.88	35.24	32.85	2.64	2.83	20.37	5.01	10.69	0.39	465.79
94.13	3.8	96.18	35.59	33.12	2.7	2.9	20.83	5.1	10.74	0.4	490.31
94.23	3.9	99.53	36.83	34.29	2.7	2.9	20.83	5.1	10.74	0.4	507.39
94.33	4	102.98	37.21	34.59	2.77	2.98	21.37	5.19	10.81	0.42	534.85
94.43	4.1	106.45	37.58	34.9	2.83	3.05	21.84	5.28	10.86	0.43	561.55
94.53	4.2	109.96	38.1	35.36	2.89	3.11	22.3	5.36	10.91	0.45	588.97
94.63	4.3	113.52	38.63	35.83	2.94	3.17	22.69	5.42	10.95	0.46	615.64
94.73	4.4	117.13	39.15	36.29	2.99	3.23	23.07	5.49	10.99	0.47	643.02
94.83	4.5	120.78	39.67	36.76	3.04	3.29	23.46	5.56	11.03	0.48	671.06
94.93	4.6	124.48	40.2	37.22	3.1	3.34	23.92	5.64	11.08	0.49	701.45
95.03	4.7	128.23	40.72	37.69	3.15	3.4	24.31	5.7	11.12	0.5	730.97
95.13	4.8	132.02	41.25	38.16	3.2	3.46	24.69	5.77	11.16	0.52	761.16
95.23	4.9	135.86	42.19	39.04	3.22	3.48	24.85	5.79	11.18	0.52	786.82
95.33	5	140	47.02	43.84	2.98	3.19	22.99	5.48	10.99	0.47	766.71
95.43	5.1	144.63	51.88	48.69	2.79	2.97	21.53	5.22	10.82	0.42	755.11
95.53	5.2	149.67	55.09	51.88	2.72	2.88	20.99	5.13	10.76	0.41	767.11
95.63	5.3	155.01	58.12	54.89	2.67	2.82	20.6	5.06	10.72	0.4	783.8
95.73	5.4	160.64	61.1	57.85	2.63	2.78	20.29	5	10.68	0.39	803.38
95.83	5.5	167.09	78.43	75.06	2.13	2.23	16.44	4.28	10.16	0.28	715.53
95.93	5.6	174.6	78.64	75.12	2.22	2.32	17.13	4.42	10.26	0.3	770.96

Velocity Formula	Mannings Equation
Roughness coefficient	Limerino's 'n"
Bed material D84	39.5 mm
Sediment Transport	Parker (1990)
	mean diameter bed material 10.4 mm
Energy slope	0.00259 (water slope)

Figure 53. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Upper Rose Creek for the Stream Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red.

Basin Characteristics Report

Date: Mon May 23 2011 08:18:28 Mountain Daylight Time
NAD27 Latitude: 43.6552 (43 39 19)
NAD27 Longitude: -92.8113 (-92 48 41)
NAD83 Latitude: 43.6552 (43 39 19)
NAD83 Longitude: -92.8115 (-92 48 41)

Parameter	Value
Channel 10-85 slope in feet per mile	9.9
Percent area covered by soil type A	0.00
Log of drainage area in square miles	1.42
Percent area covered by lakes and ponds	0.00
Drainage Area in square miles	26.3
Generalized mean annual runoff in Minnesota 1951-85	7.62

Streamstats Ungaged Site Report

Date: Mon May 23 2011 08:20:20 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.6552 (43 39 19)
NAD27 Longitude: -92.8113 (-92 48 41)
NAD83 Latitude: 43.6552 (43 39 19)
NAD83 Longitude: -92.8115 (-92 48 41)
Drainage Area: 26.3 mi2

Peak Flow Basin Characteristics			
100% Region D (26.3 mi2)			
	Value	**Regression Equation Valid Range**	
Parameter		**Min**	**Max**
Drainage Area (square miles)	26.3	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	9.9	1.49	77.2
Percent Lakes and Ponds (percent)	0.00	0	14
Generalized Runoff (inches)	7.62	2.15	7.8

Peak Flow Streamflow Statistics					
Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	305	64	3.1	108	656
PK2	436	56	3.5	173	879
PK5	856	50	6.3	386	1610
PK10	1210	51	8.8	549	2260
PK25	1730	55	11	763	3320
PK50	2180	60	13	921	4290
PK100	2700	65	14	1080	5480
PK500	4060	78	15	1410	8930

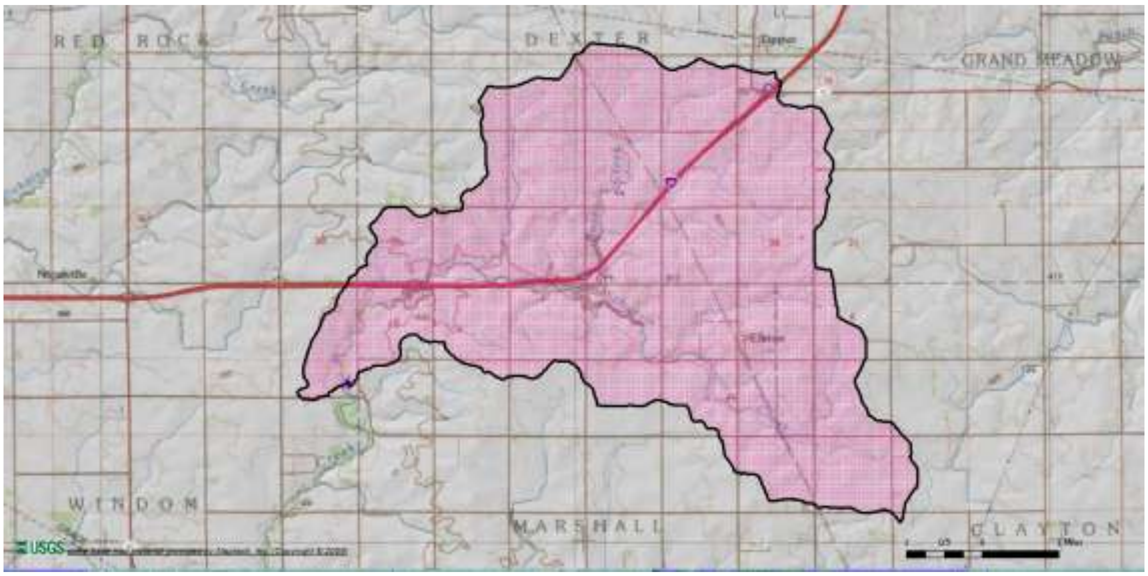


Figure 54.. Watershed (26.4 square miles) used in the USGS StreamStat Regession Flow Calaulations for Upper Rose Creek.

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Cedar Basin Tribs

Reach Name: Rose Creek Upper <-- This is not a Reference Reach

Drainage Area: 26.3 sq mi

State: Minnesota

County: Mower

Latitude: 43.65503

Longitude: -92.811426

Survey Date: 10/20/2010

Classification Data

Valley Type:	Type VIII
Valley Slope:	0 ft/ft
Number of Channels:	Single
Width:	33.17 ft
Mean Depth:	2.92 ft
Flood-Prone Width:	150 ft
Channel Materials D50:	2.27 mm
Water Surface Slope:	0.00259 ft/ft
Sinuosity:	2.78
Discharge:	0 cfs
Velocity:	0 fps
Cross Sectional Area:	96.84 sq ft
Entrenchment Ratio:	4.52
Width to Depth Ratio:	11.36

Rosgen Stream Classification: E 4

Figure 55. Stream Classification for Upper Rose Creek

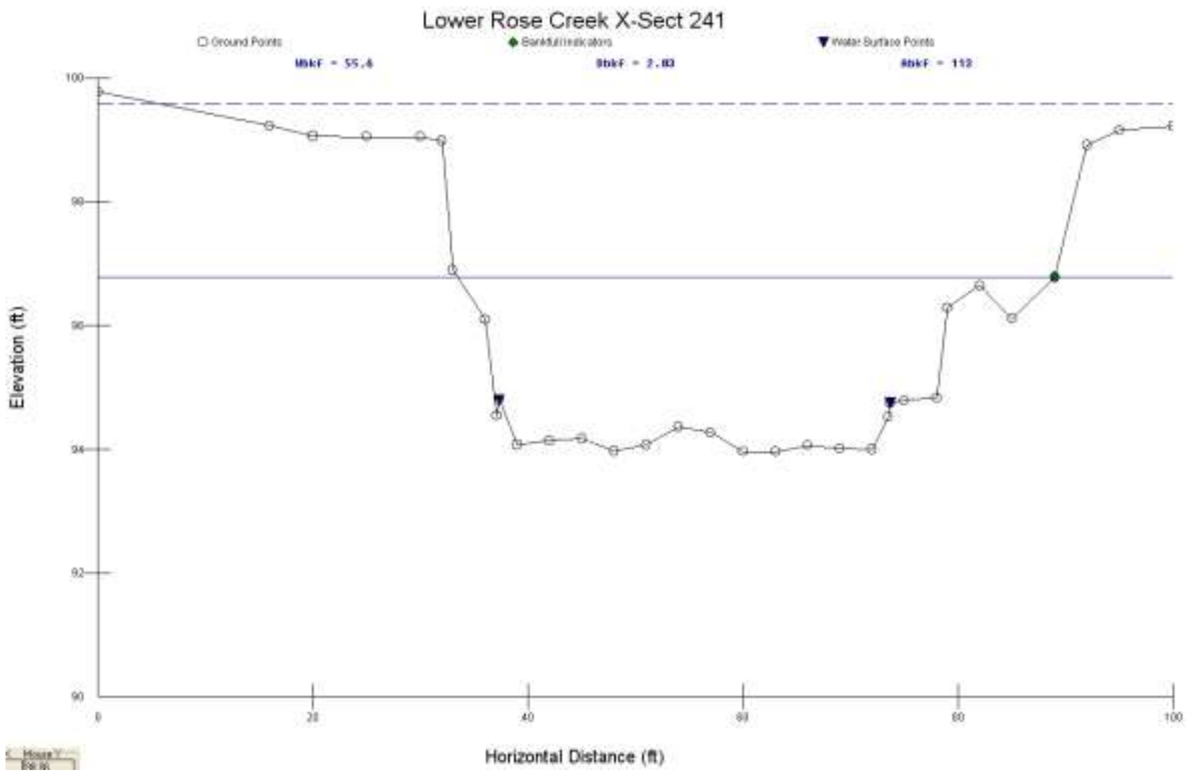


Figure 56. Riffle Cross Section for Lower Rose Creek with Bankfull and Flood Prone.

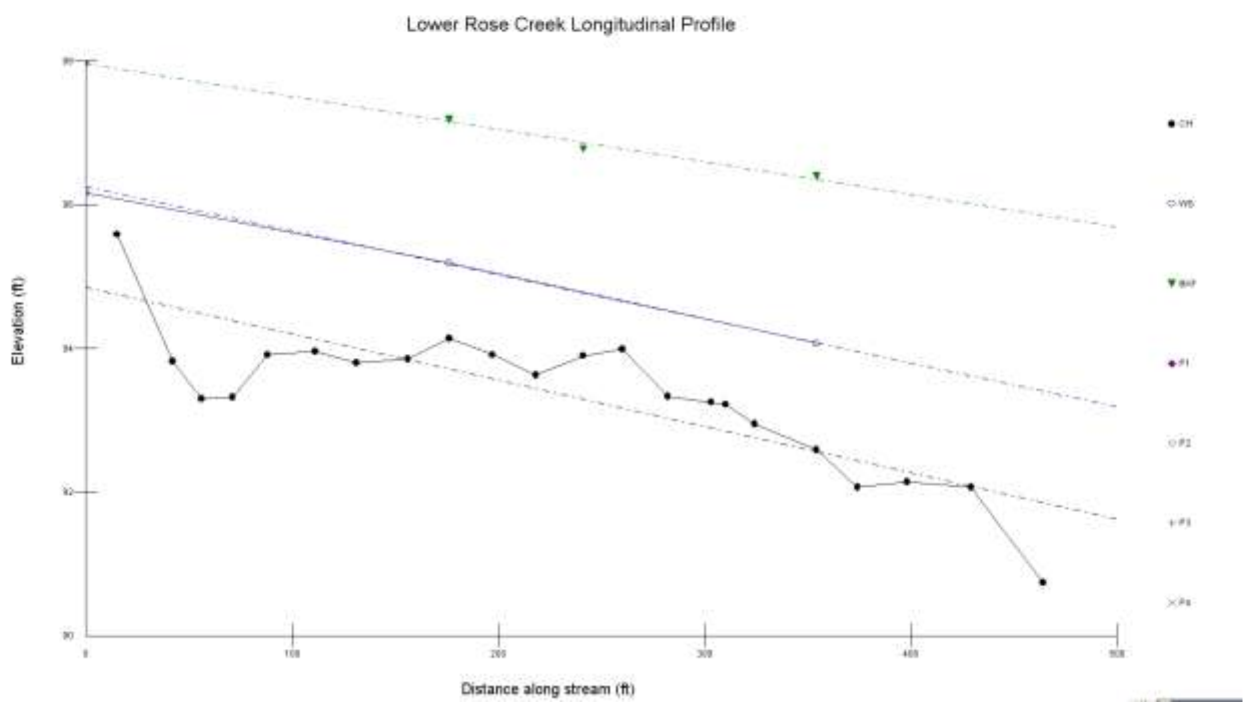


Figure 57. Stream Longitudinal Profile for Lower Rose Creek

ELEV (ft)	DEPTH (ft)	AREA (sq ft)	WET PER (ft)	WIDTH (ft)	HYD RAD (ft)	MEAN D (ft)	R/D84 (fps)	VELOCITY	U/U* (ft)	U^2/2g (cfs)	DISCHARGE
94.06	0.1	0.93	17.21	17.19	0.05	0.05	0.25	0	0	0	0
94.16	0.2	3.05	26.45	26.38	0.12	0.12	0.61	0.38	2.07	0	1.15
94.26	0.3	5.92	30.17	30.05	0.2	0.2	1.02	0.78	3.33	0.01	4.61
94.36	0.4	9.15	34.86	34.69	0.26	0.26	1.33	1.06	3.97	0.02	9.7
94.46	0.5	12.64	35.41	35.21	0.36	0.36	1.83	1.5	4.77	0.03	18.94
94.56	0.6	16.19	35.97	35.7	0.45	0.45	2.29	1.87	5.32	0.05	30.23
94.66	0.7	19.78	36.6	36.17	0.54	0.55	2.75	2.22	5.77	0.08	43.87
94.76	0.8	23.42	37.55	36.96	0.62	0.63	3.16	2.52	6.11	0.1	58.93
94.86	0.9	27.37	41.84	41.15	0.65	0.67	3.31	2.63	6.22	0.11	71.86
94.96	1	31.49	42.08	41.29	0.75	0.76	3.82	2.98	6.58	0.14	93.83
95.06	1.1	35.62	42.32	41.42	0.84	0.86	4.28	3.29	6.85	0.17	117.08
95.16	1.2	39.77	42.57	41.56	0.93	0.96	4.74	3.58	7.11	0.2	142.56
95.26	1.3	43.94	42.81	41.7	1.03	1.05	5.25	3.91	7.36	0.24	171.62
95.36	1.4	48.11	43.06	41.84	1.12	1.15	5.71	4.19	7.56	0.27	201.42
95.46	1.5	52.3	43.3	41.98	1.21	1.25	6.17	4.46	7.75	0.31	233.31
95.56	1.6	56.51	43.54	42.12	1.3	1.34	6.63	4.73	7.93	0.35	267.24
95.66	1.7	60.73	43.79	42.26	1.39	1.44	7.08	4.99	8.09	0.39	303.13
95.76	1.8	64.96	44.03	42.4	1.48	1.53	7.54	5.25	8.25	0.43	340.95
95.86	1.9	69.21	44.27	42.54	1.56	1.63	7.95	5.47	8.38	0.47	378.8
95.96	2	73.47	44.52	42.68	1.65	1.72	8.41	5.72	8.51	0.51	420.36
96.06	2.1	77.74	44.76	42.81	1.74	1.82	8.87	5.97	8.64	0.55	463.76
96.16	2.2	82.05	45.75	43.71	1.79	1.88	9.12	6.1	8.71	0.58	500.45
96.26	2.3	86.5	47.43	45.31	1.82	1.91	9.28	6.18	8.75	0.59	534.49
96.36	2.4	91.13	49.61	47.44	1.84	1.92	9.38	6.23	8.78	0.6	567.92
96.46	2.5	95.99	52.01	49.8	1.85	1.93	9.43	6.26	8.8	0.61	600.74
96.56	2.6	101.09	54.4	52.16	1.86	1.94	9.48	6.28	8.81	0.61	635.32
96.66	2.7	106.42	56.66	54.38	1.88	1.96	9.58	6.34	8.83	0.62	674.41
96.76	2.8	111.91	57.65	55.36	1.94	2.02	9.89	6.49	8.91	0.65	726.72
96.86	2.9	117.48	58.3	55.96	2.02	2.1	10.3	6.7	9.01	0.7	787.14
96.96	3	123.1	58.7	56.28	2.1	2.19	10.7	6.9	9.11	0.74	849.88
97.06	3.1	128.73	58.98	56.47	2.18	2.28	11.11	7.11	9.2	0.78	914.65
97.16	3.2	134.39	59.26	56.66	2.27	2.37	11.57	7.33	9.3	0.83	984.91
97.26	3.3	140.07	59.54	56.85	2.35	2.46	11.98	7.52	9.38	0.88	1054.03
97.36	3.4	145.76	59.83	57.03	2.44	2.56	12.44	7.74	9.48	0.93	1128.65
97.46	3.5	151.47	60.11	57.22	2.52	2.65	12.84	7.93	9.55	0.98	1201.91

Velocity Formula	Mannings Equation
Roughness coefficient	Limerino's 'n"
Bed material D84	59.8 mm

Sediment Transport	Parker (1990) mean diameter bed material 15.8mm
Energy slope	0.0085 (water slope)

Figure 58. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Lower Rose Creek for the Stream Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red.

Basin Characteristics Report

Date: Mon May 23 2011 10:21:49 Mountain Daylight Time
NAD27 Latitude: 43.6140 (43 36 50)
NAD27 Longitude: -92.9532 (-92 57 12)
NAD83 Latitude: 43.6140 (43 36 50)
NAD83 Longitude: -92.9534 (-92 57 12)

Parameter	Value
Channel 10-85 slope in feet per mile	6.7
Percent area covered by soil type A	0.06
Log of drainage area in square miles	1.81
Percent area covered by lakes and ponds	0.00
Drainage Area in square miles	65.3
Generalized mean annual runoff in Minnesota 1951-85	7.63

Streamstats Ungaged Site Report

Date: Mon May 23 2011 10:23:29 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.6140 (43 36 50)
NAD27 Longitude: -92.9532 (-92 57 12)
NAD83 Latitude: 43.6140 (43 36 50)
NAD83 Longitude: -92.9534 (-92 57 12)
Drainage Area: 65.3 mi2

Peak Flow Basin Characteristics		
100% Region D (65.3 mi2)		
Parameter	Value	Regression Equation Valid Range

		Min	Max
Drainage Area (square miles)	65.3	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	6.7	1.49	77.2
Percent Lakes and Ponds (percent)	0.00	0	14
Generalized Runoff (inches)	7.63	2.15	7.8

Peak Flow Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	526	64	3.1	185	1130
PK2	751	56	3.5	297	1520
PK5	1480	50	6.3	665	2780
PK10	2090	51	8.8	948	3930
PK25	3010	55	11	1320	5790
PK50	3800	60	13	1590	7500
PK100	4700	65	14	1870	9590
PK500	7070	78	15	2430	15700

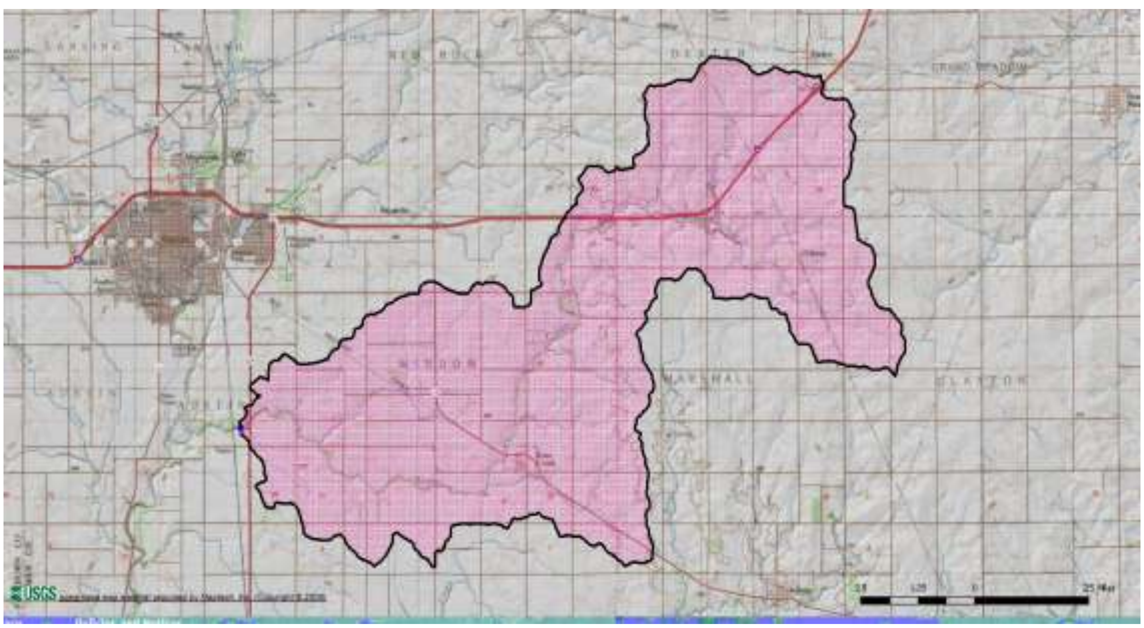


Figure 59. Watershed (65.3 square miles) used in the USGS StreamStat Regession Flow Calaulations for Lower Rose Creek.

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Cedar Basin Tribs
Reach Name: Rose Creek Lower <-- This is not a Reference Reach
Drainage Area: 63.4 sq mi
State: Minnesota
County: Mower
Latitude: 43.61419
Longitude: 92.95262
Survey Date: 10/28/2010

Classification Data

Valley Type: Type VIII
Valley Slope: 0 ft/ft
Number of Channels: Single
Width: 55.55 ft
Mean Depth: 2.03 ft
Flood-Prone Width: 180 ft
Channel Materials D50: 38.5 mm
Water Surface Slope: 0.00815 ft/ft
Sinuosity: 1.12
Discharge: 0 cfs
Velocity: 0 fps
Cross Sectional Area: 113.02 sq ft
Entrenchment Ratio: 3.24
Width to Depth Ratio: 27.36

Rosgen Stream Classification: C4

Figure 60. Stream Classification for Lower Rose Creek

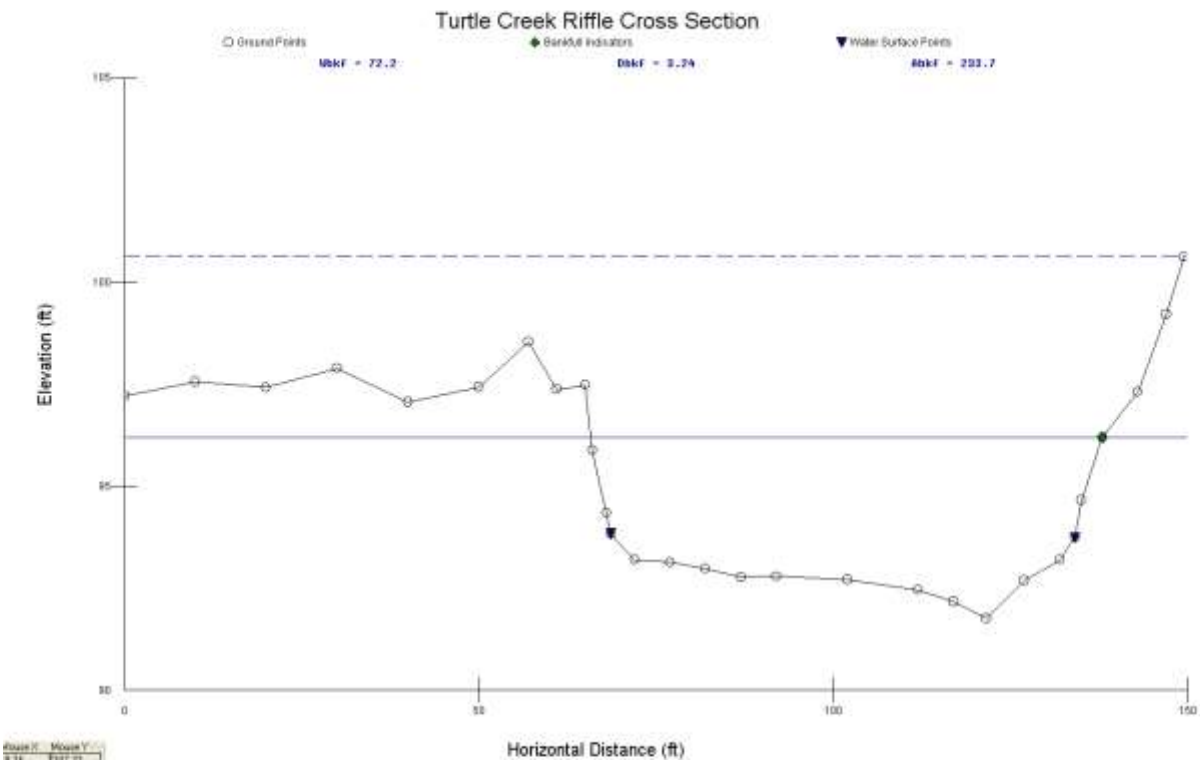


Figure 61. Riffle Cross Section with Bankfull and Flood Prone area for Turtle Creek

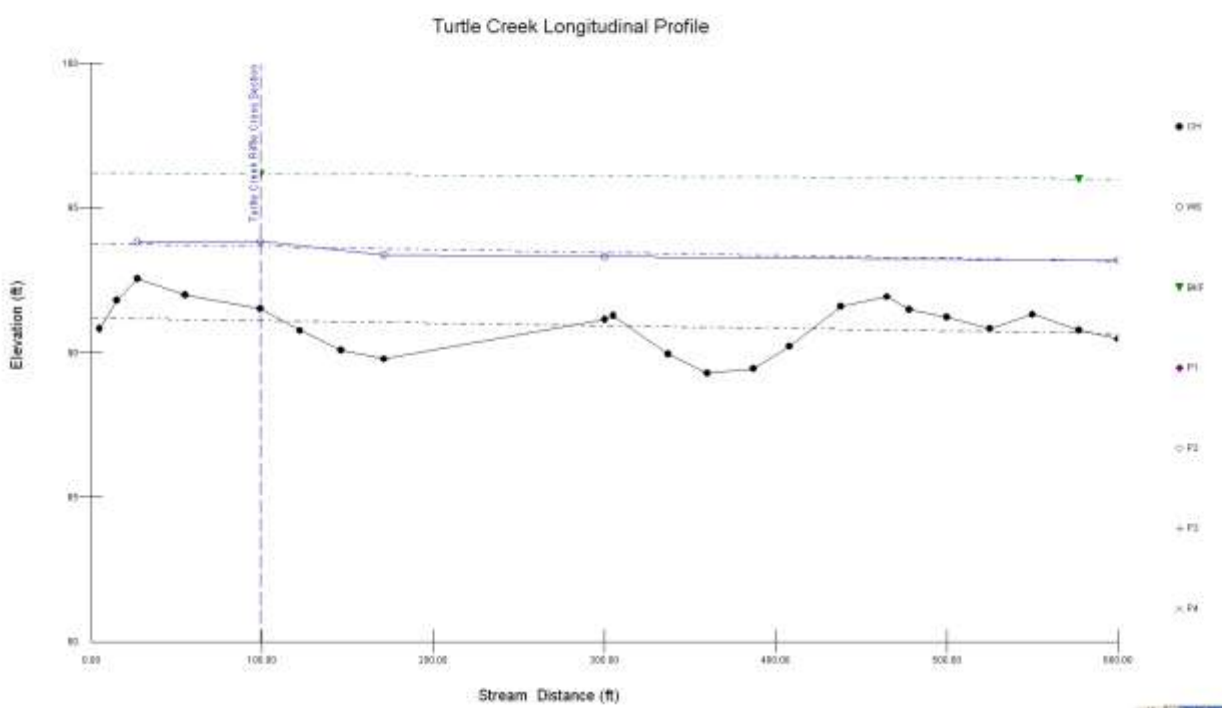


Figure 62. Longitudinal Profile for Turtle Creek

ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	MEAN D	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
95.26	3.5	167.77	70.67	69.37	2.37	2.42	12.39	2.86	9.47	0.13	480.59
95.36	3.6	174.72	71.05	69.69	2.46	2.51	12.86	2.95	9.56	0.13	514.85
95.46	3.7	181.71	71.44	70.02	2.54	2.6	13.28	3.02	9.64	0.14	548.56
95.56	3.8	188.73	71.82	70.35	2.63	2.68	13.75	3.1	9.72	0.15	584.91
95.66	3.9	195.78	72.21	70.67	2.71	2.77	14.17	3.17	9.8	0.16	620.58
95.76	4	202.86	72.59	71	2.79	2.86	14.59	3.24	9.87	0.16	657.21
95.86	4.1	209.98	72.98	71.33	2.88	2.94	15.06	3.32	9.95	0.17	696.62
95.96	4.2	217.13	73.32	71.6	2.96	3.03	15.47	3.39	10.01	0.18	735.22
96.06	4.3	224.3	73.66	71.86	3.05	3.12	15.95	3.46	10.09	0.19	776.63
96.16	4.4	231.5	74	72.12	3.13	3.21	16.36	3.53	10.15	0.19	817.13
96.26	4.5	238.73	74.5	72.55	3.2	3.29	16.73	3.59	10.2	0.2	856.58
96.36	4.6	246.01	75.08	73.06	3.28	3.37	17.15	3.65	10.26	0.21	898.98
96.46	4.7	253.34	75.65	73.57	3.35	3.44	17.51	3.71	10.32	0.21	940.32
96.56	4.8	260.72	76.23	74.08	3.42	3.52	17.88	3.77	10.37	0.22	982.59
96.66	4.9	268.15	76.8	74.59	3.49	3.6	18.25	3.83	10.42	0.23	1025.78
96.76	5	275.64	77.38	75.09	3.56	3.67	18.61	3.88	10.47	0.23	1069.94

Velocity Formula	Mannings Equation
Roughness coefficient	Limerino's 'n"
Bed material D84	58.3 mm
Sediment Transport	Parker (1990)
	mean diameter bed material 38.6 mm
Energy slope	0.0012 (water slope)

Figure 63. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Lower Turtle Creek for the Stream Stage Determination. The estimated bankfull discharge and variables used for the stage analysis are shown in red.

Basin Characteristics Report

Date: Mon May 23 2011 12:10:22 Mountain Daylight Time
NAD27 Latitude: 43.6571 (43 39 25)
NAD27 Longitude: -92.9924 (-92 59 33)
NAD83 Latitude: 43.6570 (43 39 25)
NAD83 Longitude: -92.9926 (-92 59 33)

Parameter	Value
Channel 10-85 slope in feet per mile	2.36
Percent area covered by soil type A	0.00

Log of drainage area in square miles	2.18
Percent area covered by lakes and ponds	1.73
Drainage Area in square miles	152
Generalized mean annual runoff in Minnesota 1951-85	7.3

Streamstats Ungaged Site Report

Date: Mon May 23 2011 12:13:21 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.6571 (43 39 25)
NAD27 Longitude: -92.9924 (-92 59 33)
NAD83 Latitude: 43.6570 (43 39 25)
NAD83 Longitude: -92.9926 (-92 59 33)
Drainage Area: 152 mi2

Peak Flow Basin Characteristics

100% Region D (152 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	152	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	2.36	1.49	77.2
Percent Lakes and Ponds (percent)	1.73	0	14
Generalized Runoff (inches)	7.3	2.15	7.8

Peak Flow Stream flow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	464	64	3.1	163	1000
PK2	636	56	3.5	252	1290
PK5	1180	50	6.3	529	2210
PK10	1630	51	8.8	738	3050
PK25	2300	55	11	1010	4420
PK50	2870	60	13	1210	5670
PK100	3530	65	14	1410	7200
PK500	5250	78	15	1810	11600

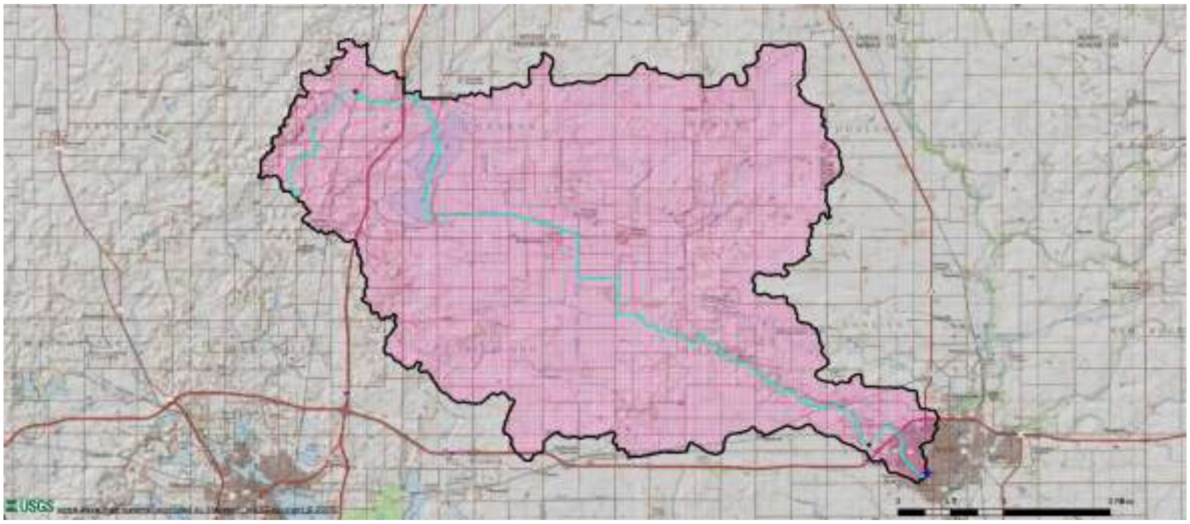


Figure 64. Watershed (152 square miles) used in the USGS StreamStat Regession Flow Calaulations for Turtle Creek.

River Name: Cedar Basin Tribs
Reach Name: Turtle Creek <-- This is not a Reference Reach
Drainage Area: 0 sq mi
State: Minnesota
County: Mower
Latitude: 43.656941
Longitude: 92.994453
Survey Date: 10/13/2010

Classification Data

Valley Type:	Type VIII
Valley Slope:	0 ft/ft
Number of Channels:	Single
Width:	111.38 ft
Mean Depth:	3.02 ft
Flood-Prone Width:	200 ft
Channel Materials D50:	28.34 mm
Water Surface Slope:	0.0012 ft/ft
Sinuosity:	1.23
Discharge:	0 cfs
Velocity:	0 fps
Cross Sectional Area:	335.86 sq ft

Entrenchment Ratio: 1.8
Width to Depth Ratio: 36.88

Rosgen Stream Classification: B 4/1c

Figure 65. Stream classification for Lower Turtle Creek.

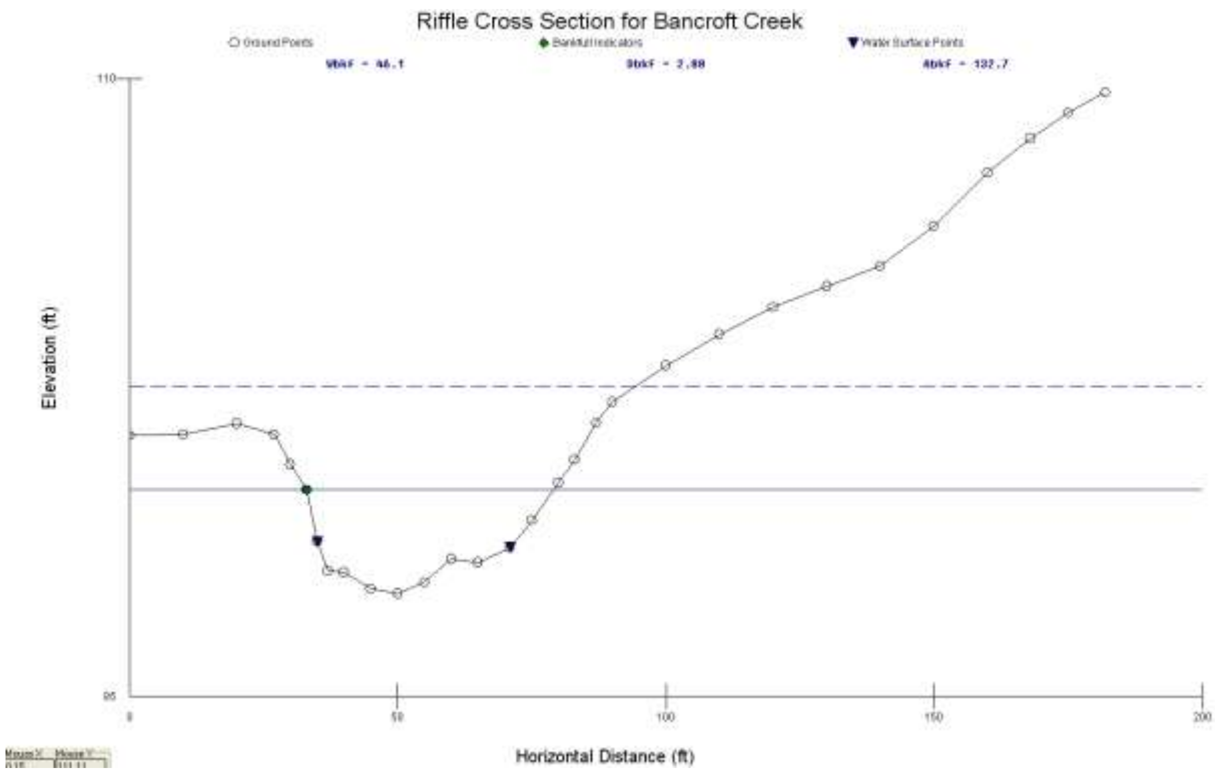


Figure 66. Riffle Cross Section with Bankfull and Flood Prone for Bancroft Creek

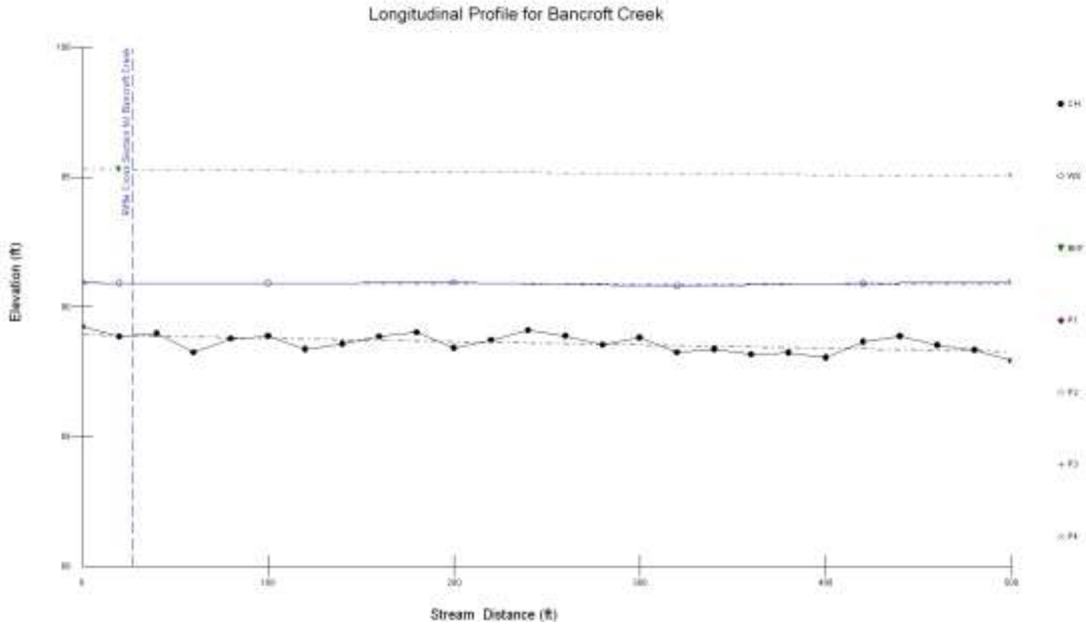


Figure 67. Longitudinal Profile of Bancroft Creek.

ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	MEAN D	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE
92.66	3.5	101.03	44.41	43.07	2.27	2.35	1172.65	2.01	20.65	0.06	203.34
92.76	3.6	105.36	44.89	43.49	2.35	2.42	1213.97	2.06	20.73	0.07	216.64
92.86	3.7	109.73	45.37	43.92	2.42	2.5	1250.14	2.09	20.8	0.07	229.76
92.96	3.8	114.14	45.86	44.34	2.49	2.57	1286.3	2.13	20.87	0.07	243.24
93.06	3.9	118.6	46.34	44.77	2.56	2.65	1322.46	2.17	20.94	0.07	257.11
93.16	4	123.1	46.82	45.19	2.63	2.72	1358.62	2.2	21.01	0.08	271.35
93.26	4.1	127.64	47.3	45.61	2.7	2.8	1394.78	2.24	21.07	0.08	285.95
93.36	4.2	132.22	47.78	46.04	2.77	2.87	1430.94	2.28	21.14	0.08	300.92
93.46	4.3	136.85	48.42	46.64	2.83	2.93	1461.94	2.31	21.19	0.08	315.6
93.56	4.4	141.55	49.07	47.26	2.88	2.99	1487.76	2.33	21.23	0.08	329.98
93.66	4.5	146.3	49.73	47.89	2.94	3.06	1518.76	2.36	21.28	0.09	345.41
93.76	4.6	151.12	50.38	48.5	3	3.12	1549.75	2.39	21.33	0.09	361.25
93.86	4.7	156	51.02	49.12	3.06	3.18	1580.75	2.42	21.38	0.09	377.49
93.96	4.8	160.95	51.67	49.74	3.11	3.24	1606.58	2.44	21.42	0.09	393.37
94.06	4.9	165.95	52.32	50.35	3.17	3.3	1637.57	2.47	21.47	0.09	410.38
94.16	5	171.02	52.97	50.97	3.23	3.36	1668.57	2.5	21.51	0.1	427.81
94.26	5.1	176.15	53.62	51.59	3.29	3.41	1699.56	2.53	21.56	0.1	445.66
94.36	5.2	181.33	54.27	52.2	3.34	3.47	1725.39	2.55	21.6	0.1	463.03
94.46	5.3	186.58	54.88	52.79	3.4	3.53	1756.39	2.58	21.64	0.1	481.67
94.56	5.4	191.89	55.49	53.36	3.46	3.6	1787.38	2.61	21.68	0.11	500.72

Velocity Formula	Mannings Equation
Roughness coefficient	Limerino's 'n"
Bed material D84	0.59.8 mm
Sediment Transport	Parker (1990)
	mean diameter bed material 2.9mm
Energy slope	0.00013 (water slope)

Figure 68. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Bancroft Creek. The estimated bankfull discharge and variables used for the stage analysis are shown in red

Basin Characteristics Report

Date: Tue May 24 2011 11:44:44 Mountain Daylight Time
NAD27 Latitude: 43.6956 (43 41 44)
NAD27 Longitude: -93.3646 (-93 21 53)
NAD83 Latitude: 43.6956 (43 41 44)
NAD83 Longitude: -93.3648 (-93 21 53)

Parameter	Value
Channel 10-85 slope in feet per mile	5.75
Percent area covered by soil type A	0.08
Log of drainage area in square miles	1.47
Percent area covered by lakes and ponds	0.00
Drainage Area in square miles	29.6
Generalized mean annual runoff in Minnesota 1951-85	7.2

Streamstats Ungaged Site Report

Date: Tue May 24 2011 10:15:01 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.6956 (43 41 44)
NAD27 Longitude: -93.3646 (-93 21 53)
NAD83 Latitude: 43.6956 (43 41 44)
NAD83 Longitude: -93.3648 (-93 21 53)
Drainage Area: 29.6 mi2

Peak Flow Basin Characteristics			
100% Region D (29.6 mi2)			
Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	29.6	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	5.75	1.49	77.2

Percent Lakes and Ponds (percent)	0.00	0	14
Generalized Runoff (inches)	7.2	2.15	7.8

Peak Flow Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	249	64	3.1	88.2	535
PK2	356	56	3.5	142	717
PK5	703	50	6.3	318	1320
PK10	998	51	8.8	455	1860
PK25	1440	55	11	636	2750
PK50	1820	60	13	770	3570
PK100	2260	65	14	908	4570
PK500	3420	78	15	1190	7500

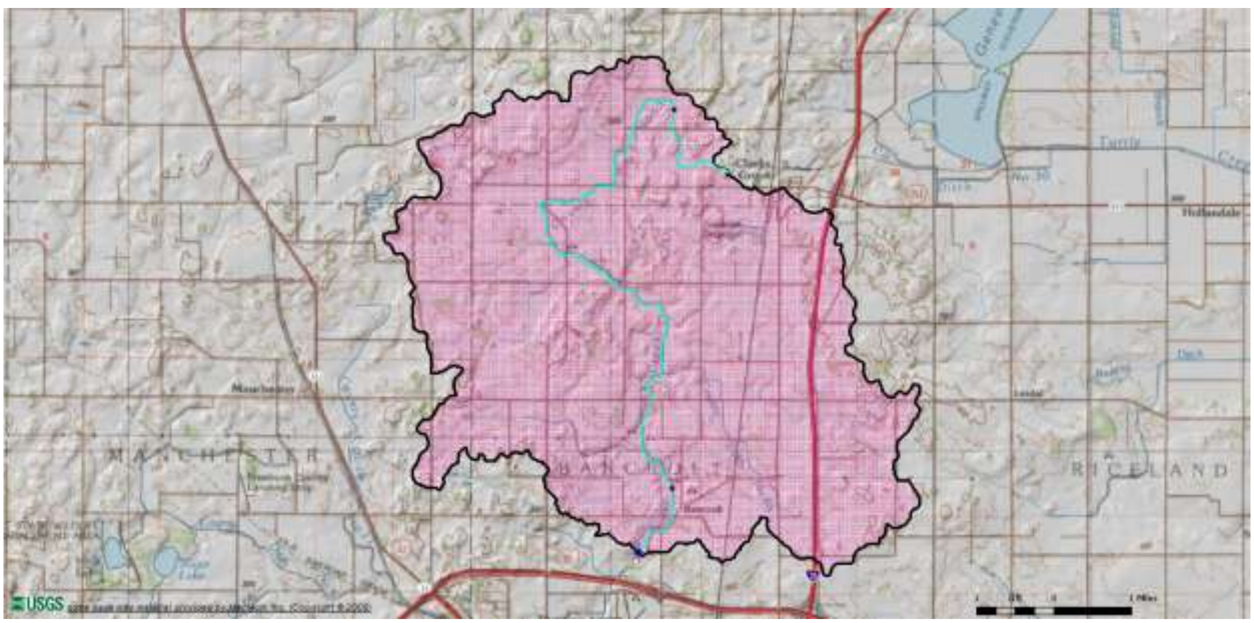


Figure 69. Watershed (26 square miles) used in the USGS StreamStat Regession Flow Calaulations for Bancroft Creek.

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Cedar Basin Tribs
Reach Name: Bancroft Creek <-- This is not a Reference
Drainage Area: 29.6 sq mi
State: Minnesota
County: Freeborn
Latitude: 43.695723
Longitude: 93.364746
Survey Date: 11/09/2010

Classification Data

Valley Type:	Type VIII
Valley Slope:	0 ft/ft
Number of Channels:	Single
Width:	46.08 ft
Mean Depth:	2.88 ft
Flood-Prone Width:	180 ft
Channel Materials D50:	0.1 mm
Water Surface Slope:	0.00013 ft/ft
Sinuosity:	1.26
Discharge:	0 cfs
Velocity:	0 fps
Cross Sectional Area:	132.68 sq ft
Entrenchment Ratio:	3.91
Width to Depth Ratio:	16

Rosgen Stream Classification: C 5c-

Figure 70. Stream classification for Bancroft Creek.

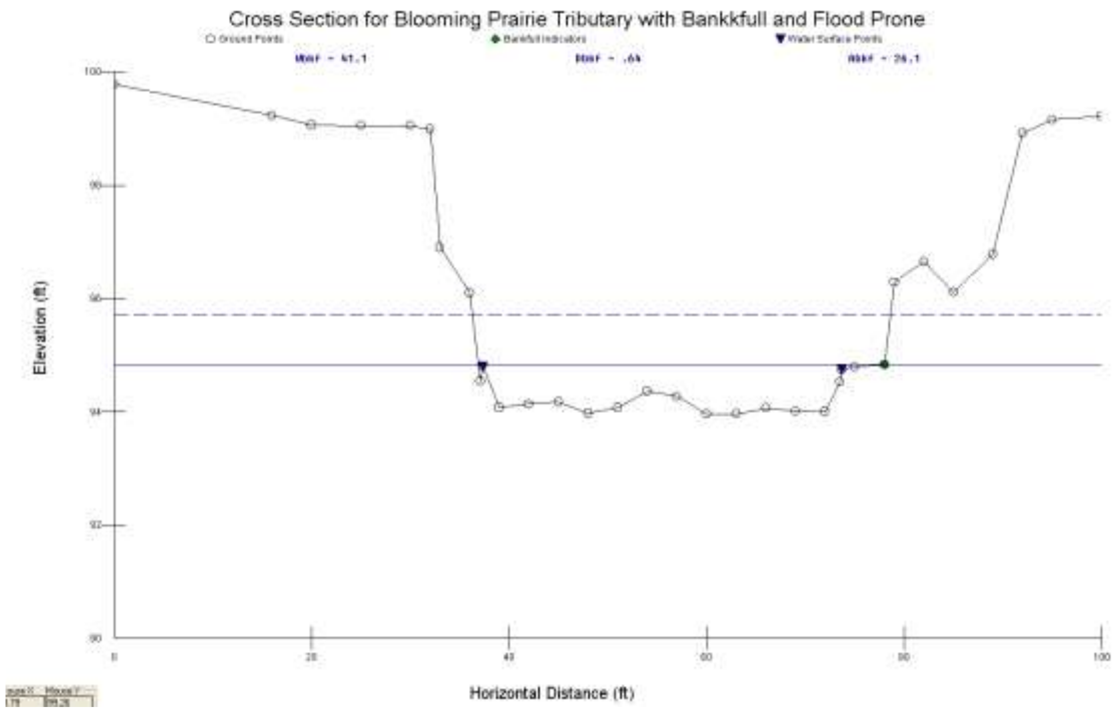


Figure 71. Riffle cross section for Blooming Prairie Creek with Bankfull and Flood Prone.

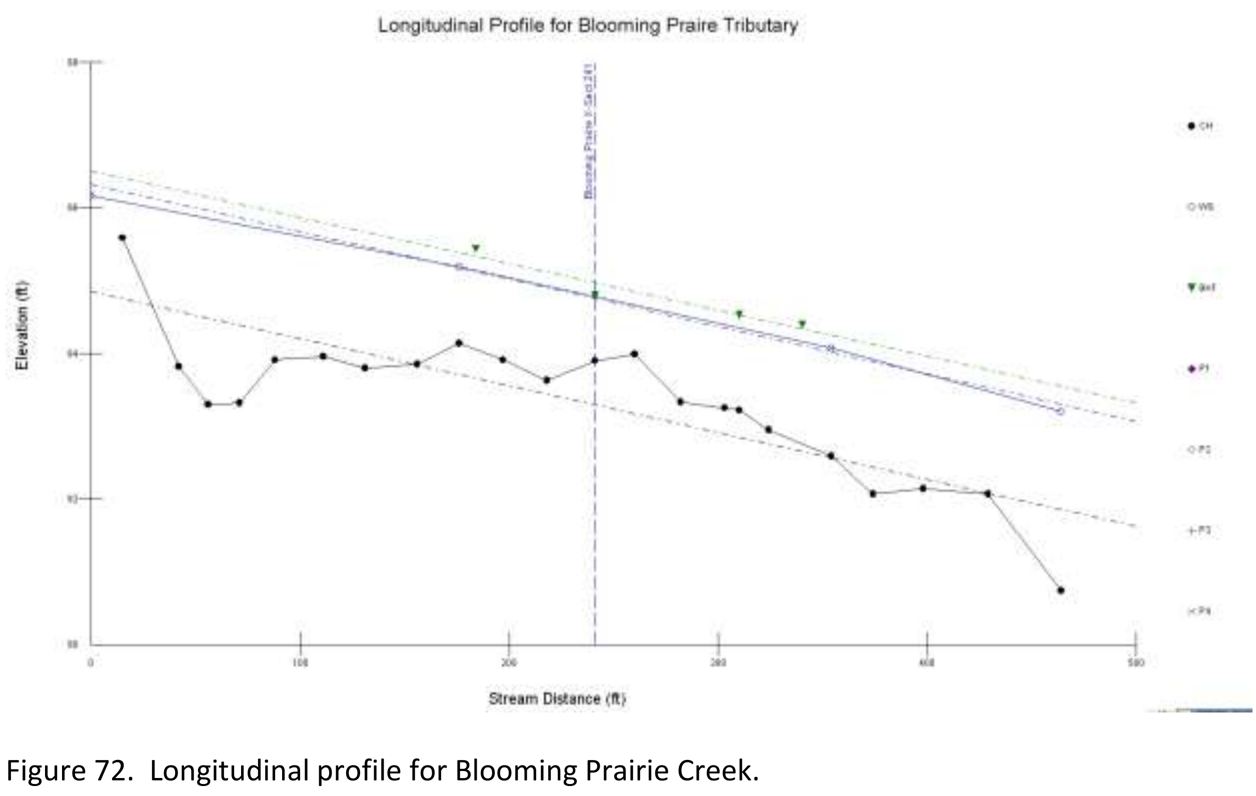


Figure 72. Longitudinal profile for Blooming Prairie Creek.

ELEV (ft)	DEPTH (ft)	AREA (sq ft)	WET PER (ft)	WIDTH (ft)	HYD RAD (ft)	MEAN D (ft)	R/D84	VELOCITY (fps)	U/U*	U^2/2g (ft)	DISCHARGE (cfs)
94.06	0.10	0.93	17.21	17.19	0.05	0.05	3.79	0.64	6.56	0.01	0.6
94.16	0.20	3.05	26.45	26.38	0.12	0.12	9.1	1.32	8.71	0.03	4.02
94.26	0.30	5.92	30.17	30.05	0.2	0.2	15.16	1.95	9.96	0.06	11.53
94.36	0.40	9.15	34.86	34.69	0.26	0.26	19.71	2.36	10.61	0.09	21.63
94.46	0.50	12.64	35.41	35.21	0.36	0.36	27.29	2.99	11.41	0.14	37.8
94.56	0.60	16.19	35.97	35.7	0.45	0.45	34.12	3.5	11.96	0.19	56.74
94.66	0.70	19.78	36.60	36.17	0.54	0.55	40.94	3.98	12.4	0.25	78.78
94.76	0.80	23.42	37.55	36.96	0.62	0.63	47.01	4.38	12.74	0.3	102.68
94.86	0.90	27.37	41.84	41.15	0.65	0.67	49.28	4.53	12.86	0.32	123.99
94.96	1.00	31.49	42.08	41.29	0.75	0.76	56.86	5	13.21	0.39	157.42
95.06	1.10	35.62	42.32	41.42	0.84	0.86	63.69	5.4	13.49	0.45	192.42
95.16	1.20	39.77	42.57	41.56	0.93	0.96	70.51	5.79	13.74	0.52	230.25
95.26	1.30	43.94	42.81	41.7	1.03	1.05	78.09	6.2	13.99	0.6	272.61

Velocity	Mannings Equation
Roughness coefficient	Limerinos “n”
D84	4.03 mm
Sediment Transport	Parker (1990) mean bed particle size 2.21mm
Energy slope	0.00593 (water slope)

Figure 73. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Blooming Prairie Creek. The estimated bankfull discharge and variables used for the stage analysis are shown in red

Basin Characteristics Report

Date: Tue May 24 2011 12:54:40 Mountain Daylight Time
NAD27 Latitude: 43.8231 (43 49 23)
NAD27 Longitude: -93.0129 (-93 00 46)
NAD83 Latitude: 43.8231 (43 49 23)
NAD83 Longitude: -93.0131 (-93 00 47)

Parameter	Value
Channel 10-85 slope in feet per mile	7.16
Percent area covered by soil type A	0.00
Log of drainage area in square miles	0.93
Percent area covered by lakes and ponds	0.00
Drainage Area in square miles	8.61
Generalized mean annual runoff in Minnesota 1951-85	7.29

Streamstats Ungaged Site Report

Date: Tue May 24 2011 12:56:20 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.8231 (43 49 23)
NAD27 Longitude: -93.0129 (-93 00 46)
NAD83 Latitude: 43.8231 (43 49 23)
NAD83 Longitude: -93.0131 (-93 00 47)
Drainage Area: 8.61 mi2

Peak Flow Basin Characteristics

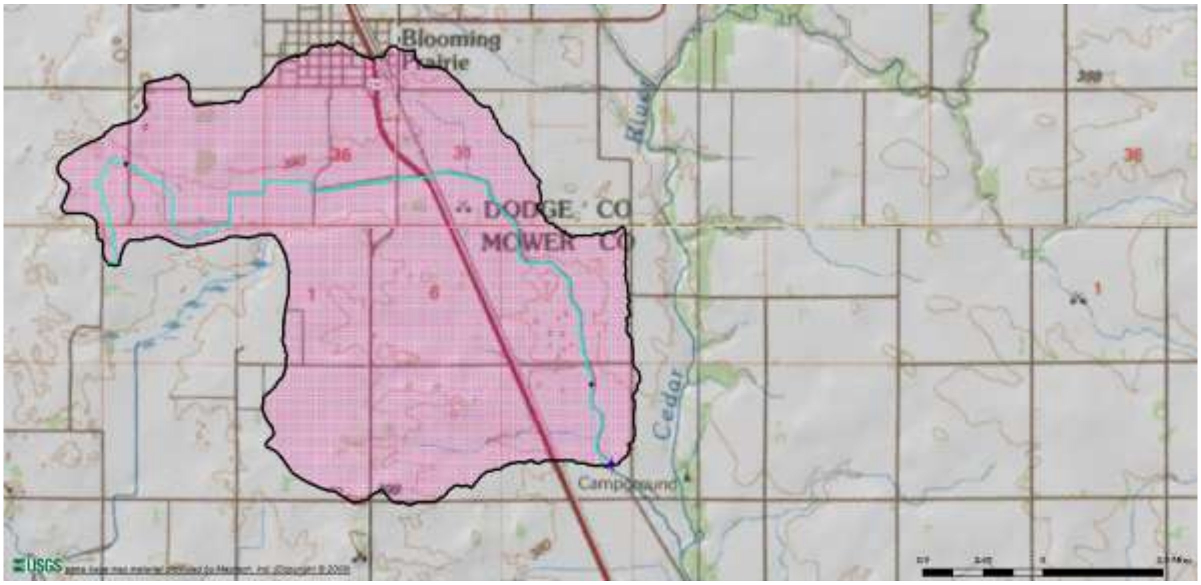
100% Region D (8.61 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	8.61	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	7.16	1.49	77.2
Percent Lakes and Ponds (percent)	0.00	0	14
Generalized Runoff (inches)	7.29	2.15	7.8

Peak Flow Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	106	64	3.1	37.6	228
PK2	151	56	3.5	59.9	303
PK5	294	50	6.3	133	550
PK10	415	51	8.8	189	773
PK25	596	55	11	263	1130
PK50	752	60	13	318	1470
PK100	931	65	14	374	1880

PK500	1410	78	15	491	3080



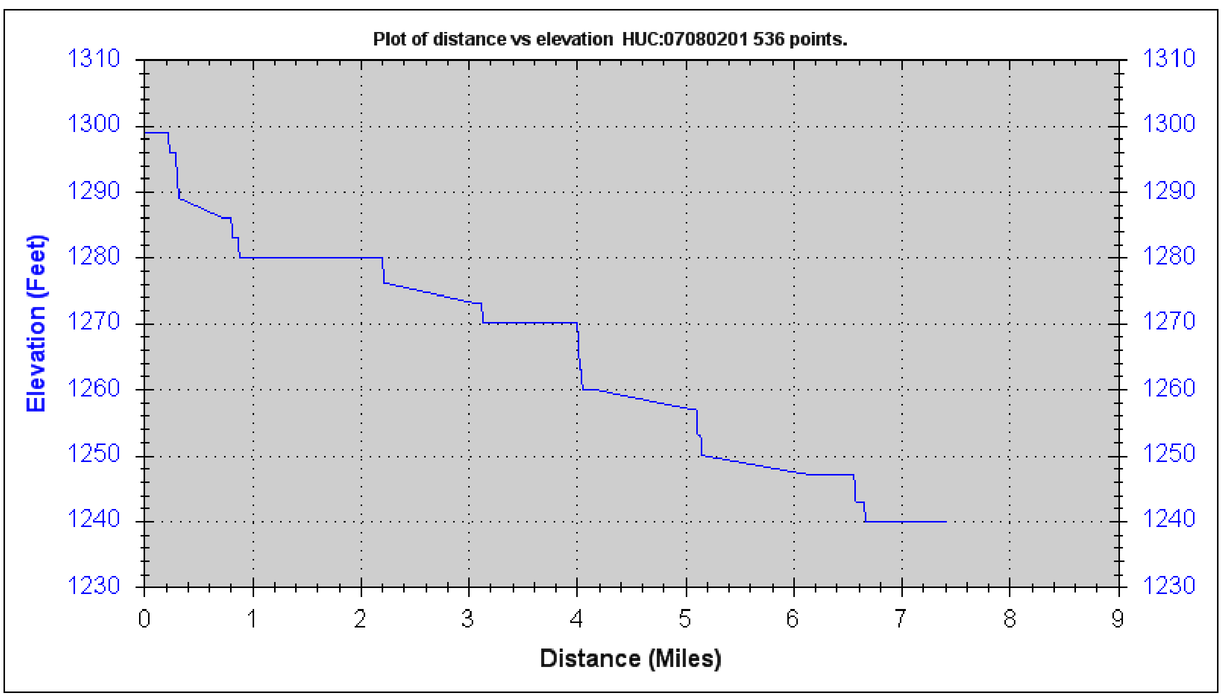


Figure 74. Watershed (8.6 square miles) used in the USGS StreamStat Regession Flow Calaulations for Blooming Praire Creek.

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Cedar River Tribs
Reach Name: Blooming Prairie Trib <-- This is not a Reference Reach
Drainage Area: 8.6 sq mi
State: Minnesota
County: Mower
Latitude: 43.82377786
Longitude: 93.01313493
Survey Date: 10/05/2010

Classification Data

Valley Type: Type VIII
Valley Slope: 0 ft/ft
Number of Channels: Single
Width: 41.1 ft
Mean Depth: 0.64 ft
Flood-Prone Width: 65 ft
Channel Materials D50: 1.88 mm
Water Surface Slope: 0.00593 ft/ft
Sinuosity: 1.13
Discharge: 0 cfs
Velocity: 0 fps
Cross Sectional Area: 26.13 sq ft
Entrenchment Ratio: 1.58
Width to Depth Ratio: 64.22

Rosgen Stream Classification: B 5c

Figure 75. Stream classification for Blooming Praire Creek.

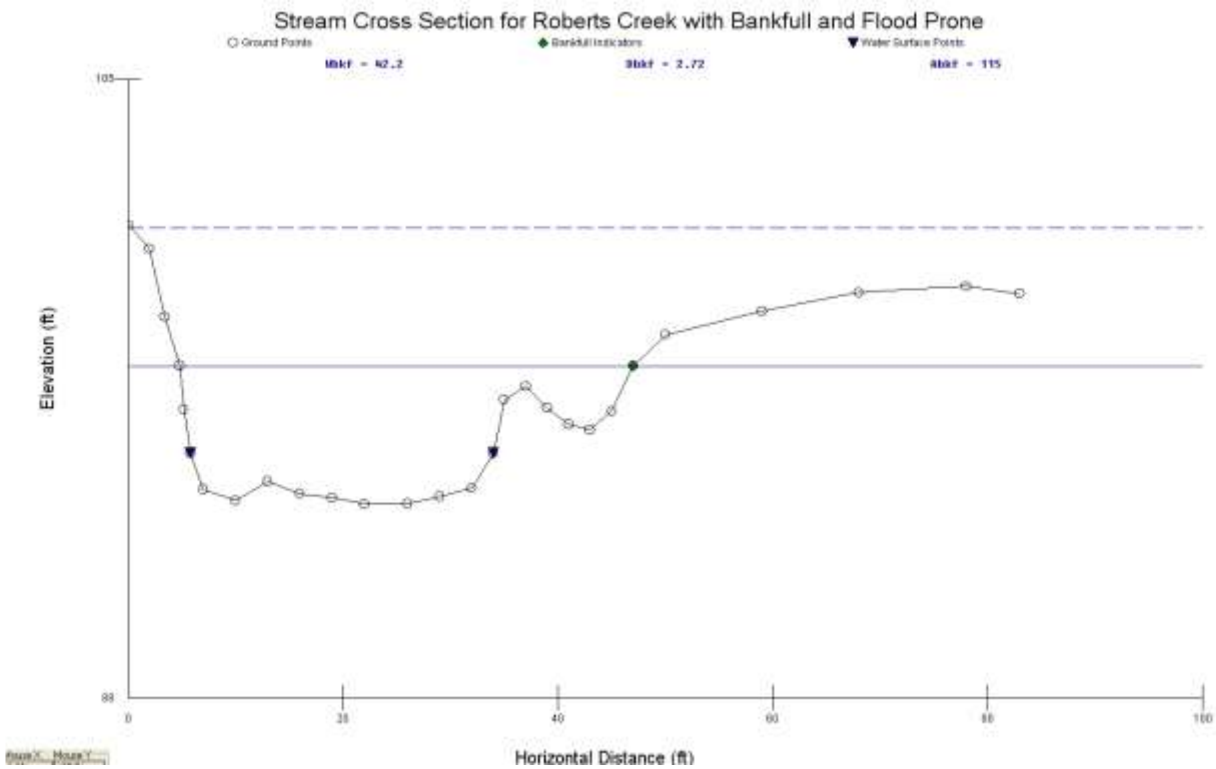


Figure 76. Riffle Cross Section with Bankfull and Flood Prone for Roberts Creek.

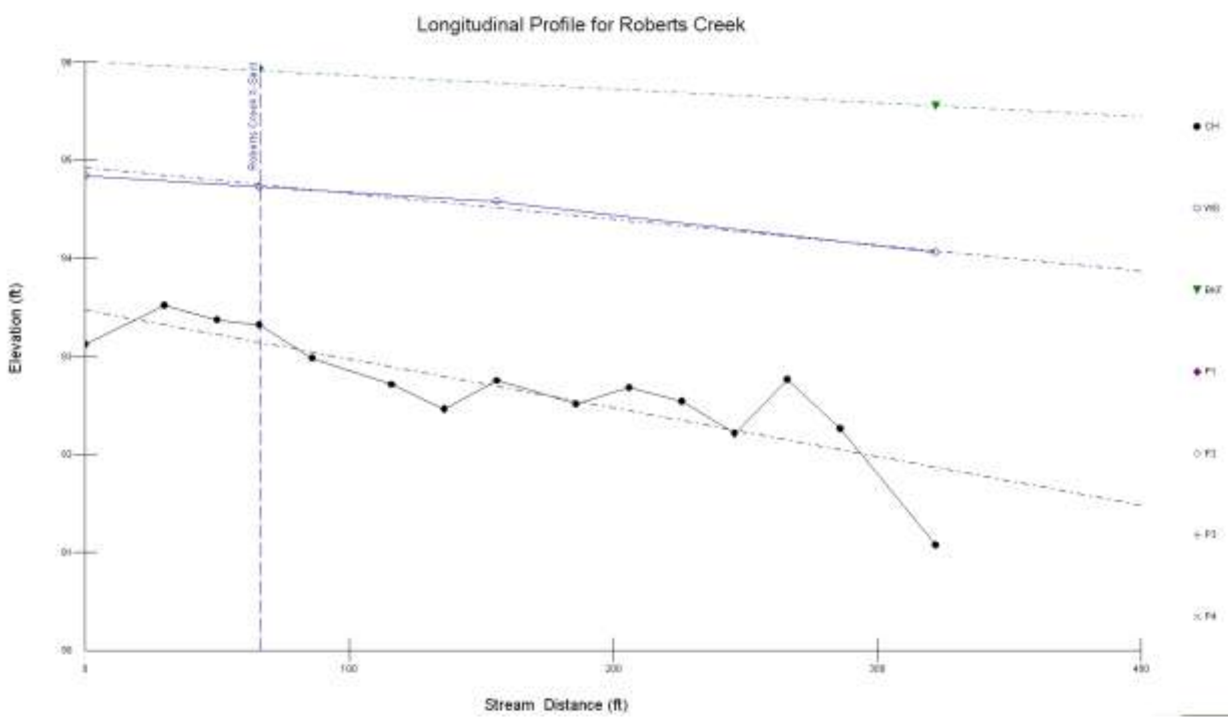


Figure 77 Longitudinal Profile for Roberts Creek

ELEV (ft)	DEPTH (ft)	AREA (sq ft)	WET PER (ft)	WIDTH (ft)	HYD RAD (ft)	MEAN D (ft)	R/D84	VELOCITY (fps)	U/U*	U^2/2g (ft)	DISCHARGE (cfs)
96.42	3.1	86.39	42.56	39.65	2.03	2.18	113.94	3.98	14.92	0.25	344.01
96.52	3.2	90.41	43.74	40.7	2.07	2.22	116.19	4.03	14.97	0.25	364.71
96.62	3.3	94.51	44.39	41.24	2.13	2.29	119.56	4.11	15.04	0.26	388.55
96.72	3.4	98.65	44.69	41.44	2.21	2.38	124.05	4.21	15.13	0.28	415.61
96.82	3.5	102.8	44.98	41.63	2.29	2.47	128.54	4.31	15.21	0.29	443.41
96.92	3.6	106.97	45.28	41.82	2.36	2.56	132.47	4.4	15.29	0.3	470.67
97.02	3.7	111.17	45.57	42.02	2.44	2.65	136.96	4.5	15.37	0.31	500.04
97.12	3.8	115.38	45.89	42.23	2.51	2.73	140.89	4.58	15.44	0.33	528.75
97.22	3.9	119.62	46.39	42.68	2.58	2.8	144.82	4.67	15.51	0.34	558.2
97.32	4	123.91	46.9	43.13	2.64	2.87	148.18	4.74	15.56	0.35	587.04
97.42	4.1	128.25	47.4	43.58	2.71	2.94	152.11	4.82	15.63	0.36	618.14
97.52	4.2	132.63	47.91	44.04	2.77	3.01	155.48	4.89	15.68	0.37	648.52

Velocity	Mannings Equation
Roughness coefficient	Limerinos "n"
D84	5.43 mm
Sediment Transport	Parker (1990) mean bed particle size 3.4 mm
Energy slope	0.00109 (water slope)

Figure 78. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from Roberts Creek. The estimated bankfull discharge and variables used for the stage analysis are shown in red

Basin Characteristics Report

Date: Tue May 24 2011 14:31:30 Mountain Daylight Time
NAD27 Latitude: 43.7490 (43 44 57)
NAD27 Longitude: -92.8937 (-92 53 37)
NAD83 Latitude: 43.7490 (43 44 56)
NAD83 Longitude: -92.8939 (-92 53 38)

Parameter	Value
Channel 10-85 slope in feet per mile	11.5
Percent area covered by soil type A	0.00
Log of drainage area in square miles	1.39
Percent area covered by lakes and ponds	0.00
Drainage Area in square miles	24.6
Generalized mean annual runoff in Minnesota 1951-85	7.45

Streamstats Ungaged Site Report

Date: Tue May 24 2011 14:32:57 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.7490 (43 44 57)
NAD27 Longitude: -92.8937 (-92 53 37)
NAD83 Latitude: 43.7490 (43 44 56)
NAD83 Longitude: -92.8939 (-92 53 38)
Drainage Area: 24.6 mi2

Peak Flow Basin Characteristics

100% Region D (24.6 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	24.6	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	11.5	1.49	77.2
Percent Lakes and Ponds (percent)	0.00	0	14
Generalized Runoff (inches)	7.45	2.15	7.8

Peak Flow Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	301	64	3.1	106	646
PK2	431	56	3.5	171	870
PK5	854	50	6.3	385	1600
PK10	1210	51	8.8	550	2260
PK25	1740	55	11	765	3320
PK50	2190	60	13	925	4300
PK100	2710	65	14	1090	5490
PK500	4080	78	15	1420	8960

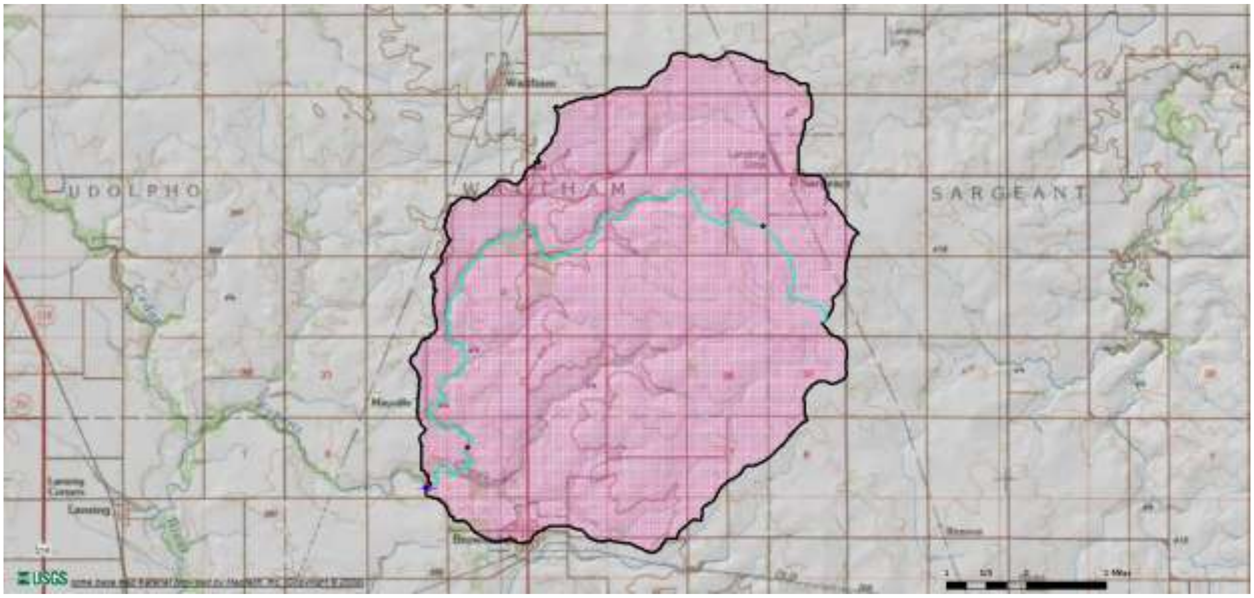


Figure 79. Watershed (24.6 square miles) used in the USGS StreamStat Regession Flow Calaulations for Roberts Creek.

River Name: Cedar Basin Tribs
Reach Name: Roberts Creek <-- This is not a Reference Reach
Drainage Area: 0 sq mi
State: Minnesota
County: Mower
Latitude: 43.74907
Longitude: 92.893954
Survey Date: 11/17/2010

Classification Data

Valley Type:	Type VIII
Valley Slope:	0 ft/ft
Number of Channels:	Single
Width:	35.52 ft
Mean Depth:	1.91 ft
Flood-Prone Width:	54.25 ft

Channel Materials D50: 1.79 mm
Water Surface Slope: 0.00109 ft/ft
Sinuosity: 0
Discharge: 0 cfs
Velocity: 0 fps
Cross Sectional Area: 67.73 sq ft
Entrenchment Ratio: 1.53
Width to Depth Ratio: 18.6

Rosgen Stream Classification: B 5c

Figure 80. Stream classification for Roberts Creek

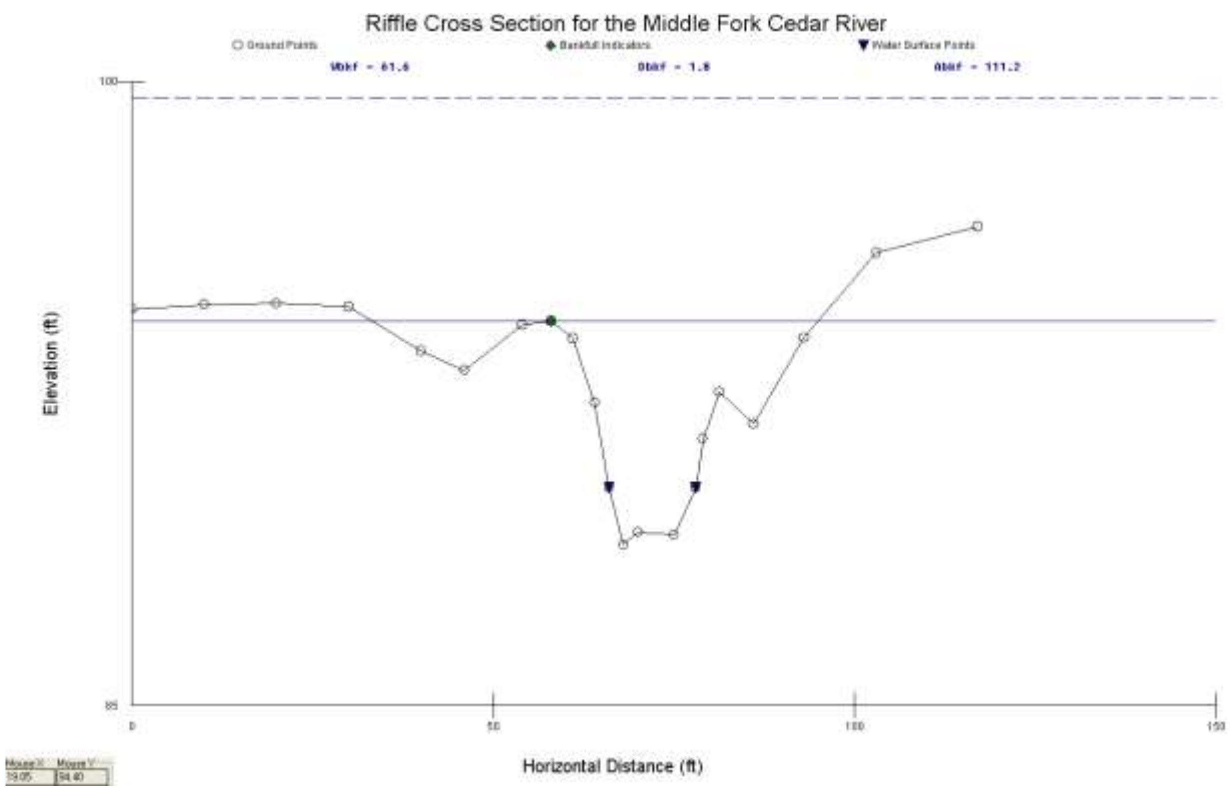


Figure 81. Riffle Cross Section with bankfull and flood prone for the Middle Fork Cedar River

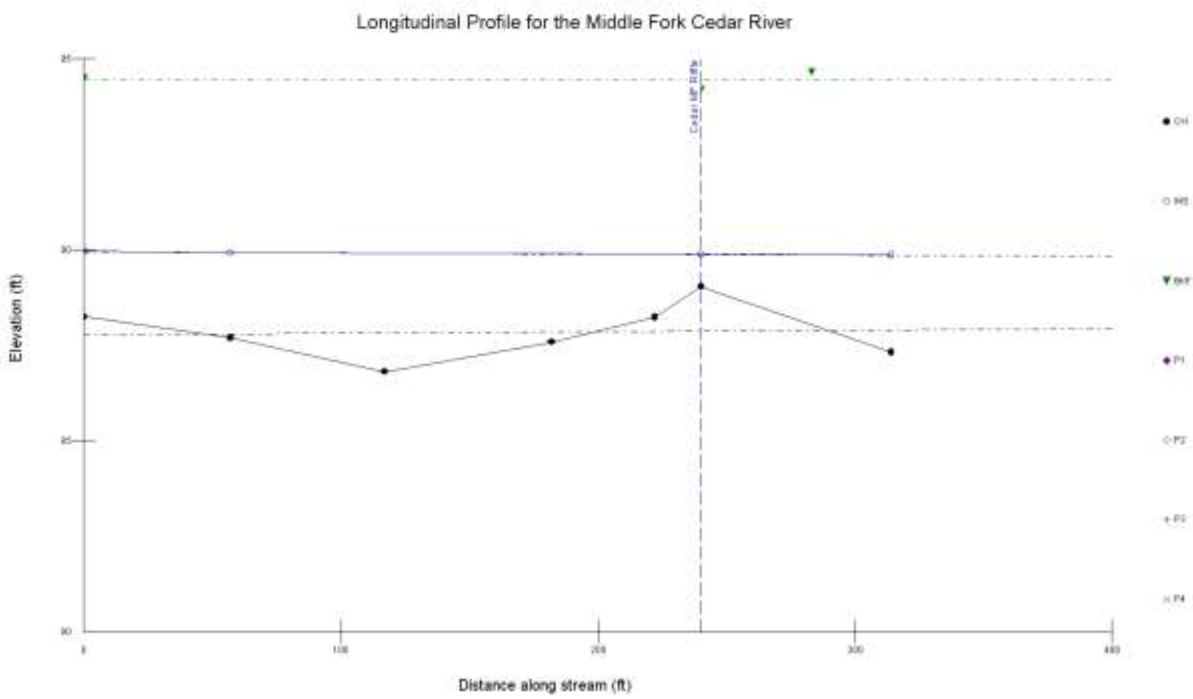


Figure 82. Longitudinal Profile for the Middle Fork Cedar River

ELEV (ft)	DEPTH (ft)	AREA (sq ft)	WET PER (ft)	WIDTH (ft)	HYD RAD (ft)	MEAN D (ft)	R/D84	VELOCITY (fps)	U/U*	U^2/2g (ft)	DISCHARGE (cfs)
93.67	4.8	82.47	45.9	42.84	1.8	1.93	173.61	2.1	15.95	0.07	173.48
93.77	4.9	86.87	48.15	45.04	1.8	1.93	173.61	2.1	15.95	0.07	182.74
93.87	5	91.49	50.64	47.49	1.81	1.93	174.58	2.11	15.97	0.07	193.16
93.97	5.1	96.38	53.56	50.38	1.8	1.91	173.61	2.1	15.95	0.07	202.75
94.07	5.2	101.56	56.49	53.27	1.8	1.91	173.61	2.1	15.95	0.07	213.64
94.17	5.3	107.04	59.83	56.59	1.79	1.89	172.65	2.1	15.94	0.07	224.35
94.27	5.4	113.03	65.3	62.04	1.73	1.82	166.86	2.05	15.86	0.07	231.68
94.37	5.5	119.3	66.75	63.47	1.79	1.88	172.65	2.1	15.94	0.07	250.05
94.47	5.6	125.72	68.2	64.91	1.84	1.94	177.47	2.13	16.01	0.07	268.29
94.57	5.7	132.36	73.32	69.98	1.81	1.89	174.58	2.11	15.97	0.07	279.44
94.67	5.8	140.36	100.48	97.02	1.4	1.45	135.03	1.78	15.34	0.05	250.32
94.77	5.9	150.09	101.08	97.51	1.48	1.54	142.75	1.85	15.47	0.05	277.66
94.87	6	159.86	101.68	98	1.57	1.63	151.43	1.92	15.62	0.06	307.45
94.97	6.1	169.69	102.28	98.49	1.66	1.72	160.11	1.99	15.75	0.06	338.52

Velocity	Mannings Equation
Roughness coefficient	Limerinos "n"
D84	3.16mm
Sediment Transport	Parker (1990) mean bed particle size 1.97 mm

Energy slope 0.0003 (water slope)

Figure 83. Stream Stage Analysis Estimates from RIVERMorph using the Channel Cross Section from the Middle Fork Cedar River. The estimated bankfull discharge and variables used for the stage analysis are shown in red

Basin Characteristics Report

Date: Fri Jun 3 2011 14:06:43 Mountain Daylight Time
NAD27 Latitude: 43.8939 (43 53 38)
NAD27 Longitude: -92.9945 (-92 59 40)
NAD83 Latitude: 43.8938 (43 53 38)
NAD83 Longitude: -92.9946 (-92 59 41)

Parameter	Value
Channel 10-85 slope in feet per mile	8.13
Percent area covered by soil type A	0.00
Log of drainage area in square miles	1.27
Percent area covered by lakes and ponds	0.00
Drainage Area in square miles	18.7
Generalized mean annual runoff in Minnesota 1951-85	7.27

Streamstats Ungaged Site Report

Date: Fri Jun 3 2011 14:09:21 Mountain Daylight Time
Site Location: Minnesota
NAD27 Latitude: 43.8939 (43 53 38)
NAD27 Longitude: -92.9945 (-92 59 40)
NAD83 Latitude: 43.8938 (43 53 38)
NAD83 Longitude: -92.9946 (-92 59 41)
Drainage Area: 18.7 mi2

Peak Flow Basin Characteristics

100% Region D (18.7 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	18.7	0.15	2640
Stream Slope 10 and 85 Method (feet per mi)	8.13	1.49	77.2
Percent Lakes and Ponds (percent)	0.00	0	14
Generalized Runoff (inches)	7.27	2.15	7.8

Peak Flow Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	204	64	3.1	72.4	437
PK2	292	56	3.5	116	586
PK5	575	50	6.3	261	1080
PK10	815	51	8.8	372	1520
PK25	1170	55	11	519	2230
PK50	1480	60	13	628	2900
PK100	1840	65	14	740	3700
PK500	2770	78	15	969	6060

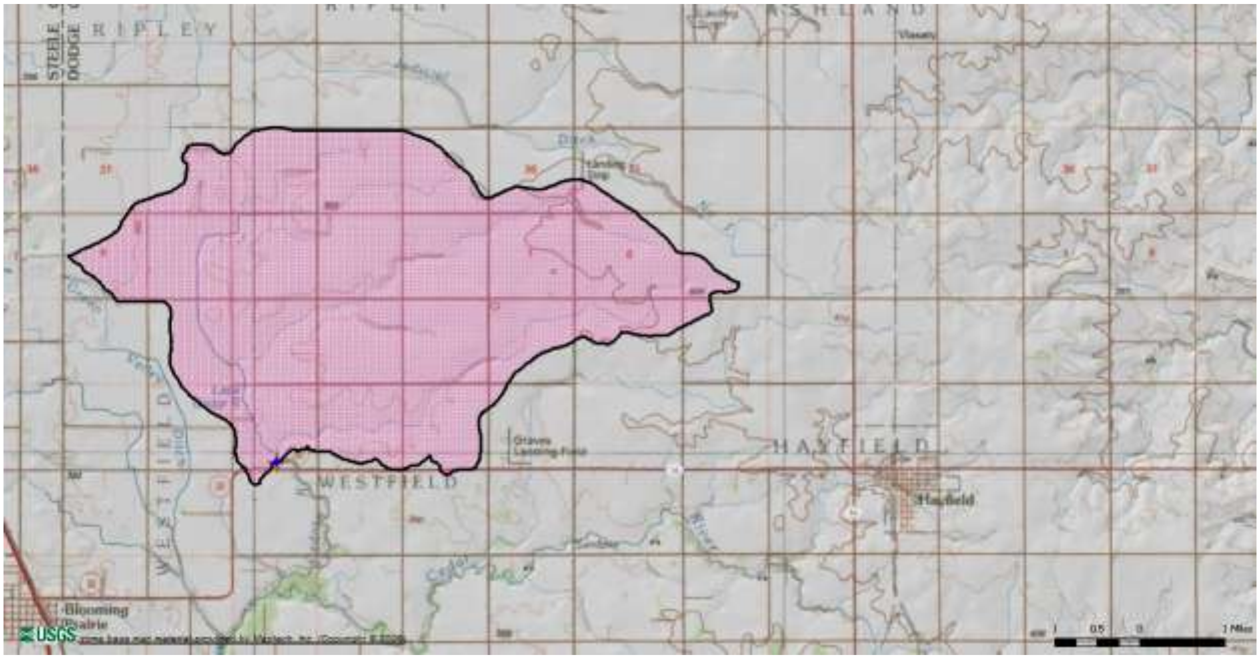


Figure 84. Watershed (18.7 square miles) used in the USGS StreamStat Regession Flow Calaulations for the Middle Fork Cedar River

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Cedar Basin Tribs
Reach Name: Cedar River MidFork <-- This is not a Reference Reach
Drainage Area: 18.7 sq mi
State: Minnesota
County: Mower
Latitude: 43.894043
Longitude: 92.994453
Survey Date: 11/24/2010

Classification Data

Valley Type:	Type VIII
Valley Slope:	0 ft/ft
Number of Channels:	Single
Width:	61.61 ft
Mean Depth:	1.8 ft
Flood-Prone Width:	200 ft

Channel Materials D50: 0.89 mm
Water Surface Slope: 0.0003 ft/ft
Sinuosity: 0
Discharge: 0 cfs
Velocity: 0 fps
Cross Sectional Area: 111.17 sq ft
Entrenchment Ratio: 3.25
Width to Depth Ratio: 34.23

Rosgen Stream Classification: C 5c-

Figure 85. Stream Classification for the Middle Fork Cedar River

Cedar River Basin Stream Bank Sediment Contribution Estimates

Reach	Length	Erosion Rate	Annual Erosion (tons/yr)	% Total Load
Site 3 to IA boarder	10.1	0.0128	682.60	2
small tribs	30.8	0.0541	8797.96	24
open ditch	55.75	0.0038	1118.57	3
Turtle Creek	43.2	0.0038	866.76	2
Total Reach length	139.85			
Subtotal (tons/yr)	11,466		82 tons/mile/yr	
Site 4- Site 3	9.8	0.0478	2473.36	7
Dobbins Creek	21.8	0.0541	6227.13	17
open ditch	27.5	0.0038	551.76	1
Total Reach Length	59.1			
Subtotal (tons/yr)	9,252		157 tons/mile/yr	
Site 7 - Site 4	6.6	0.0478	1665.73	4
small tribs	12.4	0.0541	3542.04	10
open ditch	18.2	0.0038	365.16	1
Total Reach Length	37.2			
Subtotal (tons/yr)	5,573		150 tons/mile/yr	
Site 8 - Site 7	4.7	0.0661	1640.34	4
open ditch	19.7	0.0038	395.26	1
Total Reach Length	24.4			
Subtotal	2,036		83 tons/mile/yr	
Site 11 - Site 8	4.1	0.0661	1430.93	4
small tribs	12.3	0.0541	3513.47	9
open ditch	43.6	0.0038	874.79	2
Total Reach Length	60			

Subtotal (tons/yr)	5,819		97 tons/mile/year	
Headwaters - Site 11	4.8	0.0541	1371.11	4
small tribs	3.1	0.0541	885.51	2
open ditch	31.8	0.0038	638.04	2
Total Reach Length	39.7			
Subtotal (tons/yr)	2,895		73 tons/mile/yr	

Total 37,000 tons/year

Figure 86. Conservative Estimates of Stream Bank Erosion for the Minnesota portion of the Main Cedar River Basin applying BANCS Erosion Rates for the Main Stem River, Ditches and Small Tributaries.

Add bar chart here. The chart is called "Compiled stream bank erosion estimates in the Cedar River Watershed, usi

Bank	BEHI Numeric Rating	BEHI Adjective Rating	NBS Adjective Rating	Bank Length ft	Erosion Loss cu yds/yr	Rates Loss tons/yr
1	32.2	High	High	1100	65.19	84.75
2	20.5	Moderate	Moderate	880	29.33	38.13
3	27.2	Moderate	Moderate	520	13.87	18.03
4	27	Moderate	Moderate	440	11.73	15.25
5	26.9	Moderate	Moderate	560	16.18	21.03
6	26.9	Moderate	Moderate	790	19.31	25.1
7	20.4	Moderate	High	3501	155.6	202.28
8	29.4	Moderate	High	700	33.7	43.81
9	29.8	Moderate	Moderate	1100	34.22	44.49
10	32.8	High	Moderate	730	36.5	47.45
11	29.1	Moderate	Low	400	2.22	2.89
12	23.6	Moderate	Moderate	310	2.07	2.69
13	29.6	Moderate	Low	90	0.53	0.69
14	33.6	High	Low	420	18.67	24.27
15	28.9	Moderate	Moderate	415	9.22	11.99
16	29.3	Moderate	Moderate	350	10.11	13.14
17	28.7	Moderate	Moderate	310	11.02	14.33
18	25.5	Moderate	Low	800	5.19	6.75

19	27.1	Moderate	Low	240	2	2.6
20	26.8	Moderate	Low	890	6.59	8.57
21	25	Moderate	Low	190	1.23	1.6
Totals				**14736**	**484.48**	**629.84**

Total Reach : 49,104 ft   Total loss (tons/yr) per ft of reach 0.0128

Figure 87. Stream Bank Erosion Estimates for the Cedar River from County Road 23 to 140th street covering 9.3 river miles.

BEHI Numeric Rating	BEHI Adjective Rating	NBS Adjective Rating	Length ft	Loss cu yds/yr	Loss tons/yr
25.9	Moderate	Moderate	220	1.96	2.55
28.9	Moderate	Moderate	110	2.44	3.17
33.3	High	High	210	8.17	10.62
41.5	Very High	High	130	28.89	37.56
25.9	Moderate	High	260	5.78	7.51
34	High	Moderate	170	6.61	8.59
33.8	High	High	150	4.44	5.77
41.8	Very High	High	160	23.7	30.81
34.5	High	High	230	6.81	8.85
29.7	Moderate	Low	190	3.17	4.12
38.4	High	Extreme	745	241.44	313.87
27.9	Moderate	Extreme	220	29.33	38.13
27.8	Moderate	Moderate	175	2.92	3.8
29.6	Moderate	High	230	15.33	19.93
31	High	Moderate	760	42.22	54.89
40.3	Very High	Very High	730	270.37	351.48
33.8	High	Moderate	190	8.44	10.97
30.5	High	Moderate	460	25.56	33.23
38.2	High	High	145	8.59	11.17
38.4	High	High	245	12.7	16.51
32	High	Moderate	135	5.25	6.83
40.6	Very High	High	135	10	13

40	Very High	High	175	51.85	67.41
33	High	Moderate	135	3.5	4.55
39.7	High	High	230	23.85	31.01
25.2	Moderate	Extreme	110	22.81	29.65
36	High	High	195	10.11	13.14
42.5	Very High	Very High	250	55.56	72.23
39.4	High	High	160	7.11	9.24
36.9	High	High	450	33.33	43.33
38.6	High	High	230	17.04	22.15
42.5	Very High	Extreme	210	140	182
33.1	High	Moderate	230	10.22	13.29
43.6	Very High	Very High	190	84.44	109.77
35.3	High	High	260	15.41	20.03
39.7	High	High	180	13.33	17.33
49	Extreme	High	652	154.55	200.92
41.1	Very High	High	180	213.33	277.33
28.7	Moderate	Moderate	630	11.67	15.17
37.7	High	High	240	14.22	18.49
42.8	Very High	High	190	19	24.7
36.9	High	High	730	43.26	56.24
			11627	**1708.71**	**2221.34**

Reach Ln: 46464 Total lose (tons/yr) per foot of reach 0.0478

Figure 88. Stream Bank Erosion Estimates for the Cedar River between County Road 25 and the Mill Pond covering 8.6 river miles.

BEHI Numeric Rating	BEHI Adjective Rating	NBS Adjective Rating	Length ft	Loss cu yds/yr	Loss tons/yr
29	Moderate	High	600	26.67	34.67
32.9	High	High	300	11.11	14.44
23.5	Moderate	High	230	7.67	9.97
23.7	Moderate	Moderate	210	2.33	3.03
36.8	High	Extreme	680	158.67	206.27
32.7	High	Extreme	310	48.22	62.69

30.2	High	Very h	580	116	150.8
37.3	High	High	190	7.04	9.15
33.2	High	Very h	130	10.11	13.14
36.2	High	Very h	160	17.78	23.11
29.9	Moderate	High	160	7.11	9.24
29.8	Moderate	Extreme	650	235.93	306.71
33.3	High	High	230	10.22	13.29
39	High	High	465	31	40.3
37.9	High	High	350	23.33	30.33
33.5	High	Moderate	240	6.67	8.67
34.9	High	Very h	200	11.11	14.44
30.3	High	Moderate	190	10.56	13.73
31.8	High	High	220	13.04	16.95
32	High	High	230	13.63	17.72
40.9	Very h	High	250	64.81	84.25
35.7	High	Very h	220	39.11	50.84
26.1	Moderate	High	160	4.15	5.4
23.9	Moderate	High	180	4.8	6.24
35.7	High	High	210	26.44	34.37
30.1	High	High	230	11.93	15.51
35	High	Extreme	140	21.78	28.31
36.1	High	Extreme	350	58.98	76.67
28.5	Moderate	High	410	7.59	9.87
32.8	High	High	160	4.74	6.16
30.3	High	High	1200	88.89	115.56
	Total		**9835**	**1101.42**	**1431.83**

Reach length 21648 Total loss (tons/yr) per foot of reach 0.0661

Figure 89. Estimated Stream Bank Erosion Estimates for the Cedar River between County Road 2 and County Road 1 covering 4.1 river miles.

Bank	BEHI Numeric Rating	BEHI Adjective Rating	NBS Adjective Rating	Length ft	Loss cu yds/yr	Loss tons/yr

1	39.2	High	High	120	7.11	9.24
2	19.6	Low	High	160	1.24	1.61
3	30.9	High	Very h	80	7.11	9.24
4	23.7	Moderate	High	90	2.5	3.25
5	34.6	High	High	150	6.67	8.67
6	33.7	High	High	100	5.19	6.75
7	34.8	High	High	90	6	7.8
8	30	Moderate	Moderate	110	1.71	2.22
9	37.4	High	Moderate	80	4.44	5.77
10	36.1	High	Moderate	110	4.89	6.36
11	35.1	High	Moderate	100	3.89	5.06
12	33.7	High	High	180	9.33	12.13
13	42.1	Very h	High	200	20	26
14	28.4	Moderate	High	130	2.41	3.13
15	32.5	High	Moderate	150	6.67	8.67
16	34	High	High	90	7.33	9.53
17	28.4	Moderate	Moderate	100	1.11	1.44
18	35	High	High	230	22.15	28.8
19	29.4	Moderate	High	270	6	7.8
20	31.7	High	High	150	6.67	8.67
21	29.8	Moderate	Moderate	90	1	1.3
22	32.1	High	High	90	3.33	4.33
23	25.6	Moderate	High	100	1.85	2.41
24	35.5	High	Moderate	300	18.33	23.83
25	30.9	High	Moderate	140	6.22	8.09
26	30.8	High	Moderate	160	4.44	5.77
27	37.1	High	Very h	210	39.67	51.57
28	36.5	High	High	150	13.33	17.33
29	31.2	High	High	170	3.78	4.91
30	39.8	High	High	220	16.3	21.19
31	37.8	High	High	800	71.11	92.44
32	36	High	High	420	28	36.4
33	32.3	High	High	480	42.67	55.47
34	36.3	High	High	405	30	39
35	33.6	High	Moderate	450	22.5	29.25
36	37.3	High	Extreme	190	36.94	48.02
37	25.6	Moderate	Moderate	130	1.73	2.25
38	28.3	Moderate	Moderate	90	1.2	1.56
39	30.7	High	Extreme	95	10.98	14.27
40	33	High	Moderate	95	3.69	4.8
41	33.7	High	High	460	27.26	35.44
42	29.3	Moderate	High	90	2.5	3.25
43	32.1	High	High	290	30.07	39.09

Totals	**8315**	**549.32**	**714.11**

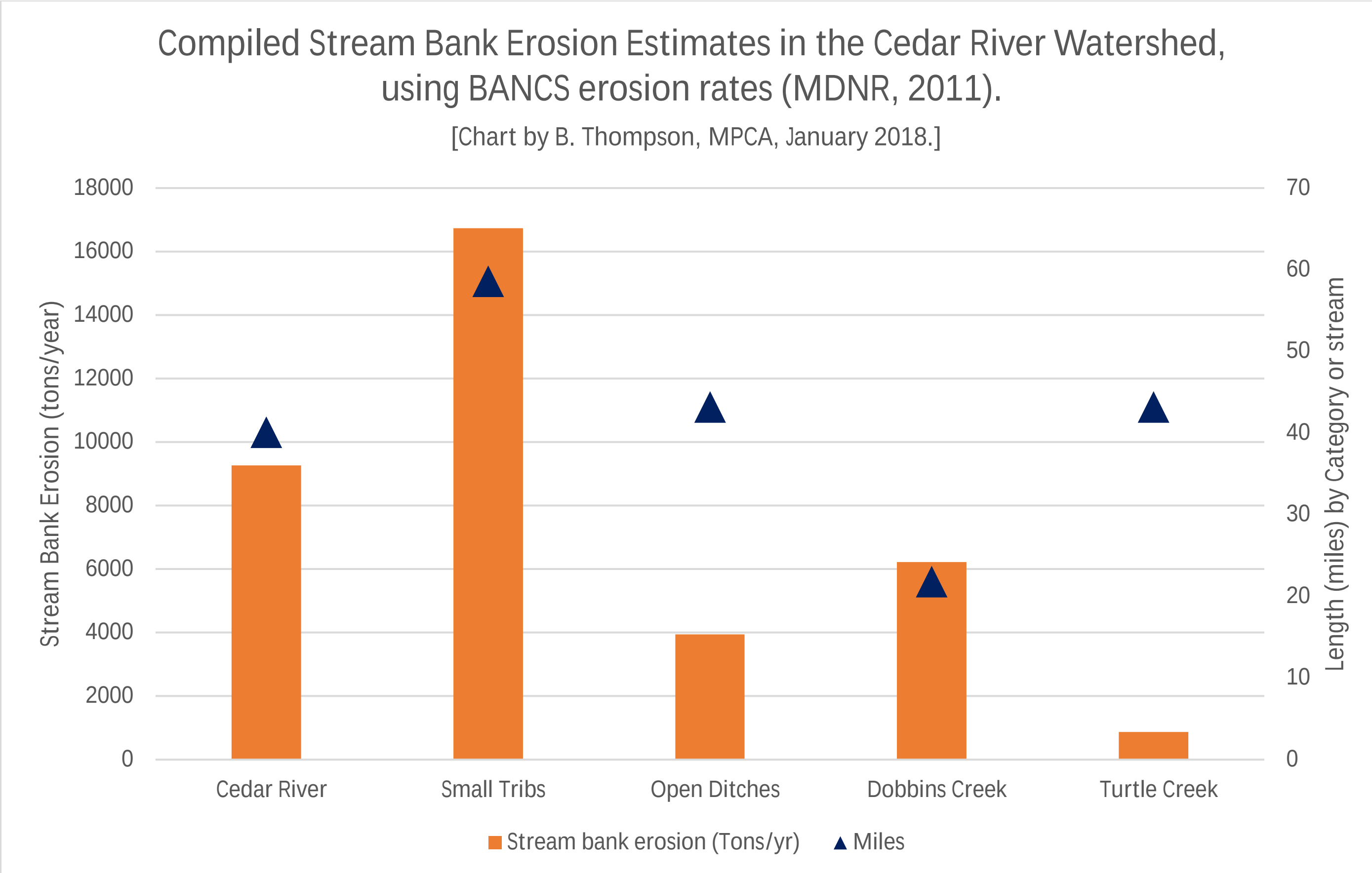
Total	Reach ln: 13200	Total loss (tons/yr) per ft of reach 0.0541

Figure 90. Estimated Stream Bank Erosion Rates for the Cedar River between 150th Street and County Road 2 covering 2.5 river miles.

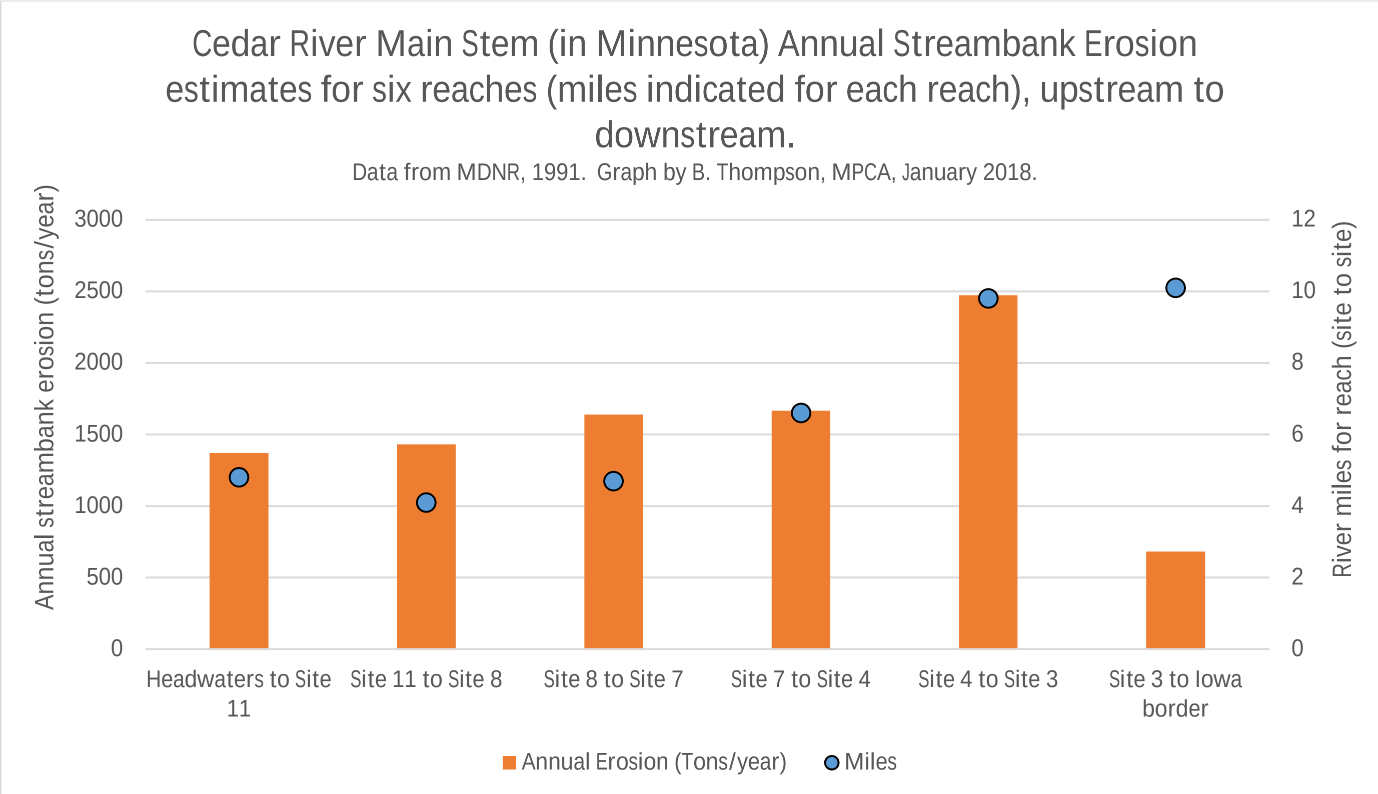
Bank	BEHI Numeric Rating	BEHI Adjective Rating	NBS Adjective Rating	Length ft	Loss cu yd/yr	Loss tons/yr
1	0	Low	Very L	11616	30.12	39.16
2	0	Moderate	Moderate	10122	112.47	146.21
3	0	Very L	Low	10510	0.97	1.26
4	29	Moderate	Very L	15312	0.85	1.11
5	0	Low	Very L	2600	0.96	1.25
			Totals	50160	145.37	188.99

Total	Reach	Ln: 50160	Total	Loss (tons/yr) per foot of reach 0.0038	

Figure 91. Estimated Stream Bank Erosion for Turtle Creek between County Road 23 and 140th Street covering 9.3 river miles.



Compiled Stream Bank Erosion Estimates in the Cedar River Watershed, using BANCS erosion rates (MDNR, 2011).
[Chart by B. Thompson, MPCA, January 2018.]
Stream Bank Erosion (tons/year)
Length (miles) by Category or stream
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
70
60
50
40
30
20
10
0
Cedar River
Small Tribs
Open Ditches
Dobbins Creek
Turtle Creek
Stream bank erosion (Tons/yr)
Miles



Cedar River Main Stem (in Minnesota) Annual Streambank Erosion estimates for six reaches (miles indicated for each reach), upstream to downstream.
Data from MDNR, 1991. Graph by B. Thompson, MPCA, January 2018.
Annual streambank erosion (tons/year)
River miles for reach (site to site)
3000
2500
2000
1500
1000
500
0
12
10
8
6
4
2
0
Headwaters to Site 11
Site 11 to Site 8
Site 8 to Site 7
Site 7 to Site 4
Site 4 to Site 3
Site 3 to Iowa border
Annual Erosion (Tons/year)
Miles

<u>Digital Terrain Analysis, Appendix C</u>

Barr used the Digital Terrain Analysis with LiDAR process as developed by teams at both the Minnesota Department of Agriculture and the University of Minnesota to determine the Stream Power Index (SPI) and Compound Topographic Index (CTI) values for the Cedar River Basin. The Cedar River Basin falls within Freeborn, Steele, Mower and Dodge Counties in southeastern Minnesota. The Stream Power Index is a function of both upland slope values and flow accumulation values, which can be thought of as the volume of water flowing to a particular point on the ground. The SPI represents the ability of intermittent overland flow to create erosion. CTI is also known as the topographic wetness index, and it attempts to identify areas in the landscape susceptible to ponding or saturation. Neither SPI or CTI index values are differentiated based on soil type or land cover effects on runoff volume or erosion.

<u>Methodology</u>

Digital Terrain Analysis relies on a Digital Elevation Model to serve as the base for all subsequent processing. In this case LiDAR data in the form of a 3m resolution DEM was available for each county from the Minnesota Department of Natural Resources at ftp://lidar.dnr.state.mn.us/data/. The grids for the four counties were merged and then clipped to a 1 mile buffer of the Cedar River watershed.

The resulting raw DEM (**dem3m)** was initially sink-prescreened by ArcHydro wherein all depressions with a drainage area <2 acres (user defined) were filled (**prefill3m)**. Then a low pass filter was run on **prefill3m** to create **filter3m.** ArcHydro's Depression Evaluation tool was used (on **prefill3m)** to try to get a sense of where the low lying, potentially drain-tiled, areas would be and to use to compare to the CTI grid created later.

A second set of data was created using a threshold of 1m in spatial analyst's pit filling tool. This provided a good compromise between the hilly terrain in the east and west regions and the flat terrain in the central regions of the watershed. The 1m threshold was expected to be enough to smooth out anomalies in the data and remove the less consequential depressions from the landscape both of which would cause interruptions in the flow path traces and the flow accumulation values generated later in the process. The primary reason not to divide the watershed into smaller regions according to the dominant terrain type or landuse was to be able to compare, relatively, the SPI and CTI values across the entire basin. This will enable an end-user to focus on the critical areas of the watershed where remediation efforts would produce the greatest results based on index ratings that are consistent throughout the basin.

From this point both the SPI and CTI grids were created according to the process laid out in the U of M and MDA documentation (Galzki et al, 2007 and Birr et al, 2010). The steps to calculate the various percentiles of the grids; however, were not applicable because the grids were too large for the available statistics software. Instead the percentile was estimated using the Quantile classification method in the raster symbology properties. For the SPI grid it was determined that the values greater than 2.44 would correspond to roughly the 99th percentile. For the CTI grid it was determined that values greater than 10.5 would correspond to roughly the 98th Percentile.

For the SPI analysis, additional processing steps were taken to enable querying of the data based on parameters of the users choosing. The raster data was converted to a polyline and then many of the line segments were converted to continuous lines. Due to the variability in the original SPI grid, areas appearing continuous may still remain segmented. The upstream and downstream elevations were determined for each line. Each line was also flagged as existing within 50ft and 100ft of an existing NHD watercourse. A point was created at the end of each line segment to represent the outfall of each high SPI area. An average SPI value was also determined for each line segment/outfall. It should be noted that all of the values calculated will be affected by any segmentation existing in each SPI line file. The SPI value was also determined for the downstream-most point of each SPI line. This may or may not be a better representation of the line as slope is a determining factor which depends on the shape of each individual channel.

SPI Results

The SPI results appear to do a good job of representing areas that may have a large number of gullies or nick points which may directly contribute to surface waters in the Cedar River watershed. Due to the large scale of the study area the number of results, greater than 300,000, can be overwhelming so a way to 'pre-screen' the data beyond the percentile analysis is required. By only considering those SPI 'channels' which are within 50 feet of a surface water and have a length of greater than 20 feet the dataset can be trimmed to 19,000 records. The 50 foot screen appears to be important in this watershed because in many cases high SPI channels are visible on a hill slope only to end on the terrace before reaching the stream bank. In cases such as this the waterborne sediment may never reach the surface water feature. One issue of the process is that in some instances the main watercourses themselves can be captured within the SPI dataset. By setting an additional query that screens out all SPI channels whose midpoint falls within 30ft of a NHD Watercourse the results can be further reduced to 12,000. The breakdown of the number of SPI results per watershed is summarized in Table 1.

Ideally, the results of digital terrain analysis should be analyzed in conjunction with some ground truthing to support the assumptions made in the computer analysis and confirm the final results. In this case we have georeferenced photos taken by Todd Kolander of the MDNR in the fall of 2009 and the spring of 2010. See Figures 1 through 4 for examples of locations where high SPI values can be linked to actual gullies seen on both Turtle Creek and the Cedar River. In Figure 5, SPI results have been overlaid on a map previously created for 1992 Austin, Minnesota East Side Lake water quality project. By comparing the Gully Source and Erosion Over 5T/Acres areas on the earlier map with the recent SPI results one can potentially pinpoint with greater accuracy areas that should be focused on for the greatest water quality improvements.

Appendix E, Table 1

Watershed Name	SPI Locations	Average SPI value across watershed	Average Watershed Slope	Acres	SPI/Acre
Shell Rock River	1380	-4.48	4.38	157375	0.009
Turtle Creek	888	-5.00	3.55	98353	0.009
Cedar River	7598	-5.50	2.29	278541	0.027
Little Cedar River	1945	-5.94	2.26	59097	0.033
Deer Creek	54	-5.10	2.2	18903	0.003

CTI Results

A CTI grid was also created during the terrain analysis using the same methodology as the SPI grid. Reviewing the CTI results, however, was more difficult and did not provide as clear a picture for identifying priority areas as was found using the SPI values. Ideally the CTI value will represent critical upland depression areas, but which areas may actually be priorities is difficult to determine without additional considerations. It isn't possible to query the CTI results based on their location relative to water features. Instead it is possible to overlay additional, related features to prioritize between areas. In Figure 6 the CTI values have been shown with depression features calculated from the original LiDAR grid, Poor and Very Poorly Drained Soils from the USDA's SSURGO database, and Restorable Wetlands from the USFWS. In Figure 7 the CTI values are again overlaid with the soil and depression features, but this time shown in a ditched, agricultural setting. Note that the restorable wetlands are only available in Freeborn and Steele counties at this time. One missing piece of data that would be very helpful would be field tile locations. This would provide information about where upland depressions are potentially discharging sediments to surface water and higher scores would represent better areas for prioritizing wetland restoration.

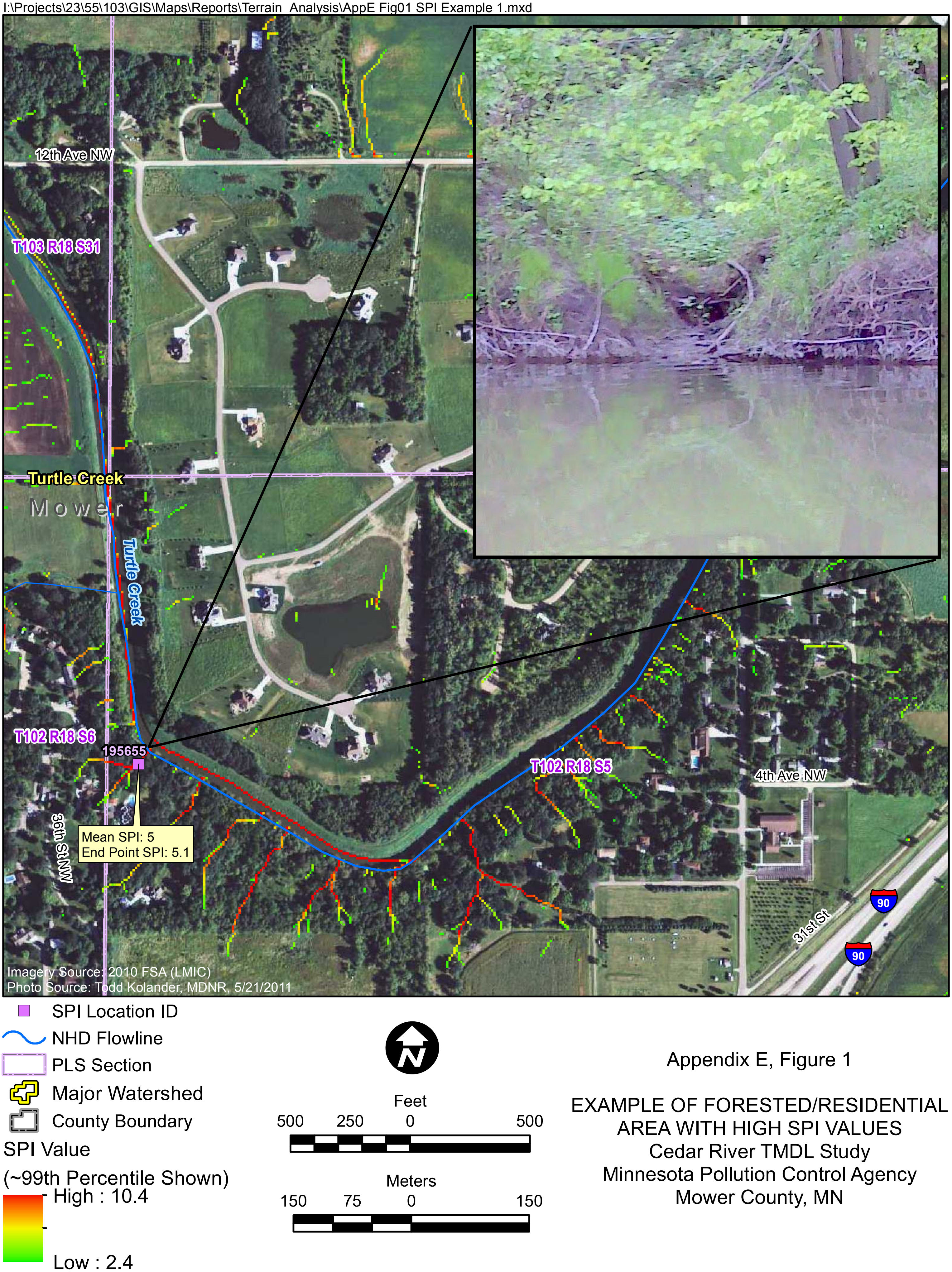
As with the SPI results, CTI results should also be field verified when possible. Unfortunately we do not have photos taken in the field to compare with our results. The terrain analysis literature from the U of M and MDA indicates that depressions are often drained through surface inlets to subsurface drainage tile. Water clarity could be improved and flows reduced if water could be retained in these depressions for longer periods of time.

References

Galzki, Jake, D. Mulla, J. Nelson, S. Wing. 2007. *Targeting Best Management Practices (BMPs) to Critical Portions of the Landscape: Using Selected Terrain Analysis Attributes to Identify High-Contributing Areas Relative to Nonpoint Source Pollution.* Minnesota Department of Agriculture.

Birr, Adam, B. Weisman, D. Mulla, J. Galzki, J. Nelson. 2010. *Digital Terrain Analysis with LiDAR for Clean Water Implementation Workshop.* Minnesota Department of Agriculture. Department of Soil, Water, and Climate: University of Minnesota.

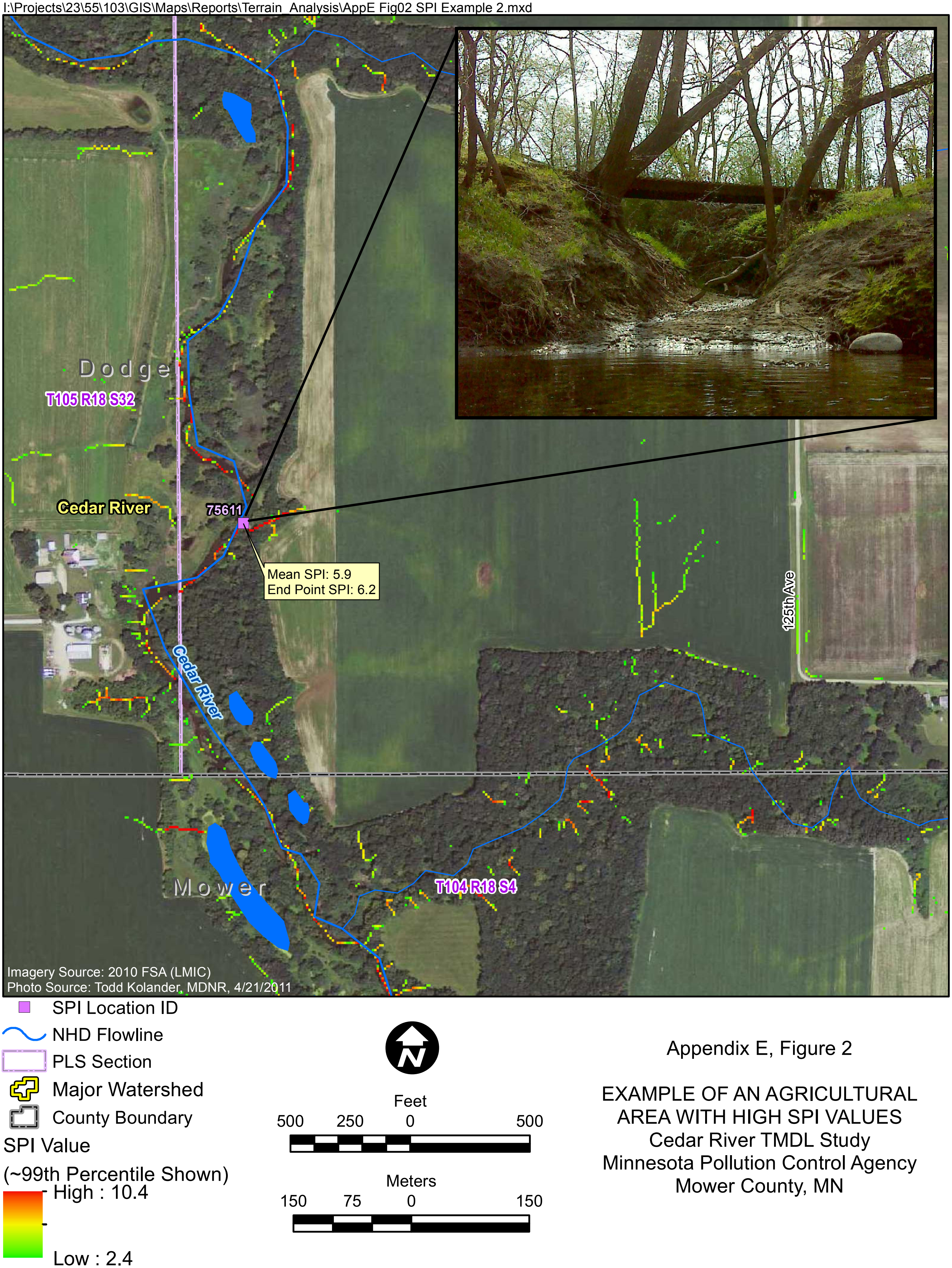
I:\Projects\23\55\103\GIS\Maps\Reports\Terrain_Analysis\AppE Fig01 SPI Example 1.mxd



Appendix E, Figure 1

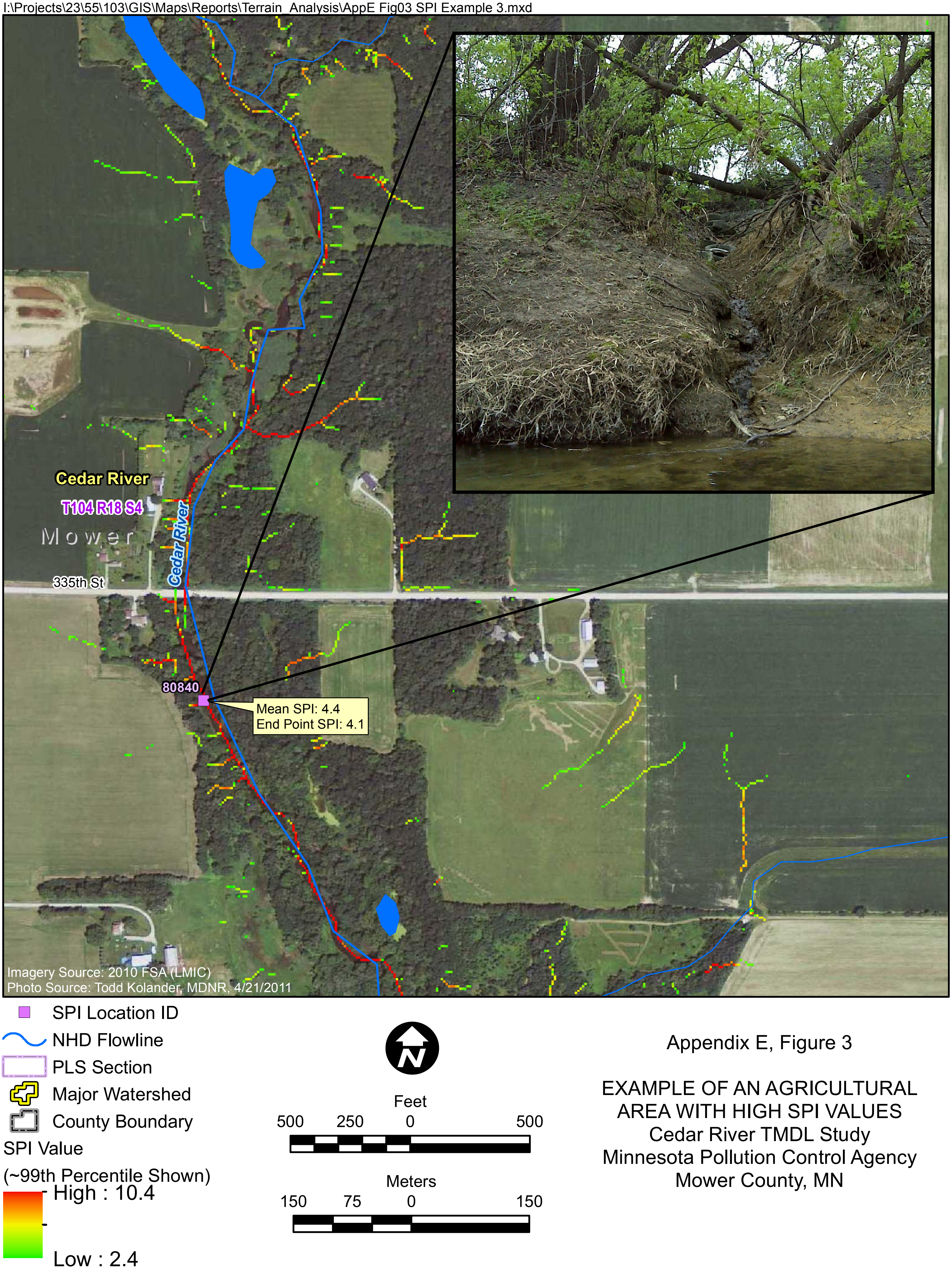
EXAMPLE OF FORESTED/RESIDENTIAL AREA WITH HIGH SPI VALUES
Cedar River TMDL Study
Minnesota Pollution Control Agency
Mower County, MN

I:\Projects\23\55\103\GIS\Maps\Reports\Terrain_Analysis\AppE Fig02 SPI Example 2.mxd



Appendix E, Figure 2

EXAMPLE OF AN AGRICULTURAL AREA WITH HIGH SPI VALUES
Cedar River TMDL Study
Minnesota Pollution Control Agency
Mower County, MN



Appendix E, Figure 3

EXAMPLE OF AN AGRICULTURAL AREA WITH HIGH SPI VALUES
Cedar River TMDL Study
Minnesota Pollution Control Agency
Mower County, MN

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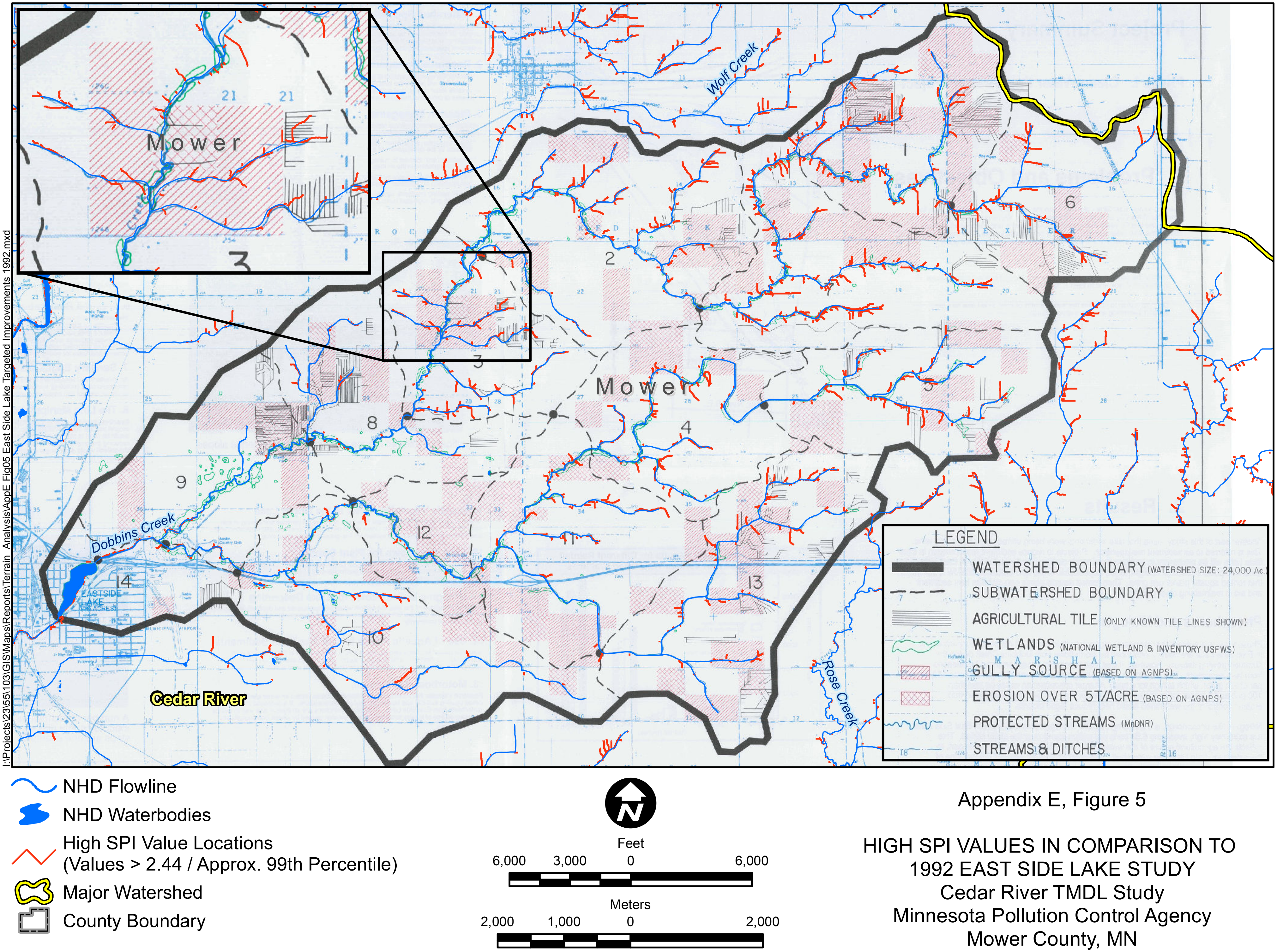
SPI Location ID
NHD Flowline
PLS Section
Major Watershed
County Boundary
SPI Value
(~99th Percentile Shown)
High : 10.4
Low : 2.4

Feet: 500 250 0 500

Meters: 150 75 0 150

Appendix E, Figure 4

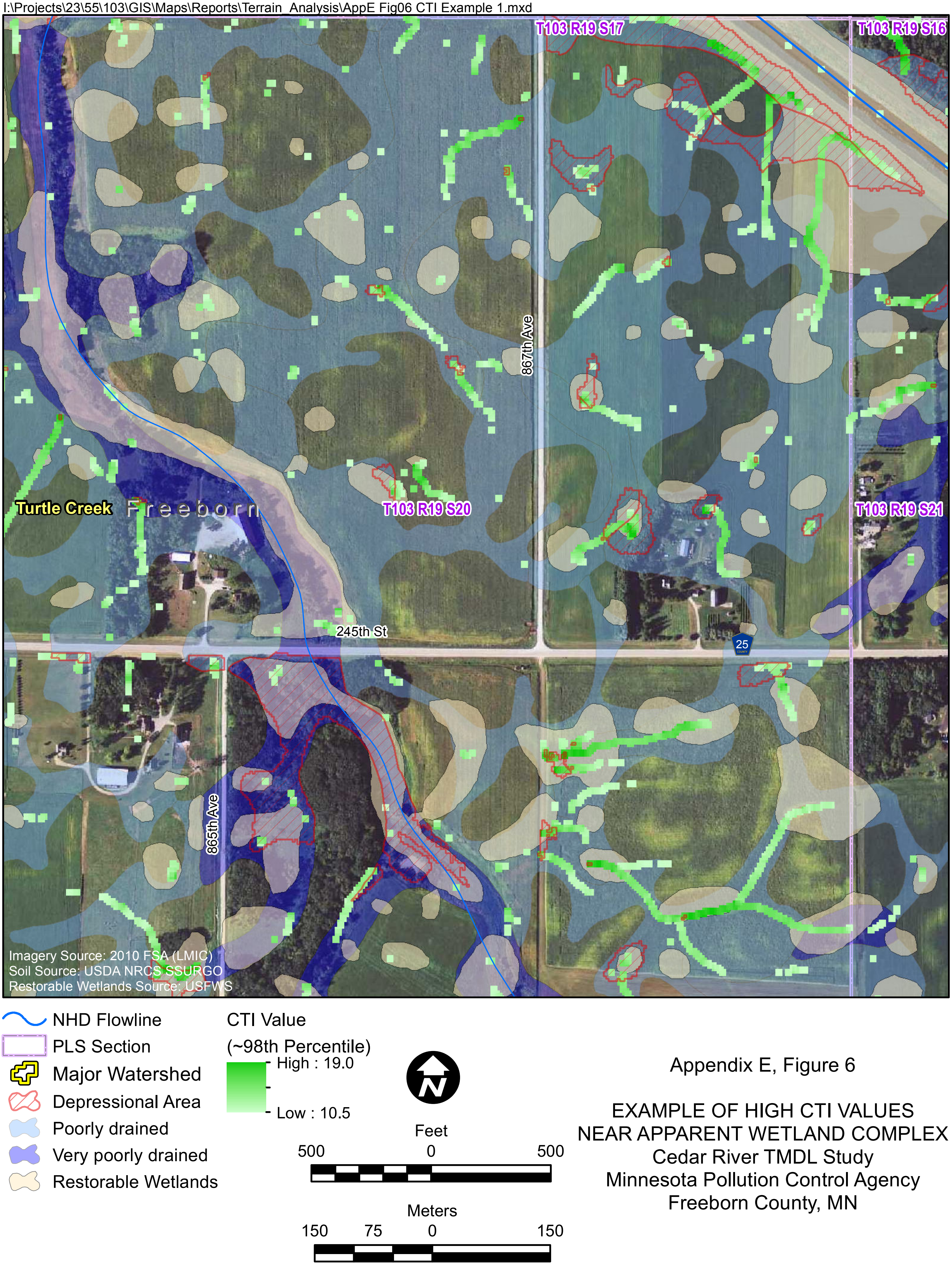
EXAMPLE OF AN AGRICULTURAL AREA WITH HIGH SPI VALUES
Cedar River TMDL Study
Minnesota Pollution Control Agency
Mower County, MN



Appendix E, Figure 5

HIGH SPI VALUES IN COMPARISON TO
1992 EAST SIDE LAKE STUDY
Cedar River TMDL Study
Minnesota Pollution Control Agency
Mower County, MN

I:\Projects\23\55\103\GIS\Maps\Reports\Terrain_Analysis\AppE Fig06 CTI Example 1.mxd



Appendix E, Figure 6

EXAMPLE OF HIGH CTI VALUES NEAR APPARENT WETLAND COMPLEX
Cedar River TMDL Study
Minnesota Pollution Control Agency
Freeborn County, MN

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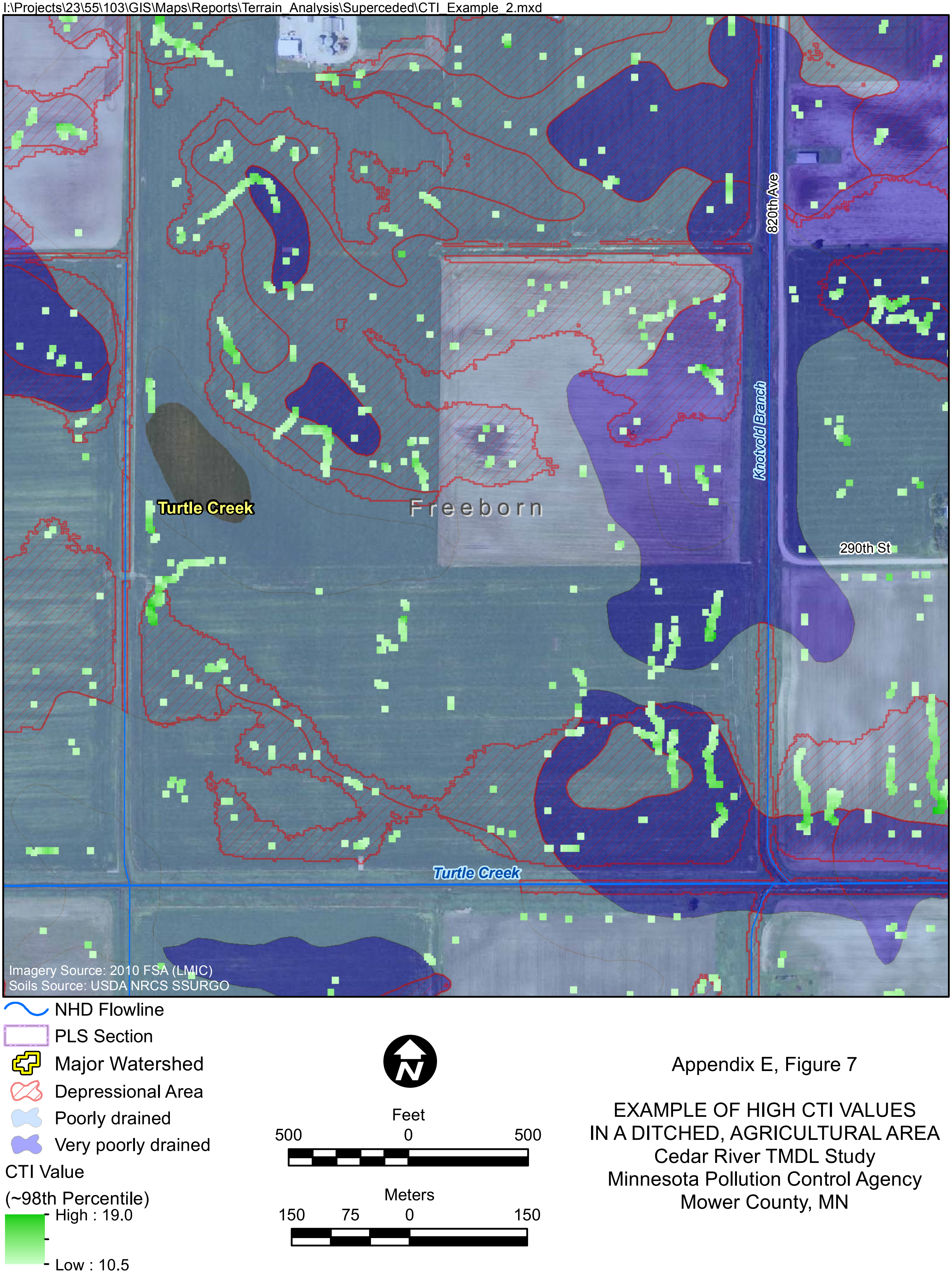


Appendix E, Figure 7

EXAMPLE OF HIGH CTI VALUES
IN A DITCHED, AGRICULTURAL AREA
Cedar River TMDL Study
Minnesota Pollution Control Agency
Mower County, MN

Technical Memorandum—FINAL

To: Project File
From: Greg Wilson
Subject: Updated SWAT Watershed Modeling
Project: Cedar River Watershed Turbidity Total Maximum Daily Load Study

A previous effort to develop and calibrate a Soil and Water Assessment Tool (SWAT) watershed model for the Cedar River basin included a limited representation of existing best management practices (BMPs) in the modeling. In addition, current information about soils data (including the new NRCS soils map interpretations for Mower, Freeborn, Steele and Dodge Counties) and agricultural management practices indicated that the previous extent of tile drainage had likely been underestimated in the original modeling effort. It was believed that in order to be the most useful tool, the model should be refined to more accurately account for current BMPs, tiling and soils and explicit tile modeling routines within the SWAT model were used as a part of the model refinement. As a result, Mower SWCD and watershed staff for the Cedar River and Turtle Creek Watershed Districts began an effort to collect more-detailed data about the locations and extent of current BMPs in the study area so that the SWAT model could then be refined to better represent how these BMPs, tiling and soils are affecting water quality. Through these refinements, the model could in turn be used to provide greater insight into identifying and prioritizing the critical source areas of turbidity in each watershed.

This memorandum describes the updated SWAT modeling, including the input data, model calibration, limitations and the approach for identifying the critical source areas for excess sediment loading in the impaired river reaches.

SWAT Model Background

SWAT (Soil and Water Assessment Tool; Arnold et al., 1993) is a basin-scale continuous distributed water quality simulation model capable of predicting long-term effects of alternative land management practices and water quality improvement features. Major components of the model include hydrology, erosion, nutrients, pesticides, crop growth, and agricultural management. Hydrologic processes include surface runoff, tile drainage, snow-melt runoff, infiltration, subsurface flow and plant uptake. The model allows for consideration of reservoirs and ponds/wetlands, as well as inputs from point sources.

Much of the previous SWAT modeling input data remained the same, including the compiled GIS and weather data as well as information about point source discharges, land use/land management, tillage methods and information about nutrient applications. The following sections describe the changes that were made to the model (used to develop the Cedar TMDL) to improve the way that existing tile drainage, treatment from regional ponds/wetlands and implementation of agricultural Best Management Practices (BMPs) and smaller wetland restoration projects were accounting for the observed water quality in the watershed.

SWAT Model Improvements

Soils and Tiling

The soil maps that were used in the development of the original SWAT model were recently updated by NRCS. The hydrologic soil group characteristics were reclassified by NRCS, since the last modeling effort. The resulting soil database was used to identify and spatially map soils classes that were hydrologic soil group "C" and "D" soils (USDA, 1980). The cultivated cropland land cover/land use areas were intersected with C or D soil types from the soils database to determine areas of the watershed that are subject to tile drainage. Because a comprehensive tile data base was not available for the modeled watershed area, this was a suitable alternative means to identify lands where tile has been placed and to more accurately account for runoff.

Determination of Hydrologic Response Units

Input for the SWAT model was derived at two different scales: the subbasin and the hydrologic response unit (HRU). HRUs are developed by overlaying soil type, slope and land cover. It is noted that HRUs in the version (2009.93.7b, Revision 481) of ArcSWAT used for this project are not defined by a flow direction; and their spatial location within each subbasin does not influence sediment loading to the stream. A newer version of ArcSWAT was released after this project began, but was not used because it was not backward compatible (and would not be able to use the files from the previous modeling effort) and some software bugs had been reported for BMP simulation in the newer version.

In addition to the crop rotations, SWAT was also used to model pasture land, forest land, water and urban land cover HRUs in each subbasin. Table 1 shows the distribution of the general SWAT model land uses applied to the watershed. The intersection with the reclassified soil types resulted in a significant increase in the amount of cropland with tile drainage, in comparison with the previous modeling effort (from approximately 51% to 84% of the cultivated cropland in the watershed being tiled). The soil types associated with pasture, alfalfa and small grains land cover components were not included in the areas that were estimated as having tile drainage.

Table 1. General SWAT Model land use distributions, as a percentage of the overall watershed.

Land Use	Percentage of Overall Watershed
Row Crops with Tile Drainage	65.0%
Row Crops without Tile Drainage	12.2%
Forested	1.8%
Pasture	6.8%
Alfalfa and Small Grains	9.9%
Water/Wetlands	2.5%
Low Density Residential	1.4%
Medium/Low Density Residential	0.3%
High Density Development	0.1%

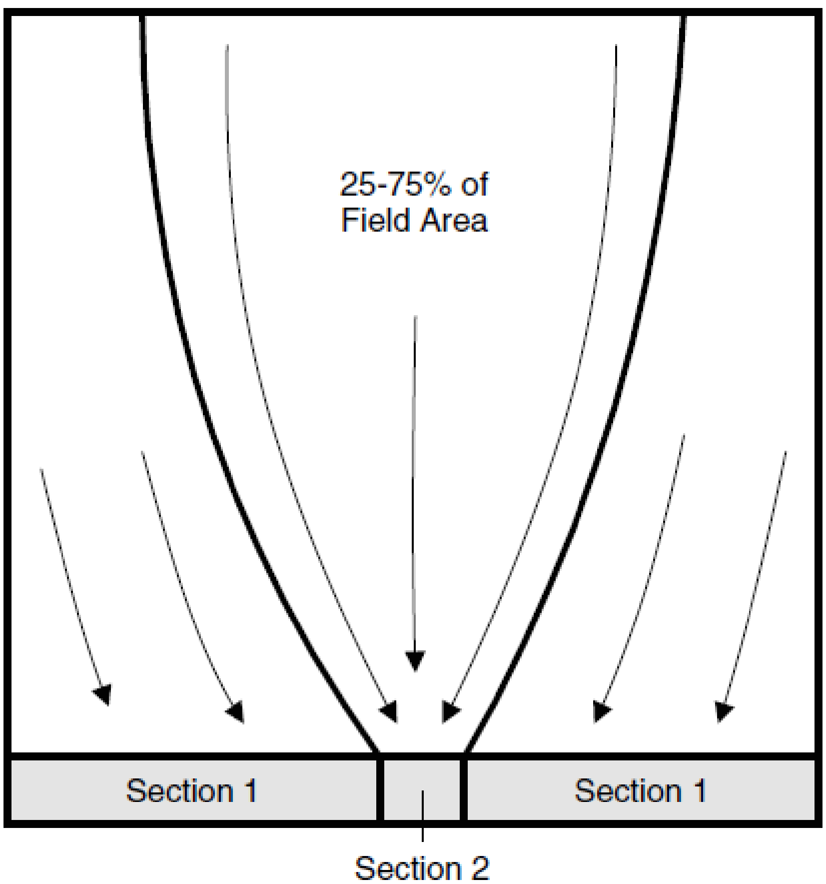
The initial HRUs set up in the ArcSWAT interface were further refined for each subbasin in the Cedar River basin to account for the various crops, crop management, tile drainage and agricultural BMPs. This resulted in more than 20,000 HRUs in each of the major watersheds, with several of the HRUs resulting from unique combinations of soils and land use that represented very small areas in each subbasin. As a result, the land use refinement feature in ArcSWAT was used to eliminate these small HRU areas from the modeling, except for the urban land use areas that were always retained (or exempt from refinement) in each subbasin. Other HRU areas that remained in the model were represented by land uses that occupied at least 5 percent of each subbasin and soil types that occupied at least 20 percent of each subbasin.

Accounting for BMP Implementation

This section describes the changes that were made to the modeling to improve the way that water quality treatment from regional and localized ponds/wetlands and existing agricultural Best Management Practices (BMPs) was determined. Since such information was not available for the original modeling effort, that model was made to approximate BMPs by using a uniform filter strip width (FILTERW) of 5 meters applied to all cultivated cropland HRUs in the basin. It is expected that this model procedure resulted in a significant overestimate of the amount of filtration that was actually occurring in the watershed. As a result, the input for this variable was eliminated from the updated SWAT model and replaced with BMP information for the tributary area receiving filtration, as determined from the District staff-provided BMP inventory locations in GIS.

As previously discussed, District staff completed an inventory to collect detailed information about the current locations and extent of agricultural BMP implementation in the Cedar River and Turtle Creek watersheds. A total of 927 practices were identified in the combined area of both watershed districts with the vast majority (830) representing filtration BMPs (such as grassed waterways, water and sediment control basins, side inlet protection and filter strips), while the remaining 97 practices were ponds/wetlands.

All of the filtration BMPs were modeled in SWAT as filter strips in the operations routine associated with each HRU area, based on specific BMP locations determined in GIS. The following six subbasin areas of the watershed (not previously represented as having reservoirs in the SWAT modeling) were explicitly modeled with wetland treatment in SWAT (based on their associated tributary area percentages): Subbasin#29 (50%), Subbasin#48 (30%), Subbasin#37 (30%), Subbasin#66 (50%), Subbasin#94 (20%) and Subbasin#56 (80%). The BMP treatment associated with the remaining ponds and wetlands was combined with the filter strip treatment for each HRU area, based on the BMP locations determined in the BMP GIS database. The resultant tributary area receiving some level of filtration treatment in the updated model was 58,418 acres for the combined watershed. The typical (area-weighted) ratio of field area to filter strip area was 60 for all of the filtration practices based on an examination of the available data. For individual HRU areas that received a combination of filtration and localized pond/wetland treatment, the FILTER_CON variable in the model (the fraction of the HRU which drains to the most concentrated ten percent of the filter strip area or Section 2 in the following figure) was area-weighted using the default value of 0.5 for filtration BMPs and a value of 0.2 for pond/wetland treatment (since a value of 0.2 results in similar sediment load reductions as a pond or wetland per White and Arnold, 2009). The weighted fraction of HRU area that is receiving filtration (assuming a value of 0 for full treatment because none of the flow would be channelized) was used to set the FILTER_CH variable in the model (the fraction of the flow within the most concentrated ten percent of the filter strip which is fully channelized [and is not subject to filtering or infiltration effects]) in the filter strips operations portion of the SWAT model.



Re-Calibration of SWAT Model and Limitations

Results of Model Re-Calibration

Although the water quality data were available from 2008-2010, the simulations were made over 11 years of record to reduce the errors associated with initial conditions. Model calibration was initially done by comparing predicted daily flows against measured data. After flows were calibrated, sediment loads did not require re-calibration by adjusting any of the same parameters that had previously controlled sediment erosion, deposition and delivery in streams and ditches that were modeled. The approach followed for the SWAT model calibration in each of the major (impaired) watersheds, involved using global parameters to optimize the model fit for several of the larger watershed areas that were monitored for both water quantity and quality in the TMDL study, that did not have questionable data, and that were not significantly affected by lake/reservoir effects on flow rates, sediment settling or internal phosphorus loading, depending on the metric (flow, sediment, total phosphorus) undergoing calibration. Global parameter changes applied to the calibrated modeling essentially means that one value was chosen for each of the calibration parameters and applied the same way to each subbasin in the Cedar River watershed model.

The model accuracy was expressed in terms of the Nash-Sutcliffe efficiency (NSE) between measured and predicted monthly flow values, cumulative modeled and measured flow volumes during the monitored portion of the 2009 and 2010 water years, and a graphical comparison of the flow hydrographs at each of the monitoring locations that had reliable stage-discharge rating curves and continuous stage measurements. NSE values above 0.75 are considered very good and a value of 0.50 would be considered satisfactory for a monthly time step (Moriasi et al., 2007). Figure 1 through 3 show examples of the graphical comparisons that were made between the observed and SWAT model predicted flows for several of the monitored (impaired) watersheds. In general, it was more difficult to match observed stream flows in the spring of each year of monitoring, since we didn’t have winter flow data and the ability to calibrate the modeling for the snowfall/snowpack/snowmelt parameters. This effect would then carry over and pose difficulty in accurately simulating soil moisture in the spring of each year and was further exacerbated in watershed monitoring locations that were downstream of lakes/reservoirs, especially during 2008 (which would have required snowmelt parameters that were outside of the accepted ranges to get the modeled snowmelt to correspond with the observed streamflow). Since 2009 and 2010 represented the critical conditions for meeting the water quality standards for each of the watershed impairments, the calibration process was given more weight for these two water years.

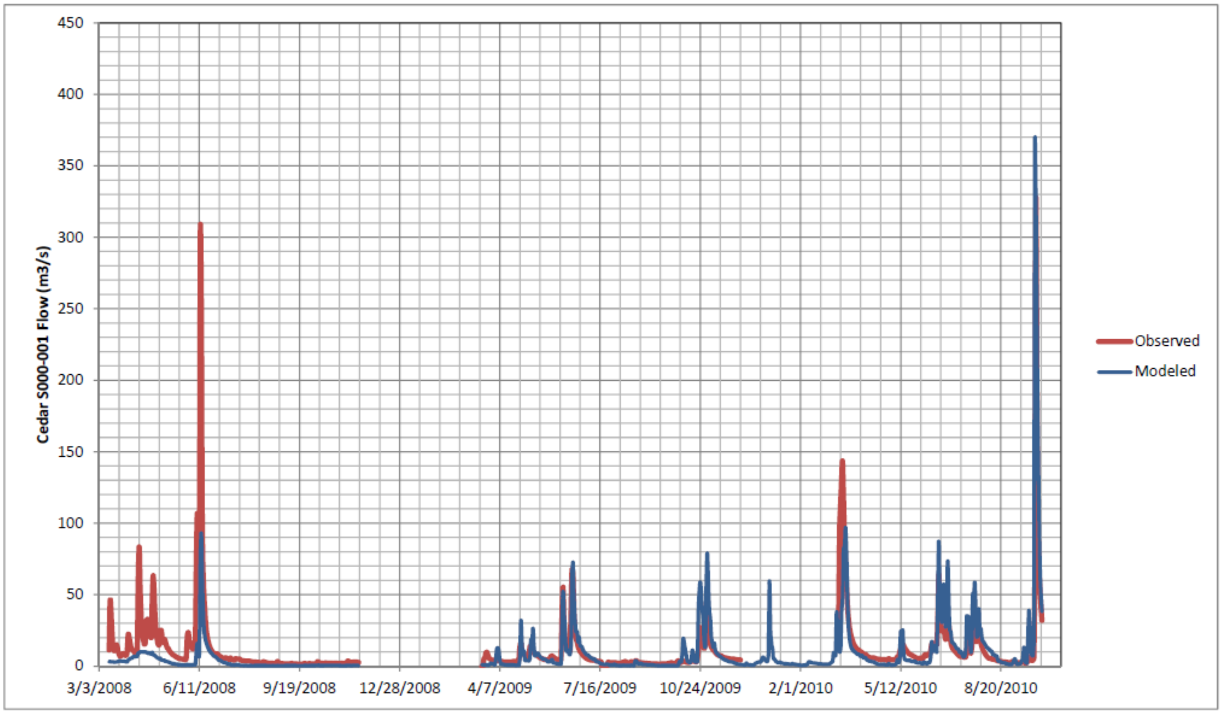


Figure 1. SWAT model flow calibration results for the Cedar River station near Austin, MN.

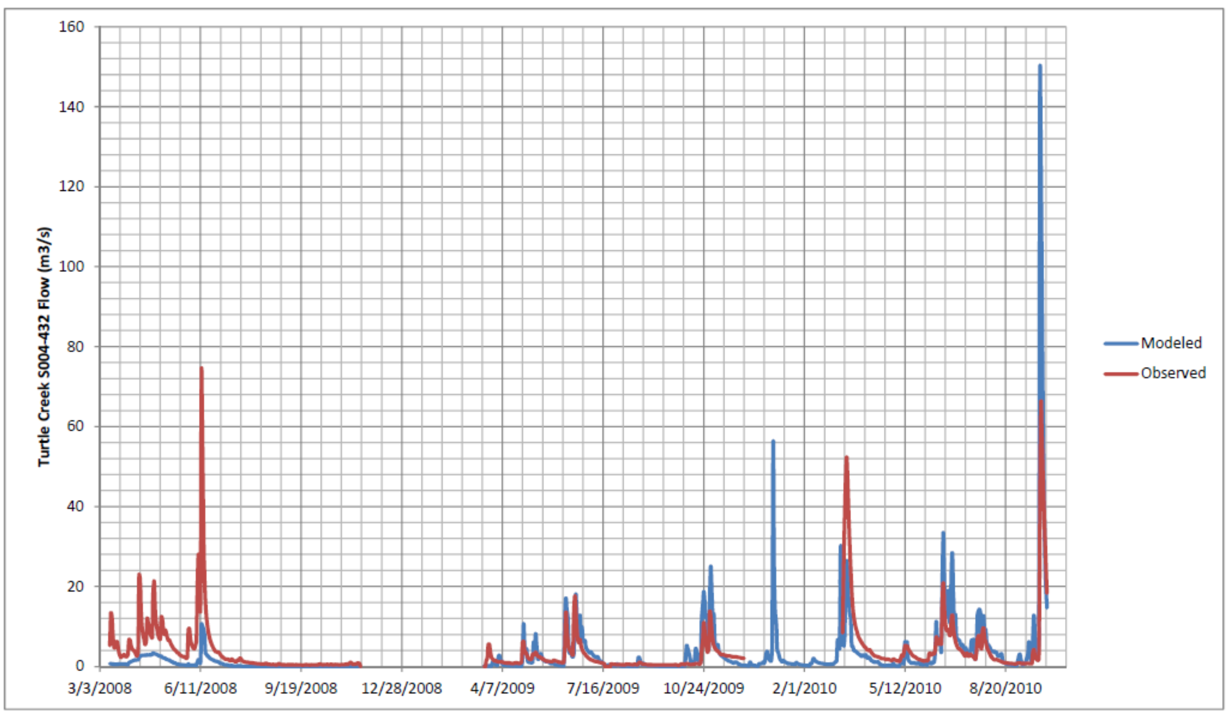


Figure 2. SWAT model flow calibration results for the Turtle Creek station near Austin, MN.

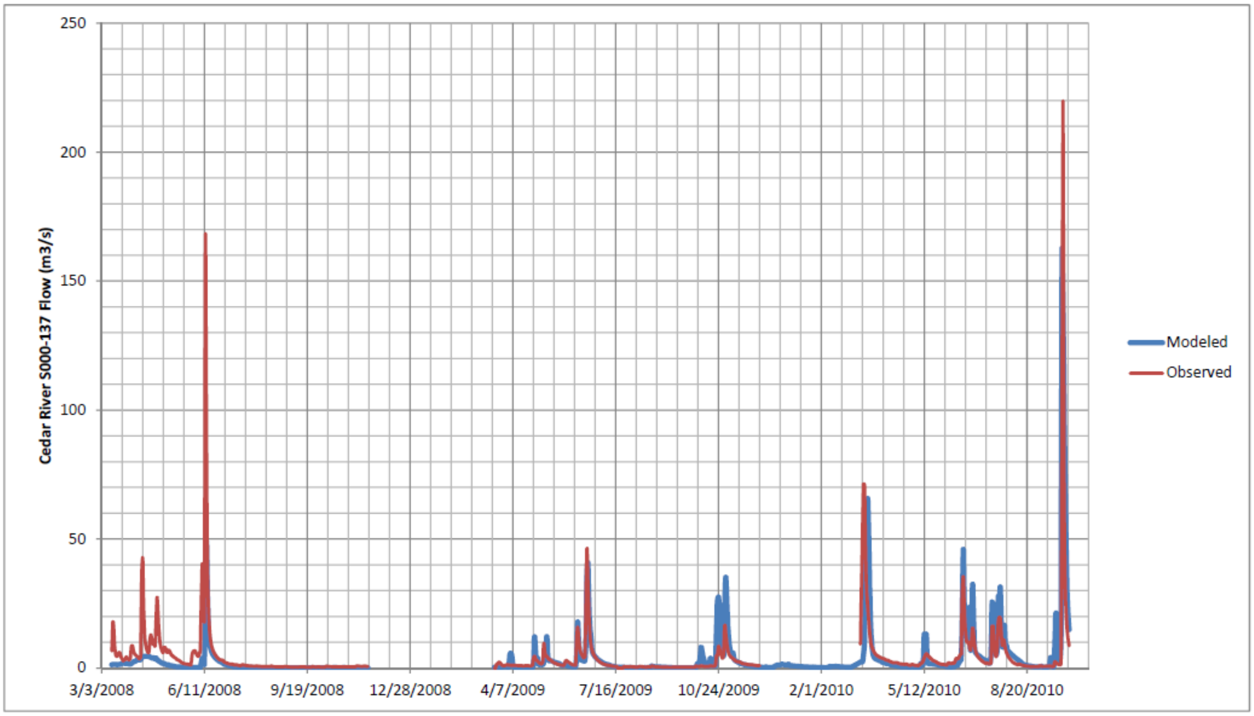


Figure 3. SWAT model flow calibration results for the Upper Cedar River station.

Table 2 shows the SWAT model parameters that were used to re-calibrate the modeling to water quantity and quality observations in each watershed. The crack flow and curve number for frozen conditions components of the model were activated based on guidance from an advanced modeling workshop (R. Srinivasan, 2008).

Table 2. SWAT Model parameter defaults and calibrated values.

SWAT Parameter	Description	Default Value	Typical or Accepted Range	Calibrated Value
ESCO	Soil evaporation compensation factor	0.95	0-1	0.65
GW_DELAY	Groundwater delay time, days	31	0-500	10
ALPHA_BF	Baseflow alpha factor, days	0.048	0-1	0.2
SURLAG	Surface runoff lag coefficient	4	1-12	0.5
RCHRG_DP	Deep aquifer percolation fraction	0.05	0-1	0.10

SWAT Parameter	Description	Default Value	Typical or Accepted Range	Calibrated Value
ICRK	Crack flow	Inactive	--	Active
CN_FROZ	Curve number for frozen conditions	Inactive	--	Active
SMTMP	Snowmelt base temperature	0.5	-5-5	5
TIMP	Snow pack temperature lag factor	1.0	0-1	0.5
DEP_IMP	Depth to impervious layer for modeling perched water tables, mm	--	1000	1000
DDRAIN	Depth to sub-surface drain, mm	--	1000	1000
TDRAIN	Time to drain soil to field capacity, hours	48	0-72	48
GDRAIN	Drain tile lag time, hours	24	0-100	10
CH_N(2)	Manning's "n" for the main channel	0.014	0-0.3	0.05
FILTER_I	Flag for simulation of filter strips	1 active/ 0 inactive	0/1	1
FILTER_RATIO	Ratio of field area to filter strip area, ha/ha	40	30-60	60
FILTER_CON	Fraction of the HRU which drains to the most concentrated ten percent of the filter strip area, ha/ha	0.5	0.25-0.75	0.5 for filtration BMPs; Area-weighted at 0.2 for HRUs with ponds/wetlands
FILTER_CH	Fraction of the flow within the most concentrated ten percent of the filter strip which is fully channelized	0	--	Weighted for the fraction of HRU that is receiving filtration (0 for full treatment)
	Channel degradation	Inactive	--	Active
RSDCO	Fraction of residue decomposing in a day	0.05	0.02-0.10	0.02
	Fertilizer application rate, kg/ha		0-500	350
FRT_LY1	Fertilizer application fraction to surface layer	1	0-1	0
PHOSKD	Phosphorus soil partitioning coefficient	175	100-200	200

The SWAT model simulates the total sediment load, i.e. the amount of sand, clay and silt particles detached, eroded and transported to the outlet of the watershed. Since the sample monitoring data is going to be a measure of suspended sediment and nutrients (both organic and inorganic) under most flow conditions, it would not include the bedload and constituents transported along the bottom of the stream channel (see Figure 4). As a result, the stream channel erosion estimates for the Cedar River watershed (discussed in Appendix C of the Draft TMDL Report) were used as a check on the calibrated SWAT model sediment load for the Cedar River gaging station and the SWAT model sediment loading results were also superimposed on the TMDL load duration curves (see Figures 5 through 7) for the sediment impaired stream reaches, that were not influenced by upstream lakes, to graphically check the model calibration. Due to the previously described flow and sampling effect (shown in Figure 4), the intent was to attain good agreement between the SWAT model results and the load duration curves under lower flows and overestimate the TSS load under high flow conditions, as depicted in Figures 5 through 7. Interpolating the streambank sediment contribution estimates from Appendix C results in an average annual load of 36,256 metric tons/year of sediment for the reach that corresponds to the calibration data shown in Figure 5. Summing the SWAT model total sediment loadings for the 2009 and 2010 water years at the lower Cedar River impaired reach results in an average annual load of 79,800 metric tons/year. As a result, the total streambank erosion tributary to this reach would account for approximately 45% of the total load. This is lower than neighboring watersheds in the Minnesota River basin that have similar watershed and land management characteristics and have estimated near-channel erosion percentages between 70 and 85% (Schottler et al., 2010).

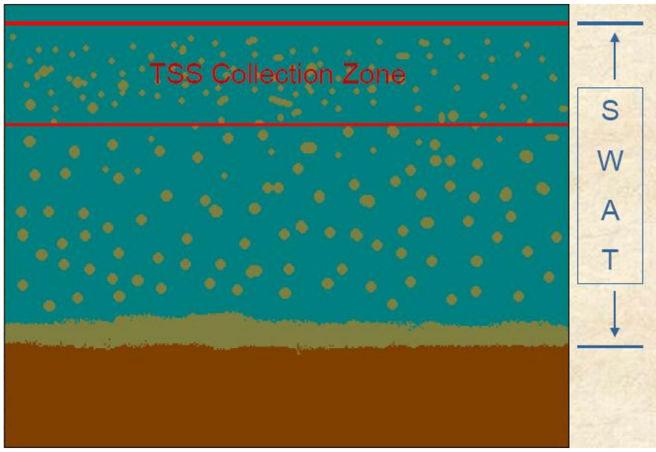


Figure 4. Depiction of water quality monitoring zone relative to sediment modeling in SWAT.

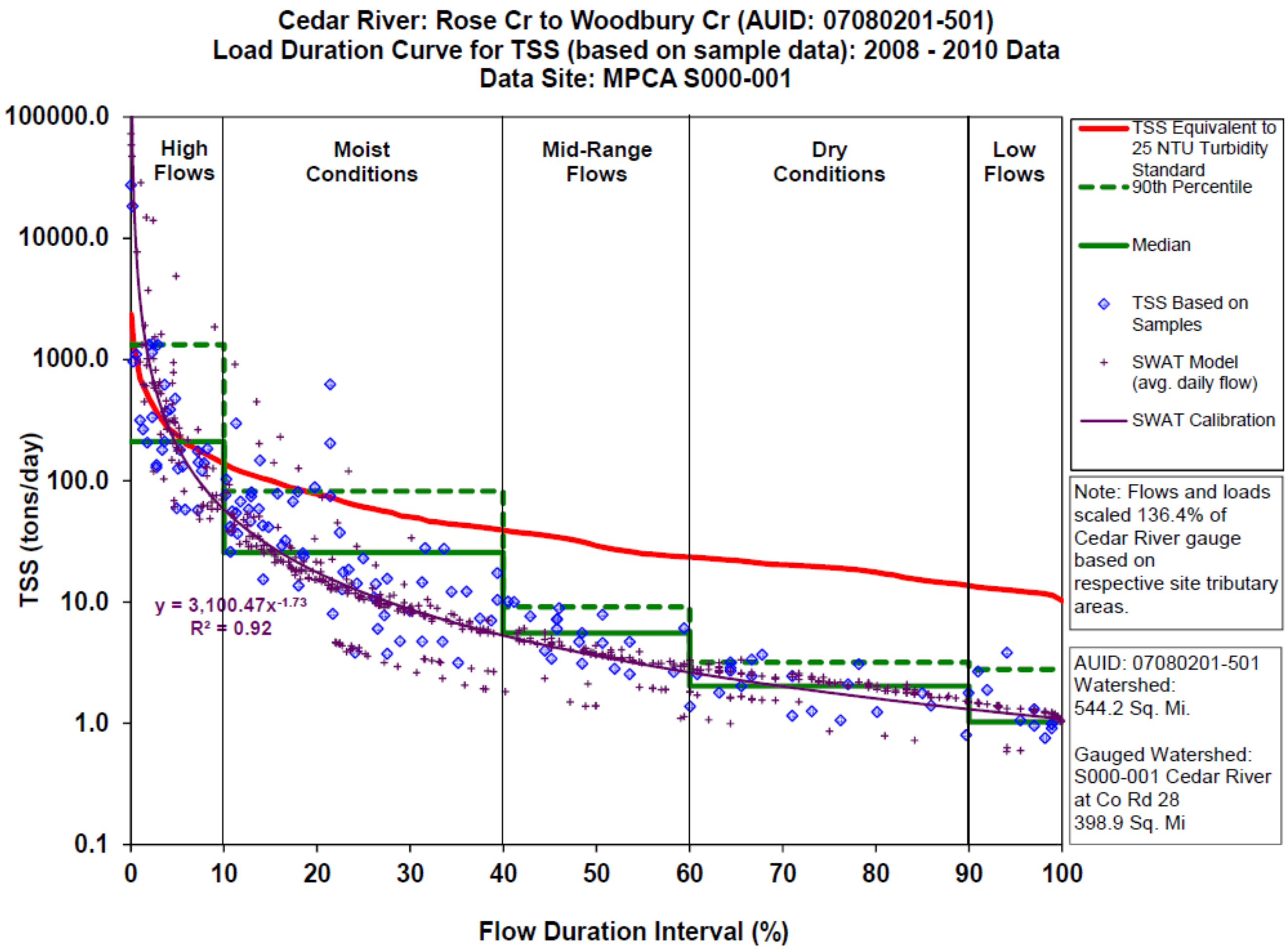


Figure 5. Lower Cedar River TSS load duration curve and calibrated SWAT model sediment loads.

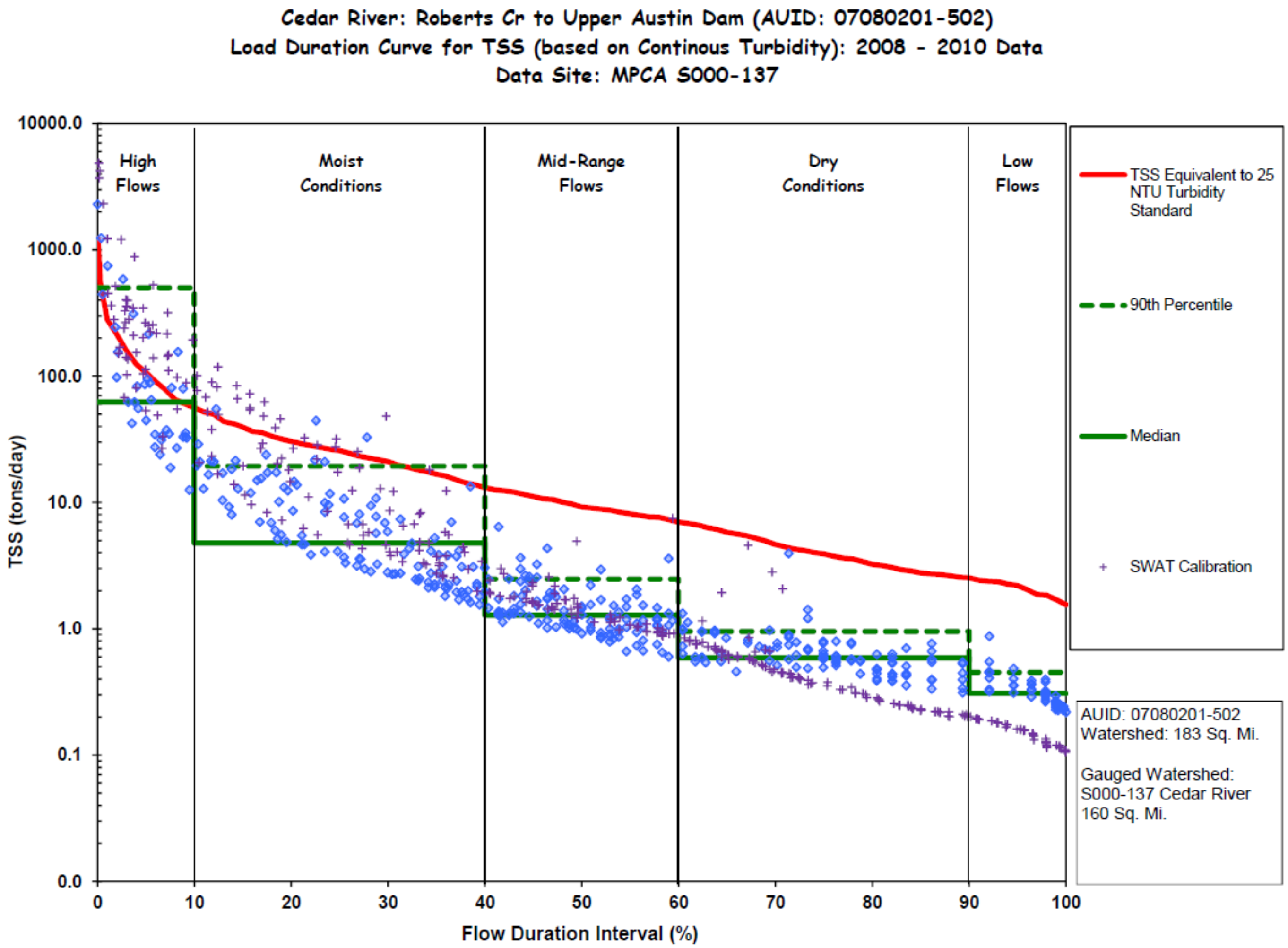


Figure 6. Upper Cedar River TSS load duration curve and calibrated SWAT model sediment loads.

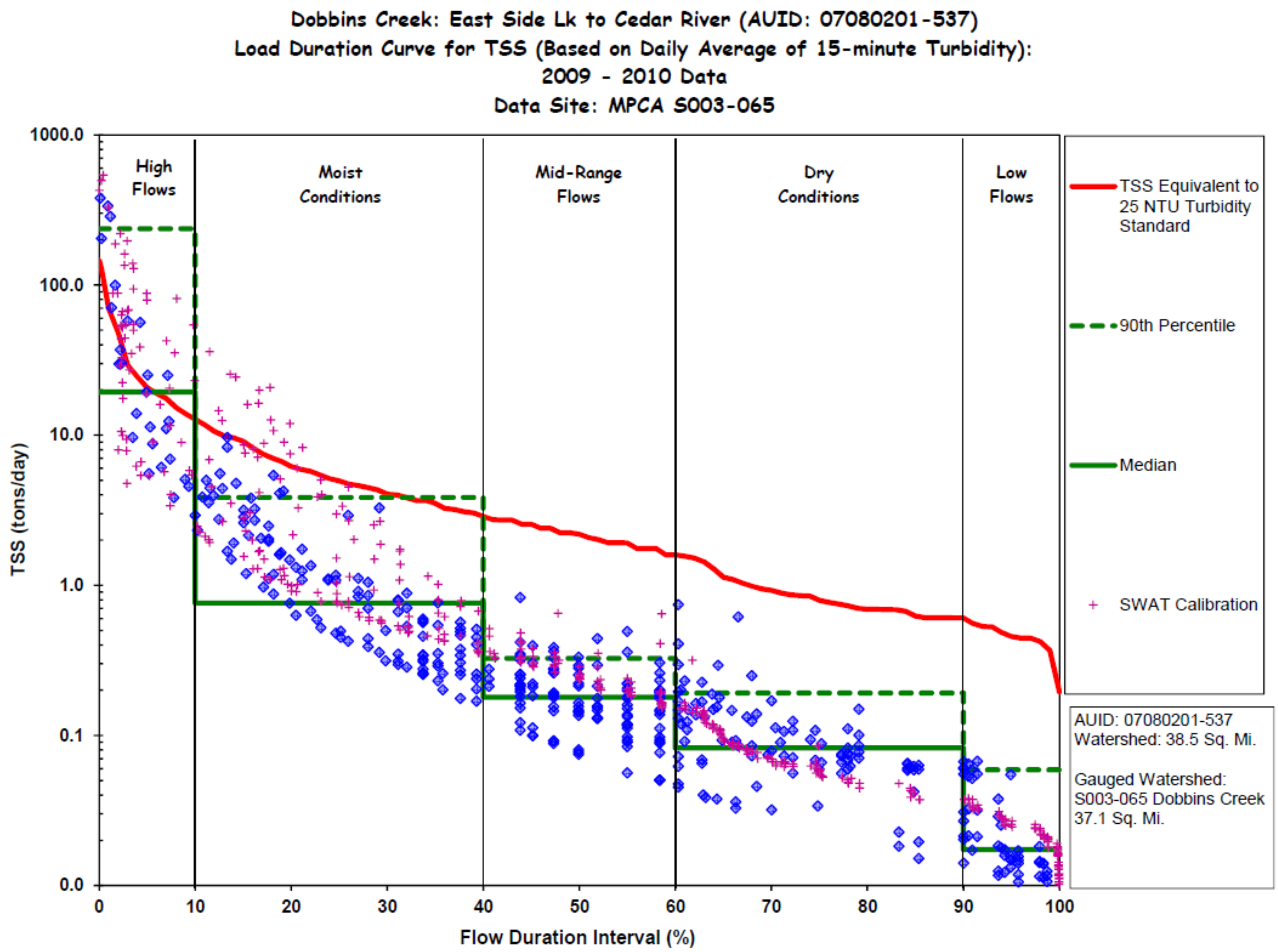


Figure 7. Dobbins Creek TSS load duration curve and calibrated SWAT model sediment loads.

A sensitivity analysis was not conducted as a part of the model calibration because we had data from multiple monitoring stations, each possessing unique watershed characteristics, some of which were nested within two larger basin areas that were monitored and progressively modeled for flow, sediment and nutrients to determine the best parameters for optimizing the fit between the modeling and monitoring.

Model Limitations and Uncertainties

Due to limitations of flow monitoring capabilities during the winter, we had a limited ability to calibrate the modeling for snowfall, snowpack and snowmelt parameters. As a result, the modeling did not necessarily provide good agreement for the winters and springs with the available streamflow data from 2008.

Sediment calibration to TSS results is confounded by effects from algae and streambank erosion. As previously discussed, depending on the streamflow, TSS may not be a good measure of the sediment load for any given time period. Figure 4 shows that, depending on the particle size distribution of the stream channel material and the streamflow velocity, TSS samples would not be expected to adequately estimate the total sediment load, except under low flow conditions when bedload is negligible.

SWAT is dynamically simulating the nature of the suspended and bedload transport in the system. Under low flows, the SWAT modeling was calibrated to the observed suspended solids loadings, but on an annual basis, matching the total sediment load (which is modeled by SWAT) required a comparison with the streambank erosion estimates provided in Appendix C of the Draft TMDL Report. Annual or long-term sediment yield was also expressed in a flow duration format for each of the sediment-impaired stream reaches in the watershed to check model agreement.

SWAT Model Results

Sources of Excess Sediment Loading

Figure 8 shows the results of the SWAT Model estimates for upland sediment yield from the combined land areas in each subbasin of the Cedar River watershed for the 2010 calendar year and does not consider the sources/sinks within each stream channel. The subbasins with the highest sediment yields have steeper land and/or higher proportions of poorly-drained soils that were likely tiled. Subbasin sediment yield is generally within a two ton per acre range throughout the watershed with more than three-quarters of the subbasin loading rates in the range of 0.8 to 2.8 tons/acre. None of subbasins would be expected to consistently contribute sediment yields above 4 tons/acre despite the fact that 2010 experienced some large runoff events.

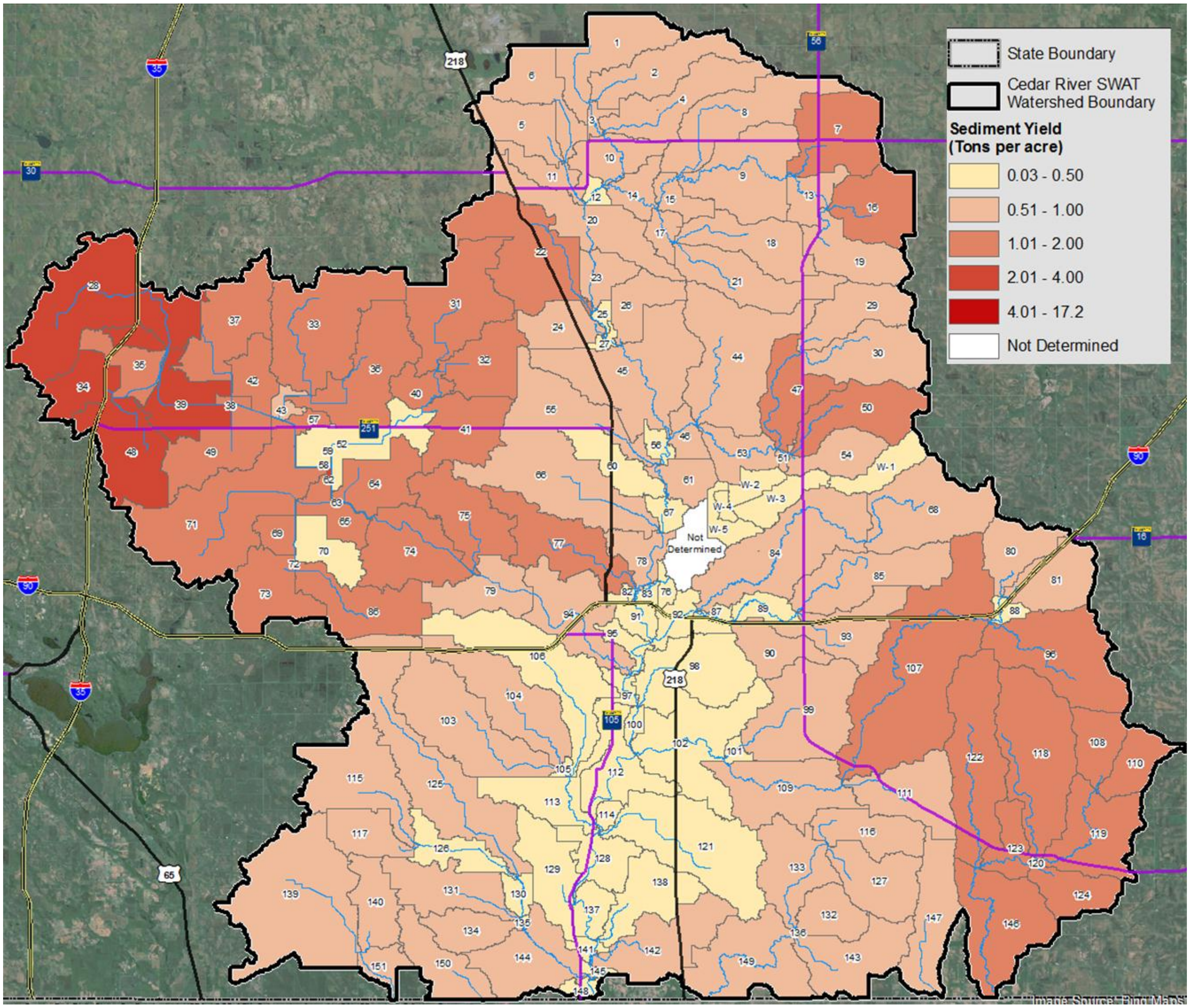


Figure 8. SWAT model upland sediment yield estimates for the Cedar River watershed.

The results shown in Figure 8 for subbasins 108, 110, 116, 118-120, 122-124, 127, 132, 133, 136, 139, 140, 143, 146, 147, and 149-151 may be misleading as the existing level of BMP implementation was not inventoried by the District staff and included in the updated modeling. As a result, the calibrated model was run a second time with all of the filtration BMPs turned off in the model operations routine. Figure 9 shows how the SWAT model upland sediment yield estimates with no BMPs would have differed from those shown in Figure 8. Without BMPs, several subbasins in the Turtle Creek and northeast portion of the Cedar River watersheds would have experienced significant increases in sediment yield. Two of the subbasins in the Turtle Creek watershed would be expected to consistently contribute sediment yields above 4 tons/acre.

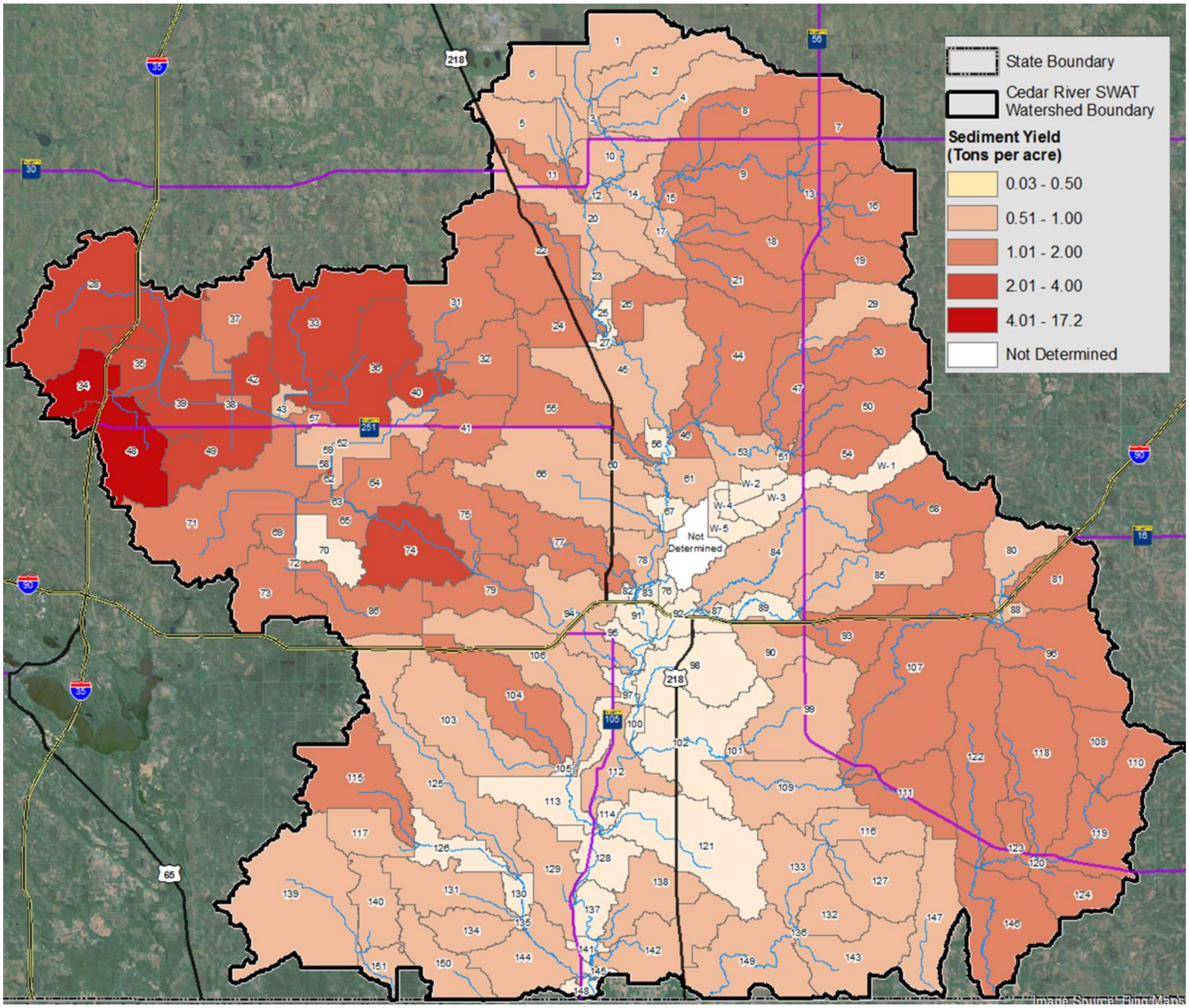


Figure 9. SWAT model upland sediment yield estimates without BMPs implemented in the Cedar River watershed.

Ignoring the subbasins (described above) that were not included in the BMP inventory, a spreadsheet comparison of the sediment yield results shown in Figures 8 and 9 indicated that the existing BMPs were removing 25% of the overall watershed sediment load that would otherwise have discharged to the nearest receiving water during 2010. As previously discussed, the watershed tributary area receiving some level of filtration treatment in the updated model was 58,418 acres, which accounts for approximately 21% of the row crop area in the overall watershed. Further examination of the subbasin results of each model run indicated that the sediment yield reductions ranged from 13% to 41% for the subbasins that have existing BMPs.

The Cedar River watershed has four impairment listings for turbidity that are addressed with the TMDL analyses involving suspended solids concentrations: two segments of the Cedar River, upstream and downstream of the city of Austin; the lower segment of Dobbins Creek; and the lower segment of Turtle Creek. This study used a variety of methods to evaluate the current loading and contributions from the various pollutant sources, as well as the allowable pollutant loading capacity of the impaired reaches to more accurately represent the impact current BMPs are having in the watershed. The load duration curve approach was used for reaches impaired by turbidity. It was originally estimated that the overall magnitude of reduction needed to the meet the turbidity standard for each impaired reach is between 80 to 90 percent for high flows (0-10% flow duration) and between 0 to 20 percent for moist conditions (10-40% flow duration) to meet the turbidity standard throughout the study area under current conditions.

Figure 10 superimposes the flow-weighted mean sediment concentrations (FWMC, expressed in mg/L) estimated from the April-September, 2010 reach modeling on the subbasin yield estimates shown in Figure 8 to assist in further identifying watershed locations where total suspended solids (TSS) reductions would be needed to comply with the 65 mg/L TSS concentration which is being proposed to replace the current turbidity standard. As previously discussed, 2010 experienced higher flow events and the sample monitoring limitations shown in Figure 4 would further limit direct comparisons of the FWMCs to the proposed TSS standard, but Figure 10 shows that the higher priority areas for further load reductions appear to correspond with some of the smaller tributaries to Lake Geneva and Turtle Creek, as well as headwater locations in the Little Cedar River and Roberts Creek watersheds. Headwater locations in the Rose Creek and Cedar River ditch watersheds, as well as subbasin #77, may also warrant consideration for future restoration efforts. The FWMC for subbasin #84 in the Dobbins Creek watershed is skewed by the presence of East Side Lake at the downstream end of the stream segment shown in Figure 10. Figure 10 also indicates that the Wolf Creek watershed should be a priority for future protection efforts.

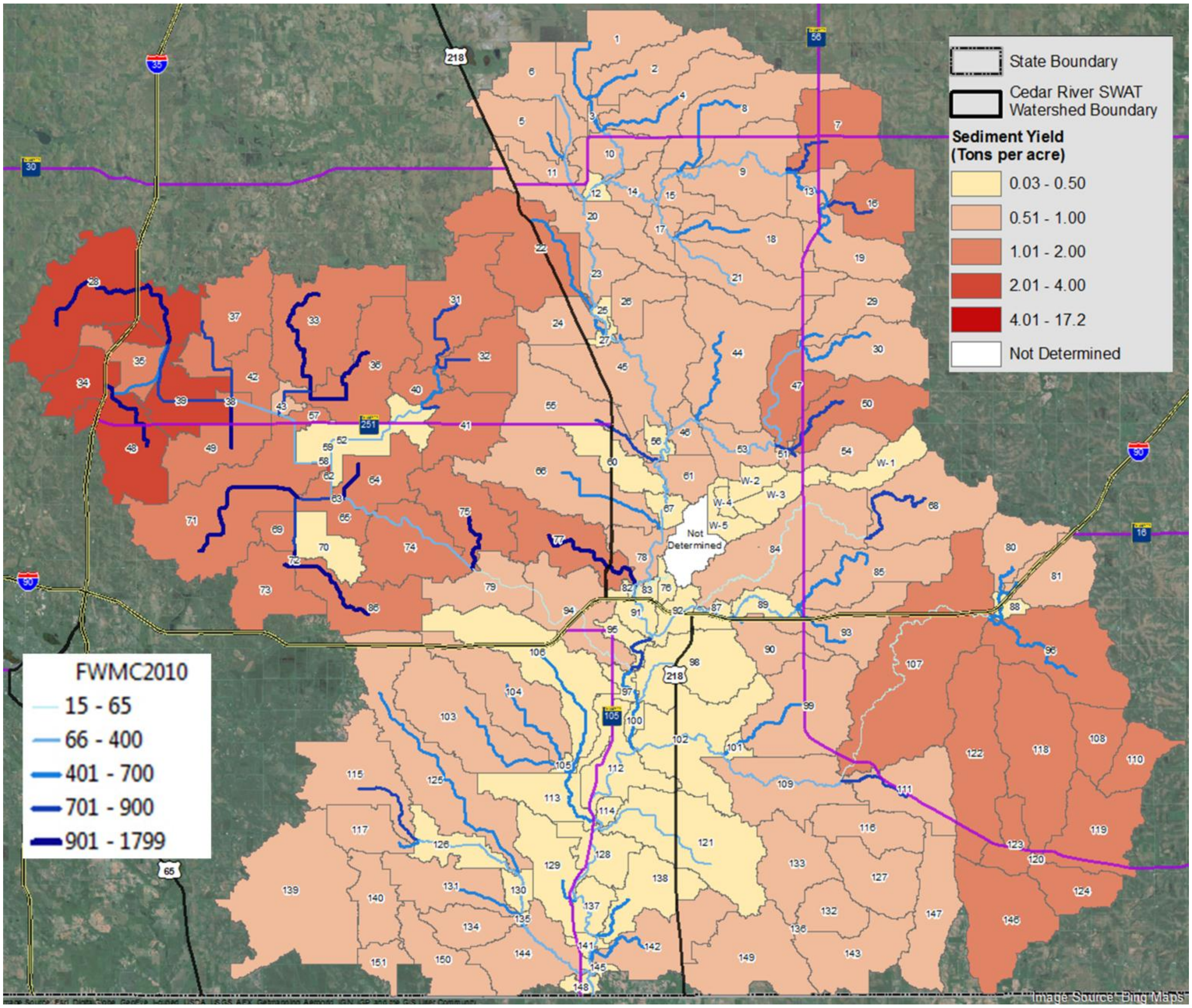


Figure 10. SWAT model upland sediment yield and flow-weighted mean sediment concentration estimates for reaches in the Cedar River watershed.

While the exact amount of sediment coming from each of the watershed sources cannot be derived, it is expected that algae in reaches downstream of reservoirs or impoundments is an important contributor to the turbidity impairments in the watershed and will need to be addressed with a more comprehensive-systems approach. It is expected that algal effects on turbidity would be more pronounced in Turtle Creek than it would be in the Cedar River flow-through reservoirs as Lake Geneva would have a longer residence time than Ramsey Mill Pond and East Side Lake.

Identifying and Prioritizing Potential Project Areas

Figure 11 shows an example of how we have combined the terrain analysis completed for the project (described in more detail in Appendix E of the Draft TMDL Report) with the available information about existing conservation practices and the modeling results to identify and prioritize the critical sediment source areas for field inspection and potential BMP implementation throughout the watershed.

The potential high priority areas were identified from the larger terrain analysis dataset developed for the TMDL study. The end points from SPI (Stream Power Index) signatures falling within the 99th percentile of results were used as a base. These SPI end points were screened in three steps. First, all points representing an SPI signature less than 100 feet long was removed. Second, all points greater than 200 feet from an NHD (National Hydrography Dataset) flowline representing surface water were removed. A search distance of 200 feet was used in order to offset some of the accuracy issues of the NHD dataset particularly in small ditches and intermittent streams. It was expected that 200 feet would be enough to capture SPI signatures that may end short of a flowline due to decreasing slope but still have the potential to deliver sediment to surface water. This process screened the results from approximately 150,000 points initially down to approximately 10,000. Finally, this set of points was inspected visually using publicly available aerial imagery, BMP information provided by the SWCD and watershed district staff, and a compilation of land use data prepared by Barr. This final screening process, when combined with the SWAT model HRU loading areas (shown in the background on Figure 11), results in a series of potential high priority areas that local staff should consider for field inspection and potential BMP implementation.

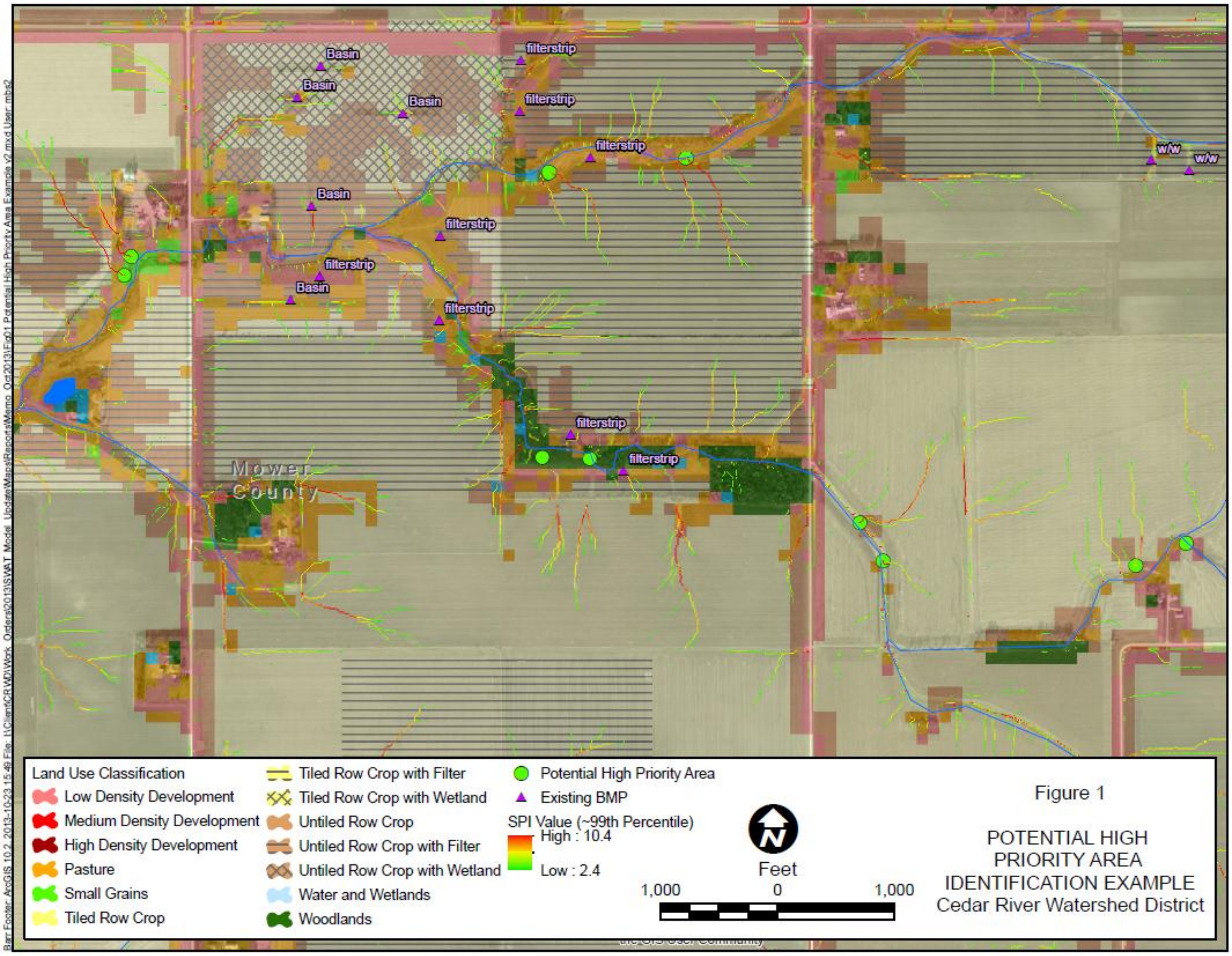


Figure 11. Example plot combining terrain analysis with locations of existing BMPs and SWAT model sediment loading areas.

References

Arnold, J.G., P.M. Allen, and G. Bernhardt. 1993. A comprehensive surface-ground water flow model. *J. Hydrol.* 142: 47-69.

Moriasi, D.N., J.G. Arnold, M.W. Van Liew, R.L. Bingner, R.D. Harmel, and T.L. Veith. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE.* Vol. 50(3): 885-900.

Schottler, S.P., D.R. Engstrom, and D. Blumentritt. 2010. Fingerprinting Sources of Sediment in Large Agricultural River Systems. St. Croix Watershed Research Station: Science Museum of Minnesota.

Srinivasan, R. 2008. Personal communication. Advanced SWAT Modeling Workshop.

White, M.J. and J.G. Arnold. 2009. Development of a simplistic vegetative flter strip model for sediment and nutrient retention at the field scale. *Hydrol. Process.* 23: 1602-16.

Appendix E
Geneva Lake Monitoring Data

Figure E 1. Geneva Lake Elevations.

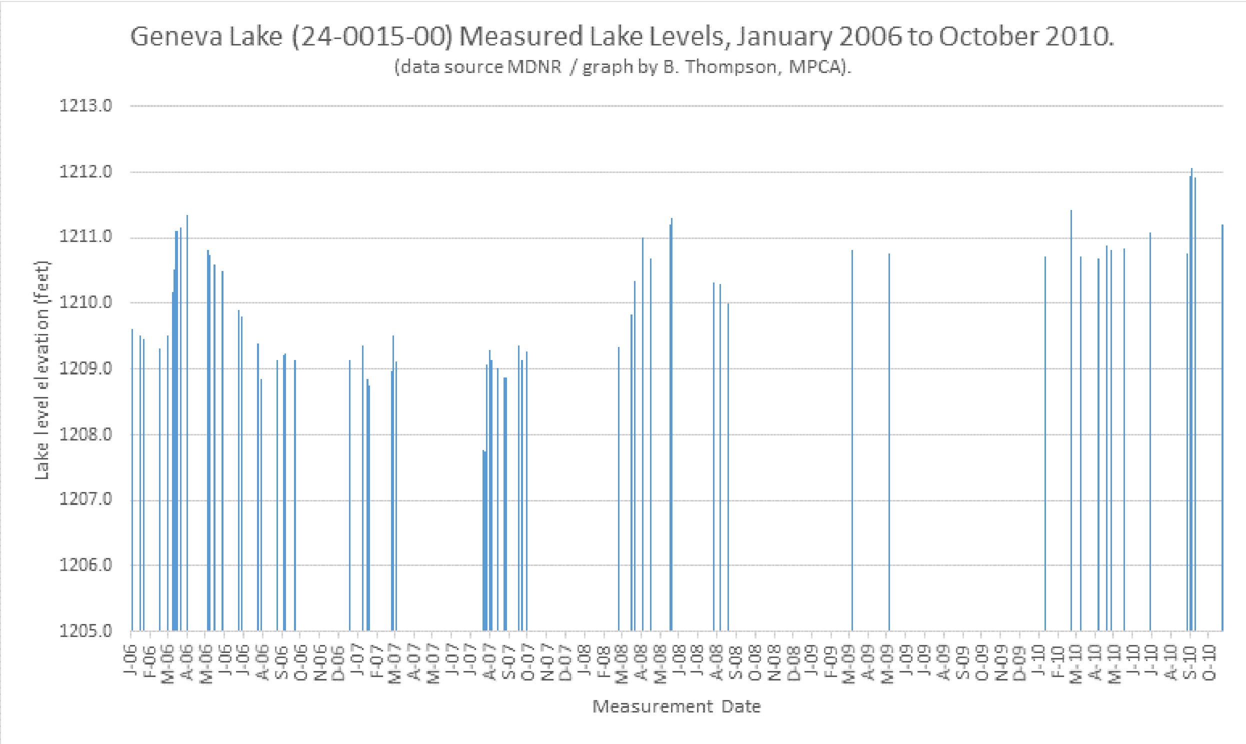
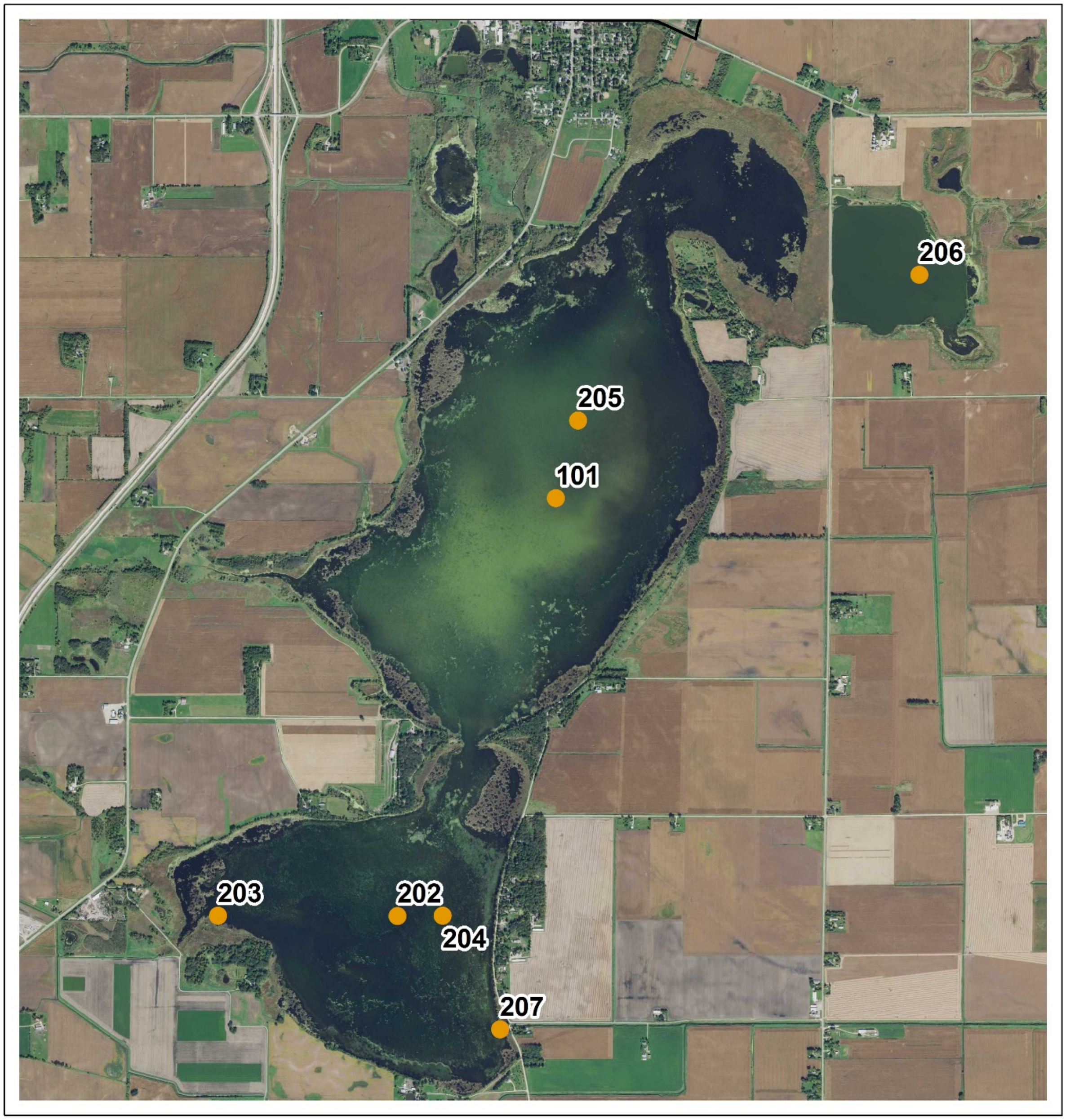


Figure E 2. Geneva Lake Sampling Locations.



Key	DU	Ducks Unlimited MN DNR Shallow Lake Wildlife Study
	MDNR	Minnesota DNR Shallow Lakes Monitoring Program
	MPCA CWL	MPCA Clean Water Legacy Surface Water Monitoring
	MPCA WR	MPCA Wild Rice Study
	SID	Cedar Watershed stressor identification monitoring

Table E 1. Geneva Lake Total Phosphorus Monitoring Data

Sample Date	Total Phosphorus, µg/L	Source	Location 24-0015-00-xxx
7/2/2002	0.251	MDNR	202
7/3/2007	0.133	MDNR	203
6/25/2008	0.104	MPCA CWL	101
7/16/2008	0.055	MPCA CWL	101
7/23/2008	0.045	MDNR	204
8/19/2008	0.093	MPCA CWL	101
9/23/2008	0.046	MPCA CWL	101
6/10/2009	0.057	MPCA CWL	101
7/15/2009	0.166	MPCA CWL	101
8/5/2009	0.189	MPCA CWL	101
9/22/2009	0.184	MPCA CWL	101
6/24/2010	0.109	MDNR	205
7/29/2011	0.056	MDNR	101
8/9/2011	0.028	DU	207
8/30/2011	0.042	SID	207
9/7/2011	0.05	MDNR	101
7/24/2012	0.041	MPCA WR	North Bay
7/24/2012	0.055	MPCA WR	South Bay
8/8/2012	0.165	MDNR	
7/31/2013	0.064	MDNR	
8/13/2013	0.108	MDNR	
9/4/2013	0.094	DU	207
9/17/2013	0.111	DU	207
7/21/2015	0.163	MDNR	
6/12/2016	0.053	MDNR	

Count:	25
Average:	99 µg/L
Median:	93 µg/L
Minimum:	28 µg/L
Maximum:	251 µg/L

Table E 2. Geneva Lake Chlorophyll a Monitoring Data

Sample Date	Chlorophyll a, µg/L	Source	Location 24-0015-00-xxx
7/2/2007	32.8	MDNR	
6/25/2008	34.4	MPCA CWL	101
6/25/2008	191	MPCA CWL	201
7/16/2008	6.22	MPCA CWL	101
8/19/2008	13.7	MPCA CWL	101
9/23/2008	5.16	MPCA CWL	101
6/10/2009	25.4	MPCA CWL	101
7/15/2009	36.5	MPCA CWL	101
8/5/2009	33.1	MPCA CWL	101
9/22/2009	49.9	MPCA CWL	101
8/9/2011	5	DU	207
7/31/2013	35.2	MDNR	
8/13/2013	59.6	MDNR	
9/4/2013	37	DU	207
9/17/2013	48	DU	207
7/21/2015	28.8	MDNR	
6/12/2016	1.75	MDNR	

Count:	17
Average:	38 µg/L
Median:	33 µg/L
Minimum:	1.75 µg/L
Maximum:	191 µg/L

Table E 3. Geneva Lake Secchi Disk Depth Monitoring Data

Sample Date	Secchi Disk Depth, m	Source	Location 24-0015-00-xxx
6/26/2002	0.12	MDNR	
7/2/2007	0.12	MDNR	
6/25/2008	1	MPCA CWL	101
6/25/2008	0.8	MPCA CWL	201
7/16/2008	0.6	MPCA CWL	101
7/23/2008	1.07	MDNR	204
8/19/2008	0.6	MPCA CWL	101
9/23/2008	1.3	MPCA CWL	101
6/10/2009	0.9	MPCA CWL	101
7/15/2009	0.3	MPCA CWL	101
8/3/2009	0.52	DNR	
8/5/2009	0.3	MPCA CWL	101
9/22/2009	0.4	MPCA CWL	101
6/24/2010	0.15	MDNR	205
6/25/2010	0.45	MDNR	206
7/28/2011	0.88	MDNR	
8/9/2011	1.1	DU	207
8/8/2012	0.25	MDNR	
7/31/2013	0.35	MDNR	
9/4/2013	0.5	DU	207
9/17/2013	0.15	DU	207
7/21/2015	0.87	MDNR	
6/12/2016	0.93	MDNR	

Count:	23
Average:	0.6 m
Median:	0.5 m
Minimum:	0.12 m
Maximum:	1.3 m

Table 4. Geneva Lake Alkalinity Monitoring Data

Sample Date	Alkalinity, mg/L	Source	Location 24-0015-00-xxx
7/3/2007	233	MDNR	203
6/25/2008	200	MPCA CWL	101
7/16/2008	130	MPCA CWL	101
8/19/2008	140	MPCA CWL	101
9/23/2008	120	MPCA CWL	101
6/10/2009	91	MPCA CWL	101
7/15/2009	120	MPCA CWL	101
8/5/2009	160	MPCA CWL	101
9/22/2009	180	MPCA CWL	101
8/30/2011	94	SID	207
6/12/2016	104	MDNR	

Count:	11
Average:	143 mg/L
Median:	130 mg/L
Minimum:	91 mg/L
Maximum:	233 mg/L

Cedar River Watershed Strategy and Implementation Plan – Phase 1

(Cedar River Major Watershed [Headwaters] WRAP Strategy)

Final Project Report, August 2013

Mower County Soil and Water Conservation District, Austin, Minnesota

1-23-2014 FINAL

Project ID: PRJ07667
Contract Number (SWIFT Contract ID): 27134
CFMS No. B57011

Contract Period: 8/19/2011 to 6/30/2013
Contract Amount: $182,205

Local Project Manager: Bev Nordby, Mower SWCD Manager and Cedar River Watershed District Administrator, Austin, MN. Bev.nordby@mowerswcd.org 507.434.2603

MPCA Project Manager: Bill Thompson, Watershed Division, Rochester Regional Office, Rochester, MN. Bill.thompson@state.mn.us 507.206.2627

Table of Contents

Cover Photo: Roberts Creek, by Nate Howard

Project Description and Summary

This report is the result of the first 2 phases of the Total Maximum Daily Load (TMDL) study that has been completed for the Cedar River Basin that includes Turtle Creek and Cedar River watersheds.

Objectives:

A. Develop a current conditions model for the hydrology and hydraulics (H&H model)
A current condition Storm Water Management Model (SWMM) was developed for the Cedar River Watershed, including the Turtle Creek. The project contracted with Barr Engineering Company to set up this model, which included the use of LiDAR, land use, soils and weather data sets. Local staff surveyed and provided data on 648 culverts and bridge crossings. Major storm events that occurred in the watershed in September 2004 and September 2010 were used as calibration and validation events, respectively. This model is being used for water flow predictions at various locations in the watershed, and will also be employed to predict the effects of various water storage implementation practices/projects on stream flows.

B. Conduct an inventory of best management practices that are currently being used in the basin. **Local staff provided data on agricultural BMPs that affect sediment and flow**. Data on 927 practices was collected, with about 90% of those practices representing "filtration BMPs," such as grassed waterways, filter strips, and water/sediment control basins. The remaining 10% of practices were either wetlands or ponds. These data were then utilized in the revised Soil and Water Assessment Tool (SWAT) model, which provided the first estimates of the effects of those practices on a large watershed scale, which is a watershed-scale model with the capacity to simulate our agricultural environment. The results indicate that 67% of the modeled subbasins in the watershed showed a reduction in upland sediment yield from 20-30%, due to the presence of the BMPs. And overall, the agricultural BMPs reduced upland sediment yield by 25%, compared to modeling runs with no BMPs present. These types of modeling results will be used in watershed reports and implementation strategy planning.

C. Develop and implement civic engagement program.
"If the public enjoys the river they will take care of the river". That sums up our motto for engaging the public in the river system that we have. We have done many educational meetings that include agricultural producers, local governments and citizens in the watershed. Our methods have included social media, along with updating our web site and making June our community's "Waterway Awareness Month." These awareness-building and communication events have been well received, and increasing popularity means we have a trend in the positive direction. We also have an active committee from the community that is focused on "Embracing and maintaining our Waterways". We envision that the citizen participation program will continue for years to come.

D. Monitoring the Streams

Approximately 10 water samples were collected each year at 10 different sites (site list on p. 2) throughout the Cedar River Watershed between March 2011 and June 2013. Samples were collected between spring snowmelt and fall ice formation each year. Samples were taken periodically and on a storm-event basis. This approach allowed sampling to capture a wide variety of flow conditions including the rising, peak, and falling limbs of rain events, along with baseflow conditions in both spring and fall. The watersheds with highest pollutant (sediment, nutrients) concentrations in 2011-3013 appear to be Rose Creek, Dobbins Creek, and the Upper Cedar River Watershed. The high E. coli concentrations also need to be noted at Dobbins Creek. Overall, these data should be taken into account for future BMP Planning Coordination. Ongoing and longer-term monitoring helps maintain a strong data set for assessing implementation effectiveness, as well as documenting seasonal and year-to-year variability.

Work plan review

The work plan for this project was developed cooperatively by MPCA staff, and local watershed/conservation staff from the area. The initial work plan was included as Attachment A to the contract between the MPCA and Mower SWCD. The work plan budget was $182,205, with a project timeframe of 8.19.2011 to 6.30.2013. The geographic scale of the project was the Cedar River Watershed (CRW), including the Cedar River and Turtle Creek Watershed Districts, and the hydrologically-defined watersheds that make up the whole CRW in Minnesota.

This work plan was titled "Cedar River Watershed Strategy and Implementation Plan – Phase 1." This effort represented the complex, difficult, time-consuming and enduring work associated with water quality and watershed management across a large and complex land area. Overall, this project was planned and completed to lay a solid foundation for the necessary implementation actions to occur, over the coming decades.

The initial work plan included six (6) objectives, as noted in the table below. We defined and executed two change orders, which resulted in the rebudgets that are also included in the table (values are rounded to the nearest dollar).

Table 1. Project Work Plan Budgets during the 2011 to 2013 timeframe.

Objective	Initial Budget	Rebudget 1	Rebudget 2
A – Hydrologic and Hydraulic Modeling	60,046	60,046	65,086
B – BMP Inventory	52,901	52,901	60,371
C – Public participation	28,291	40,290	27,797
D – Water monitoring	15,257	15,257	12,241
E – Project administration	13,711	13,711	16,707
F – Drainage system demonstrations	12,000	0	0

Rebudget 1 took place in August of 2012, when the BWSR provided funding to Mower SWCD and the watershed districts in the CRW for the demonstration of conservation drainage management practices. Since the BWSR funding covered the same type of work that was included in Objective F, this change order allowed a shift of 6.6% of the budget to Objective C. The reallocated funds for Objective C were focused on information availability via web sites, public event costs, and providing information on area streams and rivers to citizens.

Rebudget 2 occurred in April, 2013. There were several factors involved for this second rebudget. First, there was a need to revise Objective C, to improve coordination with the ongoing Austin Vision 2020 project. The Austin Vision 2020 project is a large, community-wide effort to engage people and groups for overall community improvements during the next decades. One sub-committee of the 2020 initiative involved rivers and shorelines. Mower SWCD staff were/are actively involved in this sub-committee work, and desired to sequence any other efforts with this group to maximize coordination and avoid any appearance of duplication. Project technicians also reported that due to lack of precipitation and low water levels, the amount of water monitoring was reduced. This resulted in a budget reduction of $3,000 for Objective D (staff time, lab analysis, etc.), water monitoring. In the spring of 2013, we also identified additional modeling tasks in both Objectives A and B that needed to be addressed as well – these involved model transfer and training in Objective A, and the inclusion of wetland drainage areas into the model for Objective B. Additional administrative time was also needed to process the rebudgets, for reporting, and for accounting/invoicing.
Overall, these changes resulted in a budget shift from Objective C and D, to Objectives A, B, and E. (Note: Column 3 of the final expenditure summary on p. 7 of this report corresponds to the Rebudget 2 values above in Table 1).

The overall results of this specific work plan are best assessed by reading the results section that follows, as well as the additional information in the appropriate appendix. In general, the two watershed modeling products will allow for a more systematic and targeted approach for the implementation of BMPs. Modeling predictions will further allow watershed managers and staff to better allocate technical and financial assistance, across the CRW. Civic engagement and public participation activities will continue to be an important component. In 2013 and beyond, watershed-wide events/activities will be able to move forward, with the cooperation of the Austin Vision 2020 initiative. Stream water monitoring activities are an important effort to maintain, as both natural variation and BMP changes occur. Agricultural drainage system demonstrations and management will be critical elements in the future. The fact that this project was able to adjust budgets to accommodate the BWSR initiative on drainage water management practices illustrated the coordination capacity of the involved local governmental units.

Results

Watershed Modeling

The Cedar River Watershed has been developing a set of modeling tools to assist in the comprehensive management of the watershed. Over the past 6 years, this effort has been focused on the development of modeling capability for agricultural best management practices (BMPs), and for water storage to reduce flooding risks and improve water quality. This is a long-term effort that requires investments in data collection and acquisition, model development, and maintenance/upkeep of the modeling tools. The overall objectives include using the predictive capabilities of the models to inform the decision-making and for prioritization/targeting efforts.

A description of this phase of the Cedar River Watershed modeling follows, and is organized by modeling tool.

Storm Water Management Model (SWMM)

Appendix A includes a specific report on the Cedar River Watershed Existing Conditions Model, as prepared for the Cedar River Watershed District by Barr Engineering Company of Minneapolis. This existing conditions model was developed using XP-SWMM, a version of SWMM developed by XP Solutions.

The Storm Water Management Model (SWMM) is a continuous and/or event-based rainfall-runoff simulation model that was developed for the U.S. EPA at the University of Florida. Watersheds are initially divided into subwatersheds. For the Cedar River Watershed, this involved setting up 645 subwatersheds. Flow routing is performed for surface and subsurface conveyance and groundwater systems, including the options for nonlinear reservoir channel routing and fully dynamic hydraulic flow routing (EPA, 2013).

For a technical description of the capability and modeling options available for XP-SWMM, the reader is referred to the XP-Solutions website:

http://www.xpsolutions.com/wp-content/uploads/docs/xpswmm-techdesc.pdf

Overall, SWMM is defined as an “H and H” model in that it can simulate both Hydrology and Hydraulics. Hydrology encompasses the entire water cycle, including water flow and timing for streams and rivers, in relation to the precipitation and runoff. Hydraulics deals with mechanical properties of water, including important factors like turbulence, and the effects of constrictions (culverts, bridges, etc.) to flow in open channels, as well as pipes. The SWMM model can be used for either individual storm events or continuous simulation, and it includes complete dynamic flow routing.

For a detailed examination of SWMM’s abilities and limitations, the reader is directed to Huber etal. (2006), as well as the following web sites:

http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/

While the regular "EPA" SWMM is a public domain model, the XP-SWMM is privately-held software which requires user licensing arrangements. SWMM (Version 5.0), which is a public domain model, is not currently supported by EPA, or other government agencies.

The current XP-SWMM was done for both the Turtle Creek and Cedar River watershed district areas. A total of 645 separate subwatersheds were delineated, using the county LiDAR data, which had a vertical accuracy of about 1 foot. Hydrologic inputs for model development included the watershed delineations, land use, depressional storage, overland roughness, infiltration, and subwatershed width. The model was used for both rural and urban landuses. For infiltration in urban areas, the model uses a directly connected impervious percentage, which ranged from 8% (developed, low intensity) to 30% (developed, high intensity).

Hydraulic inputs to the XP-SWMM included the drainage network of established waterways, ditches, and stream channels. A detailed survey of 648 structures was also included as model input, involving culvert size, shape, materials and invert elevations (upstream and downstream). For bridges, this included data on bridge deck length and width, elevation, pier number and size, and elevations for river channel thalweg (deepest point along a channel cross section).

Precipitation data was brought together from three main sources: NEXRAD Doppler precipitation data collected at the KMPX-Minneapolis site; hourly precipitation grids based on multi-sensor data from the National Climatic Data Center; and daily rainfall depths from many volunteer gages in the watershed.

The XP-SWMM model for the Cedar was calibrated using two river monitoring gages – the Cedar River at Lansing (MDNR gage 48023001, drainage area 164 sq. miles) and Turtle Creek above Austin on 43rd Street (MDNR gage 48027001, drainage area 147 sq. miles). The USGS gage below Austin on the Cedar River (gage 05457000) was used to validate the calibrated models. The USGS gage includes flows that pass the Lansing and Turtle Creek gages, as well as the smaller tributary streams of Wolf, Murphy and Dobbins Creek. The city of Austin is also included in this drainage area of 399 square miles.

The following storm events were evaluated with the model:

- 2-year, 24-hour rainfall event (2.9");
- 10-year, 24-hour rainfall event (4.3");
- 100-year, 24-hour rainfall event (6.2");
- 2004 event on September 14th, that ranged from about 3-9" of rain for model calibration; and
- 2010 event on September 22, that ranged from about 3-7" of rain for model validation.

The SCS Type II distribution being used to create the hyetographs for the return period events, with the actual storm distribution used for the 2004 and 2010 events. (A hyetograph is a chart showing the distribution of rainfall over a particular period of time).

Calibration of the model involved the modification of hydrologic variables, to adjust the modeled hydrograph so to best match the observed hydrograph at the three monitoring stations. The results of model calibration and validation are summarized by gage site:

Upper Cedar Gage (see Figures 9 and 10 in full report): the model slightly over-predicted river stage for the September 2004 calibration event. The receding limb of the September 2004 event was over-predicted by the model. For the model validation event in September 2010, the model over-predicted peak stage by about 1.5', with the rising limb of the hydrograph preceding the observed hydrograph by about 3-6 hours.

Turtle Creek Gage (see Figures 11 and 12 in the full report): there is a good match for the calibration (2004) event for both the rising limb and peak stage. The recessional limb was not modeled past three days. For the 2010 event, the modeled stage is consistently higher than the observed stage, with differences ranging from less than 0.5' to about 3.0' near the peak of the river stage.

Cedar River at Austin (see Figures 13 and 14 in the full report): it is difficult to determine the full extent of the relationship between modeled vs. observed data for the USGS gage, since a complete stage record is not available from the USGS. The calibration event (2004) had a larger discrepancy between modeled and observed river stage. The model under predicted peak stage at this site, by approximately two feet. Similar to the Upper Cedar river site, the rising limb for the model preceded the observed rising limb. The recessional limb was not modeled past three days.

For the validation event for the Cedar River at Austin, there was a closer match for peak stage at this location, where the modeled peak stage is approximately half a foot lower than the observed stage. However, it appears that the peak stage occurs earlier in the model than as observed.

The differences between the modeled and observed data (stream stage) are attributed to variability in subsurface tile effects across the watersheds, as well as the effects of cropping patterns and soil classifications/data.

To date the Cedar's XP-SWMM has been successfully used to estimate the effects of several water storage/wetland restoration projects, where it has proved adaptable to refinements on the smaller subwatershed scale. For example, the model was further sub-divided in the Murphy Creek subwatershed north of Austin, to assess the effects of four water storage/wetland restoration projects. The model predictions for these wetland restoration projects showed an 8% reduction in water volume from a 100-year storm event (460 acre-feet to 420 acre-feet), with the peak flows reduced by about 10%.

For an overview presentation on the Cedar's XP-SWMM project, see the following link to a January 10, 2012 PowerPoint presentation that was given at a H & H Model Roll-Out Meeting in Austin.

http://www.cedarriverwd.org/library/documents/HandHModelPresentation1-10-13.pdf

Soil and Water Assessment Tool (SWAT)

The Soil and Water Assessment Tool (SWAT) is a physically-based, continuous distributed parameter watershed/water quality model that was developed by the U.S. Department of Agriculture (USDA). The SWAT is a public domain model that is fully supported by USDA, and has had wide application in both North America and across the world (Arnold etal. 1993). The strengths of this modeling tool lie with its ability to explicitly simulate crops, crop rotations, and agricultural BMPs. It uses the SWMM functions for urban runoff, generally operates on a daily timestep, and has simple channel and reservoir routing methods. SWAT uses a good bedload transport routine, but the modeling does not simulate streambank and bluff erosion sources.

The link to the official SWAT web page is: http://swat.tamu.edu/

The SWAT model uses the modified universal soil loss equation to estimate upland erosion.

The technical report for the Cedar River Watershed SWAT is included in Appendix B. This project used the SWAT version 2009.93.7b, Revision 481. While there are newer versions of the model currently available and in use, this version was selected from modeler experience, and some reports of more current versions having difficulty in modeling vegetative filtering BMPs.

One of the important elements that should be understood regarding SWAT pertains to the application of hydrologic response units (HRUs). The HRU is one scale that is used to provide data input into SWAT. An HRU is developed by overlaying three factors: slope, soil type, and land cover. The land area in a given HRU is assigned a lumped combination of those factors. Although it is somewhat counterintuitive, the HRUs are not defined by a flow direction, are not involved with landscape routing, and the given spatial location of an HRU does not influence sediment loading to a stream. The next scale involved in the SWAT modeling is the subbasin scale, of which there are 132 in the modeled Cedar River Watershed. The average subbasin size is 2,855 acres, with a median size (50th percentile) of 2,716 acres. The subbasins range in size from less than one acre, to 12,350 acres. Subbasins can have multiple combinations of soils, slopes and landuses.

Subbasins were established using LiDAR data, for stream reaches with perennial flow, as well as considering any significant manmade alterations that would have resulted in erroneous modeling results. This last factor applies to the Wolf Creek subwatershed east of Austin, which was not modeled because an abandoned railroad grade bisects it, and the model would have treated the area upgradient from the railroad line as a large pond.

Our local watershed technicians have significantly added to this modeling effort by conducting an inventory of the current locations of agricultural BMPs that affect sediment and hydrology. Data for 927 total practices was collected in both the Cedar River and Turtle Creek drainages. Of this total, 830 represent “filtration BMPs” such as waterways, side inlet protection, filter strips, and water/sediment control basins. However, it was not initially possible to distinguish specific drainage areas for each of the 830 filtration BMPs. The remaining 97 practices are ponds or wetlands. For subbasins with only filtration BMPs, the modeling was done using filter strips, based on their GIS-defined position. Six (6) subbasins were selected for explicit wetland treatment modeling, based on upgraded data (i.e. larger restoration with more hydrology and engineering data available) for the wetland, and known contributing drainage areas. Table YY shows these subbasins where the explicit wetland modeling was undertaken. These are noteworthy since extra hydrology and water quality BMP work has occurred in them, and this resulted in extra modeling efforts to be undertaken - to provide better estimates on the effects of the implementation work. It is noted that the lower end of the Little Cedar River subwatershed, along with about 10 subbasins on the southern flank of the overall watershed, do not currently have a BMP inventory. The subbasin yield map reflects this fact, and it is reinforced here so that the reader can make valid interpretations.

Table 2. SWAT Subbasins with explicit wetland treatment modeling in the CRW, and tributary drainage area percent.

SWAT Subbasin #	Within HUC 12	Subbasin Area (acres)	Tributary Area (% of subbasin)
29	Roberts Creek	2,912	50
37	Geneva Lake	4,511	30
48	Geneva Lake	4,413	30
56	Cedar River/Austin	532	80
66	Turtle Creek	6,726	50
94	Turtle Creek	4,137	20

The remaining group of subbasins included both a pond (for more localized treatment) and a filtration BMP (or multiples of one or both). The modeling approach for this subset was to develop adjustments to filter strip treatment calculations, using both the FILTER_CON and FILTER_CH parameters in SWAT. This was a technical "work around" type approach that required the modeler to adjust the modeling code and the appropriate parameters. Overall, this involved using a technique suggested by the model support team of applying area-weighted averages, and seeking good representation at the larger scale, where an accumulation of practice effects would "balance each other out." As SWAT does not allow for more than one pond per subbasin, this approach was necessary, as budget constraints did not allow for further subdivision of the watershed into smaller subbasins.

When the filtration practices are assessed across the entire watershed, it was estimated that 58,000 acres had some level of filtration. On an area-weighted basis, the typical ratio of field area to filter strip area is 60 (i.e. 60 acres of crop field with 1 acre of filtration BMP such as a waterway or vegetative filter strip).

Model calibration was accomplished by using global model parameters to adjust the modeled hydrographs to the observed data from a set of "sentinel" watersheds. There were three watersheds utilized for this function are: Upper Cedar River near Lansing, Turtle Creek near Austin, and the Cedar River below Austin (USGS gage). The results of the calibration process showed that both early spring and spring periods were difficult to match, since flow data was not always available, and the snowmelt dynamics were highly variable.

One of the major and large-scale results of this continued work is to place upland and near-channel sediment source estimates together. Using the stream bank erosion estimate developed by MDNR (TMDL Report, Appendix C) of 39,882 tons/year of sediment, with the SWAT modeled sediment load for the Lower Cedar River of 87,780 tons/year, we can estimate that sediment from streambanks and near-channel sources accounts for about 45% of the total load.

There are three basic types of results from this present agricultural BMP condition modeling with SWAT. This includes the map of sediment yields by subbasin (Result 1), the total suspended solids (TSS) load duration curves with SWAT calibrated data displayed (Result 2), and how SWAT output data and terrain analysis can be used successfully together in the future (Result 3). Each will be summarized briefly, and the reader is referred to Appendix B for more details.

Result 1 – Upland Sediment Yield Data and Map

Modeling results are provided as estimates of upland sediment yield from the combined land areas in a subbasin. These sediment yield estimates cover the combined land areas of each subbasin, and are a total sediment load consisting of both suspended sediment and bedload sediment. A given subbasin with an upland sediment yield in the range of 1.0-2.0 tons/acre does not mean that all of the fields in that subbasin are eroding at rates within that range. There are also technical issues involved that prevent making direct comparisons of modeled output data to stream monitoring data for sediment.

Figure 1 displays the modeling results for the number of subbasins in five upland erosion categories. About 65% of the subbasins have upland sediment yields estimated to be in the range of 0.5 – 2.0 tons/acre.

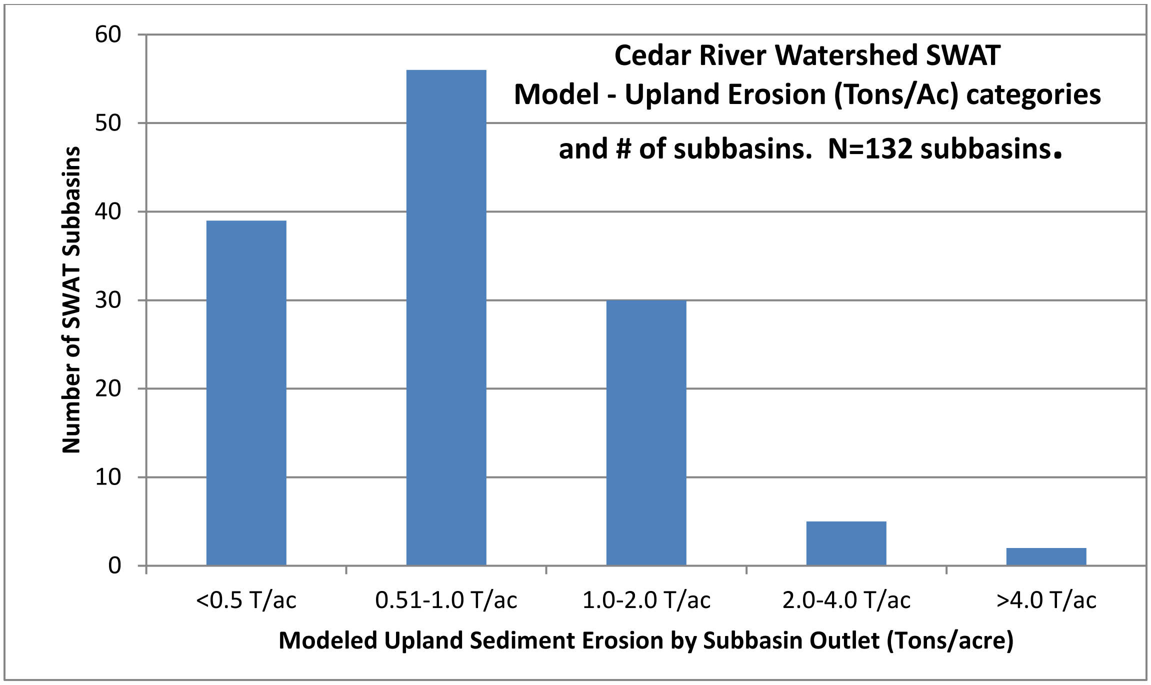


Figure 1. Frequency distribution of the subbasins in the Cedar River Watershed with modeled SWAT upland sediment erosion data for calendar year 2010.

Figure 2 displays distribution of subbasins (n=110 with inventoried BMPs) by percent reductions in upland sediment yield. When comparing the SWAT model output data with and without the 927 BMPs, about two-thirds of the subbasins showed a sediment reduction between 20% and 30%. On a sediment mass basis, the watershed-wide average in these subbasins is a 25% reduction, within a range of 13%-41%.

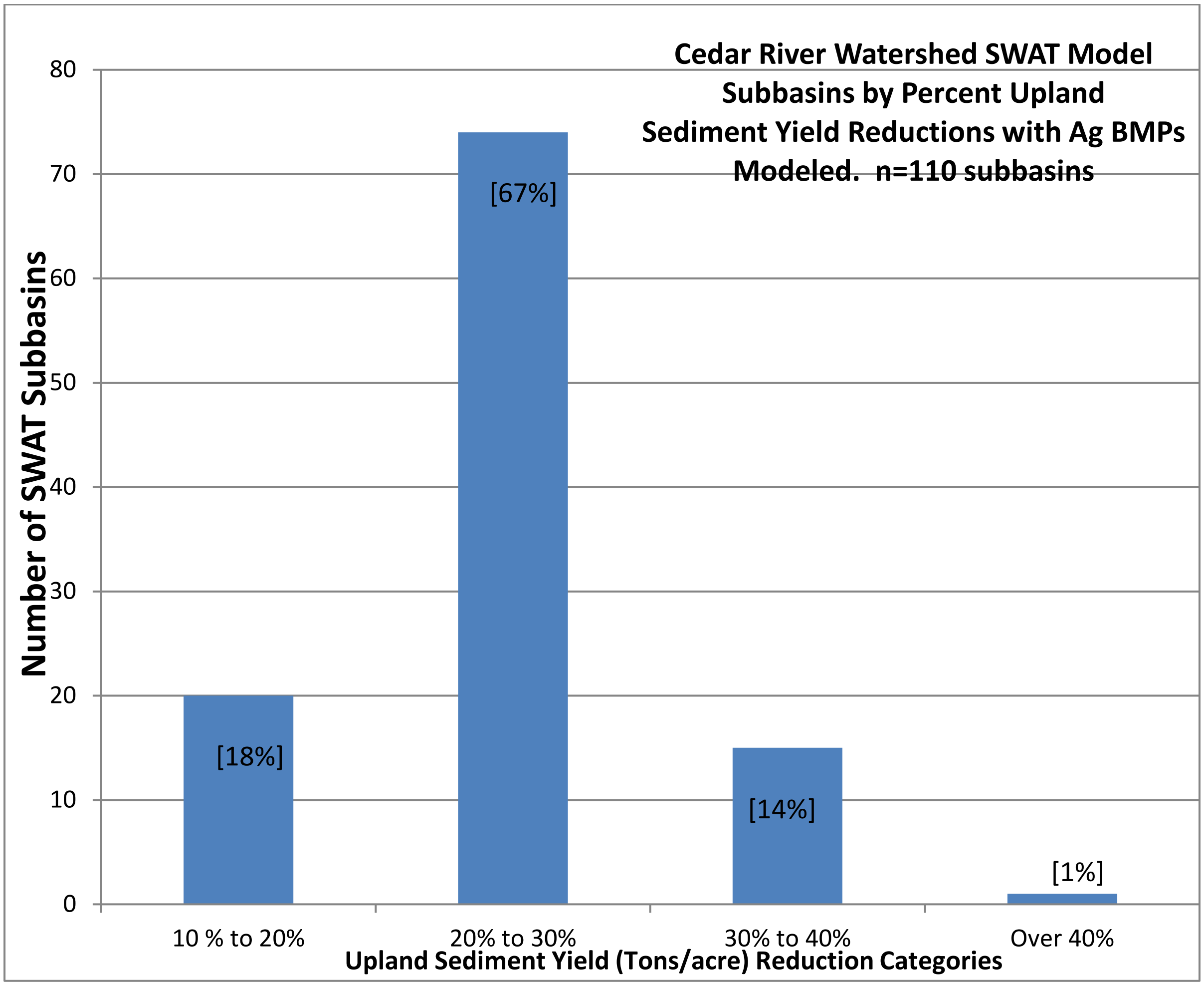


Figure 2. Frequency distribution of subbasins in the Cedar River Watershed with modeled SWAT upland sediment erosion data for calendar year 2010, comparing modeling output with and without 927 BMPs.

Result 2 – SWAT calibration data on Load Duration Curves

The reader is referred to the LDCs in the appendix for this discussion.

The current Cedar Watershed TMDL effort had previously collected data for and prepared the load duration curves (LDC) for three impaired stream reaches: Cedar River from Rose to Woodbury Creeks; Cedar River from Roberts Creek to Austin Dam; and Dobbins Creek. The LDCs for these sites are based on total suspended solids (TSS), and a red line on each plot equates to the current water quality standard, which is a turbidity standard of 25 NTU. The actual data points for TSS, with a corresponding flow frequency, had been plotted for the TMDL. With the development of the SWAT model, calibrated SWAT data was generated for the flow frequencies, and also plotted. It should be noted that the model provides estimates for total sediment load, which includes sand, silt, and clay particles. Our stream monitoring for suspended sediment is normally done via a grab sample in the mid to upper portion of the water column…and thus does not normally include the heavier sand particles, which are often lower in the water column, or transported as bedload.

The objective of plotting the modeled output data onto the TSS LDC was to show similar results under lower flow conditions, and for the modeled values to be higher than the monitored values under high flow conditions, because of the factors described above, regarding modeled total sediment vs. monitored suspended sediment.

This has importance for gaining a better understanding of sediment transport, and a greater ability to illustrate that the transport of the heavier sediment particles under higher flows. It is often these heavier particles (normally various grades of sand) that can cause embededness of coarser substrates and damage to aquatic habitats. Another benefit of this modeling result is a sharpened focus on total sediment effects, including a better picture of the range of sediment transported under a variety of flow conditions.

Result 3 – SWAT Estimates + Terrain Analysis + BMPs = Better Identification and Targeting

It was noted in Result 1 above that the SWAT model provided a map of subbasins with upland erosion estimates. We can now consider the subbasin results with the terrain analysis that was completed for the overall TMDL effort. This allows for a subbasin assessment to be used concurrently with the map of potential sites from the terrain analysis (stream power index). Appendix Figure 11 illustrates this combination of terrain analysis, existing BMPs, and SWAT model sediment loading areas.

Modeling meeting [June 2013]

As part of the overall project efforts regarding watershed modeling, a modeling technical meeting was held on June 18, 2013, at the MPCA's St. Paul office. This was the second meeting held on watershed modeling in 2013, with the first meeting being held on January 10th in Austin, for a larger and more general audience. A 13-page meeting summary of the June meeting is included in Appendix C. Overall, it was helpful to bring together the watershed modelers, the agricultural conservation implementers, and some technical staff from both Minnesota and Iowa, to both assess and critique our efforts. Together we learned about three current modeling efforts (involving SWMM, SWAT and GSSHA*), and about potential methods to better utilize/coordinate various modeling results. We developed a better understanding of the various models strengths and limitations as a result of this meeting. During the next several years, the application of these modeling tools will bring additional results, and no doubt further questions, about how best to incorporate watershed models into comprehensive watershed management. The presentations from the June meeting are included on the CD in Appendix F.

*Model names and brief descriptions and remarks

SWMM = Storm Water management model, is a rainfall-runoff simulation model developed for EPA at the University of Florida. A strength of this model is the simulation of water storage and treatment ponds. In the fully dynamic hydraulic flow routing option, SWMM simulates backwater, surcharging, pressure flow, and looped connections. The XP-SWMM version is an enhanced version of the basic EQP SWMM model, which requires a modeling agreement with the XP-Solutions company.

SWAT = Soil and Water Assessment Tool. This is a widely used and fully supported (USDA) watershed model that was initially selected for the Cedar River watershed TMDL project. It was developed by the USDA-ARS to predict the impact of land management practices in larger watersheds. One of the pros for this model is the explicit simulation of crop management practices (i.e. tillage, fertilization, etc.).

GSSHA = Gridded Surface Subsurface Hydrologic Analysis. GSSHA is a continuous, distributed-parameter, two-dimensional hydrologic model developed by the U.S. Army Corps of Engineers. This model works on a square grid-cell basis, and simulates vadose zone, groundwater flow, and interactions with surface water. Depending upon cell size, this model can require intensive data input prior to simulations.

Public participation and civic engagement

Appendix D includes a complete description of public participation and civic engagement activities in the CRW over the last two years. This work is becoming increasingly important, as watershed landowners and river users alike, become more aware of issues and activities related to comprehensive water management in the CRW.

Cedar River Watershed, Stream Monitoring Summary, March 2011 – June 2013, James Fett: CRWD / Mower SWCD

Approximately 10 water samples were collected each year at 10 different sites (site list on p. 2) throughout the Cedar River Watershed between March 2011 and June 2013. Samples were collected between spring snowmelt and fall ice formation each year. Samples were taken periodically and on a storm-event basis. This approach allowed sampling to capture a wide variety of flow conditions including the rising, peak, and falling limbs of rain events, along with baseflow conditions in both spring and fall. Each time a field visit was made to a monitoring site, grab samples were collected and submitted to Minnesota Valley Testing Laboratory for, Turbidity, Total Suspended Solids (TSS), Nitrate and Nitrite, Phosphorus, and Orthophosphorus. Field measurements included conductivity, pH, dissolved oxygen, and water temperature. A grab sample was also taken between July and September each year, for the bacterial indicator E. coli.

Flow regimes differed greatly between 2011, 2012, and 2013. In 2011 spring rainfall caused high flows that were followed by drought-like conditions for the remainder of the year. In 2012, very little snowmelt or rainfall occurred, and flows peaked from an early July storm event, and drought-like conditions followed. In 2013 many snowmelt events occurred resulting from heavy snowfalls followed by rapid melts. These conditions mixed with rain events resulted in very high flows throughout the spring.

Dissolved Oxygen, Conductivity, and pH remained at relatively normal levels throughout the year that were safe for aquatic life. The only times dissolved oxygen levels dropped below the 5mg/L threshold deemed unsafe for aquatic life, was in Judicial Ditch #5 late in the summer.

TSS and Turbidity were high during snowmelt and rain events, as expected. Monitoring results show the greatest TSS concentrations and highest turbidity levels after large rain events and snowmelts in the Dobbins Creek and Rose Creek Watersheds.

Total Phosphorus concentrations considerably boost algal production at levels greater than or equal to 0.20 mg/L. The highest concentration of Total Phosphorus during the three year monitoring period was 1.41mg/L during the 2011 snowmelt. Throughout the watershed Total Phosphorus concentrations tend to go above and beyond the 0.20mg/L threshold after rain events. Total Phosphorus concentrations typically correlate with TSS because Phosphorusattaches to silts and clay particles. . During times of base flow, Total Phosphorus concentrations tend to stay below the 0.20mg/L threshold. Dobbins Creek, the upper Cedar River, and Rose Creek watersheds appear to be the greatest contributors of phosphorus to the Cedar River.

Nitrate levels in water are considered to be harmful for humans to consume when they are above 10mg/L. Nitrate-nitrogen can also affect stream biological communities (benthic macroinvertebrates) at concentrations above a range of about 6-12 mg/L. However, there is no current Minnesota water quality standard for aquatic life in streams. Nitrate concentrations stayed relatively low throughout the years of 2010 and 2011, and rarely exceeded 10mg/L. This is most likely due to the drought-like conditions that occurred. The only time levels exceeded 10mg/L was after rainfall. Due to the dry conditions, water rarely flowed through the subsoil, through subsurface drainage, or across the surface. This caused a build-up of Nitrates in the subsoil. Nitrates were flushed out of the soil in Spring of 2013. This resulted in abnormally high Nitrate concentrations. Nitrate levels far exceeded the 10mg/L threshold, and were reported as high as 28.8 mg/L. Nitrate levels are the highest in the Upper Cedar River Watershed.

E. coli levels range widely throughout the watershed. The most highest results are from the outlet of Dobbins Creek. All E. coli samples taken have been reported as the maximum readable level from the lab.

In Conclusion, the watersheds with highest pollutant concentrations in 2011-3013 appear to be Rose Creek, Dobbins Creek, and the Upper Cedar River Watershed. These data should be taken into account for future BMP Planning Coordination. The high E. coli concentrations also need to be noted at Dobbins Creek.

All stream water quality data collected by this effort have been submitted to the MPCA for inclusion in the EqUIS (STORET) database.

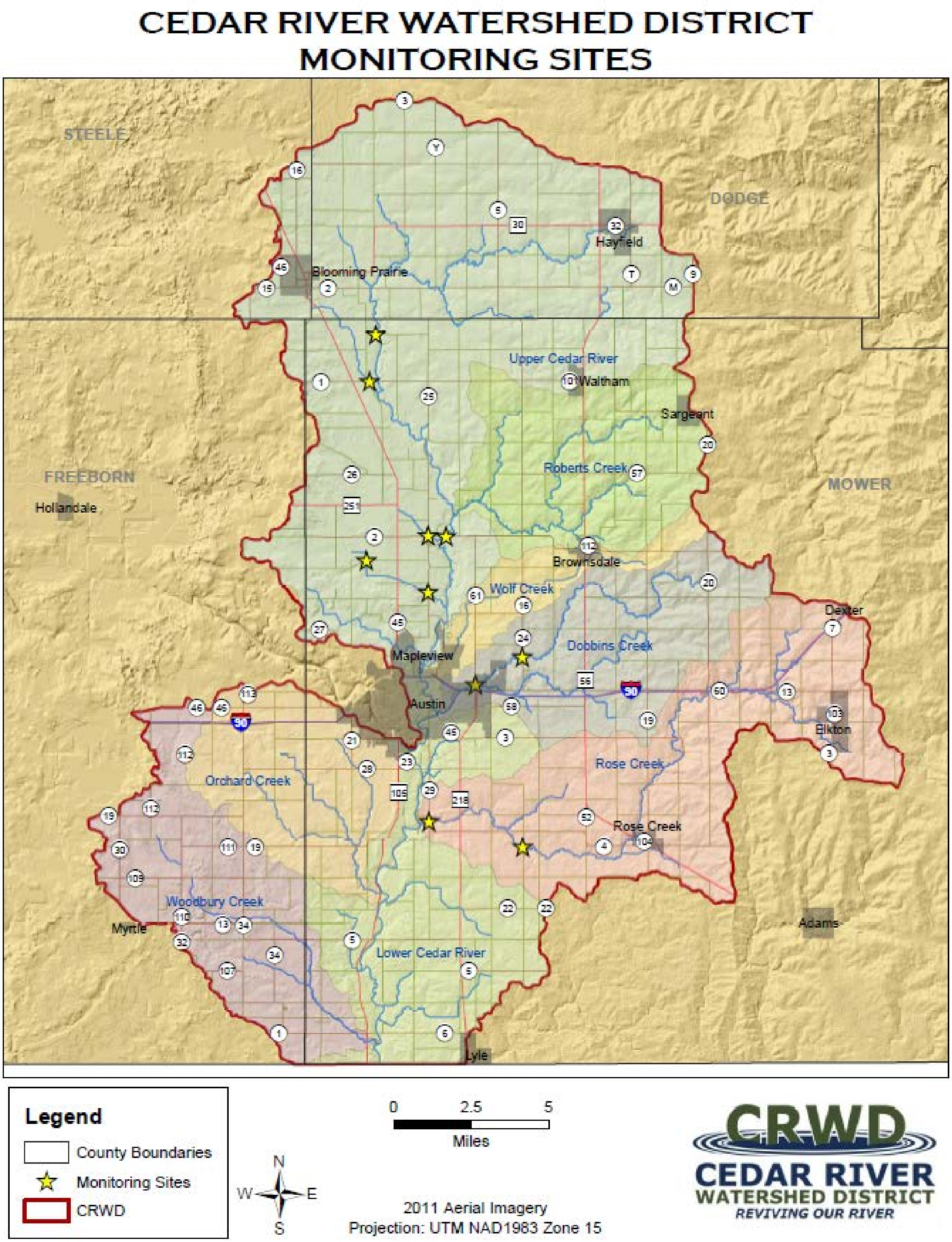


Figure 3. Stream monitoring sites 2011-2013.

Final expenditure summary Table 3

TMDL Study II

Funding/Date Paid	Original Grant Amt.	New Grant Amt.	Bills Paid/Hrs Used	Spent	Remaining
Obj. A- H & H Model	**$ 60,046.41**	**$ 65,086.41**	(BARR Engineering)		
7/2012			Barr	$ 11,970.00	$ 53,116.41
7/2012			Barr	$ 9,815.60	$ 43,300.81
10/2012			Barr	$ 10,210.50	$ 33,090.31
10/2012			Barr	$ 10,640.50	$ 22,449.81
1/2013			Barr	$ 9,992.00	$ 12,457.81
1/2013			Barr	$ 8,633.50	$ 3,824.31
3/2013			Barr (9099.50 total w/crwd)	$ 3,824.31	$ 0.00
Obj. B- BMP Inventory	**$ 52,900.54**	**$ 60,370.54**	(Mower/Freeborn/Dodge/BARR)		
12/2011			Mower SWCD-BMP Inv.	$ 9,140.00	$ 51,230.54
2/2012			Dodge SWCD-BMP Inv.	$ 3,500.00	$ 47,730.54
7/2012			Freeborn SWCD-Tillage Trans.	$ 160.88	$ 47,569.66
7/2012			Mower SWCD-Tillage Trans.	$ 1,640.00	$ 45,929.66
10/2012			Mower SWCD-BMP Inv.	$ 6,550.54	$ 39,379.12
10/2012			Freeborn SWCD-BMP Inv.	$ 23,640.00	$ 15,739.12
6/30/2013			Barr-Wtrshd Model Update	$ 15,000.00	$ 739.12
Obj. C- Public Particip:	**$ 40,290.98**	**$ 27,797.42**	(Mower/U of M)		
12/2011			Mower SWCD-Education	$ 1,100.00	$ 26,697.42
4/2012			Mower SWCD-Education	$ 150.00	$ 26,547.42
7/2012			Mower SWCD-Education-UofM	$ 340.00	$ 26,207.42
10/2012			Mower SWCD-Education	$ 1,400.00	$ 24,807.42
10/2012			Mower SWCD-Web	$ 400.00	$ 24,407.42
1/2013			Mower SWCD-Education	$ 5,110.00	$ 19,297.42
1/2013			CRWD Web	$ 1,505.00	$ 17,792.42
3/2013			Mower SWCD-Education	$ 800.00	$ 16,992.42
6/2013			Misc. Public	$ 15,217.42	$ 1,775.00
6/2013			Mower SWCD-Education	$ 1,775.00	$ (0.00)
Obj. D- Monitoring	**$ 15,256.68**	**$ 12,241.48**	(Mower)		
7/2012			MVTL-Lab	$ 106.40	$ 12,135.08
7/2012			Mower SWCD-Monitoring	$ 360.00	$ 11,775.08
10/2012			MVTL-Lab, Staples-Shipping	$ 2,691.94	$ 9,083.14
10/2012			Mower SWCD-Monitoring	$ 2,080.00	$ 7,003.14
1/2013			MVTL-Lab	$ 568.80	$ 6,434.34
1/2013			Mower SWCD-Monitoring	$ 680.00	$ 5,754.34
6/2013			Mower SWCD-Monitoring	$ 1,520.00	$ 4,234.34
6/2013			Mower SWCD-Residue Monitor	$ 2,080.00	$ 2,154.34
6/2013			Lab/Supplies/Shipping	$ 860.56	$ 1,293.78
6/2013			Residue Monitoring-Mileage	$ 440.70	$ 853.08
Obj. E- Proj. Admin.	**$ 13,710.56**	**$ 16,707.46**	(Mower)		
12/2011			Mower SWCD	$ 700.00	$ 16,007.46
4/2012			Mower SWCD	$ 1,950.00	$ 14,057.46
7/2012			Mower SWCD	$ 900.00	$ 13,157.46
10/2012			Mower SWCD	$ 3,900.00	$ 9,257.46
1/2013			Mower SWCD	$ 1,150.00	$ 8,107.46
3/2013			Mower SWCD	$ 3,850.00	$ 4,257.46
6/2013			Mower SWCD	$ 4,257.46	$ -
Total Project Dollars	**$ 182,205.17**	**$ 182,203.31**		$180,611.11	**$ 1,592.20**

Appendices

Appendix A Cedar River Watershed Existing Conditions Model, November 18, 2013
Prepared for Cedar River Watershed District. Barr Engineering Company.

Cedar River Watershed Existing Conditions Model

Prepared for Cedar River Watershed District

November 18, 2013

4700 West 77th Street
Minneapolis, MN 55435-4803
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Fax: (952) 832-2601

Cedar River Watershed Existing Conditions Model November 2013

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1.0 Introduction

1.1 Project Background

In 2009, the Cedar River Watershed District published their Cedar River Watershed District Watershed Management Plan (CRWD Plan). This plan sets the vision, guidelines, and proposed tasks for managing the water resources within the district. Within the plan, specific goals and objectives are defined in order for the district to protect and enhance safety, commerce, and natural resources of the watershed. The first set of goals for the district is in regard to flood control. The flood control goals of the district, as outlined by the CRWD Plan are as follows:

1. The protection of life, property, and surface water systems that could be damaged by flood events.
2. Correct/address existing flooding problems.
3. Prevent future flooding problems.

To achieve these goals, the district outlined a series of objectives which include regulation of runoff discharges to minimize flooding and reduce the overall flooding potential in the district. More specifically, the district would like to decrease the risk of flooding by at least 20% in the Cedar River through the City of Austin during the 100-year rainfall or snowmelt events. Meeting these objectives requires being able to quantify the existing runoff in the watershed before reductions in runoff can be evaluated.

A hydrologic and hydraulic model of the Upper Cedar River Watershed was prepared in 2007, prior to the creation of the watershed district and publication of the district's plan . This modeling effort was funded by the Upper Cedar River Ad Hoc committee and the main goal of this modeling effort was to determine if a 20% reduction in peak flow rate of the Cedar River through Austin, Minnesota was possible. The modeling effort included substantial data collection of bridge and culvert data across much of the watershed, delineation of over 400 subwatersheds, evaluation of the watershed's soils and land use data, and calibration of the final model.

The 2007 model calculated existing runoff from 435 subwatersheds (including subwatersheds in the Turtle Creek Watershed District (TCWD), which discharges to the Cedar River), and considered the effect of restricting the flow rate or establishing flow rate goals at 104 locations throughout the watershed (59 in the Dobbins Creek and Wolf Creek Watersheds, and 45 in the remainder of the watershed). The modeling effort showed that there could be a 17% reduction in peak flow rate through Austin with the construction of 104 regional basins. It was estimated that the district's goal of a 20% reduction in peak flow rate through Austin, MN would be possible with the construction of additional basins upstream of the city.

1.2 Current Modeling Effort

The current modeling effort, which is the focus of this report, includes updating the original hydrologic and hydraulic model created for the Upper Cedar River Ad Hoc Committee to create the existing conditions model for both CRWD and TCWD that will help each district define existing runoff rates. This updated model used as much information as possible from the previous modeling effort including soils data, watershed outlet locations, and survey data of bridges and culverts. Additional survey data and more detailed topographic data were used to refine the 2007 model. A more robust hydrologic and hydraulic modeling program, XP-SWMM, was also used for the current effort. A detailed description of the modeling methodology is included in Section 2. Suggestions on the variety of ways the updated model can be used by the district are included in Section 4. Figure 1 shows the area included in the 2012 modeling effort.

2.0 Modeling Methodology

2.1 Hydrologic Inputs

The amount of runoff generated from a watershed depends on numerous factors, including the total watershed area, the soil types present in the watershed, the percent impervious area in the watershed, the runoff path through the watershed, and the slope of the land within the watershed. This section summarizes the watershed runoff characteristics used in the XP-SWMM model.

Watershed Delineation

The initial watershed delineation utilized subwatershed divides developed for the 2007 modeling effort. These divides were based on the USGS quadrangle maps, which was the only available topographic data at the time. Subwatersheds were delineated to locations of major flow restrictions such as culverts or bridges. For the 2012 modeling effort, a total of 645 separate subwatersheds were delineated using the more recently obtained county LiDAR data for Mower, Steele, Dodge, and Freeborn counties. The county LiDAR data has an approximate vertical accuracy of 1-foot. The watershed divides included in the XP-SWMM model are shown in Figure 2.

Land Use and Impervious Percentage

The published 2001 National Land Cover Dataset (NLCD) impervious percentage grid was used to determine the percent impervious area for each subwatershed within CRWD and TCWD. Figure 3 shows the land use distribution across the watershed as presented in the 2001 NLCD database. Land use types listed in the database were assigned a percent impervious to each category. Table 1 lists each land use category and its associated impervious percentage.

Impervious area used in the XP-SWMM model is assumed to be hydraulically (or directly) connected to the drainage system being analyzed. This means that runoff from the portion of the impervious area that will not flow over a pervious area (such as agricultural land, open space, lawns, or other turfed areas) before reaching a storm sewer system is considered directly connected. This directly connected impervious area includes roads, driveways, rooftops, and parking areas that discharge directly to a storm sewer system. In comparison, runoff from the portion of a rooftop draining onto adjacent turfed areas would not be considered directly connected impervious areas. For modeling purposes, only directly connected impervious surfaces are considered as part of the impervious area . The majority of the impervious surfaces in the Cedar River watershed are not connected to a storm sewer; therefore, most areas have directly connected impervious percentages of zero.

Table 1 Percent Impervious by Land Use Classification Published in the NLCD Database

Land Use Classification	Directly Connected Percent Impervious Percentage
Barren Land (Rock/Sand/Clay)	0
Cultivated Crops	0
Deciduous Forest	0
Developed, High Intensity	30
Developed, Medium Intensity	16
Developed, Low Intensity	8
Developed, Open Space	0
Emergent Herbaceous Wetlands	0
Evergreen Forest	0
Grassland/Herbaceous	0
Mixed Forest	0
Open Water	0
Pasture/Hay	0
Woody Wetlands	0

Depression Storage

Depression storage, which includes the areas that must be filled with water prior to generating runoff from both pervious and impervious areas, was set within the general range of published values. It represents the initial precipitation loss caused by surface ponding, surface wetting, and interception. The model handles depression storage differently for pervious and impervious areas. The water stored as pervious depression storage is subject to both infiltration and evaporation. Alternatively, the impervious depression storage is subject to only evaporation. The depression storage was assumed to be 0.06 inches for impervious surfaces and 0.17 inches for pervious surfaces. These values are within the range of published values in the U.S. EPA SWMM Version 5.0 User's Manual. A sensitivity analysis was performed using varying depths of depression storage during the calibration process, however the analysis revealed the initially-assigned depths did not need to be changed.

Overland Roughness

Overland flow is surface runoff that occurs as sheet flow over land surfaces prior to concentrating into defined channels. In order to estimate the overland flow runoff rate, a modified version of Manning's equation is used by XP-SWMM. A key parameter in the Manning's equation is the roughness coefficient. The shallow flows typically associated with overland flow result in substantial

increases in surface friction. As a result, the roughness coefficients typically used in open channel flow calculations are not applicable to overland flow estimates. These differences can be accounted for by using an effective roughness parameter instead of the typical Manning's roughness parameter. Typical values for the effective roughness parameter are published in the U.S. COE *HEC-1 User's Manual, June 1998*; and *EPA SWMM Version 5.0 Manual, October 2005*. After reviewing the above references, the pervious roughness coefficient for all pervious surfaces was assumed to be 0.2. The impervious roughness coefficient for all impervious surfaces was assumed to be 0.015. A sensitivity analysis was performed using varying overland roughness coefficients during the calibration process, however the analysis revealed the initially-assigned coefficients did not need to be changed.

Infiltration

Infiltration is the movement of water into the soil surface, and the rate of infiltration varies of the length of a storm event. At the beginning of the storm, the initial infiltration rate is the maximum infiltration that can occur because the soil surface is typically drier and full of air spaces. As the storm event continues, the infiltration rate will gradually decrease as the air space in the soil fills with water. For long storms, the infiltration rate will reach a nearly constant value, which is the minimum infiltration rate. The Horton infiltration equation was used to simulate this variation of infiltration rate with time. Horton infiltration variables include maximum infiltration rate (Fo), minimum infiltration rate (Fc), and a parameter known as a decay rate (K), which defines the speed the soil infiltration rate declines from it maximum rate to its minimum rate. The Fo, Fc, and K values assigned to each watershed were based on the watershed's soils data, or more specifically, the hydrologic soil groups within the watershed.

The Natural Resource Conservation Service (NRCS) soil survey geographic (SSURGO) database released in July 2006 was used to determine the hydrologic soil group classifications of the soils within the study area. For areas where the hydrologic soil group was undefined, a hydrologic soil group was assigned based on the surrounding soils. Figure 4 depicts the hydrologic soil group classifications throughout the study area. The predominant hydrologic soil group in the study area is Type B, which indicates moderate infiltration rates.

No soils verification efforts were performed as part of the data gathering process. It should be noted that a review of the soils showed more uniformity than would be expected in some areas, while other areas showed abrupt changes in hydrologic soil group at county boundaries. These observations may reveal issues in the accuracy of the hydrologic classification.

Table 2 summarizes the hydrologic soil groups and their initially-assigned infiltration parameters and those arrived at after the calibration of the hydrologic model. Initial and final infiltration rates were modified based on soil type only, in order more closely match the modeled runoff and observed runoff. There were no changes of infiltration rate based on vegetation. These rates fall within guidelines established in the SWMM User's Manual. Horton infiltration parameters were calculated for each subwatershed, so a composite infiltration rate was calculated by computing a weighted average based on the percentage of each soil type in the watershed.

Table 2 Horton Infiltration Parameters

Hydrologic Soil Group	Fo before calibration (in/hr)	Fo after calibration (in/hr)	Fc before calibration (in/hr)	Fc after calibration (in/hr)	K before calibration (1/sec)	K after calibration (1/sec)
A	5	4	0.38	0.3	0.00115	0.00115
B	3	2	0.23	0.15	0.00115	0.00115
C	2	1	0.1	0.05	0.00115	0.00115
A/D, B/D, C/D, D	1	0.7	0.03	0.01	0.00115	0.00115

Subwatershed Width

The SWMM Runoff Non-linear Reservoir Method was used as the hydrograph generation method for this modeling effort. This method computes outflow as the product of runoff velocity and depth, and a watershed width factor. For this analysis, the watershed “width” was calculated using Equation (1) below:

$$W = (2 - Sk) * L \qquad (1)$$

where W = subcatchment width
L = length of main drainage channel
Sk = a skew factor calculated using Equation (2)

$$Sk = (A2 - A1)/A \qquad (2)$$

where A1 = area to one side of the main drainage channel
A2 = area to the other side main drainage channel
A = total subcatchment area

During calibration of the model a sensitivity analysis was performed using varying width values, which revealed that the originally assigned values did not need to be changed to create a calibrated model that accurately represents the watershed.

2.2 Hydraulic Inputs

Drainage Network

The drainage network consists of established waterways, open ditches, culverts, and bridges used to convey stormwater downstream to the outlet of the Cedar River at the Minnesota state border. The flow control structure information necessary for the detailed modeling was acquired from: (a) various project record drawings and construction plans available from the 4 counties, 29 townships, and the Minnesota Department of Transportation’s online database; and (b) surveys performed by the district staff, NRCS staff, and Jones, Haugh and Smith. Figure 5 shows the location of each of the flow control structures included in the existing conditions XP-SWMM model.

A total of 648 structures were surveyed for the 2007 modeling effort and this current modeling effort. Survey information collected on culverts included pipe size, shape, material, invert elevations both upstream and downstream, and the low overflow elevation of the road or berm they pass through. For surveyed bridges, elevations of the bridge deck, the bridge deck width and length, the number and size of piers, and elevation points along the river channel thalweg were surveyed or measured.

The Geneva Lake outlet within the Turtle Creek Watershed District was modeled based on construction plans provided by Ducks Unlimited. Plans provided by the Minnesota Department of Transportation were used to define the geometry at the I-90 crossing on Dobbins Creek and the CSAH 23 bridge on Turtle Creek.

The CRWD intends to update the computer model when projects are constructed to keep it current. For the 2012 modeling, the Rolfson wetland, located at the headwaters of Dobbins Creek, was included in the existing conditions model, and the project storage and control structures were based on engineering reports provided by the Minnesota Board of Soil and Water Resources.

Rainfall Information

Three storm events were evaluated as a part of the existing conditions XP-SWMM modeling: the 2-, 10-, and 100-year 24-hour rainfall events. Rainfall depths were taken from the *Minnesota Hydrology Guide* and are as follows: the 2-year 24-hour rainfall volume is 2.9 inches; 10-year 24-hour rainfall volume is 4.3 inches; the 100-year 24-hour rainfall volume is 6.2 inches. The SCS Type II distribution was used to create the hyetograph for these events. Table 3 summarizes the results of the storm events at key locations throughout the watershed.

Table 3 Peak Flow Rates for the 100-, 10-, and 2-yr Events at Select Areas of the Watershed[1]

Location	100-year Peak Flow Rate (cfs)	10-year Peak Flow Rate (cfs)	2-year Peak Flow Rate (cfs)
Cedar River at County Road 2	11,200	6,000	2,800
Cedar River at I-90	11,500	6,600	2,900
Dobbins Creek at 21st Street NE (upstream of the I-90 crossing)	6,800	3,700	1,700
Turtle Creek at I-90	2,600	1,900	1,300
Cedar River at County Road 28	16,500	9,900	5,200
Cedar River at Minnesota/Iowa Border	27,900	17,600	8,700

[1] Peak flow rates are from the existing conditions model that does not utilize the groundwater module

3.0 Model Calibration

The XP-SWMM model was calibrated so it would produce results that were a good fit with observed data collected at monitoring stations located within the study area. The calibration process included modifications to numerous hydrologic variables so the model will more accurately represent observed runoff volumes, peak runoff rates, and runoff timing. The methodology and results of the calibration are described in further detail in the following sections.

3.1 Precipitation Data

Calibration and validation of the XP-SWMM model was conducted for the two largest storms occurring in the watershed for which there was suitable rainfall information available and associated flow and stage data recorded at the gage locations. These storm events occurred on September 15 and 16, 2004 and September 22 and 23, 2010. The September 2004 event was used for calibration and the September 2010 event was used for validation. Data was also collected for two days following the events, resulting in two, four-day model scenarios. Precipitation data for these events was obtained from multiple sources including:

- NEXRAD Doppler data collected at the KMPX-Minneapolis, MN site; this data ranges from four-minute to twenty-minute intervals.
- Hourly precipitation GIS grids based on National Climatic Data Center (NCDC) multi-sensor data.
- Daily rainfall depths collected at numerous volunteer gages within the Cedar River watershed district and submitted to Minnesota Climatology Working Group's High Density Network

(HDN)

Unit hyetographs for each subwatershed were created using rainfall intensities from the NEXRAD data. Total rainfall depth in each watershed was calculated using the hourly NCDC data for the 2004 storm, and the high density network for the 2010 storm. The NEXRAD unit hyetographs were multiplied by the NCDC or HDN totals to obtain the storm event distributions for each subwatershed. Figures 6 and 7 show the total rainfall depths in each watershed for the two storm events.

3.2 Monitored Gage Data

The Minnesota Department of Natural Resources (MnDNR) operates monitoring gages at three locations within the Cedar River watershed area. These monitor the flows in the Upper Cedar River, Dobbins Creek, and Turtle Creek near their respective confluence with the Cedar River. Additionally the United States Geological Survey (USGS) has installed a monitoring gage on the Cedar River downstream of the City of Austin. Figure 8 shows the locations of these monitoring gages.
Two gages were selected to calibrate the XP-SWMM model:

- MnDNR gage 48023001, Cedar River near Lansing CR2
- MnDNR gage 48027001, Turtle Creek at Austin 43rd St

These gages were selected for calibration because they allowed for individual calibration of the Upper Cedar River Watershed and the Turtle Creek Watershed. Since the flow characteristics of these watersheds varied (overall watershed slope and the number of ditches in the Turtle Creek Watershed as opposed to the Upper Cedar River Watershed) individual calibration of each watershed allowed for more flexibility and a more accurate calibration. The USGS gage 05457000, Cedar River near Austin, MN, was selected to help validate the values selected during the calibration process.
The Cedar River near Lansing gage contains a 164 square mile tributary area of predominantly agricultural land use. This gage is located just downstream of the Cedar River and Roberts Creek confluence. The Turtle Creek gage includes drainage from Turtle, Mud and Deer Creeks, as well as Lake Geneva. This tributary area is approximately 147 square miles in size and is also predominantly agricultural land use. The USGS gage is located downstream of the city of Austin, just over a mile downstream of the Cedar River and Turtle Creek confluence. This gage also includes runoff from the Wolf Creek, Murphy Creek, Dobbins Creek, and the City of Austin.
Stream gages recorded water depth and flow at 15-minute intervals at the Cedar River near Lansing gage and the Turtle Creek gage. The USGS stream gage recorded daily flow totals, with water depth recorded at periodic intervals. Using a USGS published rating curve, flows were calculated for each water depth data point in order to check the flow calibration at that location.

3.3 Calibration Results

The XP-SWMM model was calibrated, then validated, using two storm events at three monitoring stations. During calibration (September 2004 event), hydrologic variables were modified to adjust the modeled hydrographs in effort to create a best match to the recorded data. Model calibration focused on matching the peak stage and peak flow rate, but also considered the general shape of the hydrographs for each storm event. The model was then re-run using the second storm event (September 2010 event) to validate the parameter modifications made during calibration.

Through the calibration process, it was determined it was necessary to return some of the infiltrated runoff back into the system to simulate the effects of the drain tiles located in the agricultural land. The “groundwater” module in XP-SWMM allowed infiltrated runoff to be returned to each subwatershed at a delayed rate much like a drain tile would function in a field. Though the

groundwater module was used, the module was strictly for calibration purposes and wasn't intended to simulate actual groundwater movement; only the use of tile throughout the watershed. The tiles themselves were not modeled, only simulated by using the groundwater module.
The groundwater module parameters were calibrated to determine which values would result in the best match between modeled and recorded data. Due to differences in soil types and drain tile simulations, the groundwater module parameters were calibrated separately for the Cedar River and Turtle Creek watersheds. Table 4 lists the variables within the groundwater module that were used for calibration for the two watersheds.

Table 4 Values Used in the Groundwater Module to Represent Drain Tile in Cedar River and Turtle Creek Watersheds

Parameter	Value used for the Cedar River Watershed	Value used for the Turtle Creek Watershed
Saturated Hydraulic Conductivity	0.1	0.23
Porosity Expressed as a Fraction	0.9	0.9
Curve Fitting Parameter	5	5
Initial Upper Zone Moisture (as fraction)	0.5	0.5
Coefficient for Unquantified Losses	0.0035	0.0035

Comparisons of the observed and modeled stage hydrographs from the three calibration sites and two storm events are shown in Figures 9 through 14. Both model results, with-tile simulated and without-tile simulated are presented. The following is a summary of the calibration and validation results:

- At the Cedar River at Lansing gage, the 2004 event model closely matches peak stage in both the with-tile and without-tile scenarios. For the 2010 event model, both the with-tile and without-tile scenarios over predicted peak stage by approximately 1.5-feet.

- At the Turtle Creek gage, the 2004 event model closely matched peak stage for the with tile scenario, while the without-tile scenario under predicted peak stage by approximately half of a foot. For the 2010 event model, the with-tile scenario over predicted peak stage by approximately half of a foot, while the without-tile scenario was a very close match to the observed peak stage.

- Because of gaps in data at the USGS gage, a comparison of modeled and observed stages is more difficult, but overall the 2004 event model under predicted peak stage by two to three feet for both modeling scenarios, whereas the modeled peak stage was a closer representation of the observed peak stage for the validation event (2010) for both modeling scenarios.

Calibration also included evaluation of runoff volume, as represented by the runoff depth. Observed and modeled runoff depths were calculated for each storm event at the Cedar River near Lansing and Turtle Creek gage locations. The runoff depths were calculated from the measured and the modeled runoff using the equation:
Runoff Depth = Measured (or Modeled) Runoff Volume/Drainage Area
Table 5 summarizes the runoff depths at the Cedar River near Lansing gage and the Turtle Creek

gage for both storm events and both model scenarios. Runoff depths were not compared for the USGS gage because the gaps in observed data make volume calculations inaccurate.

Table 5 Runoff Depths based on Observed and Modeled Conditions

		2004 Calibration Event	2010 Validation Event
Cedar River near Lansing Gage	Gage Runoff Depth (inches)	3.75	3.22
	With-Tile Runoff Depth (inches)	4.55	4.05
	Percent Change (%)	+21%	+26%
	Without-Tile Runoff Depth (inches)	3.67	3.36
	Percent Change (%)	-2%	4%
Turtle Creek Gage	Gage Runoff Depth (inches)	1.75	1.42
	With-Tile Runoff Depth (inches)	1.97	1.88
	Percent Change (%)	12%	32%
	Without-Tile Runoff Depth (inches)	1.67	1.59
	Percent Change (%)	-5%	11%

The volume comparison showed that the with-tile model over predicted the volume of runoff for both storms at both gage locations. The without-tile model more closely matched the runoff volumes for both storms at both gage locations.

The deviations between the modeled and observed peak stage and the modeled and observed runoff volumes are most likely due to the variability of tile across the watershed and the different crop types affecting the overland roughness. The existing conditions model is not detailed enough to vary roughness based on crop type (or time of year) nor does it take into account where tile systems are located in the watershed. For the model where tile is simulated, it is assume that tile is throughout the entire watershed. Inaccuracies in soils data can also affect the calibration results.

Either existing conditions model (with-tile or without-tile) can be utilized to compare the changes in runoff rate and volume for modifications that are proposed in the watershed. However we recommend that the district use the without-tile model since the peak stages were not drastically different than those observed, and because the without-tile model more closely represented runoff volumes.

4.0 Future Model Uses

This 2012 modeling effort is possibly the most important step in aiding the CRWD and TCWD achieve their goals for flood control, as it helps each understand the current flow dynamics for various storms throughout their respective watershed. It enables both watershed districts to understand all of the current flow control features in their respective watershed are a system and not individual autonomous structures.
The existing conditions model is a tool that will be used in the future to evaluate the hydraulic effects of any proposed flow control device or group of devices that either watershed district is considering constructing. Such devices might include, but are not limited to, new ponding basins with new outlet

structures, flow diversions, modifications to existing culverts and roads, and wetland restorations. For example, additional proposed basins to those included in the existing conditions model , or modification to any current feature could be evaluated to determine its incremental impact on achieving the 20% peak flow rate reduction for 100-year flows passing through Austin. The model can also be used to define the flow rate goals across the district where there are no current flow rate goals set. This information would then be incorporated into the next version of the CRWD's and TCWD's Watershed Management Plan.
In addition to supporting each watershed district in achieving their respective flood control goals, the following are other potential uses of the existing conditions model:

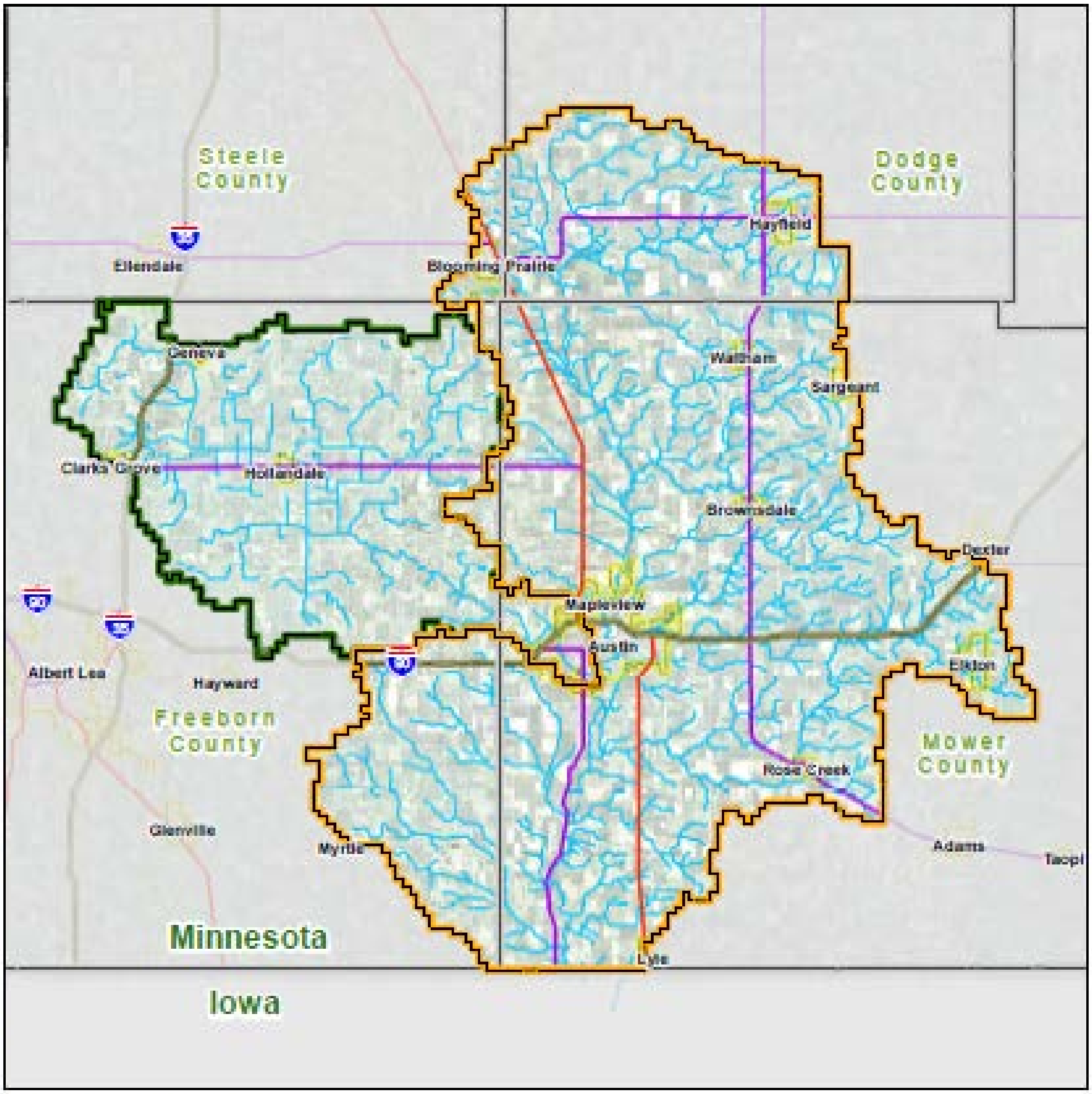
1. Proposed land use changes in the watershed (such as new residential, commercial, or industrial developments) can be integrated into the model to define the changes in runoff rates from a subwatershed and determine their effect on flood flows, and what resources are needed to ensure they do not negatively impact land or the water resources.

2. The model can be used to support County or Township road construction, or culvert or bridge replacement. Changes in road elevation or culvert and bridge configurations can easily be modeled to determine how flow rates are affected and to help size such features.

3. The model can be easily updated as projects across the two districts are implemented so a current maintained model will always be available.

4. Model output can be used concurrently with water quality software to define water quality treatment across the district.

5. The XP-SWMM model software is accepted by FEMA for development of flood insurance rate maps (FIRMs). As such it can be used when needed to rectify issues with FEMAdeveloped FIRMs that are not perceived to accurately depict the 100-year flood plain.



Sources:
Cedar River Watershed District Boundary - Barr (2013)
Turtle Creek Watershed District Boundary - Barr (2013)
County Boundary - MN Department of Transportation (2003)
City Boundary - MN Department of Transportation (2001)
Roads - MN Department of Transportation (2003)

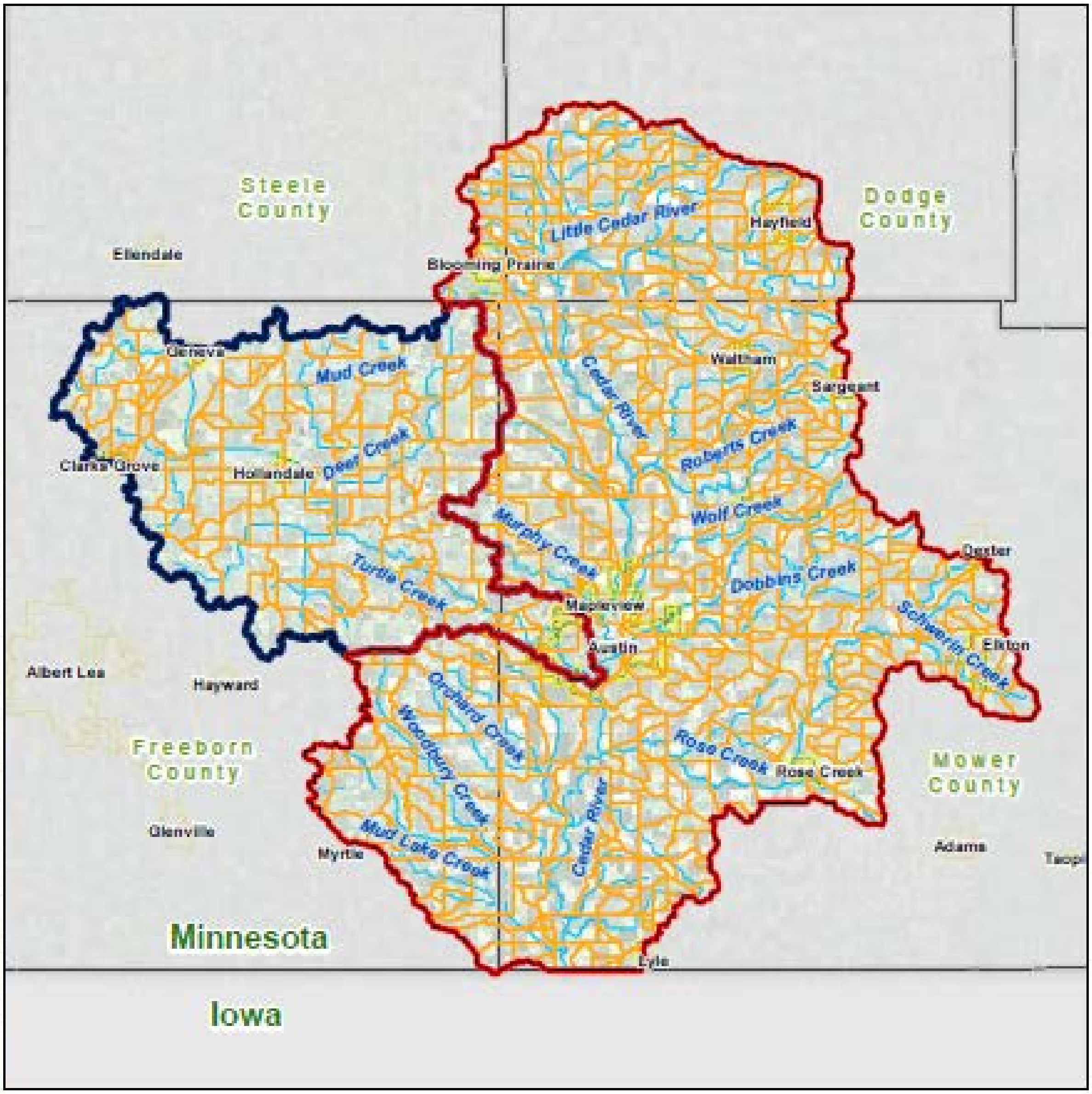
Figure 1

Project Extents

Cedar River Watershed District

Miles
0 2 4 8

Legend
Cedar River Watershed District Legal Boundary
Turtle Creek Watershed District Legal Boundary
County Boundary
City Boundaries



Sources:
Cedar River Subwatershed Divides - Barr (2012)
Cedar River Watershed District Boundary - Barr (2012)
Turtle Creek Watershed District Boundary - Barr (2012)
County Boundary - MN Department of Transportation (2003)
City Boundary - MN Department of Transportation (2001)
Flowlines - National Hydrography Database (2012)

Figure 2

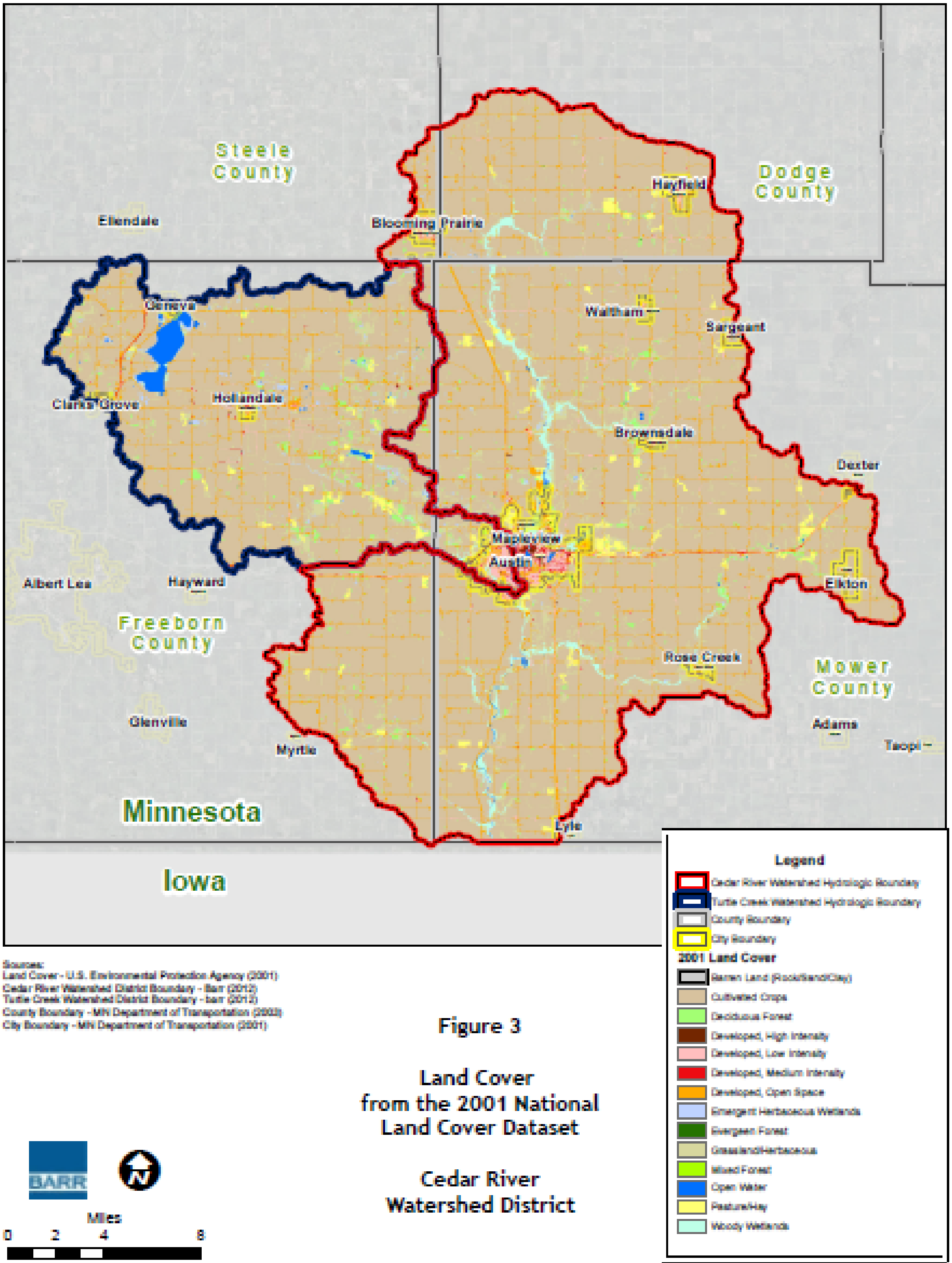
Subwatershed Divides

Cedar River Watershed District

BARR

Miles
0 2 4 8

Legend
Cedar River Watershed District Hydrologic Boundary
Turtle Creek Watershed District Hydrologic Boundary
Cedar River Subwatershed Divides (2012)
County Boundary
City Boundary
Rivers, Streams, Creeks

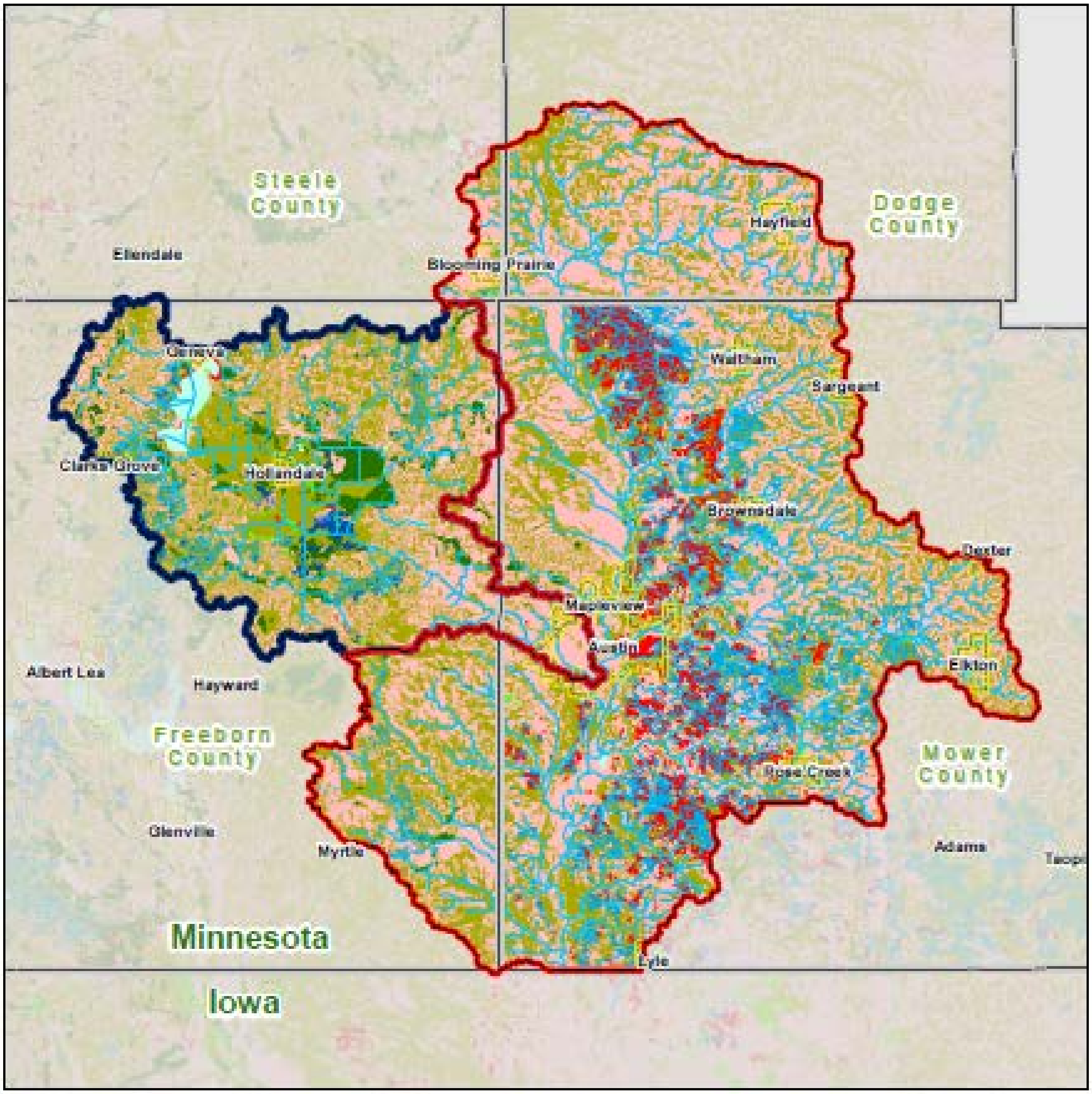


Sources:
Land Cover - U.S. Environmental Protection Agency (2001)
Cedar River Watershed District Boundary - Barr (2012)
Turtle Creek Watershed District Boundary - barr (2012)
County Boundary - MN Department of Transportation (2003)
City Boundary - MN Department of Transportation (2001)

Figure 3

Land Cover
from the 2001 National
Land Cover Dataset

Cedar River
Watershed District



Sources:
Dodge County Soils - Natural Resource Conservation Service (1961)
Freeborn County Soils - Natural Resource Conservation Service (1980)
Mower County Soils - Natural Resource Conservation Service (1989)
Steele County Soils - Natural Resource Conservation Service (1973)
Cedar River Watershed District Boundary - Barr (2012)
Turtle Creek Watershed District Boundary - Barr (2012)
County Boundary - MN Department of Transportation (2003)
City Boundary - MN Department of Transportation (2001)

Miles
0 2 4 8

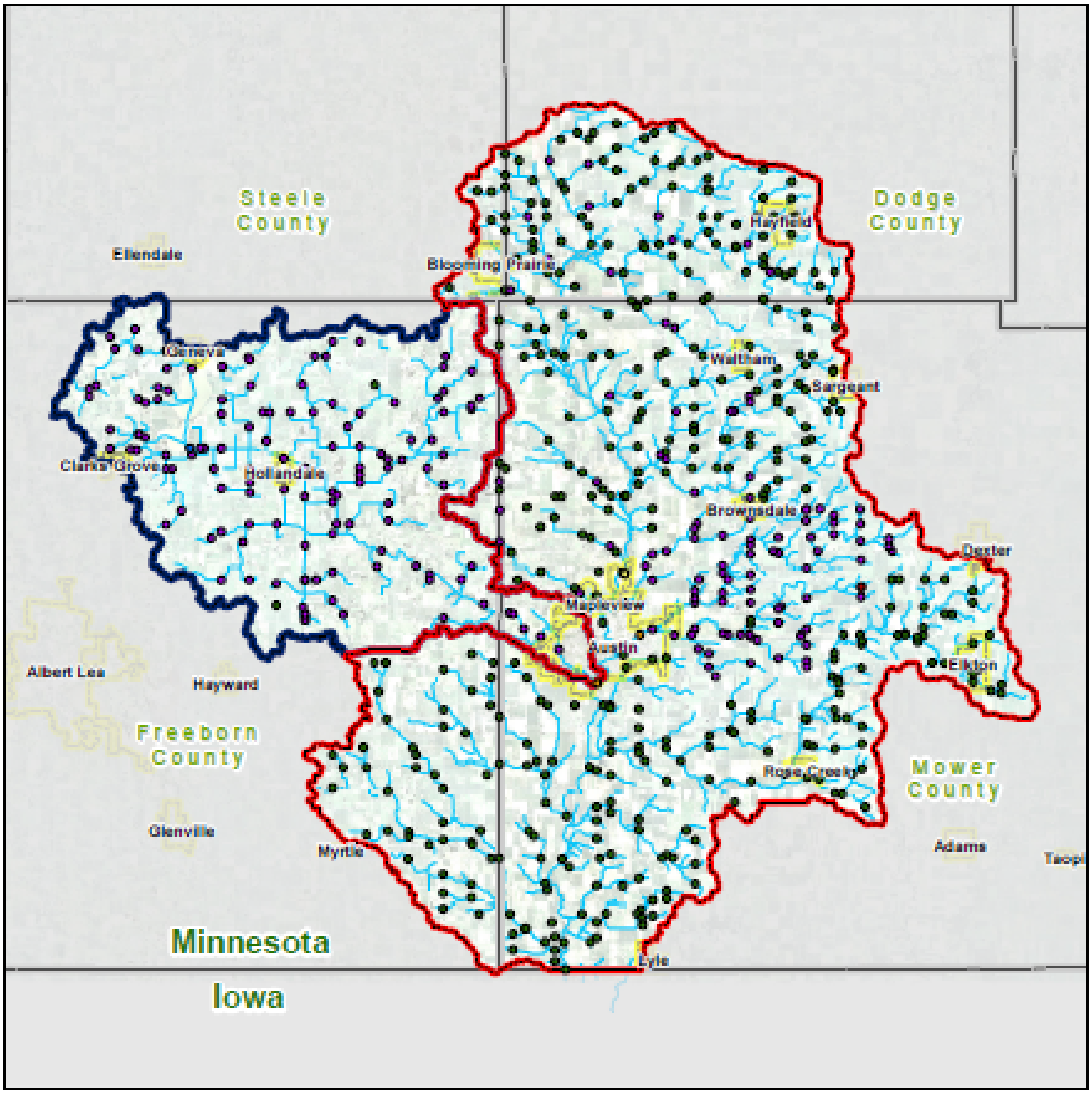
Figure 4

Soil Hydrologic Groups

Cedar River
Watershed District

Legend
- Cedar River Watershed Hydrologic Boundary
- Turtle Creek Watershed Hydrologic Boundary
- County Boundary
- City Boundary

Soil Hydrologic Group
- Open Water
- A
- A/D
- B
- B/D
- C
- C/D
- D



Sources:
2008 Survey - Jones Haugh Smith (2008)
2012 Survey - Jones Haugh Smith (2012)
MnDOT construction plans - MN Department of Transportation (2012)
Geneva Lake Outlet - Ducks Unlimited (2008)
Ramsey Dam Inventory - Army Corps of Engineers (1976)
Rolfson Wetland - MN Board of Soil and Water Resources (2010)
Cedar River Watershed District Boundary - Barr (2012)
Turtle Creek Watershed District Boundary - Barr (2012)
County Boundary - MN Department of Transportation (2003)
City Boundary - MN Department of Transportation (2001)

Miles
0 2 4 8

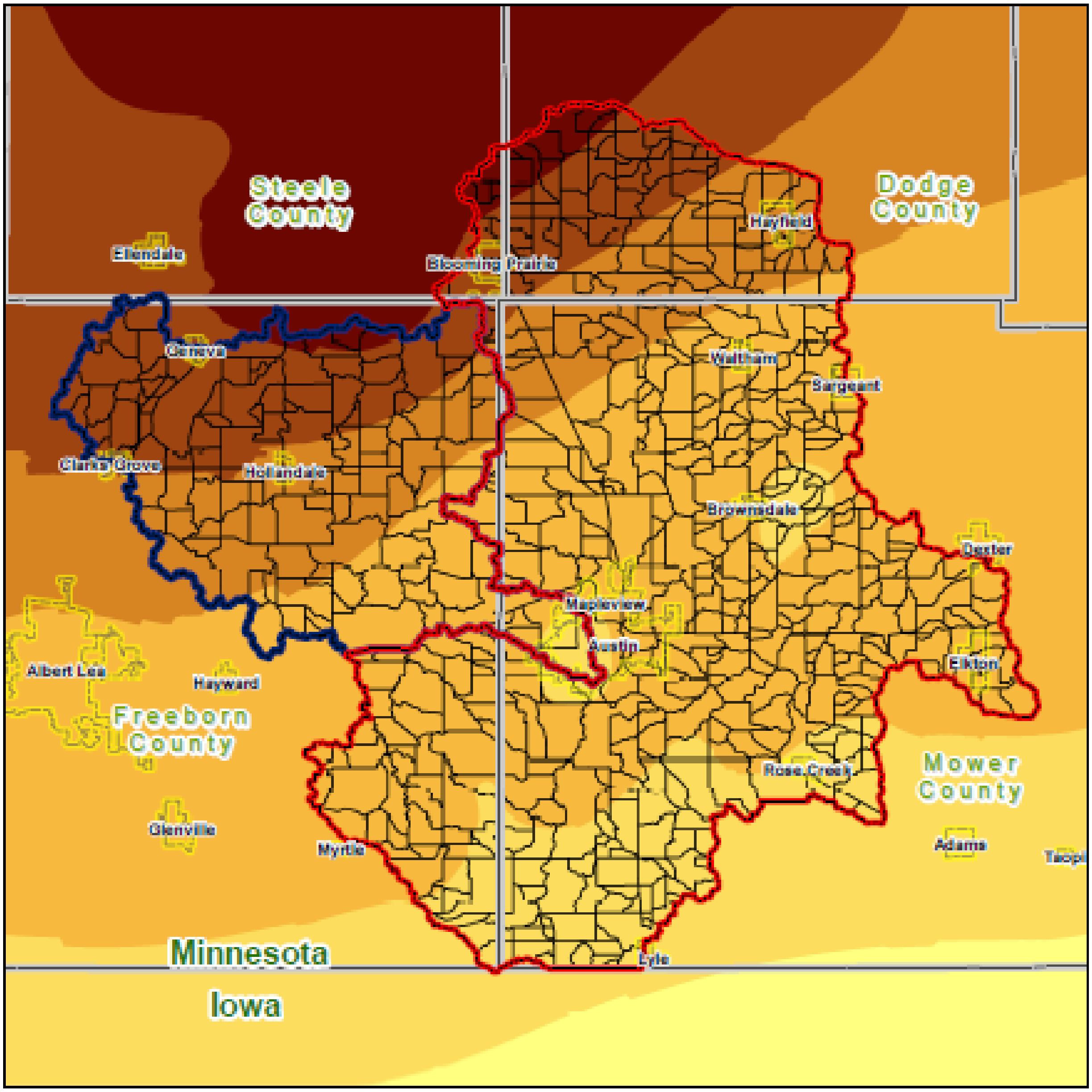
Figure 5

Flow Control Structure Locations

Cedar River Watershed District

Legend

Survey Data Source
- 2008 Survey
- 2012 Survey
- MnDOT construction plans
- Geneva Lake Outlet construction plans
- Ramsey Dam survey
- Rolfson Wetland as-builts
- Cedar River Watershed Hydrologic Boundary
- Turtle Creek Watershed Hydrologic Boundary
- County Boundary
- City Boundary



Sources:
Rainfall Distribution - MnDNR Division of Ecological and Water Resources State Climatology Office (2010)
Cedar River Watershed District Boundary - Barr (2012)
Turtle Creek Watershed District Boundary - Barr (2012)
County Boundary - MN Department of Transportation (2003)
City Boundary - MN Department of Transportation (2001)
Cedar River Subwatershed Divides - Barr (2012)

Figure 6

Event 2010 Total Rainfall Distribution

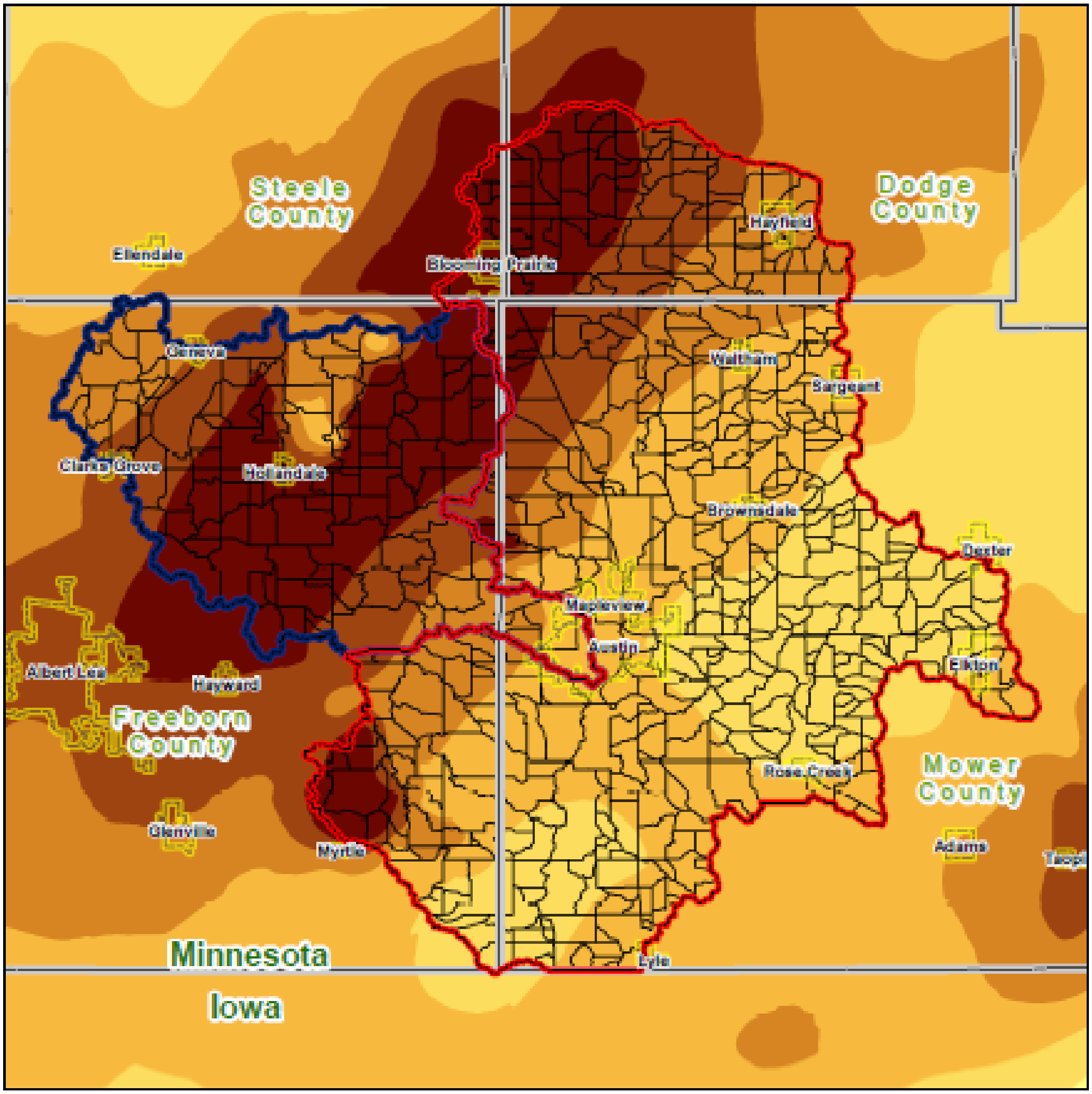
Cedar River Watershed District

BARR

Miles
0 2 4 8

Legend
- Cedar River Watershed Hydrologic Boundary
- Turtle Creek Watershed Hydrologic Boundary
- County Boundary
- City Boundary
- Cedar River Subwatershed Divides (2012)

2010 Event Total Rainfall [inches]
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9



Sources:
Rainfall Distribution - National Oceanic and Atmospheric Association (2004)
Cedar River Watershed District Boundary - Barr (2012)
Turtle Creek Watershed District Boundary - Barr (2012)
County Boundary - MN Department of Transportation (2003)
City Boundary - MN Department of Transportation (2001)
Cedar River Subwatershed Divides - Barr (2012)

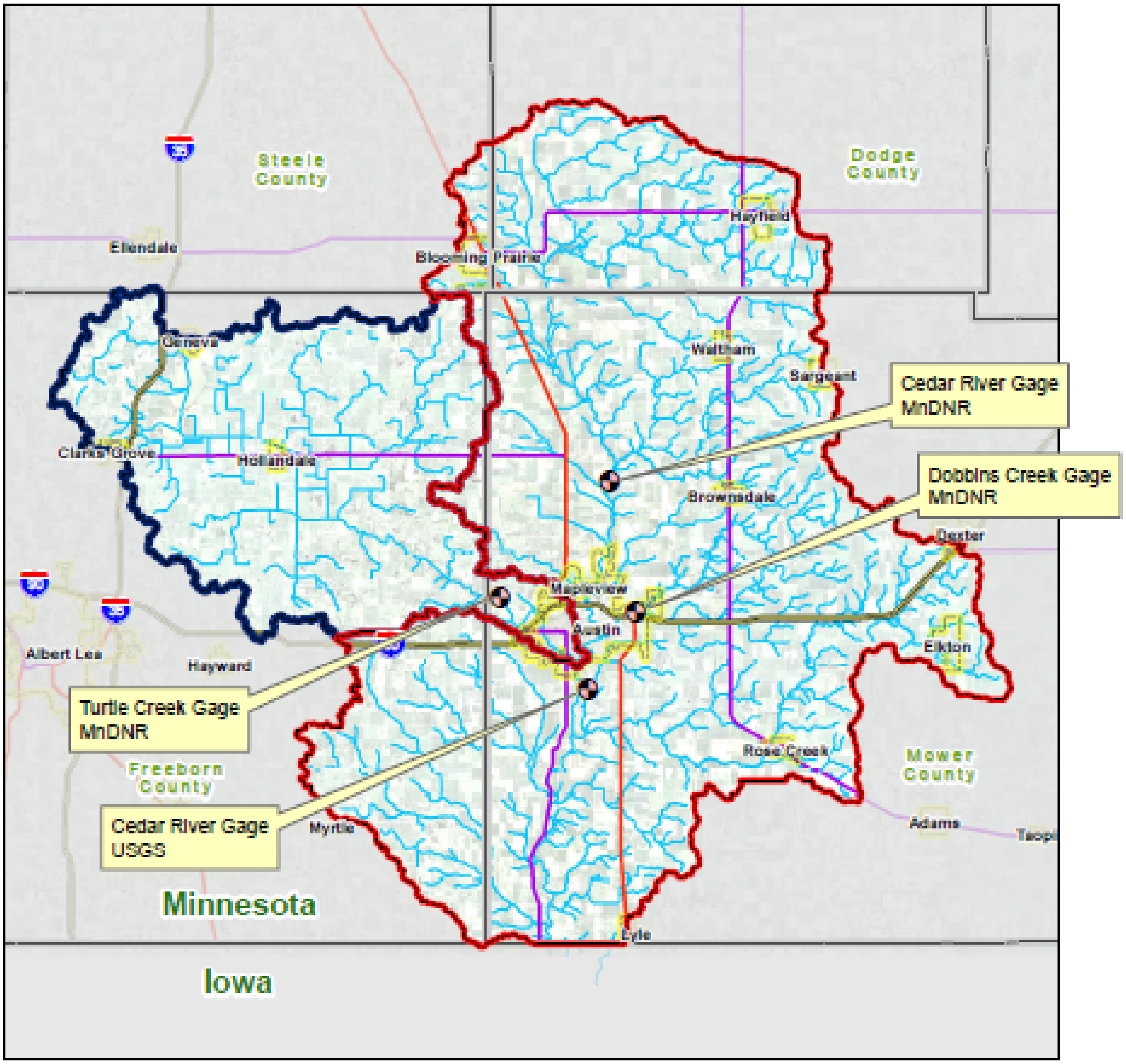
Miles
0 2 4 8

Figure 7

Event 2004 Total Rainfall Distribution

Cedar River Watershed District

Legend
Cedar River Watershed Hydrologic Boundary
Turtle Creek Watershed Hydrologic Boundary
County Boundary
City Boundary
Cedar River Subwatershed Divides (2012)
2004 Event Total Rainfall [inches]
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9



Sources:
Calibration Gage - United State Geological Survey
Calibration Gage - MN Department of Natural Resources
Cedar River Watershed District Boundary - Barr (2012)
Turtle Creek Watershed District Boundary - Barr (2012)
County Boundary - MN Department of Transportation (2003)
City and Township Boundaries - MN Department of Transportation (2001)
Roads - MN Department of Transportation (2003)

Figure 8

Monitoring Gage Locations

Cedar River
Watershed District

BARR

Miles
0 2 4 8

Legend
Calibration Gages
Cedar River Watershed Hydrologic Boundary
Turtle Creek Watershed Hydrologic Boundary
County Boundary
City Boundary

Figure 9 – Upper Cedar River Modeled and Observed Stage (2004)

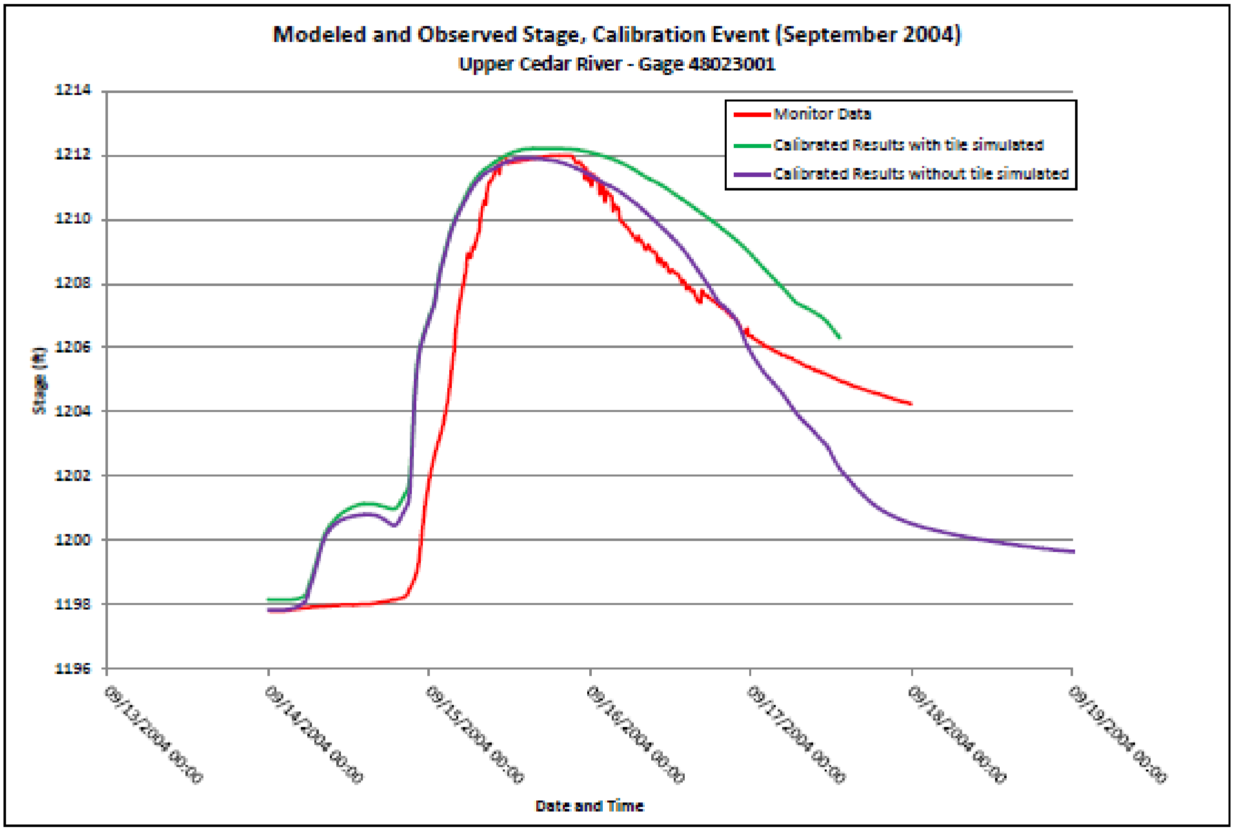


Figure 10 – Upper Cedar River Modeled and Observed Stage (2010)

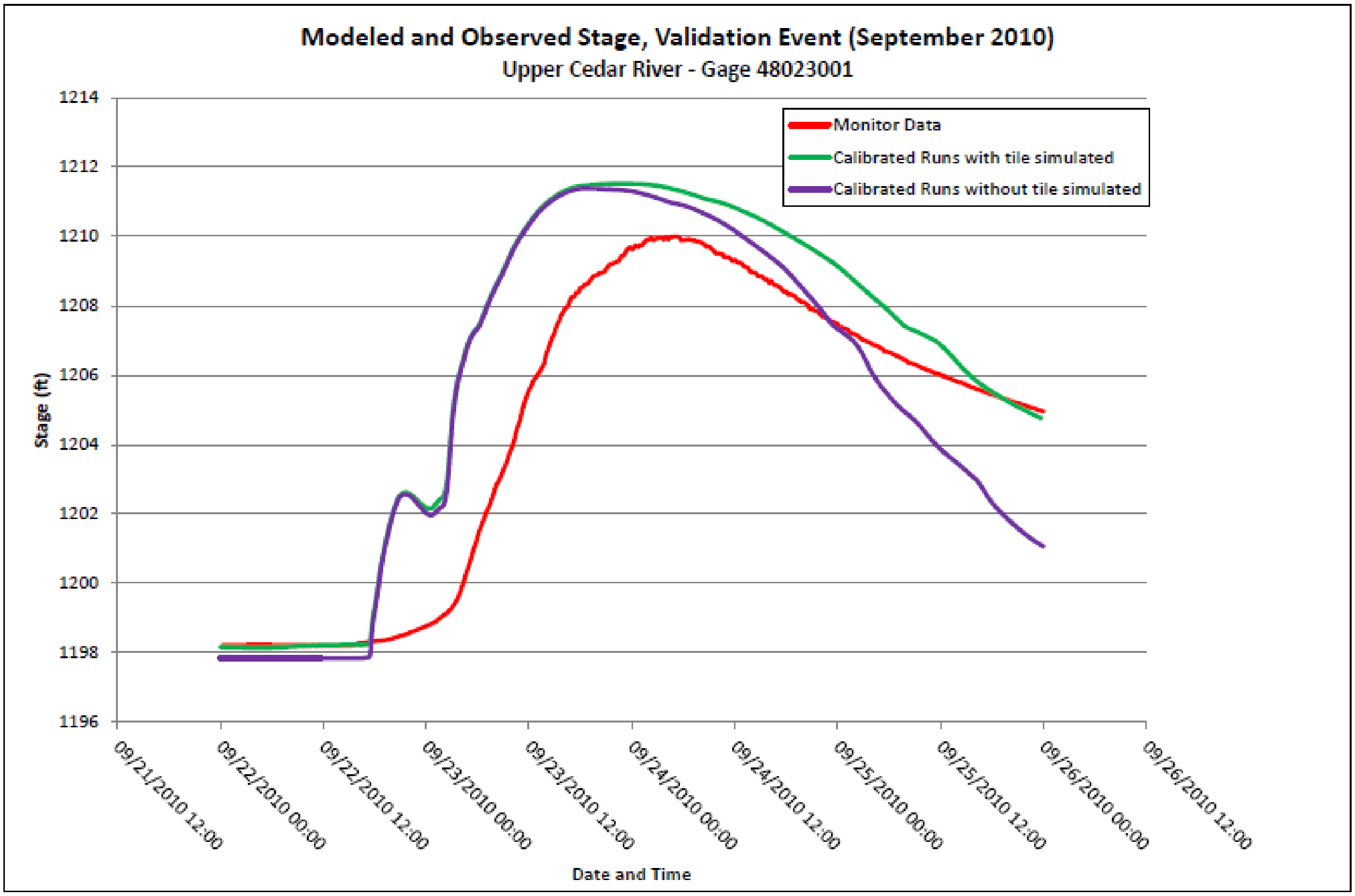
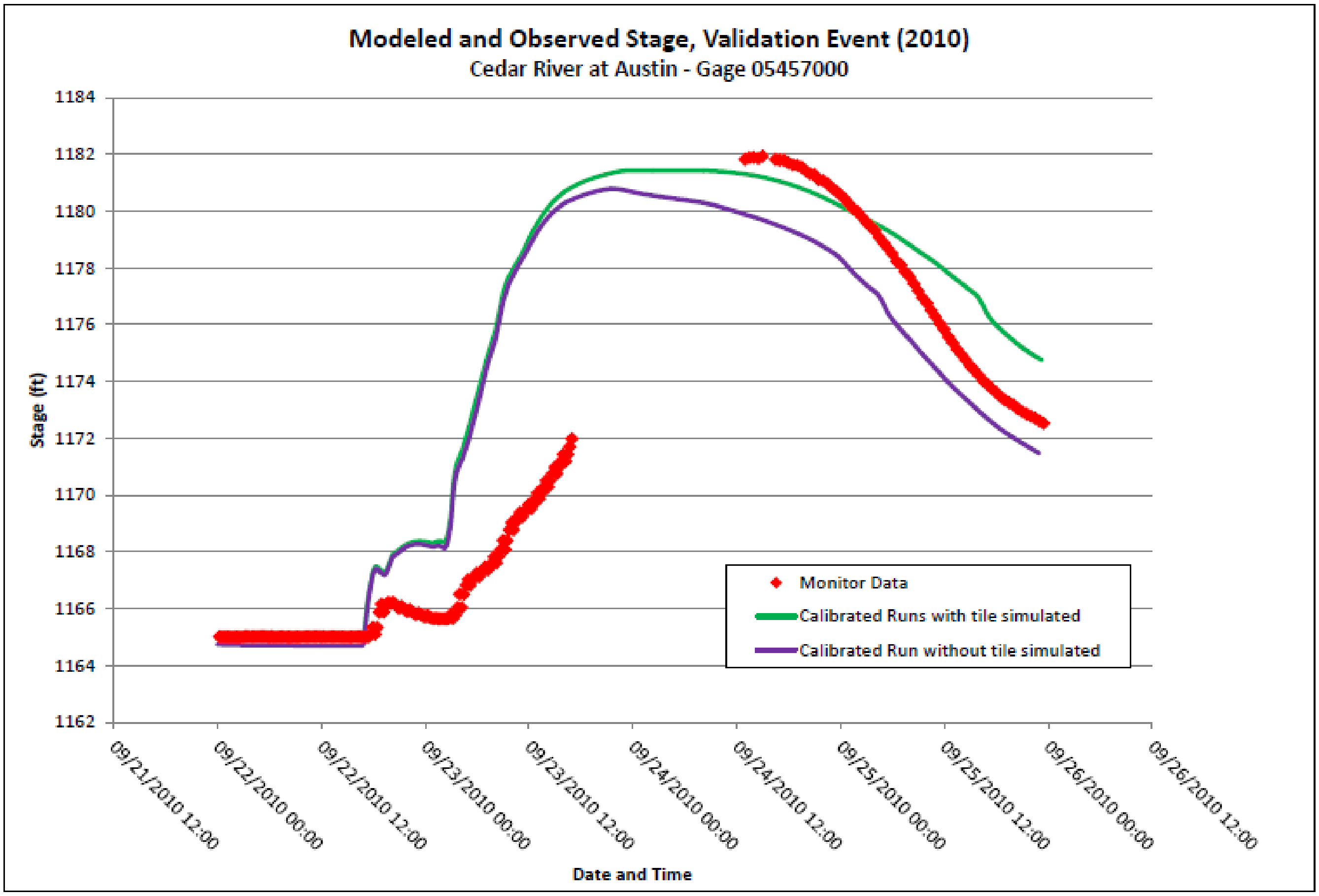


Figure 14 – Cedar River at Austin Modeled and Observed Stage (2010)



Appendix B Updated Soil and Water Assessment Tool (SWAT) Watershed Modeling Cedar River Watershed Turbidity Total Maximum Daily Load Technical Memorandum – FINAL. Barr Engineering Company.

Technical Memorandum—FINAL

To: Project File
From: Greg Wilson
Subject: Updated SWAT Watershed Modeling
Project: Cedar River Watershed Turbidity Total Maximum Daily Load Study

A previous effort to develop and calibrate a Soil and Water Assessment Tool (SWAT) watershed model for the Cedar River basin included a limited representation of existing best management practices (BMPs) in the modeling. In addition, current information about soils data (including the new NRCS soils map interpretations for Mower, Freeborn, Steele and Dodge Counties) and agricultural management practices indicated that the previous extent of tile drainage had likely been underestimated in the original modeling effort. It was believed that in order to be the most useful tool, the model should be refined to more accurately account for current BMPs, tiling and soils and explicit tile modeling routines within the SWAT model were used as a part of the model refinement. As a result, Mower SWCD and watershed staff for the Cedar River and Turtle Creek Watershed Districts began an effort to collect more-detailed data about the locations and extent of current BMPs in the study area so that the SWAT model could then be refined to better represent how these BMPs, tiling and soils are affecting water quality. Through these refinements, the model could in turn be used to provide greater insight into identifying and prioritizing the critical source areas of turbidity in each watershed.

This memorandum describes the updated SWAT modeling, including the input data, model calibration, limitations and the approach for identifying the critical source areas for excess sediment loading in the impaired river reaches.

SWAT Model Background

SWAT (Soil and Water Assessment Tool; Arnold et al., 1993) is a basin-scale continuous distributed water quality simulation model capable of predicting long-term effects of alternative land management practices and water quality improvement features. Major components of the model include hydrology, erosion, nutrients, pesticides, crop growth, and agricultural management. Hydrologic processes include

*** Bill **** check for missing section here

surface runoff, tile drainage, snow-melt runoff, infiltration, subsurface flow and plant uptake. The model allows for consideration of reservoirs and ponds/wetlands, as well as inputs from point sources.

Much of the previous SWAT modeling input data remained the same, including the compiled GIS and weather data as well as information about point source discharges, land use/land management, tillage methods and information about nutrient applications. The following sections describe the changes that were made to the model (used to develop the Cedar TMDL) to improve the way that existing tile drainage, treatment from regional ponds/wetlands and implementation of agricultural Best Management Practices (BMPs) and smaller wetland restoration projects were accounting for the observed water quality in the watershed.

SWAT Model Improvements

Soils and Tiling

The soil maps that were used in the development of the original SWAT model were recently updated by NRCS. The hydrologic soil group characteristics were reclassified by NRCS, since the last modeling effort. The resulting soil database was used to identify and spatially map soils classes that were hydrologic soil group "C" and "D" soils (USDA, 1980). The cultivated cropland land cover/land use areas were intersected with C or D soil types from the soils database to determine areas of the watershed that are subject to tile drainage. Because a comprehensive tile data base was not available for the modeled watershed area, this was a suitable alternative means to identify lands where tile has been placed and to more accurately account for runoff.

Determination of Hydrologic Response Units

Input for the SWAT model was derived at two different scales: the subbasin and the hydrologic response unit (HRU). HRUs are developed by overlaying soil type, slope and land cover. It is noted that HRUs in the version (2009.93.7b, Revision 481) of ArcSWAT used for this project are not defined by a flow direction; and their spatial location within each subbasin does not influence sediment loading to the stream. A newer version of ArcSWAT was released after this project began, but was not used because it was not backward compatible (and would not be able to use the files from the previous modeling effort) and some software bugs had been reported for BMP simulation in the newer version. **To:** Project File **From:** Greg Wilson **Subject:** Updated SWAT Watershed Modeling **Page:** 3 **Project:** Cedar River Watershed Turbidity Total Maximum Daily Load Study
Cedar River Watershed Updated SWAT Modeling--Updated Technical Memorandum--FINAL

In addition to the crop rotations, SWAT was also used to model pasture land, forest land, water and urban land cover HRUs in each subbasin. Table 1 shows the distribution of the general SWAT model land uses applied to the watershed. The intersection with the reclassified soil types resulted in a significant increase in the amount of cropland with tile drainage, in comparison with the previous modeling effort (from approximately 51% to 84% of the cultivated cropland in the watershed being tiled). The soil types associated with pasture, alfalfa and small grains land cover components were not included in the areas that were estimated as having tile drainage.

Table 1. General SWAT Model land use distributions, as a percentage of the overall watershed.

Land Use	Percentage of Overall Watershed
Row Crops with Tile Drainage	65.0%
Row Crops without Tile Drainage	12.2%
Forested	1.8%
Pasture	6.8%
Alfalfa and Small Grains	9.9%
Water/Wetlands	2.5%
Low Density Residential	1.4%
Medium/Low Density Residential	0.3%
High Density Development	0.1%

The initial HRUs set up in the ArcSWAT interface were further refined for each subbasin in the Cedar River basin to account for the various crops, crop management, tile drainage and agricultural BMPs. This resulted in more than 20,000 HRUs in each of the major watersheds, with several of the HRUs resulting from unique combinations of soils and land use that represented very small areas in each subbasin. As a result, the land use refinement feature in ArcSWAT was used to eliminate these small HRU areas from the modeling, except for the urban land use areas that were always retained (or exempt from refinement) in each subbasin. Other HRU areas that remained in the model were represented by land uses that occupied at least 5 percent of each subbasin and soil types that occupied at least 20 percent of each subbasin.

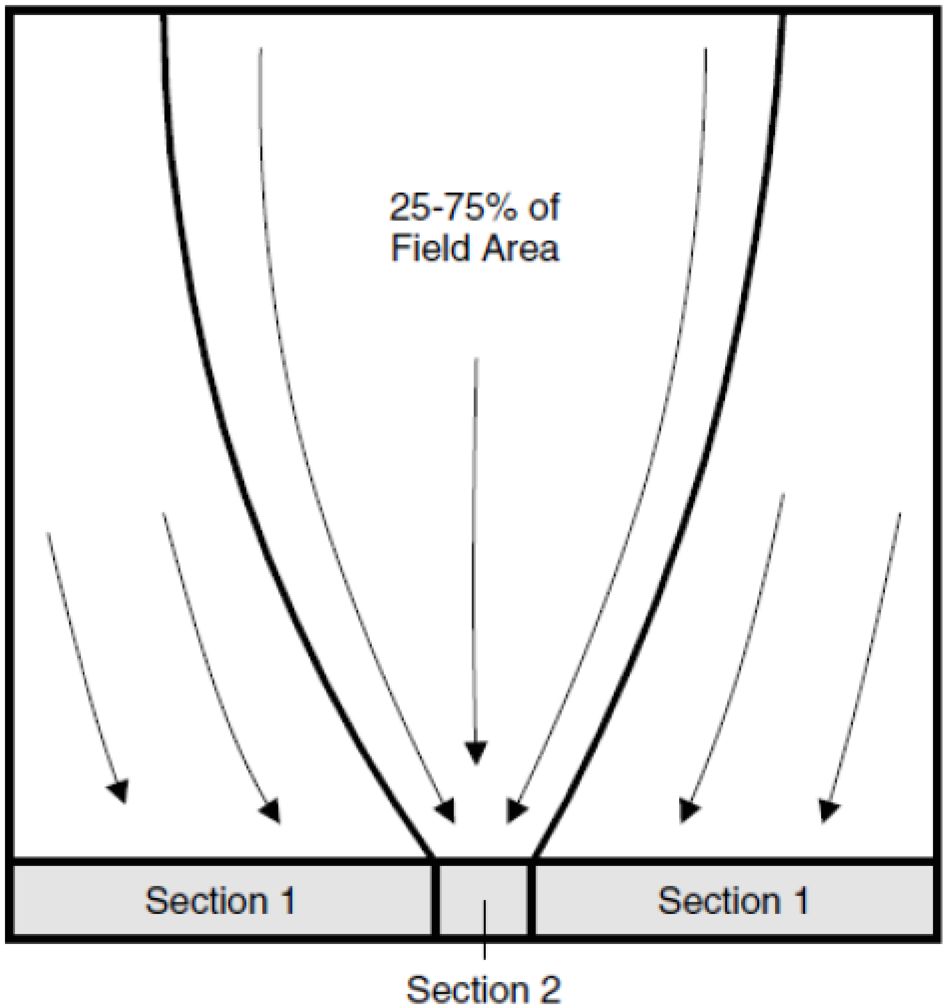
Accounting for BMP Implementation

This section describes the changes that were made to the modeling to improve the way that water quality treatment from regional and localized ponds/wetlands and existing agricultural Best Management Practices (BMPs) was determined. Since such information was not available for the original modeling effort, that model was made to approximate BMPs by using a uniform filter strip width (FILTERW) of 5 meters applied to all cultivated cropland HRUs in the basin. It is expected that this model procedure resulted in a significant overestimate of the amount of filtration that was actually occurring in the watershed. As a result, the input for this variable was eliminated from the updated SWAT model and replaced with BMP information for the tributary area receiving filtration, as determined from the District staff-provided BMP inventory locations in GIS.

As previously discussed, District staff completed an inventory to collect detailed information about the current locations and extent of agricultural BMP implementation in the Cedar River and Turtle Creek watersheds. A total of 927 practices were identified in the combined area of both watershed districts with the vast majority (830) representing filtration BMPs (such as grassed waterways, water and sediment control basins, side inlet protection and filter strips), while the remaining 97 practices were ponds/wetlands.

All of the filtration BMPs were modeled in SWAT as filter strips in the operations routine associated with each HRU area, based on specific BMP locations determined in GIS. The following six subbasin areas of the watershed (not previously represented as having reservoirs in the SWAT modeling) were explicitly modeled with wetland treatment in SWAT (based on their associated tributary area percentages): Subbasin#29 (50%), Subbasin#48 (30%), Subbasin#37 (30%), Subbasin#66 (50%), Subbasin#94 (20%) and Subbasin#56 (80%). The BMP treatment associated with the remaining ponds and wetlands was combined with the filter strip treatment for each HRU area, based on the BMP locations determined in the BMP GIS database. The resultant tributary area receiving some level of filtration treatment in the updated model was 58,418 acres for the combined watershed. The typical (area-weighted) ratio of field area to filter strip area was 60 for all of the filtration practices based on an examination of the available data. For individual HRU areas that received a combination of filtration and localized pond/wetland treatment, the FILTER_CON variable in the model (the fraction of the HRU which drains to the most concentrated ten percent of the filter strip area or Section 2 in the following figure) was area-weighted using the default

value of 0.5 for filtration BMPs and a value of 0.2 for pond/wetland treatment (since a value of 0.2 results in similar sediment load reductions as a pond or wetland per White and Arnold, 2009). The weighted fraction of HRU area that is receiving filtration (assuming a value of 0 for full treatment because none of the flow would be channelized) was used to set the FILTER_CH variable in the model (the fraction of the flow within the most concentrated ten percent of the filter strip which is fully channelized [and is not subject to filtering or infiltration effects]) in the filter strips operations portion of the SWAT model.



Re-Calibration of SWAT Model and Limitations
Results of Model Re-Calibration
Although the water quality data were available from 2008-2010, the simulations were made over 11 years of record to reduce the errors associated with initial conditions. Model calibration was initially done by comparing predicted daily flows against measured data. After flows were calibrated, sediment loads did not require re-calibration by adjusting any of the same parameters that had previously controlled sediment erosion, deposition and delivery in streams and ditches that were modeled. The approach followed for the SWAT model calibration in each of the major (impaired) watersheds, involved using global parameters to optimize the model fit for several of the larger watershed areas that were

monitored for both water quantity and quality in the TMDL study, that did not have questionable data, and that were not significantly affected by lake/reservoir effects on flow rates, sediment settling or internal phosphorus loading, depending on the metric (flow, sediment, total phosphorus) undergoing calibration. Global parameter changes applied to the calibrated modeling essentially means that one value was chosen for each of the calibration parameters and applied the same way to each subbasin in the Cedar River watershed model.

The model accuracy was expressed in terms of the Nash-Sutcliffe efficiency (NSE) between measured and predicted monthly flow values, cumulative modeled and measured flow volumes during the monitored portion of the 2009 and 2010 water years, and a graphical comparison of the flow hydrographs at each of the monitoring locations that had reliable stage-discharge rating curves and continuous stage measurements. NSE values above 0.75 are considered very good and a value of 0.50 would be considered satisfactory for a monthly time step (Moriasi et al., 2007). Figure 1 through 3 show examples of the graphical comparisons that were made between the observed and SWAT model predicted flows for several of the monitored (impaired) watersheds. In general, it was more difficult to match observed stream flows in the spring of each year of monitoring, since we didn’t have winter flow data and the ability to calibrate the modeling for the snowfall/snowpack/snowmelt parameters. This effect would then carry over and pose difficulty in accurately simulating soil moisture in the spring of each year and was further exacerbated in watershed monitoring locations that were downstream of lakes/reservoirs, especially during 2008 (which would have required snowmelt parameters that were outside of the accepted ranges to get the modeled snowmelt to correspond with the observed streamflow). Since 2009 and 2010 represented the critical conditions for meeting the water quality standards for each of the watershed impairments, the calibration process was given more weight for these two water years.

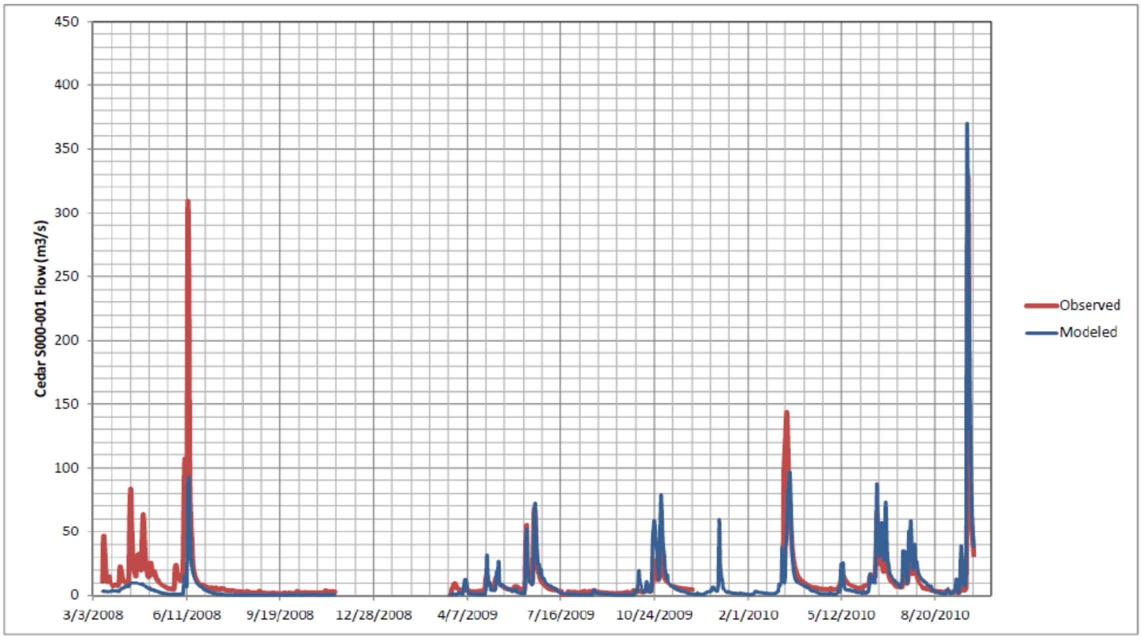


Figure 1. SWAT model flow calibration results for the Cedar River station near Austin, MN.

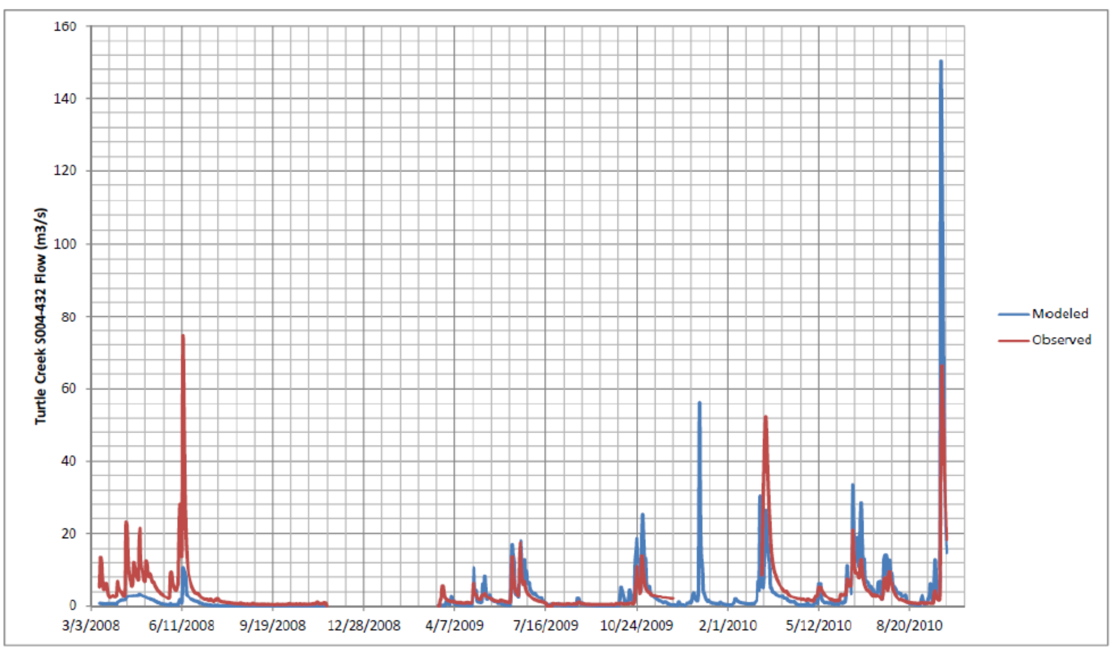


Figure 2. SWAT model flow calibration results for the Turtle Creek station near Austin, MN.

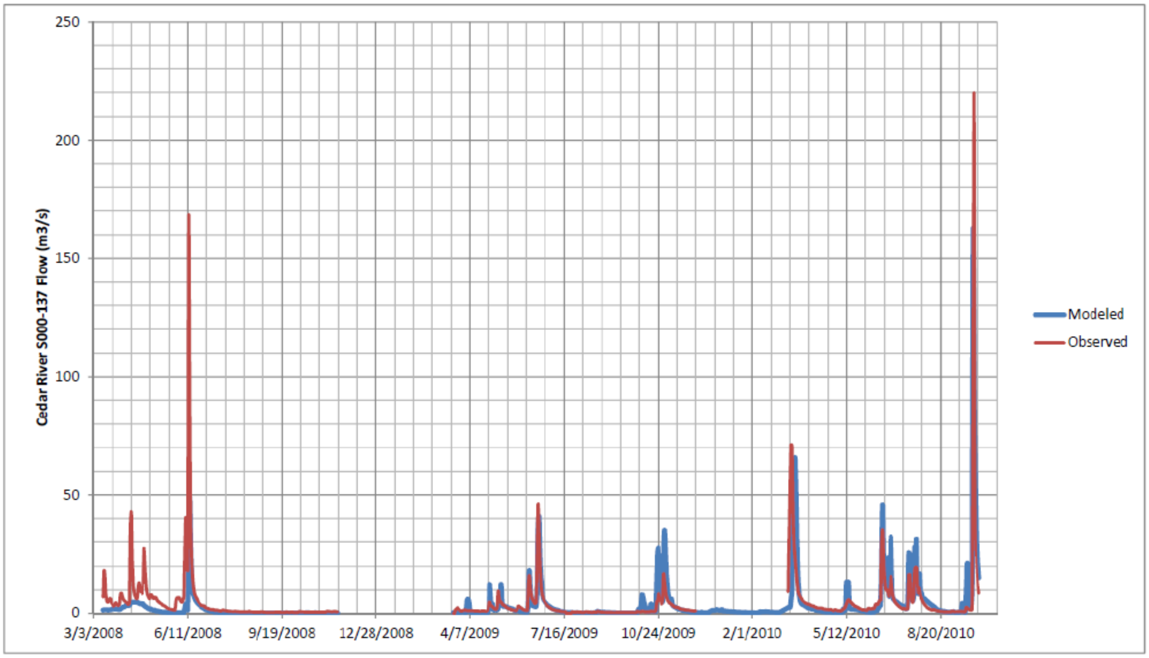


Figure 3. SWAT model flow calibration results for the Upper Cedar River station.

Table 2 shows the SWAT model parameters that were used to re-calibrate the modeling to water quantity and quality observations in each watershed. The crack flow and curve number for frozen conditions components of the model were activated based on guidance from an advanced modeling workshop (R. Srinivasan, 2008).

Table 2. SWAT Model parameter defaults and calibrated values.

SWAT Parameter	Description	Default Value	Typical or Accepted Range	Calibrated Value
ESCO	Soil evaporation compensation factor	0.95	0-1	0.65
GW_DELAY	Groundwater delay time, days	31	0-500	10
ALPHA_BF	Baseflow alpha factor, days	0.048	0-1	0.2
SURLAG	Surface runoff lag coefficient	4	1-12	0.5
RCHRG_DP	Deep aquifer percolation fraction	0.05	0-1	0.10

SWAT Parameter	Description	Default Value	Typical or Accepted Range	Calibrated Value
ICRK	Crack flow	Inactive	--	Active
CN_FROZ	Curve number for frozen conditions	Inactive	--	Active
SMTMP	Snowmelt base temperature	0.5	-5-5	5
TIMP	Snow pack temperature lag factor	1.0	0-1	0.5
DEP_IMP	Depth to impervious layer for modeling perched water tables, mm	--	1000	1000
DDRAIN	Depth to sub-surface drain, mm	--	1000	1000
TDRAIN	Time to drain soil to field capacity, hours	48	0-72	48
GDRAIN	Drain tile lag time, hours	24	0-100	10
CH_N(2)	Manning's "n" for the main channel	0.014	0-0.3	0.05
FILTER_I	Flag for simulation of filter strips	1 active/ 0 inactive	0/1	1
FILTER_RATIO	Ratio of field area to filter strip area, ha/ha	40	30-60	60
FILTER_CON	Fraction of the HRU which drains to the most concentrated ten percent of the filter strip area, ha/ha	0.5	0.25-0.75	0.5 for filtration BMPs; Area-weighted at 0.2 for HRUs with ponds/wetlands
FILTER_CH	Fraction of the flow within the most concentrated ten percent of the filter strip which is fully channelized	0	--	Weighted for the fraction of HRU that is receiving filtration (0 for full treatment)
	Channel degradation	Inactive	--	Active
RSDCO	Fraction of residue decomposing in a day	0.05	0.02-0.10	0.02
	Fertilizer application rate, kg/ha		0-500	350
FRT_LY1	Fertilizer application fraction to surface layer	1	0-1	0
PHOSKD	Phosphorus soil partitioning coefficient	175	100-200	200

The SWAT model simulates the total sediment load, i.e. the amount of sand, clay and silt particles detached, eroded and transported to the outlet of the watershed. Since the sample monitoring data is going to be a measure of suspended sediment and nutrients (both organic and inorganic) under most flow conditions, it would not include the bedload and constituents transported along the bottom of the stream channel (see Figure 4). As a result, the stream channel erosion estimates for the Cedar River watershed (discussed in Appendix C of the Draft TMDL Report) were used as a check on the calibrated SWAT model sediment load for the Cedar River gaging station and the SWAT model sediment loading results were also superimposed on the TMDL load duration curves (see Figures 5 through 7) for the sediment impaired stream reaches, that were not influenced by upstream lakes, to graphically check the model calibration. Due to the previously described flow and sampling effect (shown in Figure 4), the intent was to attain good agreement between the SWAT model results and the load duration curves under lower flows and overestimate the TSS load under high flow conditions, as depicted in Figures 5 through 7. Interpolating the streambank sediment contribution estimates from Appendix C results in an average annual load of 36,256 metric tons/year of sediment for the reach that corresponds to the calibration data shown in Figure 5. Summing the SWAT model total sediment loadings for the 2009 and 2010 water years at the lower Cedar River impaired reach results in an average annual load of 79,800 metric tons/year. As a result, the total streambank erosion tributary to this reach would account for approximately 45% of the total load. This is lower than neighboring watersheds in the Minnesota River basin that have similar watershed and land management characteristics and have estimated near-channel erosion percentages between 70 and 85% (Schottler et al., 2010).

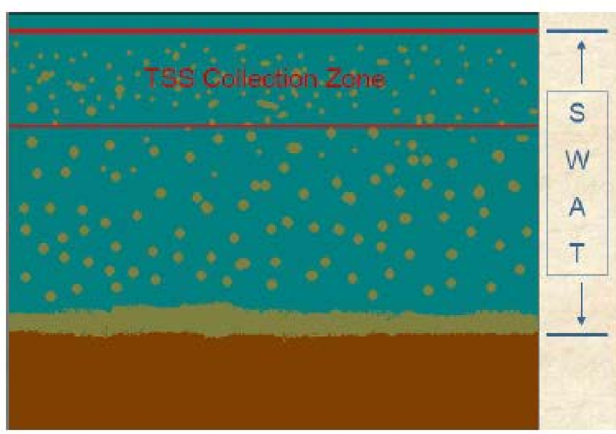


Figure 4. Depiction of water quality monitoring zone relative to sediment modeling in SWAT.

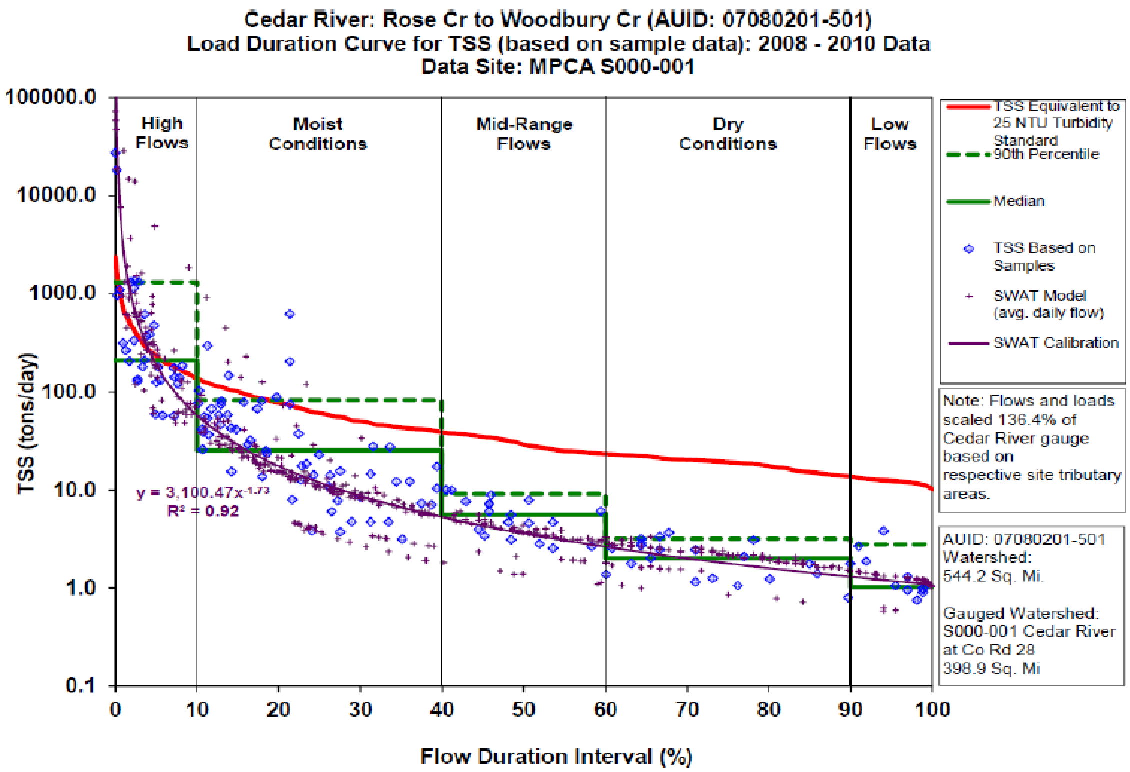


Figure 5. Lower Cedar River TSS load duration curve and calibrated SWAT model sediment loads.

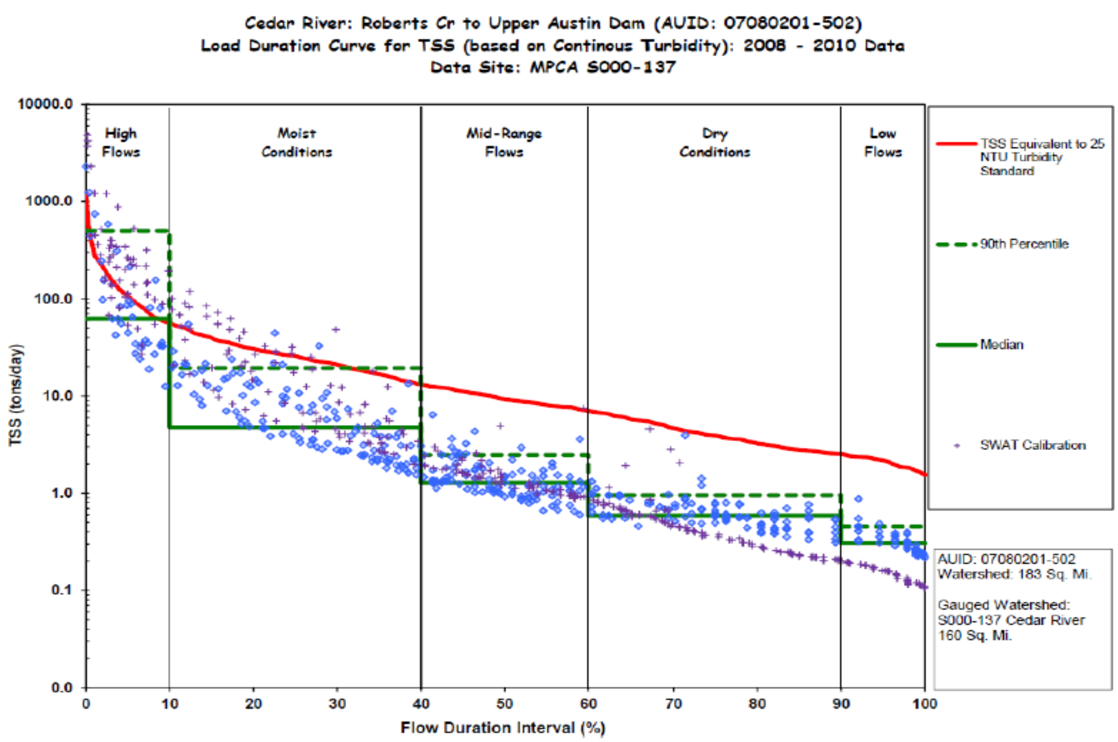


Figure 6. Upper Cedar River TSS load duration curve and calibrated SWAT model sediment loads.

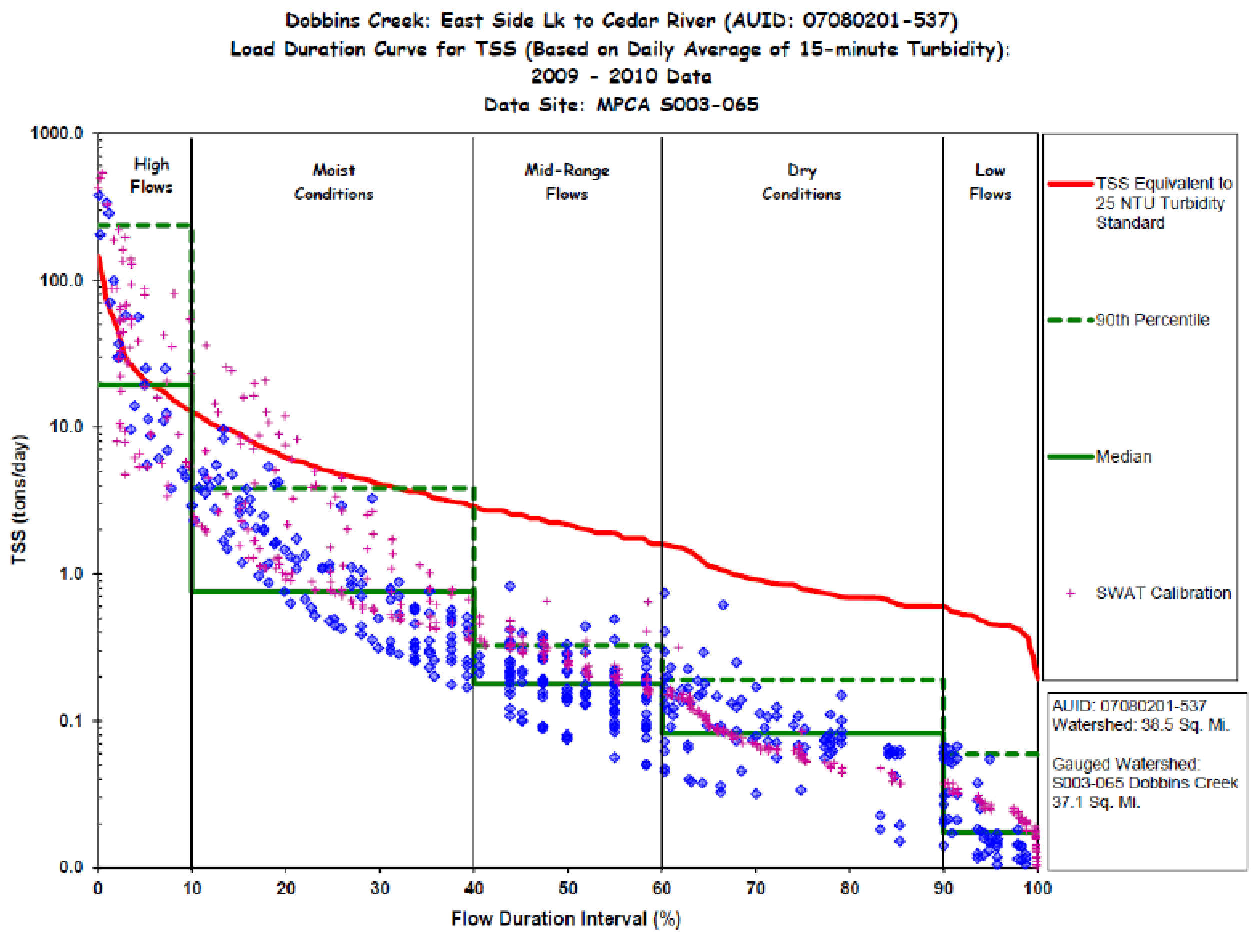


Figure 7. Dobbins Creek TSS load duration curve and calibrated SWAT model sediment loads.

A sensitivity analysis was not conducted as a part of the model calibration because we had data from multiple monitoring stations, each possessing unique watershed characteristics, some of which were nested within two larger basin areas that were monitored and progressively modeled for flow, sediment and nutrients to determine the best parameters for optimizing the fit between the modeling and monitoring.

Model Limitations and Uncertainties

Due to limitations of flow monitoring capabilities during the winter, we had a limited ability to calibrate the modeling for snowfall, snowpack and snowmelt parameters. As a result, the modeling did not necessarily provide good agreement for the winters and springs with the available streamflow data from 2008.

Sediment calibration to TSS results is confounded by effects from algae and streambank erosion. As previously discussed, depending on the streamflow, TSS may not be a good measure of the sediment load for any given time period. Figure 4 shows that, depending on the particle size distribution of the stream channel material and the streamflow velocity, TSS samples would not be expected to adequately estimate the total sediment load, except under low flow conditions when bedload is negligible.

SWAT is dynamically simulating the nature of the suspended and bedload transport in the system. Under low flows, the SWAT modeling was calibrated to the observed suspended solids loadings, but on an annual basis, matching the total sediment load (which is modeled by SWAT) required a comparison with the streambank erosion estimates provided in Appendix C of the Draft TMDL Report. Annual or long-term sediment yield was also expressed in a flow duration format for each of the sediment-impaired stream reaches in the watershed to check model agreement.

SWAT Model Results

Sources of Excess Sediment Loading

Figure 8 shows the results of the SWAT Model estimates for upland sediment yield from the combined land areas in each subbasin of the Cedar River watershed for the 2010 calendar year and does not consider the sources/sinks within each stream channel. The subbasins with the highest sediment yields have steeper land and/or higher proportions of poorly-drained soils that were likely tiled. Subbasin sediment yield is generally within a two ton per acre range throughout the watershed with more than three-quarters of the subbasin loading rates in the range of 0.8 to 2.8 tons/acre. None of subbasins would be expected to consistently contribute sediment yields above 4 tons/acre despite the fact that 2010 experienced some large runoff events.

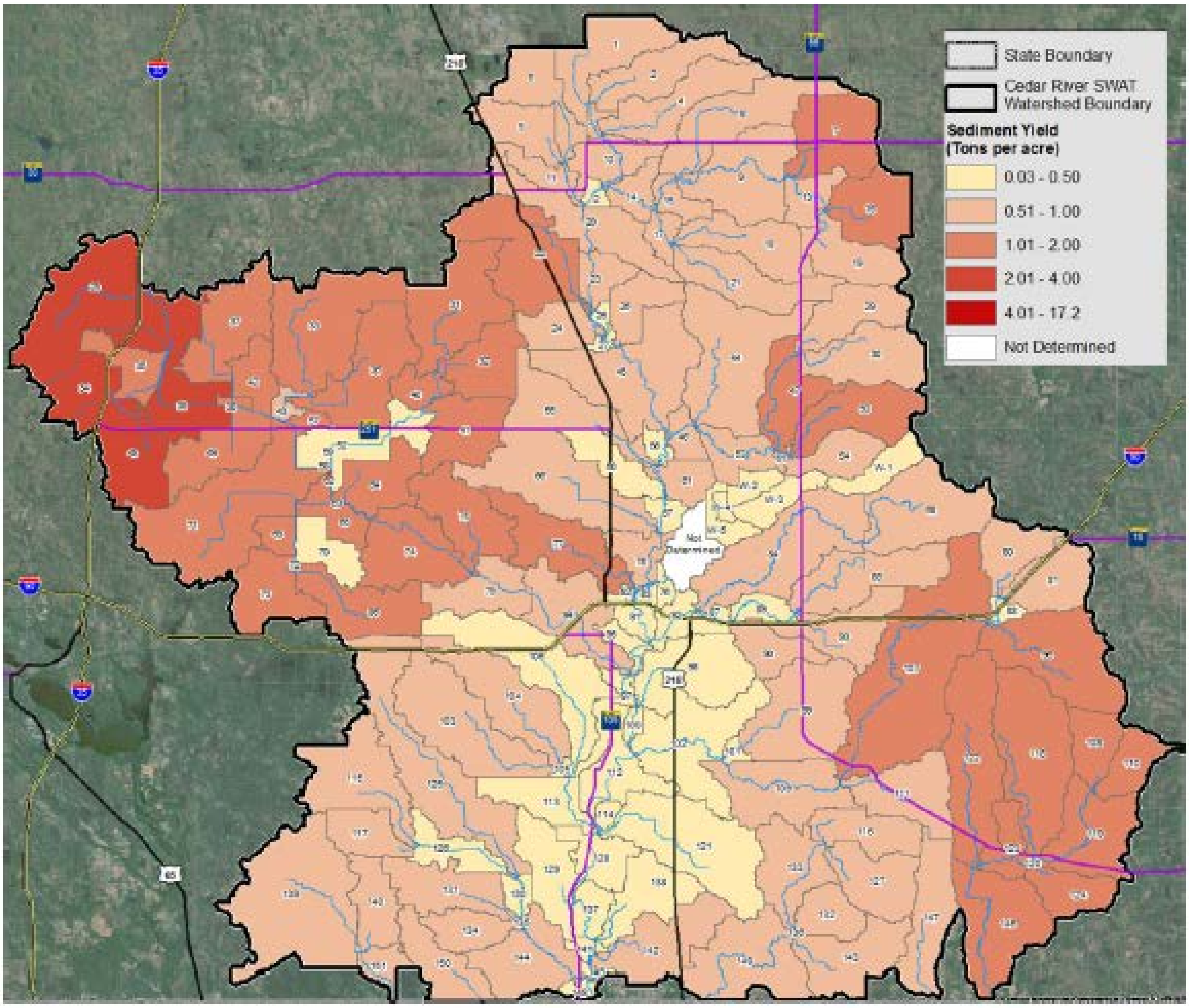


Figure 8. SWAT model upland sediment yield estimates for the Cedar River watershed.

The results shown in Figure 8 for subbasins 108, 110, 116, 118-120, 122-124, 127, 132, 133, 136, 139, 140, 143, 146, 147, and 149-151 may be misleading as the existing level of BMP implementation was not inventoried by the District staff and included in the updated modeling. As a result, the calibrated model was run a second time with all of the filtration BMPs turned off in the model operations routine. Figure 9 shows how the SWAT model upland sediment yield estimates with no BMPs would have differed from those shown in Figure 8. Without BMPs, several subbasins in the Turtle Creek and northeast portion of the Cedar River watersheds would have experienced significant increases in sediment yield. Two of the subbasins in the Turtle Creek watershed would be expected to consistently contribute sediment yields above 4 tons/acre.

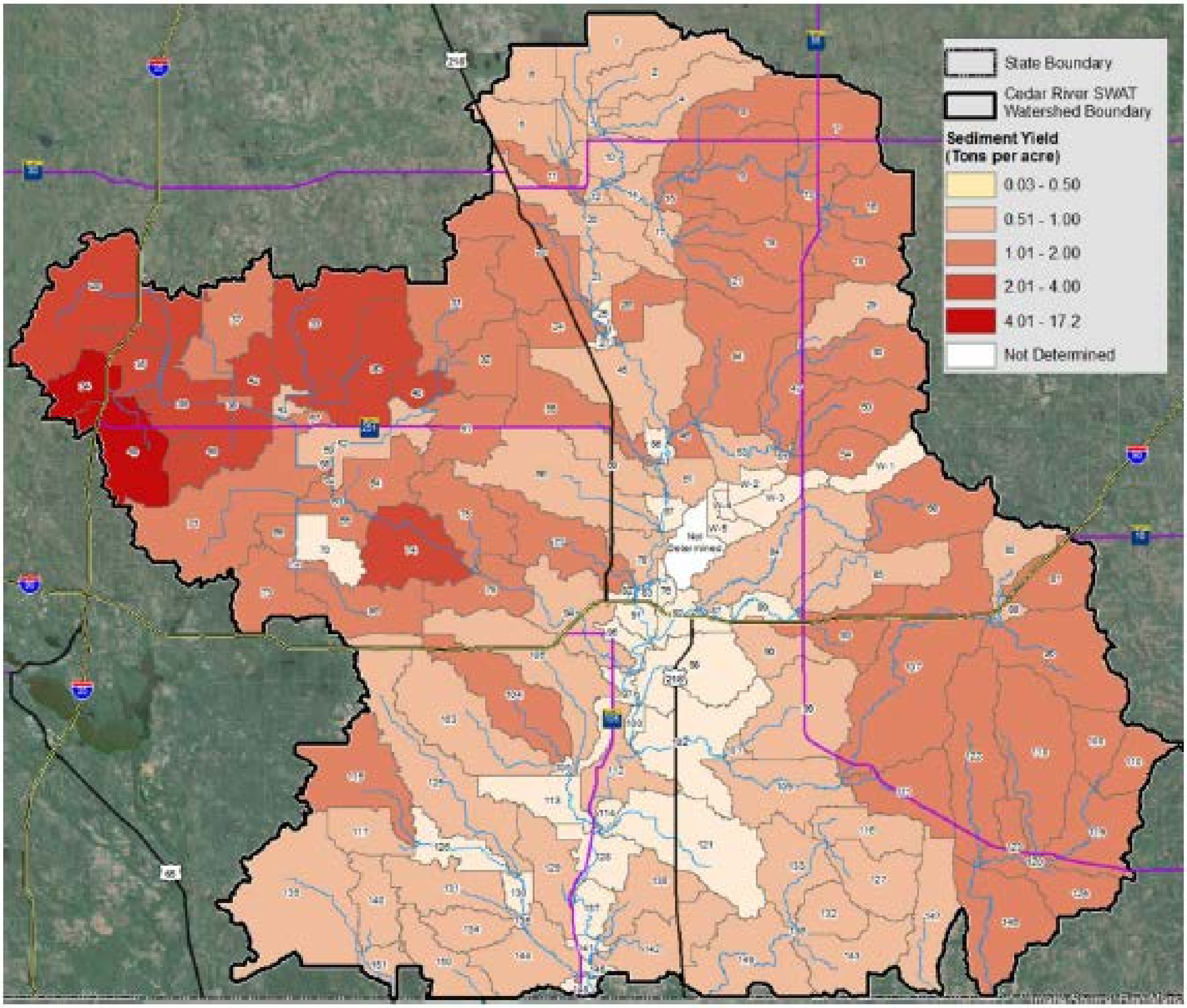


Figure 9. SWAT model upland sediment yield estimates without BMPs implemented in the Cedar River watershed.

Ignoring the subbasins (described above) that were not included in the BMP inventory, a spreadsheet comparison of the sediment yield results shown in Figures 8 and 9 indicated that the existing BMPs were removing 25% of the overall watershed sediment load that would otherwise have discharged to the nearest receiving water during 2010. As previously discussed, the watershed tributary area receiving some level of filtration treatment in the updated model was 58,418 acres, which accounts for approximately 21% of the row crop area in the overall watershed. Further examination of the subbasin results of each model run indicated that the sediment yield reductions ranged from 13% to 41% for the subbasins that have existing BMPs.

The Cedar River watershed has four impairment listings for turbidity that are addressed with the TMDL analyses involving suspended solids concentrations: two segments of the Cedar River, upstream and downstream of the city of Austin; the lower segment of Dobbins Creek; and the lower segment of Turtle Creek. This study used a variety of methods to evaluate the current loading and contributions from the various pollutant sources, as well as the allowable pollutant loading capacity of the impaired reaches to more accurately represent the impact current BMPs are having in the watershed. The load duration curve approach was used for reaches impaired by turbidity. It was originally estimated that the overall magnitude of reduction needed to the meet the turbidity standard for each impaired reach is between 80 to 90 percent for high flows (0-10% flow duration) and between 0 to 20 percent for moist conditions (10-40% flow duration) to meet the turbidity standard throughout the study area under current conditions.

Figure 10 superimposes the flow-weighted mean sediment concentrations (FWMC, expressed in mg/L) estimated from the April-September, 2010 reach modeling on the subbasin yield estimates shown in Figure 8 to assist in further identifying watershed locations where total suspended solids (TSS) reductions would be needed to comply with the 65 mg/L TSS concentration which is being proposed to replace the current turbidity standard. As previously discussed, 2010 experienced higher flow events and the sample monitoring limitations shown in Figure 4 would further limit direct comparisons of the FWMCs to the proposed TSS standard, but Figure 10 shows that the higher priority areas for further load reductions appear to correspond with some of the smaller tributaries to Lake Geneva and Turtle Creek, as well as headwater locations in the Little Cedar River and Roberts Creek watersheds. Headwater locations in the Rose Creek and Cedar River ditch watersheds, as well as subbasin #77, may also warrant consideration for future restoration efforts. The FWMC for subbasin #84 in the Dobbins Creek watershed is skewed by the presence of East Side Lake at the downstream end of the stream segment shown in Figure 10. Figure 10 also indicates that the Wolf Creek watershed should be a priority for future protection efforts.

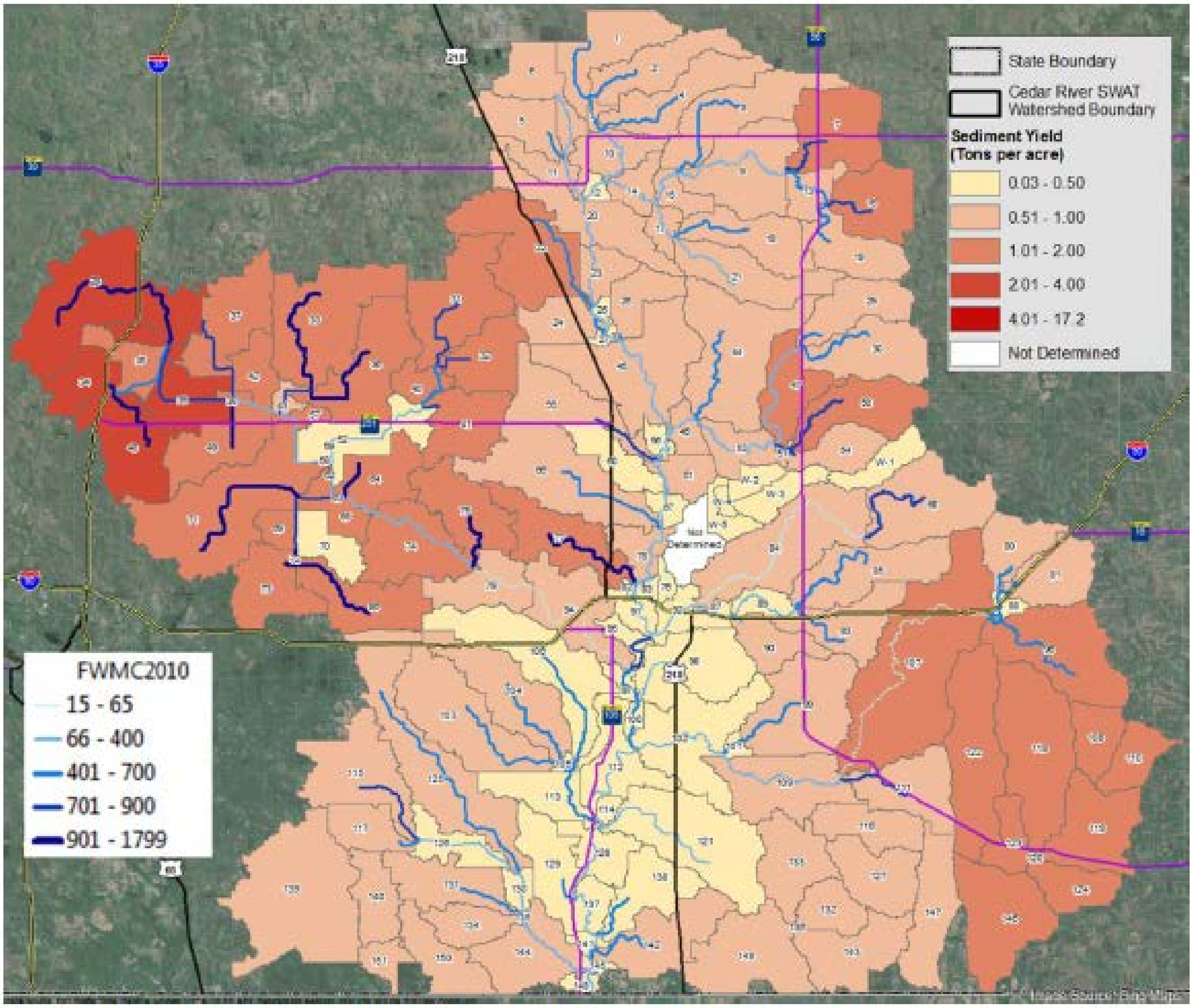


Figure 10. SWAT model upland sediment yield and flow-weighted mean sediment concentration estimates for reaches in the Cedar River watershed.

While the exact amount of sediment coming from each of the watershed sources cannot be derived, it is expected that algae in reaches downstream of reservoirs or impoundments is an important contributor to the turbidity impairments in the watershed and will need to be addressed with a more comprehensive-

systems approach. It is expected that algal effects on turbidity would be more pronounced in Turtle Creek than it would be in the Cedar River flow-through reservoirs as Lake Geneva would have a longer residence time than Ramsey Mill Pond and East Side Lake.

Identifying and Prioritizing Potential Project Areas

Figure 11 shows an example of how we have combined the terrain analysis completed for the project (described in more detail in Appendix E of the Draft TMDL Report) with the available information about existing conservation practices and the modeling results to identify and prioritize the critical sediment source areas for field inspection and potential BMP implementation throughout the watershed.

The potential high priority areas were identified from the larger terrain analysis dataset developed for the TMDL study. The end points from SPI (Stream Power Index) signatures falling within the 99th percentile of results were used as a base. These SPI end points were screened in three steps. First, all points representing an SPI signature less than 100 feet long was removed. Second, all points greater than 200 feet from an NHD (National Hydrography Dataset) flowline representing surface water were removed. A search distance of 200 feet was used in order to offset some of the accuracy issues of the NHD dataset particularly in small ditches and intermittent streams. It was expected that 200 feet would be enough to capture SPI signatures that may end short of a flowline due to decreasing slope but still have the potential to deliver sediment to surface water. This process screened the results from approximately 150,000 points initially down to approximately 10,000. Finally, this set of points was inspected visually using publicly available aerial imagery, BMP information provided by the SWCD and watershed district staff, and a compilation of land use data prepared by Barr. This final screening process, when combined with the SWAT model HRU loading areas (shown in the background on Figure 11), results in a series of potential high priority areas that local staff should consider for field inspection and potential BMP implementation.

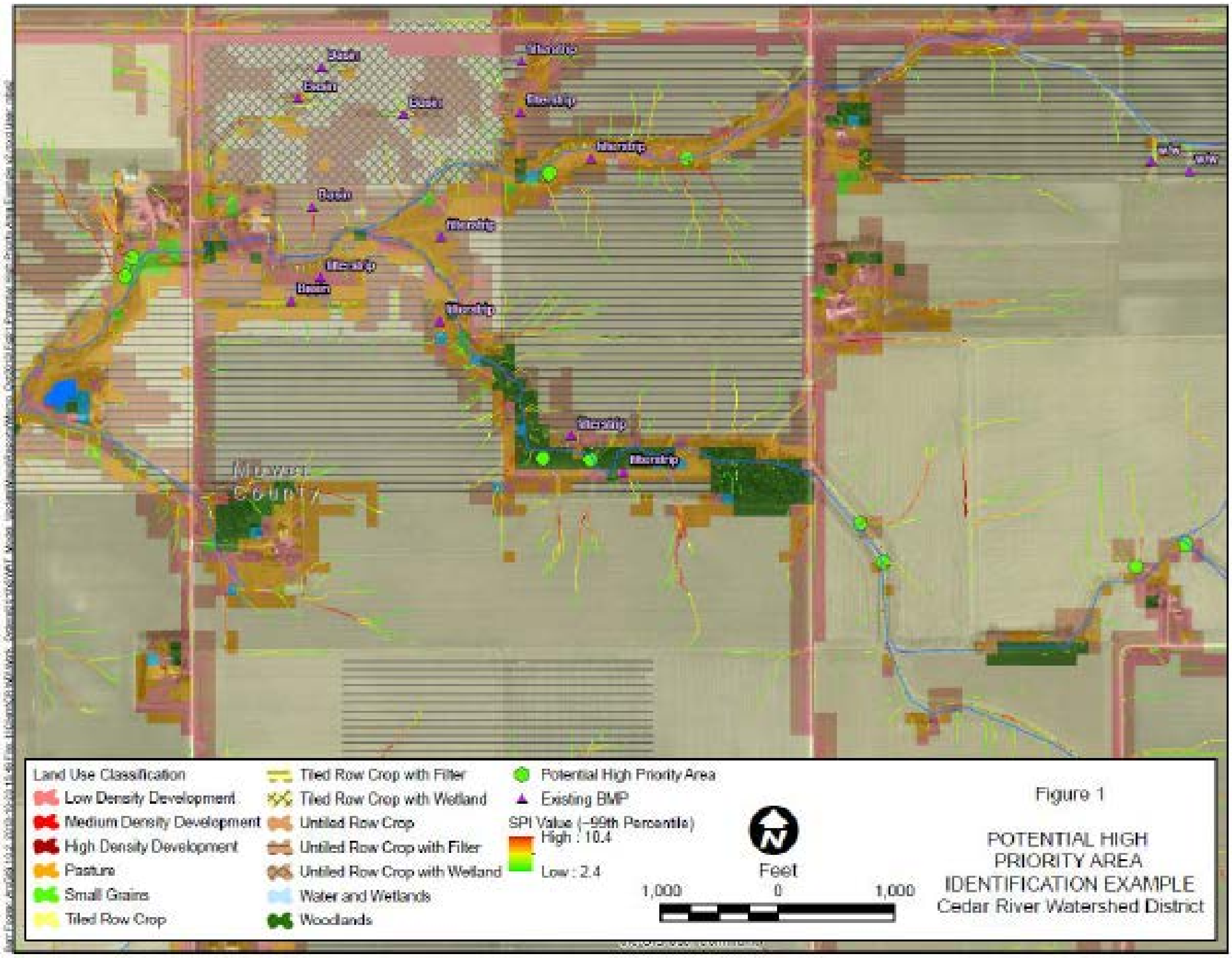


Figure 11. Example plot combining terrain analysis with locations of existing BMPs and SWAT model sediment loading areas.

References

Arnold, J.G., P.M. Allen, and G. Bernhardt. 1993. A comprehensive surface-ground water flow model. *J. Hydrol.* 142: 47-69.

Moriasi, D.N., J.G. Arnold, M.W. Van Liew, R.L. Bingner, R.D. Harmel, and T.L. Veith. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE.* Vol. 50(3): 885-900.

Schottler, S.P., D.R. Engstrom, and D. Blumentritt. 2010. Fingerprinting Sources of Sediment in Large Agricultural River Systems. St. Croix Watershed Research Station: Science Museum of Minnesota.

Srinivasan, R. 2008. Personal communication. Advanced SWAT Modeling Workshop.

White, M.J. and J.G. Arnold. 2009. Development of a simplistic vegetative filter strip model for sediment and nutrient retention at the field scale. *Hydrol. Process*. 23: 1602-16.

Appendix C Modeling Meeting Summary

Cedar River Watershed (in MN) – Modeling Technical Meeting **Meeting Summary**

Meeting Date: **June 18, 2013** (10am – 3pm)
Meeting Location: Minnesota Pollution Control Agency, St. Paul
Webinar and audio-teleconference options provided
Ten-page Meeting Summary completed and emailed: August 19, 2013

This meeting summary was completed by Bill Thompson, Minnesota Pollution Control Agency (MPCA) – Cedar Basin [in Minnesota] Project Manager, with the assistance of some notes generously supplied by several participants. The three presenters have kindly made their PowerPoint files available, to add to our meeting record.

Meeting Context:

Watershed management and water quality improvement efforts are an ongoing effort in Minnesota's portion of the Cedar River Basin. Over the past 4 or 5 years, several watershed modeling efforts have been initiated in Minnesota. The general direction of this meeting is to allow some time for professional watershed modelers and practitioners to learn from/question/critique each other, to communicate with conservation implementation staff and managers, and to momentarily "step back" and attempt to assess our overall watershed modeling effort.

Meeting Objectives (from 06.10.2013 email):

1. Continue with process started with H & H (Hydrologic and Hydraulic) rollout meeting held in Austin, and provide more technical modeling specifics;
2. Include all models done in the past 3-4 years....in particular, XP-SWMM, SWAT, and GSSHA. (Also, acknowledge and improve understanding of other modeling efforts that are pertinent).
3. Compare model results by scale, what inputs are needed, how those data were collected, and how can a model be maintained and revised?
4. Complete work plan Objective A, Task 5 (model transfer) and Task 6 (Model training). This "training" event is more in line with explaining how critical elements were set up, and is aimed at watershed professionals and/or staff familiar with watershed modeling.
5. Assess the overall results of these modeling efforts in the Cedar River Watershed (CRW). Can we consider areas where we have agreement and more confidence in the modeling results? Are the longer-term monitoring sites we have in good locations to support predictive modeling efforts?
6. Are we able to communicate and apply the modeling results to our common work? (or, to very specific efforts?). How can we help each other in these communication efforts?
7. Were some of these modeling efforts redundant? If so, justified, or in need of reductions?

Meeting Agenda (from 06.17.2013 email):

A. Introductions, review meeting purposes, and background - Bill Thompson, MPCA and Bev Nordby, Mower County SWCD and Cedar River Watershed District.
B. Cedar River Watershed SWAT - Greg Wilson, Barr
C. Cedar River Watershed XP-SWMM - Rita Weaver, Barr
< (lunch break planned about here) >
D. Dobbins Creek Subwatershed GSSHA - Jim Solstad, MDNR
E. Overall review and assessment

1. Can different models, built at different scales, be integrated into our larger watershed (8-digit HUC) efforts?
2. How should we view the relative utility of each model?
3. How about strengths, weaknesses, and credibility (with audience/stakeholder A, B, or C......and overall)?
4. What recommendations can be put forward for future modeling work in the CRW (maintenance of existing model; or - another model?)?

F. Thank you, and wrap-ups.

Participants (initial list provided by Ann Banitt):

At meeting room in St. Paul:

- Eggers, Greg. Minn. Department of Natural Resources, Drainage Engineer (MN River Integrated Watershed, case study Shakopee Cr, Dobbins Creek-Cedar (GSSHA) 651.259.5726 greg.eggers@state.mn.us
- Fett, James. Watershed Technician and Cedar River watershed, water monitoring lead, Mower County SWCD, Austin. 507.434.2603 (james.fett@mowerswcd.org
- Gervino, Nick. MPCA, St. Paul. Watershed modeling, 651.757.2388 Nick.gervino@state.mn.us
- Gillette, Tim. Minn. Board of Water and Soil Resources, St. Paul. Conservation Drainage Engineer 651-297-8287 Tim.Gillette@state.mn.us
- Hanson, Justin. Turtle Creek Watershed District and Mower Co. SWCD, Austin. 507.434.2603 justin.hanson@mowerswcd.org
- Hawker, Brooke. Minn. Department of Natural Resources, Mankato. Clean Water Specialist / stream geomorphology. 507.389.6726 Brooke.Hacker@state.mn.us
- Klein, Steve. – Barr Engineering, VP. Principle Engineering for Cedar, Shell Rock River Watershed. 952.832.2809 SKlein@barr.com

- Nordby, Bev. Cedar River Watershed District and Mower Co. SWCD, Administrator/Manager, Austin. 507.434.2603 Bev.nordby@mowerswcd.org

- Solstad, Jim. Minn. Department of Natural Resources, St. Paul. Hydrologist. 651.259.5711 james.solstad@state.mn.us

- Thompson, Bill. MPCA, Rochester, MN. State project manager for Cedar Basin in MN. 507.206.2627 bill.thompson@state.mn.us [Meeting coordinator and scribe]

- Weaver, Rita. Senior Water Resources Engineer. Barr Hydrologic Modeling, XP-SWMM, rweaver@barr.com 952.832.2844

- Wilson, Greg. Senior Water Resources Engineer. Barr Eng. Cedar Basin TMDL and SWAT, gwilson@barr.com 952.832.2672

On teleconference / webinar:

Jason Smith, USACE, Rock Island, Study Manager/Planner/ Civil Engineer. 309.794-5690 Jason.T.Smith2@usace.army.mil

- Greg Karlovits, USACE, Modeler from MVR Gregory.S.Karlovits@usace.army.mil

- Ann Banitt, USACE St Paul Ann.M.Banitt@usace.army.mil

- Jim Noren, USACE St Paul James.B.Noren@usace.army.mil

- Charles Ikenberry –Iowa DNR Des Moines Charles.Ikenberry@dnr.iowa.gov

- Laurel Foreman, Hydrologist, USDA- NRCS Des Moines Laurel.Foreman@ia.usda.gov
- Unknown Staffer – USGS, IA
- Nick Thomas
- 6-Other Unidentified Call-Ins
- Sorry if we missed you….respond if you wish to be in the final record, otherwise you will continued to be classified as an "Other."

Handout: Cedar River Basin in Minnesota - Table of Water Quality and Watershed Modeling Projects and Efforts, 1990-2013. (Included at the end of this summary)

Meeting Overview:

Agenda Item A – Intros, review meeting purposes, and background – Bill Thompson, MPCA and Bev Nordby, Mower County SWCD and Cedar River Watershed District.

Bill Thompson and Bev Nordby highlighted the objectives for the meeting. Bill described the needs to assess our modeling efforts in this watershed, and work with Iowa-based staff on common issues in the larger Cedar Basin. Bev stressed the need to use the modeling tools for conservation implementation and water storage projects.

Agenda Item B - Cedar River Watershed SWAT - Greg Wilson, Barr Engineering Co., Minneapolis.

(see attached .ppt file) SWAT = Soil and Water Assessment Tool

Presentation Title: SWAT Modeling for Cedar River Watershed

Greg provided background information on the Soil and Water Assessment Tool (SWAT) model that is supported by USDA, used widely in the US and around the world, and handles Ag BMPs well. Since this model was developed to assist the sediment (turbidity) TMDL in the CRW, Greg showed both flow duration and sediment duration curves for 2008-2010 data. The flow duration curve (FDC) for the TMDL timeframe was contrasted against the FDCs for the CR @ Austin (USGS gage) for the longer 1981 to 2010 period, as well as the entire period of record for the gage. This showed the higher discharges for the more recent timeframes, with changes in precipitation, landuse, drainage, and cropping all contributing factors. A suggestion was made to examine timeseries results, as duration curves do not reveal the antecedent moisture conditions under which the flow is generated (e.g., snowmelt, saturated, dry). The SWAT model input parameters were discussed. Row crops accounted for about 76% of the landuse in the Cedar River and Turtle Creek watersheds, with that figure split evenly between fields with tile, and fields without tile. Fields with tile were estimated using a technique employed by staff at the Minnesota State University-Mankato's Water Resources Center, which merges soil drainage classes with row-crop land cover. The soil drainage classes used were poorly drained and very poorly drained, which are soils that would benefit from artificial drainage. The presence of tile drainage creates preferential flow paths that are simulated using the SWAT crack flow option.

Observed vs. modeled flows for three sites (Turtle Creek, Upper Cedar, and the Cedar River below Austin) were shown, and calibration issues with snowmelt were noted. The initial SWAT model runs did not have the inventoried Ag BMPs incorporated, and the modeled sediment outputs were very high. To compensate for this, without attempting a higher level of model calibration steps, a watershed-wide calibration factor was used - a 5m buffer used on all cropland HRUs (Filter-W parameter). A channel degradation factor was also activated, based on field survey data of stream channels, which showed that near-channel sediment sources are important.

The next step for this Cedar SWAT is to incorporate data from about 500 points in the watershed where BMPs are in place that affect sediment and/or flow. These BMPs were inventoried by county conservation staff, and include many waterways and filter strips, as well as about 55 wetlands. Many of these wetlands will be placed explicitly into the model.

Greg Wilson concluded his presentation with several slides on terrain analysis and critical source identification, for erosion and sediment. A combination of terrain analysis with field identification work is proving useful.

Agenda Item C - Cedar River Watershed XP-SWMM - Rita Weaver, Barr Engineering Co., Minneapolis

(see attached .ppt file) SWMM = Storm Water Management Model

Presentation Title: The New Cedar River and Turtle Creek Hydrologic and Hydraulic Model

Rita Weaver's presentation was included because this is the most recent, existing conditions watershed modeling project to take place in the Cedar River Watershed in Minnesota, and it is the only watershed-wide hydrologic and hydraulic model of the two watershed districts. On January 10, 2013, a larger meeting was held in Austin to describe the Cedar Watershed XP-SWMM model to a more general audience. At that January meeting, both Rita and Steve Klein of Barr Engineering, as well as Bev Nordby of the Cedar River WD, provided presentations. The objective of that meeting was to increase general awareness of this new watershed model, and to inform stakeholders and local professionals about future modeling applications.

For this June meeting, Rita covered model setup, displaying watershed maps with delineation of 646 subwatersheds. These subwatersheds were on average 1 square mile each, and were determined by flow control structures such as culverts and bridges. The majority of the structures in the watershed were surveyed and photographed, with the data and picture stored on a web-based application. Data for the remaining structures came from plan sheets. Field survey work was completed by the Mower SWCD, the NRCS, or Jones-Haugh-Smith consultants of Albert Lea. LiDAR with 2 foot resolution was used to delineate watersheds, to determine watershed slopes, and to create channel cross section geometry. Soil hydrologic groupings (A,B, C, D) from the SSURGO dataset were used to assign Horton infiltration rates.

Two rain events, one in September 2004, and the other in September 2010, were used to calibrate the model. The selected storms utilized NEXRAD rainfall data to approximate the precipitation depths and rainfall intensities. Data from three stream gages were used for calibration: one located on the Upper Cedar River, one located on the Cedar River in Austin, and one on Turtle Creek. Model calibration began with the use of published hydrologic parameters (ex. Infiltration rate of 3"/hr.; depressional storage and vegetation interception of 0.2"), and these parameters were modified during the calibration process.

A ground water module within the XP-SWMM software provided a means to simulate tile in the watershed. However since the location of all tile throughout the watershed was unknown, the final model did not incorporate the groundwater module. Measured stage and modeled stage were compared on several plots, with and without the tile simulation module. Measured and modeled flow was evaluated by Barr, but not included in the presentation, since the calculation of the gage rating curve can introduce error into the flow measurements.

The applications for this model include evaluating wetland restoration effects, assessing bridge and culvert replacement options, evaluating flood elevation changes from upstream water management and conservation implementation, and evaluation of floodplain management techniques. An example of a project involving wetland restorations was presented, where the restoration of 4 basins in close proximity to each other resulted in a reduction in peak runoff rate of 40 cfs (10%), and an overall volume reduction of about 8% from the watershed. The cost to adjust the model for these restorations, and arrive at the reduction estimates, was just over $3,000.

Current modeling results can be viewed with an XP-SWMM viewer license. However, to accomplish model updates/revisions, an XP-SWMM modeling agreement with XP Solutions is required. Model maintenance actions are anticipated on a yearly basis, including data on altered culverts and bridges, water storage areas, and land use changes.

Because a SWAT model was developed for the watershed on a slightly earlier timeframe to evaluate water quality and the TMDL, no water quality simulations were completed using the XP-SWMM model. The reason for this is due to the understanding that a SWAT model is more useful in rural watersheds than the water quality module of XP-SWMM.

Agenda Item D – Dobbins Creek GSSHA Model, Jim Solstad, MDNR

See attached .ppt file GSSHA = Gridded Surface Subsurface Hydrologic Analysis

Presentation Title: Dobbins Creek GSSHA Model – Chapter 2?

Jim Solstad began his presentation with a note that "Chapter 1" for Dobbins Creek GSSHA modeling was done by his co-worker Greg Eggers, about 2 years ago, whose work had focused on culvert sizing. This "Chapter 2" is part of a broader effort by the MDNR to address a strategic goal of healthy watersheds and to help define a phrase heard frequently nowadays – "altered hydrology." Jim described a human tendency to routinely use increased conveyance as the answer to the vast majority of our water problems.

The GSSHA model is a continuous, distributed parameter and physically-based model developed by the Hydrologic Systems Branch of the U.S. Army Corps of Engineer's Costal and Hydraulics Lab.

Jim further placed this type of modeling effort into our current context by referencing several recent reports, and an initiative:

-Schottler, Shawn P. etal. 2013. Twentieth century agricultural drainage creates more erosive rivers. Hydrologic Processes. (published online at Wiley Online Library).

-Sands, Gary R. 2013. Developing optimum drainage design guidelines for the Red River Basin. University of Minnesota, Department of Bioproducts and Biosystems Engineering.

-Soil health initiative – increasing soil organic matter to help improve water holding capacity. (USDA nationally, and Board of Water and Soil Resources in MN).

The Dobbins Creek watershed is a flashy tributary stream to the Cedar River at Austin, with a drainage area of about 25,000 acres. Some differences were noted between Dobbins Creek watershed, and the Bear Lake watershed in neighboring Freeborn County (also GSSHA modeling effort by MDNR) – the Bear lake watershed has more rolling topography and more dispersed depressional storage areas, where the Dobbins Creek watershed is flatter, with fewer water storage opportunities outside of the flood plain, and very highly drained cropland acres.

Since GSSHA allows the specific placement of tile, it can illustrate tile effects such as higher base flows and the sponge-effect. This was demonstrated with modeled flow data for a 25 sq. mile drainage area in the Red River basin, both with and without tile.

GSSHA's rigorous overland flow and groundwater routing equations provide the opportunity to better understand the relationships between rainfall, ET, tile drainage and surface runoff, within the context of seasonal cropping patterns and natural vegetation.

In Dobbins Creek, the well-defined flood plain (about 200' wide) has a very large storage potential associated with it, and it is likely it would have a larger effect than selected culvert manipulations. Under one scenario, a change in Mannings n for the floodplain itself accounts for about a -30% reduction in flows. A method to look at culvert resizing higher in the watershed is recommended, as resizing at lower sites can lead to channel degradation, and more channel instability.

While modeling other BMP scenarios has not been completed for Dobbins Creek, the GSSHA modeling project for the Straight River (an important tributary to the Cannon River in Minnesota) Watershed has shown decent flow reductions from both conservation tillage and water/sediment control basins. A suite of BMPs is really called for in these watersheds.

Jim concluded his presentation by asking how modeling efforts could help everyone focus on issues such as tiling, channel instability, and hydrograph timing.

Agenda Item E - Overall review and assessment

This agenda item provided some excellent discussion, comments and questions, from participants in St. Paul and on the webinar. Also, some of the questions during the presentations also addressed this need. Therefore, this will simply be a listing of those items, rather than a series of solid statements that had group consensus. We simply did not have adequate time available to seek a higher level of consensus. However, each person who makes it to this point in the meeting summary ("congratulations!") may decide to add something that they have thought about, or have run across, that might help the corporate effort in the Cedar.

There is also a brief assessment of how we addressed each stated meeting objective – i.e. did we address an objective completely, partially, or not at all? And while this is fairly subjective, it can help us continue to consider these issues, as we proceed.

1. Do the models used in the Cedar show some of the same "hot spots," or logical areas for prioritization/targeting? (this had not been systematically completed)

2. Jason Smith mentioned the "scaling issue." A project in the Indian Creek watershed of Iowa , is using GSSHA, SWAT and HMS, in a comparative manner, to help tackle this issue (see Smith etal. 2013). The COE and USDA-FSA are also working on a CRP component to this effort.

   There was some agreement that we should learn from this Iowa-Indian Creek effort, and see if the three models discussed today could be used in a similar fashion. For example, Jason mentioned that HMS poorly simulated soil moisture conditions, but was better than SWAT and GSSHA at simulating peak runoff. It was noted that SWAT was underestimating the peaks with a daily time step. As a distributed model, SWAT does not track eroded materials from cell to cell (although SWAT that is run in grid mode could perform this simulation). The modeling effort in Indian Creek is using GSSHA to better understand the spatial significance of BMPs on water quantity. However, GSSHA's intensive data input process may preclude its wider use at larger scales.
   Can various levels of modeling be coordinated, so that data is appropriately used to inform the next level of effort, and confidence in our overall modeling results is increased? (While there was some general level of agreement that this can and should be done, no specific plan on how to accomplish this was developed.)

3. The conservation implementation folks who attended the meeting asked about how can the modeling products and results be made more useful for the implementation of conservation practices? Bev Nordby expressed a commitment to use the XP-SWMM model, now that it is developed and paid for - and one of the main uses will be for CRWD permitting and the assessment of culvert replacements.
   Another reoccurring question was how do we best get down to the farm scale? If a neighborhood approach to implementation is to be developed, having solid farm scale data for representative operations is critical. Some possible farm scale modeling options are using SWAT in a gridded mode, AnnAGNPS, or APEX.

4. Greg Wilson noted that a current project on defining priority management zones is looking at the combination of terrain analysis tools with modeling. This project will develop the necessary field protocols to verify model results, and to work directly with landowners.

5. Charles Ikenberry stressed the importance of pollutant transport pathways, and how problematic it can be to simulate BMPs. He noted their disappointment with the use of SWAT in regards to NO3-N leaching and transport. Charles also noted the limitations of FDCs, which don't take into account when the flows occur. He suggested using time series results in

addition to FDC, especially in regards to snowmelts, and variable antecedent moisture conditions.

6. Nick Gervino noted the clear need to use the Cedar modeling tools to run scenarios, including background conditions, subwatershed loading, and BMP scenarios. Our suite of current conditions models need to be used for predicting flow and pollutant loading changes resulting from adoption / maintenance of BMPs.

7. Bev Nordby noted that 90% cost share for ponds that detain water for 24 hours are popular with farmers, as they can plow through the pond when dry. Grassed waterways are not as popular, as they cannot be tilled.

8. Assessment Table of stated meeting objectives.

Abbreviated Objective	Accomplished	Noted	Not Addressed	Revisit
1. Continue model "roll-out"	X			
2. Include models in past 4 years	X			
3. Compare results by scale		X		
4. Complete work plan tasks	X			
5. Overall assessment of models		X		
6. Model communication to others			X	X
7. Model redundancy		X		X

A few selected **Web Links** to check out:

Cedar Basin…in IOWA….
www.iowacedarbasin.org

Mark Tomer, 2011. "The Challenge of Understanding Watershed Processes through Monitoring, Observations/Lessons from the CEAP in Iowa."

http://sentinel.umn.edu/home/establishing-sentinel-watersheds-workshop/

Cedar River Watershed District….in MN….
http://www.cedarriverwd.org/

Minnesota Department of Natural Resources, Healthy Waters
http://www.dnr.state.mn.us/conservationagenda/goals/02.html

A few selected references, to also check out:

References

Barling, Rowan D., Ian D. Moore, and Rodger B. Grayson. "A Quasi–Dynamic Wetness Index for Characterizing the Spatial Distribution of Zones of Surface Saturation and Soil Water Content." *Water Resources Research,* Vol. 30, No. 4, pp. 1029–1044, April, 1994.

Smith, Jason etal. 2013. Climate modeling and stakeholder engagement to support adaptation in the Iowa-Cedar Watershed. Draft Final Report. An FY 12 Responses to Climate Change Pilot Study. U.S. Army COE – Rock Island District.

Wilson, John P., and John C. Gallant. *Terrain Analysis. Principles and Applications.* Wiley and Sons, New York, 2000.

HUC 12 Subwatersheds in Minnesota and Minnesota-Iowa border areas

HUC_12	HU_12_NAME	ACRES	STATES
70802020107	Goose Creek-Shell Rock River	13835	IA,MN
70802010202	Little Cedar River-Cedar River	13930	MN
70802010301	Upper Rose Creek	16927	MN
70802020103	Peter Lund Creek	18380	MN
70802010104	Turtle Creek	18700	MN
70802010103	Judicial Ditch No 24	18850	MN
70802010701	City of Adams	19081	MN
70802010101	Deer Creek	19913	MN
70802010501	Orchard Creek	20402	MN
70802010402	Headwaters Deer Creek	22128	IA,MN
70802020102	County Ditch No 77	22183	MN
70802010702	Village of Meyer-Little Cedar River	22768	IA,MN
70802010505	Town of Otranto-Cedar River	22890	IA,MN
70802010502	Judicial Ditch No 77-Cedar River	23891	MN
70802010205	Dobbins Creek	24585	MN
70802010203	Roberts Creek	25040	MN
70802020104	Albert Lea Lake	25770	MN
70802010302	Lower Rose Creek	26508	MN
70802010503	Woodbury Creek	26882	IA,MN
70802020101	Bancroft Creek	27682	MN
70802020105	County Ditch No 16-Shell Rock River	28626	MN
70802010703	City of Stacyville-Little Cedar River	29170	IA,MN

70802010204 Green Valley Ditch-Cedar River	31028	MN
70802010201 Headwaters Cedar River	32252	MN
70802010206 City of Austin-Cedar River	35030	MN
70802010504 Otter Creek	39946	IA,MN
70802020106 County Ditch No 55	40075	IA,MN
70802010102 Geneva Lake	40456	MN

--- General Model Descriptions ---

SWAT: Soil and Water Assessment Tool

SWAT is a physically based watershed model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (ARS) in Temple, Texas. SWAT was developed to predict the impact of land management practices on water, sediment, nutrients, dissolved oxygen, and agricultural chemical yields in large watersheds with varying soils, land use, and management conditions over long periods of time.

- Explicitly simulates crop management practices.
- Lumps soil type, vegetation, and hydrology into hydrologic response units.
- Incorporates climate generator.
- Uses SWMM functions for urban impervious runoff.
- Daily timestep (subdaily for urban ponds).
- Simple channel and reservoir routing.

SWMM: Storm Water Management Model

SWMM is a continuous rainfall-runoff simulation model developed for EPA at the University of Florida. The original primary application of SWMM was to urban watersheds for the analysis of surface runoff and flow routing through urban sewer systems. Watersheds are divided into subcatchments which are further divided into pervious and impervious areas. Flow routing is performed for surface and sub-surface conveyance and groundwater systems, including the options of nonlinear reservoir channel routing and fully dynamic hydraulic flow routing. In the fully dynamic hydraulic flow routing option, SWMM simulates backwater, surcharging, pressure flow, and looped connections.

- Universal Soil Loss Equation used to predict pervious surface erosion.
- Simulation of storage and treatment ponds.
- Simulates sediment–adsorbed nutrients, metals, toxics.
- Detailed hydraulic routing with EXTRAN block.
- Simplistic groundwater component, but has been linked to the USGS MODFLOW model.

GSSHA: Gridded Surface Subsurface Hydrologic Analysis

GSSHA is a continuous, distributed-parameter, two-dimensional, hydrologic watershed model developed by the Hydrologic Systems Branch of the U.S. Army Corps of Engineers' Coastal and Hydraulics Laboratory. The watershed is divided into homogeneous square grid cells. Surface and subsurface hydrology within each grid are routed through the flow network and integrated to produce the watershed output. GSSHA offers the capability of determining the value of any hydrologic variable at any grid point in the watershed at the expense of requiring significantly more input than traditional approaches.

- Rigorous 2 dimensional overland flow and groundwater routing algorithms and dynamic 1–D channel routing.
- Simulates vadose zone and groundwater flow and interactions with surface flow.
- Simulates sediment, nutrients, and biochemical oxygen demand.
- Wetland simulation capabilities added due to USACOE delegated wetland regulation.
- Requires use of the proprietary Watershed Modeling System.

Cedar River Basin in Minnesota – Table of Water Quality and Watershed Modeling Projects and Efforts, 1990-2013.

Scale	Model	Who (Primary)	Completion Target Date / Notes	*Report Available*
Dobbins Creek Subshed (24,000 acres)	AgNPS	Mower SWCD, Bonestroo	Oct. 1992, CWP Project on East Side Lake, Austin	*1992,93*
Dobbins Creek Subshed	SWAT	Mower SWCD, HDR	2010 Ag. Watershed Restoration Pj., BWSR	*Feb. 2010*
Dobbins Creek Subshed	GSSHA	MDNR-Greg Eggers, Jim Solstad-MDNR	Model under development	
Cedar Basin, IA + MN	HSPF	Respec (Janson Love)	Focus on IA; 1995-2005; Hydrology & bacteria	
Cedar Basin (CR, TC, SR)* (536,000 acres)	SWAT	Barr Eng. (Greg Wilson)	TMDL development contract with Mower SWCD, MPCA w/o specific ag BMPs With ag BMPs	 *June 2012*. *July 2013*
Fountain Lake, Albert Lea Subsheds (94,000 acres)	BATHTUB	Barr Eng.(Wilson, Runke)	TMDL development contract with Mower SWCD, MPCA	*June 2012*
P-Budget Model for Fountain and A.Lea Lakes		Larry Baker etal. UM	TMDL Tools and P budget project, 319	*Fall 2013*
CR and TC	XP-SWMM	Mower SWCD, CRWD + others Rita Weaver, Barr Eng.	~2012 (in the planning phases Prioritization for water storage is primary objective	*July 2013*

CR = Cedar River Watershed (278 sq. miles)
TC = Turtle Creek Watershed (157 sq. miles)
SR = Shell Rock River Watershed (246 sq. miles)

Public participation and civic engagement

Civic Engagement Report for Cedar River Basin, 2011-2013

- **Conservation Drainage Meeting** – Educate producers on alternative conservation drainage practices to lower nitrates and sediment into streams. Gary Sands, Drainage Engineer, from the University of MN and Kurt Deter, Drainage Attorney, Cody Fox and Justin Hanson, local SWCD staff were the speakers. Topics included Trends and Changes in Drainage and Drainage law, research and innovation behind conservation drainage and local projects and cost sharing opportunities for conservation drainage. We had 50 producers in attendance. This workshop for stakeholders was sponsored by the Mower SWCD, Cedar River WD and Turtle Creek WD. We were encouraged to hear the participant's reaction to the new and upcoming trends in drainage. They also participated by bringing their ideas on how they can implement more conservation on their farms. The meeting was held on Month, XX, 2013 in Austin at the Holiday Inn.

- **H & H Meeting** – Educate local unit of governments on the benefits H & H model for the Turtle Creek and Cedar River Watershed Districts. This event drew 60 participatants, that included staff from Cities, Townships, Counties and some from the State of Iowa. We called this a "roll-out" meeting for the hydraulic and hydrology model, since it was our first exposure to this modeling tool that will continue to be used for many years. This complex, detailed model enabled the participants to see how site-specific flood detention and water quality treatment practices can be assessed. The model will continue to be applied to proposed projects on flooding and water quality. In short, it helps the local governments make good decisions that protect our district's water resources. The presentation for this meeting is linked below: ______http://www.cedarriverwd.org/library/studies.html

- **Monitoring Reports and Annual Reports** – Educating residents, businesses and local government on the activity and accomplishments of the Watershed Districts and Soil and Water Conservation District. Annual Reports and a 2011 monitoring educating piece were used to educate the public on the improvement and strides made in the basin. A mailing of 300 residents yearly as well as posting on the web site brought this information to the doorsteps of residents. http://www.cedarriverwd.org/documents/2011CRWDAnnualReport.pdf
http://cedarriverwd.org/library/documents/2012CRWDAnnualReport-fortheweb.pdf
http://www.cedarriverwd.org/documents/2011MonitoringBrochure.pdf

- **Web Page** – Our web site was totally revamped with a professional web master. Our goal is not only to provide good information, but give the users a reason to come to our web site. The web site outlines maps, exploring the watershed, what's new and how to get involved.
http://cedarriverwd.org/index.html

- **Facebook** - Our facebook page now has 183 followers. We post many history pictures as well as activities that include monitoring, fun facts and recreating on the river. The page encourages residents to use and take care of the river. It is amazing to watch the residents interact with each other on their enjoyment of the river and it's watershed. We try and keep our posts to 3 to 4 a week, and with some posts there are between 300 to 500 people seeing current information on the Cedar River . https://www.facebook.com/CedarRiverWD

- **June "Waterway Awareness Month at the Library.**

  Four public presentations completed on the topics of water quality; flooding; Cedar River photo history, history and future of East Side Lake and the Austin 2020 Waterways Project. We had a very good turnout of 120 residents. We provided a month - long display of current and old picture poster in the library overlooking Mill Pond; info handouts available to take all month. There was also an in-depth article in the Austin Daily Herald (add date and article title).

  Picture Boards – were developed to use at many different events throughout the community promoting the Cedar River, State Water Trail and Cedar River Watershed District.



- **4th of July Parade**

  SWCD staff constructed a parade float promoting the Adopt the River Program. We had piled items that were picked up by participants in the Adopt a River Program. We had staff as well as Adopt a River families a part of the parade. It was enlighting to watch the crowd when our float went by. They looked, then read, then clapped. It was very visual. Thousands of area residents attend the parade every year.

- **Vision 2020 - Embrace and Maintain Our Waterway Committee**

  Mission Statement: Clean and maintain all waterways and shorelines in the community and beyond to enhance recreational opportunities such as kayaking, canoeing, tubing, swimming and fishing, adding beauty through public gardens, lighted waterways and water features. This committee of 50 residents , with SWCD involvement has been meeting for 2 years on a bi-monthly basis. The SWCD has taken an active role in involving and educating the committee members on our river system, that includes benefits, water quality, citizen engagement and best management practices. The committee comes from many different backgrounds and takes ownership in taking care of the Cedar.

- **Adopt a River Clean Up** – 31 families and civic service organizations have signed up for a 3 year commitment to adopt a stretch of the river to clean. We have the entire Cedar signed up from the headwaters all the way to the Iowa border. It was initiated and now led by the CRWD/SWCD . It has been the first time in history that an organized effort of cleaning the Cedar river of debris has taken place. Residents took ownership and did their stretch. http://cedarriverwd.org/how_can_I_help/adopt_a_river.html

- **Nate Howard Photography** - Our general website direction is make it picture-driven, along with short video clips. We have contracted Nate Howard Photography for a creation of library images reflecting the seasonal changes of the streams and rivers. There are also video clips that will be completed for the website as well as our facebook page.

- **A Cedar 220 Project** -- hopefully in partnership with Vision 2020 Waterways -- to take and receive photos of individuals using or cleaning the Cedar River and other local waterways. The goal would be to get photos of at least 220 individuals (220 in a nod to Vision 2020) either removing trash from or along the waterways; kayaking; canoeing; or fishing sometime this spring, summer or fall on the Cedar River or other local waterways. We'd like a name, date and location for each image. Images will be shared online via the CRWD website, Facebook page and other ways. This will help promote the Cedar River and local creeks as recreational resources and show that there are a good number of people enjoying and caring for the local waterways.

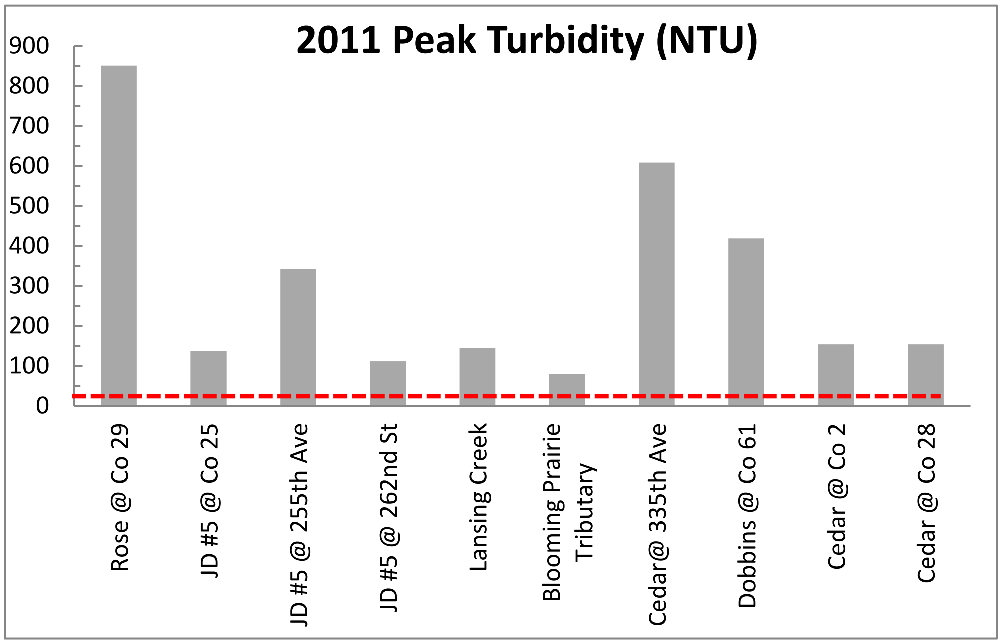
- **State Water Trail** – 25 miles of Cedar River Water Trail. We led a successful legislative effort to get approval for designating the Cedar River as Minnesota's 33rd State Water Trail. A kick off for the public and legislators took place at the Library overlooking the Mill Pond. http://cedarriverwd.org/recreation/state_water_trail.html

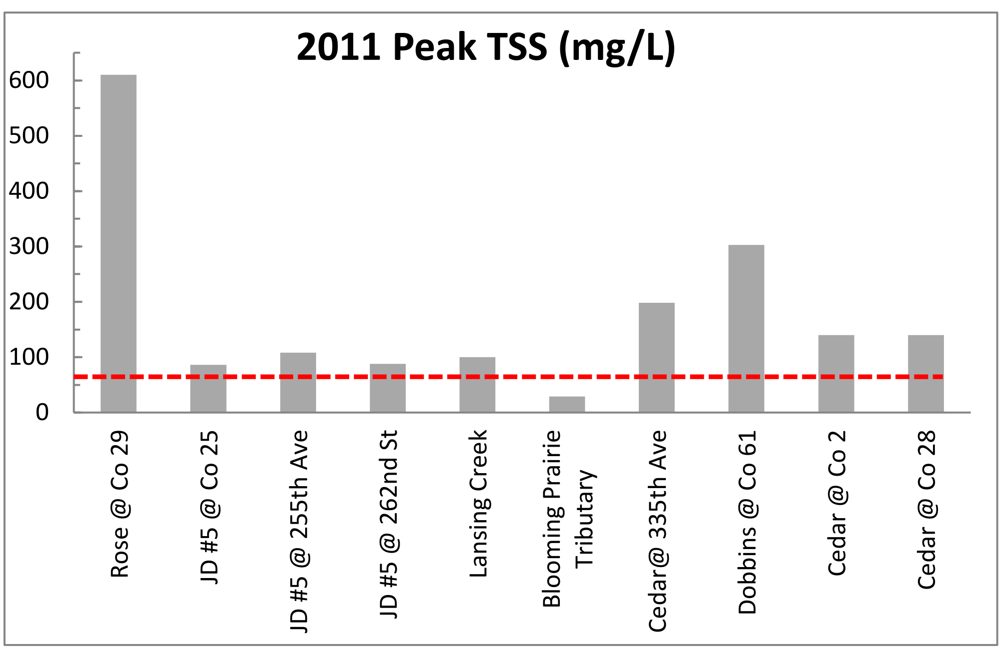
- **Signage for Streams and Rivers** - Educate the residents that "This small stream has a name and it is an important link to the Watershed and the Cedar River". We have placed 25 road signs on County roads and 11 park signs. When working on this project, we found that amazingly, many people did not know that the tributaries had names. We believe that this basic effort to provide name recognition to our smaller streams and creeks will eventually improve understanding and care of land and water resources, across our watersheds.

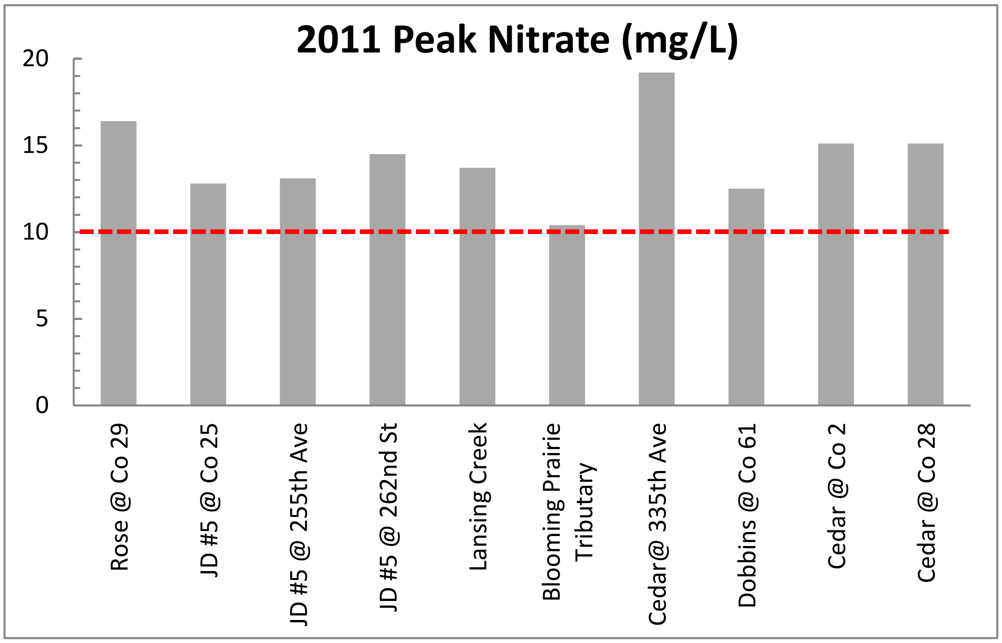
**Several fact sheets as well as flyers have been developed and are attached.
List fact sheets and flyers that are attached:

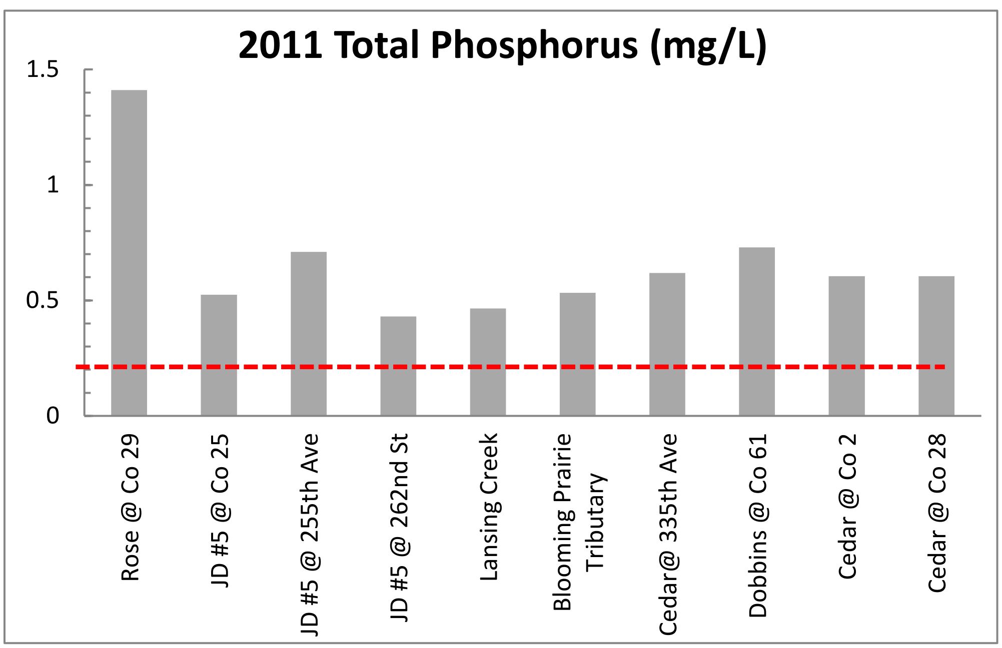
Appendix E – Water Monitoring Graphics

[James Fett, Mower SWCD]






2011 Peak Nitrate (mg/L)
20
15
10
5
0
Rose @ Co 29
JD #5 @ Co 25
JD #5 @ 255th Ave
JD #5 @ 262nd St
Lansing Creek
Blooming Prairie Tributary
Cedar@ 335th Ave
Dobbins @ Co 61
Cedar @ Co 2
Cedar @ Co 28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1
0.5
0
Rose @ Co 29
JD #5 @ Co 25
JD #5 @ 255th Ave
JD #5 @ 262nd St
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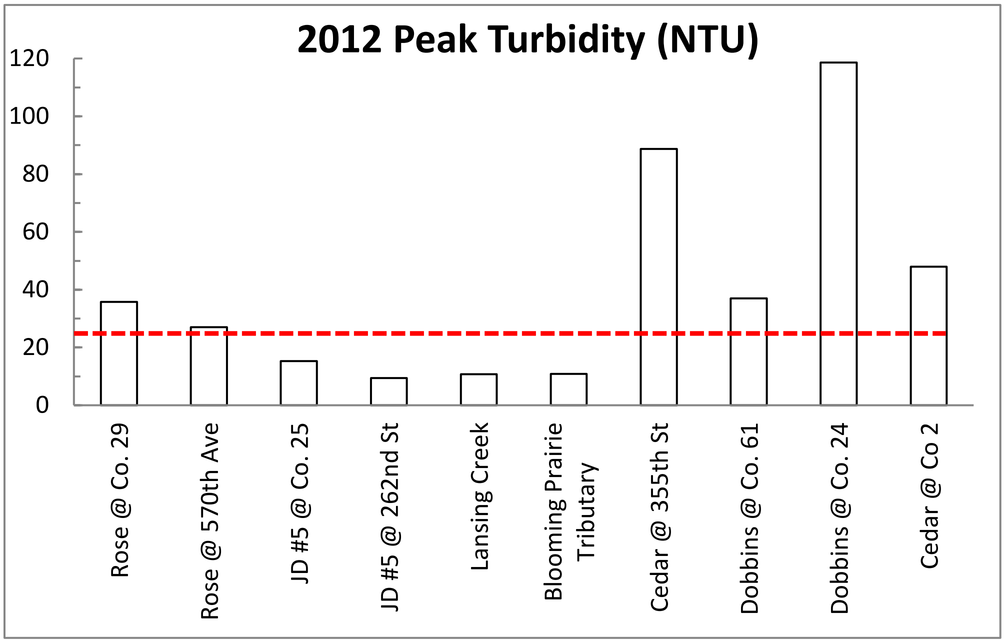
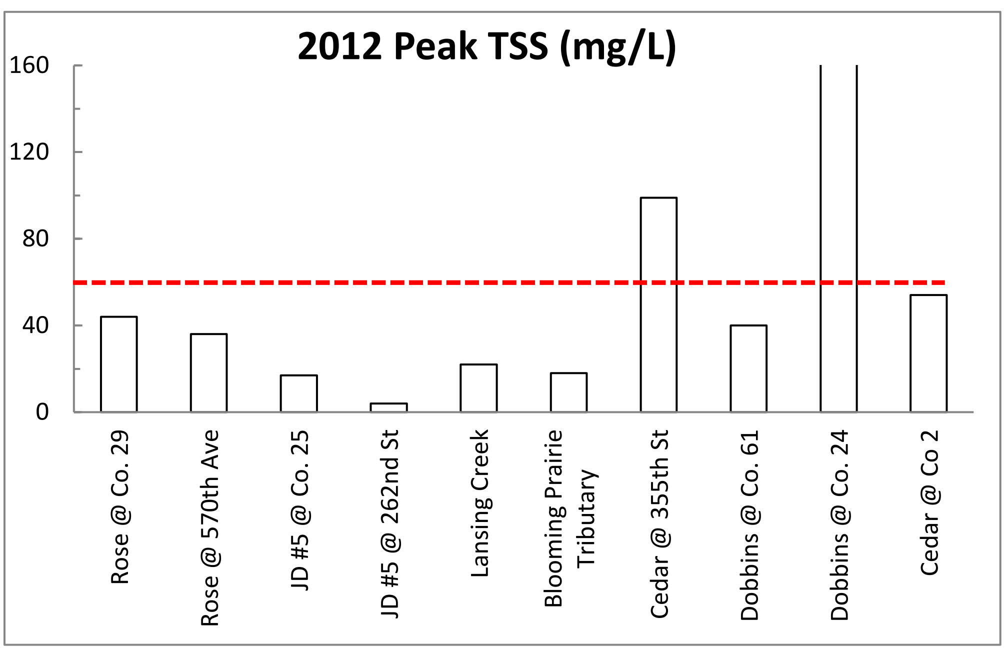
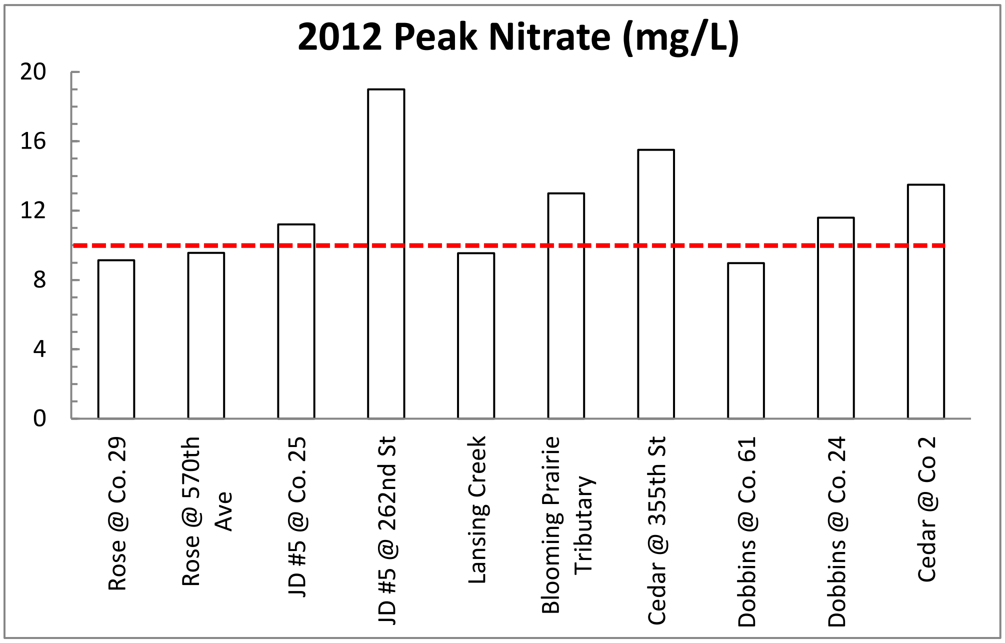
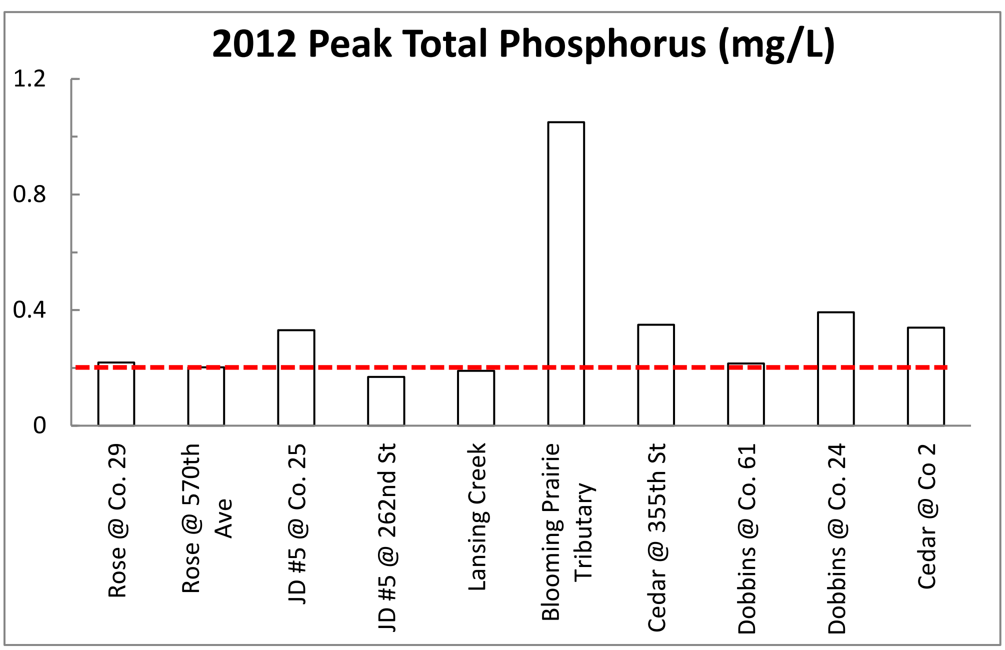
Cedar@ 335th Ave
Dobbins @ Co 61
Cedar @ Co 2
Cedar @ Co 28


2012 Peak Turbidity (NTU)
120
100
80
60
40
20
0
Rose @ Co. 29
Rose @ 570th Ave
JD #5 @ Co. 25
JD #5 @ 262nd St
Lansing Creek
Blooming Prairie Tributary
Cedar @ 355th St
Dobbins @ Co. 61
Dobbins @ Co. 24
Cedar @ Co 2


2012 Peak TSS (mg/L)
160
120
80
40
0
Rose @ Co. 29
Rose @ 570th Ave
JD #5 @ Co. 25
JD #5 @ 262nd St
Lansing Creek
Blooming Prairie Tributary
Cedar @ 355th St
Dobbins @ Co. 61
Dobbins @ Co. 24
Cedar @ Co 2


2012 Peak Nitrate (mg/L)
20
16
12
8
4
0
Rose @ Co. 29
Rose @ 570th Ave
JD #5 @ Co. 25
JD #5 @ 262nd St
Lansing Creek
Blooming Prairie Tributary
Cedar @ 355th St
Dobbins @ Co. 61
Dobbins @ Co. 24
Cedar @ Co 2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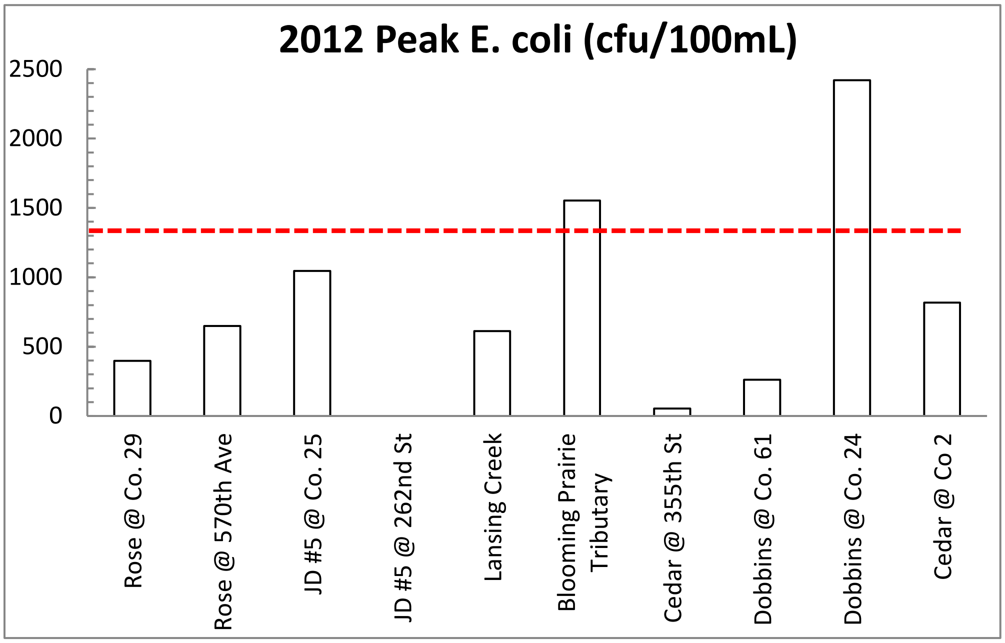
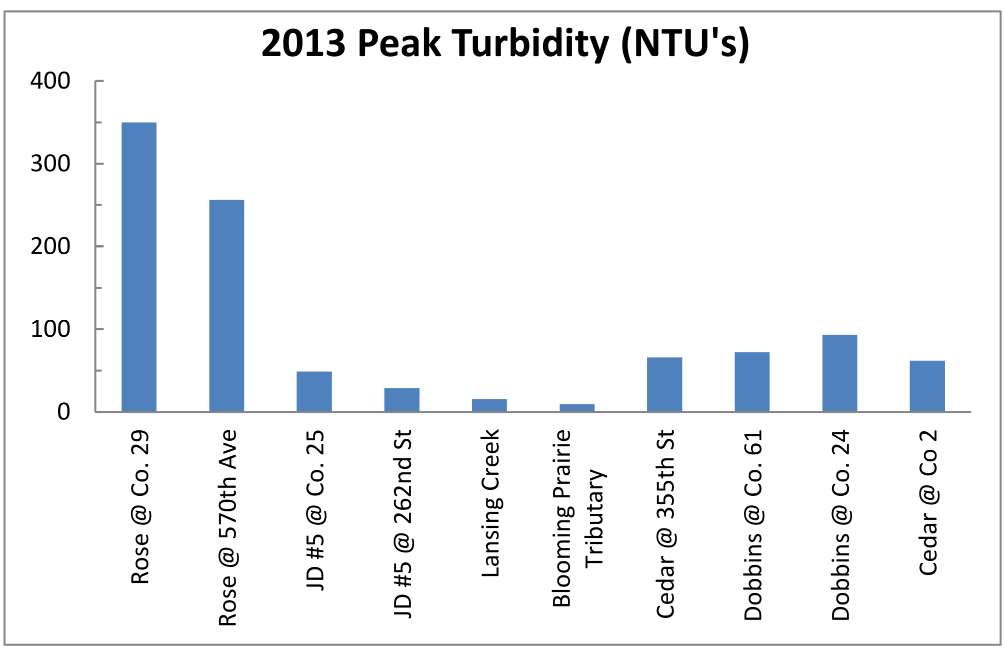
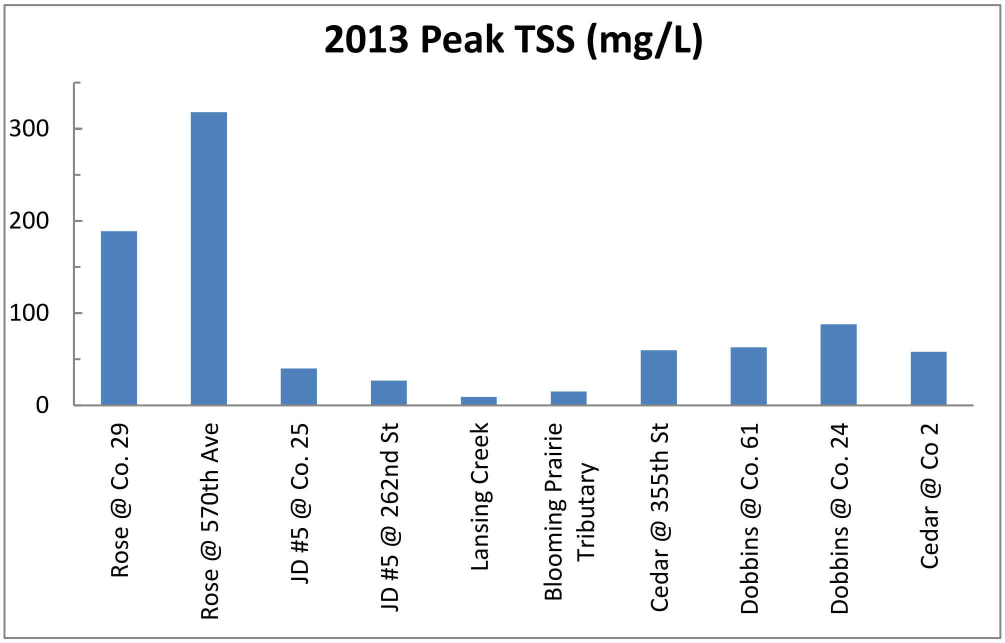
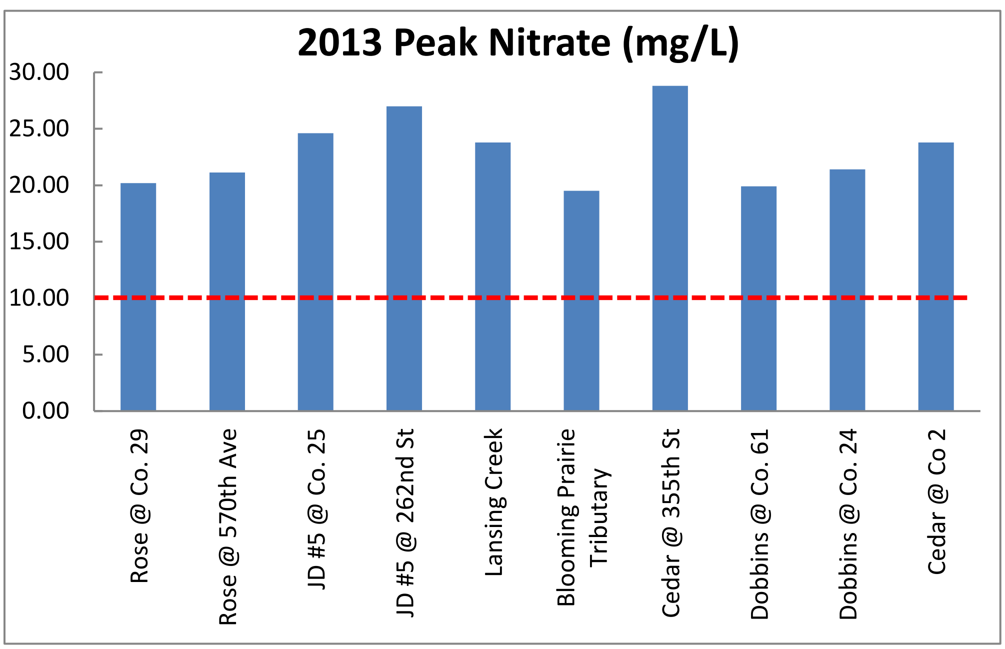
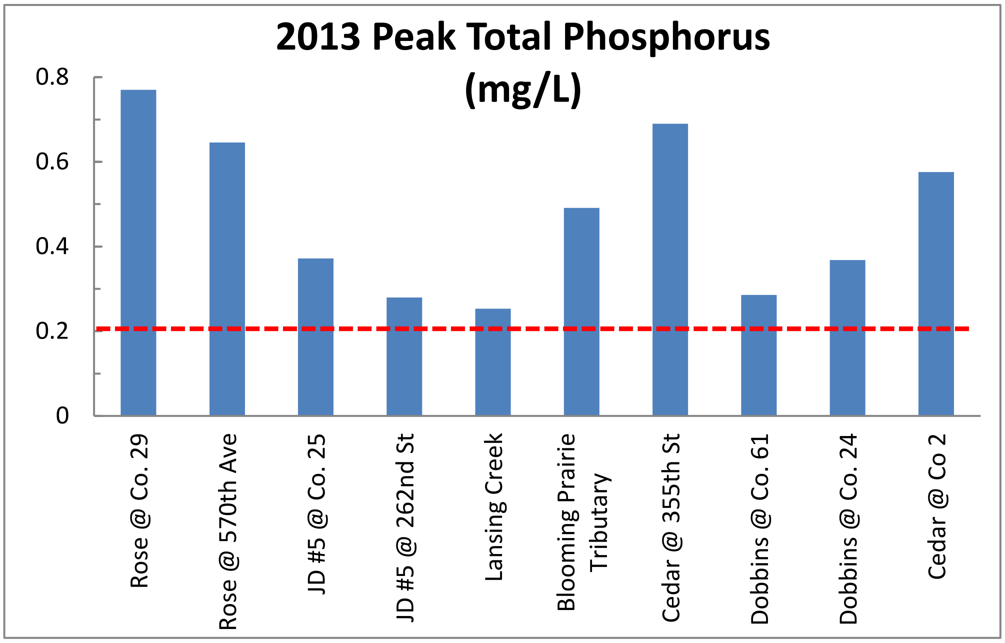
0.8
0.4
0
Rose @ Co. 29
Rose @ 570th Ave
JD #5 @ Co. 25
JD #5 @ 262nd St
Lansing Creek
Blooming Prairie Tributary
Cedar @ 355th St
Dobbins @ Co. 61
Dobbins @ Co. 24
Cedar @ Co 2

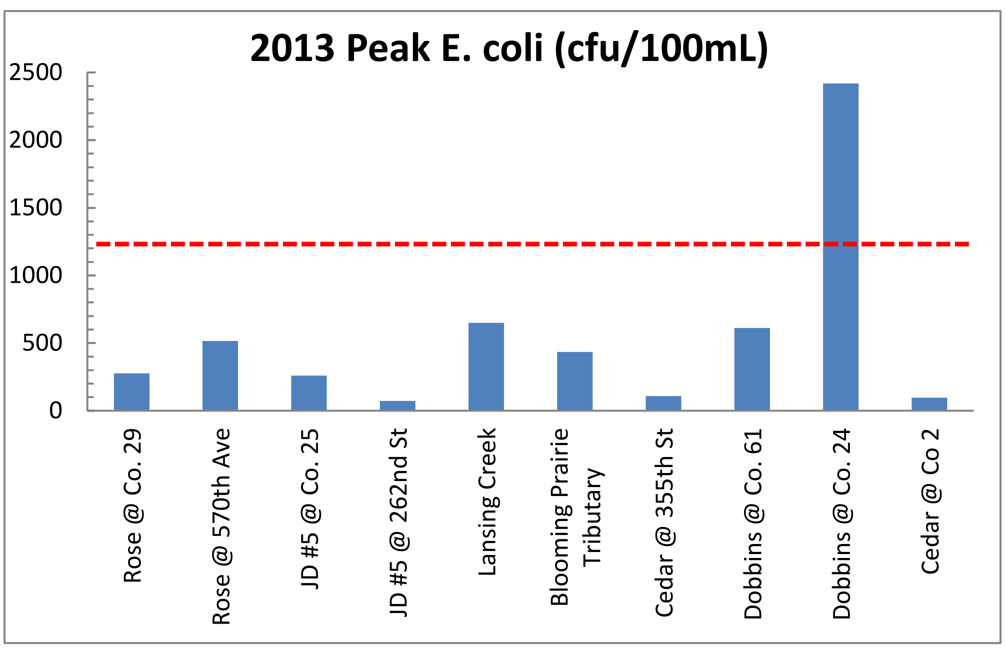

2012 Peak E. coli (cfu/100mL)
2500
2000
1500
1000
500
0
Rose @ Co. 29
Rose @ 570th Ave
JD #5 @ Co. 25
JD #5 @ 262nd St
Lansing Creek
Blooming Prairie Tributary
Cedar @ 355th St
Dobbins @ Co. 61
Dobbins @ Co. 24
Cedar @ Co 2


2013 Peak Turbidity (NTU's)
400
300
200
100
0
Rose @ Co. 29
Rose @ 570th Ave
JD #5 @ Co. 25
JD #5 @ 262nd St
Lansing Creek
Blooming Prairie Tributary
Cedar @ 355th St
Dobbins @ Co. 61
Dobbins @ Co. 24
Cedar @ Co 2


2013 Peak TSS (mg/L)
300
200
100
0
Rose @ Co. 29
Rose @ 570th Ave
JD #5 @ Co. 25
JD #5 @ 262nd St
Lansing Creek
Blooming Prairie Tributary
Cedar @ 355th St
Dobbins @ Co. 61
Dobbins @ Co. 24
Cedar @ Co 2


2013 Peak Nitrate (mg/L)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Rose @ Co. 29
Rose @ 570th Ave
JD #5 @ Co. 25
JD #5 @ 262nd St
Lansing Creek
Blooming Prairie Tributary
Cedar @ 355th St
Dobbins @ Co. 61
Dobbins @ Co. 24
Cedar @ Co 2


2013 Peak Total Phosphorus (mg/L)
0.8
0.6
0.4
0.2
0
Rose @ Co. 29
Rose @ 570th Ave
JD #5 @ Co. 25
JD #5 @ 262nd St
Lansing Creek
Blooming Prairie Tributary
Cedar @ 355th St
Dobbins @ Co. 61
Dobbins @ Co. 24
Cedar @ Co 2


2013 Peak E. coli (cfu/100mL)
2500
2000
1500
1000
500
0
Rose @ Co. 29
Rose @ 570th Ave
JD #5 @ Co. 25
JD #5 @ 262nd St
Lansing Creek
Blooming Prairie Tributary
Cedar @ 355th St
Dobbins @ Co. 61
Dobbins @ Co. 24
Cedar @ Co 2

2013 CRWD MONITORING RESULTS

HIGHEST VALUES = (red) LOWEST VALUES= (blue)

2013 AVERAGE CONCENTRATIONS	T-tube (cm)	ODO	DO%	Conductivity (µS/cm)	pH	Turb (NTU)	H2O Temp (°C)	TSS (mg/L)	E.coli	N-N (mg/L)	TP (mg/L)	OP (mg/L)
Rose 29	25.70	10.23	95.15	0.35	7.98	68.51	12.25	44.40	411.68	11.37	0.22	0.06
Rose 570	20.70	9.57	90.63	0.35	7.92	61.12	13.41	76.30	620.73	11.41	0.21	0.05
JD #5 @ 25	51.50	9.44	77.70	0.46	7.77	6.51	10.86	9.30	185.50	18.26	0.18	0.10
JD #5 @ 262	52.29	9.92	86.09	0.41	7.61	4.91	8.92	9.00		21.61	0.14	0.09
Lansing	57.00	8.89	78.40	0.46	7.81	3.10	10.42	4.10	392.35	14.80	0.10	0.06
BPT	55.30	9.12	81.42	0.55	7.73	3.25	10.45	10.40	268.83	11.37	0.34	0.25
Cedar 335	43.00	9.21	83.52	0.46	7.82	12.76	11.71	20.10	242.05	16.11	0.20	0.12
Dobbins 61	37.75	9.61	89.11	0.35	7.83	15.88	12.28	16.30	641.23	11.45	0.13	0.06
Dobbins Co. 24	31.33	10.22	96.71	0.32	7.93	27.42	13.20	37.30	1996.45	12.82	0.16	0.06
Cedar 2	38.95	9.23	84.57	0.41	7.87	14.12	12.03	16.80	300.70	13.22	0.21	0.12
Average	**41.35**	**9.54**	**86.33**	**0.41**	**7.83**	**21.76**	**11.55**	**24.40**	**562.17**	**14.24**	**0.19**	**0.10**
Minimum	**20.70**	**8.89**	**77.70**	**0.32**	**7.61**	**3.10**	**8.92**	**4.10**	**185.50**	**11.37**	**0.10**	**0.05**
Maximum	**57.00**	**10.23**	**96.71**	**0.55**	**7.98**	**68.51**	**13.41**	**76.30**	**1996.45**	**21.61**	**0.34**	**0.25**

2013 MINIMUM CONCENTRATIONS	T-tube (cm)	ODO	DO%	Conductivity (µS/cm)	pH	Turb (NTU)	H2O Temp (°C)	TSS (mg/L)	E. Coli	N-N (mg/L)	TP (mg/L)	OP (mg/L)
Rose 29	2.00	8.53	81.10	0.19	7.57	0.00	1.16	3.00	63.10	1.18	0.05	0.01
Rose 570	4.00	7.95	77.80	0.18	7.53	2.90	0.40	2.00	149.30	0.97	0.07	0.01
JD #5 @ 25	9.00	7.89	84.50	0.29	7.43	0.00	1.09	2.00	127.40	3.58	0.07	0.04
JD #5 @ 262	13.00	5.82	41.70	0.35	7.34	0.00	2.02	2.00	73.30	7.14	0.08	0.05
Lansing	38.00	7.54	71.10	0.29	7.63	0.00	0.26	2.00	235.90	3.07	0.04	0.03
BPT	33.00	7.82	65.00	0.40	7.41	0.00	-0.03	5.00	59.40	3.57	0.14	0.10
Cedar 335	9.00	7.75	73.40	0.17	7.48	0.00	-0.04	5.00	107.10	1.26	0.04	0.02
Dobbins 61	7.50	7.80	77.30	0.24	7.47	0.00	2.32	2.00	135.40	1.73	0.04	0.01
Dobbins Co. 24	6.00	7.89	79.30	0.16	7.45	1.00	-0.02	2.00	727.00	1.54	0.05	0.02
Cedar 2	9.50	7.59	73.30	0.18	7.58	0.00	0.06	3.00	66.30	1.48	0.07	0.04
Average	**13.10**	**7.66**	**72.45**	**0.24**	**7.49**	**0.39**	**0.72**	**2.80**	**174.42**	**2.55**	**0.06**	**0.03**
Minimum	**2.00**	**5.82**	**41.70**	**0.16**	**7.34**	**0.00**	**-0.04**	**2.00**	**59.40**	**0.97**	**0.04**	**0.01**
Maximum	**38.00**	**8.53**	**84.50**	**0.40**	**7.63**	**2.90**	**2.32**	**5.00**	**727.00**	**7.14**	**0.14**	**0.10**

2013 MAXIMUM CONCENTRATIONS	T-tube (cm)	ODO	DO%	Conductivity (µS/cm)	pH	Turb (NTU)	H2O Temp (°C)	TSS (mg/L)	E. Coli	N-N (mg/L)	TP (mg/L)	OP (mg/L)
Rose 29	60.00	12.43	130.80	0.51	8.57	350.00	23.05	189.00	920.80	20.20	0.77	0.12
Rose 570	60.00	11.58	124.80	0.52	8.88	256.40	25.25	318.00	1203.30	21.10	0.65	0.11
JD #5 @ 25	60.00	12.21	93.60	0.65	8.15	48.80	17.14	40.00	260.30	24.60	0.37	0.22
JD #5 @ 262	60.00	13.05	101.40	0.51	8.04	28.90	16.33	27.00	73.30	27.00	0.28	0.15
Lansing	60.00	11.49	85.10	0.58	7.99	15.50	18.91	9.00	648.80	23.80	0.25	0.18
BPT	60.00	10.83	93.50	0.78	7.93	9.20	18.27	16.00	435.20	19.50	0.61	0.40
Cedar 335	60.00	11.69	90.40	0.60	8.13	66.00	22.99	60.00	501.20	28.80	0.69	0.52
Dobbins 61	60.00	11.57	111.30	0.48	8.26	72.10	22.30	63.00	1203.30	19.90	0.29	0.18
Dobbins Co. 24	60.00	12.21	130.60	0.51	8.76	93.40	24.85	88.00	2419.60	21.40	0.37	0.18
Cedar 2	60.00	11.74	100.20	0.57	8.14	62.10	22.64	58.00	579.40	23.80	0.58	0.40
Average	**60.00**	**11.88**	**106.17**	**0.57**	**8.29**	**100.24**	**21.17**	**86.80**	**824.52**	**23.01**	**0.49**	**0.25**
Minimum	**60.00**	**10.83**	**85.10**	**0.48**	**7.93**	**9.20**	**16.33**	**9.00**	**73.30**	**19.50**	**0.25**	**0.11**
Maximum	**60.00**	**13.05**	**130.80**	**0.78**	**8.88**	**350.00**	**25.25**	**318.00**	**2419.60**	**28.80**	**0.77**	**0.52**

Appendix G – MPCA Grant Project Summary Form (on next 2 pages) 86

Grant Project Summary

Project title: Cedar River Watershed Strategy and Implementation Plan – Phase 1

Organization (Grantee): Mower County Soil and Water Conservation District

Project start date: 8.19.2011 Project end date: 6.30.2013 Report submittal date: 8.1.2013

Grantee contact name: Bev Nordby Title: Manager

Address: 1408 21st Ave. N.

City: Austin State: MN Zip: 55912

Phone number: 507.434.2603 Fax: 507.434.2680 E-mail: Bev.nordby@mowerswcd.org

Basin (Red, Minnesota, St. Croix, etc.): Cedar County: Mower

Project type (check one):

- ☐ Clean Water Partnership (CWP) Diagnostic
- ☐ CWP Implementation
- ☐x (CWF) Total Maximum Daily Load (TMDL) Development
- ☐ 319 Implementation
- ☐ 319 Demonstration, Education, Research
- ☐ TMDL Implementation

Grant Funding

Final grant amount: $182,205 Final total project costs: $180,611

Matching funds: Final cash: $na – CWF Final in-kind: $ Final Loan: $

Contract number: 27134 MPCA project manager: Bill Thompson

For TMDL Development or TMDL Implementation Projects only

Impaired reach name(s): Cedar River (07080201-501; 07080201-502); & Dobbins Creek (07080201-537)

AUID or DNR Lake ID(s):

Listed pollutant(s): Turbidity

303(d) List scheduled start date: 2009 Scheduled completion date: 2014

AUID = Assessment Unit ID
DNR = Minnesota Department of Natural Resources

Executive Summary of Project (300 words or less)

This summary will help us prepare the Watershed Achievements Report to the Environmental Protection Agency. (Include any specific project history, purpose, and timeline.)

This project continues the combined efforts of many groups that started around 2008, to improve water quality and watershed management across a large and complex area. This Cedar River Watershed (in Minnesota) covers significant portions of three counties (Mower, Freeborn, and Dodge), and encompasses 592 square miles. There are two statutory watershed districts in the broader Cedar watershed, the Cedar River and Turtle Creek Watershed Districts. Two watershed modeling products resulted from this project, which together will allow for better allocating and targeting of technical and financial assistance. One model will be used to assess the effectiveness of water storage projects, while the second model will allow for improved predictions regarding agricultural conservation practices. A major effort to inventory agricultural BMPs resulted in significant improvements to the second model. An enhanced effort in public participation has improved awareness and understanding of the Cedar River as an important resource. And stream water quality monitoring has been continued at selected sites, thereby building up a stronger dataset for evaluation of implementation measures, as well as tracking the variation of water quality over time. This effort has also involved a greater degree of communication with our downstream partners from Iowa.

Goals (Include three primary goals for this project.)

1st Goal: Develop predictive watershed modeling tools

2nd Goal: Inventory agricultural management practices

3rd Goal: Continue stream water quality monitoring at selected sites

Results that count (Include the results from your established goals.)

1st Result: Completion of a hydrologic/hydraulic model, and an agricultural management model for the watershed

2nd Result: Inventory and data collection of 927 agricultural management practices that affect water and sediment

3rd Result: Improved water quality data set for selected streams

Picture (Attach at least one picture, do not imbed into this document.)

Description/location:

See Bill Thompson's S: Cedar, photo file, for various photos from this project.

Acronyms (Name all project acronyms and their meanings.)

CRW	Cedar River Watershed (hydrologic basin in Minnesota)
CRWD	Cedar River Watershed District
TCWD	Turtle Creek Watershed District
Cedar WMA	Cedar Watershed Management Authority (in Iowa)

Partnerships (Name all partners and indicate relationship to project)

Technical partners: Mower County & SWCD

Freeborn County & SWCD

Dodge County & SWCD

Steele County & SWCD

CRWD, TCWD

City of Austin

Cedar River Watershed Model Summary

Hydrologic models are used by the Minnesota Pollution Control Agency (MPCA) to support decision-making for potential sediment and nutrient reduction strategies. The hydrologic models HSPF (Hydrological Simulation Program – FORTRAN), SWAT (Soil and Water Assessment Tool), and GSSHA (Gridded Surface Subsurface Hydrologic Analysis) were developed for this purpose in the Cedar River basin. This document describes the development of the Cedar HSPF, SWAT, and GSSHA models as well as some of the model output. For information regarding these models or for any data/reports relating to them, please contact Dr. Charles Regan (chuck.regan@state.mn.us) at the MPCA.

Cedar HSPF Development

HSPF models allow for advanced hydrologic simulation of a basin through multiple sources of spatial and temporal observed data. The model was developed and is supported by the EPA and has been consistently used in peer-reviewed watershed studies. More on HSPF can be found at http://www.pca.state.mn.us/index.php/view-document.html?gid=21398. This model was completed by the consulting firm RESPEC Engineering in 2014 and all data is part of the public domain.

Subwatershed Delineation and Land Segment Development

The watershed model is separated into subwatersheds based on hydrography data (from GIS analysis) and can be adjusted based on specific stream concerns (such as impairments). Pervious and impervious land segments within each subwatershed divide the subwatersheds into distinct sections based on land use, soil properties, and tillage practices. This data was compiled from multiple federal, state, and local organizations and government entities. Land cover data for land segments originated from the National Land Cover Database of 2006 and 2011.

Calibration - Hydrology

Data from five flow calibration gages were used for hydrologic calibration. One major gage was used for primary calibration (MN48020001, 1.5 miles south of Austin, MN on the Cedar River), while the remaining upstream gages helped parameterize model variables, including land segment flow values. The modeled period was between 1995 and 2012. Calibration involves first determining annual water balance, then modifying for seasonal changes in hydrology, ensuring high and low flow volumes are accurate, and finally modifying hydrograph to storm flows. Snow and snowmelt are also factored into the HSPF model based on meteorological inputs.

Calibration – Water Quality

Multiple constituents of water quality were modeled, including biochemical oxygen demand, dissolved oxygen, sediment, temperature, and various nutrients. Water quality calibration was more challenging because fewer daily data points exist (compared to flow data) and there is greater uncertainty in data collection. Seventy-seven sample points throughout the watershed were used to guide calibration. Observed water quality and flow data from 15 point sources, like waste water treatment facilities or industrial discharges (based on NPDES permits), were also incorporated into the model.

Sediment

Sediment parameters within the model were first based on other regional HSPF models, and then were calibrated to match the observed sediment data in the Cedar watershed. The model sediment output is also compared to historical reports and expected sediment characteristics based on local professional knowledge. Parameters of sediment transport and erosion were also compared with the Revised Universal Soil Loss Equation (RUSLE). Calibration for sediment is performed upstream-to-downstream to ensure upstream sediment parameters influence downstream reaches.

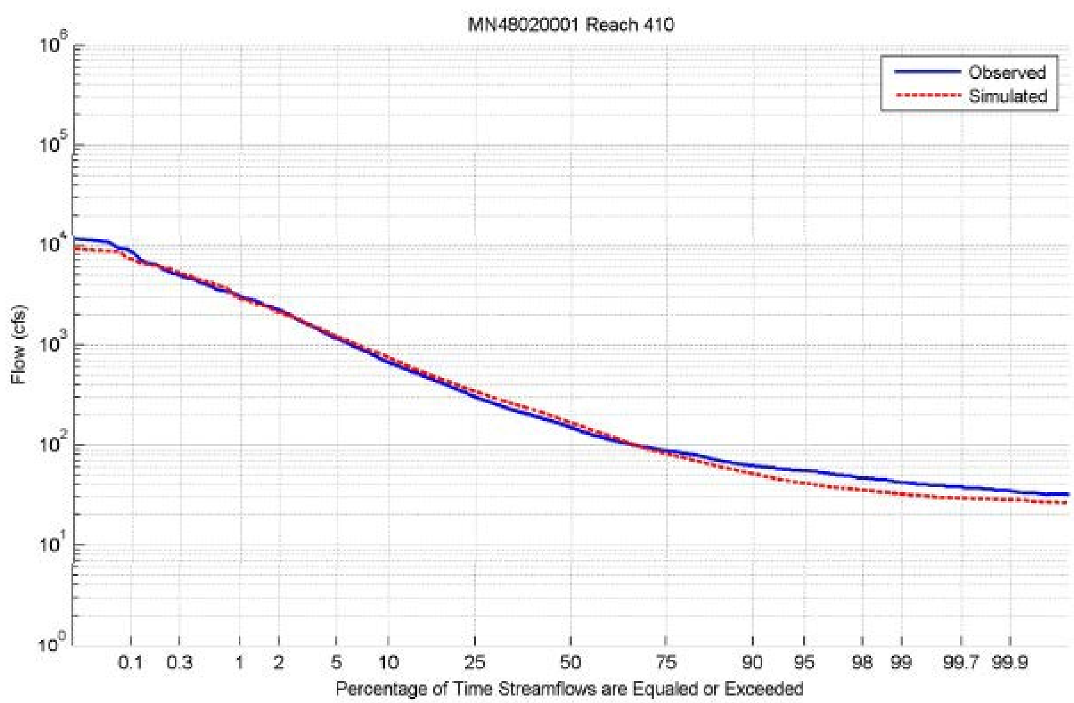
Dissolved Oxygen, Biochemical Oxygen Demand, Nutrients, and Temperature

As with sediment calibration, other water quality parameters were initially set based on regional HSPF models previously developed. The calibration process then allowed for the adjustment of water quality parameters to match observed data in the watershed. Nitrate and ammonia atmospheric deposition was also included from the National Atmospheric Deposition Program and the Environmental Protection Agency.

Calibration Results

The model was well calibrated for daily and monthly flow and water quality calibration goals based on correlation coefficient, coefficient of determination metrics, and visual comparison of observed and simulated data. Downstream observation points were the primary calibration targets while upstream observations helped to calibration land-segment runoff. *Figure 1* is a flow duration curve comparing observed and simulated flow on the Cedar River at the primary calibration station 1.5 miles south of Austin, MN.

Figure 1: Observed streamflow volume (blue) and HSPF simulated streamflow (red) on the Cedar River, 1.5 miles south of Austin. (Figure produced by RESPEC.)



Cedar SWAT Development

SWAT modeling was developed for the Cedar basin and various subbasins several times (see table at end of appendix). This summary will cover the most recent modeling done by Greg Wilson at Barr Engineering in 2014, which simulated flow and sediment data. Like HSPF, SWAT models are basin-scale; however, SWAT models are largely used for their greater accuracy concerning land-use practice simulation (while HPSF is used for simulation of in-stream fate and transport in conjunction with watershed processes).

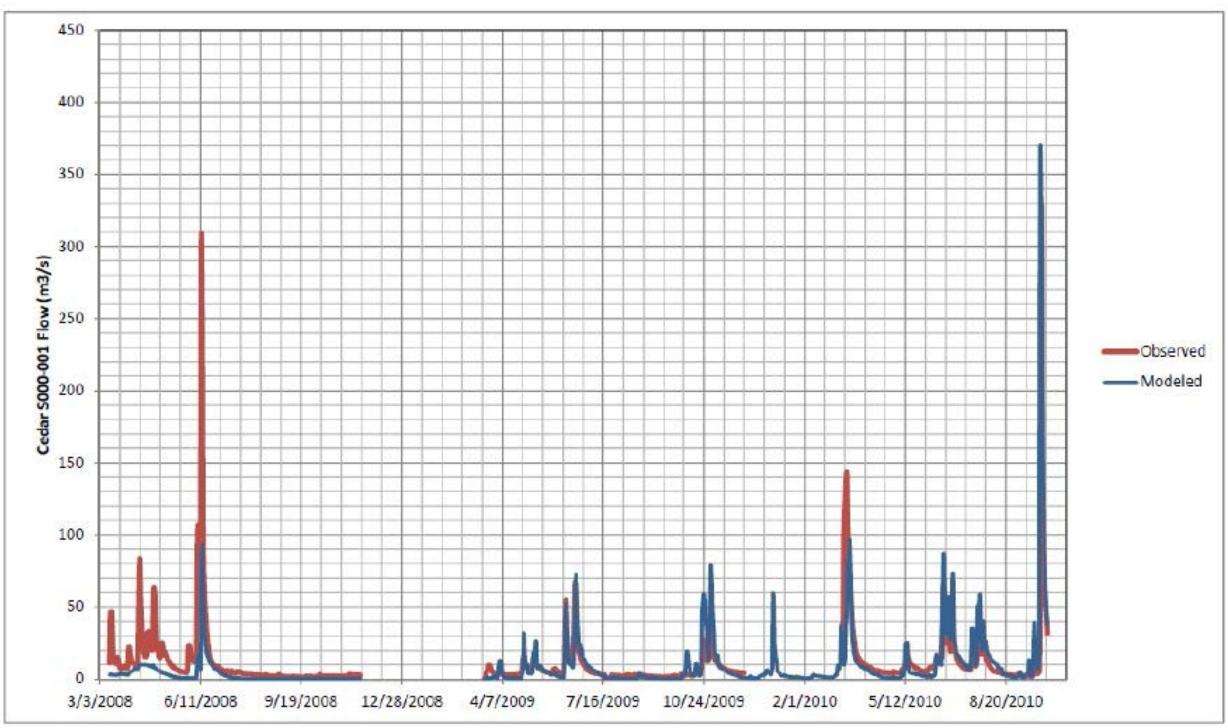
Data Sources

Wilson's Cedar SWAT model was developed as part of the Cedar Turbidity Total Maximum Daily Load (TMDL) study and focused on improved accuracy of the simulation of agriculture BMPs, while also refining simulation of soil tillage and tile flow. Soils data was collected from the Natural Resource Conservation Service (NRCS) data and subwatersheds within the Cedar were delineated using state and federal GIS data and subsequent analysis. The Cedar River Watershed District provided 927 BMP locations throughout the watershed that were then incorporated into the SWAT model.

Calibration

The model was based off observed data from 2008 to 2010 although the simulation period was 11 years. A simulation period longer than the observed data range reduces errors in the simulation while the model is "starting-up" and running through initial conditions of the model period. Flow calibration was considered acceptable, but was challenging during the spring months because the model could not account for snow pack and snowmelt data that affects spring flow values. Lack of snow pack and snowmelt data also influenced the ability to simulate soil moisture data. *Figure 2* compared observed and simulated flow on the Cedar River near Austin.

Figure 2: Observed streamflow volume (red) and SWAT simulated streamflow (blue) on the Cedar near Austin between 2008 and 2010. (Figure produced by Barr.)

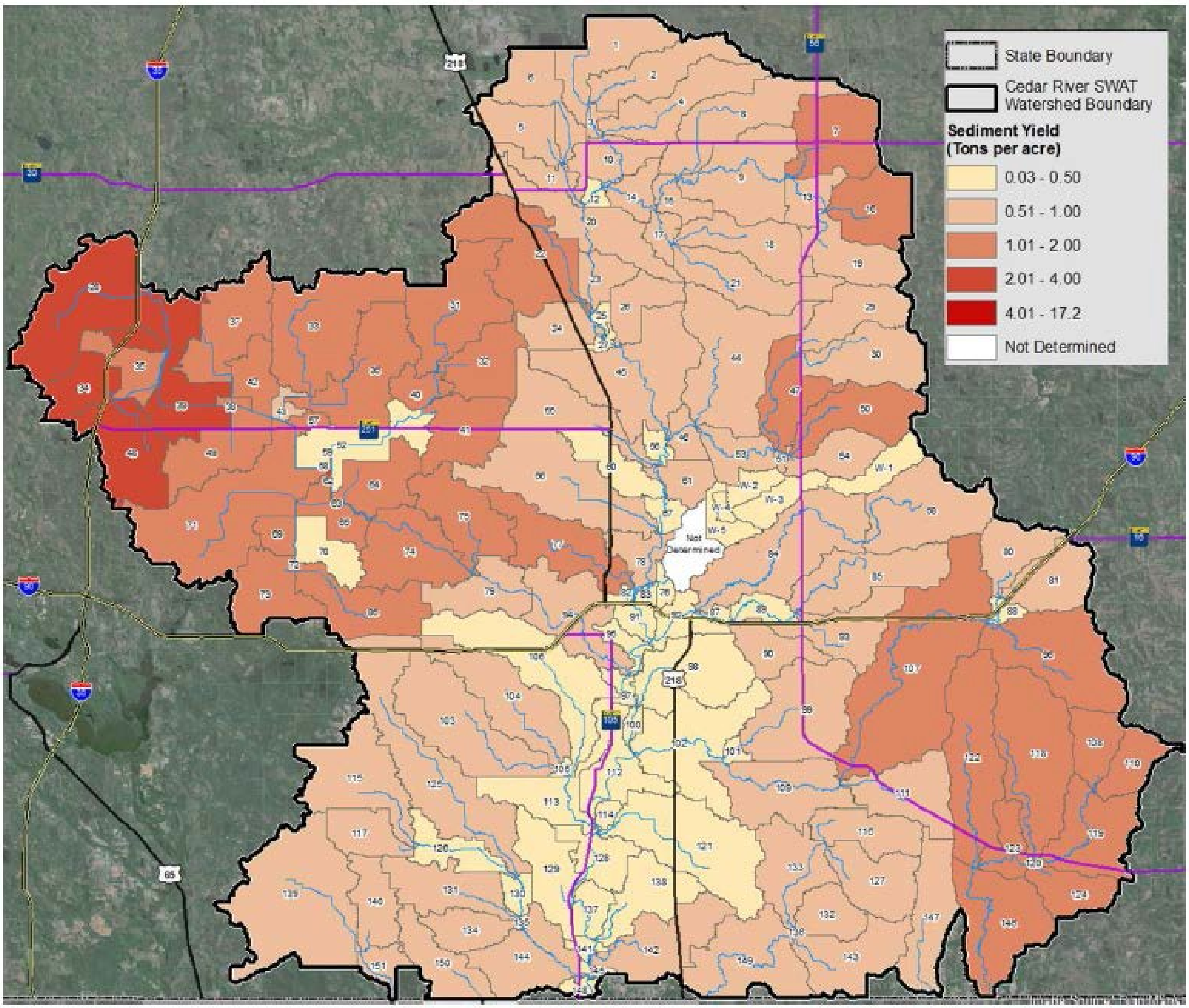


Sediment calibration was also acceptable for further use in watershed management and determined that 45% of the total sediment load was attributed to streambank erosion in the lower Cedar. However, streambank erosion calibration is challenging and is further complicated by algae loads. Additionally, simulations often “miss” large sediment bedload flux.

Results

Figure 3 is an example of data that can be accessed with the SWAT model. This figure demonstrates 2010 land segment sediment yield for subbasins of the Cedar watershed. However, 21 subbasins below did not have a BMP inventory and thus their simulated yields may be greater than observable yields.

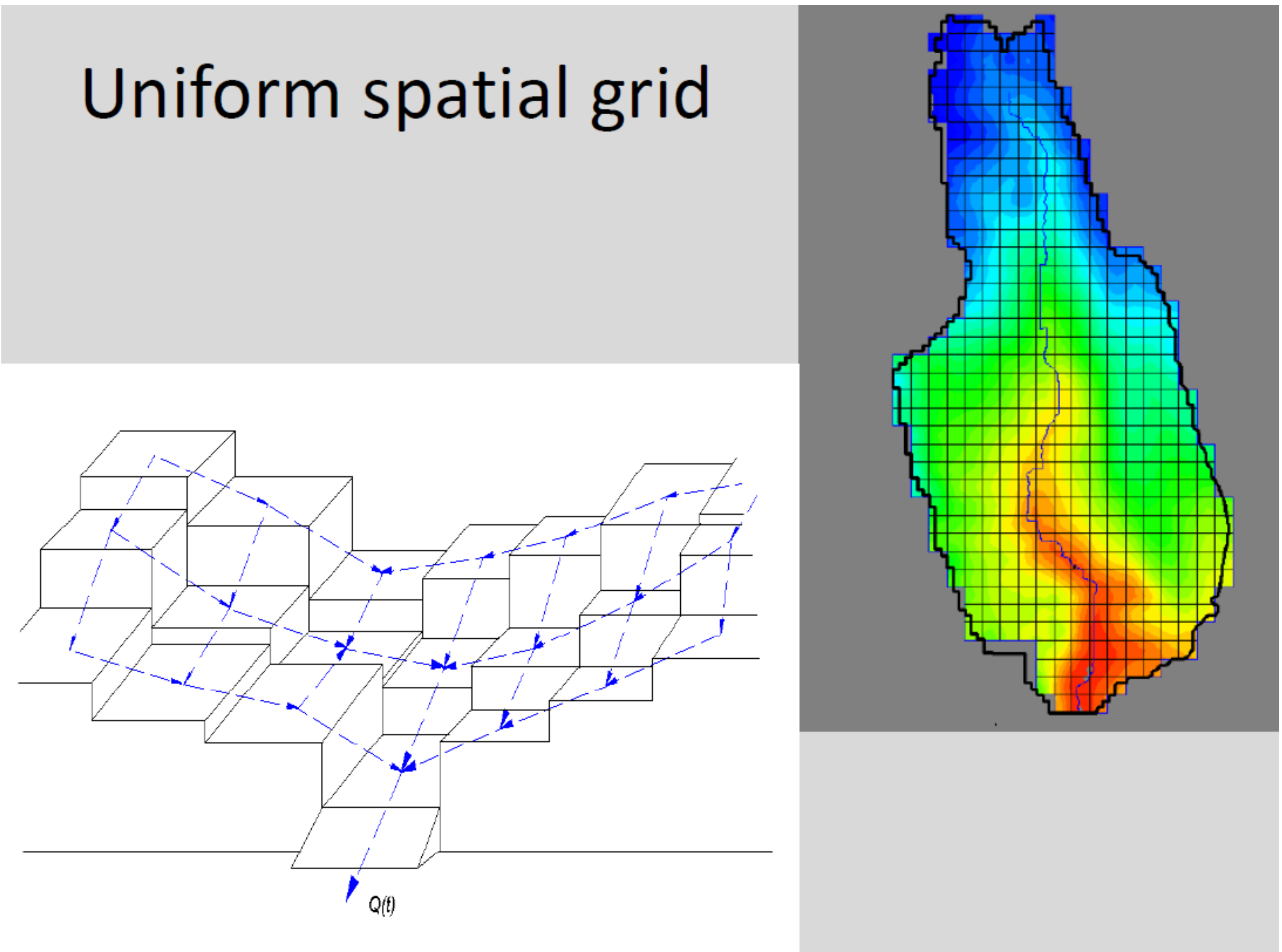
Figure 3: Sediment yield for Cedar subbasins in 2010.



Cedar GSSHA Development

GSSHA is a two- dimensional hydrologic analysis program that uses advanced fluid dynamics techniques to determine the hydrologic response of a watershed in a spatially explicit manner. GSSHA computes water flow from cell to cell using finite difference techniques rather than moving water from cell to stream using lumped parameter transformation techniques. The distributed parameter nature of GSSHA enables the discretization of a watershed to any desired level, which, in turn, facilitates the development of detailed hydrology (e.g., subsurface tile drains) and evaluation of field- scale best management practice implementation upon output variables.

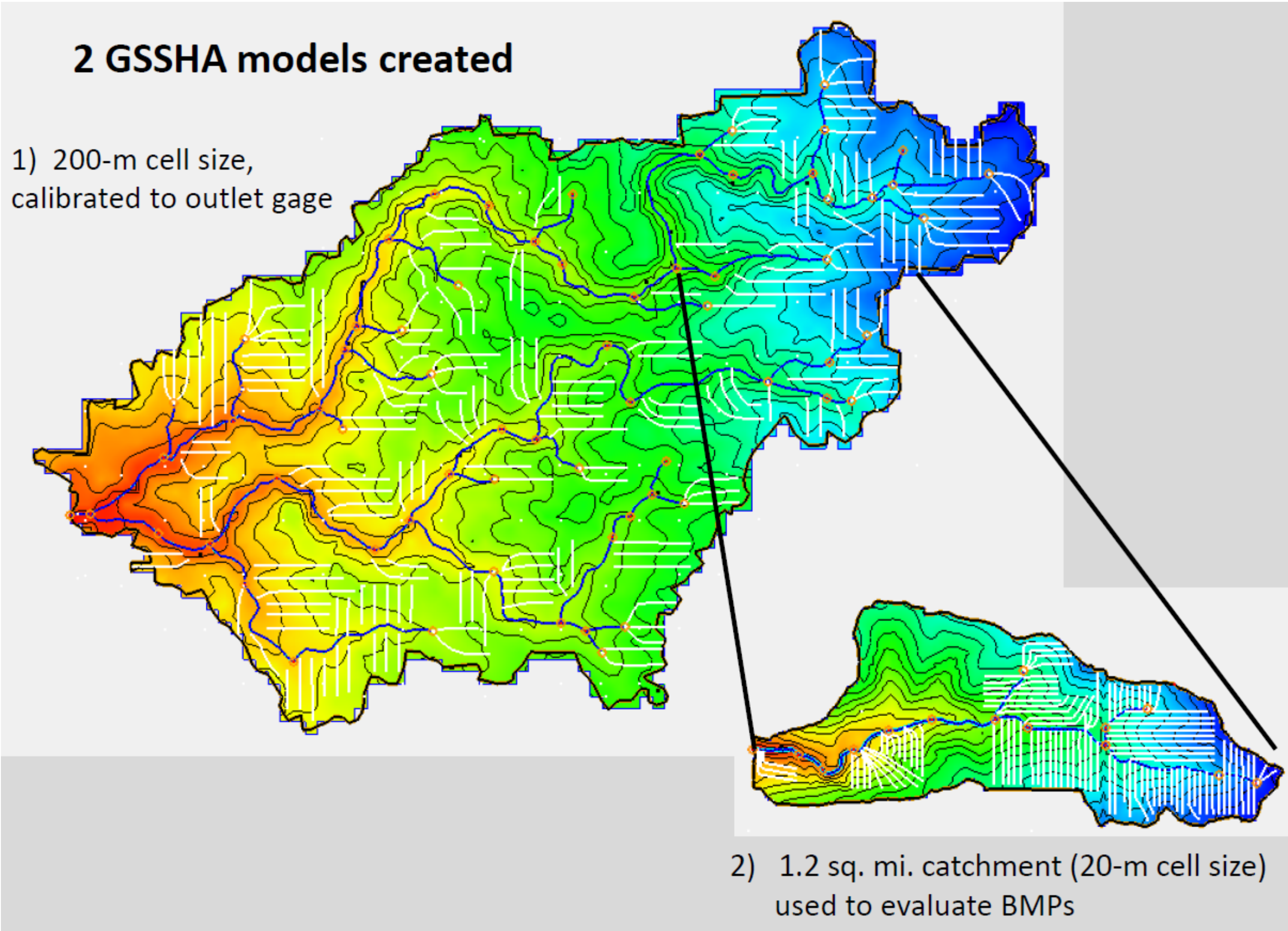
Figure 4. GSSHA conceptual watershed representation.



Model Development

The Dobbins Creek GSSHA model was developed by modeling staff at the Minnesota Department of Natural Resources office in St. Paul, MN. Given the distributed- parameter nature of GSSHA, application was limited to the Dobbins Creek HUC12 watershed to calibrate model flow rate, with a smaller subcatchment discretized to a finer scale to evaluate the effect of various BMP implementation scenarios upon outlet peak flow rates.

Figure 5. Dobbins Creek HUC12 GSSHA domains.



Calibration
The growing season simulated flow rate was compared to a Minnesota DNR flow gauge for the period of 2009 through 2014. The model showed excellent timing of peak flow rates, with some over and under prediction of peak flow.

Figure 6. Observed versus modeled flow, 2009-2014.

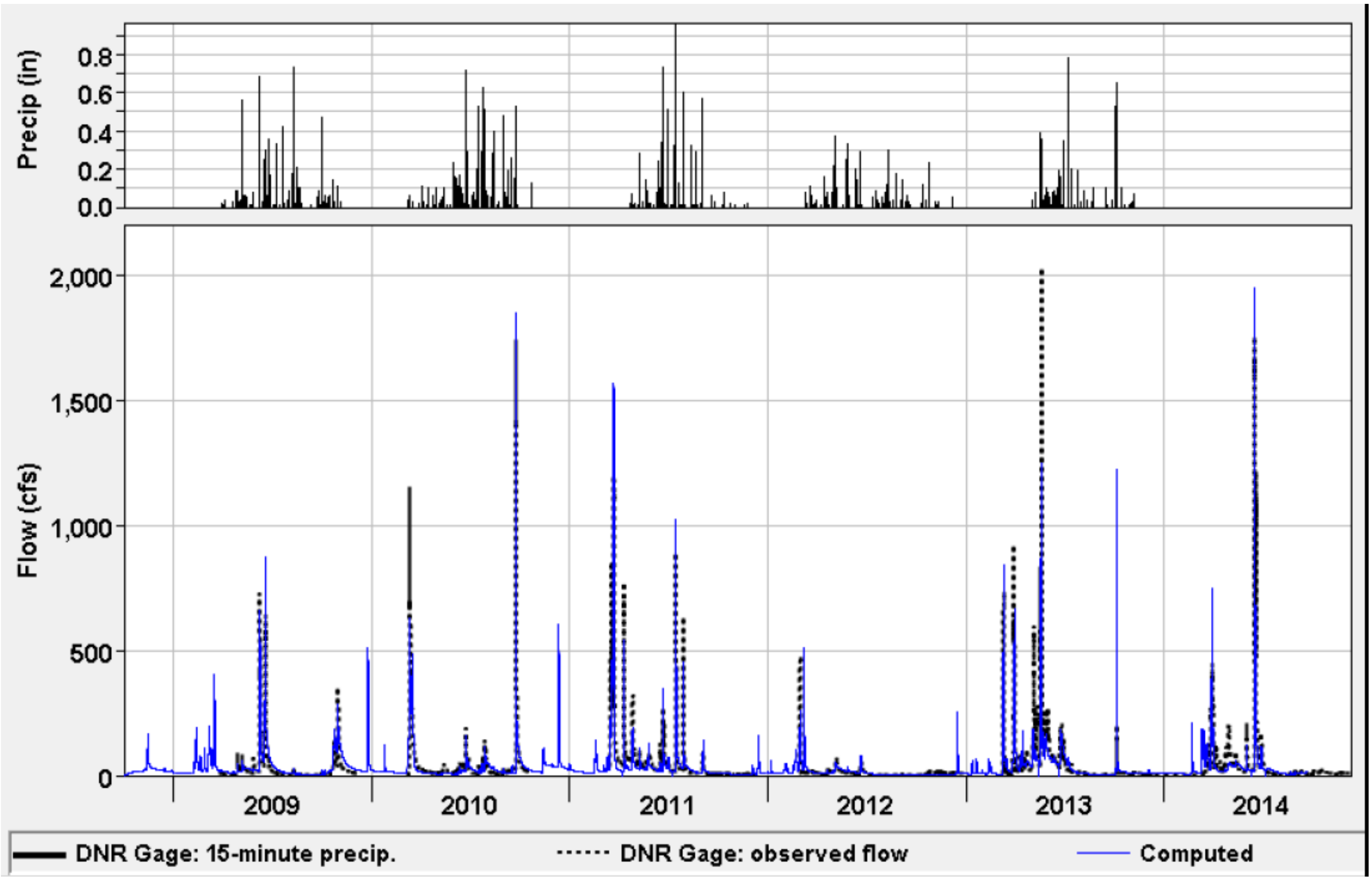
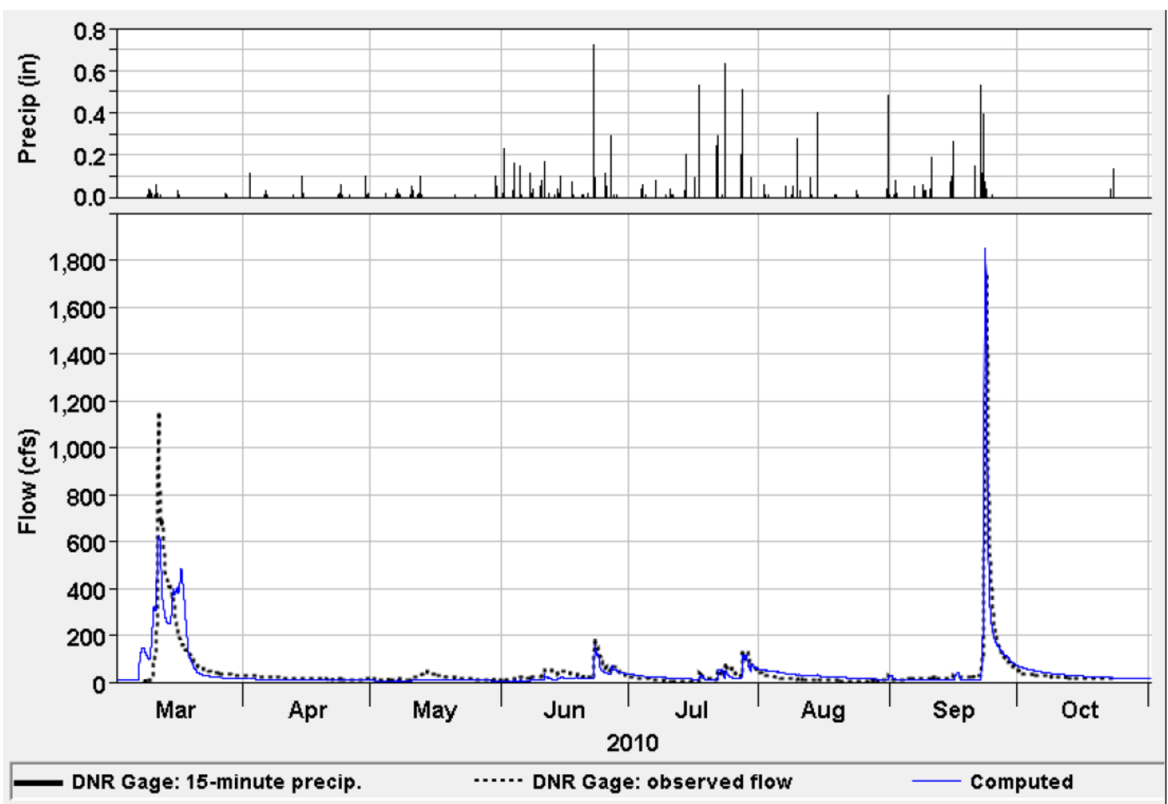


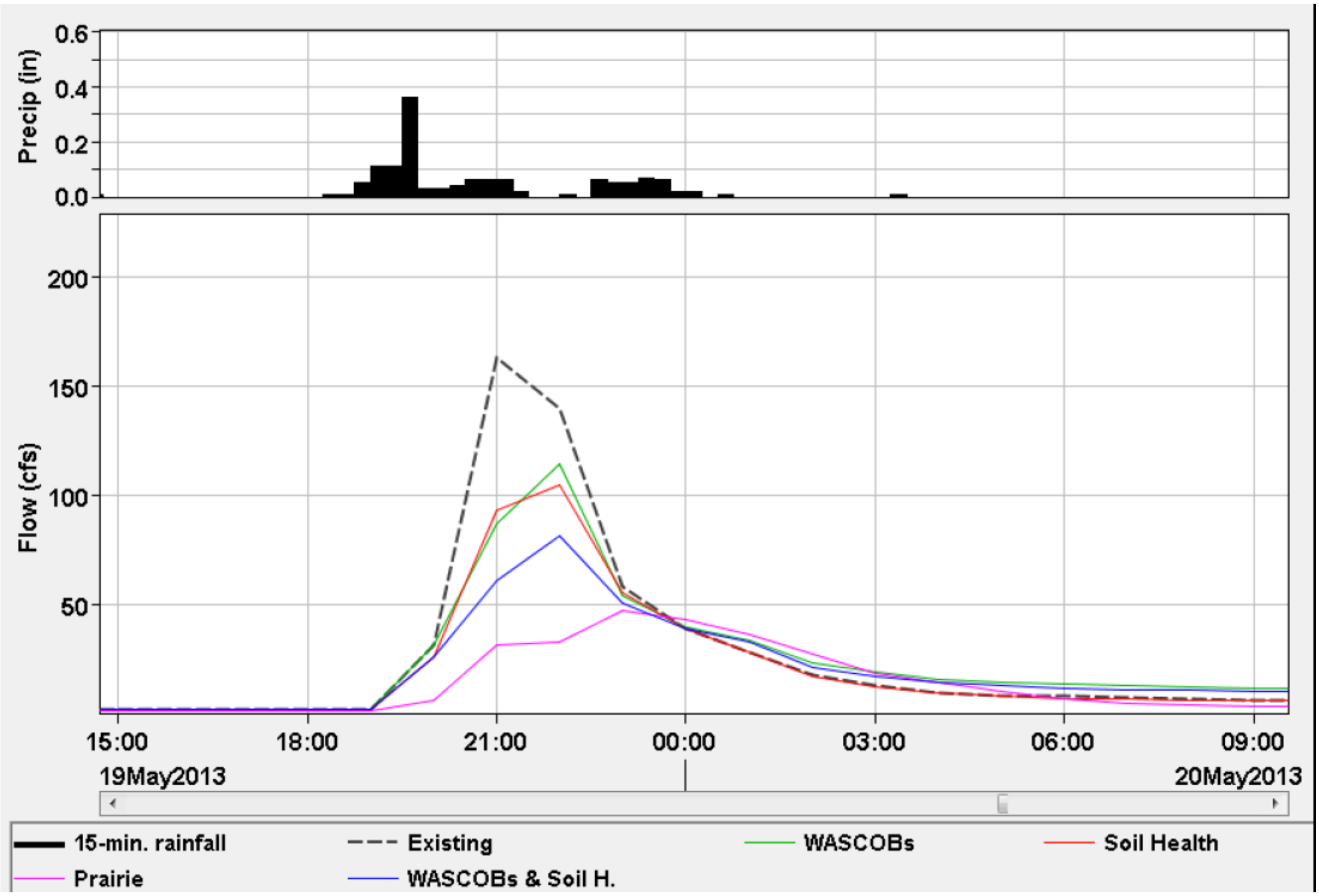
Figure 7. Observed versus modeled flow rate, March-October, 2010.



Results

Scenarios included the evaluation of conservation tillage, water and sediment control basins, improved soil health, and buffer strips. A scenario of the return to pre-settlement prairie landuse was also modeled. The detailed soil and landuse simulation ability of GSSHA resulted in illustrating significant reductions in peak flow rate due to the implementation of BMPs.

Figure 8. Storm event flow reductions due to BMP implementation.



Cedar Watershed Model Summary

The following table summarizes the various watershed models completed in the Cedar River watershed.

Cedar River Watershed Modeling Tools

Large- Scale Models

Model	Developer	Scale (acres)	Why	Applications	Approx. Cost
Soil and Water Assessment Tool (SWAT) (2012 and 2013)	Barr Eng. Co. (for MPCA)	536,000	TMDL	Targeting – subsheds	$75,000
Storm Water Management Model (SWMM-XP) (2013)	Barr Eng. Co. (For WDs)	379,520	WD Mgt.	Permitting, wetlands	$140,000
Hydraulic Simulation Program Fortran (HSPF) (2014)	RESPEC (for MPCA)	582,400	WRAP	Permitting, strategies	$65,000

Small-Scaled Models

Model	Developer	Scale	Why	Applications	Approx. Cost
Ag Nonpoint Source Pollution Model (AGNPS) (1993) Dobbins Creek Subshed	Bonestroo (for SWCD)	24,000 acres	Source ID	Reservoir improvement	$18,000
Soil and Water Assessment Tool (SWAT) (2010) Dobbins Creek Subshed	HDR (for SWCD)	24,000 acres	BMP scenarios	Ag watershed restoration	
Gridded Surface Subsurface Hydrologic Analysis GSSHA, (2015) Dobbins Creek Subshed	MDNR (for WD, SWCD)	24,000 acres	Hydrology	Targeted watershed impl.	Staff Time
Gridded SWAT (2014) in Roberts Creek and Otter Creek	Barr Eng. Co. (for MPCA)	< 1000 acres	BMP scenarios	Sediment targeting Restoration and Protection Pilots	$21,000

2009 Upper Cedar River Watershed Summary

Annual Crop	Total Points	Conservation Tillage (greater than 30% residue) No-Till	Ridge-Till	Mulch-Till	=	Total Conservation Tillage	Other Tillage Practices (15-30% residue) Reduce - Till	(0-15% residue) Intensive Till
Corn	311	2	3	2		7	70	234
Small Grain (Spring)	9	9	0	0		9	0	0
Small Grain (Fall)	0	0	0	0		0	0	0
Soybeans (Full Season)	245	42	2	4		48	106	91
Soybeans (Double-Cropped)	0	0	0	0		0	0	0
Cotton	0	0	0	0		0	0	0
Grain Sorghum	0	0	0	0		0	0	0
Forage Crops	0	0	0	0		0	0	0
Other Crops	2	0	1	0		1	1	0
Total Points	**567**	**53**	**6**	**6**		**65**	**177**	**325**

Perm. Pasture	3
Fallow	1
Forages	0
Conservation Reserve Program	13

Annual Crop	Total Points	Conservation Tillage (greater than 30% residue) No-Till	Ridge-Till	Mulch-Till	=	Total Conservation Tillage	Other Tillage Practices (15-30% residue) Reduce - Till	(0-15% residue) Intensive Till
Corn	311	0.6%	1.0%	0.6%		2.3%	22.5%	75.2%
Small Grain (Spring)	9	100.0%	0.0%	0.0%		100.0%	0.0%	0.0%
Small Grain (Fall)	0	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%
Soybeans (Full Season)	245	17.1%	0.8%	1.6%		19.6%	43.3%	37.1%
Soybeans (Double-Cropped)	0	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%
Cotton	0	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%
Grain Sorghum	0	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%
Forage Crops	0	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%
Other Crops	2	0.0%	50.0%	0.0%		50.0%	50.0%	0.0%
Total Points	**567**	**9.3%**	**1.1%**	**1.1%**		**11.5%**	**31.2%**	**57.3%**

2010 Upper Cedar River Watershed Summary

Annual Crop	Total Points	Conservation Tillage (greater than 30% residue) No-Till	Ridge-Till	Mulch-Till	=	Total Conservation Tillage	Other Tillage Practices (15-30% residue) Reduce - Till	(0-15% residue) Intensive Till
Corn	285	2	0	12		14	65	206
Small Grain (Spring)	25	19	0	0		19	2	4
Small Grain (Fall)	0	0	0	0		0	0	0
Soybeans (Full Season)	222	20	0	52		72	105	45
Soybeans (Double-Cropped)	0	0	0	0		0	0	0
Cotton	0	0	0	0		0	0	0
Grain Sorghum	0	0	0	0		0	0	0
Forage Crops	0	0	0	0		0	0	0
Other Crops	9	0	0	0		0	1	8
Total Points	**541**	**41**	**0**	**64**	**0**	**105**	**173**	**263**

Perm. Pasture	6
Fallow	2
Forages	0
Conservation Reserve Program	17

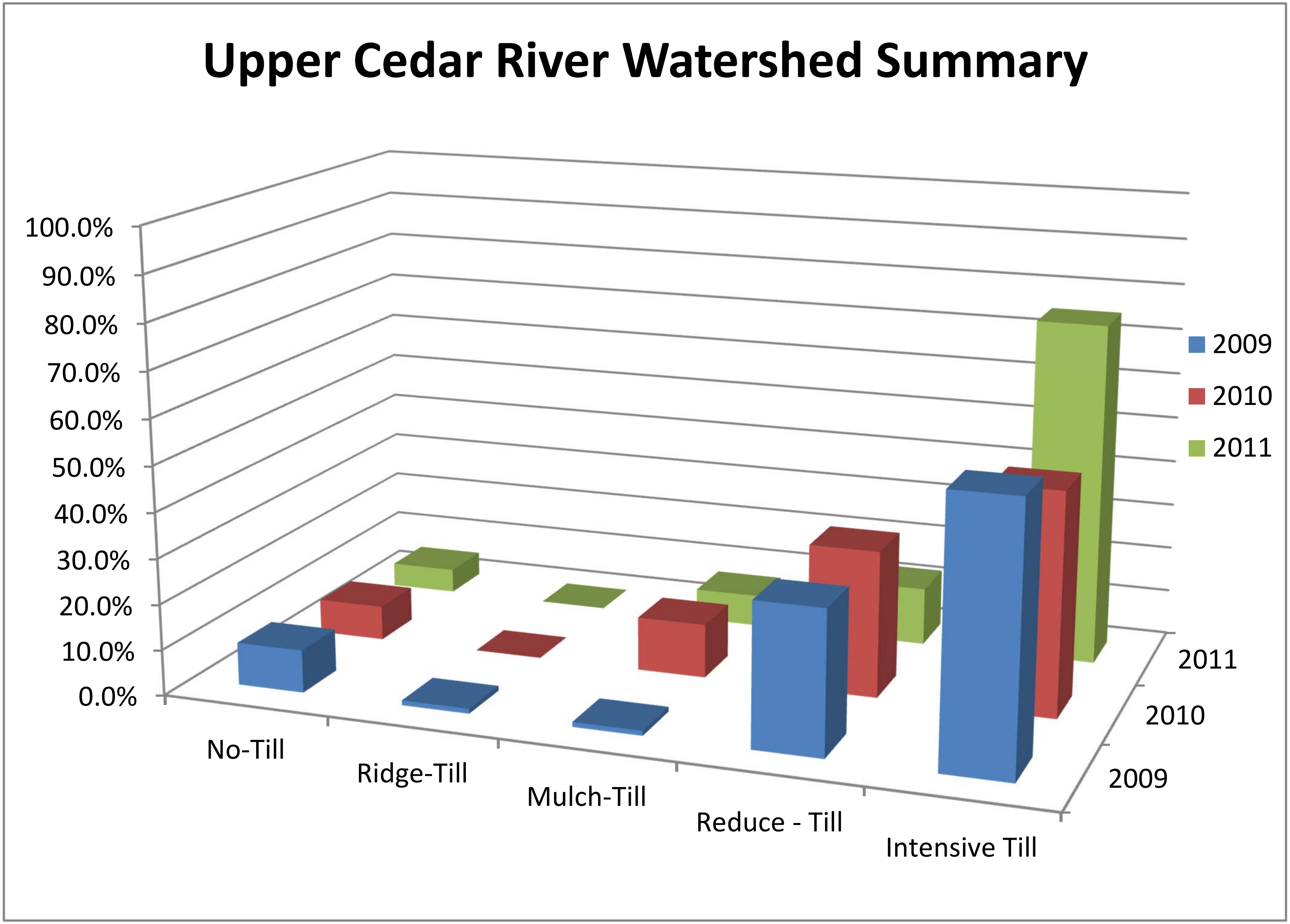
Annual Crop	Total Points	Conservation Tillage (greater than 30% residue) No-Till	Ridge-Till	Mulch-Till	=	Total Conservation Tillage	Other Tillage Practices (15-30% residue) Reduce - Till	(0-15% residue) Intensive Till
Corn	285	0.7%	0.0%	4.2%		4.9%	22.8%	72.3%
Small Grain (Spring)	25	76.0%	0.0%	0.0%		76.0%	8.0%	16.0%
Small Grain (Fall)	0	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%
Soybeans (Full Season)	222	9.0%	0.0%	23.4%		32.4%	47.3%	20.3%
Soybeans (Double-Cropped)	0	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%
Cotton	0	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%
Grain Sorghum	0	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%
Forage Crops	0	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%
Other Crops	9	0.0%	0.0%	0.0%		0.0%	11.1%	88.9%
Total Points	**541**	**7.6%**	**0.0%**	**11.8%**		**19.4%**	**32.0%**	**48.6%**

2011 Upper Cedar River Watershed Summary

Annual Crop	Total Points	Conservation Tillage (greater than 30% residue) No-Till	Ridge-Till	Mulch-Till	=	Total Conservation Tillage	Other Tillage Practices (15-30% residue) Reduce - Till	(0-15% residue) Intensive Till
Corn	323	3	0	5		8	19	296
Small Grain (Spring)	10	10	0	0		10	0	0
Small Grain (Fall)	0	0	0	0		0	0	0
Soybeans (Full Season)	205	16	0	33		49	50	106
Soybeans (Double-Cropped)	0	0	0	0		0	0	0
Cotton	0	0	0	0		0	0	0
Grain Sorghum	0	0	0	0		0	0	0
Forage Crops	0	0	0	0		0	0	0
Other Crops	6	0	0	0		0	0	6
Total Points	**544**	**29**	**0**	**38**	**0**	**67**	**69**	**408**

Perm. Pasture	5
Fallow	6
Forages	
Conservation Reserve Program	17

Annual Crop	Total Points	Conservation Tillage (greater than 30% residue) No-Till	Ridge-Till	Mulch-Till	=	Total Conservation Tillage	Other Tillage Practices (15-30% residue) Reduce - Till	(0-15% residue) Intensive Till
Corn	323	0.9%		1.5%		2.5%	5.9%	91.6%
Small Grain (Spring)	10	100.0%		0.0%		100.0%	0.0%	0.0%
Small Grain (Fall)	0	0.0%		0.0%		0.0%	0.0%	0.0%
Soybeans (Full Season)	205	7.8%		16.1%		23.9%	24.4%	51.7%
Soybeans (Double-Cropped)	0	0.0%		0.0%		0.0%	0.0%	0.0%
Cotton	0	0.0%		0.0%		0.0%	0.0%	0.0%
Grain Sorghum	0	0.0%		0.0%		0.0%	0.0%	0.0%
Forage Crops	0	0.0%		0.0%		0.0%	0.0%	0.0%
Other Crops	6	0.0%		0.0%		0.0%	0.0%	100.0%
Total Points	**544**	**5.3%**	**0.0%**	**7.0%**		**12.3%**	**12.7%**	**75.0%**


Upper Cedar River Watershed Summary
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
No-Till
Ridge-Till
Mulch-Till
Reduce - Till
Intensive Till
2009
2010
2011
2011
2010
2009

Appendix I

Cedar River Watershed TMDL Report

Impaired waters, Cedar River Watershed – with no required TMDL

Reach Name	AUID (07080201-)	Designated Use	Basis for Aquatic: MIBI	Basis for Aquatic: FIBI	Non-pollutant stressors	Note (below table)
Cedar River, Turtle Cr. to Rose Cr.	515	AQL	X		Habitat and bedded sediments; Nitrate; DO	1
Cedar River, Middle Fork	530	AQL	X		Habitat and bedded sediments; Nitrate; DO	1
Cedar River, Woodbury Cr. to MN/IA border	516	AQL				2
Unnamed Creek, Roberts Creek HUC	534	AQL	X	X	Habitat and bedded sediments; Nitrate; Flow Alternation	
Roberts Creek	506	AQL	X	X	Habitat and bedded sediments; Nitrate; Flow Alternation	
Unnamed Creek, Roberts Creek HUC	593	AQL	X		Habitat and bedded sediments; Nitrate; Flow Alternation	
Roberts Creek	504	AQL	X		Habitat and bedded sediments; Nitrate; Flow Alternation	Phosphorus stressor
Unnamed Creek, Cedar River, West Fork HUC	591	AQL	X		Flow Alteration	
Unnamed Creek, Upper Cedar River HUC	577	AQL	X		Habitat and bedded sediments; Nitrate; Flow Alternation	
Unnamed Creek, Turtle Creek HUC	547	AQL	X		Flow Alteration	
Schwerin Creek	523	AQL	X		Habitat and bedded sediments; Nitrate; Flow Alternation	
Woodson Creek	554	AQL	X	X	Habitat and bedded sediments; Flow Alternation	
Unnamed Creek, Little Cedar HUC	520	AQL	X		Habitat and bedded sediments; Nitrate; Flow Alternation	
Unnamed Creek, Little Cedar HUC	519	AQL	X		Habitat and bedded sediments; Nitrate; Flow Alternation	

Notes (by number)

1. DO stressor not conclusively linked to phosphorus load, and no TMDLs for other stressors
2. List correction for Total Suspended Solids