Credit River Protection Plan

June 2011

Prepared for the Minnesota Pollution Control Agency

By the Scott Watershed Management Organization

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Project Partners

Black Dog Watershed Management Organization
City of Lakeville
City of Prior Lake
City of Savage
Credit River Township
Minnesota Pollution Control Agency
Metropolitan Council Environmental Services
Scott County
Scott Soil and Water Conservation District
Scott Watershed Management Organization
Spring Lake Township
Three Rivers Park District

June 2011

Executive Summary

In 2002, the Credit River was listed as impaired for aquatic life based on turbidity. This project was designed to collect data necessary to assess the watershed for potential sources causing the impairment, and to develop an implementation strategy to achieve the required water quality standards. The end product initially was a turbidity Total Maximum Daily Load (TMDL) study. However, over the course of the study it became clear that the river did not exceed the turbidity standard, and the end product was changed to a Protection Plan.

The Protection Plan was developed considering existing management efforts and an assessment of management gaps. The Plan includes the continuation of existing management efforts, as well as new efforts designed to either focus on unique aspects of the Credit River, or fill gaps in existing efforts. The Plan is organized by subwatersheds, and the following implementation elements:

- Programs
- Projects
- Regulations
- Monitoring
- Inventory and Assessment

One of the main elements of the Plan is targeting the Technical Assistance and Cost Share (TACS) Program of the Scott Watershed Management Organization (WMO). The WMO maintains a docket that describes eligible practices for the TACs program - updating the docket annually. The Plan builds on this by identifying practices for more active marketing within each subwatershed. Another key element is an education and technical assistance program for small acreage (hobby farm) land owners.

Funding for implementation will largely come through existing programs of the Scott WMO. The WMO anticipates taking advantage of grants to the extent possible. Results of implementation, monitoring data and trends analysis will be periodically evaluated over the years. The Plan has been adopted by the Scott WMO as part of it Comprehensive Water Resource Management Plan and will be updated as part of the next WMO Plan update in 2019.

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Appendix D. Credit River Fluvial Geomorphic Assessment
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Section 1: Introduction

Project Summary

In 2002, the Credit River (Figure 1-1) was listed on the 303(d) list of impaired waters for aquatic life based on turbidity data. This project was designed to collect additional data necessary for modeling and assessing the watershed for potential sources causing the impairment, and the development of an implementation strategy to achieve the required water quality standards. The end product was originally intended to be a complete turbidity Total Maximum Daily Load (TMDL) study for the Credit River sufficient for EPA approval. However, over the course of the data collection effort it became clear that river may not in fact exceed the turbidity standard (see Section 3 and Appendix A). A request to de-list the river was submitted by Scott County in the spring of 2010. The MPCA concurred with the delisting and completed the transparency document to delist in late summer of 2010 (Appendix A). Delisting will not be official until the USEPA approves the 2012 303(d) list. However, with delisting there is no longer a need to complete a TMDL. Therefore, the end product of this study was changed to the completion of a Protection Plan. This Protection Plan assesses the efficacy of the existing stormwater programs and development standards, and lays out an approach for protecting the unimpaired condition.

Project efforts consisted of the completion of six tasks as follows:

- Task 1: Data Collection
- Task 2: TSS and Turbidity Relationship
- Task 3: Special Studies
- Task 4: Model Development
- Task 5: Solution Identification
- Task 6: Stakeholder Involvement
- Task 7: Technical Report
- Task 8: Final Report
- Task 9: Project Management

Details regarding the various tasks are provided in the Project Workplan attached as Appendix B.

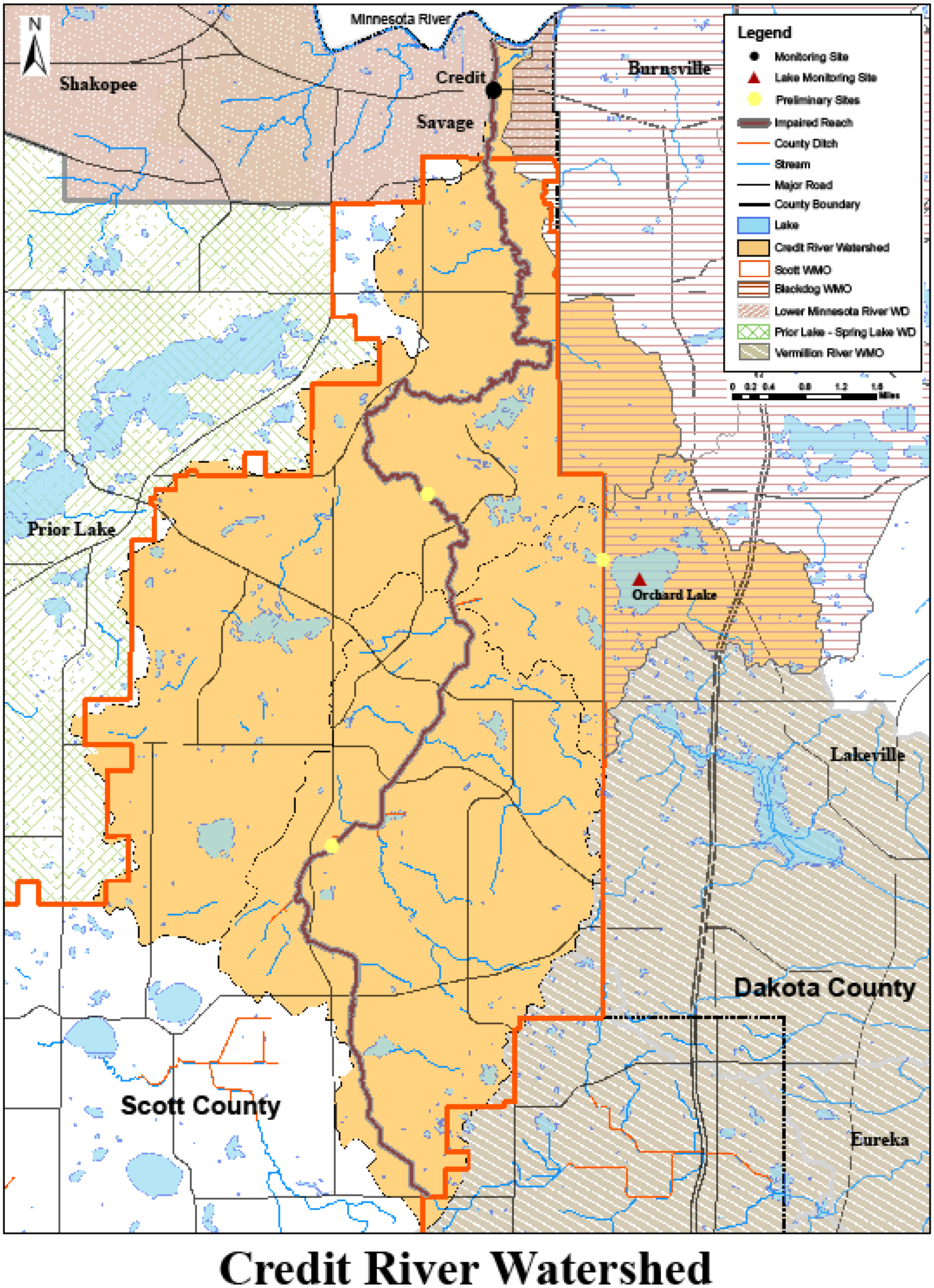


Figure 1-1. Credit River Watershed

This document is the product of Tasks 7 and 8. A summary of Task 6: Stakeholder Involvement efforts is provided at the end of Section 1. Results of Tasks 1, 2 and 3 are presented in Section 2 Watershed Characterization and Section 3 Water Quality Assessment. Results of Task 4: Model Development are presented in the Technical Modeling Report attached as Appendix C. Results of Task 5: Solution Identification are the subject of Section 4 Evaluation of Existing Management Efforts. Section 5 presents the Implementation Plan.

Problem Statement

In 2002, Credit River was listed on Minnesota's 303(d) List of Impaired Waters for aquatic life impairment due to turbidity. However, as stated in the Project Summary above data collected over the course of this planning effort found that the standard was not exceeded. Data is not sufficient to determine whether meeting the standard currently is due to improvements that have reduced turbidity since the initial listing, or to improvements in calculation methods, or to periods of lower flow which suspends less sediment. What is known is that depending on how the percent exceedence is calculated observed values are close to the standard. It is, therefore, important to have a Protection Plan detailing how to continue to meet the standard. Generally it is less expensive to protect an unimpaired water than it is to restore one.

Turbidity is commonly measured in Nephelometric Turbidity Units (NTU). Turbidity is a unit of measurement quantifying the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles. The suspended organic and inorganic particles scatter light in the water column making the water appear cloudy. The scattering of light increases with greater suspended load. Turbidity limits light penetration which further inhibits healthy plant growth on the river bottom. Turbidity may cause aquatic organisms to have trouble finding food, may affect gill function, and the sediment associated with turbidity may cause spawning beds to be covered. Suspended organic and inorganic particles also transport nutrients from lands to receiving waters causing eutrophication.

The water quality standard for turbidity in class 2B waters is 25 NTUs. A surrogate variable must be used to complete a TMDL given that turbidity is not a quantitative measure of mass (concentration). Total suspended solids (TSS) measurements are often used as a surrogate for turbidity. MCES ran statistical analyses using its TSS and turbidity data and determined that there is a strong relationship between TSS and turbidity. The project used TSS as a surrogate for turbidity.

The Scott WMO and other local units of government in the Credit River Watershed have Comprehensive Water Resource Management Plans and Local Water Plans, and several have Storm Water Pollution Prevention Plans that include efforts for controlling erosion and sedimentation. However, there has not been a systematic analysis of these efforts to determine whether they are sufficient to preserve the unimpaired condition of the river. The focal point of this document is an assessment of those existing management efforts (Section 4) and the identification of gaps. Filling these gaps along with the continuation of existing efforts becomes the substance of the Implementation Plan presented as Section 5.

Resource Goals

Overall resource goals are driven by Goal 2: Surface Water Quality as articulated in the Scott WMO approved Comprehensive Water Resources Management Plan (Scott WMO Plan) adopted June 2009"

"To Protect and Improve Surface Water Quality"

There are seven policies and a number of strategies articulated in the WMO Plan for achieving this goal. The following policies and strategies are advanced by this Protection Plan. They include:

- Policy 2.1: Promote a Sustainable System of Buffers and Green Infrastructure
- Policy 2.3: Address Impaired Waters and Improve Water Quality
    - Strategy 2.3.2: Targeted Project Implementation and Capital Improvements
- Policy 2.4: Improve Understanding of Water Quality
    - Strategy 2.4.1: Complete Diagnostic Studies/TMDLs leading to targeted implementation and monitoring
    - Strategy 2.4.2: Monitoring and Assessment Tools Development

Benchmarking of these goals and strategies from the Scott WMO Plan will occur as part of the normal plan revision and update process of the Scott WMO. The Scott WMO anticipates revising and updating its plan about once every two years.

Specific numeric goals for the Credit River are based on water quality standard for turbidity in class 2B waters which is 25 NTU. The MPCA considers a 2B water to be impaired if more the 10% of observations exceed 25 NTU. Total suspended solids (TSS) concentrations are also used as a surrogate for turbidity. A turbidity level of 25 NTU has been found by the MCES to be equivalent to 139 mg/L TSS in the Credit River (MCES, 2009). Therefore, having less than 10% of TSS concentrations less than 139 mg/L is also a goal. One important consideration in determining achievement of these goals is consideration of the distribution of the turbidity and TSS data, and whether that distribution reflects a uniform distribution over time, or whether it is biased by flow. This issue and potential sample distribution biases are discussed in more detail in Section 4.

Public and Stakeholder Involvement

Public and stakeholder involvement consisted of three efforts:

1. Updates and discussions by the **Scott WMO Watershed Planning Commission**. The Watershed Planning Commission is a citizen advisory commission that advises the Scott County/WMO Board. Updates were provided as a regular agenda topic at the monthly meetings of the Watershed Planning Commission, and special discussions of the project were held at the following monthly meetings: April, May and June 2011.
2. Updates and discussions by a **Technical Advisory Committee** established for the project. The Technical Advisory Committee was comprised of City and Township staff/officials in the watershed, Scott WMO and Scott SWCD personnel, and State agency (MPCA and MnDNR personnel). Scott WMO personnel also provided updates to the Black Dog Watershed Management Organization.
3. Involvement of the **general public and riparian property owners**. The general public was kept informed and involved through articles in the Scott WMO annual report and with an open house meeting held in April, 2011. Journalists also produced new paper articles regarding the results of the study and the delisting decision. Riparian property owners were invited to be become involved through a series of workshops on riparian zone management. The WMO sponsored two workshops in 2009 in an ongoing effort to encourage green infrastructure and a buffered environment for Scott County, and in response to the multiple riparian revegetation potential projects identified by the

geomorphic assessment completed in 2007. The first workshop titled *Introduction to Riparian Buffers*, targeted property owners directly on the Credit River. Nine homeowners attended and learned the importance of riparian buffers and functions for stream water quality. The second workshop focused on designing a riparian buffer depending on the landowner goals and needs. Installation and maintenance requirements were also covered. The workshops produced two streambank stabilization cost share projects.

Section 2: Watershed Characterization

This section summarizes the physical characteristics of the Credit River Watershed in terms of topography and drainage, soils, geomorphology, aquatic habitat and wetlands, and land use. Most watershed characteristics are documented in GIS coverages. Maps of some of these characteristics are included in this Plan where the visual image provides meaningful information.

Topography and Drainage

The Credit River is a post glacial stream originating near New Market, MN and draining north through farmland and developed land in the city of Savage (Figures 2-1 and 2-2). The Credit River drains an area of 59 square miles (15,360 hectares), emptying into the Minnesota River just north of State Highway 13 in the City of Savage.

The valley form of the Credit River is rooted in its post-glacial history. The Credit River drains through steep slopes at the edges of the Minnesota River valley, but the steep slopes defining the edges of Bloomington and Eden Prairie to the north and Savage and Shakopee to the south, were not formed by the erosion of the Minnesota River. As the Des Moines lobe of glacial ice retreated around 10,000 years ago, it left behind moraine and till deposits many feet thick across Minnesota. Behind the southernmost terminal moraine, Glacial Lake Agassiz covered a large region from the Brownsville area north to central Manitoba. As the lake overtopped the southern moraine, flowing water (Glacial River Warren) cut down into the deposited glacial sediments and carved out the valley now occupied by the Minnesota River. Smaller drainages began to develop after River Warren subsided, and those tributaries to the Minnesota River began to erode the valley walls left behind by the glacial river. The Credit River is one of these drainages, and steep valley walls are typical in the middle section of the Credit, where the channel has cut down into the old glacial river terrace.

There is little variation in topography through much of the Credit River watershed. The topographic features that are present are primarily glacial in origin, such as moraines, eskers, kames, and kettle ponds. Kettle ponds are the main feature that has resulted in the occurrence of

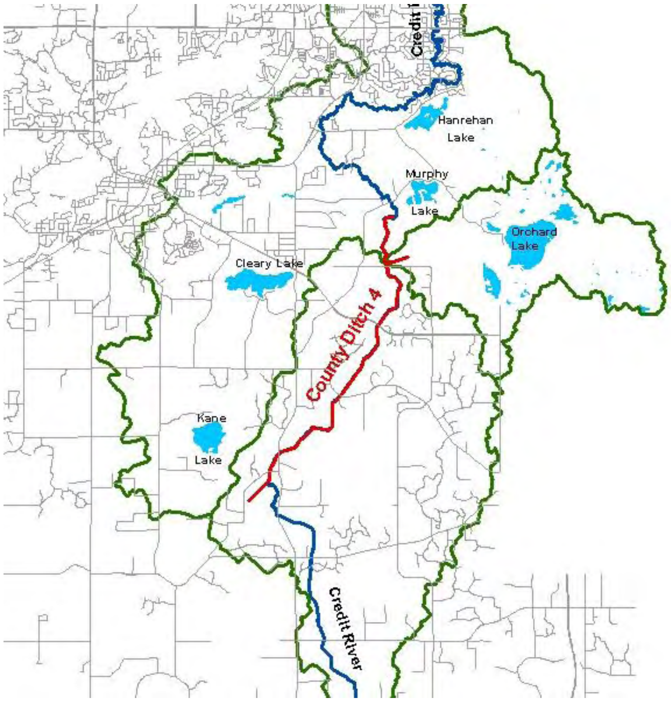


Figure 2-1. County Ditch 4 location along main stem of Credit River

landlocked bodies of water. There are many small ponds in the Credit River watershed that have no overland outlet and are dependent on precipitation to maintain their form and function.

County Ditch 4 was established in 1914 which starts just south of C.R. 75 near Murphy Lake and ends at Flag Trail, it spans a 6 mile stretch of the river covering a large portion of the main stem of the river (Figure 2-1). The most recent maintenance activity on the ditch was in 2008 when 1,800 feet of the ditch was cleaned out. The cleanout matched the 1984 and 1914 original depth.

Approximately 3,800 acres of the Credit watershed are located in Dakota County. The Orchard Lake subwatershed is approximately 2,400 acres, this area is mostly developed and consists primarily of residential areas. Water quality sampling results through the CAMP program show that the lake water has improved over the last few years and should not be contributing a large pollutant load to the river.

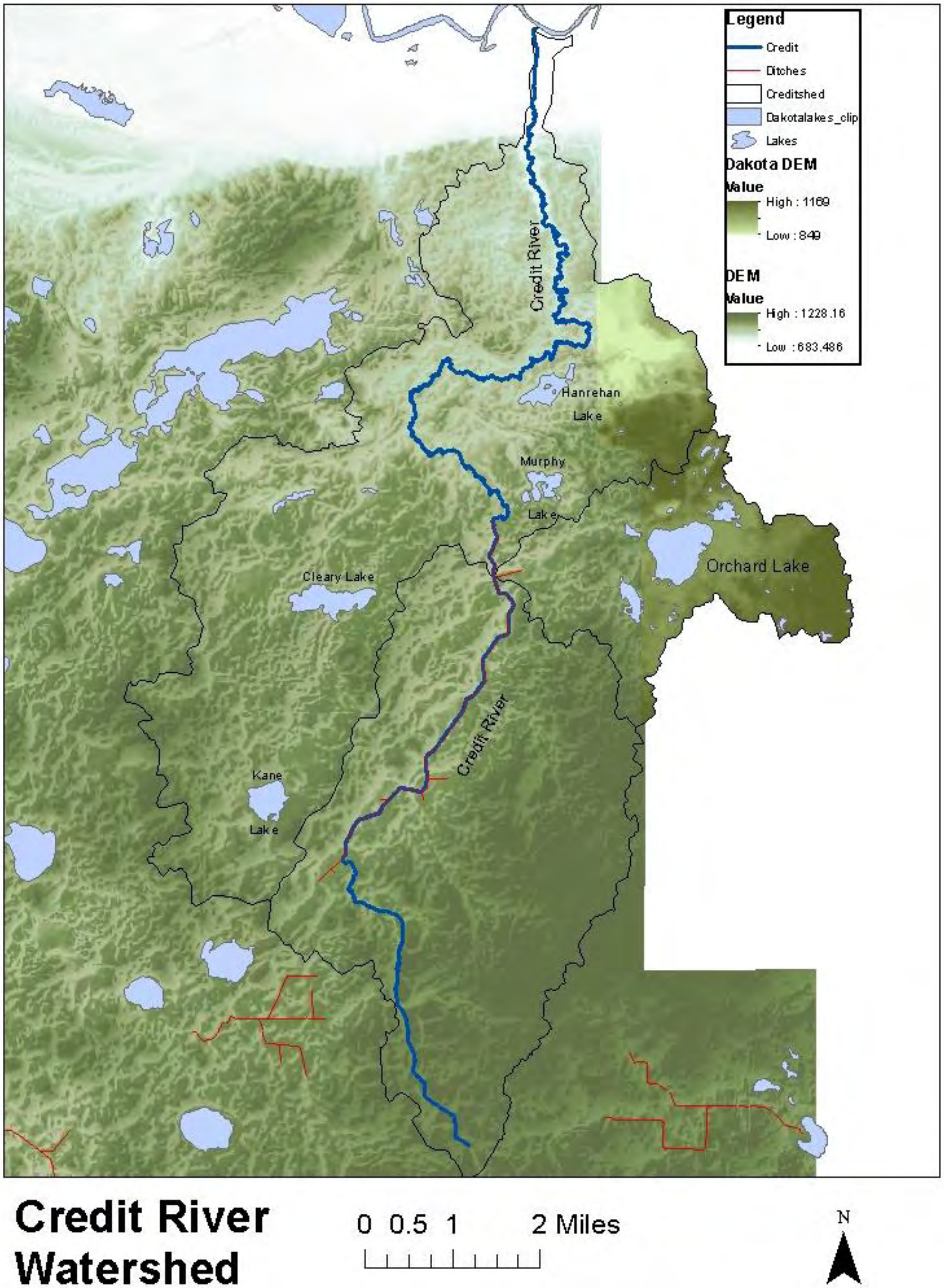


Figure 2-2. Credit River Watershed Topography & Drainage

Channels in the Credit River watershed are low-gradient for much of their lengths (Figure 2-3). The only sections with distinctly higher gradients are when the main stem is flowing through the steep bluffs of the old glacial river terrace discussed earlier. This occurs from the headwaters to approximately 18 miles downstream, the elevation of the channel decreases 250 feet. In the final 4 miles to the Minnesota River, the channel elevation drops an additional 175 feet. Most of the decrease in elevation in the first 18 miles occurs within three, 1 to 2-mile steeper sections, surrounded by a cumulative 12 miles of relatively low-gradient channel (Figure 2-3).

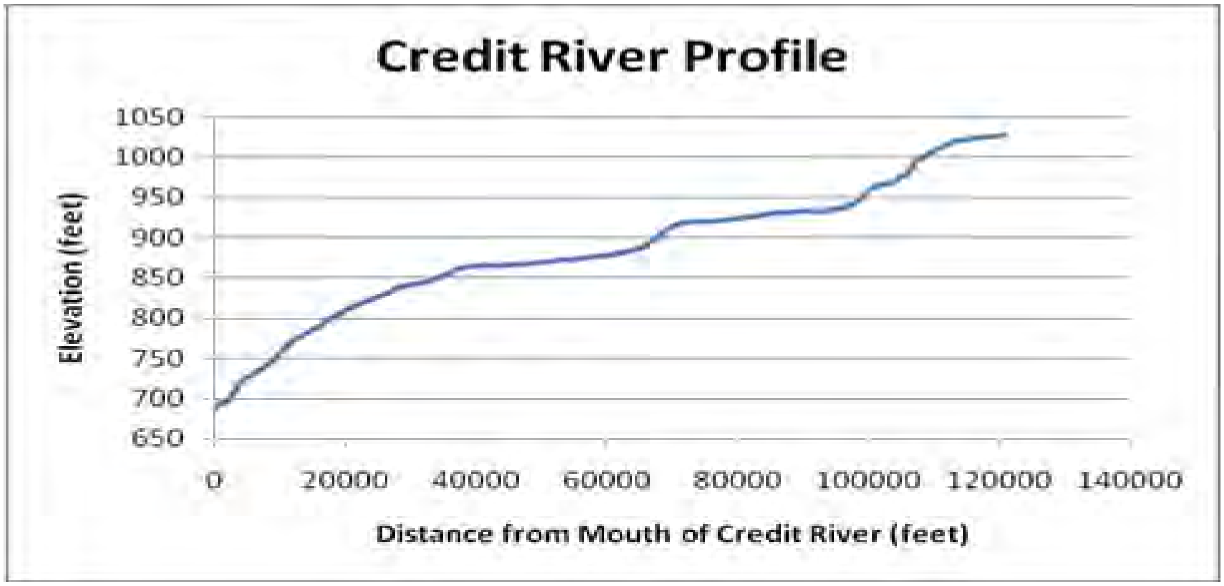


Figure 2-3. Credit River Profile (The profile is extracted from the HEC-RAS model created for the Credit River DFIRM study by Tetra Tech, dated February, 2010. Survey work to complete the model was completed in 2006).

The low-gradient sections of channel are located in wide, flat alluvial valleys; if these channels have not been straightened and ditched into agricultural channels, they are often in the form of wetland channels. The Credit River has eroded a narrow alluvial valley through the bluff near the Minnesota River with steep valley walls that rise more than 75 feet in some areas.

Geology and Soils

The bedrock in Credit River watershed is comprised primarily of Lower Ordovician crystalline dolostone, sandstone, and shale of the Prairie du Chien Group (Runkel and Mossler, 2006). Surficially, Scott County is dominated by glacial till, except along the Minnesota River, which is composed of alluvium and terrace deposits (Lusardi, 2006). The abundance of glacial till, a material with low permeability because of the silts and clays that fill in the spaces between the larger grains, provides a layer of protection for the county's aquifers that lie in the sedimentary rock below. The soils along the Credit River are composed primarily of silt, with some sand, clay and loam intermixed. The predominance of silt is due to the glacial activity during the Pleistocene Epoch that ended approximately 10,000 years ago. Glacial lobes from the northeast and northwest carried sand and clay-based drift from Lake Superior, northwestern Minnesota, northeastern North Dakota, and Manitoba, and deposited it in southern Minnesota, including throughout Scott County.

Credit River watershed has large amounts of highly erodible land (HEL). The headwaters area (subwatershed C68) holds the larger concentration of HEL and cultivated HEL (Figure 2-4). Table 2-1 below tabulates the acres in HEL by subwatershed as well as the amount cultivated. Examination of Table 2-1 and Figure 2-4 shows that most of the HEL is in stable condition as vegetated urban, rural residential land or regional parkland. As discussed in more detail in the subsection on land use (page 2-19), two large regional parks (Cleary Lake and Murphy Hanrehan), are located in the Credit River watershed.

Table 2-1. Highly Erodible Land (HEL) by Subwatershed

		HEL		Cultivated HEL	
Subwatersheds	**Acres in Subwatershed**	**Acres HEL**	**% of Subwatershed**	**Acres Cultivated**	**% of Subwatershed**
Lower Credit	5228	2617	50%	0	0
154 (Cleary)	13033	3081	24%	478	4%
Orchard Lake	3411	1597	47%	87	3%
C68 (Upper Credit)	6351	4931	78%	1075	17%

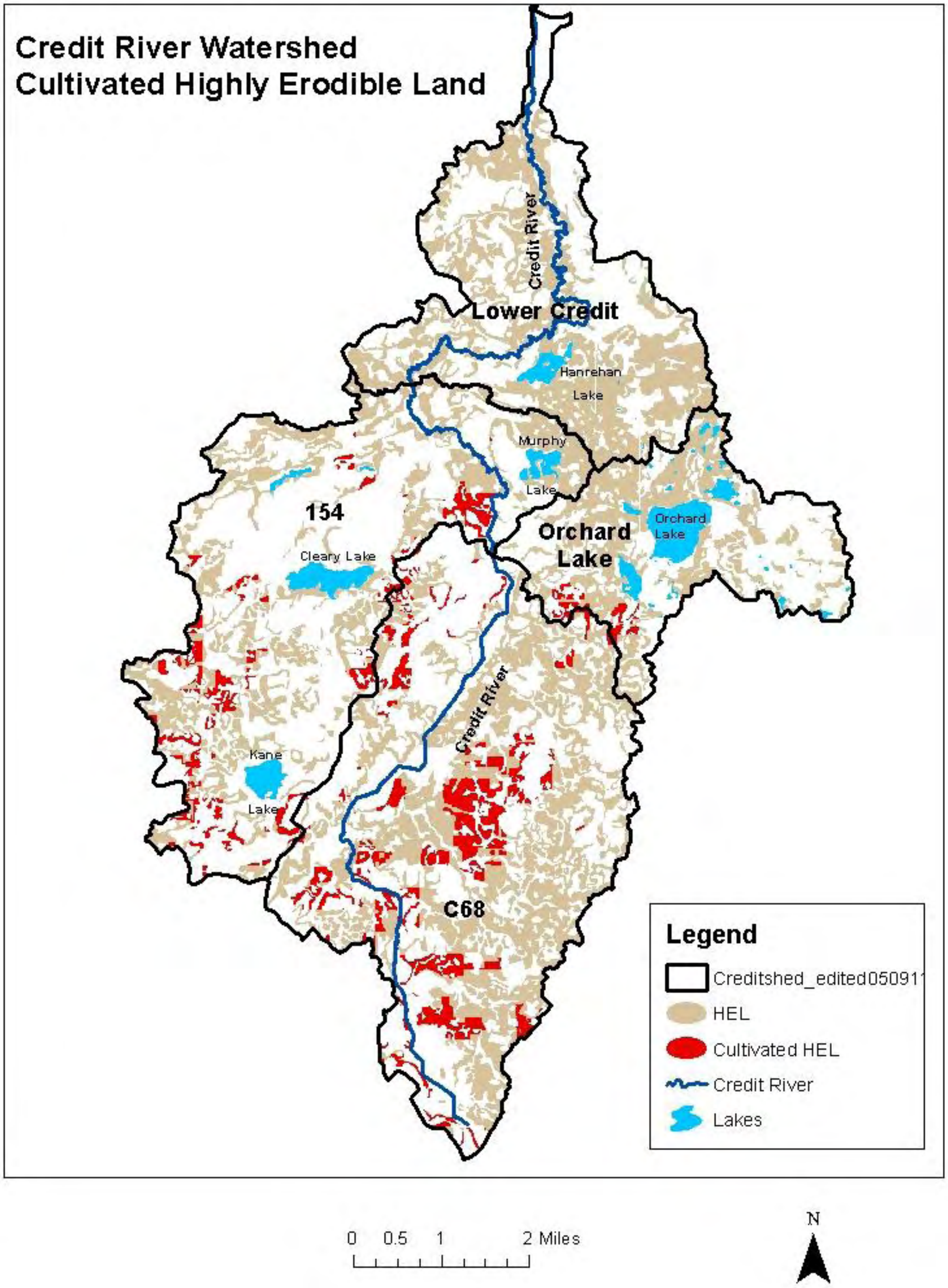


Figure 2-4. Cultivated Highly Erodible Land (Cultivated Land Source: Minnesota Agricultural Statistics, 2005)

Geomorphology

Scott WMO contracted with Inter-Fluve, Inc. to complete a Fluvial Geomorphic Assessment as part of this project. The assessment was completed since inventories conducted in 2005 and 2006 showed there was streambank erosion along the Credit River. Knowing streams are dynamic systems, it was necessary to find out where the streams were in their evolution to determine where to target corrections, and where to leave the stream to its own evolutionary processes. This section provides a summary of the Inter-Fluve report. Greater detail can be found in the attached report (Appendix C). The summary provides an overview of the principles behind fluvial geomorphology processes, and then provides a brief summary of Credit River reaches and its major tributaries.

Stable stream systems are in a delicate balance between the processes of erosion and deposition. Streams are continually moving sediment eroded from the bed and banks in high velocity areas such as the outside of meander bends and around logs and other stream features. In the slow water at the inside of meander bends or in slack water pools, some of this material is deposited. This process of erosion and deposition results in the migration of rivers within their floodplains. The process by which streams meander slowly within the confines of a floodplain is called *dynamic equilibrium* and refers mainly to this balance of sediment erosion and deposition. Streams typically have reaches that fall along the continuum of degradation (eroding) to aggradation (depositing) at any one time in the scale of channel evolution. The location and character of these individual reaches changes over time. When a stream channel is in equilibrium, it may move across the floodplain, erode and deposit sediment, but general planform geometry, cross-sectional shape, and slope remain relatively constant over human lifetimes (Figure 2-5).

Figure 2-5: Erosion along a cut bank and deposition on a point bar on Sand Creek

Many factors can influence this equilibrium by altering the input of sediment and the quantity and timing of runoff. These factors include soil types, rooted vegetation that holds soil in place, flashy flows that erode banks, large rainfall events, or increased sediment pollution that deposits sand or other fine sediment in the channel. When a channel loses its equilibrium due to changes in flood power and sediment load, it can in turn lose essential habitat features. The fundamental channel shaping variables in balance are slope, discharge (amount of water flow per time), sediment load and sediment size. The balance between the amount/size of sediment and slope/discharge is manifested in complex drainage networks of streams with a specific channel area and slope. Any change in one of the variables can upset this balance, resulting in either aggradation or degradation of the channel.

For example, given that the primary function of streams and rivers is to transport water and sediment downstream, changes in land use that affect the timing of runoff can affect sediment transport. Clearing of watershed forests, row crop agriculture and urban development cause storm water to reach the stream channel faster, and increase the peak discharge in the stream. Geomorphically, an increase in stream discharge might result in an increase in channel incision or lateral bank erosion, and hence, the amount of sediment being transported downstream. These changes may also result in changes to channel slope. The stream's evolution will persist until it reaches a new dynamic equilibrium between the channel shape, slope, and pattern (Schumm 1984, Leopold et al. 1964).

In a comprehensive geomorphic assessment, the physical attributes of the stream channel are measured to determine its geomorphic stability and the processes and factors responsible for that instability. Parameters typically measured include channel planform and profile, cross-section geometry, slope, watershed land use, riparian vegetation, soils, and channel erosion.

The Credit River is in remarkably good geomorphic condition for a stream near a major urban center with expanding development and a headwater area dominated by row crop agriculture. The following provides a reach by reach summary of the conditions observed in the river. Figure 2-6 shows the locations of the reaches.

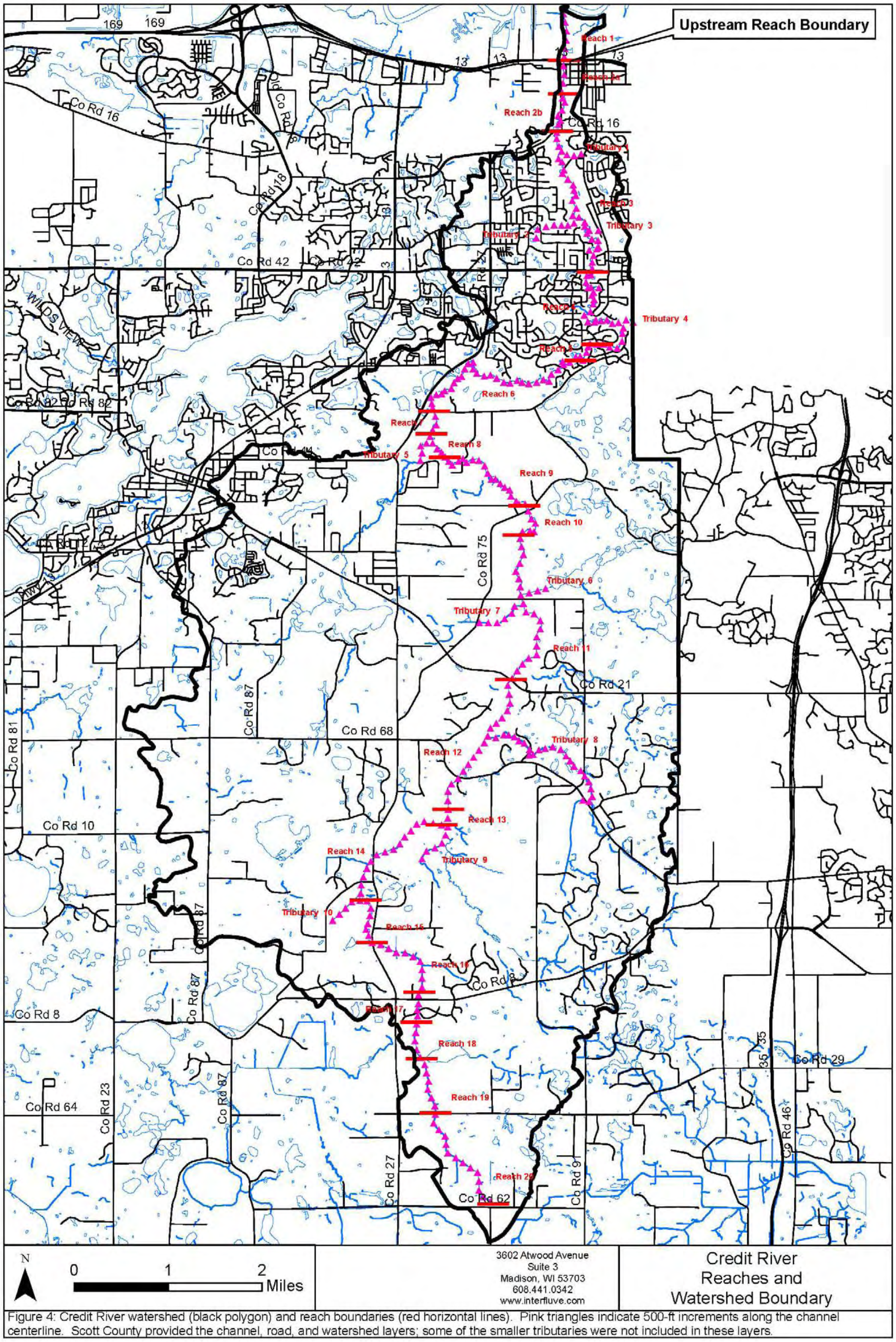


Figure 2-6. Reach Designations for the Credit River

Reach 1

This is a straightened reach with high levee walls on both banks. The original channel meandered northeast at approximately station 2200, but this is completely cut off and the current channel flows north to the Minnesota River with few meanders and little habitat. The channel is wide, and there are narrow active floodplains with ~50 year old cottonwood trees. The gradient is controlled by bedrock. This appears to be a typical urban channel that has been completely altered in the past, but has since recovered somewhat so that there are active floodplains and the flows are able to mobilize sediment, but has little habitat value because of lack of channel complexity.

Reach 2a

This is a fairly straight, urban channel with limestone bedrock outcropping in the bed of the channel in a few locations. Though it may have been straightened historically, it also might be a naturally straight river due to the steep gradient in this area. Minnows, chub, and crayfish were observed, indicating that there is some reasonable habitat with protected undercut areas caused by bedrock and shade from some overhanging vegetation.

Reach 2b

This is a stable, meandering, reach with fairly good habitat. There is channel complexity with gravel bars, sandy pools, cut banks, and meanders. Though there are dense residential neighborhoods nearby and multiple road crossings, the actual riparian corridor is wooded and mostly free of development, likely due to the steep bluffs on either side of the channel. This has resulted in good habitat conditions with abundant fish and invertebrate species present.

Reach 3

This is a stable, meandering, reach with fairly good habitat. There is channel complexity with gravel bars, sandy pools, cut banks, and meanders. The riparian corridor is wooded and mostly free of development. Hidden Valley Park is located within this reach.

Reach 4

This is a very sinuous reach with good channel complexity and good available aquatic habitat. The riparian corridor is fairly wide with an active floodplain and diverse canopy in many areas, though this corridor is sandwiched between extremely dense residential neighborhoods and developments. Most of the building is on top of the bluff, but those landowners that have built near the stream have generally cleared the natural vegetation and installed riprap to stabilize their banks. Other than these alterations, as well as the occasional small stone dam built by landowners or children, this reach is in pretty good shape. There is a good diversity of aquatic plant and animal species.

Reach 5

This reach is similar to Reach 4 with a sinuous channel maintaining geomorphic and habitat complexity. However, this shorter reach is even more natural with less riprap and less landowner interference, and it maintains greater diversity and abundance of vegetation on the floodplain.

Reach 6

This is a wetland reach, narrow channel, with well-defined and vertical banks, mostly sand bed, few riffles, and little woody debris. This wetland reach is meandering and contains many side channels.

Reach 7 & 8

This is a similar wetland reach to Reach 6, except the valley is narrower and there are trees closer to the channel in some locations. The wetland is narrower, but the dominant vegetation cover is still reed canary grass. There is turf grass managed up to the edge of the channel in a couple of locations.

Reach 9

This is a very sinuous, meandering reach that changes from a wooded reach, to a wide wetland reach, to a narrow valley that is neither wetland nor wooded. There is good channel complexity and a range in percent canopy cover, thus offering a wide range in habitat structure.

Reach 10

A wooded meandering reach with a high degree of canopy cover composed of a diverse number of species. The riparian corridor is relatively wide and the floodplains appear to be active. This channel is in good shape, though dry in most areas during the summer.

Reach 11

This is a straightened, channelized ditch through agriculture fields or through forested corridors surrounded by agriculture fields. High banks about 15 feet high bound both sides of the channel, but the river has constructed very narrow floodplains about 3-4 feet above the bed. This is a homogenous reach, geomorphically, with multiple beaver dams creating the only bit of channel complexity and habitat diversity.

Reach 12

This entire reach is channelized and ditched through a wetland and agriculture fields. There is little good quality aquatic habitat, no channel complexity, and little canopy cover. The railroad berm at station 81500 divides the wetland, forcing all flows through the narrow opening at this location. There is much potential for restoration here, as there is no development in the wetlands, there is room to create a meandering channel similar to the wetland channels downstream.

Reach 13

There is no channel here, only open pond in the middle of a reed canary grass wetland.

Reach 14

This entire reach is a straightened ditch. The channel flows through wetland through the entire reach except a 2,100 foot stretch west of Texas Avenue and south of 196th Street East, where it flows through a slightly forested area surrounded by fields and houses. As with other ditched channels, there is no channel complexity, little canopy cover, and no quality aquatic habitat.

Reach 15

This is a more natural reach than the ditches upstream and downstream, but channel movement is restricted by the road and agriculture fields on either side. Also, there are many private bridges and structures on the channel that restrict fish movement. There is better habitat available in this reach, however, unless species stay in this short reach, there is little chance of survival on either end.

Reach 16

The channel is a constructed ditch through agriculture fields. It has little to no habitat quality.

Reach 17

This is a short reach that is slightly more sinuous and shaded than the reaches on either end. There are new developments bounding both banks, and though there is slightly better habitat with increased channel complexity, this is a pretty disturbed reach also with multiple fish passage barriers.

Reach 18, 19 & 20

The channel is a constructed ditch through agriculture fields. Habitat quality is poor.

Aquatic Habitat and Wetlands

Historically, the Credit River meandered through wetlands and oak savanna (mixture of prairie and forest). Where forest occurred, it provided abundant aquatic habitat with shade cover and woody debris in the form of trunks, large branches and root masses. Large woody debris, as it is commonly known, provides channel complexity as log jams develop, which cause sediment deposition within, and upstream of, the log jam and also cause scouring downstream of the log jam. Log jams can cause the channel to change its course by eroding cut banks or directing flow onto the floodplains, which causes new channels to form. This channel complexity creates habitat complexity that allows a high diversity of macroinvertebrate and fish species to survive. Since most of the forests were eliminated in the late 1800s, many channels have become more stable and less complex, resulting in decreased habitat complexity and decreased biotic diversity. Additionally, the shade provided by forests is no longer available, likely increasing water temperatures and reducing the amount of protection from aerial predators. In some reaches of the Credit River, particularly in the steep reaches near the confluence with the Minnesota River where building could not occur because of the steep valley walls, there are still trees covering the hillsides and floodplains that provide shade and woody debris. However, this is a relatively short reach with no upstream woody

Figure 2-7. A section of the Credit River was first characterized as a wetland channel in 1855, this section later turned into farmland and was essentially dry by 1937. Since then, it has turned back into a wetland that is dominated by reed canary grass.

debris source. Wood that does reach the channel is typically too small to remain in place for very long, and is washed downstream during floods.

The 1855 platmaps indicate that the Credit River channel is sinuous through some of the wetland regions and non-existent in others, indicating that water flowed diffusely through some wetland areas rather than along a distinct channel. Though it can be assumed that these maps do not precisely indicate the planform of the channel, it is likely that sinuous channels were present in some wetlands and not in others. One difference that was observed in the 1937 photographs was the absence of wetlands that appeared to be present on the 1855 platmaps and that are currently present along Credit River (Figure 2-7). The drought that occurred during the 1930s caused many of these wetlands to diminish or disappear and created more potential farmland. The active crop rows visible in the 1937 photographs are still visible within the wetland on the 2003 aerial photographs, but these areas are no longer actively farmed and are generally dominated by reed canary grass (Figure 2-7).

To determine habitat quality in Credit River, Inter-Fluve collected data in a Stream Visual Assessment Protocol (SVAP) form. The SVAP form, developed by the Natural Resource Conservation Service (NRCS). This protocol provides an assessment based primarily on physical conditions within the assessment area such as channel condition, hydrologic alteration, the riparian zone, bank stability, water appearance, nutrient enrichment, barriers to fish movement, instream fish cover, pools, invertebrate habitat, canopy cover, riffle embeddedness, and observed macroinvertebrates. It may not detect some resource problems caused by factors located beyond the area being assessed. The use of higher tier methods is required to more fully assess the ecological condition and to detect problems originating elsewhere in the watershed. Table 2-2 shows how the SVAP score relate to the overall health of the stream. Figure 2-8 graphically displays the results.

Table 2-2. Stream Visual Assessment Protocol Scoring

SVAP	
Score	**Stream Health Rating**
<6	Poor
6.1-7.4	Fair
7.5-8.9	Good
>9.0	Excellent

Conditions are fair throughout the upper watershed with a small section just south of County Road 68 where conditions are poor because the stream is channelized through a small wetland. Stream habitat is good from approximately 165th Street East to just west of Cedarwood Road. Stream habitat then scores excellent from approximately one mile south of 154th Street West to Highway 13 in Savage when it rates good to its confluence with the Minnesota River.

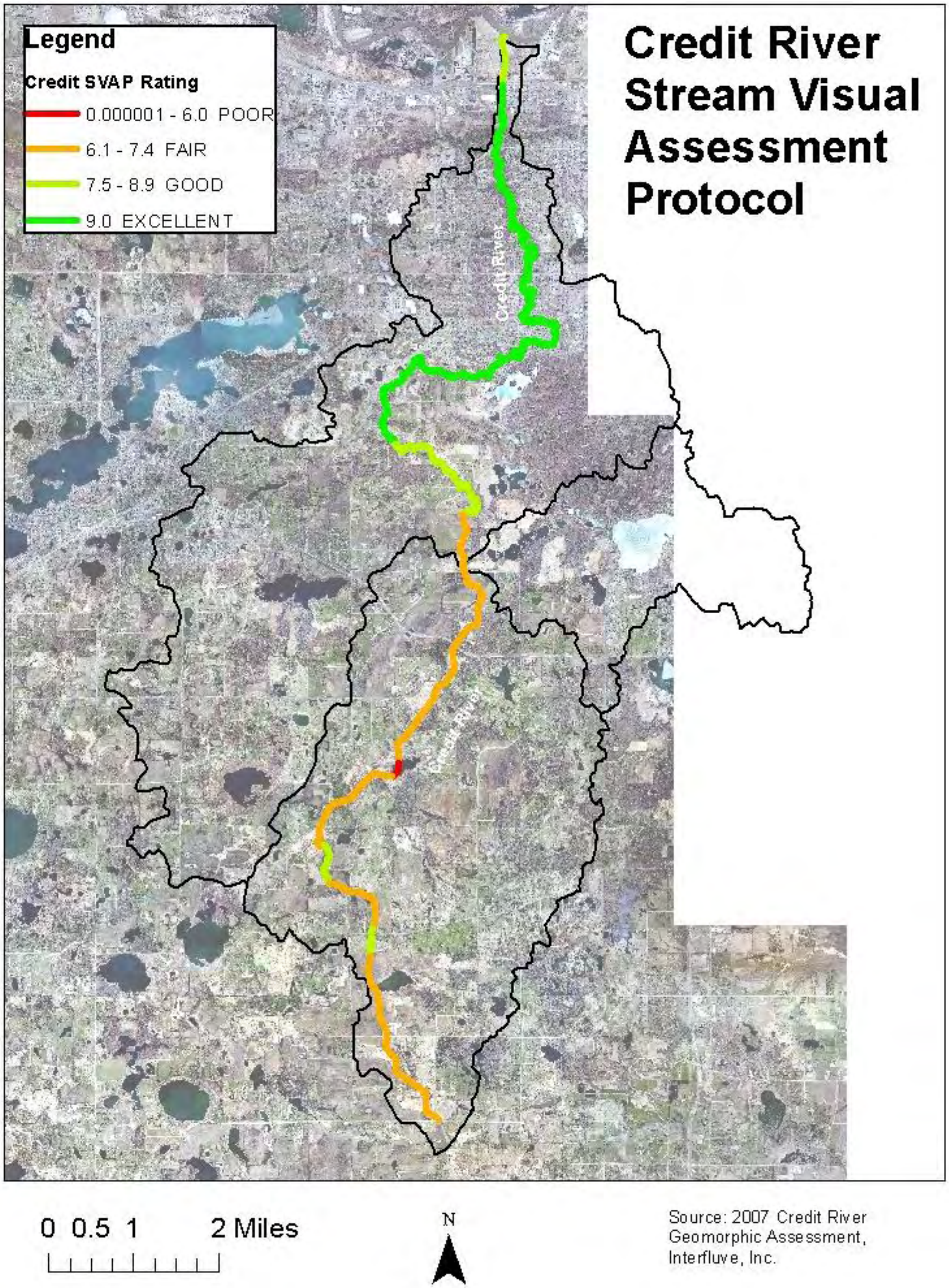


Figure 2-8: Stream Visual Assessment Ratings for Credit River

Land Use

Land use information is presented for historic, current, and future conditions.

Historic Conditions. Hardwood forests and wetlands dominated the Credit River watershed prior to the logging that began shortly after settlement in the 1850s. Today, only scattered remnants remain of what was the Big Woods and oak openings and barrens ecosystems, an expansive maple-basswood forest that covered 3,400 miles east of central Minnesota and stretching to Southern Illinois. The largest remaining tracts of Big Woods near the Credit River watershed are the Cannon River Wilderness Park (1,100 acres), Seven Mile Woods (700 acres), and Nerstrand Big Woods (1,300 acres), all in Rice County. Some remnant Big Woods and oak barren tracts are present in Credit River watershed in Murphy Hanrehan Park Reserve, and Cleary Lake Regional Park.

Most of the arable land within Scott County was converted to farmland starting approximately 150 years ago; to create this farmland many of the smaller rivers and streams were straightened and ditched and most of the wetlands were drained. Settlement began after two treaties were signed with the Dakota Indians in 1851 and 1853. As settlers arrived, the hardwood forests that dominated the region were removed to make room for crops.

The earliest survey of the region was conducted in the early 1850s and published in 1855. These platmaps indicate that the Credit River channel maintained a high degree of sinuosity from the headwaters to the mouth (Figure 2-7); additionally, the map indicates that low-gradient wetland channels were likely the predominant channel form from the present-day County Road 68 crossing upstream to the 230th St. E. crossing (the river does not continue upstream of this location on the 1855 maps). The straightened ditches that characterize many of the reaches higher in the watershed were created between 1855 and 1937. The 1937 series of aerial photographs indicate that the channel planform looks much the same in 1937 as it does today.

Current Conditions. Scott County experienced a housing boom in the early 2000s. From May 2001 through 2006, the County approved nearly 1,000 lots and issued 1,200 building permits for new homes in the unincorporated area. The northeastern portion of Scott County absorbed the bulk of this recent growth. In 1998 and 1999 the City of Savage and Credit River Township combined had over 1,000 new construction building permits. A reduction in construction activity is demonstrated by the fact that over the course of 2008 and 2009 this number has dropped to 151. Current Land Use is summarized in Table 2-3 and Figure 2-9.

There are two regional parks within the Credit River watershed: Murphy-Hanrehan Park Reserve, and Cleary Lake Regional Park which are managed by Three Rivers Park District. Murphy-Hanrehan Park Reserve is a 2,535-acre facility located in the northeast part of County with the Credit River flowing through the western portion of the park reserve. There are three lakes within the park, the largest being Hanrehan Lake. Cleary Lake Regional Park is a 1,048-acre natural area located just southwest of Murphy-Hanrehan, with Cleary Lake at 137 acres, being the central feature.

Table 2-3. 2002 Land Use for SWAT Model Calibration

Land Use	Area (Acre)	Percentage
Ag.	8240	27 %
Urban	9120	30 %
Forest	6780	22 %
Pasture	2120	7 %
Water	940	3 %
Wetland	3240	11 %
Others (Sand Mining)	180	1 %
Total	30620	

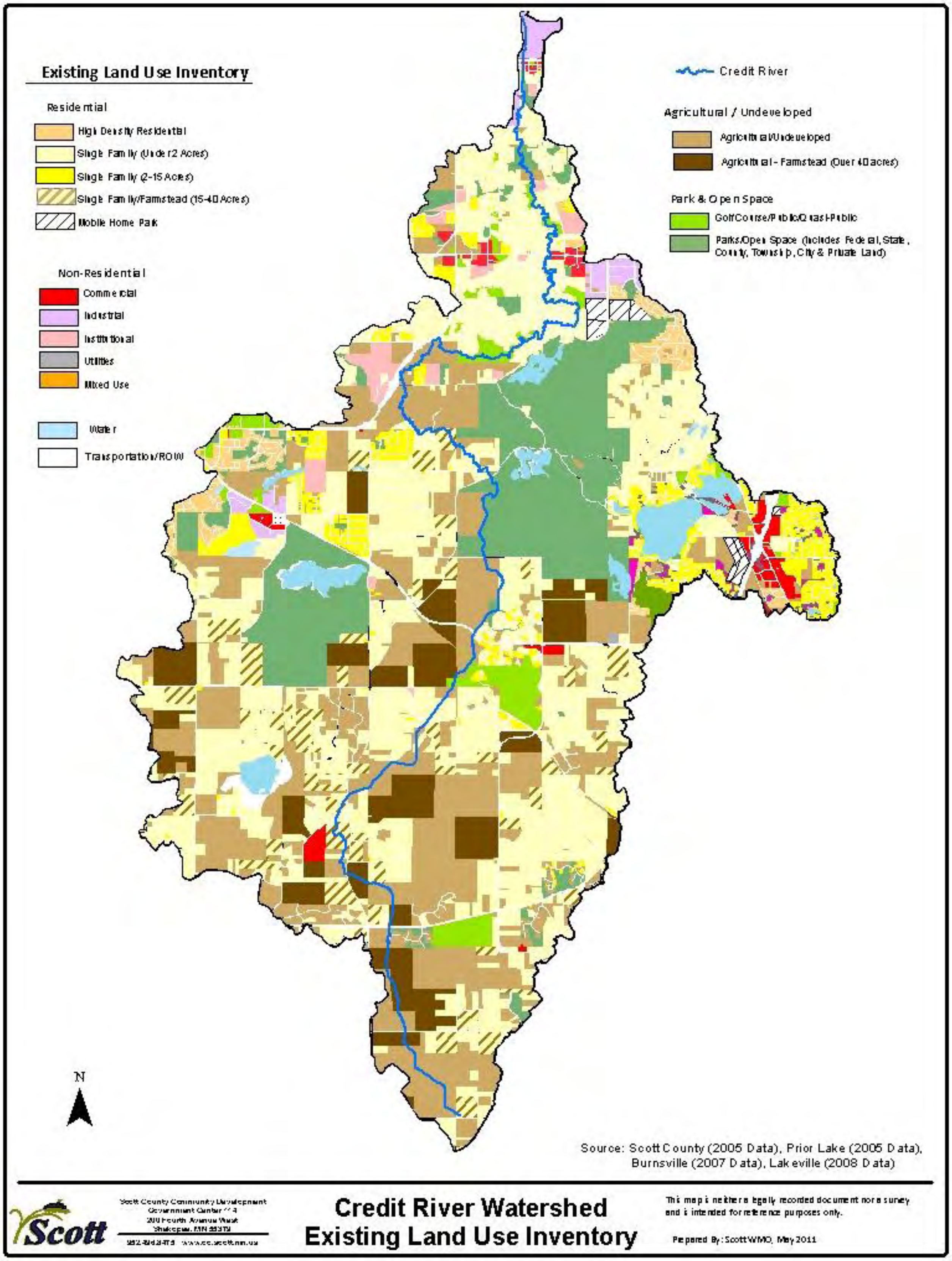


Figure 2-9: Existing Land Use in Scott County

Future Conditions. Planned future development in the Scott County 2030 Comprehensive Plan Update (Figure 2-10) guides roughly three-quarters of the county for ultimate urban development; with the remaining one-quarter (or 73 square miles) designated for rural development as the end land use. The 73-square mile area is the largest pocket in the seven-county Twin Cities region that the Metropolitan Council has formally recognized as an area that will unlikely ever be served by public sewer and water services, therefore, will unlikely ever have the potential to develop at the urban densities. The rural residential growth (i.e., 2.5 acre lots) areas are the southern portion of Credit River Township and west, covering part of Spring Lake Township and an area north of Elko New Market. Urban expansion in these areas is to be held at current densities, or a 1 in 40 acres, until sanitary sewer is provided or areas are annexed. In general the future land use in the Credit River Watershed is guided for urban in the lower (i.e., downstream, northern) portions, is guided for urban expansion in the central portions, and is guided for rural residential in the upper (i.e., upstream, southern) portions of the watershed.

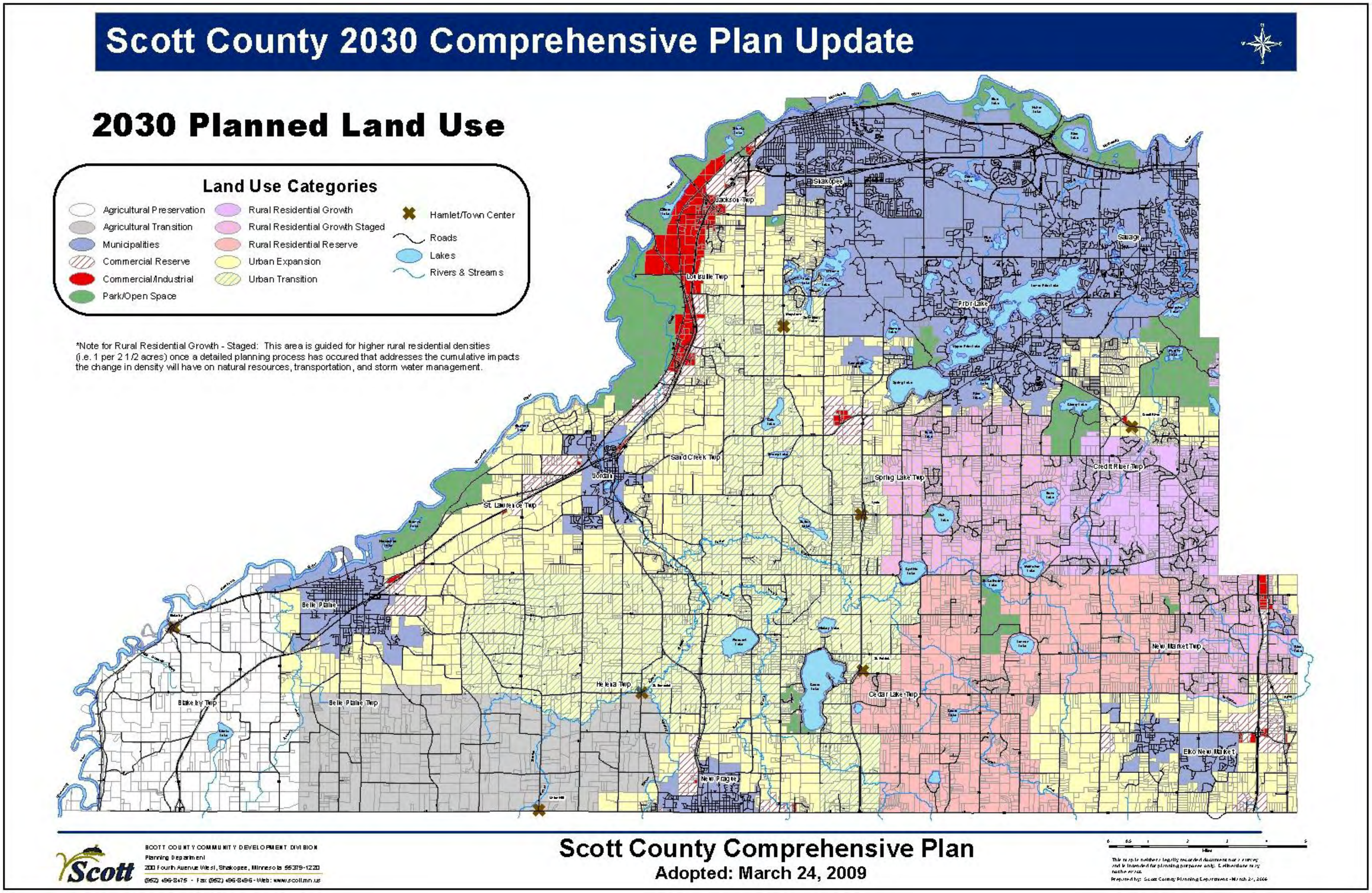


Figure 2-10. 2030 Comprehensive Plan

Section 3: Water Quality Assessment

Introduction

This section provides a summary of the monitoring data collected over the course of the study as well as the SWAT model development and calibration. A brief overview of monitoring sites, data collection methods and data quality, and model calibration is provided within this subsection. Additional information on these topics is provided in the Project Work Plan (Appendix B), internal memorandum regarding Quality Assurance and Quality Control (QA/QC) Results (Appendix E), Rating Curve Development (Appendix F), and Hydrograph Development (Appendix G), and the Credit River Hydrology and Total Suspended Solid Modeling report (Appendix C).

Monitoring data was collected over the period of 2008 and 2009 from the Credit River at multiple sites as detailed in the Work Plan (Appendix B). Stream monitoring consisted of rigorous collection of physical and chemical data at three monitoring stations including stream flow, and less intensive collection of data using meters to measure turbidity at multiple sites across the watershed. All of the sites are shown on Figure 3-1. The intensely monitored sites include sites 123, 154, and C68. The other sites were the less intensely monitored synoptic sites.

QA/QC objectives for the data collected are evaluated and discussed as part of several internal memoranda completed over the course of the Project (i.e., QA/QC Results (Appendix E), Rating Curve Development (Appendix F), and Hydrograph Development (Appendix G)). In general, the quality of the data appears to be good.

- Duplicate measurements used to assess precision generally met Data Quality Objectives
- Calibration procedures to insure accuracy were followed
- Completeness assessed as the number of samples and/or monitoring events planned versus the number completed was good, with collection of data completed as planned. The exception was the number of samples which was limited to less than planned by the lack of water and intermittent flow at some sites, and dry conditions over the sampling period.

- Samples collected were representative of the range of flows observed at the sites. However, 2008 was a dry year and was not representative of average annual hydrologic conditions for the area. The Scott WMO therefore added a second year (i.e., 2009) of monitoring at sites 154 and C68 in order to improve representativeness. The Metropolitan Council also continued monitoring at their site in 2009. Rainfall measured at the National Weather Service Station in Chanhassen just north of the Credit River Watershed was 22.4 inches in 2008 and 29.8 inches in 2009. The long term average for the area is about 29 inches.

With respect to the hydrographs it should be noted that large parts of the 2008 hydrographs for sites 154 and C68 are predicted based on a relationship developed between stage at the two sites and the MCES site (site 123) located near the mouth of the river. High water levels in the spring of 2008 and then beaver dam impacts later in the year, affected the ability to install equipment and collect accurate stage levels. This introduces some uncertainty regarding load predictions (Figure 3-8) at the upstream sites. This does not affect model calibration since was completed at the downstream site. For 2009 flows could not be predicted to fill in those parts of the year where stage was not measured at the two sites, because there were problems at the downstream MCES site.

The special monitoring effort for macroinvertebrates was cancelled because of low to no flow at the upstream sites. The Metropolitan Council already monitors at the downstream site and this data is summarized later in this section. Cancellation of this monitoring was also partly due to the fact that conditions of the upstream sites were more representative of wetlands than streams and thus it was thought that stream metrics could not be meaningfully applied to these sites.

Model calibration is covered in Appendix C: Credit River Hydrology and Total Suspended Solid Modeling. Calibration and model development was set up for hydrology and total suspended solids. TSS was used instead of turbidity since it is not possible to express turbidity as a load – a measure of transparency. Instead, a relationship between turbidity and TSS has been developed by the Metropolitan Council (MCES, 2009). Comparison of various calibration statistics and measures indicate that the SWAT model developed for the Credit River Watershed is well calibrated and able to satisfactorily predict hydrology and TSS loads for the watershed.

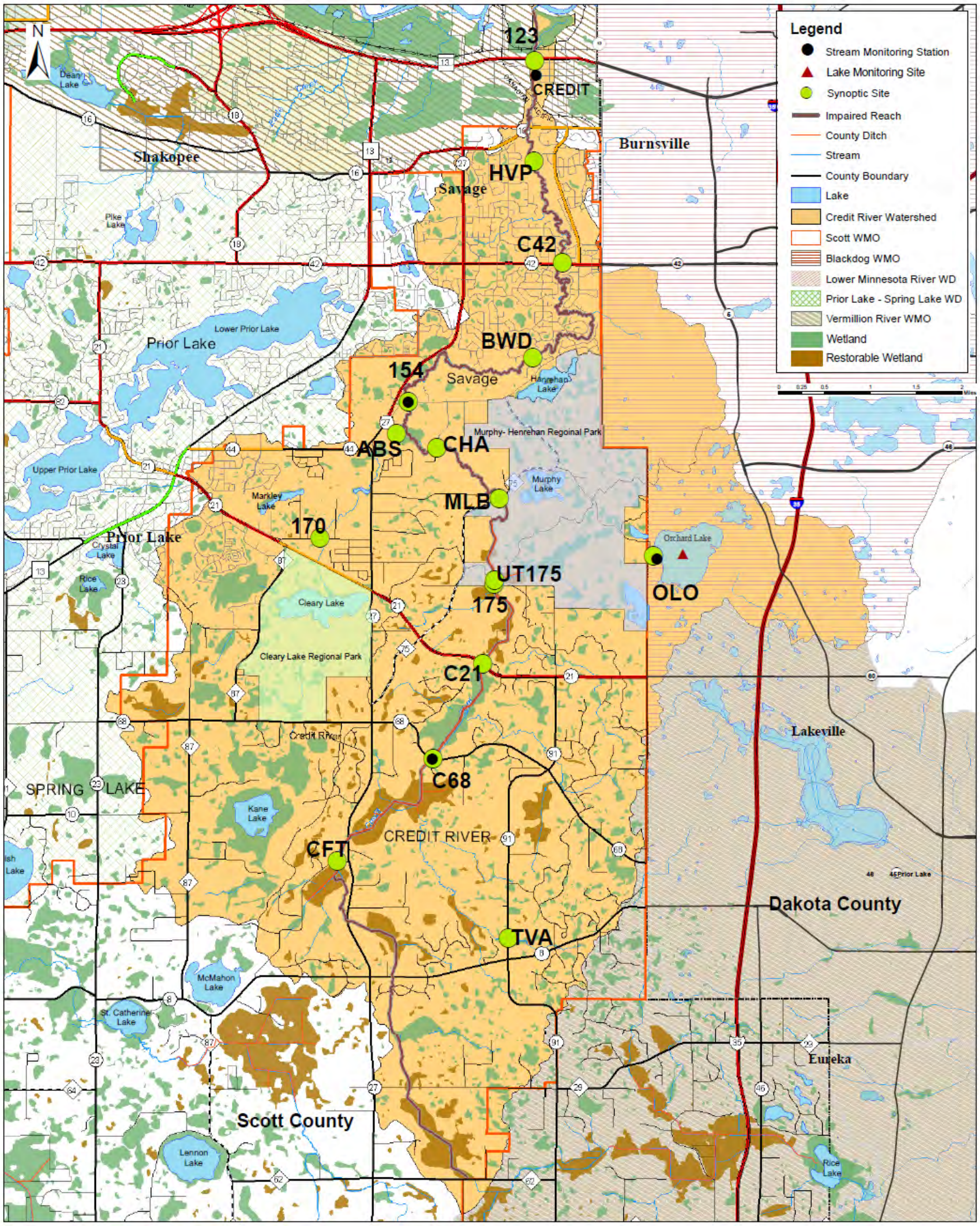


Figure 3-1. Credit River Monitoring Sites

Turbidity and Total Suspended Solids Assessment

This assessment of turbidity focused on evaluating the relationship between turbidity and other sediment related variables, comparison with the standard, documenting spatial and temporal variability, and evaluating sediment sources.

Relationship Between Turbidity and Sediment-Related Variables. The threshold for turbidity impairments, 10% of measurements exceeding a turbidity reading of 25 NTU, is straightforward. The process used to compare data in other units of turbidity and TSS data to the 25 NTU standard requires additional explanation. Figure 3-2 is a graphical representation of the relationship developed between the data sets used for this project. The central link is formed by the laboratory sample analysis, which was deemed most reliable link to the other measurements of turbidity.

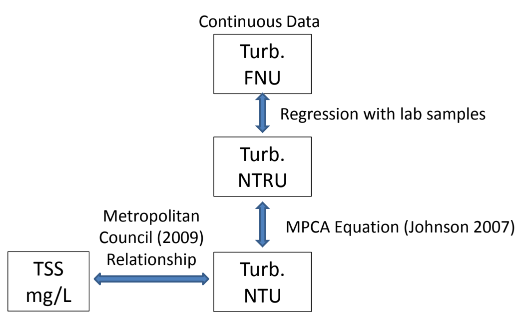


Figure 3-2. Credit River Watershed Turbidity and Sediment-Related Monitoring Data Relationships

Laboratory turbidity (NTRU) and Standard (NTU). Laboratory turbidity readings in NTRU were converted to NTU for analysis of all the laboratory readings. The equation developed by MPCA (Johnson, 2007).

NTRU to NTU equation $NTU = 10^{(-0.0734+0.926*LOG(NTRU))}/1.003635$

Continuous turbidity (FNU) and Laboratory Turbidity (NTRU). Continuous recording field meters used in the study where found to consistently provide higher turbidity readings that the laboratory meter (Figure 3-3). This was also found to be the case with other studies and creeks in the area (Scott WMO, 2010). Therefore, continuous probe results in FNU were first converted to NTRU, and then to NTU. To convert from FNU to NTRU, dates for grab samples evaluated in the lab were matched with same time and date results from the field probe to develop the regression equation in Figure 3-3. Results in NTRU were then converted to NTU using the equation developed by Johnson (2007).

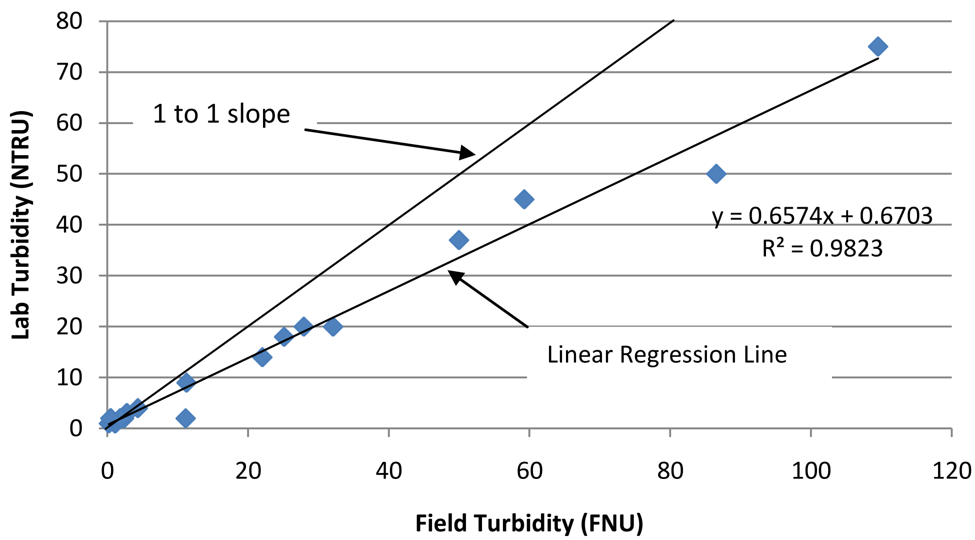


Figure 3-3. Regression between field and laboratory turbidity for the Credit River 0.9 Site (2008 and 2009)

Laboratory Turbidity (NTRU) and Total Suspended Solids (TSS, mg/L). Turbidity and TSS relationships for streams across the metropolitan area were assessed by the Metropolitan Council (2009). For the Credit River they found that 25 NTU was equivalent to 139 mg/L. This relationship is used by this study since the Metropolitan Council's analysis used a longer record of measurements than was captured in the monitoring efforts for this study. The log transformed relationship is fairly strong with a

slope of 0.210572, R-Sq of 63.7% and R-Sq (adj) of 63.1%. The equation is:
Log10(TSS) = 0.2420 +1.361Log10(Turbidity).

Additional analysis of the relationship between turbidity, total suspended solids, and volatile suspended solids (VSS) was completed to assess whether turbidity is primarily influenced by non-volatile (inorganic) solids, volatile solids or a combination. The question being whether or not algae from lakes in the watershed could be affecting turbidity in the stream, and if so, whether phosphorus, which drives the algae group needs to be part of the modeling effort. To complete this analysis the concentration of non-volatile suspended solids (NVSS) was calculated by subtracting VSS from TSS. The percent NVSS of TSS was then calculated and compared to turbidity readings at the three sites. Model calibration was to the downstream METC 123 site, but the other two sites were also assessed.

Figures 3-4 and 3-5 present the results of the analysis for 2008 and 2009 data, respectively. These results show that:

1. Turbidity readings rarely exceeded the 25 NTU standard
2. When turbidity was higher, NVSS was 75% or more of the TSS

Based on these findings the Technical Advisory Committee for the project felt comfortable proceeding with model development for TSS without simulating phosphorus and algae.

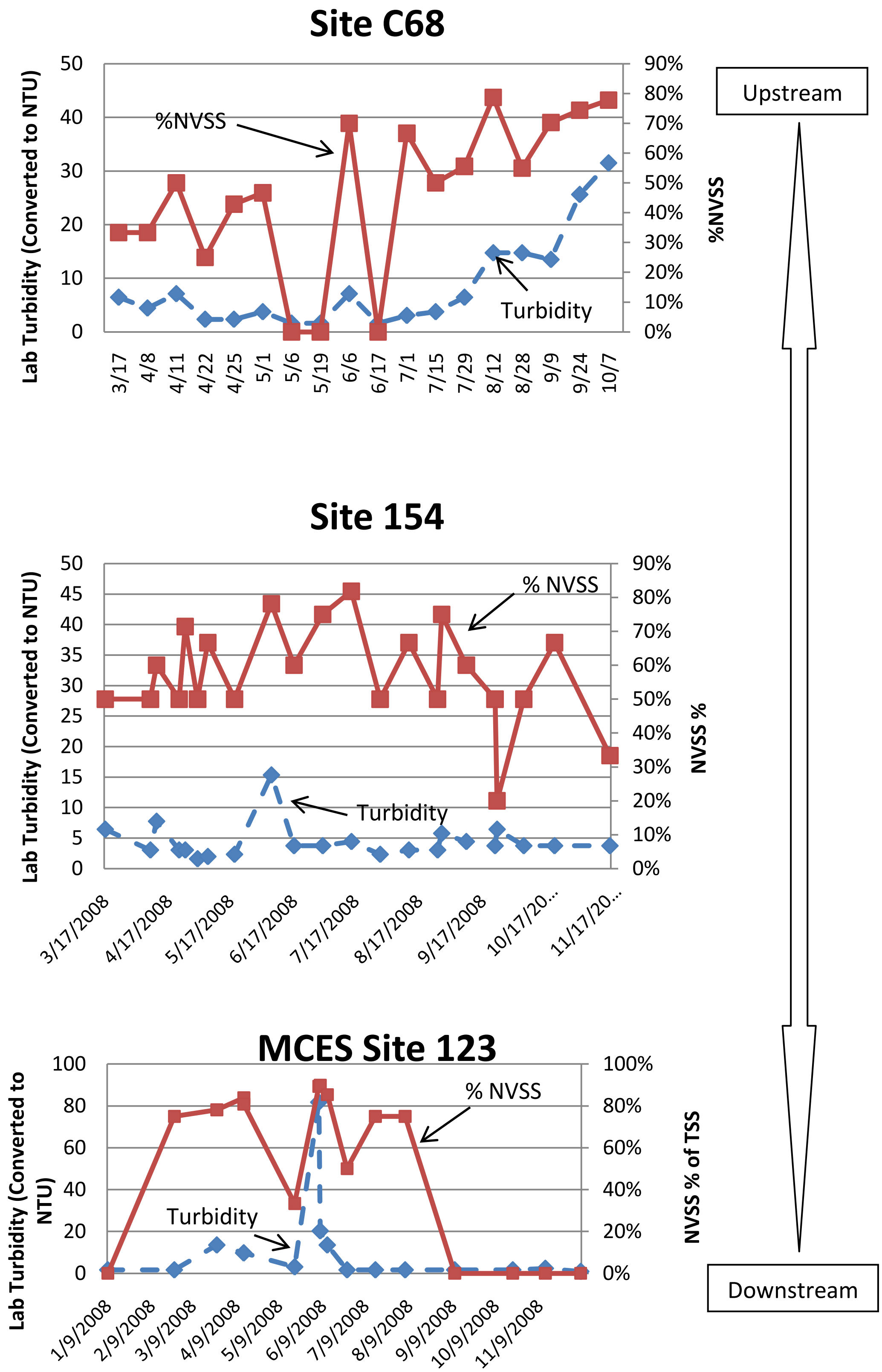


Figure 3-4. Turbidity And Percent NVSS, 2008

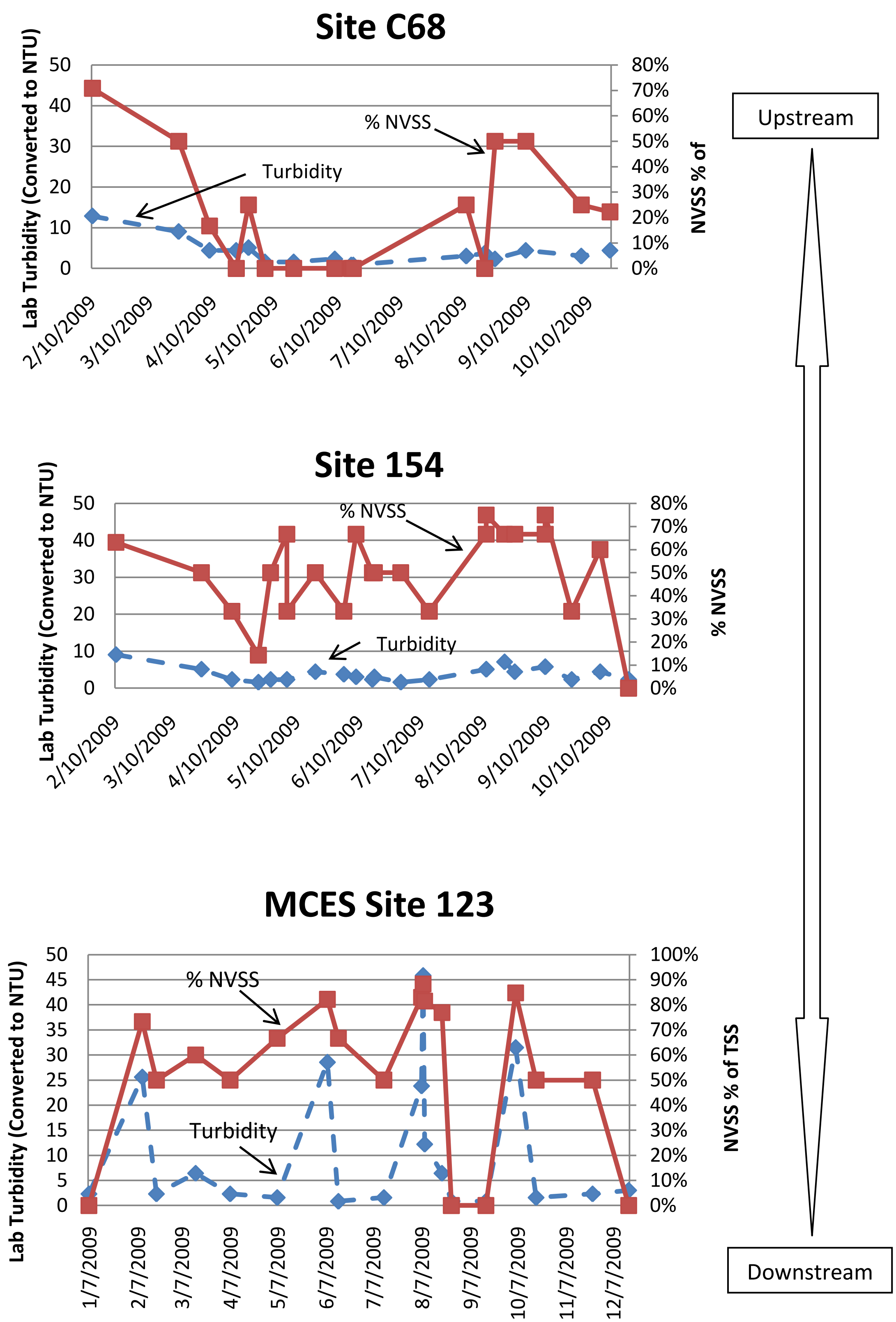


Figure 3-5. Turbidity And Percent NVSS, 2009

Relationship Between Turbidity and Flow. As demonstrated by the Metropolitan Council (2009) that there is a strong relationship between turbidity and TSS in the Credit River. It is also known that sediment and TSS loads vary with flow with higher suspended and bed loads during higher flows. Higher flows have more energy to suspend and move sediment. Since turbidity in the Credit River appears to be related to TSS loads, it is likely that turbidity is also affected by flow. To assess this both continuous field turbidity data and lab turbidity data were compared to flow at the MCES site 123. Figure 3-6 shows the relationship between continuous data for mean daily flow and mean daily turbidity. Figure 3-7 shows a similar relationship between lab turbidity sample results (converted to NTU) and flow. Both graphs show fairly strong relationships between turbidity and flow.

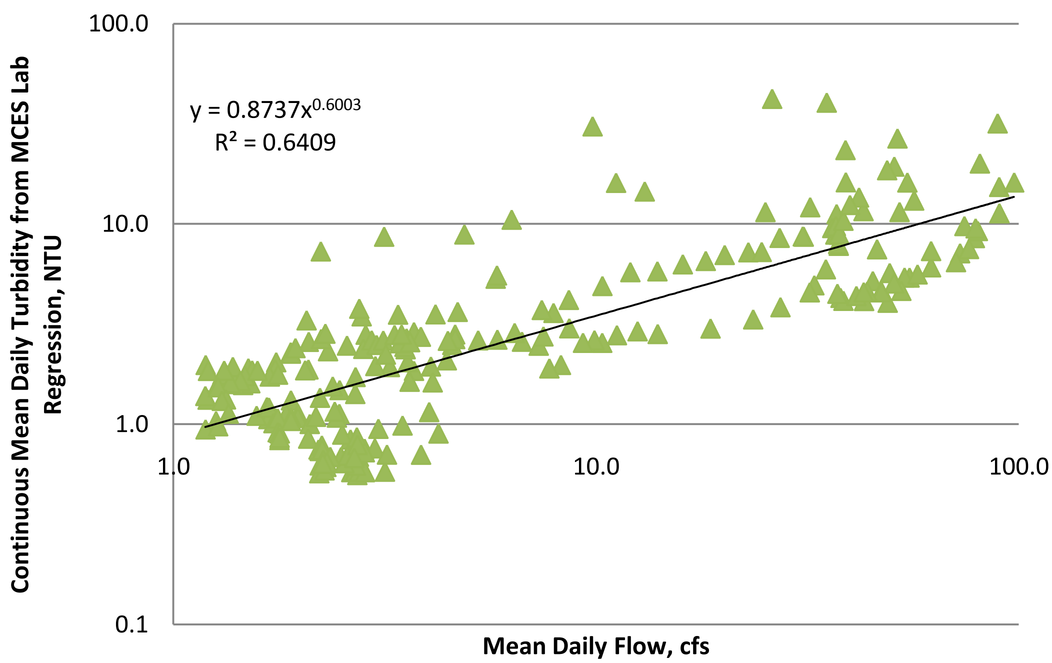


Figure 3-6. **Comparison of continuous mean daily turbidity readings and flow for the Credit River, 2008 -2009, MCES site 123**

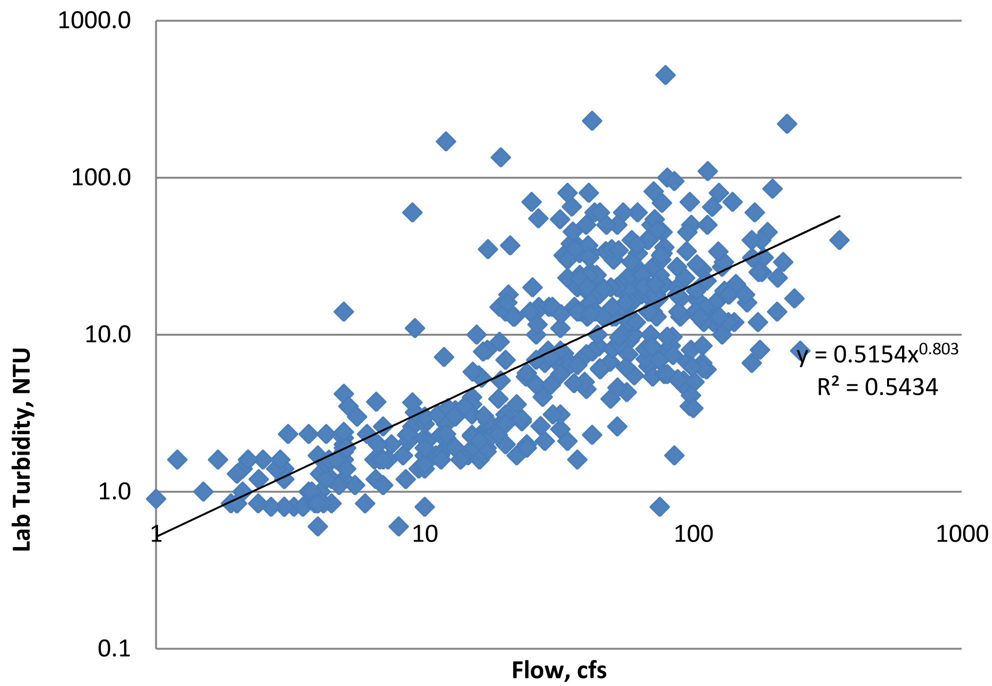


Figure 3-7. Comparison of laboratory turbidity sample analyses and flow from the Credit River, 1993-2008, Metropolitan Council site @ MR 0.6/0.9 (MCES site 123)

Comparison with Standard. As previously discussed, the threshold for turbidity impairment is based on 10% or more of the measurements exceeding a turbidity reading of 25 NTU. The data used for the 2002 original listing came from the MCES monitoring site of river mile 0.6. Analysis of this data shows that the standard was exceeded about 24% of the time. However, more recent continuous turbidity probe data for a two year period of 2008 and 2009 at the MCES site 123 shows that the turbidity level for which 10% of values exceed the standard is 8.3 NTU (Table 3-1) after conversion from FNU units to NTU units; and further that the percent exceedence of the 25 NTU standard is only 1.2%. It has been hypothesized for this data on the Credit River and for other data (Nine Mile Creek; Greg Wilson, 2009) that differences in the results for continuous probe data and Metropolitan Council laboratory sample data could be due to the following:

1. That the more recent continuous probe readings were taken during a drier period where there were lower flows where lower turbidity results typically occur, and since the

continuous data only represents two years, the data may not be as representative of long term conditions as the lab sample data.

2. The analyses using the Metropolitan Council laboratory sample results are biased high since the monitoring program under which the samples were collected was biased toward high flows under which higher turbidity results typically occur.
3. Changes in the watershed characteristics.

These hypotheses are discussed in detail in the Credit River Turbidity Delisting memo (Nelson, 2010) included as part of the MPCA Listing Transparency Document (Appendix A) and summarized below. There is some concern about using all the conversions (i.e., FNU to NTRU and NTRU to NTU). Therefore, the distribution for the continuous data was also calculated without converting. Without the conversion, the 90% percentile (i.e., the 10% exceedence) for field turbidity was 17.1 FTU which is still well below the 25 NTU standard. An analysis was also completed to assess the effects of flow because of questions about whether 2008 and 2009 are representative of long term weather and flow conditions. Rainfall at Chanhassen was 22.4 inches and 29.8, respectively for 2008 and 2009. Average annual rainfall is about 29 inches. Thus, the two year period with the continuous data represents one dry year and one year close to the average.

Table 3-1. Turbidity Distributions

Percentiles	MPCA 2000 NTU	Met Council Continuous 2008 and 2009 NTU*
90^{th}	50.5	8.3
50^{th}	12	2.0
10th	1.7	0.8

*Converted to NTU as described above: Field FNU to Lab NTRU, Lab NTRU to NTU

The analysis of the effects of flow was completed using a relationship developed between flow and laboratory turbidity to all the MCES flow records to evaluate whether the standard would have been exceeded if monitoring had been completed on a continuous basis. In other words, a relationship was developed between flow and laboratory turbidity (see Figure 3-6 above), and then turbidity was predicted for the 90^{th} percentile flow value of the entire 15 year flow record at the MCES monitoring site. Using the equation developed between continuous turbidity and flow for 2008, a value of 8.6 NTU at the 90% flow value for the 15 year flow record, would represent the 10% exceedence value for turbidity. Using the equations developed from lab turbidity and flow, gives turbidity values of 11 NTU and 18.4 NTU for the 90% flow value of the 15 year record, based on the regression and the upper 95% confidence interval, respectively. This analysis confirms that the 25 NTU standard will be meet 90% of the time with 95% confidence, based on long term flow duration characteristics.

Spatial Variability. Spatial variability is discussed as observed from the monitoring data collected over 2008 and 2009 for TSS; and as predicted by the SWAT model for TSS.

Spatial Variability of Monitoring Data. Spatial variability was assessed using the results of the monitoring at the three primary monitoring sites, the synoptic monitoring sites, and data obtained for Orchard and Cleary Lakes.

Table 3-2 presents distributions for TSS at the three primary monitoring sites (sites 123, C68, and 154; see Figure 3-1, page 3-3). At first glance it appears that site 123 has much higher TSS than the other two sites. This may, however, be due to differences in sampling protocol between the sites. The Metropolitan Council collected both composite and grab samples in 2008 while all samples collected at the other sites are grab samples. All samples at all sites collected in 2009 were grab samples. Composite samples are collected to represent the storms and are a mix of a number of small sample volumes collected over the duration of a storm. Since there is a relationship between TSS concentrations and flow, it is expected that composite samples will have a higher concentration than samples collected during non-storm periods. Similarly, “event” grab samples were collected at sites C68 and 154 to ensure that storm flows were represented in the data from these sites. Since composites were collected in 2008, the 2009 results provide the best comparison between sites. The 2009 TSS results at site 123 show much higher TSS concentrations at the high end of the distribution than at the other two sites.

Table 3-2. TSS Distributions

Percentile	Site					
	C68		154		Met Council 123	
	2008	2009	2008	2009	2008	2009
90th	88.2	10.2	13.8	8.8	269	131
50th	8.5	4	4	4	2.5	4
10th	1.9	1	2.3	2	0.5	1
n	18	17	22	23	16	19

The Metropolitan Council calculated TSS loads at the three monitoring sites for 2008 using FLUX (Figure 3-8). These results shows that most of the TSS load originates downstream of site 154. This makes sense as this is where the Credit River cuts through the Minnesota River Valley bluff and picks up grade. These lower watershed areas are also where the Geomorphic Assessment (Appendix D) found the most stream bank instability, the Scott SWCD streambank erosion survey (Scott SWCD, 2006) found the most erosion, and where a couple of eroding ravines were known to exist at the time of the study.

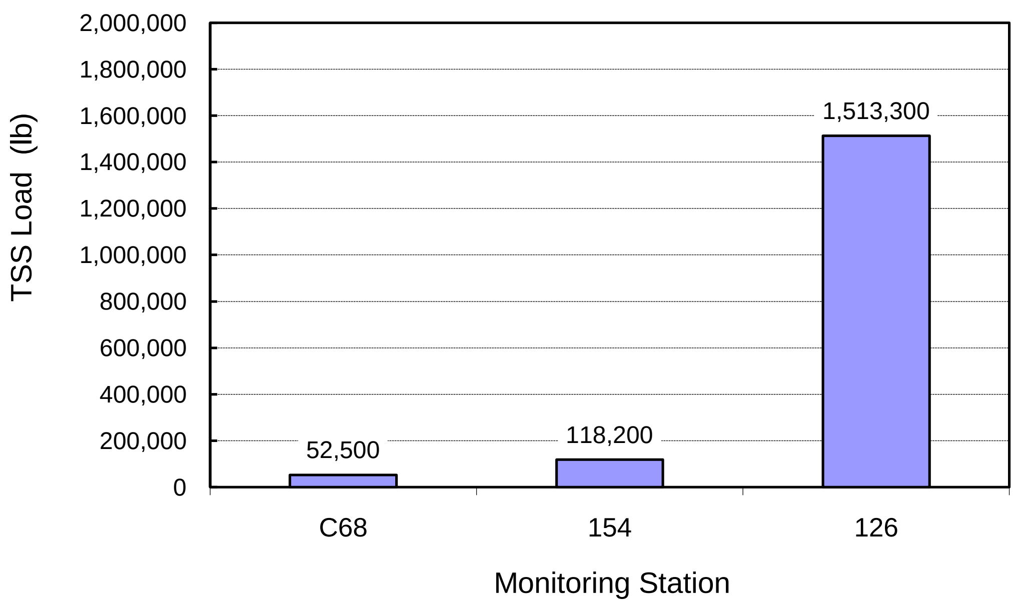


Figure 3-8. Estimated TSS Loads 2008

Results of the synoptic monitoring for field turbidity are presented in Table 3-3. Synoptic monitoring consisted of periodic (seven times) monitoring across the watershed using meters to get a wider distribution of data than at just the three primary sites. Review of the data obtained from the synoptic effort found that the data was not particularly informative, with a couple of exceptions, since there was only one observation that exceeded 25 FNU. The exceptions are that there was no flow out of Cleary and Orchard Lakes for much of the summer and the fall of 2008. This finding is important as it helps to diagnose whether the two lakes could be contributing TSS in the form of algae thereby affecting turbidity readings.

The Metropolitan Council's Lake Water Quality Grade gave Orchard Lake an "A" for 2008-2009, indicating a potential improving water quality trend, given that from 2004-2006 it received a grade of "B" and in earlier years a grade of "C". The 2008 data summary from Met Council's CAMP program (Metropolitan Council, 2009b) shows Orchard Lake's (May through September) mean chlorophyll-a at 10.1 ug/L, transparency at 3.1 meters, and total phosphorus at 22.5 ug/L. The improvement could be due to the City of Lakeville developing the Orchard Lake Management Plan in 2000, which contains recommended projects to meet fisheries goals, improve shoreland habitat, and reduce aquatic plants and nutrients. The study conducted in 1999, included water quality improvement alternatives identified in the diagnostic feasibility study, with the exception of in-lake alum treatment. The City of Lakeville is working toward implementation of all the best management practices identified in the Orchard Lake Management Plan (2000). The basic conclusion is that with the low chlorophyll-a concentrations observed and the lack of discharge, that algae growth in the lake was not significantly contributing to turbidity in the Credit River in 2008. Synoptic data were not collected, but chlorophyll-a concentrations were even lower than in 2008 averaging 3.6 ug/L (Metropolitan Council, 2009b).

Cleary Lake is listed as impaired for excessive nutrients and experiences nuisance algae blooms. These blooms could contribute to turbidity levels downstream. However, the synoptic monitoring completed in 2008 never had any flow. It is therefore concluded that Cleary Lake and areas upstream of the Lake did not contribute turbidity to the River in 2008.

Table 3-3. 2008 Synoptic Monitoring Results for Turbidity (FNU)

Site	Map ID	Date						
Order moving downstream		**8-May**	**4-Jun**	**17-Jul**	**15-Aug**	**11-Sep**	**16-Oct**	**13-Nov**
Unnamed Tributary to Credit River at Vernon Avenue (CSAH 91)	TVA	0	0	43.9			0.3	0
Credit River at Flag Trail	CFT	5.8	8.5	16.5			6.1	0.8
Credit River (CD4) at CSAH 68	C68	0	4	5.4	3.6		16.3	11.2
Credit River (CD4) at CSAH 21	C21	0	0.1	2.6		9.4	1.8	5.6
Credit River (CD4) at 175th ST	175	0	5.7	10.1	8.4	28	13.6	8.7
Unnamed Tributary at trail crossing downstream of 175th	UT175	0	2.6	10.5	16.7	10.5	4.5	9.3
Downstream of Orchard Lake Outlet	OLO	0.4	1.7					
Unnamed tributary downstream of Cleary Lake at 170th Street	170	0						
Credit River at Murphy Lake Boulevard near Murphy Lake	MLB	0	0.8	1			0	0
Credit River at Hampshire Avenue	CHA	0	1.4	17.1	16.1	9.7	0.6	0
Unnamed tributary at Allen Boulevard S	ABS	0	0	0.2	0.1	0	No data	No data
Credit River at 154th Street	154	0	2.9	6.8	2.6	4.5	4.9	2.5
Credit River at Bridgewater Drive Crossing	BWD	0.2	2.8	0.9	2.9	3.9	0.8	0.9
Credit River at CSAH 42 crossing	C42	11	0.4	3.2	1.1	0	0	0
Credit River at 132nd Street W at Hidden Valley Park	HVP	3.8	2.2	1.2	0.1	0.5	0.9	0
Credit River at 123rd Street W	123	6.8	1.9	0	0.1	0	0	0.8

* empty cell indicates no flow

Spatial Variability Assessed by the SWAT Model. The SWAT modeling effort assessed spatial variability as part of developing the model, and predicted spatial variability of TSS sources across the watershed as an output. The following discussion first summarizes the assessment of non-field (i.e, channel, ravine, etc) versus field sediment source distributions used to develop and calibrate the model, and then presents a summary of model predictions. Readers are referred to Appendix: C for the full modeling report produced by the Metropolitan Council.

The model was calibrated to the TSS loads at the MCES site 123, and to field to non-field TSS ratios. The final ratio in the model was 18.5 percent from field erosion and 81.5 percent from non-field erosion. These ratios are consistent with other reported values for the region. Figure 3-9 shows field and non-field erosion ratios for other Lower Minnesota River Watersheds estimated using the isotope fingerprint technique by the Minnesota Science Museum St. Croix Watershed Research Station (MPCA, 2009). The average TSS contribution from field erosion in the other Lower Minnesota River watersheds is 14 percent. Among the studied watersheds using isotope fingerprint technique, Carver Creek and Bevens Creek are two watersheds in close proximity to the Credit River Watershed. The field erosion ratios for these two watersheds are 10 percent and 18 percent respectively.

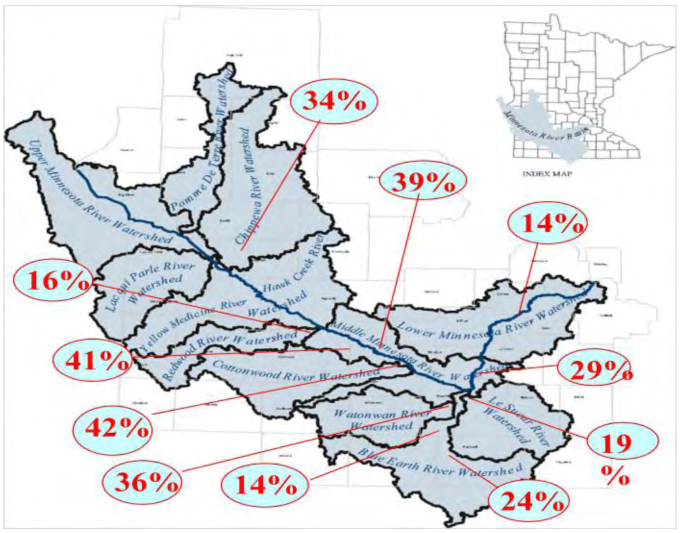


Figure 3-9. Field Erosion Percentages Estimated Using Isotope Fingerprint Techniques for Lower Minnesota River Watersheds (MPCA, 2009)

Figure 3-10 displays the annual surface runoff and total water yield compared to land use predicted by the SWAT model. The total water yield is the total amount of runoff leaving an individual Hydrologic Runoff Units (HRU) and entering the main channels. It includes surface, subsurface, and ground water flows as well as water lost due to evaporation. The results show that urban areas generated the highest surface runoff (6.9 inches), while forest contributed the lowest surface runoff (0.8 inch). Modeled results also show that sand mining had only 0.1 inch of surface runoff but it also had the largest total water yield (18.7 inches), probably due to limited evapotranspiration occurring at the sand mining sites. Wetlands were one of the land covers that yielded relatively large amounts of water; wetlands were simulated as impervious in SWAT with no water removal except for evaporation and seepage.

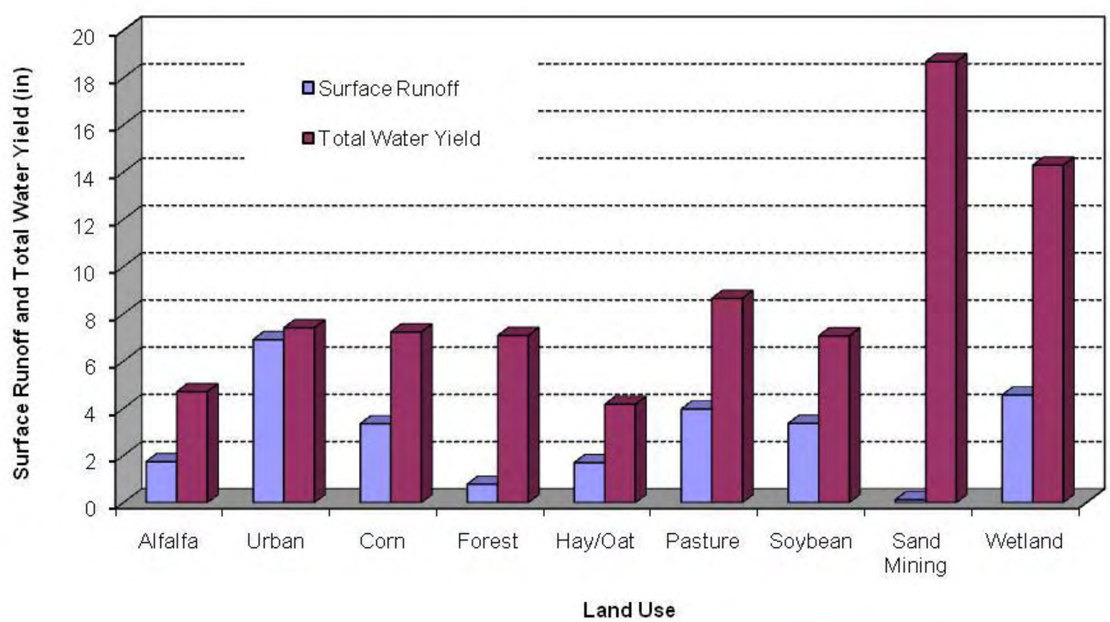


Figure 3-10. Simulated Surface Runoff and Water Yield by Land Use

For TSS yields from land uses, two values were estimated by SWAT for comparison (Figure 3-11): the TSS yield leaving the HRU and the TSS load entering the channel after flowing through impoundments and buffer strips. The two values were significantly different for the Credit River Watershed because the numerous vegetated buffers, wetlands, and ponds in each subbasin effectively remove most of the TSS from the runoff before it enters the channels.

Results show that TSS yields varied across the watershed. For example, agricultural land uses (corn, soybean and alfalfa) had the largest TSS yields leaving the HRUs. However, only a small portion of the TSS yield from agricultural lands entered the Credit River due to removal in buffer strips, wetlands, and ponds. Urban land uses, on other hand, contributed the largest TSS loads to the river, most likely due to having fewer wetlands and buffers than the agricultural areas. TSS loads from the urban land use were simulated to be 57 lb/ac. Forests together with sand mining had the smallest TSS yields and loads to the channels (4.0 and 0.2 lb/ac). Because SWAT simulated the TSS generated from the wetlands without any removal by buffers and impoundments in urban areas, the TSS load entering the channels from wetlands was similar to the HRU yield.

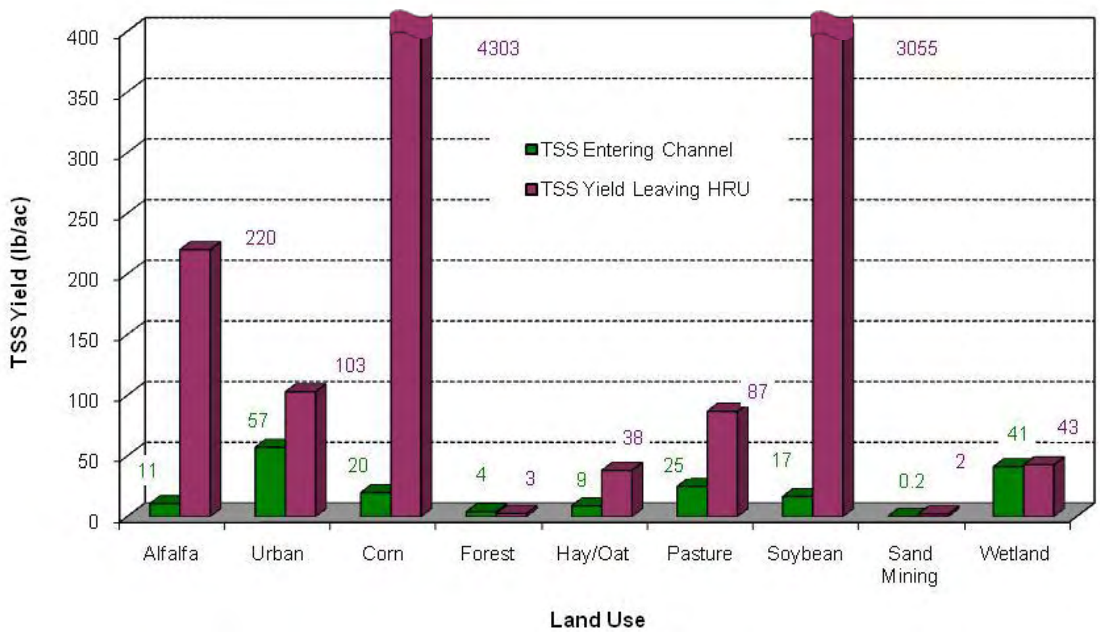


Figure 3-11. Simulated Field Erosion by Land Use

Spatial distribution of the surface runoff volume and TSS load was analyzed with the model to identify the areas that contribute major flow and TSS to Credit River and where BMP implementation for TSS control should be prioritized. Seventy subbasins have been delineated in the watershed based on SWAT, numbered roughly from upstream to downstream (Figure 3-12). Annual average runoff volumes and TSS yields per unit area from each subbasin were analyzed based on the modeled results from 1997 - 2008. To make it comparable to non-field erosion, TSS yields from field erosion were calculated based on the loads entering the channels after flowing through buffers and impoundments.

The results show that average annual surface runoff volumes from upstream subbasins, for example above Subbasin 18, were relatively small, ranging from 2 inches to 4 inches (Figure 3-12). The mostly urban downstream subbasins contributed relatively large amounts of runoff, ranging from 4 inches to 10 inches. The highest runoff was generally found from the urban subbasins (Subbasins 1-10) below the bluff area.

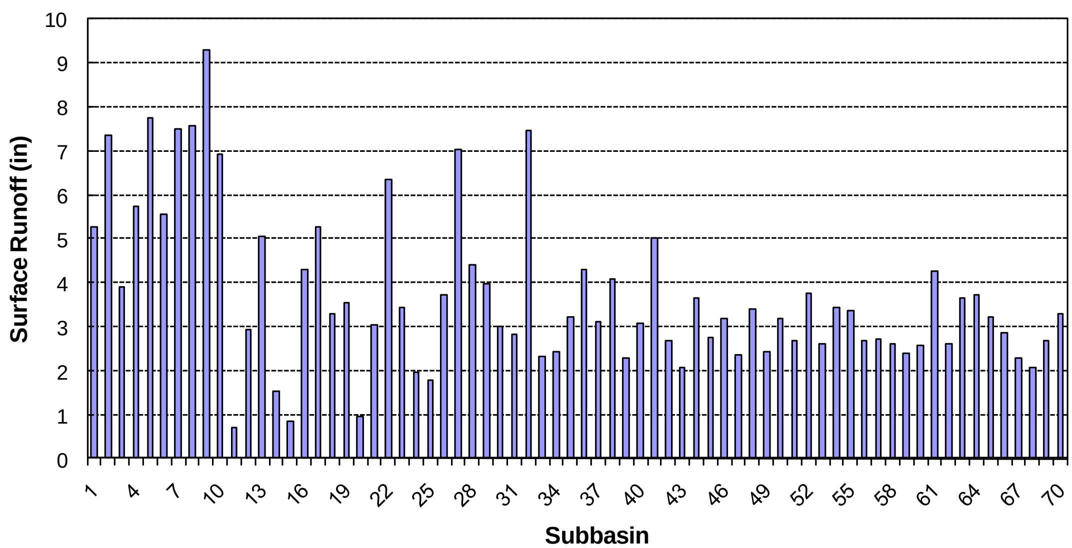


Figure 3-12. Simulated Average Annual Surface Runoff by Subbasin

Figure 3-13 shows the simulated average annual TSS yields of field erosion per unit area by subbasin. The yields ranged from 1 lb/ac (Subbasin 11) to 150 lb/ac (Subbasin 6). The yields from most subbasins were relatively small regardless of subbasin location. Subbasins 3 and 6 were exceptions, contributing extremely high TSS yields (140 lb/ac and 150 lb/ac). The yields were calculated based on the amount of TSS entering the channels, which are influenced by many factors, including land cover, slopes, soil properties, buffer application and impoundment settlement. Any combination of these factors may determine high or low TSS loads from a subbasin.

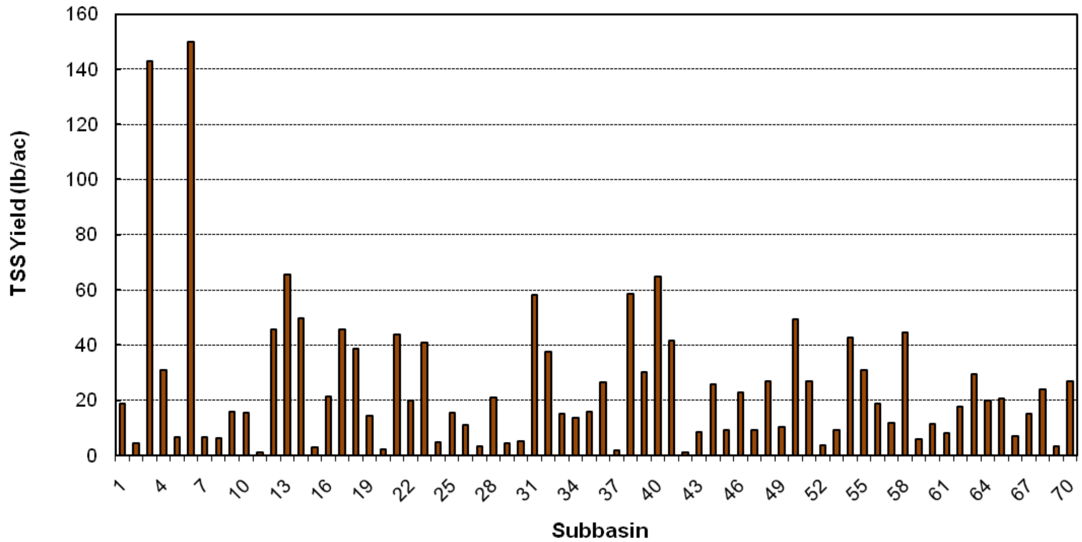


Figure 3-13. Simulated Average Annual TSS Yields by Subbasin

The total TSS load from field and non-field erosion was used to quantify TSS non-point sources in the watershed. The total TSS load is not only dependent on the TSS yield per unit area but also on subbasin area. Figure 3-14 is a spatial distribution map of annual field and non-field TSS loads by subbasin, reflecting the magnitude of field and non-field erosion by subbasin.

Figure 3-15 shows model predicted non-field erosion expressed as a percent of the total TSS load by subbasin. Figures 3-14 and 3-15 show that a large amount of non-field erosion occurs in the downstream subbasin channels below the bluff area, ranging from about 141,100 lb/yr to 315,300 lb/yr and contributing up to 74 percent of the total bank erosion load. Upstream subbasins have either no erosion or low risk for non-field erosion. These upland subbasins contributed only 26 percent of the total bank erosion load. This is consistent with the Scott SWCD (2006) stream bank erosion survey and the Geomorphic Study (Appendix D) which found more active channel process in the downstream reaches of the River. Some of the tributaries discharging to the downstream reaches of the River were also known to be unstable.

When comparing field and non-field erosion, TSS loads from field erosion are relatively insignificant. Non-field erosion from the downstream reaches of the watershed is the primary sources of TSS in the Credit River Watershed.

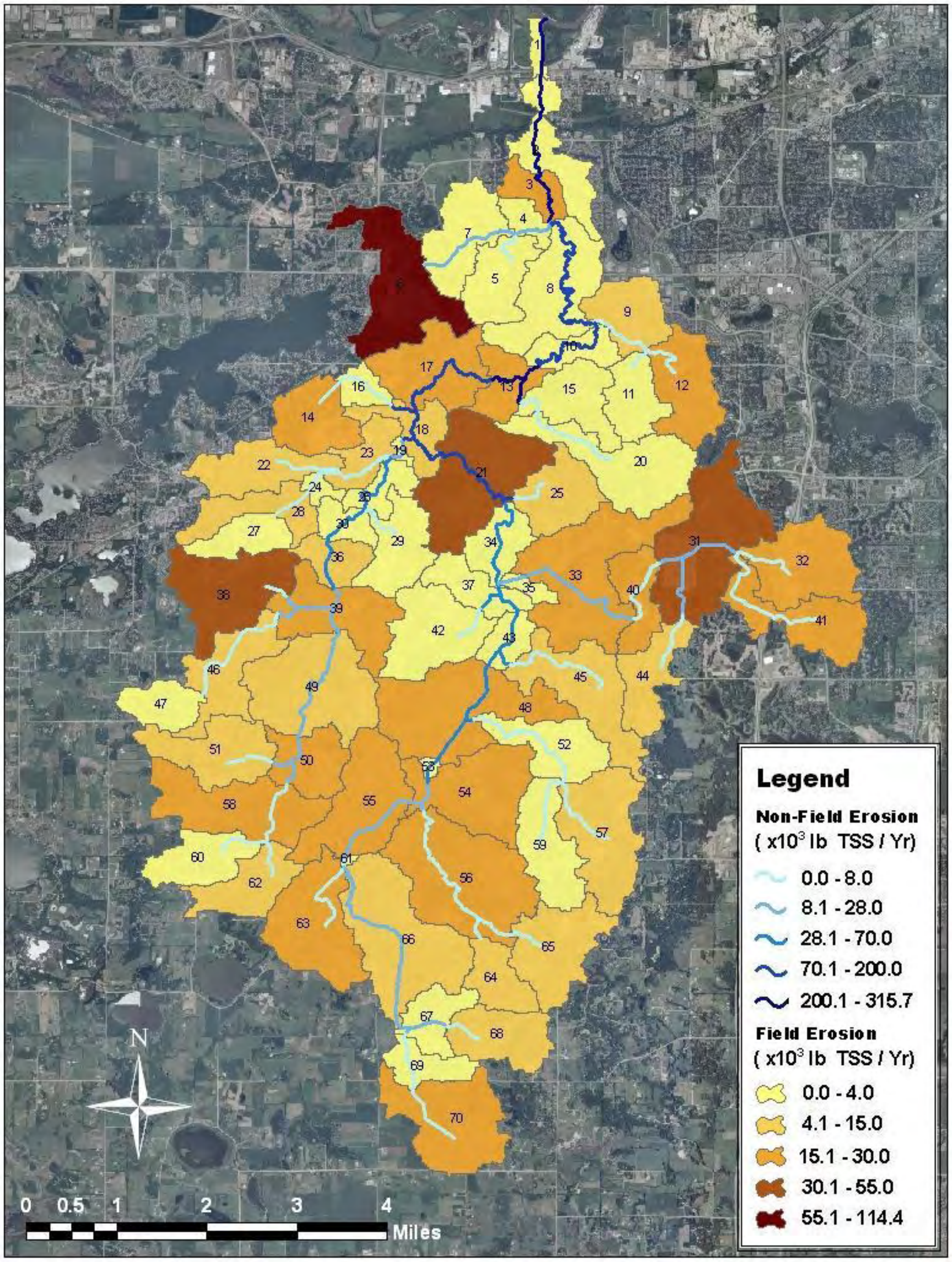


Figure 3-14. Simulated Field and Non-Field TSS Loads by Subbasin for Credit River Watershed

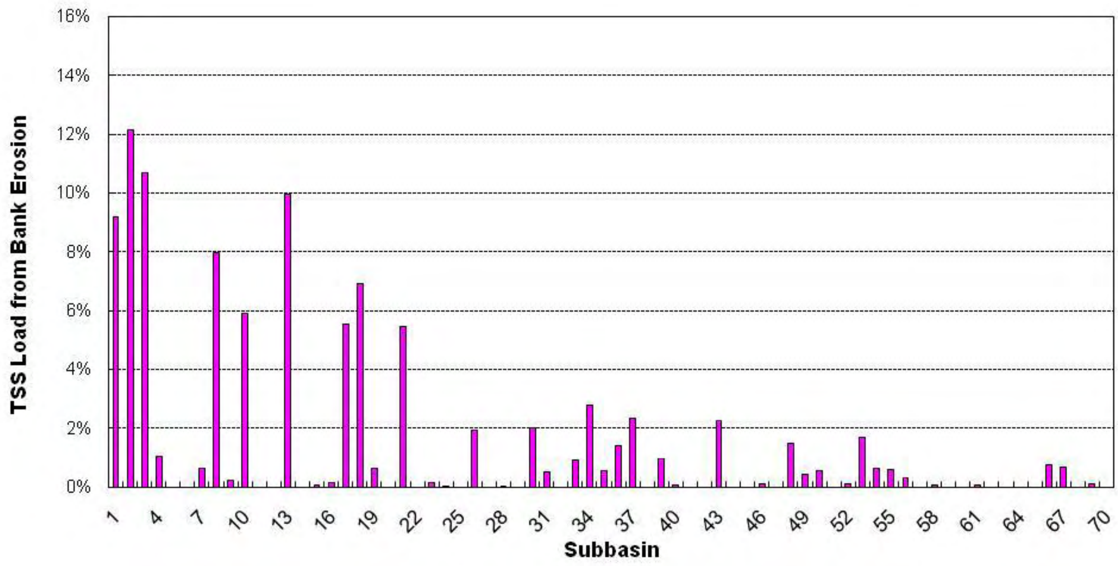


Figure 3-15. Simulated Non-field Erosion Load in Percent by Subbasin

Simulated mass balances of the TSS loads in the Credit River Watershed were analyzed and summarized in a flowchart (Figure 3-16). The TSS loadings from various sinks and sources are distinguished by color. This mass balance shows that field erosion generates the highest TSS export, but that much of that is trapped by buffers, wetlands, and lakes before reaching the river, Non-field (channel) erosion has a much smaller TSS export, but since it is directly linked to the rivers its impact is higher.

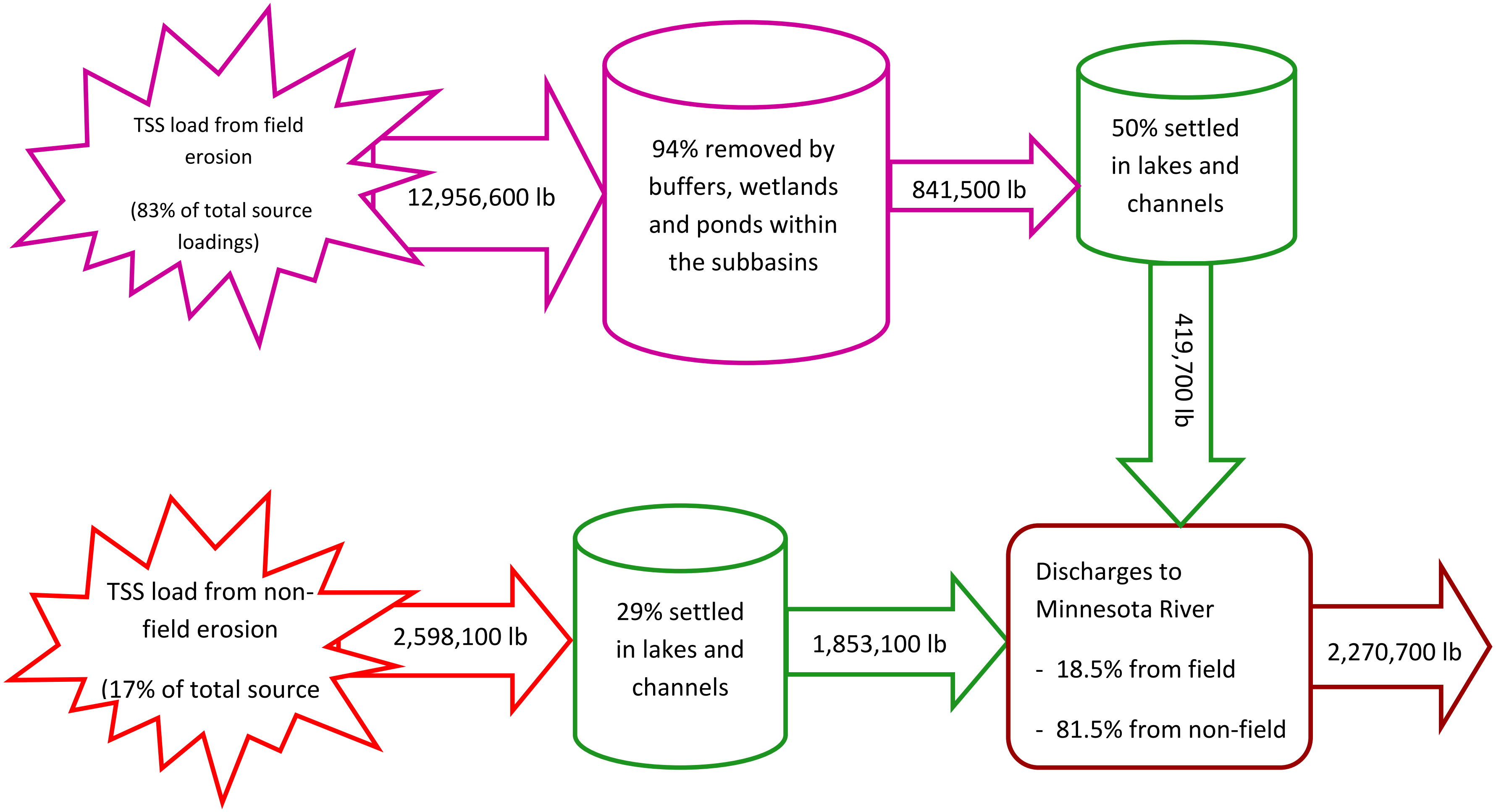


Figure 3-16. Mass Balance of Non-Point TSS Loads in Credit River Watershed

Temporal Variability. Figure 3-17 presents the continuous turbidity readings at the MCES site 123 for 2008 and 2009. This short period of record makes it difficult to identify seasonal patterns. However, since there is a strong relationship between turbidity and flow it is expected that seasonal patterns for turbidity would be similar to that of flow. Figure 3-18 presents the flow data for the MCES outlet site 123 (both when it was at RM0.6 and 0.9) for the entire period of record. This flow data shows a seasonal pattern with higher flows in the spring and early summer.

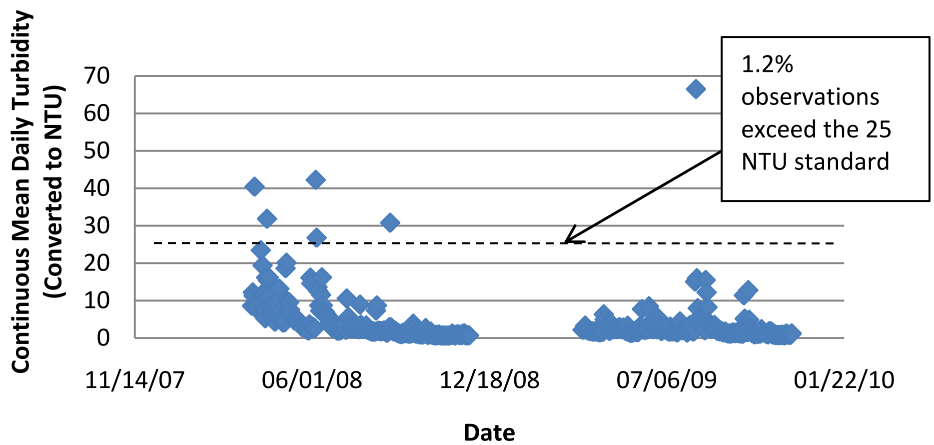


Figure 3-17. Continuous Turbidity Credit River Site 123, 2008 -2009

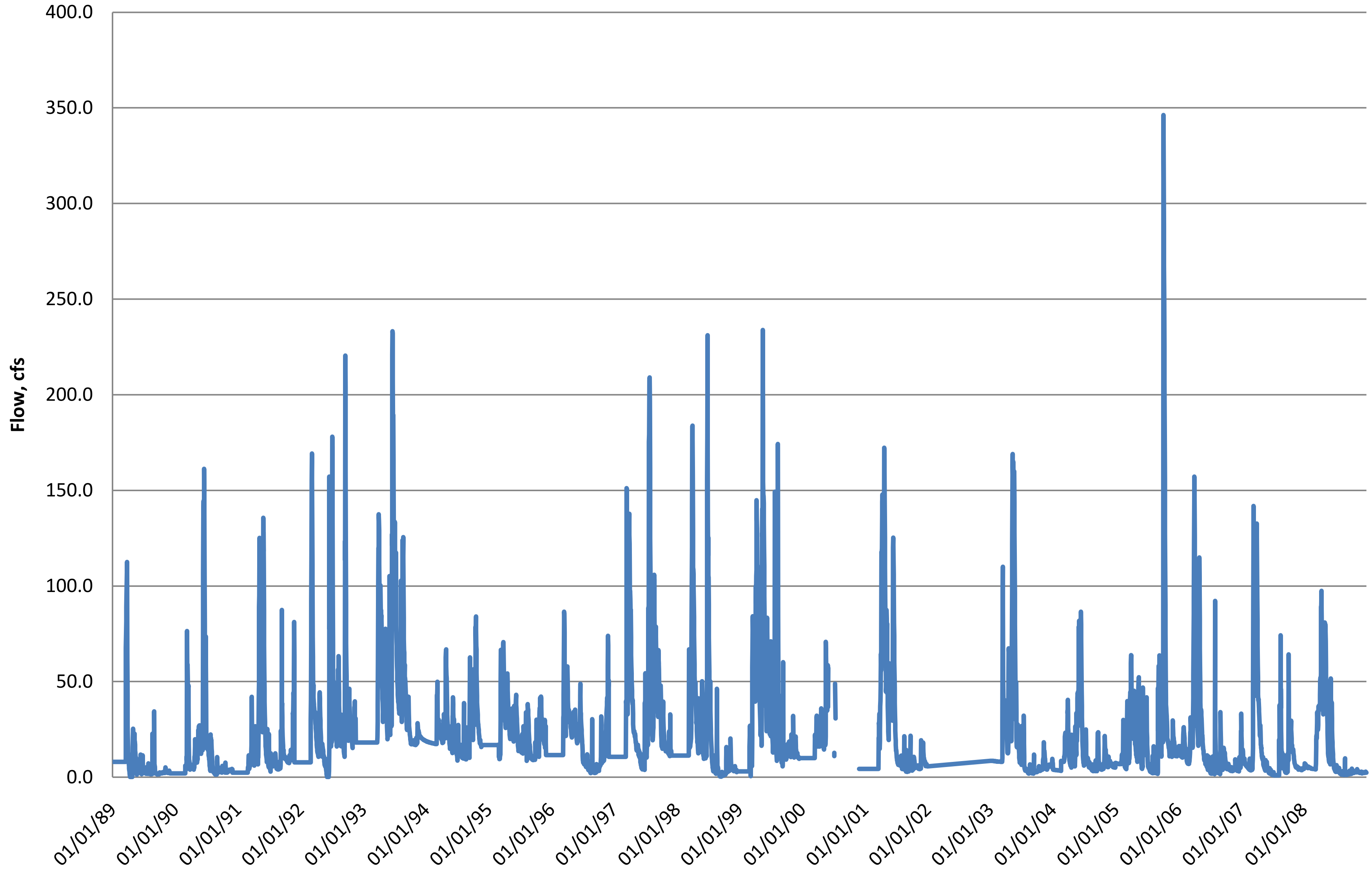


Figure 3-18. Credit River Flows at the Metropolitan Council site 123 (RM0.6/RM0.9)

Macroinvertbrates

Macroinvertebrates are organisms without a backbone (i.e., insects, leaches, etc.). They are frequently used as a means of assessing water quality and the health of aquatic communities. The presence or absence of different species, with different levels of tolerance to pollution, reflects exposure to pollution and other stressors. The Metropolitan Council collected data on macroinvertebrates at the downstream end of the watershed near their monitoring station from 2004 to 2007. This subsection provides a summary of the macroinvertebrate data collected by Metropolitan Council Environmental Services (MCES).

A number of different metrics can be calculated with macroinvertebrate data to get a sense of species diversity, the species present and their tolerance for pollution , etc. Table 3-4 below shows the metrics from 2004 to 2007 for Credit River site CR.9. The Hilsenhoff Biotic Index (HBI) was also calculated by the Metropolitan Council and was forwarded for use in this report. Results of the HBI are discussed separately below.

Interpretation of this type of data generally requires comparison with a regional reference site, and none is known for this area. Consultation with the MPCA regarding a reference site found that the Credit River had the lowest Human Disturbance Scale score for the region, and would qualify as a regional reference site. Thus, results are compared to the results reported by the Metropolitan Council for other metropolitan area streams from 2004 (Metropolitan Council, 2005). Data for other years has not been published. Comparison of the 2004 data shows that the Credit River had the highest number of taxa among the 12 streams assessed, was in the middle with respect to EPT taxa and % EPT, was highest on total Diperta taxa (flies and midges), and in the upper third on % Diptera taxa.

With respect to the Hilsenhoff Biotic Index (HBI) calculated from the 2004 through 2007 data from MCES indicated “very good” water quality in 2005 and 2006, to “good” water quality for 2004 and 2007.

Table 3-4. 2004-2007 Macroinvertebrate Metrics

Year	Total Taxa	Mean Tolerance Value	Total EPT* Taxa	% EPT* Taxa	Total Diptera Taxa	% Diptera Taxa	% Intolerant
2004	49	4.9	8	16	29	59	4
2005	33	4.2	7	21	18	54	5
2006	47	4.5	11	23	19	40	9
2007	36	4.8	10	27	19	53	8
	*EPT = Ephemeroptera, Plecoptera, and Trichoptera (Mayflies, Caddisflies, and Stoneflies)						

Conclusions

Analysis of the data collected showed the following.

1. QA/QC Review
    a. Water quality measurements and sample collection met data quality objectives
    b. Flow measurements met data quality objectives, as assessed by duplicate measurements. However, some uncertainty is introduced in the hydrographs for sites C68 and 154 because portions of the hydrographs had to be predicted using relationships developed between these sites and the Metropolitan Council site 123.
2. Turbidity and TSS
    a. There is a strong relationship between turbidity and TSS with a TSS concentration of 139 mg/L being equivalent to turbidity of 25 NTU.
    b. When turbidity was higher, NVSS was 75% or more of the TSS.
3. Turbidity and the standard
    a. The standard is not exceeded at site 123.
4. Spatial Variability

a. Most of the TSS load originates downstream of site 154. This makes sense as this is where the Credit River cuts through the Minnesota River Valley bluff and picks up grade.
b. Orchard Lake (and areas upstream) do not appear to be contributing significantly to turbidity in the Credit River.
c. Cleary Lake (and areas upstream) do not appear to be contributing significantly to turbidity in the Credit River.
d. Model calibration efforts and isotope studies in the Lower Minnesota River basin suggest that most of the TSS load in the river is from non-field sources. The SWAT model was calibrated to reflect that 18.5 percent of the TSS loads came from field erosion and 81.5 percent was from non-field erosion, consistent with isotope studies in the area.
e. Modeling suggests that the hydrologic load is greatest from urban land uses.
f. Modeling demonstrates that agricultural land uses (corn, soybeans and alfalfa) had the highest TSS export yields, but only a small portion of TSS export yield from field sources impacts the Credit River due to removal in buffers, wetlands, and ponds.
g. Modeling demonstrates that field sources of TSS have export rates 5 to 6 times that of non-field sources (channel or in stream), but much is trapped by buffers, wetlands and ponds such that non-field source directly in or adjacent to the river are the dominant TSS sources.

5. Temporal Variability
   a. There is a seasonal pattern for flow in the Credit River with higher flows occurring in the spring and early summer, and since there are strong relationships between turbidity, TSS, and flow, these seasonal patterns are also true for turbidity and TSS.
6. Macroinvertebrates
   a. Hilsenhoff Biotic Index (HBI) indicates "very good" water quality in 2005 and 2006, to "good" water quality for 2004 and 2007 for the Credit River.
   b. The Credit River qualifies as a reference site for the region due to a low Human Disturbance Scale score.

Section 4: Evaluation of Existing Management Efforts

Introduction

As part of developing the Protection Plan an assessment of the effectiveness of existing management efforts, and the identification of gaps was completed and is summarized in this Section. This assessment is not limited to regulatory controls. The Credit River watershed is largely in the Scott Watershed Management Organization (Scott WMO), with smaller portions in the Black Dog Watershed Management Organization (Black Dog WMO), and the Lower Minnesota River Watershed District. These organizations are responsible for implementing BWSR approved Comprehensive Water Resource Management Plans and have been around for 10 or more years. Thus, the water quality of the Credit River is a reflection of comprehensive watershed management, not just regulatory controls.

In addition, management is not limited to the Watershed Organizations. Cities do projects, the Metropolitan Council and Three Rivers Parks District monitor water quality, the MPCA enforces permits and does studies, the DNR also does permitting, and most of the watershed is covered by Municipal Separate Storm Sewer System (MS4) permits. The Cities of Lakeville, Savage and Prior Lake, Credit River and Spring Lake Townships, and Scott County are all MS4 permittees and are responsible for developing and implementing Storm Water Pollution Prevention Plans (SWPPPs).

This section provides a brief, but comprehensive, description of the current management efforts in the watershed. It describes future development expected under the 2030 Comprehensive Land Use Plans of the Cities and the County, and potential future impacts. It also summarizes an assessment of the effectiveness of current stormwater requirements for mitigating water quality impacts of development that is expected by 2030. Greater detail regarding this assessment can be found in Metropolitan Council's modeling report included as Appendix C. Table 4-1 at the end of the section is a summary of a matrix completed by the Technical Advisory Committee (TAC) for the project that organizes the various management efforts, identifies management gaps and ways to address the gaps. The full matrix is attached as Appendix H. The description of existing efforts focuses mostly on efforts in the Scott County areas of the watershed since the study found that the Orchard Lake subwatershed did not have much effect on turbidity in the river. Also included are descriptions of efforts that affect water quality parameters and aquatic life stressors other than turbidity. Recent data has shown that the river is not impaired for turbidity, and that the watershed is low on the Human Disturbance Scale, but other water quality parameters and factors could be threatening the river. These descriptions are not as thorough as the descriptions for programs affecting turbidity. The initial focus of this project was on turbidity, and the decision to include other efforts came later. The intent would be to incorporate additional efforts as needed in the Protection Plan based on the identification of threats as the plan is implemented and the potential for additional threats is assessed. The MPCA biomonitoring scheduled for 2014 will be particularly important for assessing additional potential stressors and management needs.

Existing Management Efforts

A short description of existing management efforts are provided below. Those interested in more detail are referred to the respective Comprehensive Water Resource Management Plans of the Watershed Organizations, and the SWPPPs of the MS4 permittees. For presentation purposes management acts are organized as follows:

- Programs
- Projects
- Regulations
- Monitoring
- Inventory and Assessment

Programs. A number of programs are offered by the organizations in the watershed that affect water quality. Programs are efforts that are re-occurring or on-going. These are briefly described below.

Scott WMO Technical Assistance and Cost Share (TACS) Program. The Scott WMO TACS program provides Technical Assistance, cost share funds and incentives for landowners to adopt conservation practices. The draft Lower Minnesota River Watershed

District (LMRWD) Plan update also has a Cost Share Incentive Program that includes "Credit River Restoration Projects" estimated at $10,000 per year for 5 years. Other programs such as the Natural Resource Conservation Service (NRCS), Environmental Quality Incentive Program (EQIP) and Conservation Reserve Program (CRP) are passively promoted.

Scott WMO program is on-going, but is generally passively promoted in the Credit River Watershed. There have been about ½ dozen projects over the last four years. These include stream bank stabilizations with private land owners along the creek, and several innovative projects with the Cities of Savage and Prior Lake involving Low Impact Development (LID) practices. The TACS program targeted riparian landowners and improvements in 2009. The LMRWD program is new.

Targeted Projects/ Capital Improvement Programs. The Scott WMO Plan and Local Water Plans by the Cities in the area have identified capital improvements for completion. The Lower Minnesota River Watershed District plan currently under revision will also identify capital improvements. The Scott WMO and the Cities routinely update their CIP list. Scott WMO does so every two years. New potential CIPs identified can be added.

The targeted projects/capital improvements identified in the Scott WMO Plan for the Credit River have all been completed in partnership with the City of Savage. These include: the Utica Ravine Stabilization and the 133rd Street grade stabilization Figure 4-1.

Education. The Scott WMO has an education program and participates with other MS4 communities in the County (including those in the Credit River watershed) to promote water quality education through the joint Scott Clean Water Education Program (SCWEP). The Cities of Prior Lake and Savage, and Credit River and Spring Lake Townships are also part of the partnership. This partnership not only helps members satisfy MS4 public education and outreach efforts, it also provides targeted education and

Utica Ravine Before

Utica Ravine After

133rd Street Before **133rd Street After**

Figure 4-1. Recent City of Savage Stabilization Projects

information for TMDLs and particular problems. The draft LMRWD Plan also has education programming, but it will target Minnesota River issues. The Black Dog WMO also provides water quality/stormwater education.

One full time staff person to implement SCWEP is housed at the Scott SWCD. A contract is in place to continue the partnership through 2011. The Scott WMO together with the Scott SWCD is also hosting a series of rain garden workshops in 2011 patterned after the Blue Thumb program. Participants can receive a small cost share incentive for installing a rain garden through the TACS program.

Scott County Household Hazardous Waste Facility. Scott County operates a Household Hazardous Waste recycling facility located in the northeast corner of Spring Lake Township. The facility can accept items from residents that are flammable, corrosive, toxic, poisonous, or reactive such as: paint products, wood preservatives or bleaches, household chemicals, yard chemicals, automotive chemicals, adhesives and putties, aerosol spray products, fuels and solvents, and mercury. Appliances, electronics, tires are accepted for a small fee. Having an option for proper disposal of waste is designed to reduce discharge into the environment.

Currently operating hours are:

Wednesday: 12:00 noon to 6:00 p.m.
Thursday: 12:00 noon to 4:00 p.m.
Saturday: 8:00 a.m. to 12:00 noon

The facility should be operational into the foreseeable future although hours of operation and services provided may change from year to year.

Natural Area Corridors. The Credit River has been identified as a Natural Area Corridor in the Scott County 2030 Comprehensive Land Use Plan. Land in Natural Area Corridors is given a priority for participation in the Scott WMO TACS program (described above) and development is eligible for Public Values Incentives (described below under Regulations). These efforts are designed to promote green infrastructure, although participation is voluntary. Ordinances are in place allowing Public Value Incentives and the County has designed an approach for the management of easements.

Municipal Stormwater Inspection and Maintenance Programs. All three cities have on-going stormwater inspection and maintenance programs. When these programs identify problems or needs the cities may choose to upgrade if it is a priority, is feasible and has a benefit. The Scott WMO has an LGU cost share strategy to encourage projects with LGUs.

The Cities and the Scott WMO routinely update their CIP list. Scott WMO updates every two years. New potential CIPs identified can be added.

Projects. Projects are one time actions. They may be actions completed as part of a larger program – for example individual construction projects that are part of a Capital Improvement Program. A few completed and/or pending projects were identified and are discussed below.

Subwatershed Assessment and Retrofit Project. The Scott SWCD is working on a subwatershed assessment with the City of Savage to identify the most cost-effective urban BMPs that could be implemented in a retrofit fashion. The study is a dynamic document to guide the City on how to best spend funds allocated for stormwater improvements over time. The types of projects that can be constructed include pond modifications, bioretention systems, pavement reductions, new storage opportunities, etc. Funding may be available from the Clean Water Fund for implementation.

City of Savage – Rain Garden Funds/Incentives. The City of Savage has $15,000 to promote rain gardens in 2011. This effort will be implemented together with the rain garden workshops and the Scott WMO TACS program.

Orchard Lake Curly Leaf Pondweed Control. City of Lakeville has been working on Curly Leaf Pondweed control in Orchard Lake for several years. The DNR is providing grant assistance. Reduction of Curly Leaf Pondweed may help control phosphorus and reduce algae turbidity. The affect on the Credit River is not expected to be significant, but the effort contributes to the overall health of the watershed. The City has received DNR grant funding for the past two years, however, they were unable to complete treatments in 2010 due to plant conditions.

Orchard Pond Aeration. City of Lakeville is planning to aerate a pond that drains to Orchard Lake as a way of reducing phosphorus discharged to the lake. This is intended to reduce phosphorus in the lake and algae growth. There may be some reduction in algae turbidity. The affect on the Credit River is not expected to be significant, but the effort contributes to the overall health of the watershed.

Geomorphic Study Potential Projects. As part of the Geomorphic Study completed by the Scott WMO 48 potential projects that would improve the stability and help maintain the dynamic equilibrium of the river were identified. A number of property owners have been contacted where some of the projects were identified and some projects have been completed. The focus to date has been on those potential projects that would improve riparian vegetation in the urban area. Other projects (particularly some of the wetland restorations) have been identified as not feasible.

The Scott WMO is currently still following up with some property owners where contacts have been made. The LMRWD has identified the completion of those in their District in their draft Plan update.

Regulations. The following summarizes some of the regulations affecting stormwater and future development.

Stormwater Standards for New and Redevelopment. In general, Scott County and cities use five management approaches for new development that can be generalized as follows.

1) All the Local Government Units (i.e., the county and the cities) require retention of ½ inch of surface water runoff from new impervious surfaces to mitigate the anticipated increases in runoff volume associated with new development.
2) All of the Local Government Units (LGUs) require some form of peak runoff rate control. For the cities in Scott County the requirement is that the peak runoff rates cannot exceed the peak rate that occurred under the pre-development land use. For the unincorporated areas of the County, the requirement is that the peak runoff rate cannot exceed the peak rate that occurred under pre-settlement land use.
3) All of the LGUs require some form of post construction water quality treatment, typically a water quality pond constructed in conformance with the MPCA specifications in the NPDES Construction General permit.
4) All of the LGUs require buffers adjacent to water courses and wetlands. The County and the Cities of Savage and Prior Lake have requirements equivalent to the Scott WMO, which requires wetland buffer widths from 25 to 65 feet (depending on wetland quality) and watercourse buffer widths of 30 feet.
5) All of the LGUs have construction erosion control programs to control erosion during construction.

All requirements under the current Scott WMO Plan are in County ordinance and are being applied. Other Local Units of Government are required to update their Local Water Plans to include the new WMO requirements by the end of May 2011, and will then have 180 days to begin implementation. However, new WMO requirements are largely the same as they were under the previous WMO Plan, the biggest exceptions being the need for a buffer adjacent to waterways such as the Credit River. The Cities of Savage and Prior Lake have Local Water Plans approved as equivalent under previous Scott WMO Plan. Thus, cities are largely implementing the standards.

Scott County, the Cities of Savage, Prior Lake, Lakeville, and Credit River Township all have Construction Erosion Control programs for development. Scott County and Credit River Township use the Scott SWCD to complete inspections.

MS4 NPDES Permits. The entire Credit River watershed is covered by Municipal Separate Storm Sewer System (MS4) communities with Stormwater Pollution Prevention Plans (SWPPPs) under the Clean Water Act National Pollution Discharge Elimination System (NPDES) program, except the southernmost part of the watershed in New Market Township.

Scott County, the Cities of Savage, Prior Lake, and Lakeville; and Credit River and Spring Lake Townships all have MS4 permits and SWPPPs. The three cities also have nondegradation plans. Implementation of the SWPPPs is on-going and the MS4s in Scott County work together to implement a joint education program called the Scott Clean Water Education Program (described above under Programs). The current general permit under which the communities are operating expires May 31, 2011. A new general permit is not expected to be produced by the MPCA until the end of 2011.

Land Use Planning. The Cities of Savage, Prior Lake and Lakeville, and the County have recently completed Comprehensive Land Use Plan Updates. Scott County portions of the watershed are guided as "urban expansion" and "rural residential". "Urban expansion" is guided for 40 acre lots with the expectation that the area would not be annexed or served by public utilities until after 2030. "Rural residential" is 2.5 acre lots, although clustering and community septic systems can be used allowing smaller lots.

County ordinances are in place for the zoning, and a Detailed Area Plan has been completed identifying the infrastructure needs for developing at rural residential densities of 2.5 acre lots.

Development Incentives. Scott County has Public Value Incentives for development in the rural residential areas to promote Planned Urban Developments that incorporate attributes that benefit the public. In exchange for incorporation of these attributes, incentives such as extra density of a few lots can be considered. Specific Public Values that may help protect the Credit River include preserving land in Natural Area Corridors, dedicating parkland, restoring wetlands, dedicating lands for regional stormwater facilities, or using Low Impact Development practices. Enabling ordinances have been written and adopted.

Spring Lake Township LID Requirements. Spring Lake Township has developed requirements for new development in addition to the County's and Scott WMO's stormwater management standards. These include the requirements to use Low Impact Development practices. The Township has written the necessary ordinances.

Cleary Lake TMDL. Cleary Lake is considered water quality impaired due to excessive nutrients. This means that a Total Maximum Daily Load (TMDL) study is required to determine the necessary phosphorus load reduction to achieve the standard. This may affect MS4 stormwater permits, and improve the quality of discharges from the lake to the Credit River. The TMDL study is scheduled to start in 2014 and be complete by 2018.

Hobby Farm Requirements. Farm program participants are required to have a conservation plan on any fields containing highly erodible land. Currently Scott County code regarding maximum animal unit (AU) densities states that parcels less than 40 acres in size need to have 2 productive acres of land for the first animal unit and one productive acre for each animal unit thereafter. Landowners may exceed maximum AU densities by obtaining an administrative permit with approved management practices and subject to annual review if necessary. MPCA rules chapter 7020 and 7053 regulate animal waste pollution to waters of the state through proper management of manure storage and handling. MN Extension service has small landowner information publications and occasionally workshops for education and outreach. Applicable USDA, MPCA and Scott County requirements are administered by Scott SWCD and NRCS staff. Scott SWCD and MN extension service provide technical assistance to educate hobby farm owners.

Monitoring. Monitoring is a necessary part of protecting water bodies since it provides the basis for assessing trends and identifying and taking corrective actions. The following summarizes known monitoring efforts in the watershed.

Metropolitan Council Environmental Services (MCES) Outlet Monitoring. MCES operates a monitoring station at RM0.9 where data on flow and a number of water quality parameters is collected. MCES also collects information on macroinvertebrates. Water quality monitoring at RM0.9 is expected to remain in place. Macroinvertebrate monitoring was completed 2004 through 2009, however samples have been analyzed from 2004-2007 at this time. There is a need to find a funding source to help with analysis. MCES plans to keep collecting samples.

Lakes. Orchard Lake is monitored annually through the MCES Citizen Assisted Monitoring Program (CAMP). Cleary Lake and other Lakes in the Murphy Harahan Regional Park are monitored by the Three Rivers Park District. Markley Lake is not monitored, but is land locked and does not discharge.

MPCA Intensive Watershed Monitoring (IWM). MPCA is scheduled to complete its monitoring program for the Lower Minnesota River Watershed in 2014, and then on 10 year cycles. Monitoring of the Credit River is expected to be part of this effort. This monitoring is for Aquatic Life, Aquatic Recreation and Aquatic Consumption and includes biological sampling (macorinvertebrates, fish and habitat).

Well Water Level Monitoring. The Department of Natural Resources coordinates a water level monitoring network. Discussions with Michael McDonald who Administers the program found that there is currently one monitoring well in the watershed. There were additional limited time sites historically, and the DNR also gets water level information from the appropriators in the area (i.e., from wells operated by the cities in the area).

Inventory and Assessment. This management element includes efforts to convert data into information, the collection of physical inventory information, assessing trends, and other forms of assessing progress and learning to adapt.

Water Quality Trend Analysis. On-going or periodic assessment of water quality trends is important for a protection program in order to have early detection of trends and have a basis for making adaptive management decisions. Metropolitan Council has not completed a trend analysis of the data at the RM0.9 site, but is currently completing such an analysis with publication of results expected in 2011. They expect to do additional trend analyses on a periodic basis, on a 10 year cycle at a minimum.

Water Quality Data Assessments. The Metropolitan Council assesses and publishes the CAMP Lake monitoring data annually. Three Rivers Parks also assesses their lake monitoring data annually and provides summary reports to local WMOs to publish on their websites.

The Metropolitan Council provides some level of data assessment and calculates loads annually for their stream sites. The MPCA evaluates available stream data for impairments every other year as part of their biannual impaired waters listing (303d) review.

MPCA will assess the data they collect as part of the Lower Minnesota River Basin monitoring effort in the years immediately following data collection. Results will be disseminated through reports and publications of the MPCA. The first monitoring cycle by the MPCA is scheduled for 2014. Data analysis is expected to be completed in 2015 and 2016, and then on 10 year cycles.

Observation of Sediment Delta Formation. The Lower Minnesota River Watershed District receives reports and observes sediment delta formation where the Credit River discharges to the Minnesota River.

Groundwater Assessment and Planning. The Scott County Groundwater Management Plan expired in 2009. Efforts in the old plan were voluntary. Recent studies have shown that projected development will negatively affect the baseflow of the river. Cities are currently assessing whether they can work together more through cross connections to maintain supply. Scott WMO is planning a well sampling effort to screen for pesticides and nitrates in the unincorporated areas. This effort is scheduled for the summer of 2011.

The County is assessing whether to complete a new plan. To make that decision the County is waiting for the results of the study by the cities and the rural well pesticide screening. It is expected that these studies will be complete early summer of 2011, with the County anticipating on revisiting the planning process in the fall of 2011.

Minnesota Land Cover Classification System Update. The Minnesota Land Cover Classification System (MLCCS) inventory completed by the County provides an important tool for managing natural systems and the Natural Areas Corridor. The current inventory for the unincorporated areas of the watershed was completed in 2007. The Scott WMO is planning to update portions of the inventory in 2013. It is uncertain whether the update planned for 2013 will focus on the Credit River watershed or other portions of the Scott WMO. Priority areas will be determined early 2013.

Plan Progress Tracking and Review. Scott WMO has metrics for measuring implementation of the Scott WMO Plan that are assessed and reported on in the WMO Annual Report. The Scott WMO Plan was recently amended to add the Credit River Protection Plan as an implementation strategy. The draft Lower Minnesota River Watershed District Plan includes similar metrics.

Assessment of Future Conditions

The SWAT model was used to assess future runoff and total suspended solids loads and concentrations under expected 2030 land use conditions.

To simulate future development conditions for the Credit River Watershed, the projected 2030 land use map was incorporated into the original model developed using the 2002 land cover map. A new 2030 land use map was created by MCES using the Scott County 2030 land use map for the unincorporated areas and the Metropolitan Council 2030 land use map for the incorporated areas (see Appendix C for details).

The Metropolitan Council 2030 land use map was developed specifically for use in SWAT modeling. The urban areas of the watershed located in Dakota County are not included in the map. These areas include portions of the Cities of Burnsville and Lakeville, preserved regional parks, forests or wetlands. It was assumed that the differences between the 2002 and 2030 land use conditions would be marginal for those areas. Therefore, the 2002 land cover map, which was used for model development, was used for the portions of the watershed not defined by the Council's 2030 map. According to the Scott County 2030 planned land use map, all rural areas in the Credit River Watershed will be used either as urban expansion or as low density rural residential area in 2030. The boundary of these areas was defined using the Scott County 2030 planned land cover map.

New databases for the new urban and rural residential land uses in the 2030 map were also created in the SWAT model for simulations. Based on inputs received from the Scott County staff, the land covers for all rural residential area were simulated as switch grass, except for a small portion of the existing rural residential areas in the Metropolitan Council's 2002 map, which were simulated at various residential densities following the 2002 model. Switch grass was used as land cover for rural residential areas to reflect the low residential densities planned for the rural residential areas in the County. The rural residential medium and high densities and commercial land uses account for a very minimal amount of land cover. These land uses were eventually excluded by SWAT in model setup.

Representing the rural residential development as switch grass will underestimate runoff and TSS generated from this land use, since there will be impervious surfaces such as roads, driveways and rooftops associated with the rural residential development. This needs to be considered when interpreting the modeling results.

In the end, a new SWAT model based on the calibrated 2002 model was built for the Credit River Watershed using the developed 2030 land use map. Except for the land use information, the 2030 model has the same inputs and parameters as 2002 model. For scenario assessments, the model was run using precipitation records from 1997 - 2008.

According to SWAT delineation based on the created 2030 land use map, there will be about 6,540 acres of new development in the Credit River Watershed by 2030. Total urban and rural residential area in the watershed will be 8,700 acres (18 percent increase) and 10,700 acres (94 percent increase) respectively. Agricultural land uses will be eliminated in urban and rural areas in 2030 except for in the urban expansion area, which has about 1,650 acres of agricultural land use and is not expected to be developed by 2030. Forests will be reduced by 34 percent to 4,440 acres and pasture lands will be reduced by 26 percent to 1,550 acres. Wetlands and lakes are preserved and therefore have minimal changes. Figure 4-2 shows a comparison of land uses between 2002 and 2030 conditions.

Urban and rural residential land uses will be the dominant land uses in the watershed in 2030, accounting for 28 percent and 35 percent of the total watershed area respectively (Figure 4-3). The remaining land uses will be forests (15 percent), wetlands (11 percent), agriculture (5 percent), water (3 percent), and pasture (3 percent).

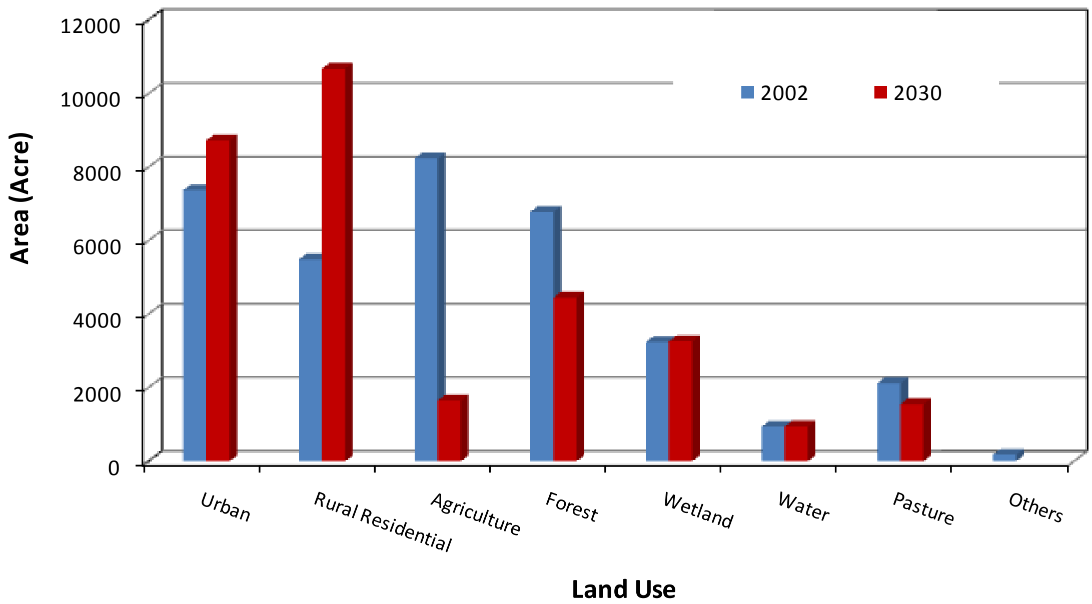


Figure 4-2. Comparison of Land Uses between 2002 and 2030

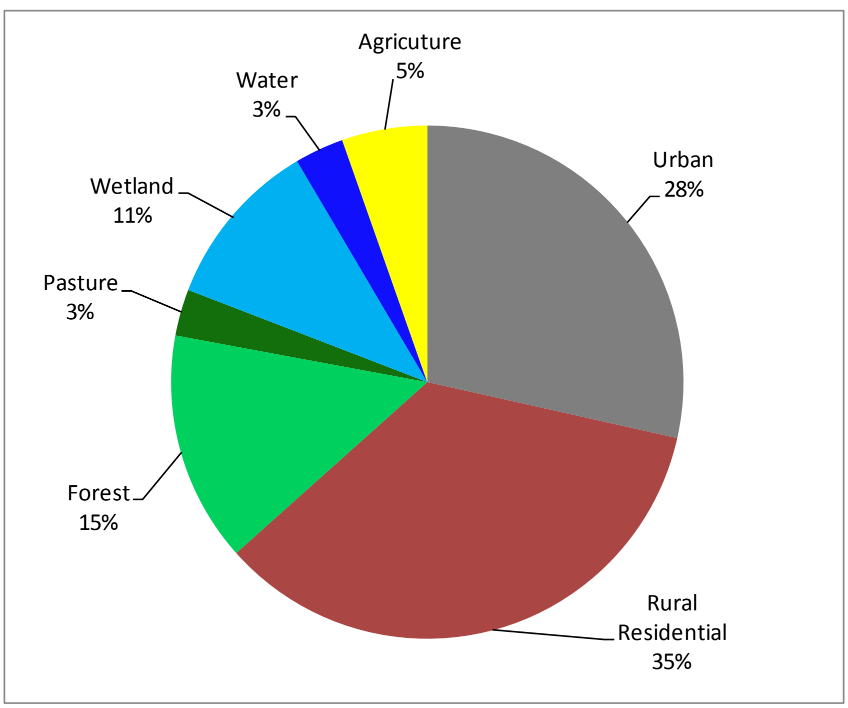


Figure 4-3. Land Use Conditions of Credit River Watershed in 2030

Figure 4-4 breaks down the 2030 urban and new rural residential areas by densities for existing and new development. In the urban and new rural residential areas in 2030, 45 percent will be urban and 55 percent will be rural residential. New development will account for 51 percent of the total urban and new rural residential areas. Of the new development area only about 20 percent will be urban and 80 percent of it will be rural residential.

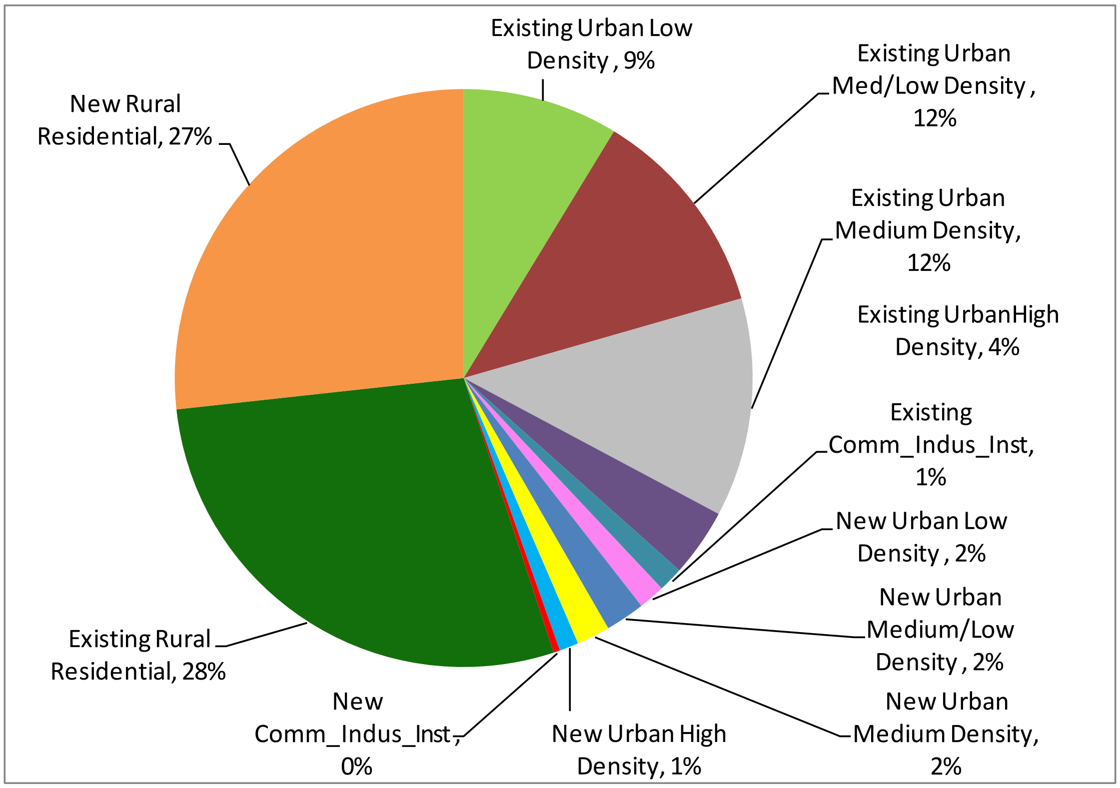


Figure 4-4. Urban and Rural Residential Land Uses in 2030

Figures 4-5 and 4-6 present annual flow rates and TSS loads for 2002 and 2030 land use conditions without runoff or water quality controls. The results were simulated at the watershed outlet using the 2002 and 2030 land use models and precipitation records from 1997 - 2008. Comparisons between the two models show that the average flow rate at the watershed outlet will increase about 6 percent from 2002 to 2030 if the projected new development occurs without runoff volume control standards. Increased flow from new development not only brings more TSS from runoff from upland, but also leads to a potential increase in bank erosion downstream. As a result, the TSS load in the watershed will likely increase by 10 percent. Relatively larger increases in flow and TSS load were simulated for 1997, 2000, 2002, 2004 and 2008, probably due to the relatively high precipitation totals in those years. Without application of the County's storm water standard, average flow rate and TSS load from new development were predicted to increase only slightly, even though the extent of new urban area is projected to increase by 18 percent and rural residential by 94 percent.

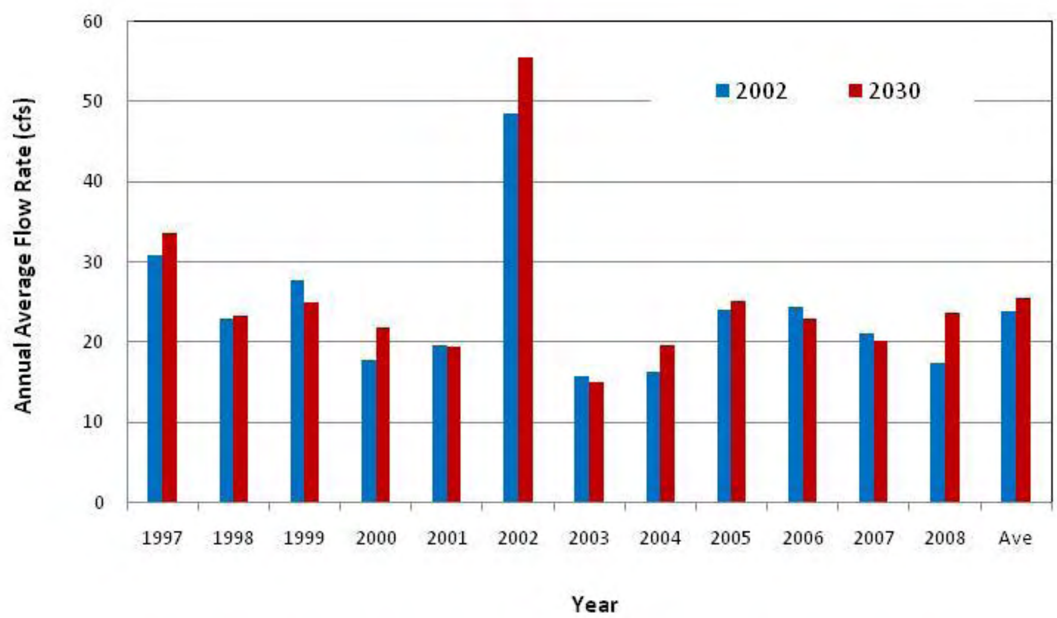


Figure 4-5. Comparison of Flow Rates between 2002 and 2030 Land Use Conditions

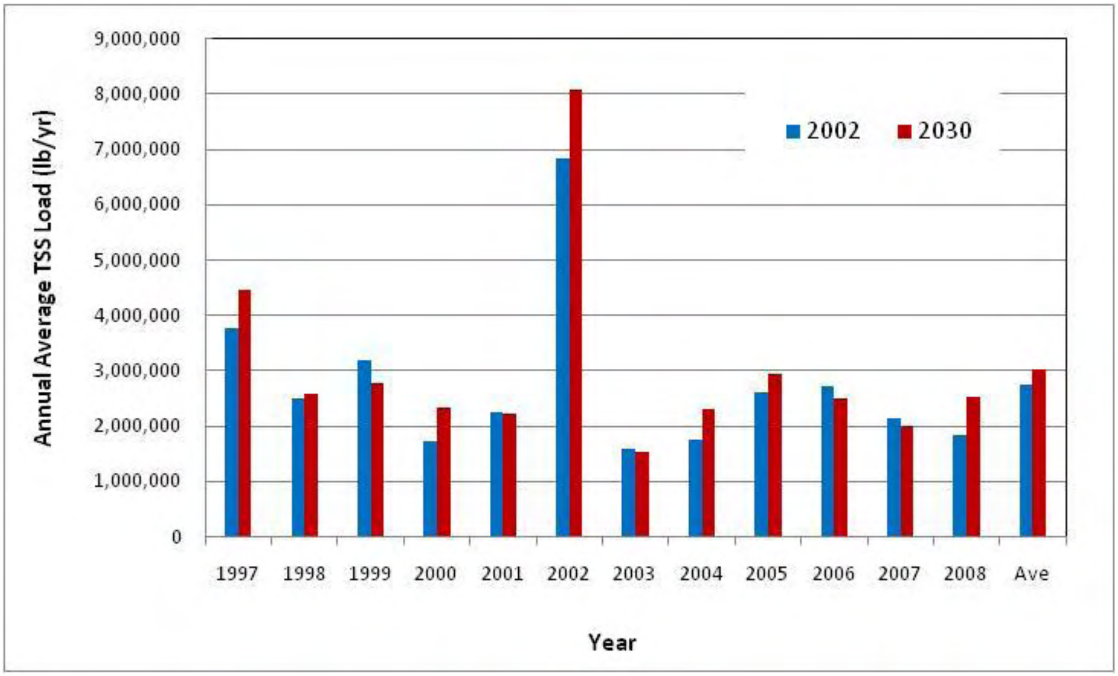


Figure 4-6. Comparison of TSS Loads between 2002 and 2030 Land Use Conditions

Assessment of Existing Stormwater Controls

The future conditions SWAT model was used to assess the effectiveness of local stormwater standards. This study was different from most SWAT modeling studies, which tend to focus on how site-specific BMPs reduce flow and pollutant loads. Representing the application of watershed-wide development standards in SWAT is not straight forward. After much discussion it was determined that:

1) Construction erosion control standards did not need to be modeled as these are temporary efforts, and what was of interest was the post construction condition.
2) The peak runoff control standard and the water quality pond standards could not be explicitly modeled in SWAT because of the site specific nature of building ponds could not be easily identified and represented in SWAT.
3) The runoff volume standard would be represented by adjusting the curve numbers (CN) associated with new development impervious surface.
4) Required buffers would be represented using 30 foot wide filter strips.

The scenarios for this study should be reviewed with the understanding that SWAT is a predictive tool developed for general watershed hydrology and non-point source studies. It was not developed for use in site-specific engineering design. In addition, two of the standards could not be modeled using SWAT; thus modeling results likely under-represent the collective effectiveness of the standards. In addition, other assumptions regarding how to represent the future rural residential land uses in the model probably underestimate the impact from land use changes as well. As always, the proposed scenario results are to be used to inform management decisions, in the context of how things are represented in the model, and not to be used for engineering design (see Appendix G for additional detail).

The model was run from 1997 to 2008 under 2030 land use conditions with the following scenarios:

- Implementation of storm water volume control standard by adjusting impervious CN from 98 to 82.7, and
- Implementation of the standard plus 30 foot buffer strips to the water bodies in new development areas.

The results were compared to the 2002 baseline and 2030 land use condition without the standards to understand impacts of land use changes and implementations of the local standards on the watershed hydrology and TSS load.

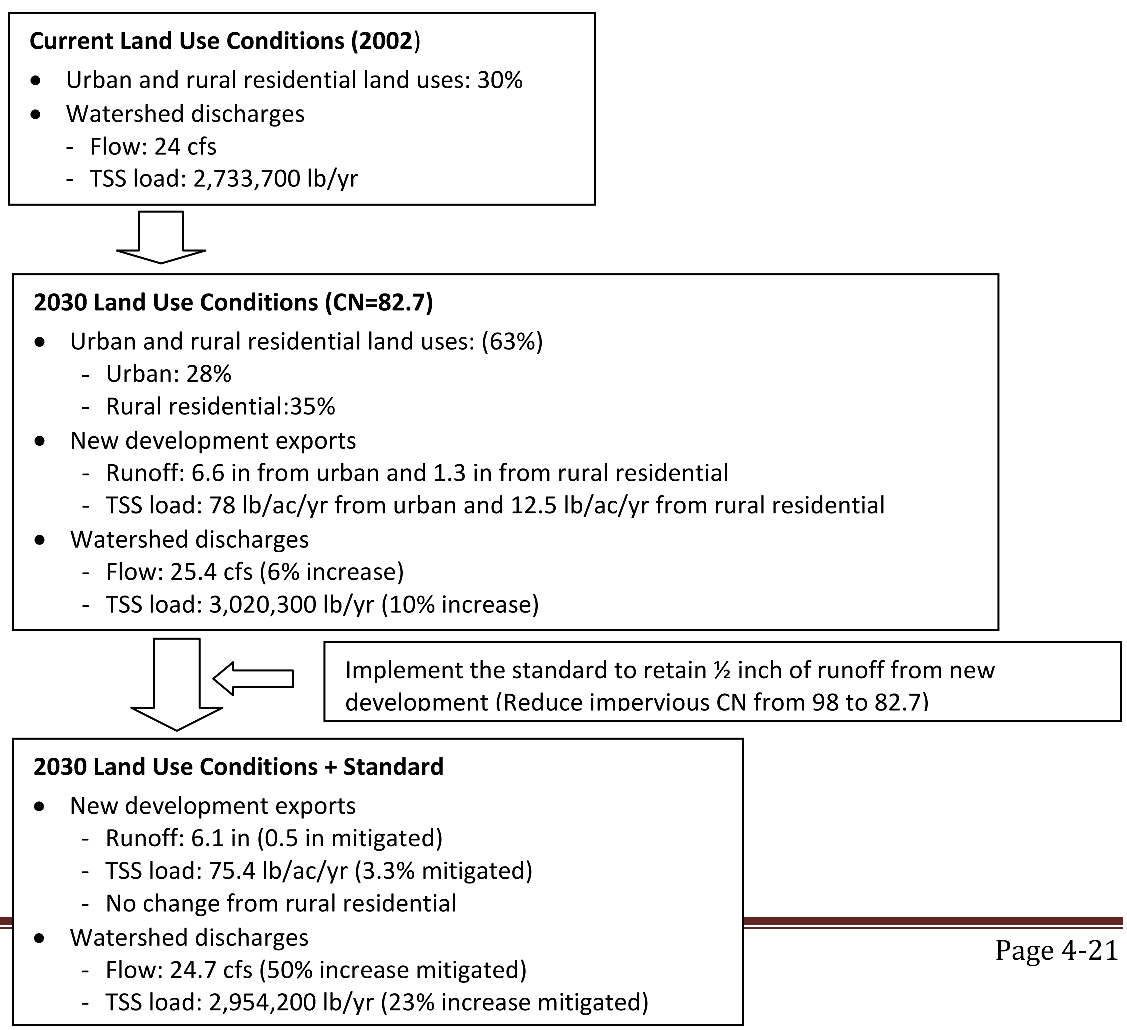
Scenarios based on SWAT simulations provided the following findings:

- With implementation of the volume control standard (½ inch runoff retention from new development impervious surface), the watershed flow and TSS load were estimated to be 24.7 cfs and 2,954,200 lb/yr, which are about 3 percent and 2 percent lower than 2030 conditions without the standard, but still 4 percent and 8 percent higher than the 2002 conditions for flow and TSS respectively.
- With implementation of 30 foot buffers the watershed TSS load was estimated to be 3 - 6 percent less than 2030 conditions but still 4 - 8 percent higher than 2002 conditions. No storm volume retention was simulated for buffer strips in SWAT.

Therefore, it was concluded that:

- New development as guided for 2030 is expected to have limited impacts on overall watershed hydrology and TSS loading (about 6 percent and 10 percent increases respectively). This is most likely due to the fact that the majority of new development is expected to occur in the rural residential area at lower densities with less impervious cover and this area was modeled using switch grass.
- The local storm water volume control standard and buffer requirements have the potential to mitigate much of the volume, TSS and turbidity increases from future development. The volume control standard and 30 foot buffers are expected to mitigate 50% of the expected flow increase and 23% - 62% of expected TSS increase in 2030.

Figure 4-7 provides a summary of the future conditions and management scenarios modeling results.



Implement 30 ft buffers to new development for TSS control

2030 Land Use Conditions + Standard + 30 ft buffers

- New development exports
  - Runoff: no change
  - TSS load: 22.3 lb/ac/yr (74% mitigated)
- Watershed discharges
  - Flow: 24.7 cfs (50% increase mitigated)
  - TSS load: 2,954,200 - 2,844,000 lb/yr (23% - 62% increase mitigated)

Conclusions based on the scenarios:

- New development is expected to have limited impacts on watershed hydrology and TSS loads (about 4% and 8% increases respectively). This is most likely due to the fact that the majority of new development is in the rural residential areas where densities are much lower and the model simulated this area with switch grass.
- Standard and buffer implementation has the potential to mitigate watershed flow volume, TSS and turbidity impacts from future development (3% and 6% lower than without standard and buffers or 23% - 62% mitigations of the expected increases of flow and TSS by 2030).

Figure 4-7. Summary of Management Scenarios Modeling

Management Gaps Analysis

The Technical Advisory Committee (TAC) for the project considered available monitoring data, the SWAT modeling results, and information on various management efforts in April 2011, and identified management gaps listed in Table 4-1. The complete gaps analysis matrix completed by the TAC is provided as Appendix H.

Review of Table 4-1 shows that most of the gaps identified were in Inventory and Assessment rather than other management areas. For example, only one management gap was identified for Regulations. This emphasis on Inventory and Assessment may be due to several reasons as follows:

1. The TAC recognized that protection is different than restoration. Water quality restoration needs to reduce pollutant loads and may require significant physical corrections or capital improvements. Protection relies mostly on measures that preserve existing conditions.

2. A number of capital improvements and cost share projects were recently completed in the watershed. Suspended solids reductions from most of these improvements occurred after the collection of the data that showed the river is meeting the turbidity standard. Thus, these reductions provide a safety factor.
3. The Credit River Watershed is covered by three Watershed Organizations; cities, townships, and a County that are holders of MS4 permits and are already implementing SWPPPs. The regulatory programs of these organizations are fairly mature.
4. The SWAT modeling of existing stormwater controls showed that they would likely mitigate much of the expected hydrologic and suspended solids load increases expected from future development. Most future development in the watershed is guided as rural residential or large lot development with agriculture largely being eliminated.
5. While there are a number of agencies and local organizations managing stormwater, it became apparent that there were gaps with respect to coordinating and assessing monitoring data. In addition, the importance of monitoring and data assessment was recognized in a Protection Plan since these actions form the basis for identifying trends and threats. It was recognized that protection is less costly than restoration, with the ability to recognize trends and adapt appropriately as a critical need.
6. None of the local Watersheds had an exclusive role managing the Credit River Watershed, and thus it became apparent that there was a gap with respect focusing and tracking efforts on the Credit River.

Summary

This section provides a review of current management programs and an assessment of management gaps. Gaps identified form the basis of the Management Plan presented in Section 5.

Table 4-1. Assessment of Management Gaps

Management Element	Gaps Identified	Potential Solution
Programs		
Education	Education efforts targeting hobby farms and continuation of SCWEP beyond 2011 are gaps or uncertainties.	Scott WMO and Scott SWCD to develop specific education and technical assistance efforts targeting hobby farms. The discontinuation of SCWEP may not be a gap in education program delivery since the MS4 partners will still need to continue education efforts in their permits. However, education programs may not be as efficient.
Projects		
Subwatershed Assessment and Retrofit Project	Current funding has been used for other projects.	Expecting to be able to access unused funds from other projects.
City of Savage – Rain Garden Funds/Incentives	Currently only identified for completion in 2011.	The Scott WMO and the City will evaluate the 2011 workshop(s) and decide on the value of continuing in 2012 as part of the WMOs annual review of the cost share and incentive program docket (completed annually in December).
Geomorphic Study Potential Projects	The Scott WMO has only followed up on a few of the potential projects identified.	A systematic approach to assess, track and follow-up on the potential projects is needed. More detailed feasibility and benefits analyses also need to be completed with property owner contacts for those deemed feasible and beneficial.

Management Element	Gaps Identified	Potential Solution
Regulation		
Hobby Farms	Education efforts targeting hobby farms are a gap. Education on livestock exclusion is a gap.	Additional education and outreach efforts needed for Hobby Farm management through SCWEP or Extension. County code could be revised to include provisions that prohibit uncontrolled livestock access to streams, wetlands, etc., and feedlots without adequate control measures.
Monitoring		
MCES Outlet Monitoring	There is a gap with respect to funding and sustaining biomonitoring.	The Metropolitan Council, Scott WMO and LMRWD to coordinate to ensure macroinvertebrate monitoring occurs every other year. Will be coordinated with the 2014 biomonitoring by MPCA to prevent duplication.
Biomonitoring	There currently is a gap for fish biomonitoring.	Fish biomonitoring is part of the MPCA biomonitoring scheduled for 2014.
Well Water Level Monitoring	There is only one water level monitoring well in the watershed. Data is also obtained from water appropriators in the area, but this level of monitoring is not adequate.	Consider expanding the number of monitoring sites as part of updating the County Groundwater Management Plan.

Management Element	Gaps Identified	Potential Solution
Inventory and Assessment		
Water Quality Trend Analysis	Metropolitan Council has not completed a trend analysis at the RM0.9 site, but is currently completing such an analysis with publication of results in expected in 2011. They expect to do additional trend analyses on a periodic basis (every 10 years at a minimum)..	Metropolitan Council to consider assessing trends on a cycle of 5 to 10 years.
Water Quality Data Assessments	Three Rivers Parks District and the Scott WMO have not coordinated to get summary reports posted on the WMO website.	The Park District and the WMO to coordinate to get reports posted.
Observation of Sediment Delta Formation	Observations need to be relayed to the Scott WMO.	LMRWD and Scott WMO to coordinate transfer of information.
Groundwater Assessment and Planning	There is a gap regarding how to mitigate predicted baseflow reductions in the river.	Consider updating County-wide Groundwater Plan, Cities to consider cross connections and additional conservation. Additional ideas to be developed as art of updating the Groundwater Plan.
Minnesota Land Cover Classification System Update	Uncertain whether the update planned for 2013 will focus on the Credit River watershed or other portions of the Scott WMO.	Priority areas will be determined early 2013.
Plan Progress Tracking and Review	There is not a specific metric for tracking and reporting implementation of the Protection Plan.	Scott WMO will add a metric for the Protection Plan in the Scott WMO Comprehensive Water Resources Management Plan. This metric will be assessed each year when the WMO completes its Annual Report.
Reviewing and Updating the Protection Plan	There needs to be a process for reviewing and updating the plan. Since the Protection Plan is currently under development a process has not yet been developed.	The implementation section of the plan will include a process for updating the plan: 1) when trend analyses or the annual assessment suggest a change is needed, and 2) after a set period of time. It is most efficient to update concurrent with the Scott WMO Plan update so that it can be included as an implementation strategy and tracked by the WMO. The Scott WMO Plan is scheduled to be updated in 2019.

Section 5: Implementation Plan

Introduction

This section presents the implementation plan for protecting the Credit River. The Plan was developed considering the existing management efforts and gaps identified in Section 4, and the advice of the Technical Advisory Committee. Advice on the Plan was also solicited from the Scott Watershed Management Organization's (Scott WMO) Watershed Planning Commission. This Commission is made up of citizens appointed to advise the County/Scott WMO Board, and acts as the Citizen Advisory Committee for the Scott WMO. The Watershed Planning Commission considered implementation plan elements at their April, May and June 2011 meetings. A Public Open House was also held to obtain input on the Plan April 26, 2011.

The Plan includes the continuation of existing management efforts, as well as new efforts designed to either focus existing efforts on unique aspects of the Credit River, or fill gaps in existing efforts. The Plan is organized by subwatersheds so that readers and implementers of the Plan can quickly find what is planned for their particular area of the watershed. This makes sense as there are topographic, landuse, and suspended solids load differences between the subwatersheds. The subwatersheds are shown in Figure 5-1 and described below.

- **Lower Credit River subwatershed** extends from 154th Street W. to the confluence with the Minnesota River. It is predominately urban, includes the Minnesota River valley bluffs and is the area with the highest suspended solids loads. It also includes a portion of Murphy-Hanrehan Regional Park.
- **Cleary Lake subwatershed** includes areas tributary to Clearly Lake, a small portion of Murphy-Hanrehan Regional Park, and areas immediately tributary to the Credit River upstream of 154th Street W. This subwatershed with the exception of the areas downstream of Cleary Lake and the Regional Park, is guided for development as rural residential. Areas downstream of Cleary Lake are guided for urban expansion, meaning that the area is zoned as 40 acre lots until annexed or services are provided which is anticipated for sometime after 2030.

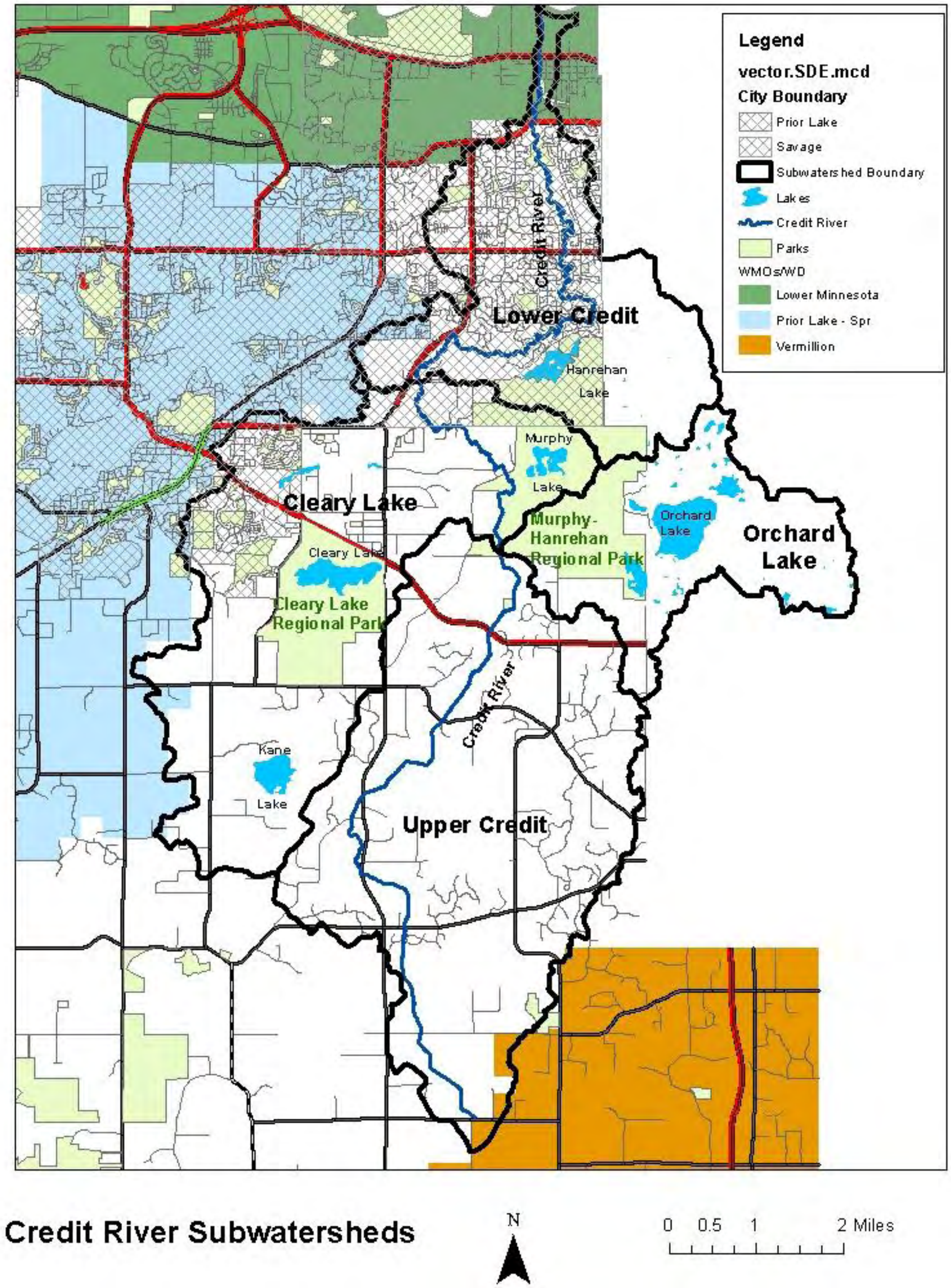


Figure 5-1. Credit River Subwatersheds

- **Upper Credit River subwatershed** covers the headwaters in New Market Township downstream to 175th Street E. This subwatershed is primarily guided for development as rural residential, and currently contains the most agriculture.
- **Orchard Lake subwatershed** includes the area draining to Orchard Lake and portions of Murphy-Hanrehan Regional Park.

In addition to the four subwatersheds, an implementation component is also presented for common efforts across the entire watershed called "All Subwatersheds". Thus, the following Plan is organized into five components, one covering common implementation efforts across the entire watershed, and four components detailing unique efforts for the subwatersheds.

Implementation Elements

The overall Plan and each subwatershed Plan are organized into program elements as follows:

- Programs
- Projects
- Regulations
- Monitoring
- Inventory and Assessment

Tables 5-2 through 5-5 present the Implementation Plans. Less detailed is presented on management efforts in the Black Dog WMO and City of Lakeville portions of the watershed since study results showed these areas do not contribute much toward suspended solids and turbidity problems in the river.

One of the main elements of an overall approach is targeting of the Technical Assistance and Cost Share (TACS) Program of the Scott WMO. Table 5-6 provides a summary of how the TACS program will be promoted and targeted by subwatershed. The Scott WMO maintains a docket that describes eligible practices under the program, and updates the docket annually (Appendix I). Active promotion will include aggressive marketing of the practices and land owner contacts or mailings. Passive promotion includes general advertising of the program on websites, in local newspapers, and the Scott County SCENE.

Another key component of the Plan is starting an education and technical assistance program for small acreage (hobby farm) land owners. This will be an emphasis for the Cleary Lake and the Upper Credit River subwatersheds. Planning for such an effort will start in the fall of 2011 with kick-off in 2012. The education program will also be used to help market the actively promoted BMPs for the various subwatersheds. In particular the Scott WMO anticipates a focused effort on the benefit of riparian vegetation over the next few years.

Table 5-1. Credit River Implementation Plan: All Subwatersheds

Element	Targeted Effort	Schedule
Programs		
TACS Program	Passively Promote BMPs in the Scott WMO Docket that are not actively promoted in the individual subwatersheds. See subwatershed plans for actively promoted BMPs.	Update Docket annually and promote through the Scott County SCENE and press releases.
Targeted CIPs	None known at this time.	Consider additional CIPs when identified through bi-annual CIP update and Plan Amendments.
Education	Implement general SCWEP efforts, and City of Lakeville, Black Dog WMO, and Lower Minnesota River Watershed District education programs.	On-going
Regulation		
Existing Stormwater Standards	Continue to implement existing standards.	On-going
MS4 NPDES Permits	Continue to implement existing permits.	On-going. Complete revised SWPPPs in 2012.
Land Use Planning	Continue to implement existing Land Use Plans.	On-going
Monitoring		
MPCA Intensive Watershed Monitoring	Comprehensive effort by the MPCA including biomonitoring.	Scheduled for 2014
Well Water Level Monitoring	Increase the number of monitoring sites. Coordinate with DNR for operation.	Consider in 2011 as part of the County Ground Water Plan update.
Assessment		
Track Protection Plan Implementation	Create a metric specific to implementation of the Credit River Protection Plan.	Complete annually as part of the Scott WMO Annual Report.
Review and update the Protection Plan	Make a part of the Scott WMO Plan, and update concurrent with the next Scott WMO Plan update.	The Protection Plan has already been added to the Scott WMO Plan as an implementation strategy by an Amendment approved the BWSR April 2011. The next scheduled update will be adopted in 2019 with planning efforts occurring in 2018.
MPCA Watershed Assessment	Assess data collected as part of the MPCA Intensive Watershed Monitoring effort and other available data.	Scheduled for 2016
MLCCS update	Update land cover characteristics (MLCCS). Areas to	Scheduled for 2013

	update are not known at this time. Will likely focus on those areas with the most change (i.e., development) over the past 10 years.	

Table 5-2. Credit River Implementation Plan: Lower Credit River Subwatershed

Element	Targeted Effort	Schedule
Programs		
TACS Programs	Actively promote rain gardens, and riparian vegetation management in the Scott WMO. Lower Minnesota River Watershed District (LMRWD) to start a cost share program.	Complete a minimum of two one-year cycles actively promoting listed BMPs for this subwatershed between 2012 and 2018 through the Scott WMO TACS program. LMRWD to start cost share program in 2012.
Targeted CIPs	None known at this time.	Consider additional CIPs when identified through bi-annual CIP update and Plan Amendments.
Education	Complete special education efforts focusing on the targeted BMPs in the TACS program.	Complete concurrent with the active promotion cycles.
Projects		
Subwatershed Assessment & Retrofit	Implement most beneficial practices depending on funding availability.	2011 – 2012 depending on funding.
Rain gardens	Promote through workshops and cost share. Coordinate with TACs program and City of Savage.	Planned and budgeted for 2011. Will evaluate effectiveness of 2011 efforts and depending on success consider for future years.
Geomorphic Study	Create database for tracking implementation and prioritize. Consider implementing high priorities as targeted TACS projects or as CIPs. Pursue medium and lower priorities passively through the TACS program.	Create database in 2011. Prioritize and start feasibility assessments in 2012.
Monitoring		
Outlet Monitoring	Continue MCES outlet monitoring and add biomonitoring.	MCES monitoring is on-going. Add biomonitoring for invertebrates for 2012, 2016, and 2018. Coordinate with MPCA basin monitoring for 2014.
Lakes	Three Rivers Park District to continue its monitoring efforts.	Annually

Assessment		
Water Quality Trend Analysis	Complete periodic trend analyses.	MCES currently is assessing trends in 2011, and again in 5 to 10 years. Will encourage MCES to complete analysis in 2017 or 2018 to inform the planning process for the Scott WMO Plan update scheduled for adoption in 2019.
Water Quality Data Analysis	Convert data collected into information, and make available to decision makers and the public.	MCES completes a summary of the outlet monitoring results annually or bi-annually. Three Rivers provide summary results annually to the Scott WMO who will post results on its website.
Sediment Delta Formation	Lower Minnesota River Watershed District to forward information regarding complaints.	As complaints are made.

Table 5-3. Credit River Implementation Plan: Cleary Lake (154) Subwatershed

Element	Targeted Effort	Schedule
Programs		
TACS Program	Actively promote livestock exclusion, riparian vegetation, wetland restoration and native grasses. Consider actively promoting additional targeted practices if the Clearly Lake TMDL shows a need.	Complete a minimum of two one-year cycles actively promoting listed BMPs for this subwatershed between 2012 and 2018. The Cleary Lake TMDL is scheduled to start in 2014.
Targeted CIPs	None known at this time. Consider CIPs if the Cleary Lake TMDL identifies any.	The Cleary Lake TMDL is scheduled to start in 2014.
Education	Start technical assistance program targeting small acreage (hobby farms) land owners. Complete special education efforts focusing on the targeted BMPs. Consider special education efforts based on results of the Cleary Lake TMDL.	Complete concurrent with the active promotion cycles, and following completion of the Cleary Lake TMDL. Start small acreage technical assistance in 2012.
Regulation		
Development Incentives	Implement Scott County Comprehensive Land Use Plan as planned with Public Values Incentives for wetland restoration, Natural Area Corridors protection, and LID practices.	On-going
Spring Lake Township LID	Implement as planned	On-going
Cleary Lake TMDL	Consider revising standards based on results of the TMDL.	The Cleary Lake TMDL is scheduled to start in 2014.
Hobby Farm Requirements	Consider the need for a regulatory approach.	To be considered in 2018 during the process to update the Protection Plan and the Scott WMO Plan.
Monitoring		
Lakes	Three Rivers Park District to continue its monitoring efforts.	Annually
Assessment		
Water Quality Trend Analysis	Complete periodic trend analyses.	Analyze trends as part of completing the Cleary Lake TMDL. The Cleary Lake TMDL is scheduled to start in

		2014.
Water Quality Data Analysis	Convert data collected into information, and make available to decision makers and the public.	Three Rivers to provide summary results annually to the Scott WMO who will post results on its website.

Table 5-4. Credit River Implementation Plan: Upper Credit River Subwatershed

Element	Targeted Effort	Schedule
Programs		
TACs Program	Actively promote livestock exclusion, riparian vegetation, wetland restoration and native grasses.	Complete a minimum of two one-year cycles actively promoting listed BMPs for this subwatershed between 2012 and 2018.
Targeted CIPs	None known at this time.	Consider additional CIPs when identified through bi-annual CIP update and Plan Amendments.
Education	Start technical assistance program targeting small acreage (hobby farms) land owners. Complete special education efforts focusing on the targeted BMPs.	Complete concurrent with the active promotion cycles. Start small acreage technical assistance in 2012.
Projects		
Geomorphic Study	Create database for tracking implementation and prioritize. Consider implementing high priorities as targeted TACS projects or as CIPs. Pursue medium and lower priorities passively through the TACS program.	Create database in 2011. Prioritize and start feasibility assessments in 2012.
Regulation		
Development Incentives	Implement Scott County Comprehensive Land Use Plan as planned with Public Values Incentives for wetland restoration, Natural Area Corridors protection, and LID practices.	On-going
Hobby Farm Requirements	Consider the need for a regulatory approach.	To be considered in 2018 during the process to update the Protection Plan and the Scott WMO Plan.

Table 5-5. Credit River Implementation Plan: Orchard Lake Subwatershed

Element	Targeted Effort	Schedule
Projects		
Orchard Lake Wetland Aeration	Continue wetland aeration project.	On-going
Orchard Lake Curlyleaf Pondweed Control	Continue Curlyleaf Pondweed control project.	On-going
Monitoring		
Lakes	Continue to monitor Orchard Lake using the CAMP program.	Annually
Assessment		
Water Quality Data Analysis	Convert data collected into information, and make available to decision makers and the public.	Lakeville/MCES to provide summary results annually to the Scott WMO who will post results on its website.

Table 5-6. Technical Assistance and Cost Share Targeting by Subwatershed

Subwatershed	Actively Promote	Passively Promote	Rationale
All	See subwatersheds	All practices in the docket not actively promoted for specific subwatershed	Specific practices for active promotion are identified by subwatershed, however, general practices in the docket may still be appropriate.
Lower Credit River	Rain gardens and riparian vegetation Management	Balance of the docket.	The urban environment precludes many of the practices in the docket. In addition, the geomorphic study found a number of potential riparian vegetation improvement projects along the river in this subwatershed.
Cleary	Livestock exclusion, riparian vegetation, wetland restoration and native grasses.	Balance of the docket.	The primary emphasis for the rural residential portions of the watershed is to improve riparian conditions and promote runoff volume reductions.
Upper Credit River	Livestock exclusion, riparian vegetation, wetland restoration and native grasses.	Balance of the docket.	The primary emphasis for the rural residential portions of the watershed is to improve riparian conditions and promote runoff volume reductions.
Orchard Lake	None	None	Most of the Orchard Lake subwatershed is not in the Scott WMO, and the Orchard Lake subwatershed does not appear to contribute to suspended sediment issues in the river.

Adapting and Updating

Results of implementation, monitoring data and the additional data collected will be periodically evaluated over the years. This will include trend analysis for turbidity and TSS, tracking and evaluation of individual practices, and tracking of public acceptance and participation. The Scott WMO performs an evaluation of its programs annually as part of developing its annual report. Water quality metrics tracked by the WMO are provided in Table 5-7. Additional metrics are tracked regarding wetland, and education and stewardship goals, and a specific metric regarding implementation of this Protection Plan will be added. The Scott WMO also updates it cost share and incentive program docket annually based on previous year results. The Scott WMO consults with both its citizen based Watershed Planning Commission and its Technical Advisory Committee to help the Scott WMO learn and adapt. Partners from this project are invited to be part of the Technical Advisory Committee. Finally, the Plan includes provisions for updating once the Cleary Lake Nutrient TMDL is complete, and for incorporating and updating concurrent with the next Scott WMO Comprehensive Water Plan update scheduled for 2019.

Table 5-7. Scott WMO Surface Water Quality Goal Metrics

Short Term Metrics	Long Term Metrics
• Number and types of practices approved and installed with the cost share and incentive program • Number and types of targeted projects completed • Completion of scheduled studies and TMDLs	• Trends in water quality parameters as identified from monitoring efforts • Achievement of target levels or ranges for nutrients, sediments and bacteria as established by state water quality standards, ecoregion means, or specific goals established by TMDL studies.

Source: Scott WMO (2009) Comprehensive Water Resource Management Plan.

Funding

Funding for the effort will be opportunistic taking advantage of grants to the extent possible. The Scott WMO, the Lower Minnesota River Watershed District and the Black Dog Watershed Management Organization all have Water Resources Management Plans that identify potential levels of funding. However, the Lower Minnesota River Watershed District and the Black Dog Watershed Management Organization plans are currently in the process of being updated and funding levels are unknown. Likewise the State Clean Water Fund long term level of funding for protection efforts is also unknown. The current Senate version for the next biennium includes some funding for protection efforts, but the legislation has not been passed at this time.

The Scott WMO spends about $700,000 to $800,000 per year for land and water treatment (including the TACS program), and $70,000 to $100,000 annually for education. However, these budgets are for the entire Scott WMO and most of the funds go toward addressing impaired waters in other parts of the Scott WMO's jurisdiction. The Scott WMO also anticipates spending about $50,000 to update the County's Minnesota Land Cover Classification System (MLCCS) GIS coverage in 2013, a portion of which will be in the Credit River Watershed. The City of Savage has also has $15,000 to promote rain gardens in 2011.

State cost share and USDA/NRCS EQIP, WHIP and CRP funds will also be used as appropriate for promoting practices identified in the subwatershed implementation matrices. However, since agriculture is decreasing in the watershed and these programs generally have an agricultural focus it is anticipated that the use of these funds will decrease over time. The amount of agricultural land has already declined in the watershed such that the amount of highly erodible land being cultivated in low and is largely confined to the Upper Subwatershed where monitoring results have shown the suspended solids load is small (see Figure 2-4, Section 2)).

Finally, the institutional efforts being promoted through the Scott County Comprehensive Land Use Plan such as the incentives for preserving corridors and restoring wetlands, will be paid for through the on-going development review process. Erosion control inspections and stormwater rule compliance efforts by the Scott County are also paid for through the development review process and fees. Implementation of Local Water Plans by the City of Savage and Prior Lake are financed by the cities with the Scott WMO doing annual checks to make sure the plans are being implemented. MS4 program implementation is financed by each individual municipality.

Section 6: References

Johnson, G. 2007 Evaluation of “Paired” Turbidity Measurements from Two Turbidimeters for Use in Two TMDL Projects. Minnesota Pollution Control Agency – Watershed Section. St. Paul, MN.

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Lusardi, B.A. 2006. Surficial Geology. Geologic Atlas of Scott County, MN – Plate 3. Minnesota Geological Survey.

MASS, 2005. Minnesota Agricultural Statistics. Minnesota Agricultural Statistics Service (MASS), St. Paul, Minnesota.

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MC, 2009. Metropolitan Council’s Impaired Waters Project: Development of TSS/Turbidity Relationship. Metropolitan Council, St Paul, MN

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Willson, G. 2009. Turbidity Delisting Analysis for Nine Mile Creek. Memorandum by BARR Engineering.

Appendix A. MPCA Delisting Transparency Document

SCOTT COUNTY NATURAL RESOURCES

GOVERNMENT CENTER 114 · 200 FOURTH AVENUE WEST · SHAKOPEE, MN 55379-1220
(952) 496-8475 · Fax (952) 496-8496 · Web www.co.scott.mn.us

Memorandum

To: Louise Hotka, Minnesota Pollution Control Agency (MPCA)

From: Paul Nelson, Natural Resource Program Manager; Melissa Bokman, Sr. Water Resources Planner

Subject: Credit River Turbidity Delisting

Date: April 6, 2010

Cc: Brooke Asleson, MPCA

This memorandum provides justification and conveys a request to delist the Credit River for impaired aquatic life due to turbidity. This request was authorized by the Scott County Board on April 5, 2010. Also attached is a CD with the data and analyses presented in this memo. The Credit River was originally included on the 303(d) impaired waters list for turbidity, as described below:

- AUID (Assessment Unit ID#) – 07020012-517
- Reach name / descriptions – Credit River: Headwaters to Minnesota River
- Pollutant / Impairment – Turbidity

Background Information

The data used for the 2002 original listing came from the Metropolitan Council monitoring site of river mile 0.6. Analysis of this data shows that the standard was exceeded about 24% of the time (Figure 1). However, more recent continuous turbidity probe data for a two year period of 2008 and 2009 shows that the turbidity level for which 10% of values exceed the standard is 8.3 NTU after conversion from FNU units to NTU units (Table 1); and further that the percent exceedence of the 25 NTU standard is only 1.2%. It has been hypothesized for this data on the Credit River and for other data (Nine Mile Creek; Greg Wilson, 2009) that differences in the results for continuous probe data and Metropolitan Council laboratory sample data could be due to the following:

1. That the more recent continuous probe readings were taken during a drier period where there were lower flows where lower turbidity results typically occur, and since the continuous data only represents two years, the data may not be as representative of long term conditions as the lab sample data.
2. The analyses using the Metropolitan Council laboratory sample results are biased high since the monitoring program under which the samples were collected was biased toward high flows under which higher turbidity results typically occur.
3. Changes in the watershed characteristics.

Each of these possibilities is evaluated separately below. However, an analysis is first presented showing how the various turbidity units (FNU, NTRU, NTU) were all converted to a common unit, NTU.

Another confusing item is the turbidity distribution in Table 1 for the more recent reporting cycle (e.g., 10 years) from the MPCA data set. The data in the MPCA data set comes from the Metropolitan Council, yet comparison with almost the same 10 year period using Metropolitan Council data gives different results (Table 1). Comparison of the two data sets showed that the MPCA data set had removed the composite sample results collected by Metropolitan Council – otherwise the data is identical. Granted the composite samples are not discreet measurements, but they are how the Metropolitan Council tries to represent conditions under the highest flows. Removing these could be biasing the data set in the opposite direction. However, values predicted below where the affect of flow is considered are lower than the levels from the "groomed" MPCA data set. To make this a little more confusing, the MPCA data set labels the data received from the Metropolitan Council as having units of NTU, but it is known that since March 2006 Metropolitan Council has a meter that reads in NTRU. Conversion from NTRU to NTU for this data will further lower the levels compared to the standard.

Turbidity Units

There is some confusion between the various data sets regarding the turbidity unit. This is due to the meter that was used. Up until March 8, 2006 the Metropolitan Council Laboratory used a meter that provided results in NTU. Starting March 23, 2006, however, the laboratory changed meters to one that presented results as NTRU. The continuous probe uses a slightly different methodology which provides results in units known as FNU. The following provides a description of the conversions used.

- Continuous probe results in FNU were first converted to NTRU, and then to NTU. To convert from FNU to NTRU dates for grab samples evaluated in the lab were matched with same time and date results from the field probe to develop the regression equation in Figure 2. Results in NTRU were then converted to NTU using the equation developed by Johnson (2007).

  FNU to NTRU equation: $NTRU = 0.6574 \times FNU + 0.6703$

- Metropolitan Council laboratory sample results in NTRU were converted to NTU using the equation developed by Johnson (2007).

  NTRU to NTU equation $NTU = 10^{(-0.0734+0.926*LOG(NTRU))/1.003635}$

Affects of Flow

Flow distributions for the long term, a ten year period, and for 2008 are shown in Table 2. Unfortunately reliable flow data was not available from the Metropolitan Council for 2009. Rainfall at Chanhassen was 22.4 inches and 29.8, respectively for 2008 and 2009. Average annual rainfall is about 29 inches. Thus, the two year period with the continuous data represents one dry year and one year close to the average. The flow distributions in Table 2 show that the 10% to 90% range is fairly consistent across the long term, recent 10 years and then 2008. However, the median flow and the extreme high flows are lower in the more recent data sets. Therefore, an analysis was completed using a relationship developed between flow and laboratory turbidity to all the MCES flow records to evaluate whether the standard would have been exceeded if monitoring had been completed on a continuous basis.

The first step of this analysis was to show that there are relationships between flow and turbidity. Figure 3 shows the relationship between continuous data for mean daily flow and mean daily turbidity. Figure 4 shows a similar relationship between lab turbidity sample results (converted to NTU) and flow. Using the equation from Figure 3 gives a turbidity value of 8.6 NTU at the 90% flow value for the 10 year flow record. Using the equations for Figure 4 gives turbidity values of 11 NTU and 18.4 NTU for the 90% flow value of the 10 year record, based on the regression and the upper 95% confidence interval, respectively. This analysis confirms that the 25 NTU standard will be meet 90% of the time with 95% confidence, based on long term flow duration characteristics.

Watershed Changes

Much has occurred in the watershed since the original listing in that used data from 2000 and earlier. This portion of Scott County was one of the fastest growth areas in the Country during that period, and into the early part of the 2000s. In addition, communities were just learning how to implement construction erosion control programs. More recent data could reflect lower amount of construction erosion because: 1) the City of Savage, the Credit River Township, and Scott County now all have robust construction erosion control programs; 2) a decrease in construction activity; and 3) the large lot development that has occurred in Credit River Township has come at the expense of agriculture. A reduction in construction activity is demonstrated by the fact that in 1998 and 1999 the City of Savage and Credit River Township combined had over 1,000 new construction building permits. Over the course of 2008 and 2009 this number has dropped to 151. The net result of the third item is that there has been a significant reduction in the amount of agricultural land in the watershed and an increase in permanent vegetation on the large lots.

The City of Savage, Scott SWCD, and Scott WMO have also completed a number of projects in the watershed in recent years. Some of these listed below and are shown on Figure 5. Some these are rather significant as shown in Figures 6, 7, and 8.

- Grassed Waterway (1999)
- City of Savage Stream Channel Stabilization (1999)
- City of Prior lake Raingardens (2008 & 2009)
- City of Savage Stream Channel Stabilization (2007)
- Deb Atchison Cedar Tree Revetment (2008)
- Deb Atchison Cedar Tree Revetment (2008)
- Scott Allison Cedar Tree Revetment (2008)
- City of Savage Environmental Learning Center (2008)
- City of Savage Grade Stabilization (2010)
- City of Savage Hidden Valley Park Raingardens (2008)

Conclusions

1. The original decision to list was based on a set of data collected using a sampling protocol that was designed for a different purpose, and that this data set when used for the purposes of making a decision on regarding listing is biased toward higher turbidity results.
2. Correcting the biases in the original data, and more recent data, confirms that the 25 NTU standard will be meet 90% of the time with 95% confidence.

3. More recent continuously collected turbidity data from 2008 and 2009 shows that 25 NTU standard is being met more than 98.8% of the time.
4. Changes have occurred in the watershed since the original listing that should have reduced erosion and sediment transport, and thus turbidity.
5. The macroinvertebrate community (organisms that do not have a backbone) is the river appears to be healthy.

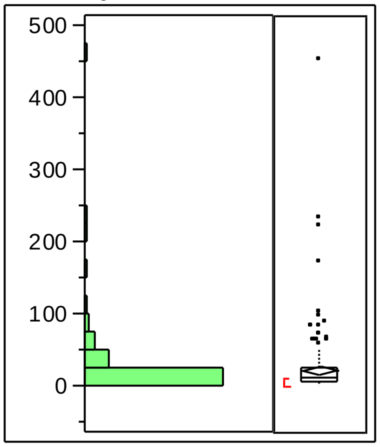
References

Johnson, G. 2007. Evaluation of "Paired" Turbidity Measurements from Two Turbidimeters for Use in Two TMDL Projects. Minnesota Pollution Control Agency.

Wilson, G. 2009. Nine Mile Creek Turbidity Delisting. Memorandum to Louise Hotka, MPCA December 11, 2009.

Figure 1: Credit River Turbidity Distribution Using MPCA Data for 2000 Reporting Cycle

Turbidity, NTU



Quantiles

100.0%	maximum	450.00
99.5%		450.00
97.5%		101.75
90.0%		50.50
75.0%	quartile	24.00
50.0%	median	12.00
25.0%	quartile	4.75
10.0%		1.70
2.5%		1.10
0.5%		0.80
0.0%	minimum	0.80

Moments

Mean	22.888384
Std Dev	43.130593
Std Err Mean	3.0651578
upper 95% Mean	28.933117
lower 95% Mean	16.84365
N	198

Figure 2: Regression between field and laboratory turbidity for the Credit River 0.9 Site (2008 and 2009)

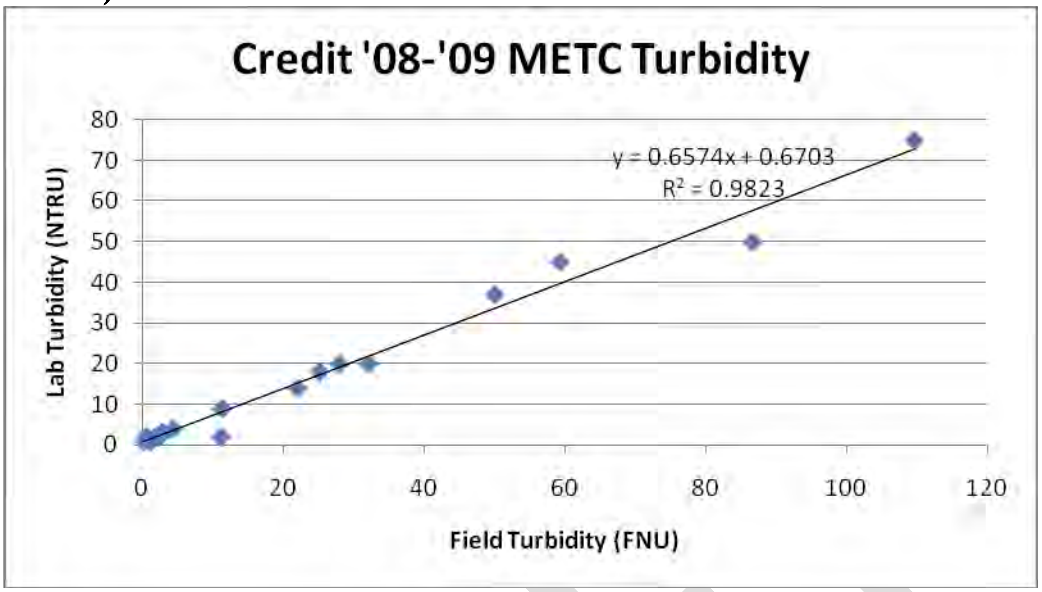


Figure 3: Regression between continuous mean daily turbidity readings and flow for the Credit River

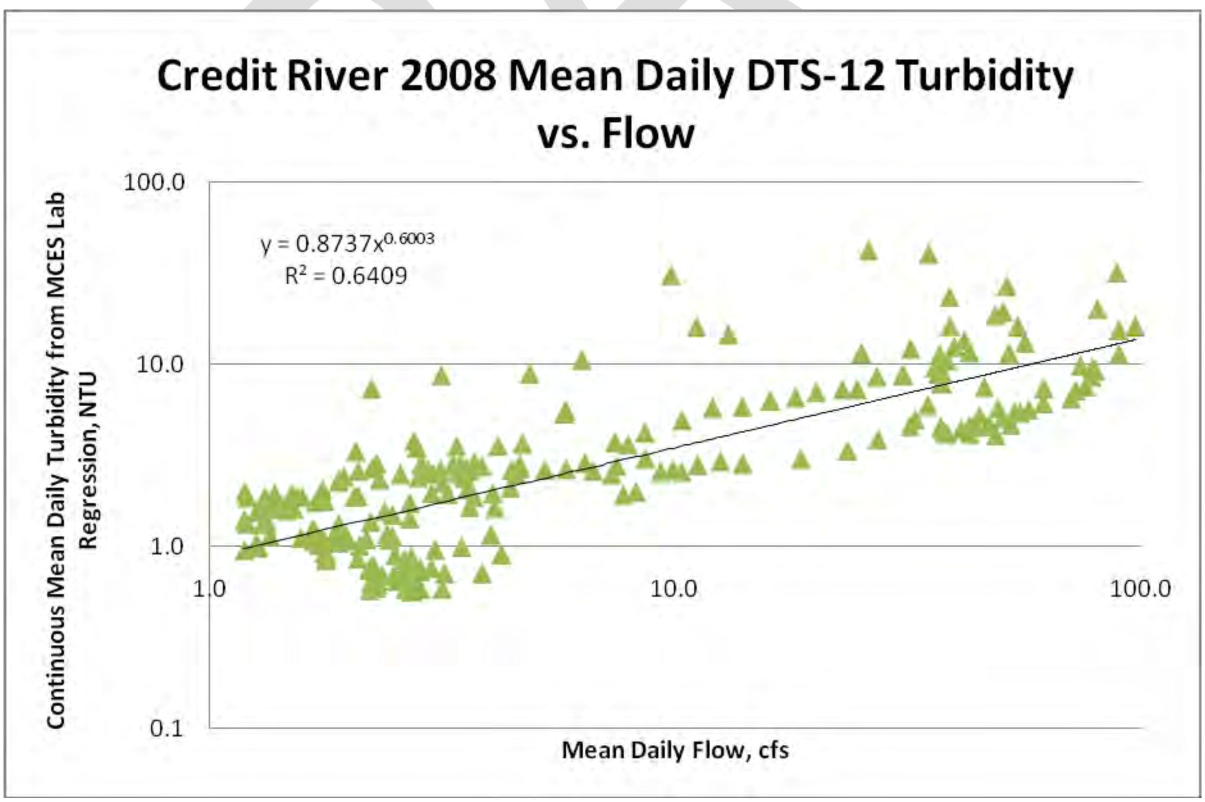
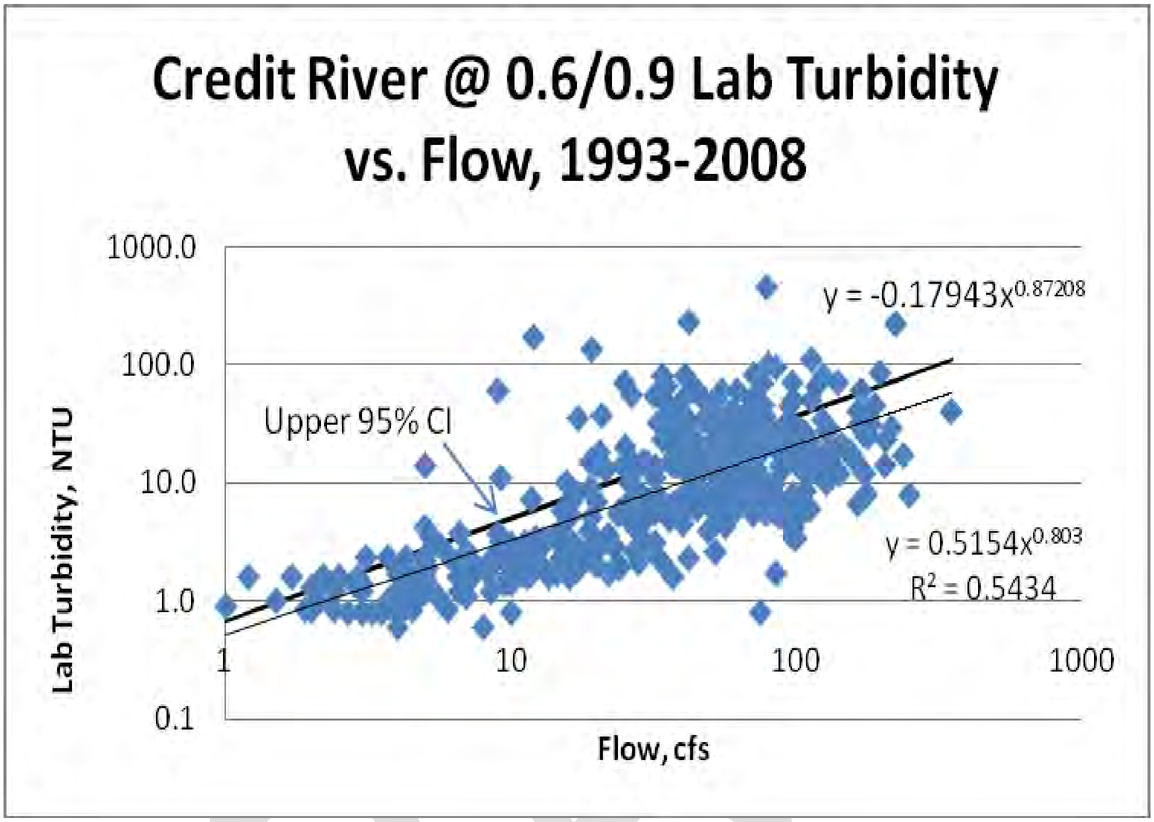


Figure 4: Regression between laboratory turbidity sample analyses and flow from the Credit River



Note equation for upper 95% CI based on log 10 transformed data. Thus, need to use antilog with the equation.

Figure 5: Recent Watershed Projects

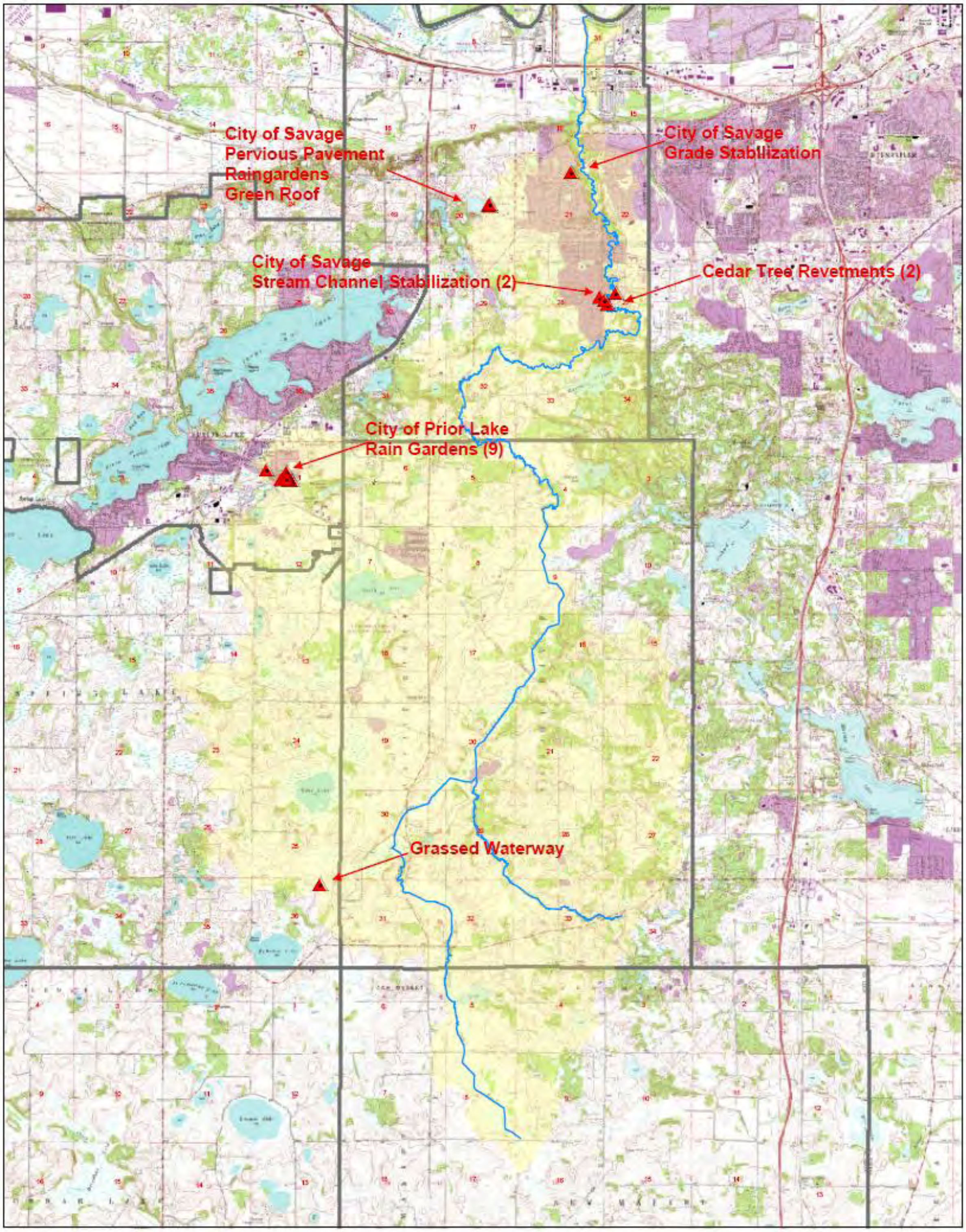


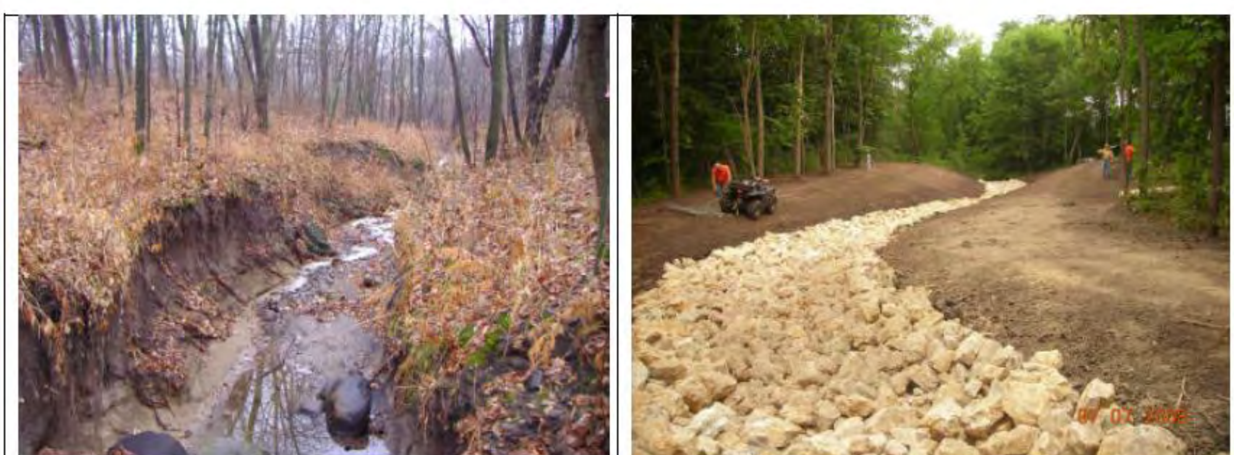
Figure 6: City of Savage Grade Stabilization (2010)

City of Savage Grade Stabilization

Before Construction	During Construction

Figure 7: City of Savage Stream Channel Stabilization (2007)

City of Savage Stream Channel Stabilization



Before Construction	During Construction

Figure 7:

City of Savage Stream Channel Stabilization (1999)

Before Construction

After Construction

Table 1: Credit River Turbidity Distributions For Various Data Sets and Time Periods

Quantiles	Continuous Meter		MCES Lab Data, NTU		MPCA Data, NTU	
	FNU(1)	NTU(2)	Ten years(3)	2008 & 2009(4)	Historic(5)	Ten Years(6,7)
90%	17.1	8.3	37	35.8	50.5	18.8
50%	2.8	2.0	5.4	2.3	12	2.6
10%	0.44	0.8	1.1	0.8	1.7	0.8

(1) 2008 and 2009 data from MCES

(2)Converted from FNU using y = 0.6574x + 0.6703 to get to NTRU and then equation by Johnson (200&) converting NRTU to NTU

(3)1999 through 2009 NTRU converted to NTU using equation by Johnson (2007)

(4) NTRU converted to NTU using equation by Johnson (2007)

(5) Labeled as 2000 Assessment reporting cycle

(6) Most recent 10 years 1999 through 2008

(7) Unit as presented in the MCPA data set, however, since this data was originally collected by MCES the unit is actually NTRU for data since March 2006.

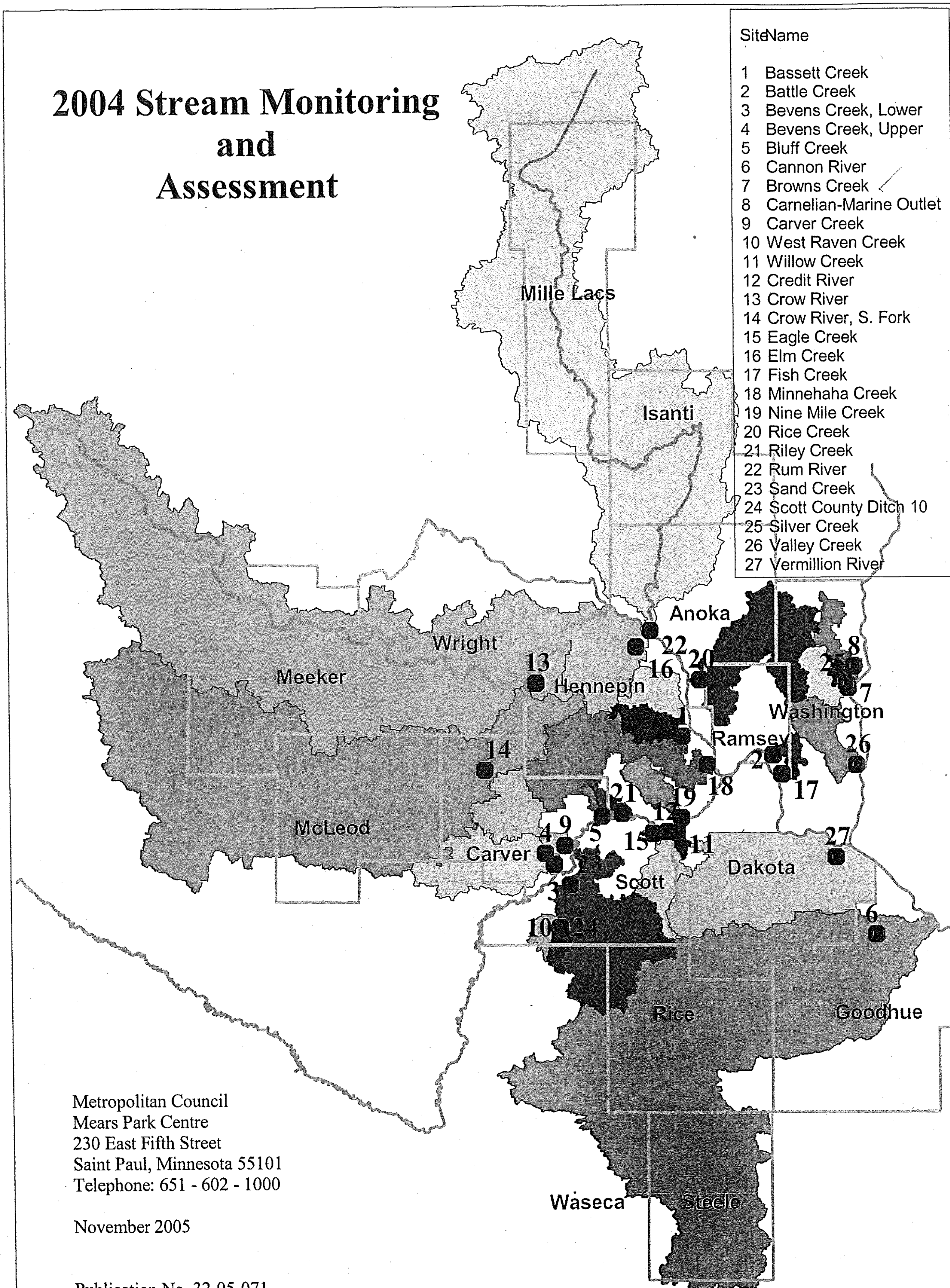
Table 2: Credit River Flow Distributions

Quantiles	Long Term (1)	Ten Year(2)	2008
99.5%	174.75	167.24	94.39
97.5%	109.75	109.99	78.98
90.0%	46.30	45.04	47.30
50.0%	11.30	8.40	2.80
10.0%	2.60	2.90	1.60
2.5%	1.70	1.70	1.30
0.5%	0.75	1.00	1.20

(1) 1989 through 2008

(2) 1999 through 2008

2004 Stream Monitoring and Assessment



Metropolitan Council
Mears Park Centre
230 East Fifth Street
Saint Paul, Minnesota 55101
Telephone: 651 - 602 - 1000

November 2005

Publication No. 32-05-071

Table 4. 2004 Macroinvertebrate Metrics

River	Date	Total Taxa	Mean Tolerance Value	Total EPT* Taxa	% EPT* Taxa	% EPT* Individuals	Total Diptera Taxa	% Diptera Taxa	% Diptera Individuals	% Chironomidae Individuals
Battle Creek	10/11/04	24	5.5	2	8	39	17	71	30	18
Bevens Creek - Lower	10/17/04	35	4.9	9	26	41	19	54	41	35
Bluff Creek	10/17/04	29	5.4	6	21	11	15	52	31	29
Browns Creek	10/07/04	45	4.7	12	27	60	22	49	14	10
Credit River	10/17/04	49	4.9	8	16	23	29	59	36	32
Eagle Creek	10/16/04	20	5.0	1	5	81	15	75	9	4
Fish Creek	10/11/04	28	5.4	4	14	27	17	61	10	9
Minnehaha Creek	10/11/04	26	5.5	6	23	17	15	58	79	76
Sand Creek	10/17/04	38	4.7	14	37	59	20	53	28	20
Silver Creek	10/07/04	35	4.7	9	26	32	18	51	45	39
Vermillion River	10/15/04	33	4.3	12	36	71	15	45	16	5
Valley Creek	10/07/04	48	4.9	15	31	39	25	52	10	9

* EPT = Ephemeroptera, Plecoptera, and Trichoptera

Mile 6 and Mile 8.2

Table 5. Hilsenhoff Biotic Index*

River	Date	HBI*	Water Quality	Degree of Organic Pollution
Battle Creek	10/11/04	4.62	Good	Some organic pollution
Bevens Creek – Lower	10/17/04	4.41	Very Good	Slight organic pollution
Bluff Creek	10/17/04	4.87	Good	Some organic pollution
Browns Creek	10/07/04	3.74	Very Good	Slight organic pollution
Credit River	10/17/04	4.91	Good	Some organic pollution
Eagle Creek	10/16/04	4.21	Very Good	Slight organic pollution
Fish Creek	10/11/04	4.07	Very Good	Slight organic pollution
Minnehaha Creek	10/11/04	5.83	Fair	Fairly significant organic pollution
Sand Creek	10/17/04	4.34	Very Good	Slight organic pollution
Silver Creek	10/07/04	4.26	Very Good	Slight organic pollution
Vermillion River	10/15/04	2.10	Excellent	No apparent organic pollution
Valley Creek	10/07/04	4.12	Very Good	Slight organic pollution

* Hilsenhoff Biotic Index (HBI) modified to include non-arthropod taxa

Summary information

AUID:	**07020012-517**	**Credit River -- Headwaters to Minnesota River**				
Pollutant or stressor:	Turbidity					
First listed:	2002					**Use**
Original data period:	Oct90-Sep00		**Obs**	**Exceed**	**% Exceed**	**support**
Actual data:	Mar93-Aug00		**203**	**46**	**22.7%**	NS
Stations:	CR 0.6					

Assessment requirements

1. At least 20 observations in the most recent 10 years.
2. Supporting: No more than 10% of observations exceeding the water quality standard.
   Not Supporting: Both at least 3 observations and more than 10% of observations exceeding the water quality standard.

Delisting requirements

1. At least 20 observations (new and old data) in the most recent 10 years, of which at least 10 observations (new and old data) are in the most recent 5 years, or
2. At least 20 observations (new data) in the most recent 5 years, and evidence of action in the watershed of sufficient dimension to change impairment status, and
3. In either case, no more than 10% of samples exceeding the water quality standard.

The measurements used to support de-listing must be collected during the appropriate time of day and year and under appropriate stream flow conditions.

							Flow-Adj
New data:			**Range**	**Obs**	**Exceed**	**% Exceed**	**% Exceed**
Stations:	CR 0.6	Jul00-Dec08	1-74	**126**	**5**	**4.0%**	**5.0%**
	CR 0.9	Mar08-Nov08	0-103	**246**	**19**	**7.7%**	**10.0%**

Recommendation:

De-list.

Significant changes and corrective measures have taken place in the watershed. Using new data, adjusted to take into account differences in turbidity meters, exceedances are no longer greater than 10%. This improvement in water quality is corroborated by the results from invertebrate monitoring conducted by the Metropolitan Council. (See supporting information contained in the Delisting Request Memo and the Met Council Inverts Report.)

Appendix B. Project Workplan

CREDIT RIVER WATERSHED TURBIDITY TMDL DEVELOPMENT
WORK PLAN, ~~January 2008~~ ~~September 2010~~ February 2011

Project Contact Information:

Lead Organization Name:	Scott Watershed Management Organization
Type of Organization:	Watershed Management Organization
Project Contact:	Paul Nelson, Administrator
Address/Phone:	200 4th Avenue W Shakopee, Minnesota 55379 952-445-7750
Financial Agent:	Scott County
Type of Organization:	County Agency
Project Contact:	Paul Nelson, Natural Resources Program Manager
Address/Phone:	Same as WMO information above
Project Partner:	Lower Minnesota Watershed District
Contact:	Terry Schwalbe
Address/Phone:	Lower Minnesota River Watershed District 1600 Bavaria Road Chaska, MN 55318 952-227-1037
Project Partner:	Metropolitan Council Environmental Services
Contact:	Joe Mulcahy
Address/Phone:	MCES 390 Robert St. N St. Paul, MN 55101 joe.mulcahy@metc.state.mn.us 651-602-1104
Project Partner:	Three Rivers Park District
Contact:	John Barten
Address/Phone:	12615 County Road 9, Suite 100 Plymouth, MN 55441 763-694-7841
Project Partner:	Black Dog Watershed Management Organization
Contact:	Terry Schultz
Address/Phone:	City of Burnsville 100 Civic Center Parkway Burnsville, MN 55337 952-895-4505

Project Information:

Project Title:	Credit River Watershed Turbidity TMDL Development
Reaches:	Headwaters to Minnesota River
Reach (AUID) No.:	07020012-517
Pollutant:	Turbidity
Impaired Uses:	Aquatic Life
303(d) List Schedule:	2006-2010
Project Dates:	January 1, 2008 to ~~March 1, 2011~~ June 30, 2011
Requested Amount:	$~~125,000~~ $84,575.15

Project Summary:
The Minnesota Pollution Control Agency (MPCA) is required to assess the quality of rivers and lakes in Minnesota. Waters not meeting water quality standards and not meeting beneficial uses such as aquatic life are designated by the MPCA as impaired. The MPCA updates the list of impaired waters and submits this list to the EPA every two years. This report is known as the 305(b) list.

Waters designated as impaired are then included on the state's Section 303(d) list also known as the impaired waters list. The Clean Water Act establishes a directive for developing Total Maximum Daily Loads (TMDLs) to achieve Minnesota water quality standards established for designated uses of State water bodies. A minimum of ten data points over a ten-year period were required to designate a water body as impaired when the Credit River was first listed. If greater than 10 percent of the samples exceed the water quality standard, the water body is listed (MPCA, 2005). In 2002, the Credit River was listed on the 303(d) list of impaired waters for aquatic life based on turbidity data collected for the stream. Once listed, a TMDL analysis is required.

This project is designed to collect additional data necessary for modeling and assessing the watershed for potential sources causing the impairment, and the development of an implementation strategy to achieve the required water quality standards. The end product to be submitted to the MPCA ~~will~~ was originally intended to be a completed turbidity TMDL for the Credit River sufficient for EPA approval. However, over the course of the course of the data collection effort it became clear that the river may not in fact exceed the turbidity standard. A request to de-list the river was submitted by Scott County in the spring of 2010. The MPCA concurred with the delisting and completed the transparency document to delist in late summer of 2010. With the delisting there is no longer a need to complete a TMDL. Therefore, the end product of this study was changed to the completion of a Protection Plan. This Protection Plan assesses the efficacy of the existing stormwater programs and development standards, and lays out an approach for protecting the unimpaired condition. It is anticipated that completing the Protection Plan will not be as costly as it was to complete the TMDL. Funds not spent will remain with the State.

Background Information:

The Credit River watershed is located in Scott County, Minnesota. The creek starts in New Market Township and flows generally north through Credit River Township before discharging into the Minnesota River in the city of Savage. Credit River has a drainage area of approximately 51 square miles (32,865 acres). Although there are a few lakes in the watershed, the creek does not directly flow through them.

The major land uses in the Credit River watershed are undeveloped land (37%), agriculture (26%), single family residential (17%) and parks and open space (14%). The remaining 6% of land in the watershed is classified as multi-family residential, industrial, commercial, public semi-public, roads, or water.

Metropolitan Council Environmental Services (MCES) has conducted water quality monitoring of Credit River since 1989. MCES' monitoring station is located 0.9 miles upstream from the river confluence with the Minnesota River. The Scott SWCD on behalf of the Scott WMO completed a stream bank erosion inventory of Credit River in 2006. This inventory identified over 5.5 miles of slight to moderate stream bank erosion along the river and its tributaries. In 2007 the Scott WMO initiated Fluvial Geomorphic Assessment of the river to diagnose the factors contributing to the bank erosion, and develop a strategy for restoring more natural fluvial processes. The assessment was completed in November of 2007 ~~and the final report is currently under review~~.

Potential pollutant sources in the watershed include sediment from stream bank erosion, agricultural practices, and some input from single-family residential development.

Problem Statement:

In 2002, Credit River was listed on Minnesota's 303(d) List of Impaired Waters for aquatic life impairment due to turbidity. Turbidity is commonly measured in Nephelometric Turbidity Units (NTU). Turbidity is a unit of measurement quantifying the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles. The suspended organic and inorganic particles scatter light in the water column making the water appear cloudy. The scattering of light increases with greater suspended load. Turbidity limits light penetration which further inhibits healthy plant growth on the river bottom. Turbidity may cause aquatic organisms to have trouble finding food, may affect gill function, and the sediment associated with turbidity may cause spawning beds to be covered. Suspended organic and inorganic particles also transport nutrients from lands to receiving waters causing eutrophication.

The water quality standard for turbidity in class 2B waters is 25 NTUs. A surrogate variable must be used to complete a TMDL given that turbidity is not a quantitative measure of mass (concentration). Total suspended solids (TSS) measurements are often used as a surrogate for turbidity. MCES ran statistical analyses using its TSS and turbidity data and determined that there is a strong relationship between TSS and turbidity. The project will be using TSS as a surrogate for turbidity. A preliminary TSS value calculated by the Metropolitan Council as the surrogate for turbidity for this study is 79 mg/l. This value will be checked and corroborated using the additional data collected, and will be subject to the reviews, discussions, and reporting of this study.

Known data on the creek comes from the Metropolitan Council's WOMP monitoring program which established a monitoring site on the creek near its confluence with the Minnesota River (i.e., RM 0.6). A summary of data from 2003 and 2004 is presented here. A more detailed summary of existing studies and data will be prepared as part of this study.

In 2003 Total Phosphorous at the site averaged 170 ppb with minimum and maximums of 20ppb and 750ppb. Turbidity averaged 8 NTU with minimum and maximum observations of 1 NTU and 60 NTU. Total suspended solids (TSS) concentrations averaged 52ppm with minimum and maximum concentrations of 1ppm and 634 ppm. Based on a metric developed by the Metropolitan Council, Credit River in 2003 had the second best water quality (along with Elm Creek) of the 11 metropolitan area streams monitored (Metropolitan Council, 2004).

In 2004 the Metropolitan Council monitored for macroinvertebrates as well as water chemistry. With respect to macroinvertebrates the creek had the highest number of taxa of all the stream sampled at 49, and was third highest with respect to the percent of EPT individuals at 60% and percent of chironomidae individuals. Also the Hilsenhoff biotic index calculated from the data indicated "good" water quality. Thus, in general the macroinvertebrate community appeared to be reasonably healthy, except that the percent of diptera was rather high at 36%. The Total Phosphorus concentration in 2004 averaged 260 ppb with minimum and maximum concentrations of 10 ppb and 560 ppb. TSS concentrations averaged 50 ppm with minimum and maximum concentrations of 1 ppm and 226 ppm. Turbidity averaged 13 NTU with minimum and maximum observations of 1 ppm and 37 ppm (Metropolitan Council, 2005).

MCES will continue to monitor at the outlet for flow and water quality.

Data collected over the course of the study showed the river did not exceed the turbidity standard. Therefore, the problem has changed from restoration to protection.

Project activities and schedule:

Task 1 – Data collection
Data collection will be lead by the Scott WMO and MCES. MCES will continue to monitor at the outlet for flow and water quality. Two additional monitoring sites will be added and operated by the Scott WMO for the term of this contract. Negotiations will take place after completion of the project to determine the future use of the equipment and the responsible parties for the equipment. If continued use of the equipment is requested by Scott WMO for additional monitoring, the MPCA requests that data continue to be entered into STORET. Data will be analyzed at MCES' certified lab. Samples will be analyzed for:

- Turbidity (NTU)
- Total Phosphorus (TP)

- Total Dissolved Phosphorus (TDP)
- Chlorophyll-a (Chl-a)
- NO2 + NO3 (NOx)
- Total Suspended Solids (TSS)
- Volatile Suspended Solids (VSS)

Monitoring consists of three simultaneous efforts: stream monitoring, lake monitoring, and special studies. Precipitation and lake level monitoring will also be completed. Precipitation monitoring will consist of continuous recording meters at one of the stream monitoring sites. Lake level monitoring will be completed through the DNR lake level monitoring program on Orchard Lake.

Stream monitoring consists of both routine efforts and special studies. Routine efforts consist of the collection of physical and chemical data at 3 monitoring stations. The monitoring sites are shown on Figure 1. These sites were selected to capture the influence of different land use areas in the watershed: the lower watershed is primarily urbanized, the middle is parkland and residential, and the upper watershed is farmland and rural residential.

Lake monitoring is being supported/continued in order to assess whether algae from the lakes could affect turbidity in the creek. Markley and Orchard Lakes are currently monitored as part of the Metropolitan Council's CAMP program. Cleary Lake is currently monitored by the Three Rivers Park District. Weekly observations will also be completed at the outlet of Orchard Lake to measure the depth of flow at the outlet. Dissolved oxygen concentrations, temperature, and turbidity measurements using meters will also be collected.

Data collection at the three stream sites includes the collection of samples for laboratory analysis; in-situ measurements of temperature, turbidity and turbidity tube; and stage and flow gaging information. Laboratory analysis will be completed by the Metropolitan Councils' certified lab for the parameters listed in Table 1. The exception is the historic Credit River site operated by the Metropolitan Council which will continue to be analyzed the full suite of parameters. Standard operating procedures for the collection of these samples and environmental data are given in the Minnesota Pollution Control Agency (2006), Water Quality Programs Sampling and Monitoring Standard Operating Procedures (SOPs) manual, and the project's Quality Assurance Project Plan (QAPP).

Meters will be used at each site to collect continuous stage elevations for conversion to flow based on rating curves. Flow measurements will be taken when samples are collected. Rating curves for the other sites and gaging will be developed using SOP I-13 and I-15 from MPCA (2006).

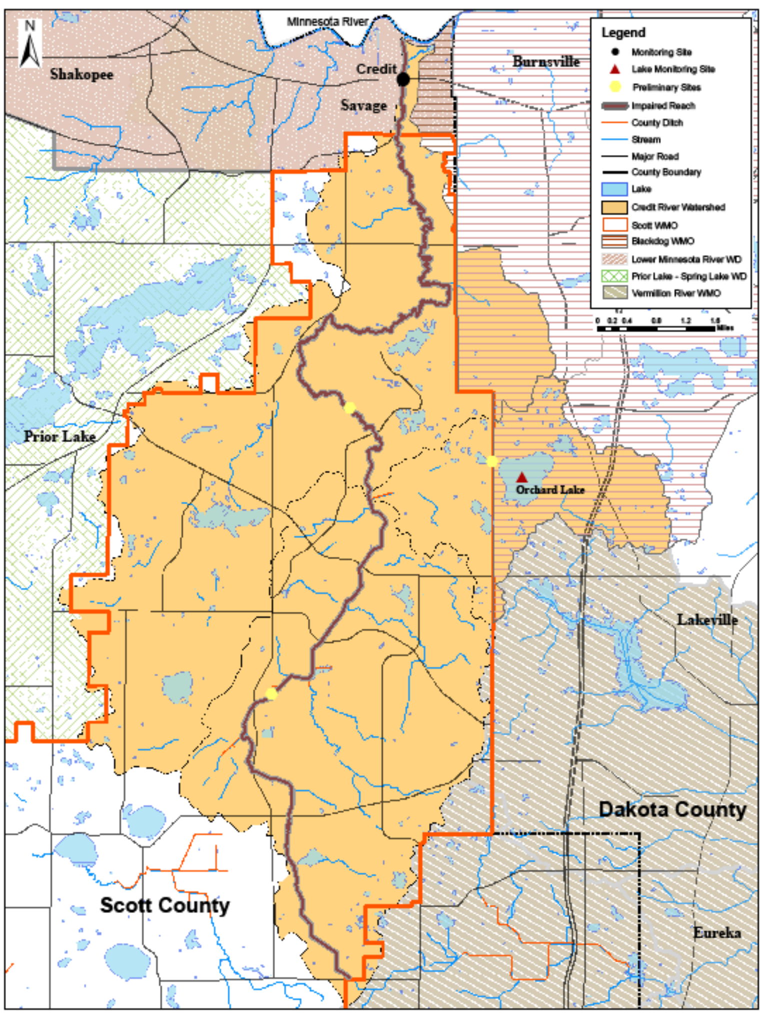
Table 1. Laboratory Analysis Parameters for Stream Sites

Turbidity
Total Phosphorus (TP)
Total Dissolved Phosphorus (TDP)
Chlorophyll-a (Chl-a)

NO2 +NO3 (NOx) Total Suspended Solids (TSS) Volatile Suspended Solids (VSS)

In-situ measurements will be taken using calibrated meters, with the exception of turbidity tube measurements. Samples and in-situ measurements will be taken for twenty five (25) observations starting with snow melt to include 8 base flow grab samples, and 17 event flow grab samples representing different part of the storm hydrographs. The exception is the Credit River in Savage site where Metropolitan Council Protocol will be followed where up to 30 samples are collected with some being event composite samples.

Figure 1. Monitoring sites on the Credit River



Credit River Watershed

In-situ measurements will also be taken for turbidity and transparency tube. Black Dog WMO will continue to support monitoring of Orchard Lake through the MCES CAMP program. MDNR lake level monitoring data will be used to track levels in Orchard Lake over the monitoring period and will be compared to lake outlet elevations and dimensions to estimate discharge from the lake over the project period. In addition, bi-weekly observations will be made at the lake outlet, when there is discharge, to estimate the depth of flow in the outlet, and to take in-situ turbidity and transparency tube measurements. Data will be used for model development and verification.

Watershed and stream characterization and data collection consists of collecting necessary data to assess the problems and populate the water quality models. Watershed characterization data will consist of topographic, land use, soils, cropping practices, feedlot information, land cover, drainage practices, and wetlands information in Geographic Information System coverages. Most of these coverages have already been created by Scott County, and are available for use with minor adjustments. Stream characterization is also already largely complete by the Scott WMO with the erosion survey and the geomorphic assessment. Special studies to supplement this information are described under Task 4 below. Data will be used for model development and verification.

Deliverables: Water quality monitoring data representative of different flow conditions for the watershed. All data will be entered into the MCES EIMS database and be made available to the MPCA STORET database system. Watershed and stream characterization data will be used in the following tasks and presented in the draft TMDL. Monitoring will be completed in 2008 with data submittal by December 1st, 2008.

Task 2 - TSS and turbidity relationship
MCES will use monitoring data to develop the TSS/turbidity relationship for Credit River. MCES will look at seasonal differences. MCES will refine the draft relationship with input from stakeholders.

Deliverable: TSS standard equal to 25 NTU for Credit River. TSS/turbidity relationship development report will be sent to MPCA. Draft report /analysis of the relationship will be submitted to MPCA in the winter of 2009, corresponding with the project team meeting scheduled to cover this topic.

Task 3 – Special Studies
Ancillary data are included in this budget to ascertain turbidity sources in the Credit River Watershed, in particular to differentiate landscape and stream corridor turbidity sources. Scott WMO is in the process of completing a geomorphic assessment of the river. Additional special studies for this project include:

- Assessment of riparian vegetation conditions
- Additional geomorphic information to supplement the existing Geomorphic Assessment where analysis shows a needs
- ~~Analysis of stream power and stream flashiness using the historic flow data from the Metropolitan Council for the existing monitoring site in Savage.~~

- Installation of in-stream continuous turbidimeters at top and bottom of specific stream reaches
- Monthly synoptic surveys across the watershed for in-situ turbidity and turbidity tube measurements
- ~~Macroinvertebrate sampling and analysis to assess biotic impairment at two additional sites beyond the current Metropolitan Council site~~

Deliverables: Outcomes of these efforts will be recorded and analyzed in the Protection Plan ~~draft and final technical reports and the TMDL reports~~ scheduled for completion in the fall of 20~~09~~10. In addition, progress reports and memoranda with results will be prepared for discussion at various meetings of the partners.

Task 4 – Model Development

Develop, calibrate and validate SWAT model for TSS analysis. Use data collected, land use assessment, and probable cause assessment to develop SWAT model for the watershed. SWAT model will be verified and calibrated with monitoring data. Model will be ready to run scenarios which identify best management practices and potential locations to be used in the watershed to reduce the TSS load in the creek.

Watershed and stream modeling consists of:

1. Developing a relationship between turbidity and TSS so that a model based on TSS can be used for the turbidity ~~TMDL~~ Protection Plan.
2. Assessing annual and seasonal loads for TSS and TP, and estimating flow weighted mean concentrations using the FLUX model.
3. Developing, calibrating and validating a model for both TSS and TP.
4. Applying the model to help define existing conditions and develop load duration curves.
5. Evaluating Best Management Practices (BMP) Scenarios.
6. Developing a final report, as part of the ~~TMDL~~ Protection Plan.

Turbidity – TSS Relationship (to be completed by MCES). Per Task 2, MCES will estimate the relationship between turbidity and total suspended solids (TSS). The MPCA has listed Credit River as impaired for turbidity based on a standard of 25 NTU. Stream turbidity can be influenced by a variety of factors – suspended sediment and soil, dissolved and particulate organic matter, water color, trash and debris – however in most Twin Cities Metropolitan Area streams total suspended solids has the greatest influence on turbidity. Turbidity is not readily simulated by existing water quality models; therefore a surrogate parameter is used for simulation of turbidity dynamics. Evaluation of existing TSS and turbidity data for Credit River indicates a strong statistical relationship between the two parameters, so TSS will be modeled in SWAT as the surrogate for turbidity. In general, laboratory-derived turbidity values will be used to develop the TSS-turbidity statistical relationship due to variation between field meters.

Model Development, Calibration, and Validation.

Model Inputs. SWAT is a watershed scale model developed to predict impacts of land management practices on water, sediment, and agricultural chemical yields (nutrients, pesticides, conservative metals, bacteria) over long periods of time in large, complex watersheds that have varying soil, land use, and management conditions. The physical, chemical and biological processes associated with water and sediment movement, crop growth, nutrient cycling are modeled by SWAT.

For Credit River, MCES will use SWAT to simulate stream and watershed hydrology and total suspended solids (TSS) and total phosphorus (TP) mass loads and mean flow-weighted concentrations.

The basic spatial inputs required for SWAT include watershed digital elevation, soil, land use/cover maps, and locations of weather stations, point sources and watershed outlets. The temporal inputs include daily climate data, point source loads, inlet discharges, impoundment flows, and irrigation. In addition, the interface requires land use designations, soil properties, groundwater parameters, plant growth, agricultural management information, impoundment and stream water quality data, as well as kinetic rates describing physical and biogeochemical processes associated with hydrological cycles and chemical behaviors in the watershed.

In addition to the previously described data, the following data sources will be used by MCES to develop the model:

1. Digital elevation model: NED (National Elevation Data) 30-ft DEM
2. Watershed delineation: ARCSWAT based on DEM with corroboration by county personnel
3. Land cover: NLCD (National Land Cover Data)
4. Weather Stations: Minnesota Climatology Working Group and Scott WMO precipitation gauges
5. Feedlots: MPCA and counties
6. Point sources: MPCA
7. Soils: SSURGO (Soil Survey Geographic Database), NRCS
8. Agricultural management practices: In general, agricultural management information used in the model includes crop types and rotations, approximate planting dates, fertilizer application rates, tillage types and timing.
9. Stream network: National Hydrography Dataset (NHD)
10. Wetlands, lakes: National Wetland Inventory (NWI)
11. Drained wetlands: surveys provided by Scott County
12. 2030 development conditions will be based on development projections provided by Scott County, and the Cities of Burnsville, Lakeville, Savage, Elko-New Market, and Prior Lake
13. Stream water quality/hydrology: MCES, Scott SWCD, and Scott County

SWAT is a large scale, low resolution model; therefore individual farms and fields will not be modeled. The watershed will be divided into approximately 20-50 subwatersheds. General agricultural management practices will be included in the model, but resolution will not allow for modeling of site-specific field practices or farm BMPs.

Model Calibration and Validation. Model calibration consists of optimizing model parameters in an attempt to match local conditions (e.g. daily, monthly or annual flows and mass loads) within reasonable scales and criteria. Model validation is a process of testing the performance of the calibrated model without further changing input parameters against an independent set of measured data. The data sets used for calibration and validation cover either different time periods or involve separate monitoring locations.

The accuracy of the model results for the calibration and validation periods will be evaluated using graphical comparisons and statistical tests. To evaluate model performance, predicted daily, monthly and annual flow, sediment, nitrate and phosphorus loads will be compared against field observations. The results will be tested with a variety of statistical techniques, including

- Observed, predicted means (OM and PM) and difference
- Root mean square deviation (RMSD)

$$RMSD = \sqrt{\sum_{i=1}^{N} \frac{1}{N} (P_i - O_i)^2}$$

  where N is the number of data points; P_i and O_i are the predicted and observed values respectively.
- Root mean square deviation in percentage of OM (RMSD %)
- The slope, intercept and regression coefficient of least square correlation between observed and predicted values (a, b and r^2)
- The index of agreement (IA), which is the degree to which the predicted variation accurately estimates the observed variation

$$IA = 1 - \frac{\sum_{i=1}^{N} (P_i - O_i)^2}{\sum_{i=1}^{N} (|P_i - OM| + |O_i - OM|)^2}$$

The MCES monitoring station at Jordan will be used as the primary source of data for model calibration and validation. Data collected by Scott County during 2008 will be used for secondary calibration and validation. Analysis of the collected data to assess annual and seasonal loads and estimate flow weighted mean concentrations will be completed using the FLUX model.

Model application. After model calibration and validation, MCES will perform simulations of existing and 2030 land use conditions to estimate hydrology, total suspended solids, and total phosphorus loads and concentrations for each subwatershed.

~~MCES will also prepare load and flow duration curves for those stream stations fitted with continuous flow gauging equipment providing average daily flow, following the method described in "An Approach for using Load Duration Curves in Developing TMDLs", U.S. Environmental Protection Agency, Office of Wetlands, Oceans, & Watersheds, December 2006.~~

Deliverable: Calibrated and validated model to use to run scenarios which will be used for the load allocations. Text will be written that includes information on land use, model development, maps of subwatersheds, model runs, and final results. Outcomes of these efforts will be recorded and analyzed in the Protection Plan ~~draft and final technical reports and the TMDL reports~~ scheduled for completion in the ~~fall of 200910~~ spring of 2011. In addition, progress reports and memoranda with results will be prepared for discussion at various meetings of the partners.

Task 5 – Solution Identification

The calibrated SWAT model will be used to identify nonpoint source loadings in the watershed, ~~to assess exceedence of water quality against standards, to develop waste load allocation, load allocation, and margin of safety~~, and to run up to 3 scenarios representing volume and water quality control Standards of the Scott WMO. This information will then be used to assess the efficacy of current local requirements for protecting the river, and will guide development of the Protection Plan. ~~that identify best management practices to be used in the watershed.~~ An additional scenario based on the 2030 Comprehensive Plans will also be run. The scenarios will be developed in conjunction with project partners.

Deliverables: Nonpoint source pollution loadings and best management practice scenarios for the watershed, information on whether or not meeting water quality standards, and load allocations. Results will be included in the Protection Plan ~~draft and final TMDL reports~~ scheduled for completion ~~fall winter of 200911~~ by June 30, 2011.

Task 6 – Stakeholder participation

Successful implementation of a ~~TMDL project~~ Protection Plan requires active stakeholder participation throughout the development of the ~~TMDL~~ Plan. The process used will focus on three groups:

1) The public at large, particularly riparian land owners along the river,
2) Technical staff , and
3) Community officials/decision makers.

The public at large will be engaged in ~~two~~ one open house meeting~~s~~, and through press releases to the Burnsville, Savage and Lakeville Prior Lake news papers. The open house meeting~~s~~ will be scheduled at ~~60% and~~ the 90% completion stage~~s~~ to present initial findings and the ~~final results of the TMDL~~ draft Protection Plan. In addition to the open house meeting~~s~~ one to two more focused meetings targeting riparian residents will be held at about the 70% completion stage. These meetings will be set up with the intent of allowing the riparian residents to RSVP and schedule time to meet in a small group with project staff to specifically identify and discuss options available for their property. The geomorphic assessment completed by the Scott WMO includes recommendations for restoring natural fluvial processes by reach, and the Scott WMO has cost share dollars for incentives to work with land owners.

Technical staff will be engaged as a Technical Advisory Group (TAG). Representatives of the following organizations will be invited to participate in the TAG:

- The project partners: Black Dog WMO, Lower Minnesota River Watershed District, MCES, Scott WMO, Scott County, and Three Rivers Park District
- Cities of Burnsville, Savage, Lakeville and Prior Lake

- Credit River and New Market Townships
- MPCA, BWSR, and DNR

Scott WMO will host and facilitate the meetings. Project partners will participate in the meetings and provide technical assistance. First meeting (spring of 2008) will bring the partners together to understand the task and decide on roles and operating procedures for members and to get input on watershed characteristics needed for developing the watershed model. The second (winter of 2008/09) meeting will discuss TSS and turbidity relationship analysis, and discuss solutions identification and start to identify management scenarios. The third meeting (spring of 2009) will get input on model validation and calibration and finalize scenarios to be modeled. The fourth meeting (summer of 20~~09~~10) will discuss model results and best management practices scenarios. The fifth meeting (~~fall~~ ~~winter of 200911~~ spring/summer 2011) will discuss the draft Protection Plan ~~draft TMDL report~~ based on model results. Additional meetings will be added as needed

Community officials and decision makers will be updated throughout the projects by the respective technical staff of the project partners. Two to three updates will be targeted for each organization. Scott WMO will track the occurrence of these updates.

Deliverables: Open house meetings, focused riparian owner meetings, TAG meeting and decision maker updates designed to inform and get buy in and support from project partners and stakeholders on the development of the model and the draft ~~TMDL~~ Protection Plan. Public outreach materials if developed will be submitted with the draft ~~TMDL~~ Protection Plan. Meeting summaries will also be incorporated into the draft ~~TMDL reports~~ Protection Plan scheduled for completion ~~fall~~ ~~winter of 200911~~ by June 30, 2011.

Task 7 – Technical Report

MCES will prepare draft and final technical reports on SWAT model inputs and results. MCES will work with Stakeholders to develop land use for model, best management practices scenarios to run for model, and overall model assumptions and results. Scott County/WMO staff will also complete an analysis of the spatial and temporal variation of the TSS and turbidity data for inclusion in the Protection Plan.

Deliverable: Draft and final technical reports on SWAT modeling. This information will be incorporated into the draft ~~TMDL reports~~ Protection Plan scheduled for completion ~~fall~~ ~~winter of 2009~~ by June 30, 2011.

Task 8 – Final report(s)

This task consists of completing draft and final ~~reports based on EPA guidelines; MPCA, EPA, WMO, and stakeholder reviews~~ Protection Plan. The draft and final ~~TMDL~~ Plan will include:

1. Description of water body, pollutant of concern, pollutant sources, and priority ranking
2. Description of the applicable water quality standards and numeric water quality target

3. An assessment of the data collected with respect to spatial distribution of sediment and hydrologic loads
4. A summary of the modeling (with detail provided in a technical appendix)
5. A description and assessment of current watershed protection efforts, programs and Standards
6. Loading capacity
7. Load Allocations (LAs)
8. Wasteload Allocations (WLAs)
9. Margin of Safety (MOS)
10. Critical Conditions
6. Monitoring Plan
7. Protection Implementation strategy
8. Reasonable Assurance
8. Public Outreach Activities.

The Protection Plan TMDL report will be submitted to the MPCA for submittal to EPA. All reports, documents, data files, modeling information, public information summary and outreach materials, fact sheets which were developed during the project will also be submitted to the MPCA. A final progress report with a final financial report will be submitted electronically to the MPCA as well.

Deliverables: Draft and final Protection Plan TMDL report in both hard copy and digital format. Draft reports are scheduled for completion by the fall winter of 2009 by June 30, 2011. The schedule for final reports will depend on agency and public review and approval times.

Task 9 – Project Management
This task includes development of project tracking and financial reporting tools and procedures. Scott WMO will provide twice annual progress reports to the MPCA and a final financial report.

Deliverables: Semi-annual progress reports submitted by February 1st and August 1st. A final financial report within 30 days of final TMDL approval. An additional year of monitoring was added at the Scott WMO's and Met Council's expense. This created an amended schedule as shown in the following table.

TASK SCHEDULE AND RESPONSIBLE PARTY

TASK	SCHEDULE	LEAD
1. Data Collection	January through December 2008 and 2009	MCES/Scott WMO
2. TSS/Turbidity Relationship	2008 - Spring 2009	MCES
3. Special Studies	2008-2010	Scott WMO
4. Model Development	Fall 2008- Summer 200910	MCES
5. Solution Identification	Winter 2008- Spring Summer 200910 2011	All project partners

6. Stakeholder Participation	**January 2008- ~~October 2009~~ ~~December 2010~~ June 2011**	**All project partners**
7. Technical Report	**Spring 2009- ~~Fall 2009~~ ~~Winter 2010 -2011~~ Summer 2011**	**MCES, Scott WMO**
8. Draft Final Report	**Summer 2008 – ~~Winter 2008/9~~ ~~2010-2011~~ Summer 2011**	**Scott WMO**
9. Project Management	**On-going**	**Scott WMO, Scott County**

~~It is anticipated that a contractor will be hired to assist with portions of tasks 3, 4, 7, and 8.~~ Scott WMO water quality technician and Scott SWCD will operate the additional monitoring sites and lead the special studies.

BUDGET ~~(see attached spreadsheet for detailed budget)~~

TASK	**Estimated Cost/Budget**	**Amended Cost/Budget**	**Change**
1. Data Collection	$29,557	$29,636.33	$79.33
2. TSS/Turbidity Relationship	$704*	$181.38	-$522.62
3. Special Studies	$40,638	$24,019.36	-$16,618.64
4. Model Development	$0*	$0	$0
5. Solution Identification	$0*	$0	$0
6. Stakeholder Participation	$8,169	$5,251.08	-$2,917.92
7. Technical Report	$23,880	$11,381.42	-$12,498.58
8. Draft Final Report	$19,764	$11,203.50	-$8,560.50
9. Project Management	$2,288	$2,902.08	$614.08
Total	**$125,000**	$84,575.15	-$40,424.85

* Provided by project partners

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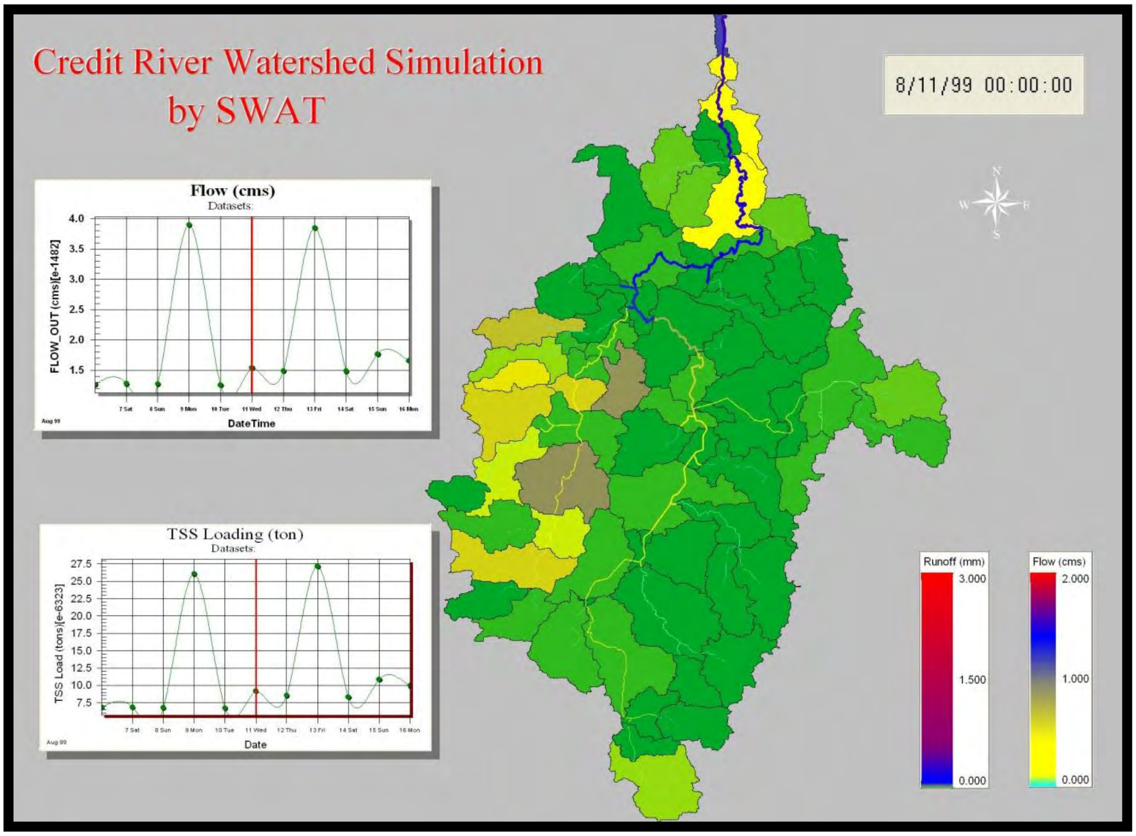
Metropolitan Council, 2004. 2003 Stream Monitoring and Assessment for 11 Metropolitan Area Streams. Publication No. 32-04-064.

Metropolitan Council, 2005. 2004 Stream Monitoring and Assessment. Publication No. 32-05-071.

MPCA, 2005. Guidance Manual For Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List.

Appendix C. Credit Modeling Report

Credit River Hydrology and Total Suspended Solids Modeling



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The hydrologic and water quality data used for model calibrations were collected and analyzed by MCES Environmental Monitoring/Water and Air Quality, Scott County staff and Scott County Water Management Organization (WMO).

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Questions about the contents of this study can be referred to Dr. Hong Wang at 651-602-1079.

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1. INTRODUCTION

In 2002, Credit River in Scott County of the Metropolitan Area, Minnesota, was listed by the Minnesota Pollution Control Agency (MPCA) as “impaired” on the MPCA’s 303(d) Impaired Waters List. The river (MPCA Assessment Unit Identity Number: 07020012-517) was listed from the headwaters to the Minnesota River due to its high turbidity measurements that surpassed the water quality standard of 25 Nephelometric Turbidity Units (NTUs). The higher turbidity measurements indicate that the river does not meet beneficial uses for a Class 2B water as designated.

Turbidity is commonly measured in NTUs, a unit of measurement quantifying the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles or total suspended solids (TSS). The scattering of light in the water column makes the water appear cloudy, and the cloudiness increases with greater suspended loads. Turbidity limits light penetration which further inhibits healthy plant growth on the river bottom. Turbidity may cause aquatic organisms to have trouble finding food, affect gill function and cause spawning beds to be covered. TSS also transports nutrients from fields and stream banks to receiving waters aiding in eutrophication. Increased turbidity in a stream is associated generally with alterations of the landscape and environmental conditions such as increased agricultural production, urbanization and precipitation due to climate change.

Section 303(d) of the Clean Water Act establishes a directive for developing Total Maximum Daily Loads (TMDLs) to achieve water quality standards established for designated uses of water bodies of the state. The MPCA has the responsibility to conduct TMDL studies for waters of the state if the waters are listed as impaired according to their designated uses and water quality standards. In 2008 the MPCA entered into a contract with Scott County (County) to develop a TMDL for Credit River.

The Metropolitan Council (Council) is the regional water quality-planning agency for the seven county Metropolitan Area under Section 208 of the Clean Water Act (33 U.S.C. 1288). The Council has the responsibility to assist the MPCA and local authorities with assessments of Waters of the State in the Metropolitan Area (M.S. 103F.721) and to review and assist with preparations of water resources plans for watersheds in the Metropolitan Area (M.S. 473.157). Furthermore, the Council has authority to engage in a continuous program of research and study of the control and prevention of water pollution in the Metropolitan Area (M.S. 473.244, Sub. 4) and to engage in activities to implement total watershed management (M.S. 473.505). The Council, under a Memorandum of Agreement between Scott County and the Council, is providing technical support to the County’s water quality studies and pollution mitigation efforts. Based on the memorandum and discussions with the County, the Council is responsible for the following tasks:

- Conduct water quality monitoring including TSS, turbidity and associated hydrologic and water quality parameters
- Develop, calibrate and validate a watershed model for flow and TSS
- Use the developed model to identify and quantify TSS loadings from nonpoint source
- Evaluate various best management practice (BMP) scenarios, based on direction from Scott County, to prioritize management practices and implementation schemes for TSS reductions.

Over the course of the study effort new monitoring data showed that the river was in fact not impaired for turbidity. In 2010 Scott County submitted a request to the MPCA to delist Credit River from the Minnesota's 303(d) Impaired Waters List. The request was based on the following facts:

- The original decision to list was based on a set of data collected using a sampling protocol that was designed for a different purpose, and this data set when used for the purposes of making a decision regarding listing is biased toward higher turbidity results.
- Correcting the biases in the original data and more recent data confirms that the 25 NTU standard will be met 90 percent of the time with 95 percent confidence.
- More recent continuously collected *in situ* turbidity data from 2008 and 2009 shows that the 25 NTU standard is being met more than 98.8 percent of the time.
- Storm water management and erosion control for the watershed have been significantly improved since the original listing. These actions should have reduced erosion and sediment transport, and thus turbidity.
- The macro-invertebrate community (i.e. aquatic insects) in the river appears to be healthy.

The MPCA has agreed to pursue delisting of the river. Instead of completing the TMDL, the County is preparing a Protection Plan that will assess how to keep the river from reverting back to an impaired. In other words the goal has changed from reducing turbidity to preventing increased turbidity.

This report is part of the Credit River Protection Plan being developed by Scott County for the MPCA and includes results of the Council's work tasks described above, which were agreed upon through the Memorandum of Agreement. Detailed information on the project will be provided by Scott County's protection and BMP implementation plans.

2. SWAT MODEL AND STUDY AREA

2.1 Model Selection

Based on the objectives and tasks established for this study, the simulation model to be used should be:

- A watershed scale model
- Able to simulate natural, agricultural and urban ecological systems relevant to the hydrologic cycle
- Able to simulate TSS transport and fate in the watershed.

The SWAT (Soil and Water Assessment Tool) model developed by the U.S. Department of Agriculture Research Service and Texas A&M University was therefore chosen. SWAT is one of the advanced models recommended for watershed studies and TMDL development by the United States Environmental Protection Agency (US- EPA).

SWAT was created initially for agricultural non-point source pollution studies in the early 1990s. It includes subroutines and databases related to weather, soil properties, topography, vegetation and land management practices. These databases are used to simulate the hydrology, TSS and pollutant yields, and fate/transport in the complex ecological systems of watersheds. Since original development, the model has undergone continued review and expansion of capabilities. An urban routine, which is an important feature for watersheds with mixed land covers, was incorporated into SWAT in 1999. The routine includes a set of United States Geological Survey (USGS) linear regression equations (Driver and Tasker, 1988) and build-up/wash-off equations (Huber and Dickinson, 1988) for estimating constituent loads. The urban routine developed in SWAT makes it possible to assess the effectiveness of Scott County's storm water management standards using the calibrated model.

2.2 Watershed and Monitoring Descriptions

The Credit River watershed is located in Scott County, Minnesota (Figure 1). The watershed is one of the subwatersheds within the Lower Minnesota River Basin. Credit River begins in New Market Township and flows generally north through Credit River Township before discharging into the Minnesota River in the City of Savage. The definitions of the land cover codes in Figure 1 are listed in Table 1.

Based on the SWAT delineation using the Council's 2002 land cover map and topographical data, Credit River has a drainage area of approximately 30,610 acres. Urban, agriculture and forest are the three primary land covers in the watershed, accounting for approximately 30, 27 and 22 percent, respectively, in 2002 (Figure 2). Remaining land covers include wetlands (11 percent), pasture (7 percent), open water (3 percent) and other (1 percent).

The MCES monitoring station is located at 4975 126th Street in the City of Savage, which is about 0.9 miles upstream from the confluence with the Minnesota River. Flow and TSS measured at the station were used for the model calibration and validation. Scott County has two monitoring stations located upstream at 154th Street and County Highway CSAH-68. Data from the two stations were used to estimate TSS sources from field and non-field erosion.

Flow and water quality have been monitored at the MCES station since 1989. Continuous stream flow is measured from spring to fall using automated monitoring equipment that records stage. Stream stage is converted into flow according to a stage-discharge relationship or rating curve.

Table 1 Land Cover Definitions

Codes	Land Covers
URLD	Low density residential
URML	Medium-low density residential
URMD	Medium density residential
URHD	High density residential
UCII	Commercial, industrial and institutional
FRSD	Forest
PAST	Pasture
WATR	Water
WETL	Wetlands
ALFA	Alfalfa
AGRR	Agriculture row crops
OATS	Oats
SWRN	Sand mining

Water quality is measured from grab and storm composite samples. Grab samples are collected periodically during baseflow conditions. In the spring, summer and fall, baseflow samples are collected twice a month. In addition to the baseflow samples, event-based composite samples are collected using automatic samplers. Composite samples are collected on an equal-flow increment (EFI) basis. With EFI sampling, composite samples are collected throughout the event with discrete sub-samples representing equal volumes of flow. Due to safety issues, no samples were collected during winter seasons (December to February). Water quality and flow for winter was estimated by filling in the data using a straight line analysis from the previous fall to the following spring. This approach assumes that winter flow consisted primarily of baseflow and that there were no runoff events during this time period. Water quality loads were calculated with the Flux32 model developed by the United States Army Corps of Engineers based on relationships between water quality and flow for varying flow conditions (Walker, 1996).

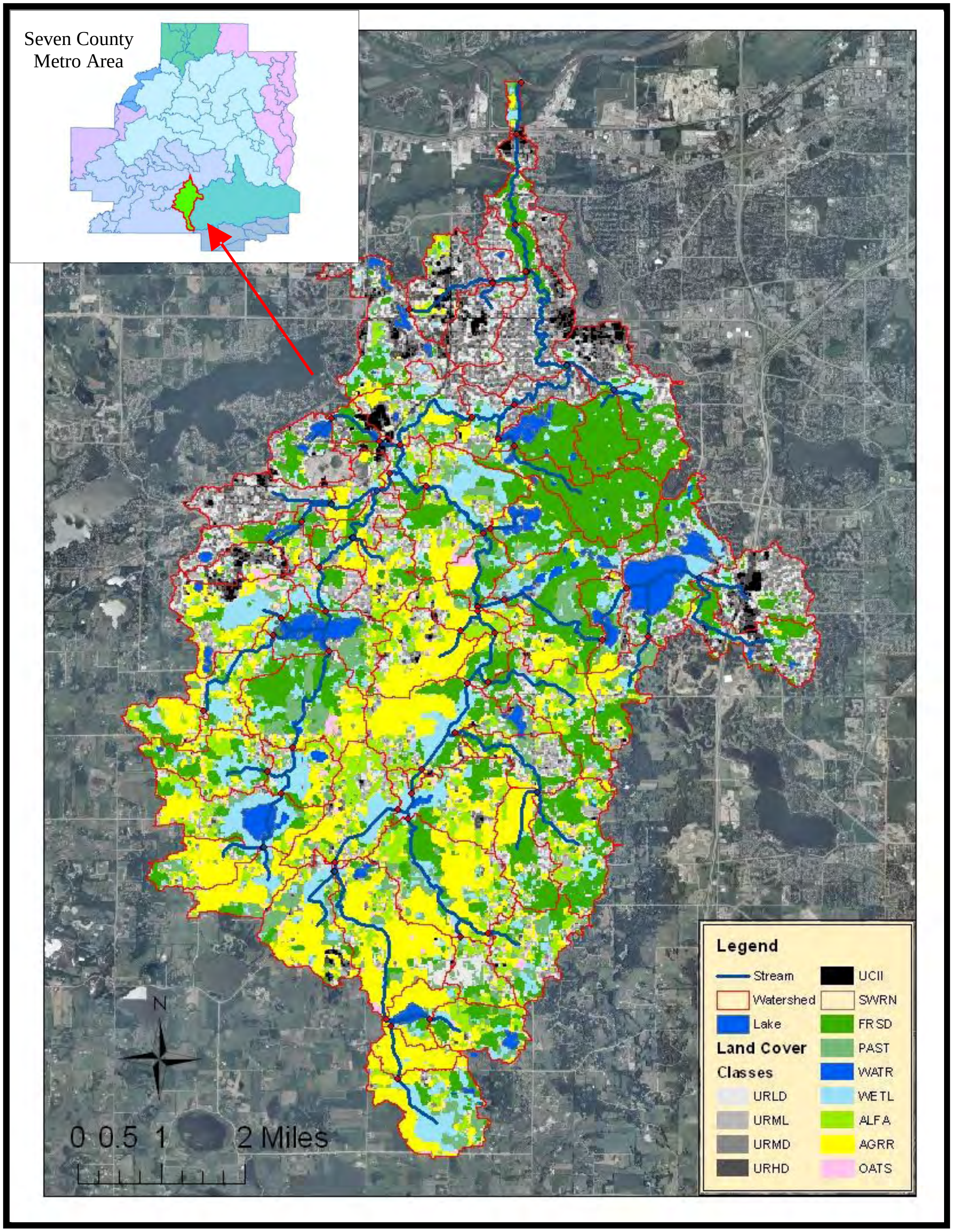

Figure 1 Credit River Watershed and 2002 Land Cover

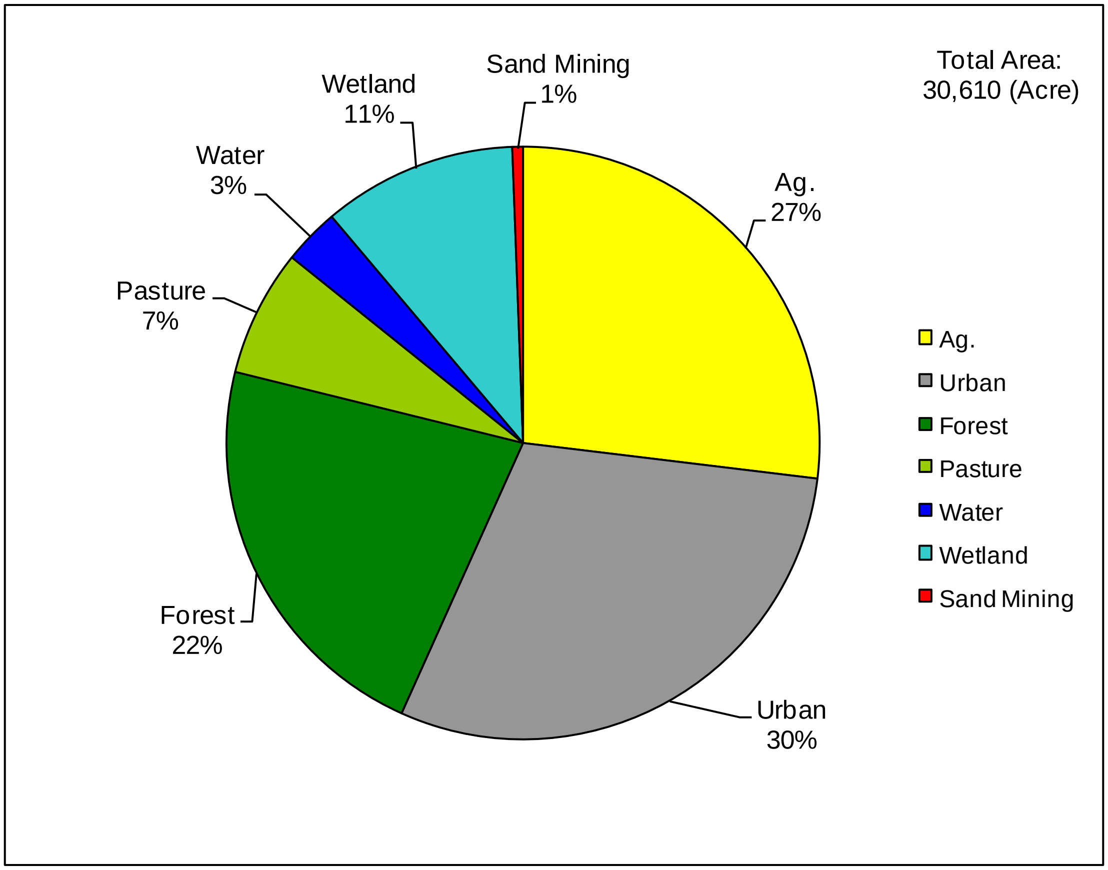

Figure 2 2002 Land Cover Summary for Credit River Watershed

3. MODELING APPROACH

3.1 SWAT Model Framework and Process

SWAT is a watershed scale model developed to predict impacts of land management practices on water, sediment, and chemical yields (nutrients, pesticides, conservative metals, bacteria) over a long period of time in a large, complex watershed with varying soils, land use and management conditions. The physical, chemical and biological processes associated with water and sediment movement, crop growth and nutrient cycling are modeled by SWAT.

SWAT simulates hydrology, pollutant yield and transport in two major phases. The first is to simulate hydrologic cycle associated yields and movements of sediments, nutrients and pesticides and their loadings to the channels in each subbasin. The second is to simulate hydrology, physical and biogeochemical processes of the sediments and chemicals during transport through the channel network and impoundment. Table 2 summarizes the major processes involved in field and channel routing phases in SWAT.

Table 2 Major Processes in SWAT Field and Channel Routing Phases

Water	Sediments	Nutrients	Pesticides
– Precipitation – Canopy storage – Infiltration – Soil redistribution – Evapotranspiration – Lateral flow – Surface runoff – Crop rotation – Water use – Storage in impoundments – Base flow – Point sources	– Land cover and plant growth – Soil erosion – Settling – Resuspension – Point sources – Urban buildup and wash off	– Fertilization – Partitioning – Mineralization – Nitrification – Denitrification – Biological uptake – Volatilization – Settling – Resuspension – Leaching – Point sources – Urban buildup and wash off	– Degradation – Partitioning – Settling – Resuspension – Volatilization – Foliage wash-off – Leaching – Burial

The SWAT model developed to run under ArcGIS for the personal computer environment is called ArcSWAT. ArcGIS provides both the Geographic Information System (GIS) computation engine and a common Windows-based user interface. With ArcSWAT, the SWAT simulation is completed with a graphical user interface. Several sets of customized tools are used by the SWAT model for computations. These tools are designed to:

- Generate specific parameters from user-specified GIS coverage
- Create SWAT input data files
- Establish agricultural management scenarios

- Control and calibrate SWAT simulations
- Extract and organize SWAT model output data for charting and display

The most relevant components of the SWAT simulation system include an advanced watershed delineator and a tool for the definition of the Hydrologic Response Units (HRUs). SWAT has eight modules used to complete this simulation (Figure 3):
- Watershed delineation
- HRU definition
- Definition of the weather stations
- SWAT databases
- Input parameterization, editing and scenario management
- Model execution
- Read and map-chart results
- Calibration tool

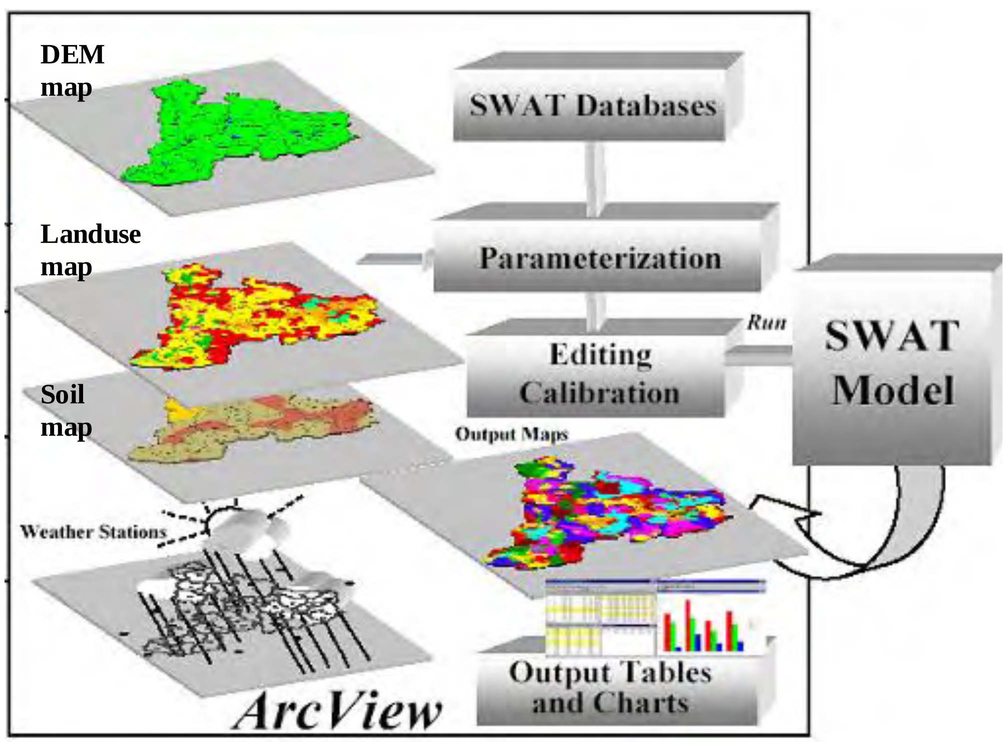

Figure 3 SWAT Model Components and Inputs (Modified from Neitsch et al., 2002)

Development and application of the SWAT model for the Credit River Watershed includes the following steps for watershed analysis and scenario studies:
- Watershed identification and site visit
- Modeling plan development
- Input database development
- Watershed delineation and segmentation
- Hydrology and water quality calibration/validation
- Model application and management scenarios

3.2 Model Inputs and Development

SWAT requires a variety of spatial and temporal input data and constants to characterize the topography, climate and ecological systems of the watershed. The basic spatial inputs include watershed digital elevation, soil and land cover maps, locations of weather stations, point sources and watershed outlets. The temporal inputs include daily climate data, point source loads, inlet discharges, impoundment flows, irrigation and other water usage. In addition, the model requires land use designations, soil properties, groundwater parameters, plant growth, agricultural management information, impoundment and stream water quality data, as well as kinetic rates describing physical and biogeochemical processes for hydrologic cycles and chemical behaviors in the watershed.

3.2.1 Geographic Data

Topography

The topographical data used was a 10-meter digital elevation model (DEM) downloaded from USGS National Map Seamless Server (http://seamless.usgs.gov/index.php). The data represented an elevation surface of the region in a regular grid where each grid cell is 10×10 square meters with a single elevation value for each cell given in feet above mean sea level. The DEM provided basic information for watershed delineation to calculate relevant topographic parameters, such as lengths, slopes, boundaries, areas of watershed tributaries, main channel, HRUs and sub-watersheds.

Land Cover

A 2002 land cover map was used to represent land use conditions for model development. The data was developed by the MCES and the University of Minnesota based on 2002 multi-temporal Landsat Thematic Mapper data (Yuan et al., 2005). The various land covers were aggregated into 13 major categories for analysis, reflecting agricultural, urban and natural land covers (Table 3).

For agricultural land coverage, alfalfa and brome grass were considered "non-row crop," corn and soybean as "row crop" and wheat, oat and rye as "grain." The SWAT model requires each group of land covers to be broken down into individual categories. In order to match the SWAT designations, original "non-row crop" was, therefore, redefined to "alfalfa." The classification of "row crop" was redefined as general agriculture and split into "corn" and "soybean" using the SWAT split tool. The splitting was based on the total planting acreage ratio of corn and soybean. The ratio estimated using the National Agricultural Statistic Services data from 1991 to 2007 for Scott County was 58 percent and 42 percent, respectively, for corn and soybean.

"Grain" was redefined as "spring wheat." A new urban land cover classification of UCII and relevant database were created for high density urban to represent commercial, industrial and institutional land uses. The new classification is represented using identity number (ID) 5 in Table 3. The redefined land use categories and relevant SWAT land cover codes are listed in Table 3. The redefined 2002 land covers for the Credit River Watershed are shown in Figure 1.

Table 3 Land Cover Categories and Definitions

ID	Land Covers in Original Map	ID	Land Covers used in SWAT	Code
1	Low density urban	1	Low density residential	URLD
2	Medium-low density urban	2	Medium-low density residential	URML
3	Medium density urban	3	Medium density residential	URMD
4	Medium-high density urban	4	High density residential	URHD
5	High density urban	5	Commercial, industrial and institutional	UCII
8	Mixed forest	8	Forest – deciduous	FRSD
9	Grass – lawns, sod	9	Pasture	PAST
10	Open water	10	Water	WATR
11	Wetland	11	Wetlands – mixed	WETL
12	Non-row crop: alfalfa, brome grass, pasture	12	Alfalfa	ALFA
13	Row crop: corn, soybean	13	Corn	CORN
		13	Soybean	SOYB
14	Grains: wheat, oats, rye	14	Oats	OATS
16	Herbaceous	9	Pasture	PAST

<u>Soil Database</u>

The STATe Soil GeOgraphic (STATSGO) database was used for the soil inputs for model development. STATSGO is a digital soil association map developed by the National Cooperative Soil Survey (http://www.soils.usda.gov/survey/geography/statsgo/). The maps were compiled by generalizing more detailed soil survey maps. This data set consists of geo-referenced digital map data and computerized attribute data, containing up to 21 different soil components. Soil map units are linked to attributes in the Map Unit Interpretations Record (MUIR) relational database which gives physical and chemical soil properties and interpretations for engineering uses. A total of 50 categories of soils were identified in the region, represented by different color polygons (Figure 4). In the entire Credit River Watershed there are only seven soil categories. MN081 and MN172 are the dominant soil map units in the watershed. MN 081 and MN 172 represent two groups of composite soils primarily including Lester, Kingsley, Hayden and 28 other soil species.

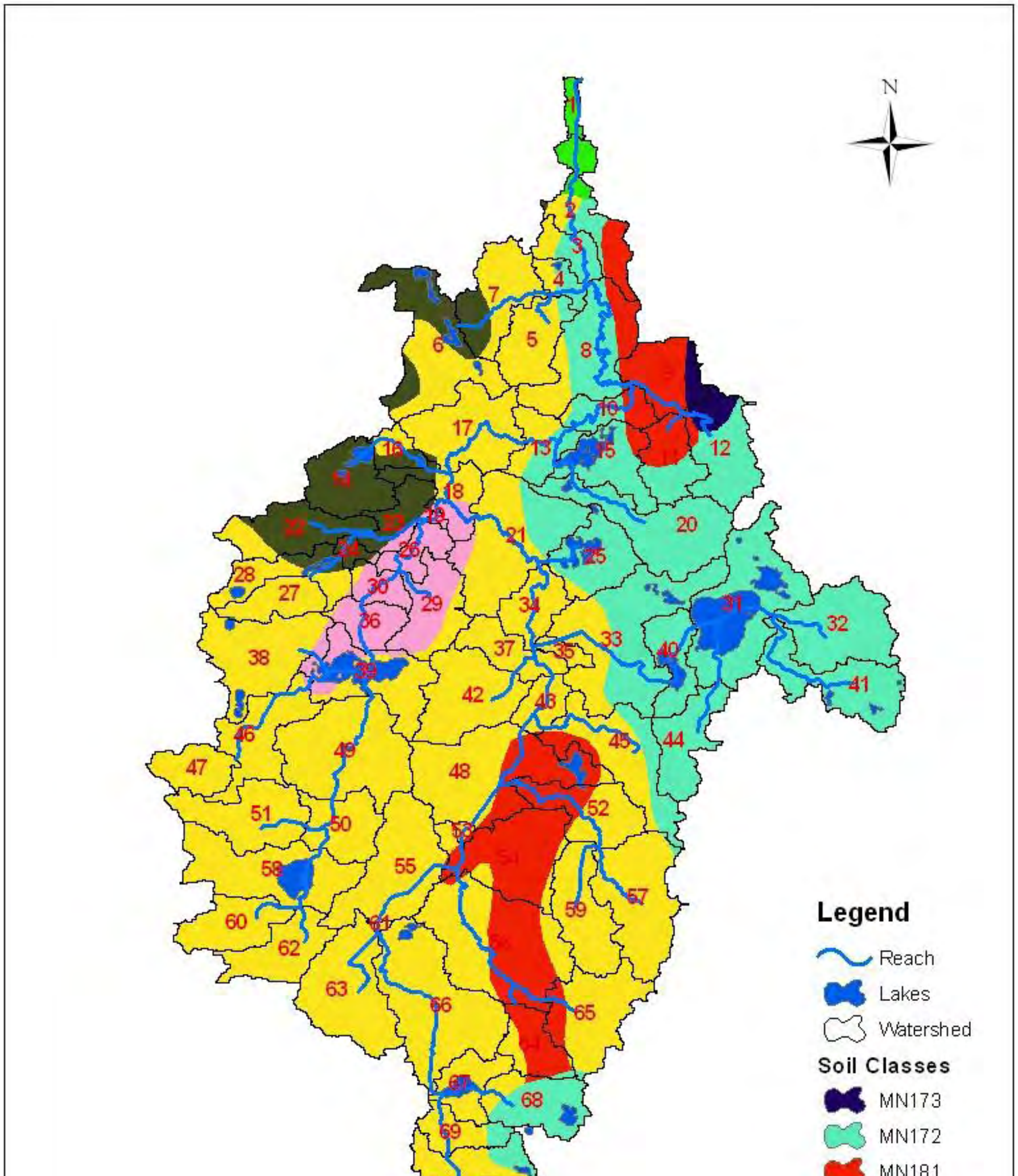

Figure 4 STATSGO Soil Map of the Credit River Watershed

3.2.2 Climate, Groundwater and Impoundment Data

Historical time-series climate data sets were provided by the Minnesota Climatology Working Group. The data included daily precipitation, minimum and maximum temperature, solar radiation, humidity and wind speed. Time-series climate data is used in SWAT to simulate processes such as the hydrologic cycle, plant growth and potential evapotranspiration. Since there is no single national or local weather station with continuous climate records for the last 20 years close to the Credit River Watershed, precipitation and temperature data from the National Weather Service stations at Farmington and Jordan were used. Temperature, humidity and wind speed data were obtained from the National Weather Service station at the Minneapolis-St Paul International Airport, which is located about 15 miles east of the watershed.

Impoundment information required for SWAT inputs includes the areas and volumes for the emergency and principal spillways. The principal areas and mean depths of lakes and ponds were obtained from lake finder and water quality websites of Minnesota Department of Natural Resources (http://www.dnr.state.mn.us/lakefind/index.html) and MPCA (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/lake-water-quality-data-search.html). The emergency spillway areas of the lakes and ponds were assumed to be equal to 120 percent of the principal areas, and the volumes were estimated with the areas and mean depths. For small ponds unavailable from above sources, mean depths of 5 and 3 feet were assumed to estimate the volumes at the emergency and principal spillways respectively.

For wetlands, GIS data from the 2002 land cover map were used to determine areas and volumes at the maximum water levels. Thirty percent of the maximum areas were used to estimate water surface areas at normal water levels. To estimate volumes, 3 and 1.5 feet were assumed to be the mean depths of the wetlands at the maximum and normal water levels.

3.2.3 Agricultural Management Practices

Agricultural management information used in the model includes crop types, planting dates, fertilizer application rates, tillage, harvesting, rotation, water use and soil nutrient concentration. Agricultural management practices, particularly planting dates, fertilizer application rates, and tillage types, often vary throughout the region. It is difficult, expensive and time-consuming to determine field-level practices for individual watersheds. Therefore, representative data and information were collected and generalized based on interviews with local soil and water conservation district technicians and farmers, and publications of the Minnesota Extension Service (Rehm, et al., 1993a, 1993b, 1996) and the Minnesota Agricultural Statistics Service (MASS, 1999; 2000 and 2003).

In Scott County, the dominant crops are corn, soybean and alfalfa. Farmers typically use crop rotation, which involves the rotation of corn and soybean every year. Alfalfa is partially rotated with corn and soybean each year (about 20 percent) and killed every three to four years. Due to limitations of the SWAT setup for partial rotation, no rotation

of alfalfa with row cops was simulated in the model. The typical crop production practices include:
- Spring fertilizer application
- Planting
- Harvesting and kill
- Fall fertilizer application to soybean after harvest and kill
- Fall tillage

A variety of fertilizers are applied on farmlands. The types of fertilizers used are dependent on crop types, farmer preferences, availability of fertilizer, and time of year. For example, some farmers may use anhydrous ammonia while others may use urea or manure for nitrogen fertilization. Others may use the composted manure produced from feedlot operations on their farms. For this study it was not feasible to identify fertilization practices for individual farms in the watershed. General fertilization information provided by Scott County was therefore applied. It was assumed that phosphorus is applied to corn, soybean and alfalfa and nitrogen is only applied to corn.

Irrigation is not commonly used in this watershed. The harvesting and kill operations are used in the model setup to terminate the growth of row crops during fall before the lands are rotated to other crops. Table 4 summarizes the agricultural practices used in the model development.

Table 4 Agricultural Practices Used in Model Development

Year	Date	Operation	Fertilizer Application Rate
Corn			
1	5/4	Fertilizer (09-23-30)	100 lbs/ac
1	5/15	Planting	
1	10/31	Harvest / Kill	
1	11/15	Chisel plow tillage	
Soybean			
2	5/15	Planting	
2	9/15	Harvest / kill	
2	10/15	Fertilizer (82-0-0)	170 lbs/ac
2	10/15	Chisel plow tillage	
Alfalfa			
1	4/30	Planting	
1	7/5	Harvest	
1	7/15	Fertilizer (0-44-0)	150 lbs/ac
1	7/16	Fertilizer (0-0-60)	300 lbs/ac
1	9/5	Harvest	
2	6/1	Harvest	
2	7/15	Harvest	
2	9/1	Harvest	
2	10/15	Kill	
2	11/1	Chisel plow tillage	

Nutrient concentrations in soils vary widely depending on region, land use, tillage, fertilizer application rates and previous crops planted. During model development, median concentrations were used, ranging from 8 to 15 ppm for phosphorus and 6 to 15 ppm for nitrogen. These ranges were based on documented fertilizer application rates for corn, soybean and alfalfa issued by the Minnesota Extension Service (Rehm, et al., 1993a, 1993b, 1996).

Drainage tiles have been historically used in the Credit River Watershed to drain wetlands fields for use as agriculture lands. There was no data available on the extent of drain tiling in the watershed. In the model setup, drain tiles were assumed for those agriculture fields with slopes equal to or less than five percent.

Buffer strips are a widely used agricultural BMP to prevent soil loss. Based on site inspections and aerial photography, it is apparent that most stream and drainage ditches in the watershed currently have some type of filter strip. However, filter strip width varies throughout the watershed. To reflect average existing conditions, 3-foot wide filter strips were built into the SWAT model for all agricultural areas.

3.2.4 Field Measurements and Comparison with SWAT Parameters

Field measurements of river flow and water quality are important for model calibration and validation. MCES and local partners initiated a monitoring program to record stream flow and water quality in metropolitan area watersheds in the late 1980s. Currently, event-based and baseflow monitoring data is collected at 21 stations on 20 streams in the region. In Credit River, continuous stream flow and water quality based on composite and grab samples have been monitored at the MCES station since 1989.

Field and laboratory measurements of turbidity and TSS concentrations are available for model calibration and validation. The current water standard for class 2b waters is based on turbidity. However SWAT simulates only concentration-based pollutants. A strong relationship exists between turbidity and TSS, therefore TSS was assumed to represent a turbidity surrogate in the water quality simulations. TSS is typically composed of inorganic and organic matter transported in the water column. SWAT simulates total sediment loads from land, channel bed and bank erosions based on maximum flow velocity and sediment particle sizes. Sediment loads consist of suspended solids within the water column and bed-load sediment transported along the channel bottom. Because bed-load sediment usually occupies only a small portion (less than 10 percent) of total sediment load (Tolson & Shoemaker, 2004) and is usually transported a limited distance due to large particle size, the measured TSS is assumed to be comparable with the total sediment loads simulated by SWAT. Flux32 was used to estimate monthly TSS loads from grab and event-based composite samples and daily average flow. The resulting monthly loads were used for model calibration and validation.

3.3 Watershed Delineation and Segmentation

Watershed delineation and segmentation is the primary step in model development. It includes the following tasks:

– Delineating the watershed boundaries and stream network
– Defining the watershed outlet(s) and reservoirs
– Segmenting the watershed into a number of subbasins
– Defining HRUs
– Calculating the topographic parameters

The Credit River watershed was delineated and segmented according to the following:

- 10 meter DEM and GIS stream networks
- Locations of monitoring stations
- Locations of lakes acting as reservoirs
- Locations of point source discharges, if any
- Channel and floodplain characteristics (e.g., slope, roughness)
- Size and number of subbasins

The delineated Credit River watershed, subbasins and stream networks were shown in Figure 4. A total of 70 subbasins were delineated for the watershed. The outlet of Subbasin 2 was located at the MCES monitoring station and the simulation from this subbasin was used for model calibration. The watershed delineation was extended beyond the MCES monitoring station to the confluence with the Minnesota River. The use of subbasins is particularly beneficial when different areas of the watershed are dominated by land uses or soils dissimilar enough to impact hydrology. By partitioning the watershed into subbasins, it becomes possible to spatially compare the different water and chemical yields across the watershed.

Within each subbasin, the components of the watershed are further grouped or organized into HRUs. The HRUs were defined using a combination of land uses, soil types and slopes that occurred within each subbasin with threshold values. The threshold values used were five percent for land uses, ten percent for soil type and five percent for slopes. HRUs are the smallest areas that have unique land uses, soils, slopes and management practices. A total of 1,713 HRUs were identified in the watershed. HRU delineation increases the accuracy of load predictions and provides a better physical description of the water balance.

3.4 Methodology for Model Calibration and Validation

Model calibration consists of optimizing model parameters in an attempt to match local conditions (e.g., daily, monthly or annual flows and mass loads) within reasonable scales and criteria. Model validation is a process of testing the performance of the calibrated model without further changing input parameters against an independent set of measured data. The data sets used for calibration and validation cover either different time periods or involve separate monitoring locations. Prior to calibration, the SWAT model uses the default built-in databases developed from literature and research results to characterize default values and define varying ranges for these parameters.

There are hundreds of physical, chemical and biological parameters in the model describing water and chemical yields, transformation and transport in the watershed. It would be impractical and time-consuming to calibrate these parameters individually. For this study, the calibrated parameters were chosen based on their impacts on model outputs or parameter sensitivities. Model parameter sensitivities may differ from watershed to watershed and need to be analyzed for each watershed modeled. In the Credit River Watershed, calibration was completed for parameters that characterized subbasin and channel roughness, groundwater flow, hydrology, soil erosion, snowfall and snow melt, physical and biogeochemical processes regulating hydrology, sediment yields and transport.

The accuracy of the model results for the calibration and validation periods was evaluated using graphical comparisons and statistical tests. To evaluate model performance, predicted daily, monthly and annual flow and sediment loads were compared against field observations. The results were tested with a variety of statistical techniques, including:

- Observed and predicted means (OM and PM), and difference (relative deviation, RD)
- Root mean square deviation (RMSD)

$$RMSD = \sqrt{\sum_{i=1}^{N} \frac{1}{N}(P_i - O_i)^2}$$

  where N is the number of data points, P_i and O_i are the predicted and observed values respectively.
- The coefficient of determination (r^2)

$$r^2 = \frac{\sum_{i=1}^{N}(O_i - OM)(P_i - PM)}{\left[\sum_{i=1}^{N}(O_i - OM)^2\right]^{0.5}\left[\sum_{i=1}^{N}(P_i - PM)^2\right]^{0.5}}$$

  where OM and PM are the observed and predicted means, respectively.
- The index of agreement (IA)

$$IA = 1 - \frac{\sum_{i=1}^{N}(P_i - O_i)^2}{\sum_{i=1}^{N}(|P_i - OM| + |O_i - OM|)^2}$$

- The Nash-Sutcliffe Coefficient of Efficiency (NSCE)

$$NSCE = 1 - \frac{\sum_{i=1}^{N}(O_i - P_i)^2}{\sum_{i=1}^{N}(O_i - OM)^2}$$

Good model performance occurs when RD and RMSD approach zero, r^2 and IA approach one, and NSCE is larger than 0 (NSCE varies from $-\infty$ to 1).

There are no universally accepted "goodness-of-fit" criteria that apply in all cases. However, it is important that modelers make every attempt to minimize the difference between model simulations and measured field conditions. As a general guideline, a range of calibration and validation tolerances are recommended by Donigian (2000) for hydrology, sediment, nutrient and pesticide predictions in watershed studies (Table 5). The ranges were initially used for the application of the Hydrological Simulation Program Fortran (HSPF) model, a watershed scale model similar to SWAT. Recommended tolerances were provided for monthly and annual simulations. Tolerance application is dependent on the quality and detail of input and calibration data, modeling purpose, capability of personnel, and availability of other resources such as time and budget.

Table 5 Recommended Calibration and Validation Tolerances

Parameters	Difference Between Simulated and Observed Means (%)		
	Very Good	Good	Fair
Hydrology	<10	10-15	15-25
Sediments	<20	20-30	30-45
Nutrients	<15	15-25	25-35
Pesticides	<20	20-30	30-40

4. MODEL PERFORMANCE

The SWAT model was developed for the Credit River Watershed according to the general procedures as described in the SWAT user guide (Di Luzio et al., 2002). The guide contains procedures for database development, watershed delineation, segmentation, calibration and validation. The model was calibrated and validated for hydrology and then for TSS after the watershed was delineated. The model was calibrated based on field measurements collected during 1997-2002 at the MCES monitoring station in Savage, Minnesota and validated using measurements from the period 2003-2008. The measurements did not include 2000 and 2002 due to equipment failure at the monitoring station.

Most watershed modeling studies are calibrated and validated with a monthly or annual time-step (Dalzell, 2000; MPCA, 2003; OEPA, 2003). In this study, the hydrology was calibrated using a daily time-step in an attempt to capture daily variations of the flow for individual rainfall and snowmelt events. Flow magnitudes are critical for accurately modeling flow-associated sediment loads. TSS calibration was completed on a monthly basis because daily measurements of TSS were not available. The monthly TSS loads were estimated using Flux32. Flux32 uses daily flow rates and TSS concentrations collected in grab and composite samples. The model performance was analyzed statistically based on monthly averages as discussed previously.

4.1 Hydrology

Figures 5 -7 plot the simulated daily flow rates in comparison to field measurements and precipitation from 1997 to 2000, 2001 to 2004 and 2004 to 2008 respectively. Comparisons of monthly and annual flows are shown in Figures 8 and 9. No measurements are available for 2000 (June to December) and 2002 due to equipment failure. The results show that the developed SWAT model for the Credit River is able to adequately recreate daily flows for both the calibrated (1997 – 2002) and validated (2003 – 2008) periods. Minnesota has complex surface hydrology characterized by winter baseflow, spring snow-melt and widely varying summer and fall flows due to intensive precipitation events. These characteristics were identified and used during the model development and calibration to ensure that the model accurately predicted the hydrology for Credit River for such a dynamic climatic environment. The simulated monthly and annual flows are also consistent with observations in magnitudes and seasonal variations (Figures 8 and 9).

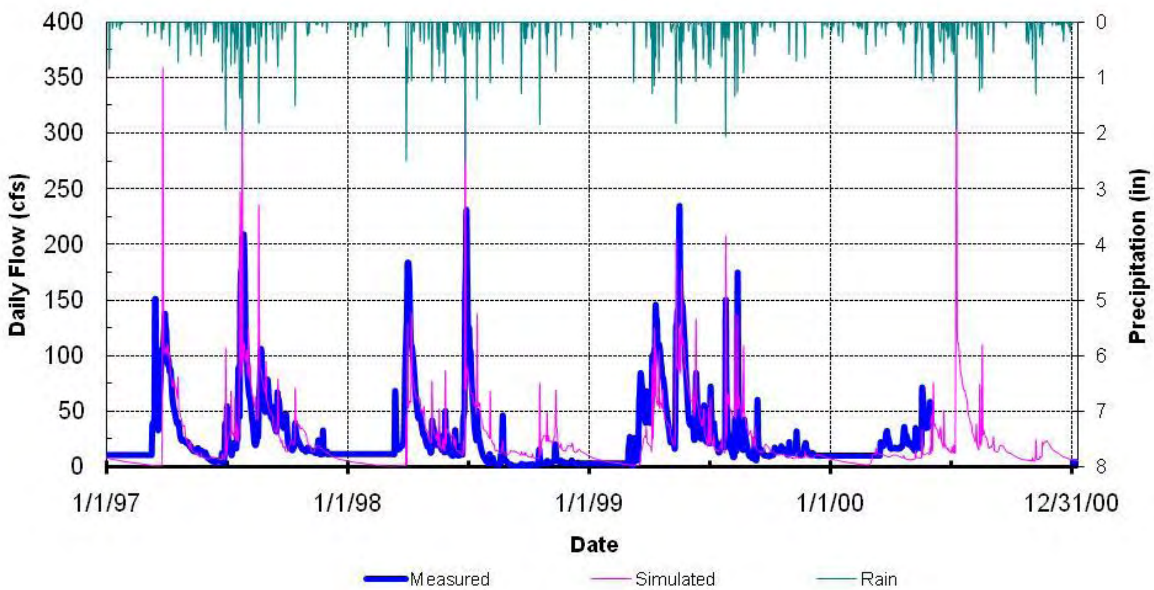

Figure 5 Comparisons of Simulated to Measured Daily Flow and Precipitation (1997 – 2000)

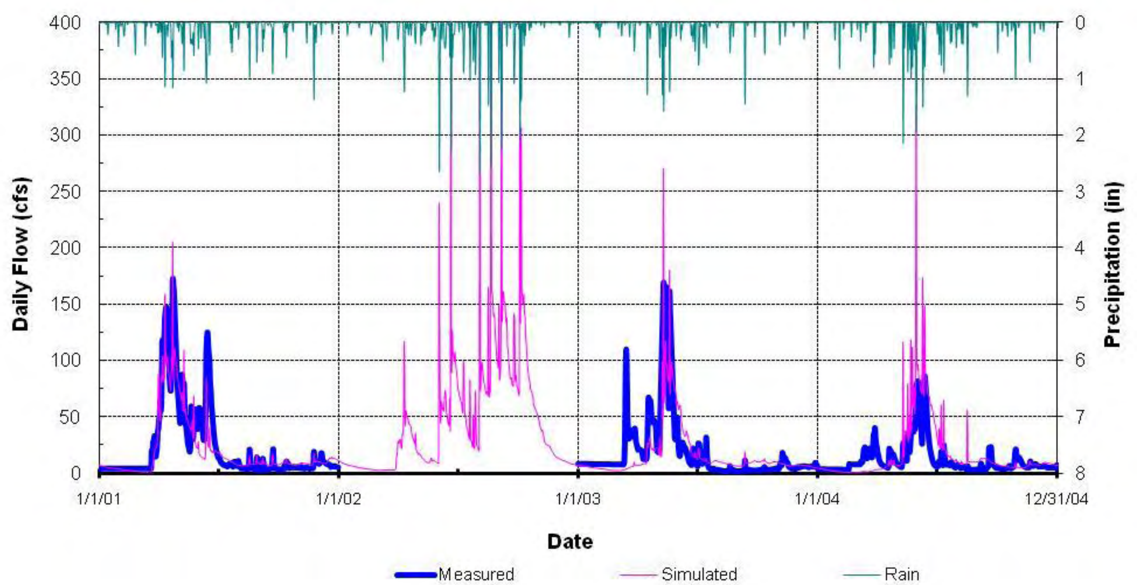

Figure 6 Comparisons of Simulated to Measured Daily Flow and Precipitation (2001 – 2004)

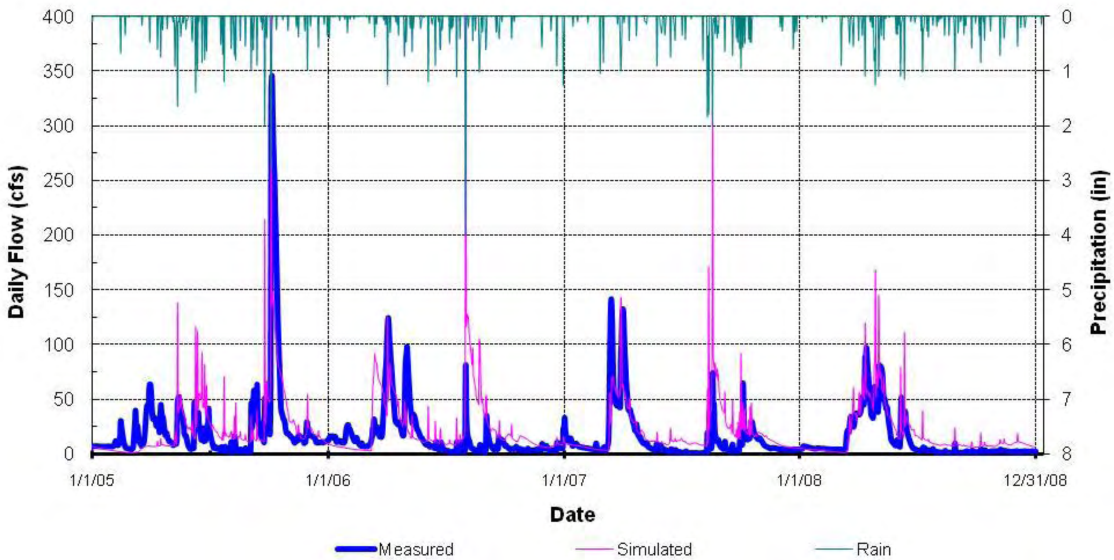

Figure 7 Comparisons of Simulated to Measured Daily Flow and Precipitation (2005 – 2008)

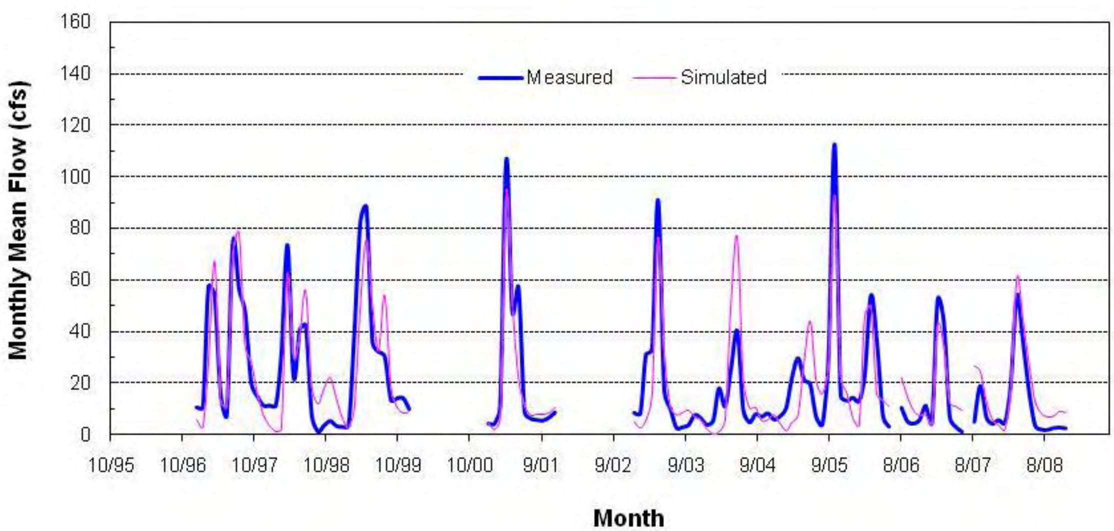

Figure 8 Comparison of Simulated to Measured Monthly Flow

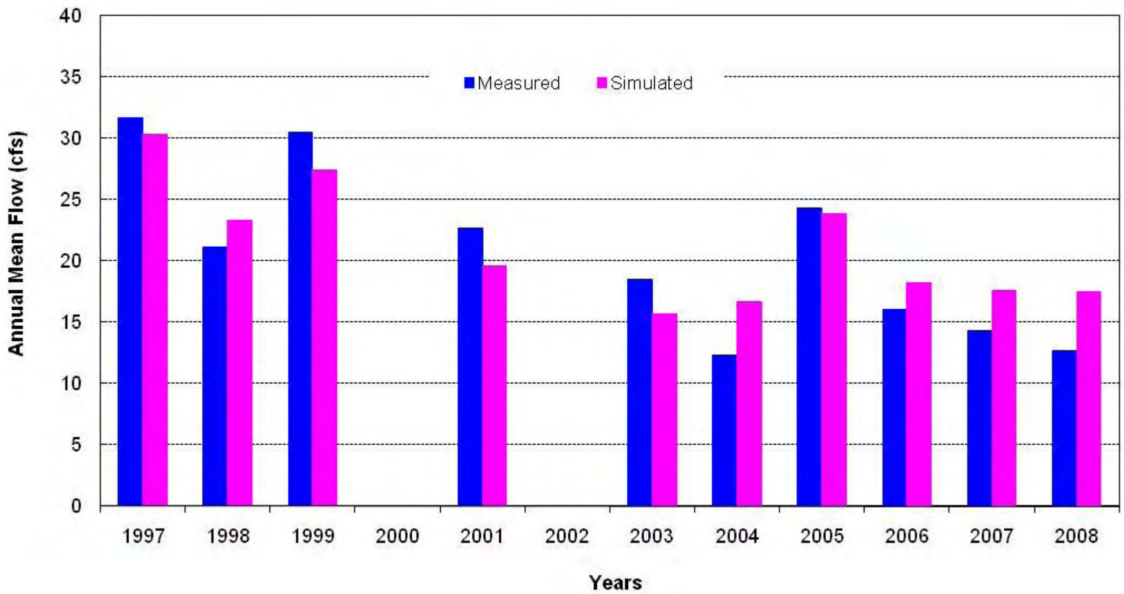

Figure 9 Comparison of Simulated to Measured Annual Flow

Statistical tests were used to assess performance of the calibrated Credit River Watershed model. As discussed earlier, good model performance occurs when RD and RMSD approach zero, r^2 and IA approach one, and NSCE is larger than 0 (NSCE varies from $-\infty$ to 1). Table 6 lists the statistical results of the hydrologic simulations. Overall relative deviation for the simulation period (1997 - 2008) was -2.9 percent. The model slightly over-predicted flow. The predictions were "very good" according to the recommended calibration and validation tolerance (<10 percent) (Table 5). The results indicate that the developed SWAT model for the Credit River Watershed has an excellent performance for hydrologic simulation. The average root mean square deviations (RMSD) for the simulated daily, monthly and annual averages flows were 21.9, 12.4 and 3.2 cfs respectively. The coefficients of determination (r^2) were 0.52, 0.73 and 0.84, the indexes of agreement (IA) were 0.84, 0.92 and 0.99, and the Nash-Sutcliffe coefficient of efficiency (NSCE) were 0.47, 0.72 and 0.79, respectively for daily, monthly and annual predictions.

Table 6 Statistical Analysis of Hydrology Performance

Index	RD	RMSD	r^2	IA	NSCE
Possible Range	($-\infty$ - ∞)	(0 - ∞)	(0 - 1)	(0 - 1)	($-\infty$ - 1)
Optimal Value	~ 0	~ 0	~ 1	~ 1	> 0
Predicted Daily	-2.9%	21.9 cfs	0.52	0.84	0.47
Predicted Monthly		12.4 cfs	0.73	0.92	0.72
Predicted Annual		3.2 cfs	0.84	0.99	0.79

Compared with similar studies (Table 7) (King et al. 1996; Allred and Haan, 1996; Liu et al. 1998; Srinivasan et al., 1998; Dalzell, 2000; MPCA, 2003; Hummel et al., 2003; Tolson & Shoemaker, 2004), the Credit River Watershed model is one of the higher performing models with a small deviation and high correlation between simulated and observed results. All of these assessments (graphical comparisons, statistical analysis and literature comparisons) indicate that the Credit River model is well calibrated and able to satisfactorily predict hydrology for the watershed.

Table 7 Comparisons of Model Performance for Hydrology

Watershed	Deviation (%)	r^2	Model/Author
Credit River, MN	-2.9	0.73	SWAT in this study
Bluff River, MN	21.0	0.47	ADAPT[a] by Dalzell (2000)
Long Prairie River, MN	1.9-20.0	–	SWAT by MPCA (2003)
Watersheds, GA	1.8-19.9	0.61-0.9	HSPF[b] by Hummel et al. (2003)
2 watersheds, TX	–	0.65-0.87	SWAT by Srinivasan et al. (1998)
15 watersheds, GA, TX, OH, MS	0-38.8	0.01-0.85	WEPP[c] by Liu et al. (1998)
6 watersheds, TX	6.6-37.0	0.74-0.82	EPIC[d] by King et al. (1996)
6 watersheds, GA, TX, Ok, NC, OH, ID	–	0.31-0.90	SWMHMS[e] by Allred & Haan (1996)
Cannonsville Basin, NY	1.0-15.7	0.59-0.80	SWAT by Tolson & Shoemaker (2004)

Notes:
a: ADAPT: Agricultural Drainage and Pesticide Transport model
b: HSPF: Hydrological Simulation Program Fortran model
c. WEPP: Watershed Erosion Prediction Project
d: EPIC: Erosion Productivity Impact Calculator
e: SWMHMS: Small Watershed Monthly Hydrological Modeling System

4.2 Total Suspended Solids

Because TSS is collected as either composite or grab samples and daily TSS load is not available, TSS was calibrated on a monthly basis. Monthly and annual TSS loads were estimated using Flux32 which estimates concentrations for unmonitored dates based on regressions between measured TSS concentrations and flows.

TSS calibration is traditionally performed at watershed outlets without accounting field and non-field erosion sources. This may not reflect actual watershed conditions, particularly TSS loading. Application of such watershed models could lead to uncertainty in watershed analysis and BMP assessment. In this study, calibrating TSS involved both sources from both field (i.e. non-channel) and non-field (i.e. channel, gully, and ravine) erosion. Field and non-field erosion sources were expressed as fraction or ratio in TSS calibration. The fraction can be estimated using isotope fingerprinting, which uses radio-nuclides as tracers to determine sediment source by measuring tracer concentrations in stream TSS and comparing it to concentrations measured in each of the potential erosion sources. The method has been used to quantify TSS sources in several watersheds in the Lower Minnesota River Basin (MPCA, 2009).

Because no fingerprint studies have been completed for the Credit River Watershed, the field and non-field TSS yields were estimated directly using monitored flow rates and TSS concentrations from three stations in the watershed. Figure 10 displays the Credit River Watershed with the three monitoring stations and related topographic conditions. The stations are located at the watershed outlet (MCES station at 4975 126th Street in Savage), at the bluff area in the watershed where land slope starts to change significantly (Scott County station at 154th St., Savage) and at an upland section where the landscape is relatively flat (Scott County station at CSAH-68). Because information is available downstream of the outlet, above the bluff and upstream in the flat areas, these three sites provide enough information to adequately estimate the watershed field and non-field sources of TSS.

The estimation using measurements from the three stations was based the following assumptions:

1) Most non-field erosion in the watershed came from the reaches downstream of Station 154
2) Non-field erosion from upstream subbasins is marginal
3) Field erosion for mixed rural areas is consistent watershed wide
4) Field erosion for urban areas is assumed equal to that in the Shingle Creek Watershed

Based on above assumptions, the following formulas for the field and non-field erosion were used to estimate the source information needed for modeling.

Non-field erosion: $Load_{NFE} = Load_{126} – Load_{FE}$

Field erosion: $Load_{FE} = Load_{154} + Load_{Rural} + Load_{urban}$

Mixed rural area field erosion: $Load_{Rural} = R_{rural} \text{ x } A_{rural}$

Mixed urban area field erosion: $Load_{Urban} = R_{urban} \text{ x } A_{urban}$

where $Load_{NFE}$ is the TSS load from non-field erosion below Station 154 (lb/yr),
$Load_{FE}$ is the total TSS load from field erosion in the entire watershed (lb/yr),
$Load_{126}$ is the TSS load observed at Station 126 (lb/yr),
$Load_{154}$ is the TSS load observed at Station 154 (lb/yr),
$Load_{Rural}$ is the TSS load from field erosion of the mixed rural subbasins below Station 154 (lb/yr),
$Load_{Urban}$ is the TSS load from field erosion of the urban subbasins below Station 154 (lb/yr),
R_{rural} is the average TSS export rate for the mixed rural subbasins estimated from subbasins above Station 126 (lb/ac/yr),

R_{urban} is the average TSS export rate for the urban subbasins estimated from the Shingle Creek Watershed using watershed area and monitoring data at the outlet (lb/ac/yr),
A_{rural} and A_{urban} are respectively the areas of mixed rural and urban subbasins below Station 154 (ac).

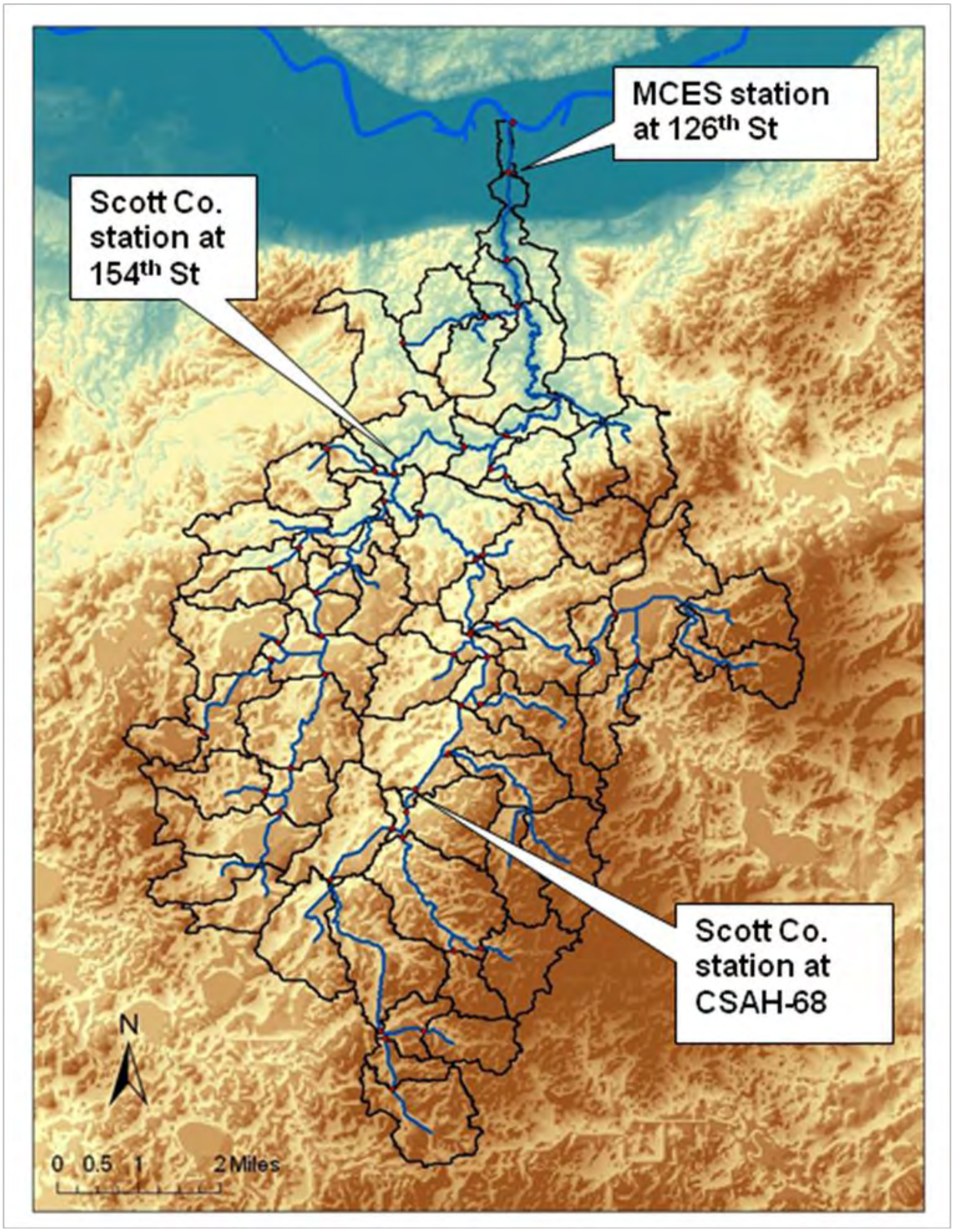

Figure 10 Locations of MCES and Scott County Monitoring Stations

The above assumptions were validated using 2008 TSS loads from the three stations. Loads for these stations were calculated using Flux32 (Figure 11) and daily 2008 flow rates and TSS concentrations. Estimated annual TSS loads are 52,500 lb, 118,200 lb and 1513,300 lb respectively at Stations C68, 154 and 126. TSS loads from the upper watershed Stations C68 and 154 are only 4 percent and 8 percent of the total watershed load measured at MCES Station 126, although the area upstream of Station 154 accounted for about 90 percent of the total watershed area. Marginal TSS loads from the upstream watershed validated assumptions 1 and 2. If assumptions 3 and 4 are acceptable, it is easy to conclude that the TSS load observed at the outlet is primarily from non-field erosion of the lower subbasins. Shingle Creek was used to define the TSS export rate for the urban area because it is a fully developed urban watershed located in the same region and has well-measured data available.

To estimate field erosion from the mixed rural subbasins ($Load_{Rural}$), Subbasins 11, 12, 15 and 20 were used. The subbasins were identified based on SWAT model delineation results. Those subbasins are located below Station 154 and their land uses are mostly agriculture, forest, wetland and pasture. The total area for the mixed rural subbasins is 1,872 acres. The subbasins representing the mixed urban area below Station 154 included Subbasin 1 - 10, 13 and 17. They are identified as mostly urban from the SWAT delineation. The total area for the mixed urban subbasins below Station 154 is 4,525 acres. Estimated field and non-field erosion based on the above discussions are respectively 236,600 lb/yr and 1,276,700 lb/yr. The numbers represent a field and non-field ratios of 18.5 percent from field erosion and 81.5 percent from non-field erosion.

The ratios estimated in this study are consistent with other reported values for the region. Figure 12 shows field and non-field erosion ratios for other Lower Minnesota River Watersheds estimated using the isotope fingerprint technique by the Minnesota Science Museum St. Croix Watershed Research Station (MPCA, 2009). The average TSS contribution from field erosion in the other Lower Minnesota River watersheds is 14 percent. Among the studied watersheds using isotope fingerprint technique, Carver Creek and Bevens Creek are two watersheds in close proximity to the Credit River Watershed. The field erosion ratios for these two watersheds are 10 percent and 18 percent respectively. The ratio of field erosion to non-field erosion for this study may slightly over-estimate the amount of field erosion because the non-field erosion from upper reaches was ignored.

With the estimated TSS source ratios, TSS calibration was done by manipulating the parameters associated with TSS erosion and transport processes in fields, impoundments and channels. Field erosion was calibrated with non-field erosion processes turned off and the parameters adjusted to let the simulated watershed TSS load equal 18.5 percent of the observed load. Non-field erosion was then turned on to add TSS load from non-field erosion, making the simulated TSS load at the watershed outlet match the observations. Because SWAT uses simple processes of settling and re-suspension to simulate bank erosion without considering gully and raven erosion, non-field erosion was assumed to be entirely channel-based in this study, but in reality is an amalgam of channel, gully, and ravine sediment. The TSS load calibration process is summarized in Figure 13.

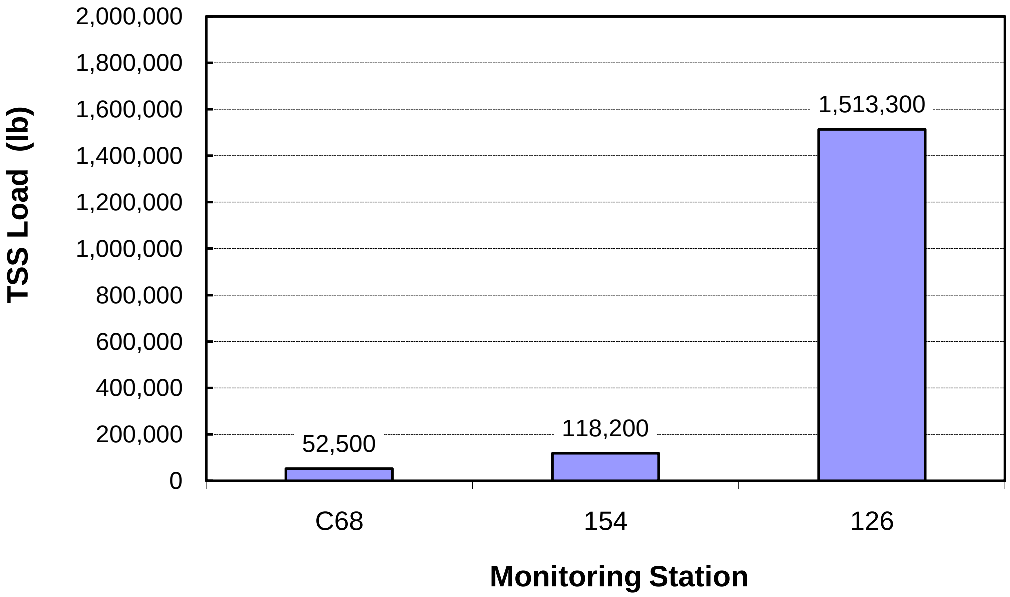

Figure 11 Annual TSS Loads for 2008 at Three Monitoring Stations in Credit River

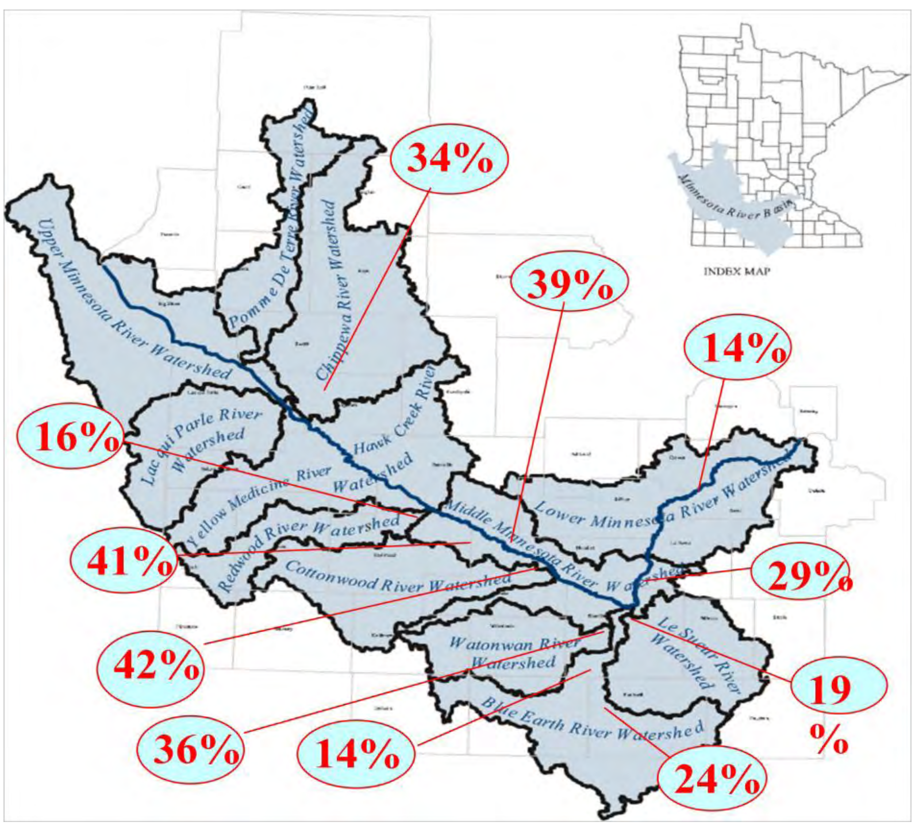

Figure 12 Field and Non-Field Erosion Ratios Estimated Using Isotope Fingerprint Techniques for Lower Minnesota River Watersheds (MPCA, 2009)

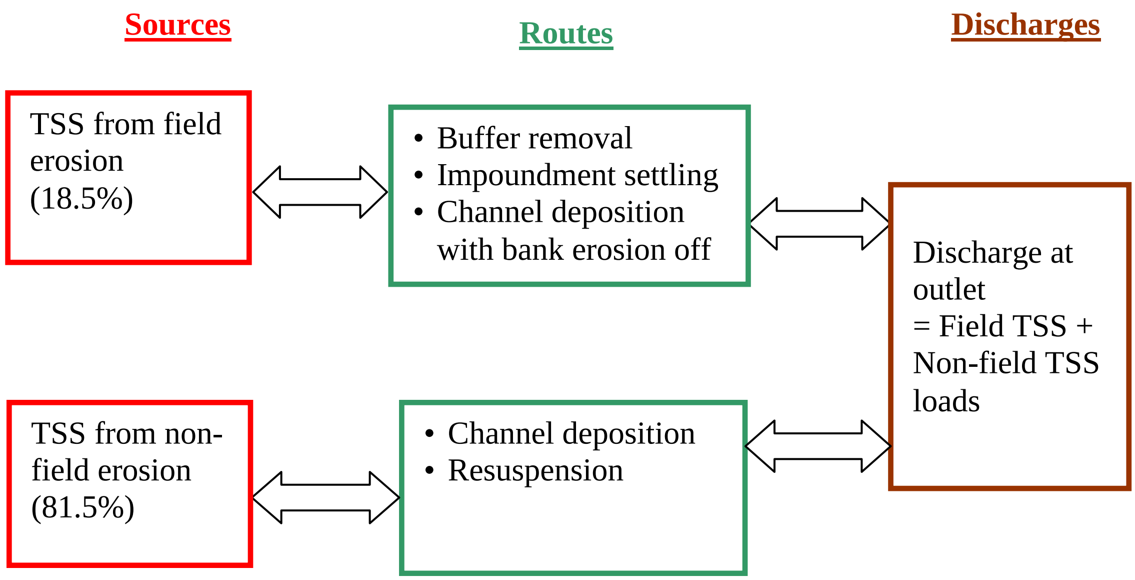

Figure 13 Flowchart of TSS Calibration

After field and non-field erosion was calibrated, the TSS load at the outlet was estimated by SWAT simulation. The monthly and annual results are plotted in Figures 14 and 15. The TSS loads from non-field erosion sources simulated at the outlet are also plotted in the monthly figure. The results are for the period of 1997 - 2008, with missing observations in 2000 and 2002. The simulated TSS load from field erosion was 18.5 percent of the observed load, which was consistent with the field and non-field erosion ratio. Total TSS load, which is the sum of the contributions from field and non-field erosion, generally follows observations.

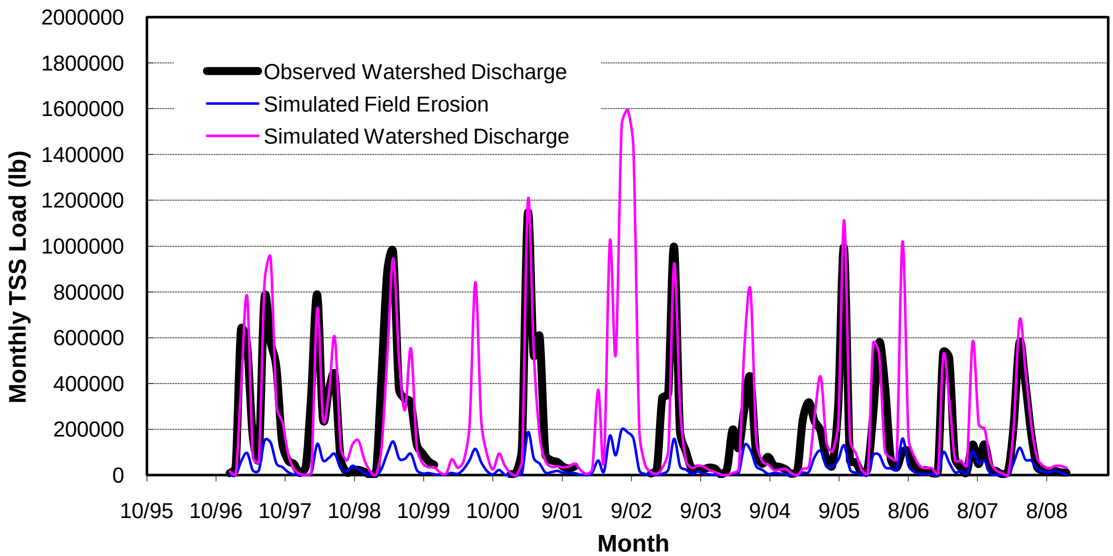

Figure 14 Calibrated Monthly TSS Load for Credit River at 126th Street

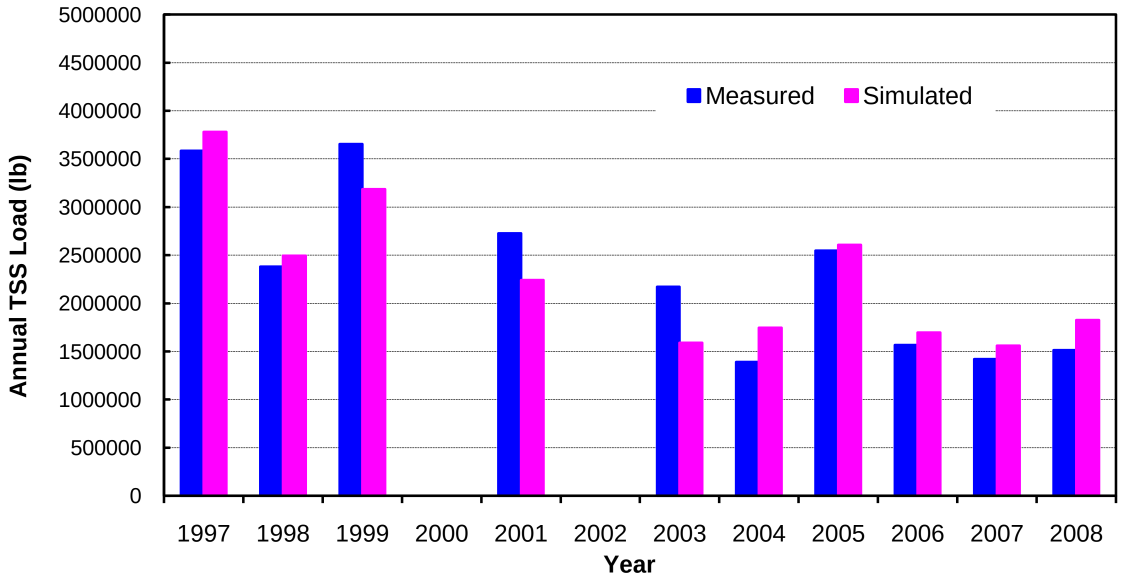

Figure 15 Calibrated Annual TSS Load for Credit River at 126th Street

Statistical analysis of the simulated TSS loads compared to observations for the calibration and validation periods show that the developed SWAT model accurately predicts TSS loads for the Credit River Watershed (Table 8). The overall predicted mean TSS load was 236,800 lb per month, which is 1 percent smaller than the observed value of 239,200 lb per month. In general, the calibrated model slightly over-predicts the TSS load. The difference (relative deviation) is much less than the recommended modeling tolerance for "very good" model performance of 20 percent (Table 5). The RMSDs for TSS loads were 213,800 lb and 282,200 lb respectively for monthly and annual averages for the simulation period. The coefficients of determination were 0.78 and 0.80, the indexes of agreement were 0.91 and 0.95, and the Nash-Sutcliffe coefficients of efficiency were 0.62 and 0.83, respectively for monthly and annual averages.

Table 8 Statistical Analysis of SWAT Model Performance for TSS

Index	RD	RMSD	r^2	IA	NSCE
Possible Range	$(-\infty - \infty)$	$(0 - \infty)$	(0 - 1)	(0 - 1)	$(-\infty - 1)$
Optimal Value	~ 0	~ 0	~ 1	~ 1	> 0
Predicted Monthly	1.0%	213,800 lb	0.78	0.91	0.62
Predicted Annual		282,200 lb	0.80	0.95	0.83

Table 9 lists comparisons of the Credit River results to other reported studies (Dalzell, 2000, MPCA, 2000, Reyes et al., 1995, King et al., 1996, Liu et al., 1998 and Tolson & Shoemaker, 2004). For example, Bluff Creek in Carver County, which is close to the Credit River, was studied using the ADAPT model by Dalzell (2000). The study reported a mean deviation of 9 percent, the RMSD of 156 percent, and the index of agreement of 0.57. Compared to those reported studies, the developed model for the Credit River is able to predict TSS load more accurately. In conclusion, the SWAT model developed for the Credit River is well calibrated and able to satisfactorily predict TSS loads in the watershed according to the performance assessments and comparisons with reported studies.

Table 9 Comparisons of Model Performance for TSS

Watershed	Deviation (%)	r^2	Model/Author
Credit River, MN	1.0	0.78	SWAT in this study
Bluff River, MN	9.0	0.25	ADAPT by Dalzell (2000)
Long Prairie River, MN	9.3-37.1	–	SWAT by MPCA (2003)
Experimental fields, LA	51.0-400.0	0.46	GLEAMS* by Reyes et al. (1995)
6 watersheds, TX	4.8-43.6	0.15-0.72	EPIC by King et al. (1996)
15 watersheds, GA, TX, OH, MS	4.5-137.6	0.02-0.89	WEPP by Liu et al. (1998)
Cannonsville Basin, NY	2.2-52.2	0.42-0.71	SWAT by Tolson & Shoemaker (2004)

*GLEAMS: Groundwater Loading Effects of Agricultural Management System

Simulations for the Credit River Watershed using the developed model were visualized using commercial software VIZSWAT to allow the simulated digital results to be displayed using multimedia as an animated movie. The animations include both curves and spatial GIS maps. The visualization of the simulations is not included in the report but is available in model documents. Figure 16 gives an example of the animation for August 11, 1999. The example animation displayed daily surface runoff volume and flow rate expressed (GIS map and curve) and TSS load (curve).

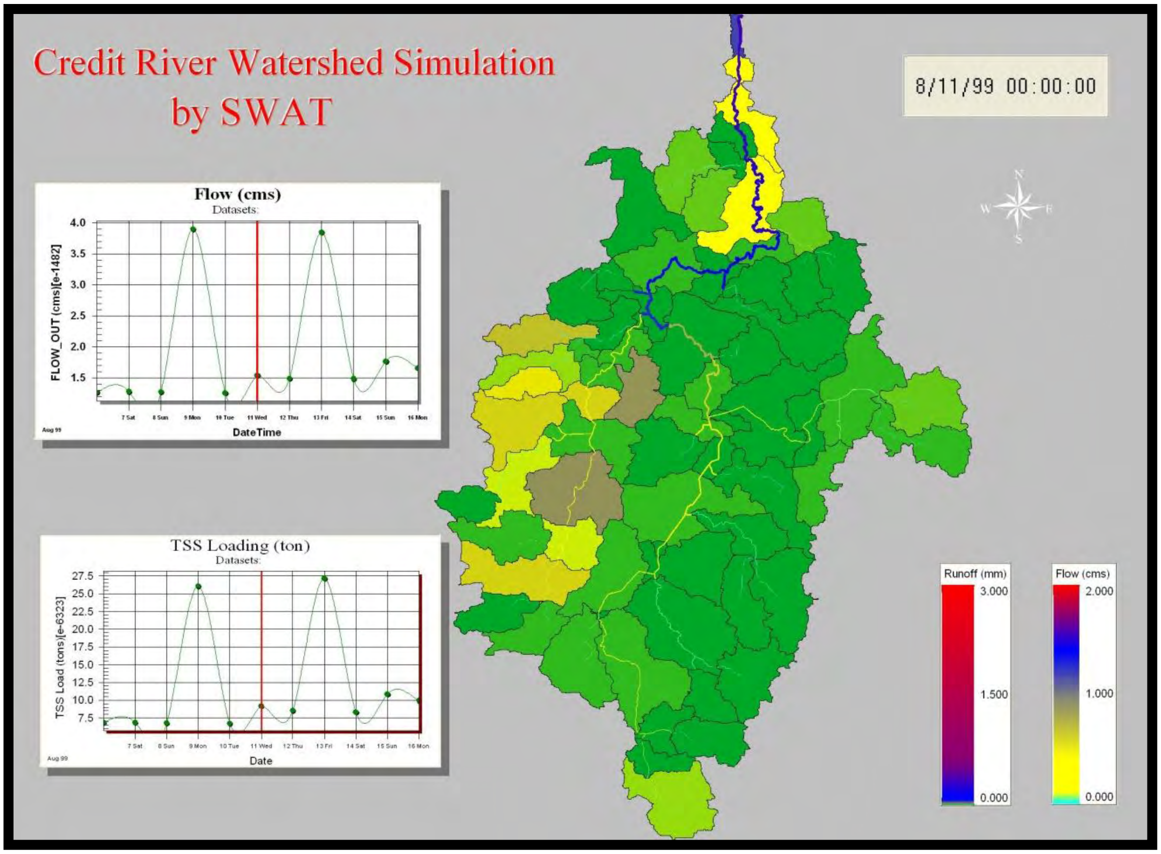

Figure 16 Visualization of Watershed Modeling for Credit River

5. NON-POINT SOURCE ANALYSIS USING SWAT

5.1 Methodology for Non-Point Source Analysis

Calibration of watershed models is usually a black-box process for most reported studies. Due to high costs associated with sampling and measurements as well as limited available data, the calibration process examines the model performance only according to observations at the watershed outlet without considering processes occurring within the watersheds. Therefore SWAT estimates typically are inherently uncertain, particularly when the model is used to analyze watershed non-point sources and to assess the effectiveness of the management scenarios. In this study, some of that uncertainty was removed since the model was not only calibrated at the watershed outlet, but also calibrated with TSS sources from field (non-point source) and bank erosion.

For non-point source analysis, the simulated surface runoff and TSS loads from field and non-field sources were quantified in terms of land uses and subbasins. The values are a long-term average based on the simulation period (1997 - 2008). In processing TSS loads from field erosion based on HRUs, it was found that the export rates of water and TSS loads from the same category of land use varied substantially subbasin by subbasin due to variation of soils and slopes. Therefore, an area-weighted statistical method was proposed to estimate mean flow and TSS export rates from individual HRUs or subbasins:

$$R = \frac{a_1 r_1 + a_2 r_2 + a_3 r_3 + \ldots\ldots\ldots\ldots + a_i r_i}{a_1 + a_2 + a \;\; + \ldots\ldots\ldots\ldots + a_i}$$

where R is the water or TSS export rate for Land Use i; a_i is the area of HRU or Subbasin i, and r_i is the water or pollutant export rate corresponding to an individual HRU or Subbasin i.

5.2 Surface Runoff and TSS Yield by Land Uses

Annual flow and TSS yield per unit area summarized from SWAT model simulations were used to identify the land uses that have relatively high surface runoff and TSS loads. The land uses with high TSS yields should be looked at first when implementing BMPs for TSS load mitigation. Figure 17 displays the annual surface runoff and total water yield compared to land use. The total water yield is the total amount of runoff leaving an individual HRU and entering the main channels. It includes surface, subsurface, and ground water flows as well as water lost due to evaporation. The results show that annual surface runoff from various land uses ranged from 0.1 inch to 6.9 inches. Urban areas generated the highest surface runoff (6.9 inches), while forest contributed the lowest surface runoff (0.8 inch). Modeled results also show that sand mining had only 0.1 inch of surface runoff but it also had the largest total water yield (18.7 inches), probably due to limited evapotranspiration occurring at the sand mining sites. Wetlands were one of the land covers that yielded relatively large amounts of water; wetlands were simulated as impervious in SWAT with no water removal except for evaporation and seepage.

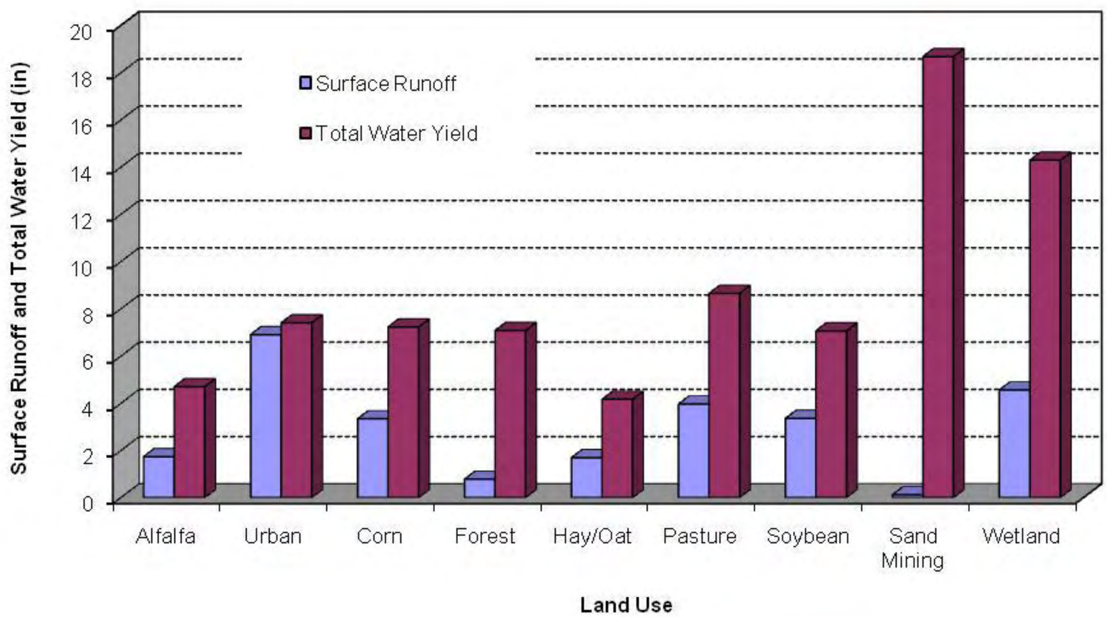

Figure 17 Simulated Surface Runoff and Water Yield by Land Use

For TSS yields from land uses, two values were estimated by SWAT for comparison (Figure 18): the TSS yield leaving the HRU and the TSS load entering the channel after flowing through impoundments and buffer strips. The two values were significantly different for the Credit River Watershed because the numerous vegetated buffers, wetlands, and ponds in each subbasin effectively remove most of the TSS from the runoff before it enters the channels.

Results show that TSS yields varied across the watershed. For example, agricultural land uses (corn, soybean and alfalfa) had the largest TSS yields leaving the HRUs. However, only a small portion of the TSS yield from agricultural lands entered the Credit River due to removal in buffer strips, wetlands, and ponds. Urban land uses, on other hand, contributed the largest TSS loads to the river, most likely due to having fewer wetlands and buffers than the agricultural areas. TSS loads from the urban land use were simulated to be 57 lb/ac. Forests together with sand mining had the smallest TSS yields and loads to the channels (4.0 and 0.2 lb/ac). Because SWAT simulated the TSS generated from the wetlands without any removal by buffers and impoundments in urban areas, the TSS load entering the channels from wetlands was similar to the HRU yield.

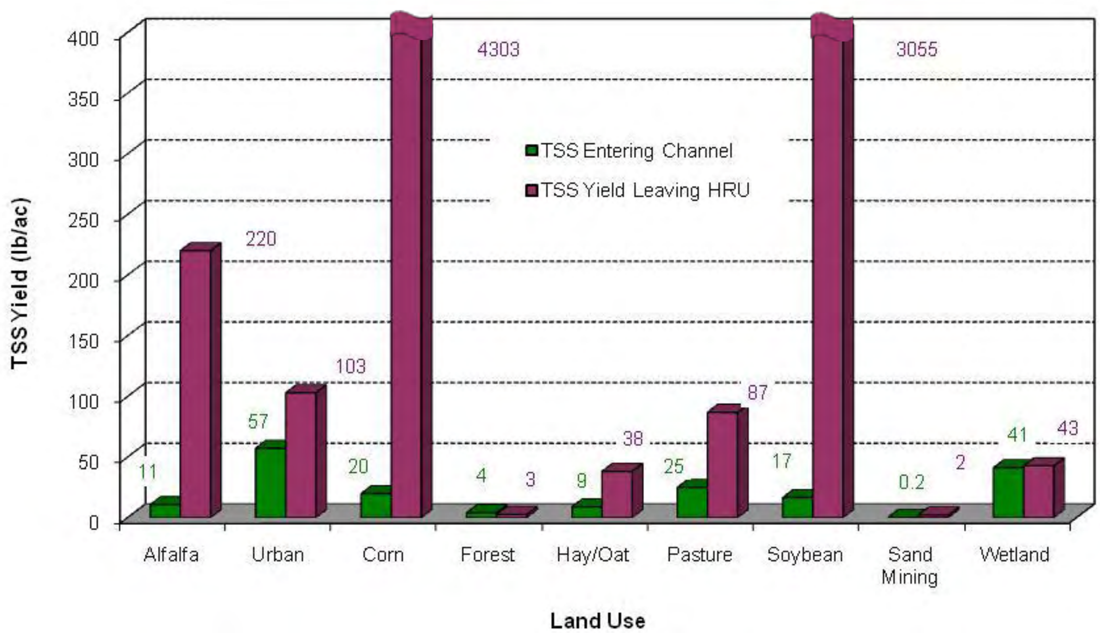

Figure 18 Simulated Field Erosion by Land Use

5.3 Surface Runoff and TSS Yields by Subbasin

Spatial distribution of the surface runoff volume and TSS load was analyzed to identify the areas that contribute major flow and TSS to Credit River and where BMP implementation for TSS control should be prioritized. Seventy subbasins have been delineated in the watershed based on SWAT, numbered roughly from upstream to downstream (Figure 4). Annual average runoff volumes and TSS yields per unit area from each subbasin were analyzed based on the modeled results from 1997 - 2008. To make it comparable to non-field erosion, TSS yields from field erosion were calculated based on the loads entering the channels after flowing through buffers and impoundments.

The results show that average annual surface runoff volumes from upstream subbasins, for example above Subbasin 18, were relatively small, ranging from 2 inches to 4 inches (Figure 19). The mostly urban downstream subbasins contributed relatively large amounts of runoff, ranging from 4 inches to 10 inches. The highest runoff was generally found from the urban subbasins (Subbasins 1-10) below the bluff area.

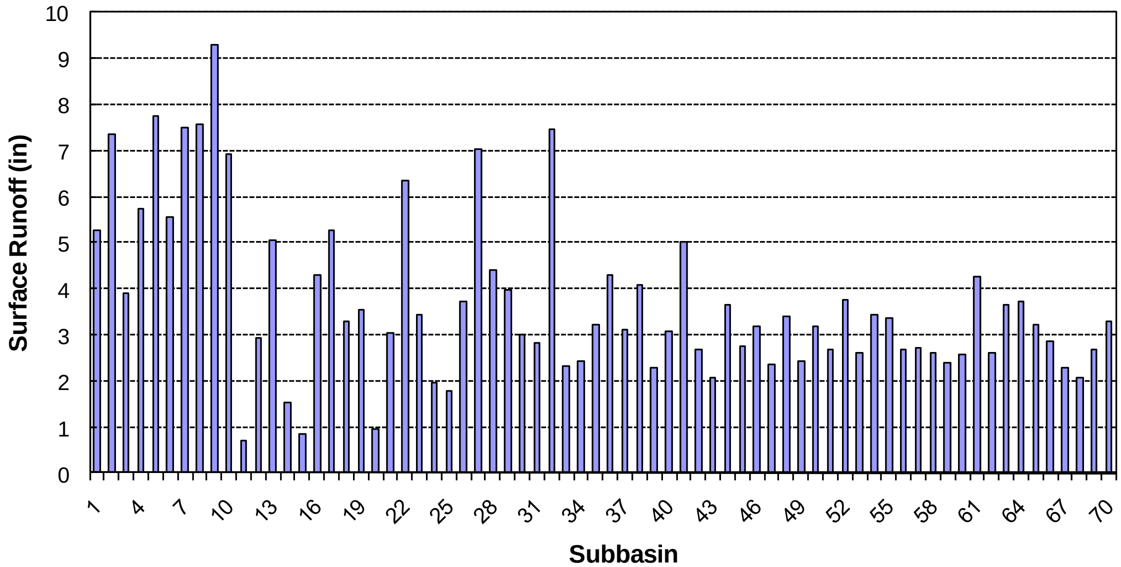

Figure 19 Simulated Average Annual Surface Runoff by Subbasin

Figure 20 shows the simulated average annual TSS yields of field erosion per unit area by subbasin. The yields ranged from 1 lb/ac (Subbasin 11) to 150 lb/ac (Subbasin 6). The yields from most subbasins were relatively small regardless of subbasin location. Subbasins 3 and 6 were exceptions, contributing extremely high TSS yields (140 lb/ac and 150 lb/ac). The yields were calculated based on the amount of TSS entering the channels, which are influenced by many factors, including land cover, slopes, soil properties, buffer application and impoundment settlement. Any combination of these factors may determine high or low TSS loads from a subbasin.

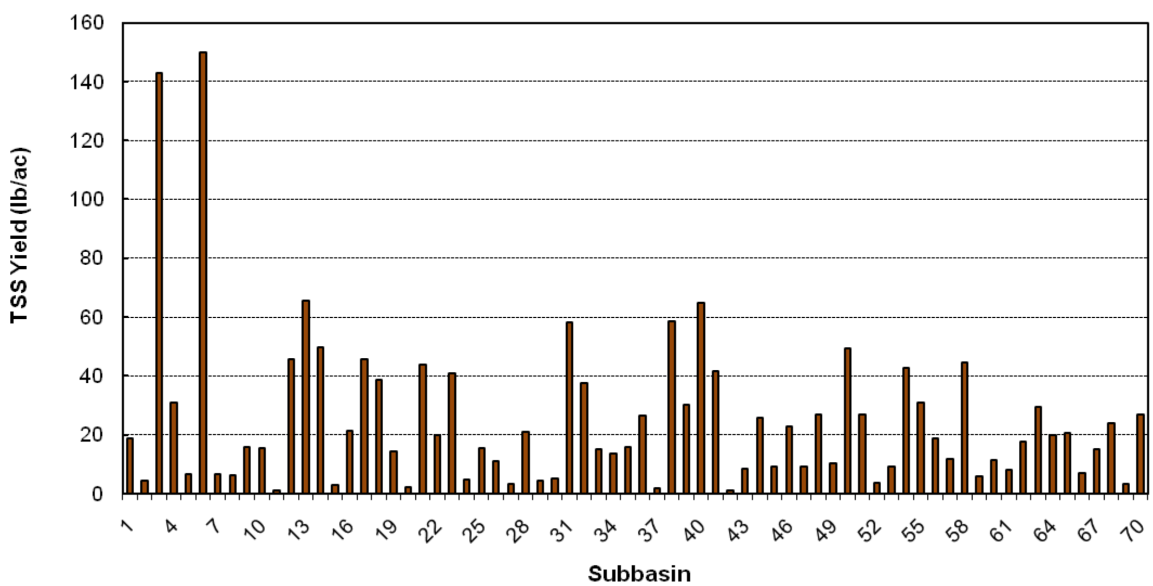

Figure 20 Simulated Average Annual TSS Yields by Subbasin

5.4 Field and Non-Field Erosion TSS Loads

The total TSS load from field and non-field erosion was used to quantify TSS non-point sources in the watershed. The total TSS load is not only dependent on the TSS yield per unit area but also on subbasin area. Figure 21 is a spatial distribution map of annual field and non-field TSS loads by subbasin, reflecting the magnitude of field and non-field erosion by subbasin.

Based on the SWAT simulation, the total average annual TSS load for field erosion from the subbasins ranged from 90 lb/yr to 114,400 lb/yr. The results show that most subbasins in the Credit River Watershed had relatively low TSS loads contributing to the channel. About 84 percent of the subbasins contributed less than 20,000 lb/yr, and 13 percent had TSS loads ranging 20,000 lb/yr to 40,000 lb/yr. Subbasins 6 and 31 were found to have the highest TSS loads (114,400 lb/yr and 53,000 lb/yr respectively). Generally a subbasin will contribute a large TSS load if it has a high TSS export rate (may be due to larger slopes, or agricultural or urban land uses) and large geographic area.

Non-field erosion is a significant source of TSS in the Credit River Watershed. The SWAT model was calibrated to reflect that 18.5 percent of the TSS loads came from field erosion and 81.5 percent was from non-field erosion, consistent with actual measurements. Simulated TSS loads per unit area and total load expressed in percent from non-field erosion and non-field erosion by subbasin are displayed in Figures 21 and 22. The figures show that a large amount of non-field erosion occurs in the downstream subbasin channels below the bluff area, ranging from about 141,100 lb/yr to 315,300 lb/yr and contributing up to 74 percent of the total bank erosion load. The channels in Subbasins 1, 2, 3, 8, 10, 13, 17 and 21 have high potential for non-field erosion. Upstream subbasins have either no erosion or low risk for non-field erosion. The loads from the upstream subbasins ranged from 0 to 70,000 lb/yr. These upland subbasins contributed only 26 percent of the total bank erosion load.

When comparing field and non-field erosion, TSS loads from field erosion are relatively insignificant. Non-field erosion from the downstream reaches of the watershed is the primary sources of TSS in the Credit River Watershed.

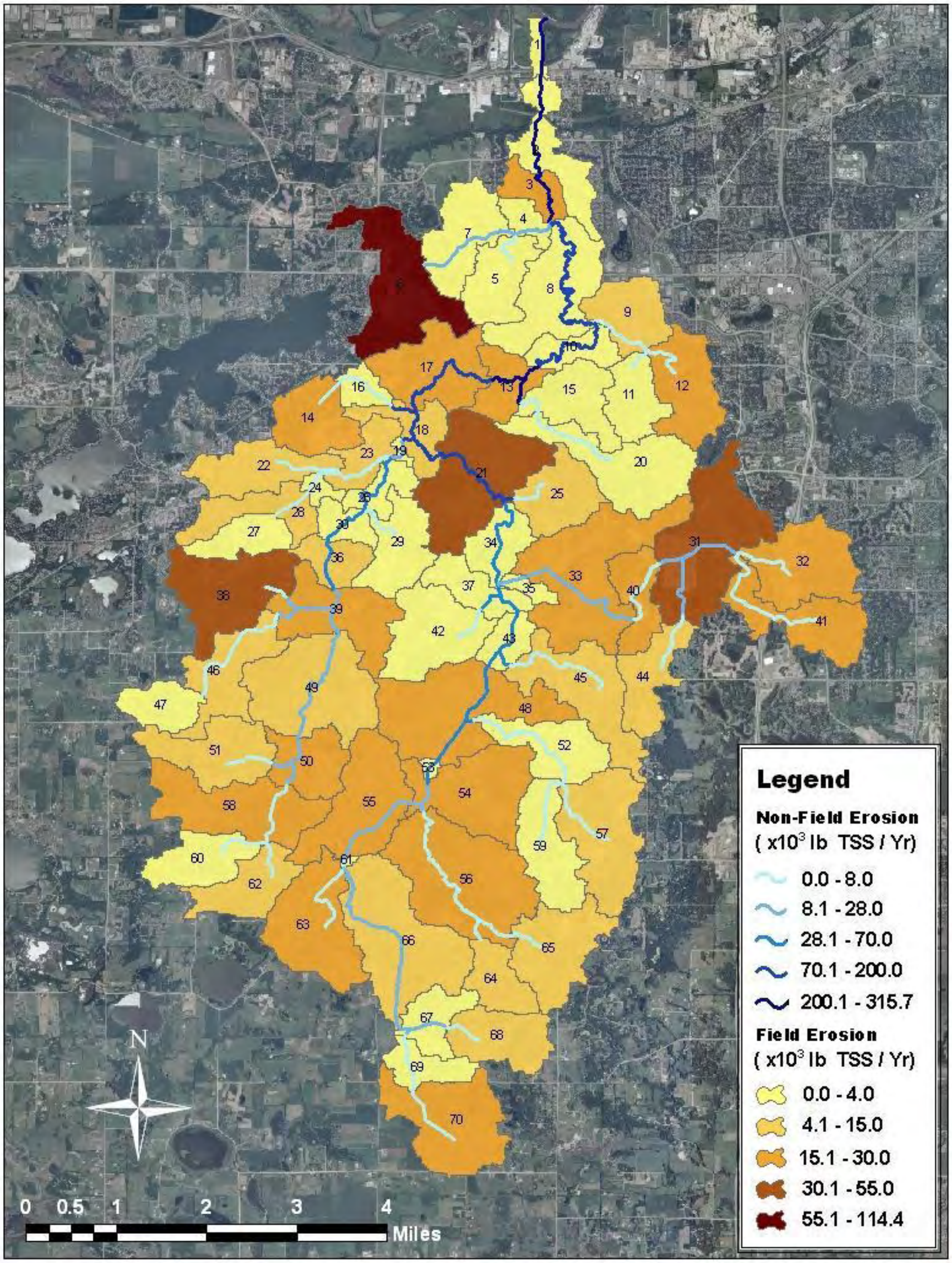

Figure 21 Simulated Field and Non-Field TSS Loads by Subbasin for Credit River Watershed

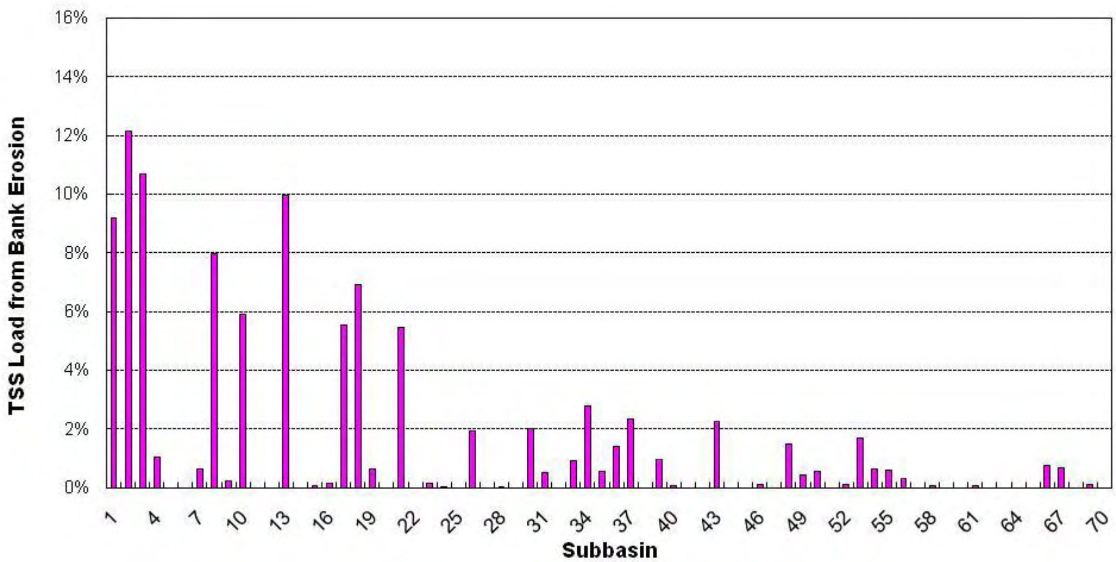

Figure 22 Simulated Non-field Erosion Load in Percent by Subbasin

5.5 Mass Balance for TSS Load

Simulated mass balances of the TSS loads in the Credit River Watershed were analyzed and summarized in a flowchart (Figure 23). The TSS loadings from various sinks and sources are distinguished by color. The simulated results show that about 12,956,600 lb of TSS was eroded each year from fields in the watershed, accounting for 83 percent of the total non-point source load. However, about 94 percent of the TSS load eroded from fields was removed by existing buffer strips, wetlands and ponds within the subbasins. Only about 841,500 lb of TSS from field erosion entered the downstream lakes and channels. In the lakes and channels, about 50 percent of the TSS from field erosion was further settled; thus only 419,700 lb (about 3 percent of total field erosion load) reached the watershed outlet. This accounts for 18.5 percent of the total Credit River Watershed TSS load discharged to the Minnesota River.

There was 2,598,100 lb of TSS eroded each year from bank and other non-field erosion in the Credit River, accounting for 17 percent of the total nonpoint source TSS loads in the watershed. However 29 percent of the non-field TSS load settled out in lakes and channels during routing towards the watershed outlet. About 1,853,100 lb of TSS (71 percent) from bank erosion reached the outlet, contributing 81.5 percent of the total TSS load discharged at the watershed outlet, which was about 2,272,700 lb per year.

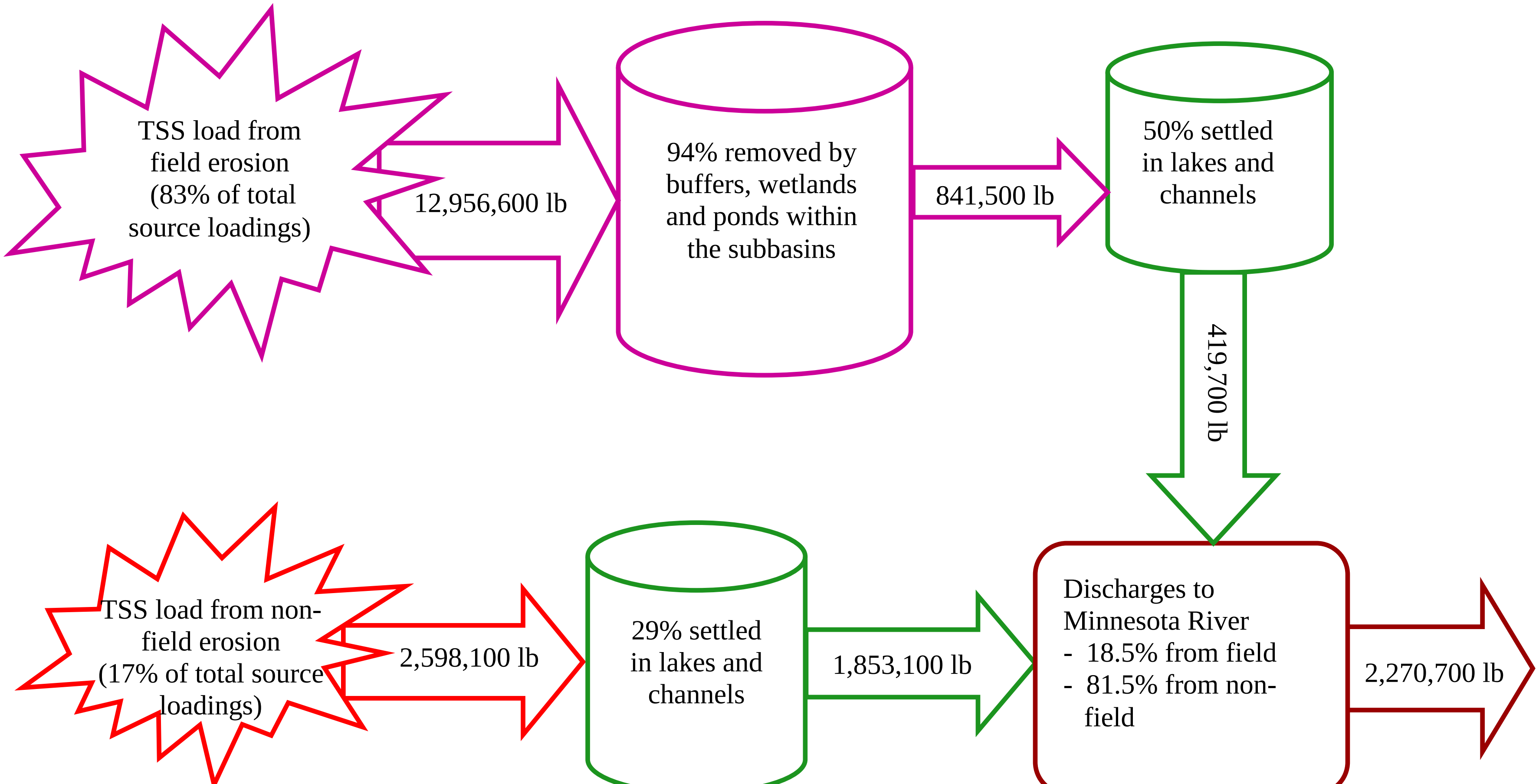

Figure 23 Mass Balance of Non-Point TSS Loads in Credit River Watershed

6. 2030 CONDITIONS AND BMP SCENARIOS

6.1 Scenario Background

Credit River was initially listed as impaired for aquatic life due to turbidity in 2002. In 2008 the MPCA entered into a contract with Scott County and the Scott County WMO to complete a TMDL for the river addressing the turbidity impairment. As part of this effort the Council agreed to provide water quality modeling assistance. Over the course of the study effort new monitoring data showed that the river was not impaired for turbidity. The MPCA has agreed to pursue delisting of the river. Instead of completing the TMDL, the county is now completing a Protection Plan that will assess how to keep the river from reverting back to an impaired condition.

One of the key elements of the Credit River Protection Plan that prevents an increase in turbidity for the river is the standards used for managing runoff and erosion from new development. Scott County and cities in the County have standards, and regulations for mitigating storm water impacts with new development. One of the key questions that the Protection Plan attempts to address is whether or not these standards are sufficient to prevent turbidity increases given the expected future development.

MCES staff used the calibrated SWAT model to run scenarios designed to assess how future planned land use conditions along with the application of current storm water management standards would impact the storm water and TSS entering into Credit River. The scenarios were designed based on inputs from Scott County staff and members of the Credit River TMDL technical advisory committee.

In general, standards for Scott County and cities use five management approaches for new development that can be generalized as follows.

1) All the Local Government Units (i.e., the county and the cities) require retention of ½ inch of surface water runoff from new impervious surfaces to mitigate the anticipated increases in runoff volume associated with new development. This requirement is largely intended to help manage stream bank erosion by runoff volume control.
2) All of the Local Government Units (LGUs) require some form of peak runoff rate control. For the cities in Scott County the requirement is that the peak runoff rates cannot exceed the peak rate that occurred under the pre-development land use. For the unincorporated areas of the County, the requirement is that the peak runoff rate cannot exceed the peak rate that occurred under pre-settlement land use. These control measures are largely directed at managing flooding, but are also expected to help moderate stream flow and associated channel erosion.
3) All of the LGUs require some form of post construction water quality treatment, typically a water quality pond constructed in conformance with the MPCA specifications in the NPDES Construction General permit. In general, water quality ponds constructed to these specifications have been shown to have the following

removal efficiencies: 80 percent TSS, 30 to 40 percent nutrients, 60 percent metals, 70 percent pathogens, and 80 percent toxins (MPCA, 2005).
4) All of the LGUs require buffers adjacent to water courses and wetlands. The County and the Cities of Savage and Prior Lake have requirements equivalent to the Scott County WMO, which requires wetland buffer widths from 25 to 65 feet (depending on wetland quality) and watercourse buffer widths of 30 feet.
5) All of the LGUs have construction erosion control programs to control erosion during construction.

For this study, Scott County staff directed MCES to use the SWAT model to assess the effectiveness of the County's standards. This study was different from most SWAT modeling studies, which tend to focus on how site-specific BMPs reduce flow and pollutant loads. Representing the application of watershed-wide development standards in SWAT is not straight forward. After much discussion it was determined that:

1) Construction erosion control standards did not need to be modeled as these are temporary efforts, and what was of interest was the post construction condition.
2) The peak runoff control standard and the water quality pond standards could not be explicitly modeled in SWAT because of the site specific nature of building ponds could not be easily identified and represented in SWAT.
3) The runoff volume standard would be represented by adjusting the curve numbers (CN) associated with new development impervious surface.
4) Required buffers would be represented using 30 foot wide filter strips.

The scenarios for this study should be reviewed with the understanding that SWAT is a predictive tool developed for general watershed hydrology and non-point source studies. It was not developed for use in site-specific engineering design. In addition, two of the standards could not be modeled using SWAT; thus modeling results likely under-represent the collective effectiveness of the standards. In addition, other assumptions regarding how to represent the future rural residential land uses in the model probably underestimate the impact from land use changes as well. As always, the proposed scenario results are to be used to inform management decisions, in the context of how things are represented in the model, and not to be used for engineering design.

6.2 Scenario Methods and Input Data

6.2.1 2030 Land Use Condition Model

To simulate future development conditions for the Credit River Watershed, the projected 2030 land use map was incorporated into the original model developed using the 2002 land cover map. A new 2030 land use map was created for the scenarios by MCES according to the following data and methods. Descriptions and SWAT codes on the 2030 land use map are listed in Table 10.

1) Scott County 2030 land use map
    - Used to define boundaries of urban, urban expansion and rural residential policy areas

2) Metropolitan Council 2002 land cover modeling map
   - Used to fill in missing portion of the Credit River Watershed (Approximately 10 percent of the watershed area located in the Dakota County. This was considered a reasonable assumption since the area is already developed with little change expected by 2030)
   - Used for existing urban and rural residential (IDs 1 – 5 and IDs 21 – 25) and to calculate new development in 2030 (IDs 100 – 500)
   - Used for 2030 urban expansion policy area (No new development is planned for this area until after 2030 (IDs 12 -14 and parts of IDs 8 – 11)
3) Metropolitan Council 2030 land use map
   - Used for 2030 urban land uses of new development (IDs 1 – 16)
4) 2002 Scott County parcels
   - Used to divide the Scott County rural residential policy area into currently considered developed areas (ID 19) and new development areas (ID 20). Currently developed areas were identified based on allowable housing density policies as specified in the Scott County 2030 plan. 2030 new development is expected in those areas with parcels equal to or greater than 15 acres.
5) To make the scenarios more accurate and comparable with the developed 2002 model, existing residential land use in the planned rural areas are unchanged from the map used for 2002 model (IDs 21- 25).

Table 10 Land Use Description and SWAT Code for 2030 Map

ID	Code	Land Cover	Note
1	URLD	Existing urban low density	Existing residential in the planned urban area based on 2002 land cover map
2	URML	Existing urban medium-low density	
3	URMD	Existing urban medium density	
4	URHD	Existing urban high density	
5	UCII	Existing urban commercial, industrial or institutional	
7	SWRD	Sand and/or gravel mining operations, sandbars, etc.	Agriculture mainly shows up in the urban expansion area. No change is anticipated for this land use prior to 2030.
8	FRST	Forest, including hardwood, coniferous, and mixed forest types	
9	PAST	Grass, such as lawns, golf courses, and sod fields	
10	WATR	Water, as in permanent open water.	
11	WETL	Wetland, including wet meadow, and palustrine emergent, etc.	

12	ALFA	Non-row crop, as in alfalfa, bromegrass, and conservation reserve program lands.	
13	CORN	Row crop: corn and soybean rotation	
14	OATS	Grains, as in wheat, oats, and rye	
16	PAST	Herbaceous remainder	
19	NRR	New rural residential (Switch grass)	Determined based on 2002 non-urban parcels equal to or larger than 15 acres in the planned rural residential area.
20	SWCH	Existing rural residential parcel (Switch grass)	Created based on 2002 non-urban land on existing rural residential parcels less than 15 acres in the planned rural residential areas. This area was assumed not to be developed by 2030.
21	RRL	Existing rural residential low density	Existing land covers from 2002 planned rural residential areas. Simulated at various residential densities based on 2002 model. RRM, RRH and RCII were excluded in model development due to very small percentage of land in this area.
22	RRML	Existing rural residential medium-low density	
23	RRM	Existing rural residential medium density	
24	RRH	Existing rural residential high density	
25	RCII	Existing rural commercial, industrial or institutional	
100	NULD	New urban low density	New development from 2002 to 2030 in the planned urban areas
200	NUML	New urban medium-low density	
300	NUMD	New urban medium density	
400	NUHD	New urban high density	
500	NCII	New urban commercial, industrial or institutional	

The Metropolitan Council 2030 land use map was developed in 2004 specifically for use in SWAT modeling. The urban areas of the watershed located in Dakota County are not included in the map. These areas include portions of the Cities of Burnsville and Lakeville, preserved regional parks, forests or wetlands. It was assumed that the differences between the 2002 and 2030 land use conditions would be marginal for those areas. Therefore, the 2002 land cover map, which was used for model development, was used for the portions of the watershed not defined by the Council's 2030 map. According to the Scott County 2030 planned land use map, all rural areas in the Credit River Watershed will be used either as urban expansion or as low density rural residential area in 2030. The boundary of these areas was defined using the Scott County 2030 planned land cover map.

New databases for the new urban and rural residential land uses in the 2030 map were also created in the SWAT model for simulations. Based on inputs received from the Scott County staff, the land covers for all rural residential area were simulated as switch grass, except for a small portion of the existing rural residential areas in the Metropolitan Council's 2002 map, which were simulated at various residential densities following the 2002 model. Switch grass was used as land cover for rural residential areas to reflect the low residential densities planned for the rural residential areas in the County. The rural residential medium and high densities and commercial land uses account for a very minimal amount of land cover. These land uses were eventually excluded by SWAT in model setup.

Representing the rural residential development as switch grass will underestimate runoff and TSS generated from this land use, since there will be impervious surfaces such as roads, driveways and rooftops associated with the rural residential development. This needs to be considered when interpreting the modeling results.

In the end a new SWAT model based on the calibrated 2002 model was built for the Credit River Watershed using the developed 2030 land use map. Except for the land use information, the 2030 model has the same inputs and parameters as 2002 model. For scenario assessments, the model was run using precipitation records from 1997 - 2008.

6.2.2 Implementation of County Storm Water Volume Control Standard

The SWAT model simulates surface runoff using the modified SCS curve number (USDA Soil Conservation Service) based HRUs. The curve number (CN) is used to quantify distributions of storm water between surface runoff and infiltration. In urban areas, surface runoff is calculated separately using CNs for pervious and impervious portions. The CN for impervious areas is set to 98 as a constant in the model database. A lower CN results in greater infiltration and less surface runoff. Adjustment of the curve number can be used to simulate the infiltration processes to retain storm water volume in impervious urban areas.

To replicate retention of ½ inch of surface runoff volume from new development impervious surfaces, the impervious CN for new development land uses was adjusted from 98 to various lower values. The model was run to determine the sensitivity of changing the CN values. The CN value that best corresponded to the ½ inch storm water volume retention standard was used to simulate the County's storm water volume control standard in the scenario models. The TSS loadings from the scenarios were also assessed to understand how the storm water volume control standard impacts TSS exports from new development and the overall watershed TSS loads. Because new development in the rural residential areas was simulated as switch grass, the impact of the standards in the rural residential areas was not included. It is reasonable to ignore the impervious surface area in the rural residential area in the modeling analysis because the impervious portion in the area was very small compared to the pervious portion.

6.3 Results and Discussions

6.3.1 2030 Land Use Conditions

Figure 24 is a map of new development and other land uses in the watershed in 2030. The map was developed for SWAT modeling and may differ from planning maps developed by the County or cities. The definitions of the land uses in the map are provided in Table 10. According to SWAT delineation based on the created 2030 land use map, there will be about 6,540 acres of new development in the Credit River Watershed by 2030. Total urban and rural residential area in the watershed will be 8,700 acres (18 percent increase) and 10,700 acres (94 percent increase) respectively. Agricultural land uses will be eliminated in urban and rural areas in 2030 except for in the urban expansion area, which has about 1,650 acres of agricultural land use and is not expected to be developed by 2030. Forests will be reduced by 34 percent to 4,440 acres and pasture lands will be reduced by 26 percent to 1,550 acres. Wetlands and lakes are preserved and therefore have minimal changes. Figure 25 shows a comparison of land uses between 2002 and 2030 conditions.

Urban and rural residential land uses will be the dominant land uses in the watershed in 2030, accounting for 28 percent and 35 percent of the total watershed area respectively (Figure 26). The remaining land uses will be forests (15 percent), wetlands (11 percent), agriculture (5 percent), water (3 percent), and pasture (3 percent).

Figure 27 breaks down the 2030 urban and new rural residential areas by densities for existing and new development. In the urban and new rural residential areas in 2030, 45 percent will be urban and 55 percent will be rural residential. New development will account for 51 percent of the total urban and new rural residential areas. Of the new development area only about 20 percent will be urban and 80 percent of it will be rural residential.

Figures 28 and 29 present annual flow rates and TSS loads for 2002 and 2030 land use conditions without runoff or water quality controls. The results were simulated at the watershed outlet using the 2002 and 2030 land use models and precipitation records from 1997 - 2008. Comparisons between the two models show that the average flow rate at the watershed outlet will increase about 6 percent from 2002 to 2030 if the projected new development occurs without runoff volume control standards. Increased flow from new development not only brings more TSS from runoff from upland, but also leads to a potential increase in bank erosion downstream. As a result, the TSS load in the watershed will likely increase by 10 percent. Relatively larger increases in flow and TSS load were simulated for 1997, 2000, 2002, 2004 and 2008, probably due to the relatively high precipitation totals in those years. Without application of the County's storm water standard, average flow rate and TSS load from new development were predicted to increase only slightly, even though the extent of new urban area is projected to increase by 18 percent and rural residential by 94 percent.

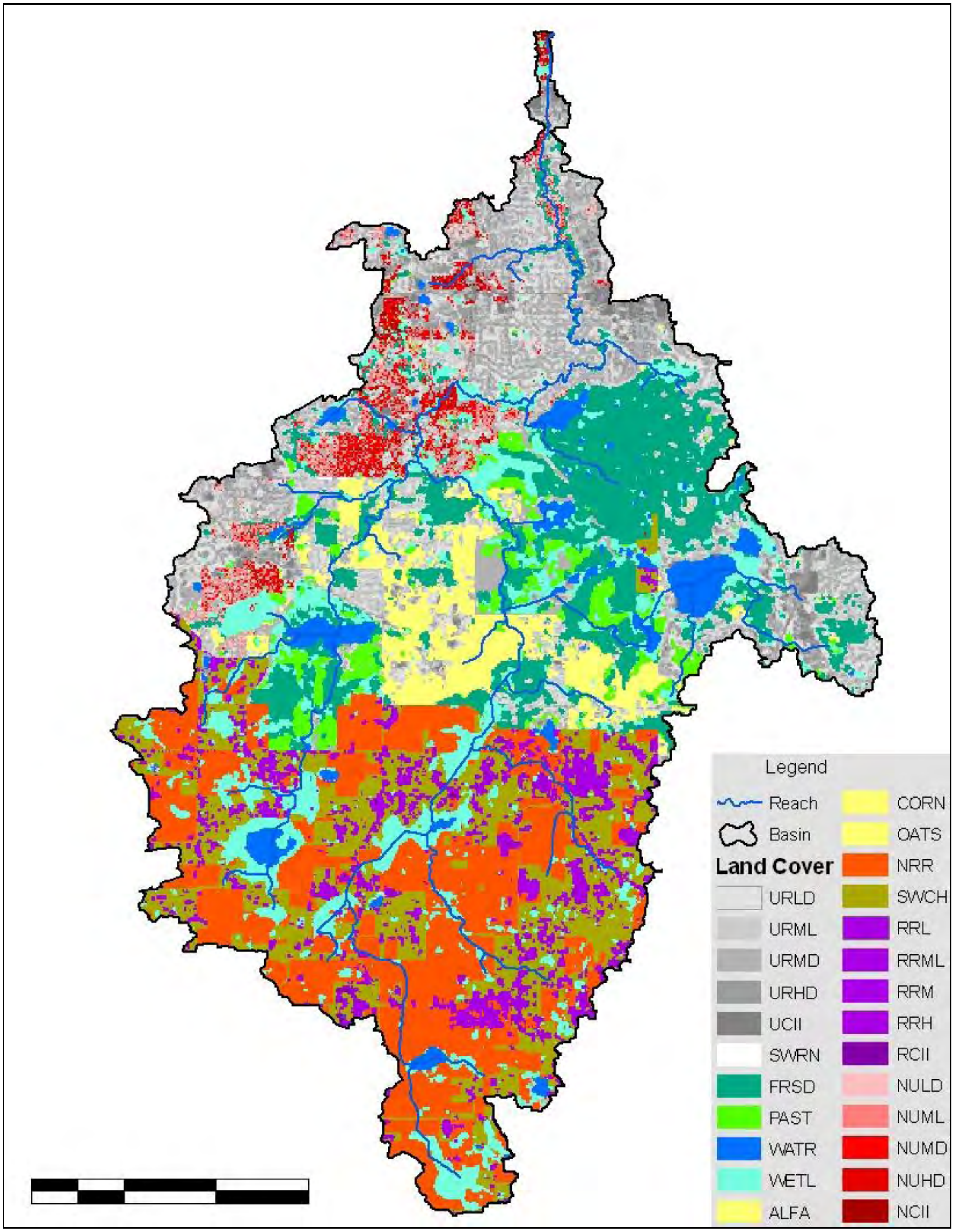

Figure 24 New Development and Other Land Uses in Credit River Watershed in 2030

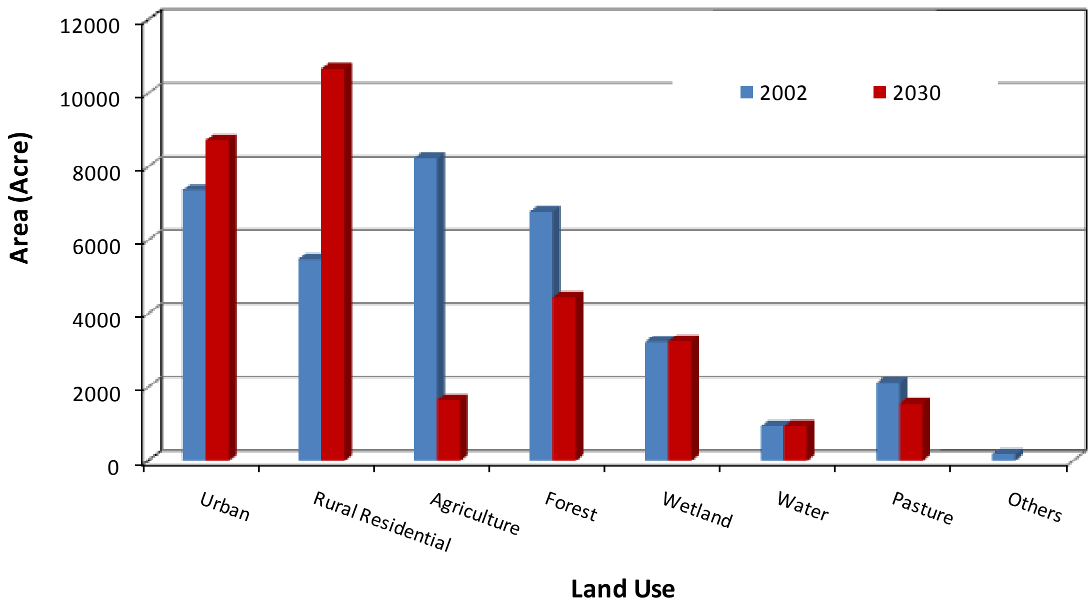

Figure 25 Comparison of Land Uses between 2002 and 2030

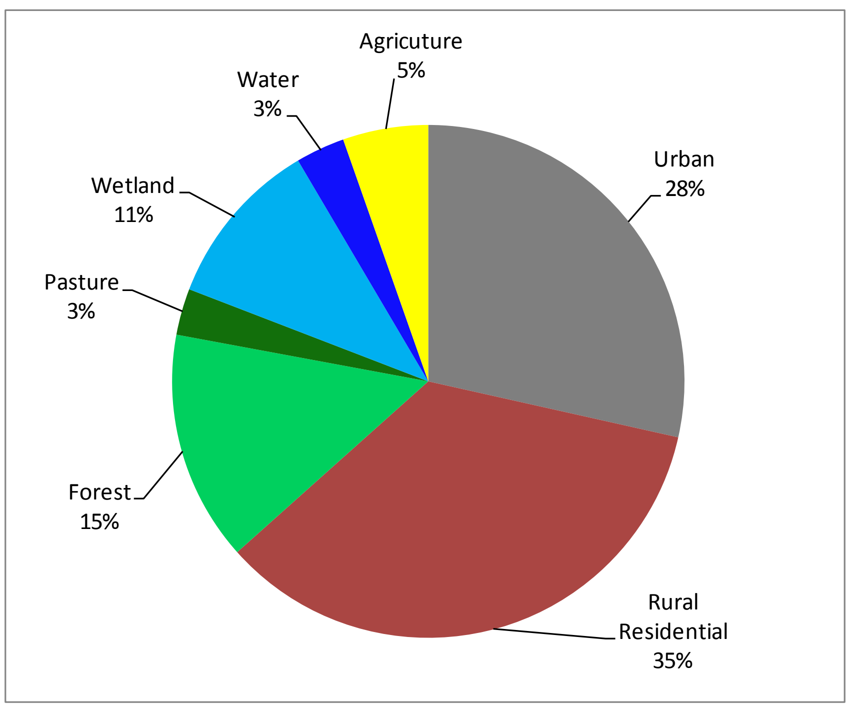

Figure 26 Land Use Conditions of Credit River Watershed in 2030

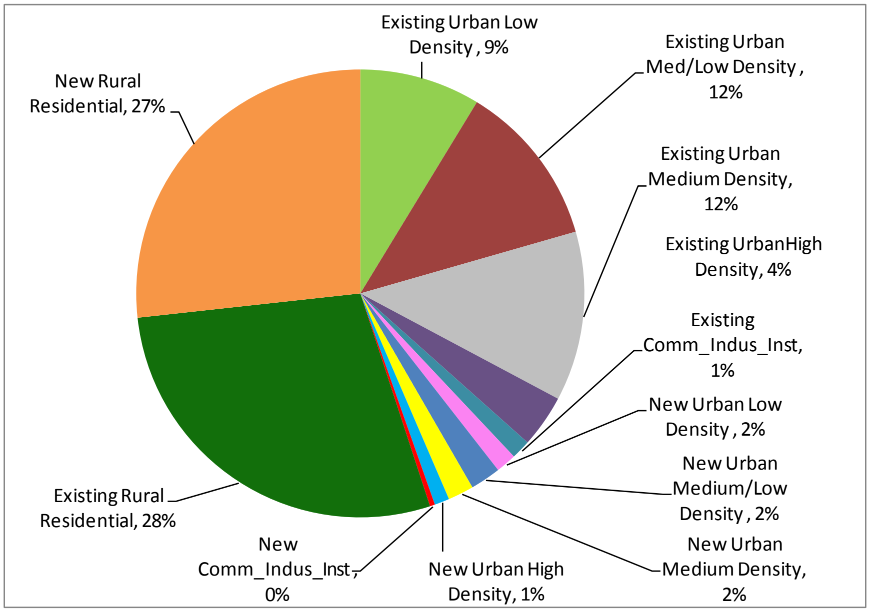

Figure 27 Urban and Rural Residential Land Uses in 2030

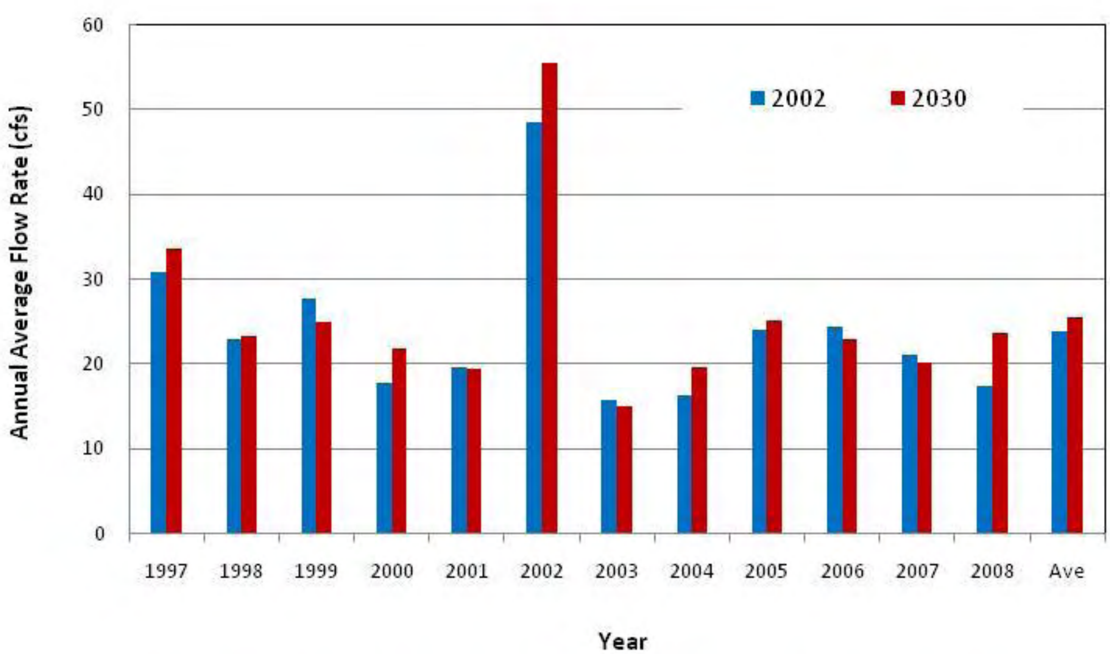

Figure 28 Comparison of Flow Rates between 2002 and 2030 Land Use Conditions

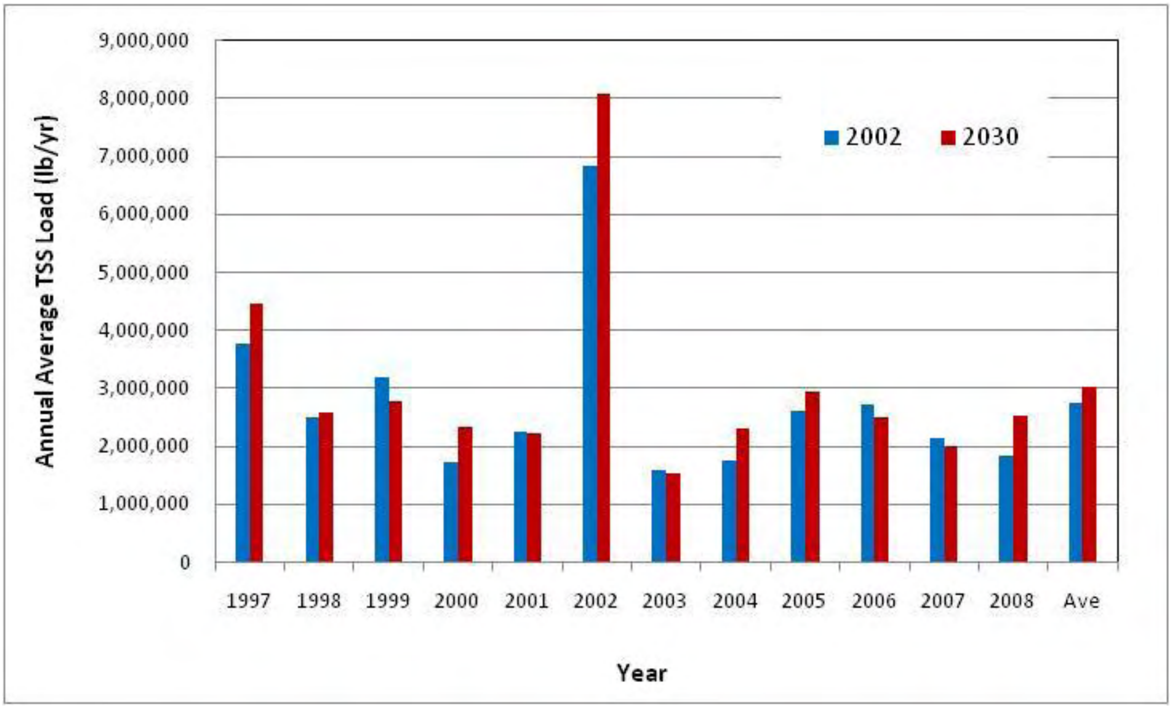

Figure 29 Comparison of TSS Loads between 2002 and 2030 Land Use Conditions

6.3.2 Runoff Retention Using Volume Control Standard

Volume Retention from New Development

Figure 30 displays simulated retention rates of surface runoff volumes from the planned new urban development areas in response to various impervious CN values for the Credit River Watershed. Runoff from the new rural residential land use is unchanged. This is because the new rural residential areas were simulated as switch grass which in a natural state would have very high infiltration. The runoff volumes are a long term average based on the period from 1997 - 2008. The default CN value for the impervious portion of the urban areas was 98. This scenario was developed to attempt to understand surface runoff in response to changes in impervious CNs and to determine the CN value that best corresponded to the ½ inch of runoff volume retention required for new development impervious surface.

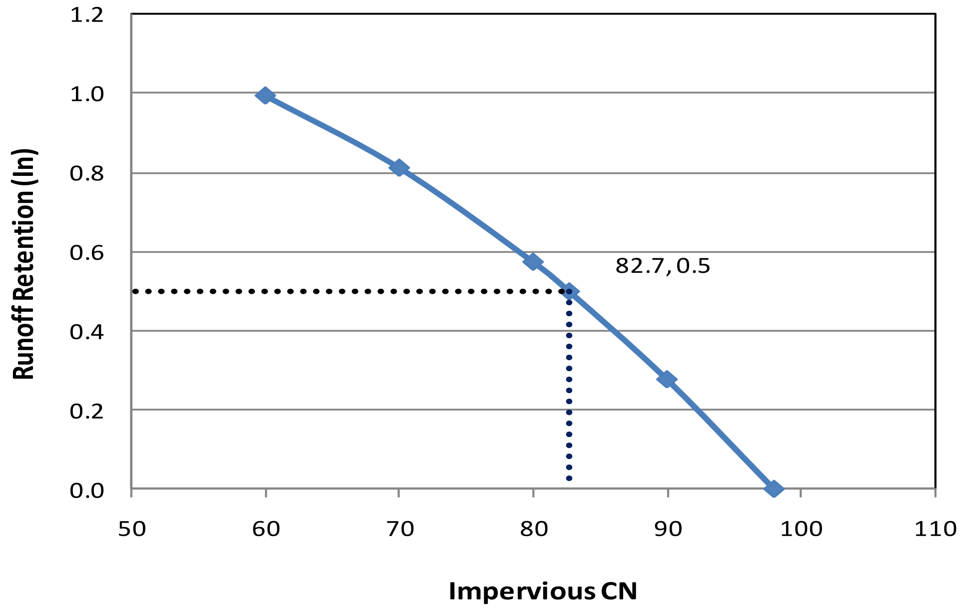

Figure 30 Surface Runoff in Response to CN for New Development

The results indicate that when impervious CN values are lowered, the runoff from new development in the urban areas will decrease correspondingly. At the default impervious CN of 98, the average surface runoff volumes predicted from new urban and rural residential areas are 6.6 inches and 1.3 inches respectively. The runoff from the rural residential areas is significantly lower than the runoff from the urban areas because the rural residential areas are simulated as switch grass. Using switch grass for the rural residential areas without including imperviousness, such as driveways and local streets, may under-estimate the surface runoff from the areas for this scenario study.

When the impervious CN is lowered to 82.7, the urban surface runoff is predicted to be 6.1 inches, which is ½ inch less than the surface runoff volume when the CN is at the default value of 98 (Figure 28). The CN of 82.7, therefore, is used to represent the results achieved when implementing the County's storm water volume control standard. To evaluate the overall impact of the standard on watershed hydrology and water quality, 2030 model results simulated using CN values of 82.7 and 98 were compared.

Table 11 lists the surface runoff volumes with and without the standard using 2030 land use conditions, which are represented using CN values of 82.7 and 98. The runoff volumes were broken down into new rural residential and various urban densities. The results indicate that with the standard, the average surface runoff volumes will be 1.3, 3.2, 4.5, 7.0, and 9.7 and 12.6 inches respectively from rural residential, low, medium-low, medium, high densities and commercial-industrial-institutional land uses. Implementation of the storm water standard will retain 0.1 to 0.7 inches of runoff from new urban development, which is 5.5 percent - 8.7 percent lower than the volumes without the standard. For the scenario in this study, the standard will have no or minimal impact on surface runoff rates in the rural residential areas.

Table 11 Surface Runoff from New Development

Scenarios	Runoff from New Development (in)					
	SWG	LD	MLD	MD	HD	CII
2030	1.3	3.4	4.8	7.7	10.6	13.3
2030 + Standard	1.3	3.2	4.5	7.0	9.7	12.6
	0%	- 5.7 %	- 6.7%	- 8.7%	- 8.4%	- 5.5%

LD - Low density residential
MLD - Medium -low density residential
MD - Medium density residential
HD - High density residential
CII - Commercial, industrial and institutional
SWG - Switch grass (rural residential)

Impact of Volume Retention on Watershed Flow

Figure 31 presents comparisons of watershed discharges using 2030 land use simulated with and without implementation of the storm water volume control standard under 2002 land use conditions. With the standard of ½ inch runoff retention from impervious surface of new development, the average watershed flow at the outlet will be 24.7 cfs for the simulation period (1997 - 2008). The flow will be about 3 percent lower than the 25.4 cfs flow without the standard, but still about 4 percent higher than the flow (24.0 cfs) from 2002 conditions. Thus modeling suggests the standard mitigates 50 percent (0.7 cfs) of the increase (1.4 cfs) created under the future 2030 land use conditions.

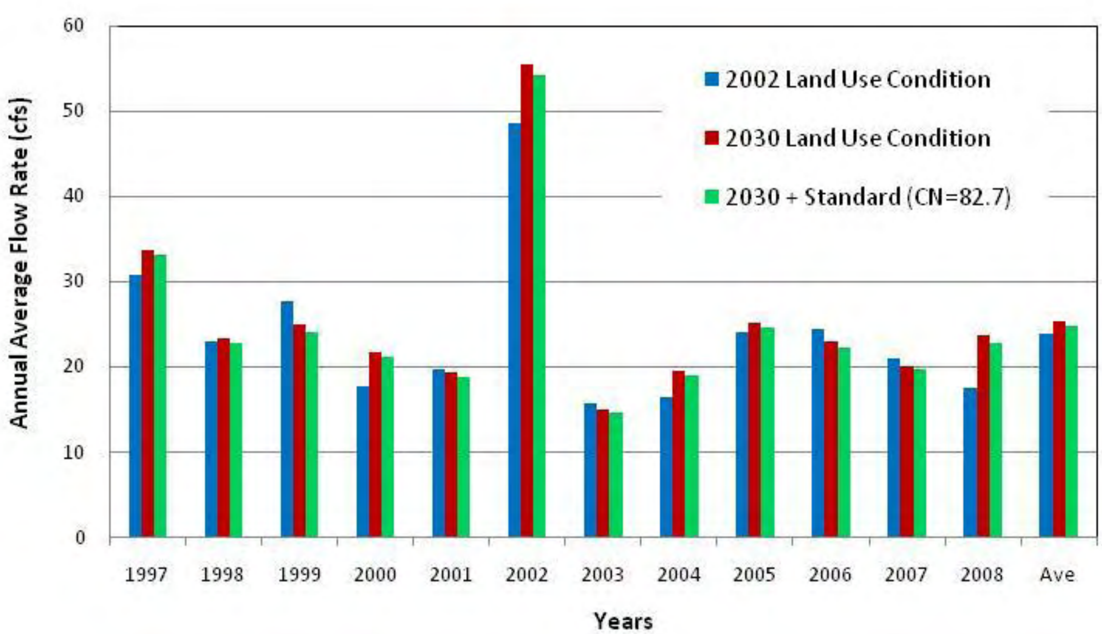

Figure 31 Comparisons of Watershed Flow Rates

6.3.3 TSS Loads with Volume Control Standard

TSS Retention in New Development

Retaining ½ inch runoff from the new impervious surface areas will consequently impact TSS exports from new development and overall watershed TSS loads. Figure 32 displays the simulated reduction of average TSS yields from new urban development in response to changes in curve numbers. TSS yields from rural residential areas were not included because they were assumed to be effectively pervious.

The results show that TSS yields from the new urban development decrease as CN values decrease. At a CN of 82.7 which represented the standard to retain ½ inch runoff from impervious surface, the TSS yield is predicted to be 3.3 percent lower than the TSS yield without the standard. Figure 33 provides the relationship between TSS yield and surface runoff volume. There is a linear trend between TSS load reduction and surface runoff. The scenario shows that before implementing the storm water volume control standard (CN = 98), the TSS yield from new urban development is 78.0 lb/ac/yr. With the standard, the TSS yield will be 75.4 lb/ac/yr.

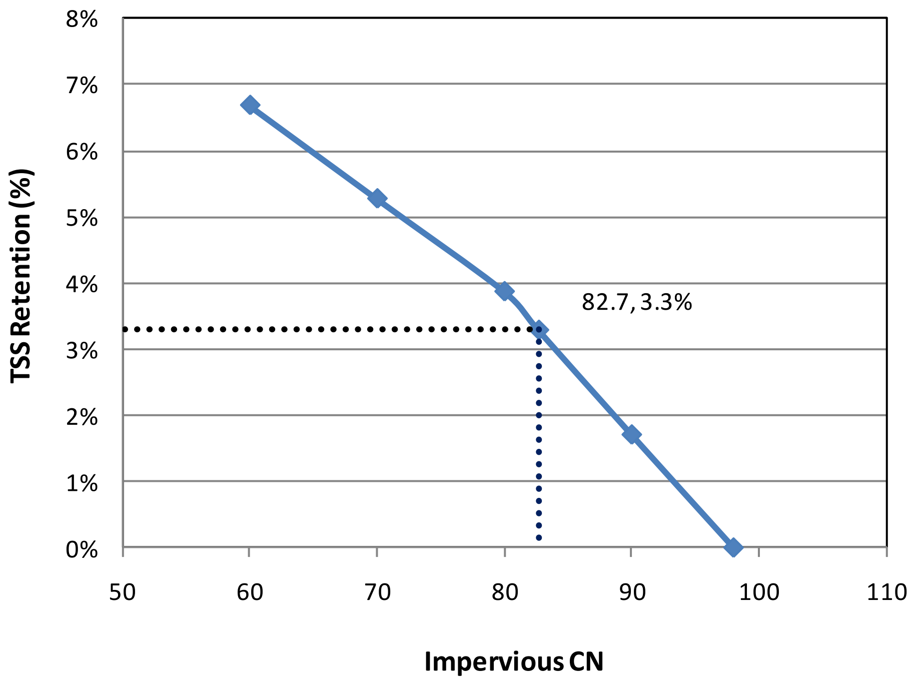

Figure 32 TSS Retention in Response to CN for New Urban Development

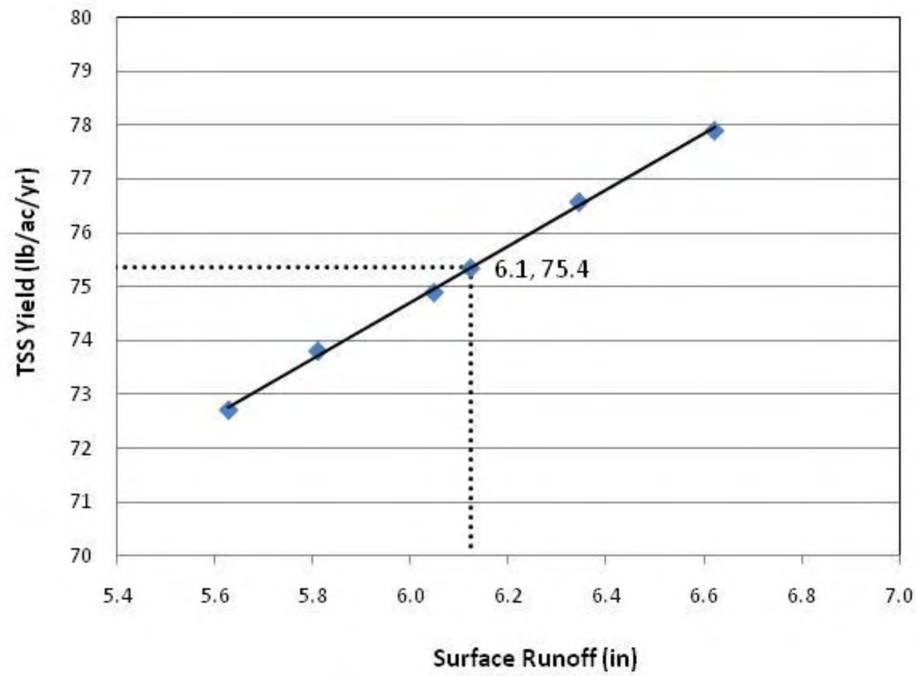

Figure 33 TSS Yield Compared to Surface Runoff Volume for New Urban Development

Buffer Application Scenario

Buffers (filter strips) are one of the widely used BMPs to control TSS. They are generally narrow and long areas of vegetation (mostly grasses). Filter strips are usually placed along watercourses, streams, ponds and lakes as part of a conservation system designed to conserve water, soil and protect receiving waters (Figure 34). Buffers are highly efficient in removing sediment particles transported from the fields to the river. However, they may not be efficient enough to reduce flow and other soluble pollutants. The County's standard requires buffer widths varying from 25 to 65 feet depending on wetland quality for wetlands, and 30 feet for other watercourses. Scott County staff recommended running a scenario based on using a 30 foot buffer for all of the wetlands and stream banks in the new development areas.

Because SWAT simulates buffer application based on edge-of field strips defined in an HRU, the strips can be applied exclusively to new development areas to remove sediments from surface runoff and protect the receiving water bodies. SWAT predicts TSS removal in a straight forward way using the following empirical equation:

$$\text{Trap efficiency} = 0.367 \times (W)^{0.2967}$$

where w is the buffer width in meters.

Figure 34 Grass Filter Strip Along a Stream Course (Photo by BERBI)

SWAT does not simulate surface runoff volume reduction by buffers. For this study, SWAT simulated unreasonably low TSS trapping efficiency when relatively small buffer widths were applied, probably due to limited TSS loading from the upland watershed in the built model. Therefore a spreadsheet model was used to estimate the TSS trapping rates based on the above equation and initial TSS yield without buffers.

Figure 35 shows the calculated TSS export rates from new urban development in response to various filter strip widths. The dashed-lines in the figure represent the TSS export before and after the volume control standard are applied. Before the standard is applied, the TSS export rates from new urban and rural residential areas are 78.0 lb/ac/yr and 12.3 lb/ac/yr, respectively. The TSS yield after the runoff volume control standard is applied is 75.4 lb/ac/yr for urban areas; there was no change for TSS yield from rural residential.

The results show that the TSS export rates from new urban and rural residential development are lowered non-linearly in proportion to the buffer strip widths. When the buffer width increases to 15 feet, TSS loading from new development is about 33.9 lb/ac/yr or about 60 percent lower than without buffer strips. With increasing buffer strip widths, the TSS load reduction from new development continues to improve. When the buffer width increases to 30 feet, the TSS export rates will be 22.3 lb/ac/yr, which is 74 percent lower than the export rate without the application of a buffer and 75 percent lower than the export rate without the volume control standard. If the width of the filter strips is further increased to 100 feet, removal increases to approximately 99 percent of the TSS export rate from new development areas.

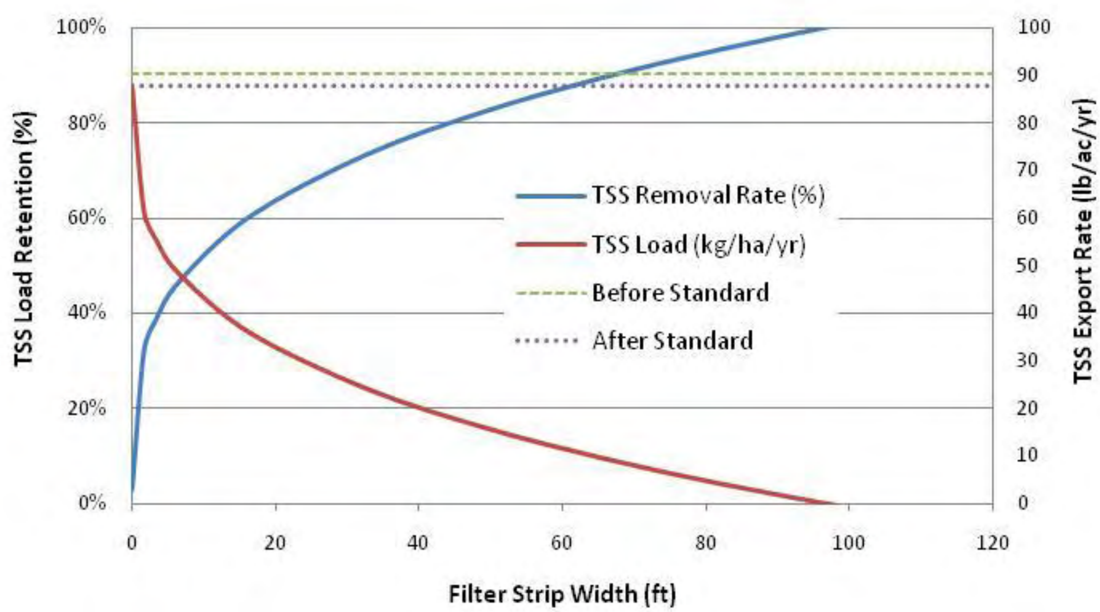

Figure 35 TSS Load Retention in Response to Buffer Strip Widths

A limitation of this scenario is that in the developed condition, especially in the urban areas, the landscape is frequently graded such that storm water is picked up in a collection system, routed to storm water ponds and then discharged directly to channels or receiving waters, thereby not flowing through buffers or filter strips. Therefore, this analysis may overstate the mitigation provided by buffers simply because in the developed conditions much of the runoff would not flow to the filters as simulated. However, the analysis of the 30 foot wide filter, which has a TSS removal efficiency of 75 percent, may be a good surrogate for representing the mitigation potential of water quality ponds which are expected to have similar (70 percent - 80 percent) TSS removal efficiencies; and should treat most if not all of the runoff.

Table 12 lists comparisons of average watershed TSS export rates simulated without the standard, with the standard, and with the standard plus 30 foot buffers (all using 2030 land use conditions). The TSS export rates were broken down into rural residential and various urban densities of new development. The results show that with the standard the TSS exports from various new urban residential densities are likely lower than without the standard by 3 percent to 5 percent. No TSS will be mitigated with just the standard from rural residential areas. After applying the 30 foot buffer and the standard, the average TSS export rates are reduced by 74 percent for rural residential and 75 percent for urban areas.

Table 12 TSS Exports from New Development Land Uses (Percentage based on 2030)

Scenarios	TSS Exports from New Development (lb/ac/yr)					
	SWG	LD	MLD	MD	HD	CII
2030	12.5	62.5	78.5	95.5	73.2	54.4
2030 + Standard	12.5	60.7	75.8	91.9	71.4	51.7
	0%	-2.9%	-3.4%	-3.7%	-2.4%	-4.9%
2030+Standard+ 30 ft Buffer	3.6	16.1	19.6	24.1	18.7	13.4
	-74%	-75%	-75%	-75%	-75%	-75%

Impact of Standards on Watershed TSS Load

The 2030 model was used to predict the watershed flow and TSS load after the standards were applied. Figure 36 shows comparisons of watershed TSS loads simulated at the watershed outlet for current (2002), 2030 land use conditions and two scenarios. The scenarios are:

- Implementation of storm water volume control standard (Impervious CN = 82.7), and
- Implementation of the standard plus a 30 foot buffer strip.

Because SWAT simulations showed that TSS trapping efficiency was less sensitive or not properly predicted when the buffer width was set at a low range such as 30 feet, a 100 foot buffer was used in the SWAT model simulation instead of 30 feet. Impact of 30 foot buffer on TSS mitigation can be inferred based on simulated results using 100 foot buffer. Applying a 100 foot buffer in SWAT can retain most (99 percent) TSS from new development (Figure 33). Based on the simulated results (Figure 36), the average TSS load at the watershed outlet is predicted as 2,954,200 lb/yr with the standard as compared to 3,020,300 lb/yr without the standard. The average annual TSS load with the standard will be about 3 percent less than the TSS load without the standard, but about 8 percent higher than the TSS load under current (2002) land use conditions (2,733,700 lb/yr).

If a 100 foot buffer is used for all new urban development, the watershed TSS load at the outlet will be about 2,844,000 lb/yr, which is about 6 percent lower than the load without the standard and buffer (3,020,300 lb/yr), but about 4 percent higher than the 2002 baseline (2,733,700 lb/yr). In other words, a 100 foot buffer together with the runoff volume standard is predicted to mitigate 176,300 lb/yr or 62 percent of the expected increase of TSS load (286,600 lb/yr) under future 2030 land use conditions. The results also imply that a 30 foot buffer could achieve a 3 to 6 percent TSS reduction as compared to the TSS load without the standard and buffers, but still be 4 to 8 percent higher than 2002 conditions.

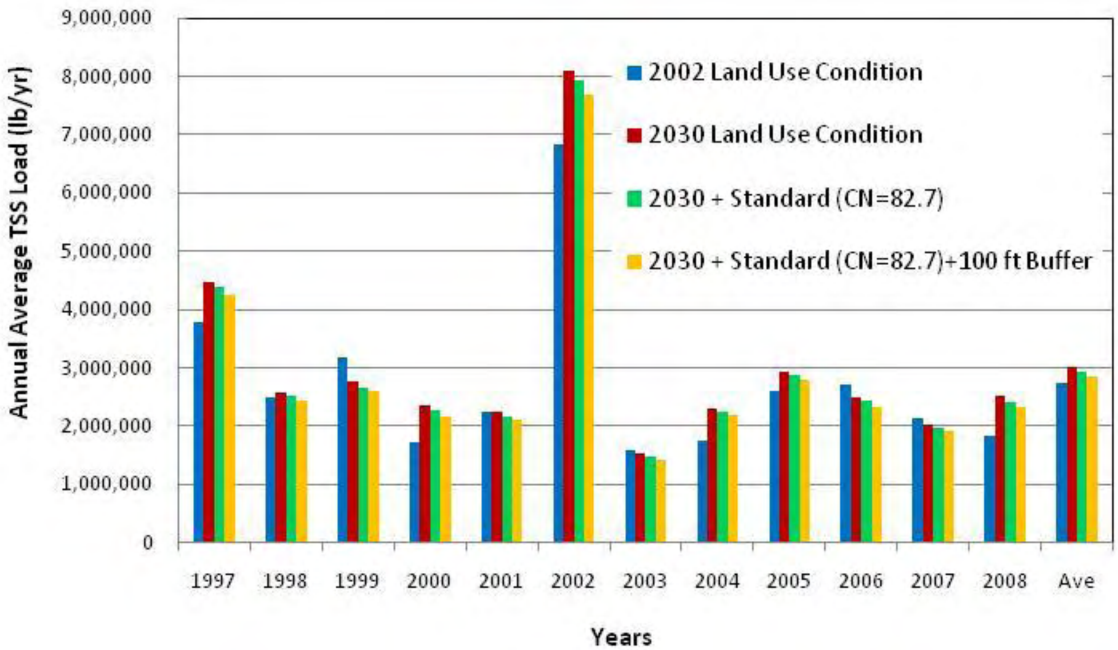

Figure 36 Comparison of Watershed TSS Loads

Table 13 and Figure 37 summarize scenario assessment processes and simulated results of various scenarios for watershed flow and TSS loads in comparison with the 2002 baseline. The scenarios built for this study show that new development has limited impacts on overall watershed hydrology and TSS loadings (about 6 percent and 10 percent increases respectively). Implementation of Scott County's storm water control standard and buffer width requirements have the potential to mitigate watershed flow volume, TSS and turbidity impacts from future development (3 percent and 6 percent lower than without standard and buffers or 23% and 62% mitigation of the expected TSS increase by 2030). Limited impact of the new development on the watershed may be a result of the lower densities and thus less impervious surface in the rural residential new development area. In addition, simulating the rural residential area as switch grass may also under-estimate the impact because in the scenario imperviousness was ignored in rural residential areas.

Table 13 Summary of Watershed Flow and TSS Loads for Various Scenarios

Scenarios	Flow (cfs)			TSS (lb/yr)		
	Rate	Increase[1]	Mitigated[2]	Rate	Increase[1]	Mitigated[2]
2002 baseline	24.0			2,733,700		
2030	25.4	1.4 (6%)		3,020,300	286,600 (10%)	
2030 + Standard	24.7	3.4 (3%)	-0.7 (50%)	2,954,200	220,500 (8%)	-66,100 (23%)
2030+ Standard +100 ft buffer[3]	24.7	3.4 (3%)	-0.7 (50%)	2,844,000	110,300 (4%)	-176,300 (62%)

Note:

1. Compared to 2002 baseline
2. Compared to the expected increases in 2030
3. Based on the results for 100 foot buffers, a 30 foot buffer likely results in a watershed TSS load that is 4 to 8 percent higher than 2002 baseline, but 3 to 6 percent lower than 2030 conditions.

Current Land Use Conditions (2002)
- Urban and rural residential land use: 30%
- Watershed discharges
  - Flow: 24 cfs
  - TSS load: 2,733,700 lb/yr

2030 Land Use Conditions (CN=82.7)
- Urban and rural residential land uses: (63%)
  - Existing urban: 24% and rural residential: 18%
  - New urban: 4% and rural residential:17%
- New development exports
  - Runoff: 6.6 in from urban and 1.3 in from rural residential
  - TSS load: 78 lb/ac/yr from urban and 12.5 lb/ac/yr from rural residential
- Watershed discharges
  - Flow: 25.4 cfs (6% increase)
  - TSS load: 3,020,300 lb/yr (10% increase)

Implementing the standard to retain ½ inch of runoff from new development (Reduce impervious CN from 98 to 82.7)

2030 Land Use Conditions + Standard
- New development exports
  - Runoff: 6.1 in (0.5 in mitigated)
  - TSS load: 75.4 lb/ac/yr (3.3% mitigated)
  - No change from rural residential
- Watershed discharges
  - Flow: 24.7 cfs (50% mitigated)
  - TSS load: 2,954,200 lb/yr (23% mitigated)

Implementing 30 ft buffers to new development for TSS control

2030 Land Use Conditions + Standard + 30 ft buffers
- New development exports
  - Runoff: no change
  - TSS load: 22.3 lb/ac/day (74% mitigated)
- Watershed discharges
  - Watershed discharges Flow: 24.7 cfs (50% mitigated)
  - TSS load: 2,954,200 - 2,844,000 lb/yr (23% - 62% mitigated)

Conclusions based on the scenarios:
- New development has limited impacts on overall watershed hydrology and TSS loadings (about 4% and 8% increases respectively). This is most likely due to the fact that the majority of new development is in the rural residential areas where densities are much lower and the model simulated this area with switch grass.
- Standard and buffer implementation has the potential to mitigate watershed flow volume, TSS and turbidity impacts from future development (3% and 6% lower than without standard and buffers or 23% and 62% mitigations of the expected increases of flow and TSS by 2030).

Figure 37 Flowchart for SWAT Application for 2030 Scenarios

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Model Development and Calibration

SWAT is a dynamic model developed to predict the impact of land management practices on flow, sediment, and agricultural chemical yields in watersheds with varying soils, land use, and management conditions over long periods of time. Data sets for topography, land use, soils, climate and agriculture management have been developed to construct a watershed model for Credit River. The model segmented the watershed into 70 subbasins and 1,713 HRUs.

The model was calibrated for flow and TSS with six years of monitoring data (1997 - 2002) and validated with data from 2003 - 2008. Statistical tests of the model performance and comparisons of the model results with reported similar studies indicate that the developed model can satisfactorily predict spatial and temporal variations of flow and TSS load in the watershed.

When calibrating TSS, non-field (channel, gully, ravine) erosion was also calibrated using the estimated TSS loading ratio from field and non-field erosion (18.5% and 81.5%). The results show that the calibrated SWAT model performs well at predicting bank erosion in Credit River. Simulated bank erosion potentials consistently follow the watershed topographical conditions: lower or no non-field erosion risks in the upland areas and higher erosion potentials in downstream subbasins below the bluff area.

7.2 Non-Point Source Analysis in the Watershed

Surface Runoff and TSS Yield by Land Uses
The SWAT model was used to identify areas with relatively high surface runoff and TSS load contributions to the Credit River for BMP implementation.

It was found that surface runoff from various land uses ranged from 0.1 inch (sand mining) to 6.9 inches (urban). Forest had the lowest surface runoff (0.8 inch) among the major land uses. Agricultural land uses including corn, soybean and alfalfa had the largest amount of TSS yields leaving the HRUs. However, only a small portion of the TSS yield from agricultural lands entered the Credit River. Urban land uses contributed the largest TSS loads (57 lb/ac) to the river most likely due to having fewer wetlands and buffers in the urban areas. Forests together with sand mining had the smallest TSS yields and loads to the channels (4 and 0.2 lb/ac).

Spatial Distributions of Flow and TSS Yields in the Watershed
Spatial analysis of flow and pollutant yields determined the areas with relatively high flow and TSS export rates and areas where BMP implementation for pollutant load reduction should be a priority. It was found that surface runoff from the 70 subbasins in Credit River Watershed ranged from 2 inches (uplands) to 10 inches (downstream urban

subbasins). The simulated average annual TSS yields ranged from 1 lb/ac (Subbasin 11) to 150 lb/ac (Subbasin 6). The loads from most subbasins were relatively small no matter where the subbasins were located.

Field and Non-Field Erosion TSS Loads

The total TSS loads for field erosion ranged from 90 lb/yr to 114,400 lb/yr. The results show that most subbasins in the Credit River Watershed had relatively low TSS loads contributing to the channel. About 84 percent of the subbasins contributed less than 20,000 lb/yr, and 13 percent had between 20,000 lb/yr to 40,000 lb/yr. Subbasins 6 and 31 were found to have the highest TSS loads (114,400 lb/yr and 53,000 lb/yr respectively). Generally, a subbasin will contribute a large TSS load if it has a high TSS export rate and large geographic area.

Bank erosion is a significant source for TSS in the Credit River Watershed according to the estimated TSS load ratios. Based on the simulated TSS loads from bank erosion, a large amount of bank erosion occurred in the downstream subbasin channels below the bluff area (141,100 lb/yr to 315,300 lb/yr). The bank erosion from downstream subbasins contributed up to 74 percent of the total TSS load from bank erosion in the watershed. Subbasins 1, 2, 3, 8, 10, 13, 17 and 21 have high potential for bank erosion. Upstream subbasins have either no bank erosion or low risk for bank erosion. The loads from the upstream subbasins ranged from 0 to 70,000 lb/yr. These upland subbasins contributed only 26 percent of the total TSS load from bank erosion.

TSS Load Balance in the Watershed

Based on the SWAT simulations, about 12,956,600 lb of TSS eroded each year from fields in the watershed, accounting for 83 percent of the total non-point source loads. However, about 94 percent of the field erosion was removed by existing buffer strips, wetlands and ponds within the subbasins. Only about 841,500 lb of TSS from field erosion entered the downstream lakes and channels. In the lakes and channels, about 50 percent of the TSS from field erosion was further settled and only 419,700 lb (about 3 percent of total field erosion load) reached the watershed outlet. This accounts for 18.5 percent of the total watershed TSS loads discharged to the Minnesota River.

There was 2,598,100 lb of TSS eroded each year from bank and other non-field erosion in the Credit River, accounting for 17 percent of the total nonpoint source TSS loads in the watershed. However, 29 percent of the eroded TSS loads from non-field erosion settled out in lakes and channels during routing towards the watershed outlet. About 1,853,100 lb of TSS (71 percent) from bank erosion reached the outlet, contributing to about 81.5 percent of the total TSS load (2,272,700 lb) discharged to the Minnesota River.

7.3 2030 Conditions and BMP Scenarios

By 2030 there will be 6,540 acres of new development in the Credit River Watershed. Total urban and rural residential areas in the watershed will be about 8,700 acres (18 percent increase) and 10,700 acres (94 percent increase), accounting for 28 percent and 35 percent of total watershed area, respectively, in 2030.

Not all storm water management standards could be represented in the model. This was particularly true of the storm water pond standards for water quality and runoff rate control. Storm water pond treatment may be approximated with the application of the 30 foot buffer requirement since in a developed condition runoff would be directed to ponds much more than to the buffers. A 30 foot buffer and a storm water quality pond are expected to have similar TSS removal efficiencies. Since not all requirements could be represented, the model results may under predict the performance of the combined package of standards used with new development in the watershed.

Scenarios in this study were assessed using SWAT and meteorological data from 1997 to 2008 and provided the following findings:

- For 2030 land use conditions without storm water volume control, the annual average watershed flow and TSS loading at the outlet are predicted as 25.4 cfs and 3,020,300 lb/yr, which are about 6 percent and 10 percent higher than the 2002 baseline.
- With implementation of the volume control standard (½ inch runoff retention from new development impervious surface), the watershed flow and TSS load are estimated to be 24.7 cfs and 2,954,200 lb/yr, which are about 3 percent and 2 percent lower than 2030 conditions without the standard, but still 4 percent and 8 percent higher than the 2002 conditions for flow and TSS respectively.
- With implementation of 30 foot buffers the watershed TSS load was estimated to be 3 - 6 percent less than 2030 conditions but 4 - 8 percent higher than 2002 conditions. No storm volume retention was simulated for buffer strips in SWAT.

In conclusion:

1. Based on the scenarios assessed in this study, new development had limited impact on overall watershed hydrology and TSS loading (about 6 percent and 10 percent increases respectively). This is most likely due to the fact that the majority of new development was expected to occur in the rural residential area at lower densities with less impervious cover and this area was modeled using switch grass.
2. Scott County's storm water volume control standard and buffer requirements have the potential to mitigate much of the volume, TSS and turbidity increases from future development. With implementation of the volume control standard and 30 foot buffers, the average annual flow rate and TSS load in the watershed were predicted as 3 percent and 6 percent lower than 2030 land use conditions without volume control and buffers. In other words, the volume control standard and 30 foot buffers can mitigate 50% of the expected flow increase and 23% - 62% of expected TSS increase in 2030.

Because the scenario simulations were based on climate data from 1997 - 2008, the average results expressed in this report may not reflect storm-by-storm effects of the Scott County's volume control standard (½ inch volume retention for all storms). Storm event based studies are recommended for future assessments.

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Appendix D. Credit River Fluvial Geomorphic Assessment

Credit River, MN

Final Report - Fluvial Geomorphic Assessment

March 5, 2008

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1. Introduction

In the spring of 2007, the Scott County Natural Resources Department contracted with Inter-Fluve to conduct a fluvial geomorphic assessment of the Credit River Watershed. The project is an attempt to locate channel stability problems, assess overall stream condition and address the concerns of landowners regarding erosion, flooding and threats to infrastructure. Through several meetings, Inter-Fluve and County officials identified the following objectives:

1) *Conduct a reconnaissance level geomorphic assessment that collects information regarding channel stability, infrastructure, fish habitat, and general stream health*
2) *Identify potential restoration or reclamation projects in the watershed*
3) *Create a system of prioritization for identified projects*
4) *Integrate the results of the study with the existing Scott County Geographic Information System (GIS) platform*

Scott County staff assisted with collection of existing data (aerial photographs, maps etc.) and created field maps. Inter-Fluve scientists identified distinct study reaches within the Credit River watershed. Fieldwork commenced in June and July 2007, and Inter-Fluve met with interested landowners on site and with officials from the City of Savage.

The report that follows is a brief summary of the data collected, and outlines general stream conditions by reach for the main stem and tributaries. This report is supplemented by completed project forms which the County will integrate into the Scott County GIS platform.

This fluvial geomorphic assessment was geared toward project identification so that Scott County can eventually develop a long term restoration and watershed management strategy. This type of assessment typically results in a large number of total projects; in this case 48 significant projects were identified on the Credit River mainstem. In order to prioritize these projects for funding allocation, a ranking system for potential restoration projects was developed for the watershed. This ranking system scores potential project sites based on 11 metrics (Table 1). Each metric contributes a value of 1 through 7 for the site, and the total of all of the metrics is the potential project score. Each project can be ranked by a single metric or multiple metrics, so that priority can be a result of any combination of metrics chosen by Scott County staff.

In this system, metrics refer mainly to the degree that a completed project will affect each metric. For example, an infrastructure risk score of 1 reflects that if nothing is done, there will still be no risk to infrastructure from channel instability, either because no infrastructure exists at the site, or risk is extremely low. Conversely, a score of 7 indicates that if nothing is done, public safety and property are under immanent risk. This project did not include any formal structural engineering survey or risk assessment. If infrastructure is determined in this survey to be at

Table 1: Metrics for scoring potential projects.

Metric Score:	*1*	*3*	*5*	*7*
Infrastructure risk	No risk to infrastructure with no action, or no infrastructure present	Low to moderate infrastructure risk and minimal risk to public safety with no action, or inf. value <$100,000	Infrastructure at moderate but not immediate risk, moderate public safety risk, or infrastructure value <$200,000	Infrastructure at high or immanent risk of failure with no action. Public safety at risk or infrastructure value >$200,000
Erosion/channel stability	Minimal improvement to overall stream stability and function, <250 ft of channel bank	Low to moderate improvement of 250-1000 ft of channel bank	Moderate improvement 1000-2500 ft of channel bank	Significant improvement to overall stream stability and function or >2500 ft
Project complexity	Groundwater and surface water issues, professional specialty design services required, heavy oversight, major earthwork, EAW/EIS permitting	Surface water restoration, engineering plans required, earthwork involved, significant permitting	Moderately complex, no specialty engineering required, minor earthwork, some basic permitting	Elementary solution, shelf design, volunteer and hand labor implementation, no permits
Location	Mouth to lower ¼ of watershed	Lower 1/4 to 1/2 of watershed	1/2 to upper 3/4 of watershed	Upper 3/4 to headwaters
Sediment/nutrient loading	No load reduction resulting	Some minor reduction in sediment pollution, increased filtration of nutrients	Moderate reduction in bank erosion and surface runoff entering stream through buffer or other BMPs > 30 ft	Major erosion control through significant BMP installation, stormwater detention, infiltration or buffer filter.
Project cost	> $300K	$201 - $300K	$51 - 200K	$0 - $50K
Aesthetic impact	No impact	Low impact	Moderate positive impact	High positive impact
Fish passage	No impact on fish passage	Low impact (eg. improve depth through culvert, minimal velocity reduction)	Moderate impact (removes perch or other small barrier, natural bottom culvert replacement)	High impact (dam removal)
Public Education	No public education value	Low value - Poor site access, difficult to see, small project	Moderate value - Good access, moderate demonstration value	High value - Easy access, cooperating landowner, good demonstration and high visual impact
In-stream Ecological Benefit	No in-stream ecological benefit	Low benefit - Spot location, small size	Moderate benefit - subreach based, moderate sized project	High benefit - Reach based, >1000 ft of stream
Riparian Ecological Benefit	No riparian ecological benefit	Low benefit - Spot location, small size	Moderate benefit - subreach based, moderate sized project	High benefit - Reach based, large riparian areas, floodplain scale

some risk, we advise local officials to conduct their own formal structural engineering assessment. This scoring does not reflect any risk from flooding. Other metrics gauge the potential project's effect on channel stability, ecological benefit, nutrient loading and fish passage. Because of the interconnectivity of river systems, Inter-Fluve believes strongly that watershed restoration and management should focus on the headwaters and move in a downstream direction. To incorporate this science into the project ranking, we have ranked headwaters projects higher, and scores for this metric decrease with distance from the headwaters.

Potentially expensive projects are scored lower, and more complicated larger projects score lower as well. Sediment and nutrient loading, erosion control and public education metrics are reflective of project size, and thus the ranking system allows for some cost versus benefit analysis. A relatively inexpensive project that can restore a large area or length of stream with manageable design and permitting will score among the highest under this system.

Inter-Fluve has introduced this method of prioritization for other communities, and the system can be a very valuable planning tool. All of the metrics have been developed by Inter-Fluve in conjunction with Scott County staff. To some degree, these metrics have been tailored to fit the size of the watershed, the landuse and the goals of the County managers.

1.1. Review of fluvial geomorphology principles

In order to fully visualize the relationships between habitat formation and stream ecology, it is important to have a basic understanding of fluvial geomorphology. This section discusses the principles behind fluvial processes and how they relate to stream habitat. Stable stream systems are in a delicate balance between the processes of erosion and deposition. Streams are continually moving sediment eroded from the bed and banks in high velocity areas such as the outside of meander bends and around logs and other stream features. In the slow water at the inside of meander bends or in slack water pools, some of this material is deposited. This process of erosion and deposition results in the migration of rivers within their floodplains. The process by which streams meander slowly within the confines of a floodplain is called *dynamic equilibrium* and refers mainly to this balance of sediment erosion and deposition. Streams typically have reaches that fall along the continuum of degradation (eroding) to aggradation (depositing) at any one time in the scale of channel evolution. The location and character of these individual reaches changes over time. When a stream channel is in equilibrium, it may move across the floodplain, erode and deposit sediment, but general planform geometry, cross-sectional shape, and slope remain relatively constant over human lifetimes. Many factors can influence this equilibrium by altering the input of sediment and the quantity and timing of runoff. These factors include soil types, rooted vegetation that holds soil in place, flashy flows that erode banks, large rainfall events or increased sediment pollution that deposits sand or other fine sediment in the channel. When a channel loses its equilibrium due to changes in flood power and sediment load, it can in turn lose essential habitat features. The fundamental channel shaping variables in balance are slope, discharge (amount of water flow per time), sediment load and sediment size. The balance between the amount/ size of sediment and slope/discharge is manifested in complex drainage networks of streams with a specific channel area and slope. Any change in one of the variables can upset this balance, resulting in either aggradation or degradation of the channel.

For example, given that the primary function of streams and rivers is to transport water and sediment downstream, changes in landuse that effect the timing of runoff can effect sediment transport. Clearing of watershed forests, row crop agriculture and urban development cause storm water to reach the stream channel faster, and increase the peak discharge in the stream. Geomorphically, an increase in stream discharge might result in an increase in channel incision or lateral bank erosion, and hence, the amount of sediment being transported downstream. These changes may also result in changes to channel slope. The stream's evolution will persist until it reaches a new dynamic equilibrium between the channel shape, slope, and pattern (Schumm 1984, Leopold et al. 1964).

In a geomorphic assessment, the physical attributes of the stream channel are measured to determine its geomorphic stability and the processes and factors responsible for that instability. Parameters typically measured include channel planform and profile, cross-section geometry, slope, watershed landuse, riparian vegetation, soils, and channel erosion.

1.1.1. Channel dimension

The cross-sectional size and shape of a stream are products of evolutionary processes that have, over time, determined what channel size is necessary to accommodate the most frequent floods. Several parameters can be used to determine the effect of channel shape on stream flow, including channel width, depth, width to depth ratio, wetted perimeter (the length of cross-section perimeter contacting water), hydraulic radius (cross-sectional area divided by wetted perimeter), and channel roughness. The bankfull surface is a common measure used to scale cross-section features to allow for comparisons with different sections within the same watershed or in different watersheds. In a natural river in equilibrium, the bankfull surface is at the top of the banks, the point where water begins to spill out onto the floodplain. In rivers not in equilibrium, the bankfull surface can occur elsewhere on the cross-section.

1.1.2. Channel planform

Flowing water is constantly encountering friction from streambed and banks, and the energy of the stream is dissipated through work. This work is manifested mainly as the entrainment or movement of soil and sediment particles. Energy in linear systems such as rivers is dissipated in the manner that minimizes work (the rate of energy loss), the sine wave form. The energy of a straight line is thus dissipated over a lower slope by the formation of sinuosity, or the typical "S" shape of stream channels (Figure 1). The erosion and deposition of sediment balanced by the resistance of particles to erosion causes and maintains this condition. *Sinuosity* can be measured as either the stream slope/valley slope, or the thalweg length/valley length, where the thalweg is the highest energy point (usually approximated by the deepest point) in the stream channel (Leopold 1994).

1.1.3. Channel profile

The gradient or slope of a stream channel is directly related to its cross-sectional geometry, soils, and planform geometry. Higher gradient streams in hilly or mountainous areas tend to have a lower sinuosity and dissipate energy over turbulent step-pools of harder substrates whereas low gradient streams such as those common to the Midwest have a higher sinuosity and dissipate energy through lower slopes and regular riffle pool sequences. Degradation of streambeds caused by disturbance is problematic, for unlike lateral bank erosion that tends to be localized, changes in bed elevation can be felt over several miles. Channel incision, or downcutting, generally migrates upstream until a stable gradient is achieved.

Figure 1: 2003 aerial photograph showing the sinuous nature of the Minnesota River in the western part of Scott County. Flow is from the south to the north.

1.1.4. Channel stability

As discussed in the above paragraphs, a channel in equilibrium may erode and deposit without being considered unstable. Some erosion in stream channels is normal, and a channel in dynamic equilibrium, balancing erosion with sediment transport, is considered stable. The stability of channel planform and profile are dependent on many factors, including soils, roughness, slope, and disturbance. The *vertical stability* of a channel refers to the state of incision or aggradation of the streambed.

Vertical instability often follows a certain pattern whereby changes in the bed elevation of a stream are translated upstream through a series of small vertical drops called *knickpoints* or *headcuts*. This situation can arise from straightening of streams and thus decreasing channel length or by direct changes in the bed

Figure 2: A headcut and incised channel on Tributary 1 of the Credit River.

elevation of a stream (eg. improper road crossing installation or decreased bed elevation in a main channel). This process of downcutting is called *incision*. A waterfall would be an extreme example of a knickpoint in bedrock. As a headcut moves upstream, the stream becomes more incised and the flood energy increases as more and more volume is confined to an incised or *entrenched* channel (Figure 2). Whereas prior to incision, the stream was able to dissipate its energy over a wide floodplain, after incision this energy is concentrated. Following incision, the stream typically begins to erode laterally with the end result being new floodplain formation at a lower grade. The Schumm channel evolution model demonstrates how a headcut creates an incised channel that becomes laterally unstable and eventually forms a new stable channel at a lower elevation (Figure 3).

Channels in equilibrium provide structure and complexity to support habitat for aquatic species. When a channel becomes unstable, aquatic species have a difficult time adjusting to rapidly changing conditions. Erosion and incision can remove habitat features, and deposition can fill pools and cover spawning gravels.

In a reconnaissance-level fluvial geomorphic assessment, a stream is examined for signs of channel instability such as active headcuts, bank erosion and channel scour, bed sediment type and stability, type, age and stability of bank and bar vegetation, algae, macrophyte and macroinvertebrate populations, type and sorting of various depositional features, floodplain

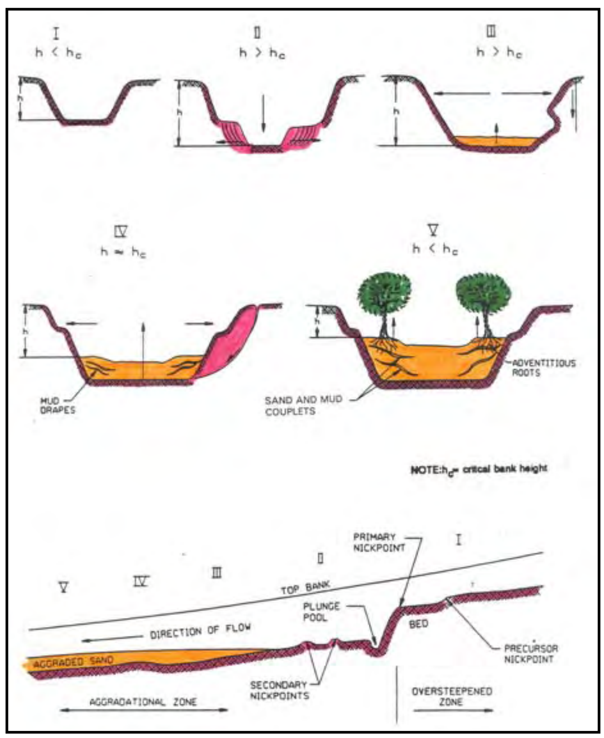

Figure 3: The Schumm channel evolution model (from Schumm, 1984).

deposition, type and consolidation of floodplain soils, and bank erodibility.

1.1.5. Sediment transport

One of the most common misconceptions about streams is that erosion is inherently bad. As discussed above, the dynamic equilibrium of streams involves the opposing forces of erosion and deposition, and this process is normal when equilibrium is maintained. As streams flow, particularly during rainfall or snowmelt events, they entrain particles from the channel bottom and banks. Particles small enough to become suspended in the water column are called *washload*, while particles that move along the channel bottom are called *bedload*. Together, these components make up the sediment transported in the channel. When this balance of erosion and deposition is upset by changing landuse, streams respond in various ways depending on the change. For instance, after clear cut logging, runoff from rainfall reaches the stream faster and the erosive power of a stream can increase, causing excessive incision and/or bank erosion in some areas. As that sediment moves downstream, it will eventually come to areas of low gradient and will be dropped out of the water column. Thus streams can erode excessively in some areas and deposit excess sediment in other areas of the same system. Both consequences of a disturbed sediment equilibrium can have detrimental effects on fish and wildlife habitat.

2. Data Collection / Methods

2.1. Existing data

Inter-Fluve personnel collected and analyzed existing information about the Credit River watershed. U.S. Geological Survey topographic maps from 1985 and Flood Insurance Study (FIS) maps were analyzed for changes in gradient throughout the watershed. Aerial photographs from 2003 were analyzed in a GIS to determine reach breaks based on land use and changes in valley form, soils, profile, and planform. These photographs were compared with aerial photographs taken in 1937, 1947, and 1957, and plat maps from early surveys completed in 1855 to identify temporal changes in land use as well as changes to the planform of the Credit River channel. Information was also gathered from existing soil, erosion, and water quality studies and incorporated into this report.

2.2. Fluvial Geomorphology

Two Inter-Fluve fluvial geomorphologists walked most of the length of the Credit River, collecting information on soils, streamflow, stream bed grain size, observed aquatic biota, fish passage barriers, infrastructure, landuse, and vegetation. This information was compiled on two forms for each reach, a customized reconnaissance form and a Stream Visual Assessment Protocol (SVAP) form. The reconnaissance form was developed by Inter-Fluve scientists and includes information on general channel and fluvial geomorphic conditions, sediment composition, depositional features, riparian vegetation and floodplain morphology, aquatic habitat structures, channel stability, channel geometry, and human impacts on the channel and floodplain. The time of floodplain formation was estimated based on the ages of the oldest trees growing on the floodplain, which was determined by extracting tree cores and counting the tree rings. The SVAP form was developed by the U.S. Department of Agriculture (USDA) in 1989 and includes information regarding channel condition, hydrologic alteration, the riparian zone, bank stability, water appearance, nutrient enrichment, barriers to fish movement, instream fish cover, pools, invertebrate habitat, canopy cover, riffle embeddedness, and observed macroinvertebrates.

2.3. Hydrology

Inter-Fluve hydrologists completed flood frequency analyses for the Credit River based on mean daily discharge gage data collected within 1 mile of the confluence with the Minnesota River from 1989 to 2006. The greatest mean daily discharge in each year that data was collected was used for the analysis as instantaneous peak flow data were unavailable. The magnitude of floods calculated from this analysis will therefore be slightly lower than if instantaneous peak flow data were used.

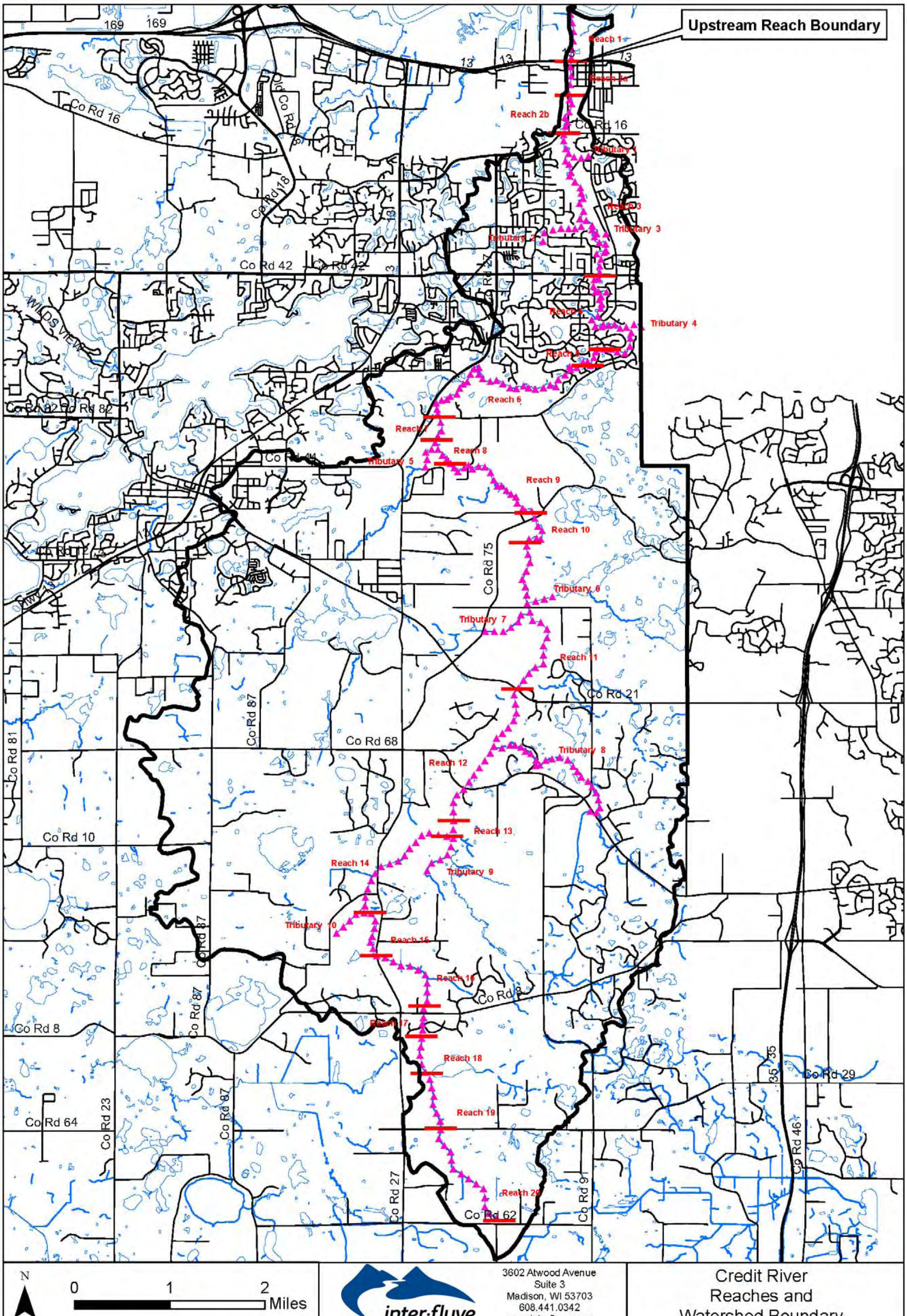

Figure 4: Credit River watershed (black polygon) and reach boundaries (red horizontal lines). Pink triangles indicate 500-ft increments along the channel centerline. Scott County provided the channel, road, and watershed layers; some of the smaller tributaries were not included in these layers.

3. Results

3.1. Geology, topography and soils

The Credit River is a post glacial stream originating near New Market, MN and draining south through farmland and developed land in the city of Savage (Figure 4). The Credit River drains an area of 59 square miles (15,360 hectares), emptying into the Minnesota River just north of State Highway 13 in Savage. Scott County is underlain by early to middle Paleozoic rock. The western half of Scott County is comprised primarily of Upper Cambrian sandstone and siltstone of the St. Lawrence Formation, whereas the eastern half is made up of Lower Ordovician crystalline dolostone, sandstone, and shale of the Prairie du Chien Group (Runkel and Mossler, 2006, Figure 5A). Surficially, Scott County is dominated by glacial till, except along the Minnesota River, which is composed of alluvium and terrace deposits (Lusardi, 2006, Figure 5B). The abundance of glacial till, a material with low permeability because of the silts and clays that fill in the spaces between the larger grains, provides a layer of protection for the county's aquifers that lie in the sedimentary rock below.

The valley form of the Credit River is rooted in its post-glacial history. The Credit River drains through steep slopes at the edges of the Minnesota River valley, but the steep slopes defining the edges of Bloomington and Eden Prairie to the north and Savage and Shakopee to the south, were not formed by the erosion of the Minnesota River. As the Des Moines lobe of

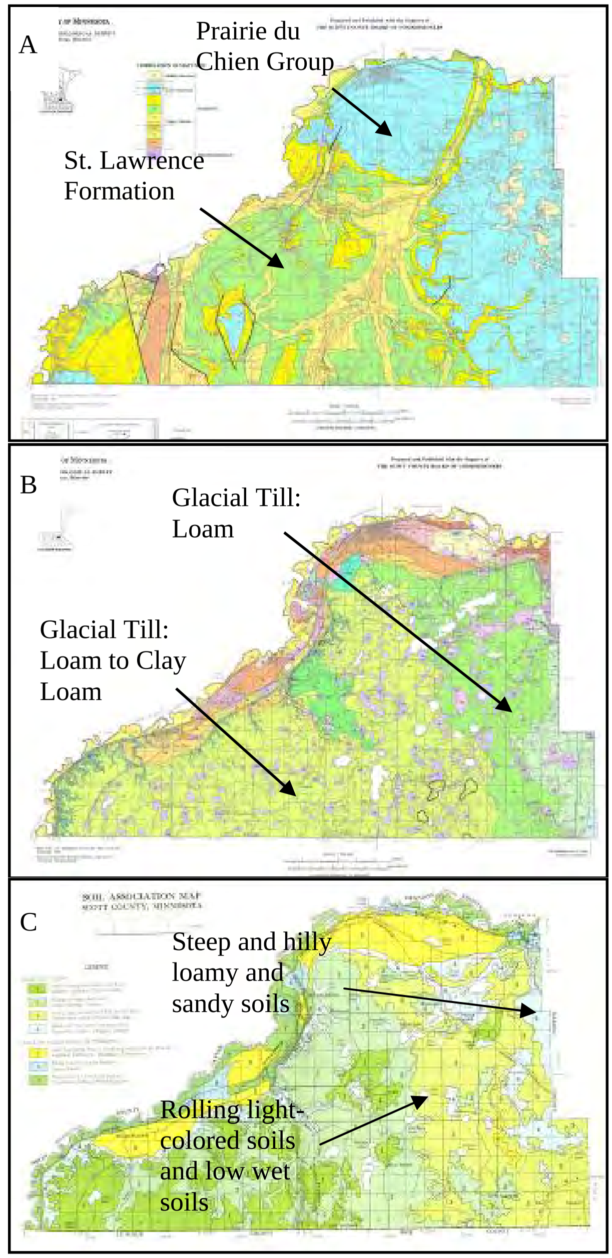

Figure 5: (A) Bedrock (Runkel and Mossler, 2006) and (B) surficial (Lusardi, 2006)) geology for Scott County. (C) Soil map for Scott County (USDA, 1959).

glacial ice retreated around 10,000 years ago, it left behind moraine and till deposits many feet thick across Minnesota. Behind the southernmost terminal moraine, Glacial Lake Agassiz covered a large region from the Brownsville area north to central Manitoba. As the lake overtopped the southern moraine, flowing water (Glacial River Warren) cut down into the deposited glacial sediments and carved out the valley now occupied by the Minnesota River. Smaller drainages began to develop after River Warren subsided, and those tributaries to the Minnesota River began to erode the valley walls left behind by the glacial river. The Credit River is one of these drainages, and steep valley walls are typical in the middle section of the Credit, where the channel has cut down into the old glacial river terrace.

The soils along the Credit River are composed primarily of silt, with some sand, clay and loam intermixed (Figure 5C). The predominance of silt is due to the glacial activity during the Pleistocene Epoch that ended approximately 10,000 years ago. Glacial lobes from the northeast and northwest carried sand and clay-based drift from Lake Superior, northwestern Minnesota, northeastern North Dakota, and Manitoba, and deposited it in southern Minnesota, including throughout Scott County.

There is little variation in topography through much of the Credit River watershed. The topographic features that are present are primarily glacial in origin, such as moraines, eskers, kames, and kettle ponds. Kettle ponds are the main feature that has resulted in the occurrence of land-locked bodies of water. There are many small ponds in the Credit River watershed that have no overland outlet and are dependant on precipitation to maintain their form and function. These land-locked ponds are particularly susceptible to polluted runoff as it takes the water much longer to cycle out of the system than in ponds with inlets and outlets.

From the headwaters to approximately 18 miles downstream, the elevation of the channel decreases 250 feet. In the final 4 miles to the Minnesota River, the channel elevation drops an additional 175 feet. Most of the decrease in elevation in the first 18 miles occurs within three, 1 to 2-mile steeper sections, surrounded by a cumulative 12 miles of relatively low-gradient channel (Figure 6). The low-gradient sections of channel are located in wide, flat alluvial valleys; if these channels have not been straightened and ditched into agricultural channels, they are often in the form of wetland channels. The Credit River has eroded a narrow alluvial valley through the bluff near the Minnesota River with steep valley walls that rise more than 75 feet in some areas (Figure 7).

3.2. Historic Conditions

Most of the arable land within Scott County was converted to farmland starting approximately 150 years ago; to create this farmland many of the smaller rivers and streams were straightened and ditched and most of the wetlands were drained. Settlement began after two treaties were signed with the Dakota Indians in 1851 and 1853. As settlers arrived, the hardwood forests that dominated the region were removed to make room for crops.

The earliest survey of the region was conducted in the early 1850s and published in

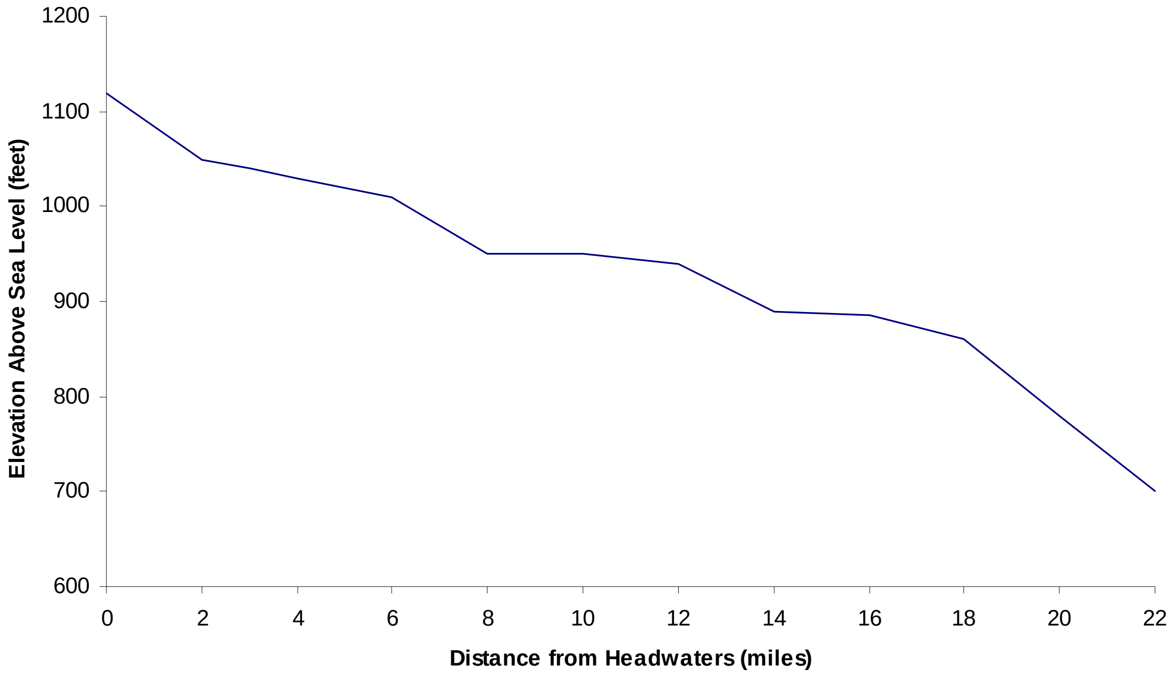

Figure 6: Longitudinal profile of the Credit River based on 1:100,000 scale topographic maps.

1855. These platmaps indicate that the Credit River channel maintained a high degree of sinuosity from the headwaters to the mouth (Figure 8); additionally, the map indicates that low-gradient wetland channels were likely the predominant channel form from the present-day County Road 68 crossing upstream to the 230th St. E. crossing (the river does not continue upstream of this location on the 1855 maps). The straightened ditches that characterize many of the reaches higher in the watershed were created between 1855 and 1937. The 1937 series of aerial photographs indicate that the channel planform looks much the same in 1937 as it does today (Figure 9).

3.2.1. Wetlands

The 1855 platmaps indicate that the Credit River channel is sinuous through some of the wetland regions and non-existent in others, indicating that water flowed diffusely through some wetland areas rather than along a distinct channel. Though it can be assumed that these maps do not precisely indicate the planform of the channel, it is likely that sinuous channels were present in some wetlands and not in others. One difference that was observed in the 1937 photographs was the absence of wetlands that appeared to be present on the 1855 platmaps and that are currently present along the Credit River (Figure 10). The drought that occurred during the 1930s caused many of these wetlands to diminish or disappear and created more potential farmland.

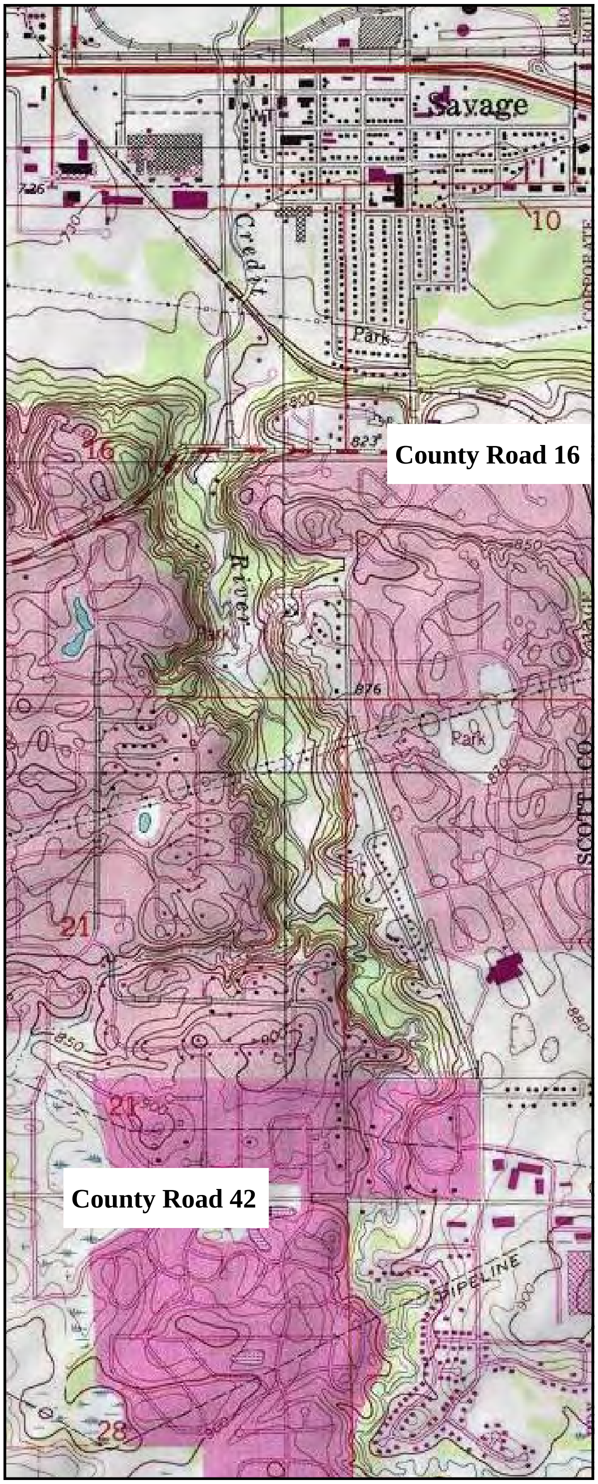

Figure 7: Shaded topographic image of the Credit River and the steep bluff between County Roads 42 and 16. Contour lines are 10 feet.

Figure 8: 1855 plat map from first survey completed in the area. The Minnesota River is the large river into which the Credit River flows.

Figure 9: The planform of the Credit River has remained largely unchanged between 1937 (A) and 2003 (B).

The active crop rows visible in the 1937 photographs are still visible within the wetland on the 2003 aerial photographs, but these areas are no longer actively farmed and are generally dominated by reed canarygrass (Figure 11).

3.2.2. Forestry

Hardwood forests dominated Scott County prior to the logging that began shortly after settlement in the 1850s. Today, only scattered remnants remain of what was the Big Woods

Figure 10: A section of the Credit River was first characterized as a wetland channel in 1855 (A); this section was later turned into farmland and was essentially dry by 1937 (B), but it has since returned to a wetland that is dominated by reed canarygrass (C). Each grid in *A* are equal to 1 mile.

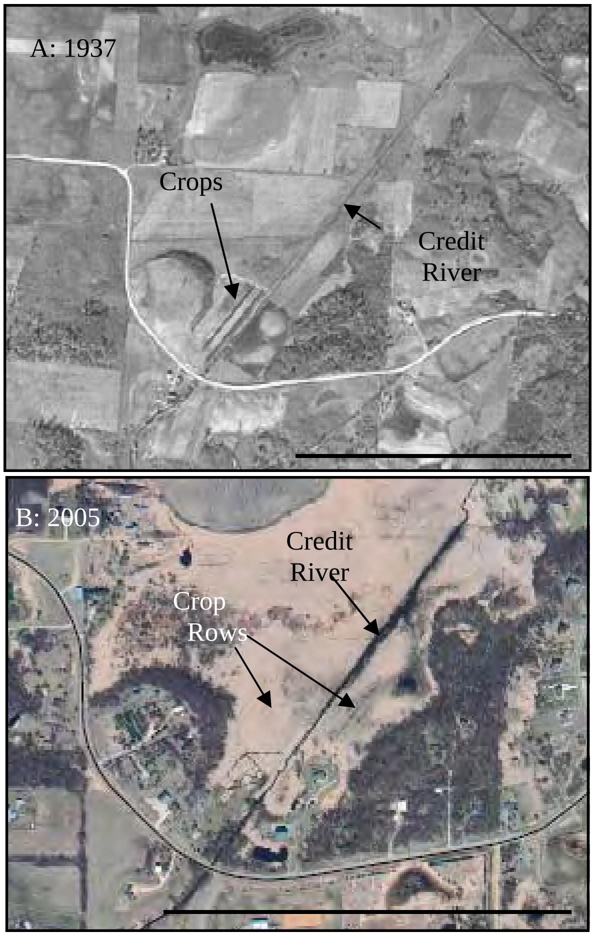

Figure 11: Some land adjacent to the Credit River that was farmland in 1937 (A) has since been converted to wetland with the crop rows parallel to the Credit River still visible from the air during spring or fall (B). Scale bar is approximately equal to 0.5 miles.

ecosystem, an expansive maple-basswood forest that covered 3,400 square miles east of central Minnesota and stretching to Southern Illinois. The largest remaining tracts of Big Woods are the Cannon River Wilderness Park (1,100 acres), Seven Mile Woods (700 acres), and Nerstrand Big Woods (1,300 acres) in Rice County. These hardwood forests provided abundant aquatic habitat with shade cover and woody debris in the form of trunks, large branches and root masses. Large woody debris, as it is commonly known, provides channel complexity as log jams develop, which cause sediment deposition within, and upstream of, the log jam and also cause scouring downstream of the log jam. Log jams can cause the channel to change its course by eroding cut banks or directing flow onto the floodplains, which causes new channels to form. This channel complexity creates habitat complexity that allows a high diversity of macroinvertebrate and fish species to survive. Since most of the forests were eliminated in the late 1800s, many channels have become more stable and less complex, resulting in decreased habitat complexity and decreased biotic diversity. Additionally, the shade provided by the hardwood forests is no longer available, likely increasing water temperatures and reducing the amount of protection from aerial predators. In some reaches of the Credit River, particularly in the steep reaches near the confluence with the Minnesota River where building could not occur because of the steep valley walls, there are still trees covering the hillsides and floodplains that provide shade and woody debris. However, this is a relatively short reach with no upstream woody debris source. Wood that does reach the channel is typically too small to remain in place for very long, and is washed downstream during floods.

3.2.3. Agriculture

Agriculture began with initial settlement in the 1850s. Currently, corn and soybeans are the primary crops with more than 38,000 acres of corn and 34,000 acres of soybeans harvested in

2005 (Scott County data available on website: http://www.city-data.com/county/Scott_County-MN.html). In addition, there was less than 1000 acres of wheat and vegetables harvested. Crops occupied approximately 75% of all farmland, with cattle likely occupying much of the remaining 25%.

3.2.4. Development

Although the major road systems around the Credit River valley have been in place since prior to the 1880s, development was limited prior to World War II. In the early 1980s, the first subdivisions were being constructed (based on 1984 county landuse map – Appendix A), and by the late 1990s, most of the existing developments were in place (based on 1997 county landuse map – Appendix B). In 2005, over 20% of the land in Scott County was residential, 1.4% was non-residential (commercial, industrial, extraction, or utilities), 0.3% was public or institutional, 5% was parks and open space, 54% was agricultural or undeveloped, and 19% was municipal or tribal land (Scott County Community Development, 2007). There is likely a similar distribution of land use in the Credit River watershed as most of the watershed is farmland, with residential development increasing with increased proximity to the Minnesota River. Though data for the Credit River watershed is unavailable, more than one third of the residents in Scott County use a septic system (http://www.co.scott.mn.us/wps/portal/ShowPage?CSF=876&CSI=35146192801002ps). A map developed by the University of Minnesota indicates that impervious cover accounts for approximately 5% of the Credit River watershed (http://land.umn.edu/quickview_data/index.html). Studies have shown that development of watersheds beyond 10% impervious cover results in the extirpation of most coldwater species, including salmonids from coldwater streams (Schueler, 1994). Minnesota DNR fisheries studies from 1985 and 1991 show only warmwater species such as black bullhead, green sunfish, carp, and fathead minnows (Ebbers 1985).

Subdivisions continue to be built as more people move into the suburbs of Minneapolis/St. Paul. There were multiple subdivisions encountered while conducting fieldwork that were not on the 2003 aerial photographs. This expansion will likely continue as farmland is sold to developers to accommodate the influx of residents. Amidst all of this development, there are two parks encompassing 3445 acres within the Credit River watershed that are managed by the Three Rivers Park District. Murphy-Hanrehan Regional Park Reserve (2400 acres) is undeveloped except for trails and provides high quality native plant and animal habitat. Cleary Lake Regional Park (1045 acres) provides many recreational opportunities including boating on Cleary Lake and golf at the Cleary Lake Golf Course.

3.3. Existing Geomorphology

Inter-Fluve geomorphologists conducted

Table 2: Length of each reach along the mainstem of the Credit River and the river station for the upstream and downstream extents of each reach.

Reach Number	Length of Reach (miles)	Distance from Mouth of Credit River (miles)	Begin-ning Station (ft)	End Station (ft)
1	0.61	0.61	0	3200
2a	0.38	0.99	3200	5200
2b	0.61	1.60	5200	8400
3	2.61	4.21	8400	22200
4	2.42	6.63	22200	35000
5	0.44	7.07	35000	37300
6	3.11	10.18	37300	53700
7	0.30	10.48	53700	55300
8	0.42	10.90	55300	57500
9	1.72	12.62	57500	66600
10	0.61	13.23	66600	69800
11	1.86	15.09	69800	79600
12	1.69	16.78	79600	88500
13	0.19	16.97	88500	89500
14	1.50	18.47	89500	97400
15	0.59	19.06	97400	100500
16	0.91	19.97	100500	105300
17	0.40	20.37	105300	107400
18	0.42	20.79	107400	109600
19	0.63	21.42	109600	112900
20	1.29	22.71	112900	119700
Total	22.71			

detailed investigations of the Credit River watershed in an effort to identify areas of bank instability, excessive incision or deposition, channel change due to human engineering, and fish-passage barriers. More than 22 miles of the Credit River were divided into 20 distinct reaches based primarily on channel planform and adjacent land use. The average reach length was 1 mile, though reaches ranged from less than 0.5 miles to more than 3 miles in length (Table 2). In addition to the mainstem of the Credit River, we also assessed the geomorphology and habitat quality of 10 tributaries (Table 3).

3.3.1. Reach 1

Reach 1 of the Credit River is a single-thread channel that extends 0.61 miles from the Minnesota River upstream to the state Rt. 13 bridge crossing. The channel is trapezoidal in cross-section and is 15 to 25 feet wide with 3 to 4-foot steeply sloping banks (Figure 12). The floodplains are 5 to 15 feet wide benches inset into a high terrace on the left bank (horse race track in the early 1900s) and an engineered levee

Table 3: Location of tributaries to the Credit River.

Tributary Number	Distance of conflu-ence from mouth of Credit River (miles)	Mainstem Station at Confluence (ft)
1	1.9	10100
2	3.0	15700
3	3.3	17400
4	6.0	31600
5	10.6	55900
6	13.9	73400
7	14.0	74100
8	15.8	83600
9	16.9	89000
10	18.3	96600

Figure 12: Reach 1 of the Credit River; station 1750 looking upstream. Notice the high berm on the left side of the photograph (river right).

on the right bank that is 15 to 20 feet higher than the channel bed. Large cottonwoods growing on this narrow floodplain are 40 to 50 years old, a finding supported by aerial photograph comparison. In the 1957 aerial photographs, the Credit River channel meandered northeast to the Minnesota River; by 2003, the main channel flowed north in a straight channel with no sinuosity and little channel complexity. The meandering channel of 1957 is visible on the 2003 aerial photographs, and was apparent during the field investigations in 2007 (Figure 13). The bed of this relict meandering channel is currently buried under approximately 8 to 10 inches of organic material and silt. The current, engineered channel was likely completed in the 1960s for flood control as the high levees extend along the Minnesota River as well. The channel alterations have resulted in a channel with few riffles or bars and no interaction with the original floodplain; there is little bank erosion and few pieces of large woody debris that might result in some channel and habitat complexity.

Upstream from the reconstructed portion of Reach 1 the gradient is higher and the channel is in sediment deficit resulting in the emergence of bedrock in a number of locations. Near the mouth of the Credit River, there is a backwater effect from the higher water surface elevation of the Minnesota River (one cause of this is likely the altered location of the mouth of the Credit River). This backwater effect has resulted in a lower water velocity and subsequent increased sediment deposition. The channel in the lower 0.2 miles of Reach 1, therefore, is in sediment surplus and the bed has aggraded multiple feet with sand and silt and has resulted in increased overbank floodplain deposition.

3.3.2. *Reach 2*

Reach 2 extends nearly a mile from State Highway 13 upstream to County Road 16. We divided Reach 2 into two subreaches, with Subreach 1 extending 0.38 miles upstream from State Highway 13. Subreach 1 is a relatively straight, urban channel with limestone bedrock outcropping in the bed of the channel in a few locations. Though it may have been straightened historically, the channel in Subreach 1 might be naturally straight due to the steep gradient in this area. There are few gravel/sand bars but pools are common. The riparian corridor is narrow with active floodplains that extend about 20 feet on either side of the channel and provide the only buffer from the heavy development to the east and the industrial zone to the west. Culverts

Figure 11: The location of the lower Credit River changed between (A) 1957 and (B) 2003.

under the road crossings of State Highway 13 and 123rd St. may be fish barriers at low flows. However, minnows, chub, and crayfish were observed, indicating that there is some reasonable habitat with protected undercut areas caused by bedrock or shade from some overhanging vegetation.

Subreach 2 is a stable, meandering reach with fairly good habitat (Figure 14). There is channel complexity with gravel bars, sandy pools, cut banks, and meanders. Though there are dense residential neighborhoods nearby and multiple road crossings, the actual riparian corridor is wooded and mostly free of development, likely due to the steep bluffs on either side of the channel. The floodplains are wide and contain recent (1 to 2 years) deposition of sand and silt as well as 1 to 2-year old reed canarygrass and other forbs. The channel complexity combined with an active floodplain has resulted in good habitat conditions with abundant fish and invertebrate species present.

3.3.3. Reach 3

The Credit River through Reach 3 maintains a high-gradient, sinuous channel for 2.61 miles from County Road 16 to County Road 42.

Figure 14: Reach 2, Subreach 2, station 6600 looking upstream.

Though the riparian corridor is surrounded by densely populated residential developments, the channel and floodplains have remained free from substantial alterations because of the steep valley walls that allow little development from occurring within a few hundred feet of the channel (Figure 15). Therefore, this is a relatively natural, meandering reach with active cut banks and developing point bars, floodplains that are inundated on a 1 to 5 year recurrence interval, a channel with a steep gradient that results in regularly spaced riffle-pool sequences, and

Figure 15: Reach 3, station 9000 looking upstream.

riparian vegetation of varying maturity that provides large woody debris as well as fine and coarse organic matter to the channel. This channel complexity provides habitat variability important to aquatic life.

Despite the relatively healthy state of this reach, there are a number of concerns. Of the few landowners residing adjacent to the channel, we observed evidence of one that had excavated gravel from the channel and deposited material elsewhere in the channel. Another landowner had built a small stone dam across the channel providing a fish-passage barrier at low flows and had also cleared all of the riparian vegetation from the channel banks with mowed turfgrass being managed to the edge of the channel. In the vicinity of Hidden Valley Park (Station 10700 to 12300) a poorly constructed footbridge has modified local hydraulics and caused excessive bank erosion, and the bridge footing area with poured concrete. This concrete is already being undercut and should be viewed as a temporary solution. At one corner of the Hidden Valley Park parking lot, there is an asphalt drainage chute that concentrates all parking lot runoff during rainstorms directly into the channel. There is no riparian buffer and no opportunity for excess water to drain more slowly through floodplain soils. Hidden Valley Park is well used and this has caused many of the banks to experience excessive bank erosion and loss of riparian vegetation. This reduces canopy cover, increases sediment delivery to the channel, and reduces the

Figure 16: Tributary 1 looking downstream; confluence with Credit River is at station 10100.

effectiveness of any remaining riparian corridor.

Tributary 1 is a small tributary that enters Reach 3 approximately 1.9 miles from the mouth of the Credit River (Station 10100). This tributary originates in the residential developments built on the bluff above the Credit River and has eroded an incised channel with steep banks. The channel is 2 to 4 feet wide and there are no well-defined floodplains (Figure 16). There is an active knick-point about 200 feet from the Credit River that is progressing slowly upstream as a result of abnormally high concentrated flows originating from the upstream residential development and possibly a base-level drop in the main channel. The knick-point has created a 6-foot headcut in the channel.

Tributary 2 extends about 2000 feet from its confluence with the Credit River (Station 15700) to a pond between Vernon Avenue and Utica Avenue (Figure 17). The tributary flows through a 5-foot concrete pipe underneath Utica Avenue 500 feet downstream from the pond. The pipe is perched 2.5 feet on the downstream side, and much of the riprap that was placed to stabilize the banks has been washed downstream. Active progression of successive headcuts has caused the channel to down cut roughly 5 to 6 feet. This incision has, for the time being, been slowed at Utica Avenue, but the crossing is in danger of failure due to future incision and subsequent erosion around the outlet. Previous reconstruction of the channel has occurred near the Princeton Court development. Riprap was placed within the channel and along the banks, but does not appear to have accounted for incision, and does not include any visible gravel or fabric filter component. Riparian vegetation was removed and the right bank is managed for turfgrass, although the degree of incision is independent of vegetation treatment in this case. Much of this riprap has been moved by high flows and downcutting, and is no longer providing the designed stability. The lack of riparian vegetation has reduced bank stability and canopy cover.

Figure 17: Tributary 2 looking upstream; confluence with Credit River is at station 15700.

Tributary 3 is a short tributary that originates in the residential developments on top of the bluff and empties into the east side of the Credit River at Station 17500. Similar to Tributary 1, this is a steep, narrow channel with some scouring and incision (Figure 18). There are no headcuts, but the channel is deeply incised with steep hillsides for banks. This may be the natural form of the tributary, or it may be exacerbated by the channeling of rainwater off of the streets and driveways directly into the channel.

3.3.4. Reach 4

Reach 4 extends 2.42 miles from County Road 42 to River Crossing Road. This is a sinuous reach with wide, undeveloped floodplains similar to Reach 3 (Figure 19). The gravel and sand bed is mobile and there are riffles and pools regularly spaced; active cut banks are prevalent as are point and bank-attached gravel bars. There is floodplain deposition and the riparian vegetation is of varied maturity, providing a mix of large and small woody debris and organic matter to the channel.

Residential development, though dense, has been limited, with a few exceptions, to the relatively flat land on top of the bluff, high above the channel and separated from the channel by steep valley walls. Of the residences near the channel, eight landowners have replaced the riparian vegetation adjacent to the channel with mowed turfgrass, gardens, or stone walls. Riprap has been installed in a few locations, with some treatments failing and increasing bank degradation. Additionally, two small stone dams crossing the channel are fish passage barriers at low flows.

Figure 18: Tributary 3 looking upstream; confluence with the Credit River is at station 17500.

Figure 19: Reach 4, station 30500 looking upstream.

Tributary 4 is a low-gradient tributary that joins the Credit River 6 miles from its mouth. Two branches of the tributary that originate in residential developments come together in a wetland that extends to the Credit River. The wetland channels are in good condition; the only restoration needed would be native wetland plant restoration to combat the exotic reed canarygrass (*Phalaris arudinacea*) that currently dominates the reach.

3.3.5. Reach 5

Reach 5 is a short reach that extends 0.44 miles from River Crossing Road upstream to the beginning of a low-gradient, wetland channel. This reach has most of the same fluvial geomorphic and ecological characteristics as Reach 4, but landowners have not negatively impacted the floodplains or channel to the same degree. There is little development within the vegetated riparian corridor that is up to 200 feet wide and there are few occurrences of attempts at restricting channel migration with riprap or concrete bank stabilization methods. The channel is meandering with active cutbanks and gravel bars and there is some large woody debris within the channel (Figure 20). The channel bed alternates between riffles and pools with the riffles composed primarily of cobbles and the pools composed primarily of sand and cobbles. This channel diversity creates high quality habitat for the fish and macroinvertebrates observed. There is evidence of overbank sandy deposition and previous channels found on the floodplains indicate active channel migration.

Figure 20: Reach 5, station 35400 looking upstream.

The canopy cover is diverse and includes green ash, black willow, cottonwood, elm, maple, and oak; these trees range in age from saplings a few years old to approximately 50 years old. One landowner is managing mowed turfgrass in the riparian area, but there is a narrow buffer of riparian vegetation between the lawn and the channel. Another landowner has cleared much of the undergrowth on the floodplain but has retained the overstory.

3.3.6. Reach 6

Reach 6 is a wetland reach extending over 3 miles from the upstream extent of Reach 5 to County Road 74 (Station 37300 to 53700). The channel geometry is primarily rectangular with sporadic narrow sand bars (Figure 21). The channel planform is extremely sinuous and there are many secondary channels and abandoned channels, indicators that this wetland channel is actively migrating within the alluvial valley. The bed of the channel consists primarily of sand, whereas the banks are silt with some peat; there are a few short riffles created by large woody debris or large embedded clasts and many pools of varying depths. Though there is no canopy cover from riparian vegetation, there are overhanging banks in some locations that provide protection from predators and heat. The wetland is dominated by exotic invasive reed canarygrass. There are three wooden box culverts under County Road 74 that are fish passage barriers at low flows.

The form of the channel in this reach is somewhat dependant on the regional climate. The boundaries of the current wetland are similar to those made by the first surveyors on the 1855 plat maps. The construction of County Road 27, and the berm associated with the road, appears to have forced the Credit River to the east of the road and eliminated the possibility of any westward channel migration. However, analysis of the 1855 maps indicates that there was a trail in the same location as County Road 27, and this trail does not pass through the wetland. Therefore, the Credit River has likely remained in its current location since early settlement except for local migration within the meander beltwidth of the channel, and the highway may have had little impact on the Credit River within Reach 6. In 1937, Reach 6 was entirely farmland. The historic Credit River was still a meandering channel, but the land was cultivated to the channel banks, except in some areas where there were a few trees separating the crops from the channel. A long period of drought or dewatering must have occurred for the wetlands to disappear and riparian trees to flourish.

3.3.7. Reaches 7-8

Reaches 7 and 8 are grouped together in this discussion due to similarity of character (Figure 22). Reach 7 extends 0.3 miles upstream from County Road 74 through a narrow (100 to 300 feet) wetland with adjacent farmland. Reach 8 extends another 0.42 miles upstream through a much wider (more than 1500 feet wide) wetland that is adjacent to both farmland and newly developed residential neighborhoods. The channel through Reach 7 is single-thread, whereas the Reach 8 channel has multiple active

Figure 21: Reach 6, station 52300 looking upstream.

Figure 22: Reach 7, station 53300 looking upstream.

side channels as well as some abandoned channels. The channel through Reach 8 is able to migrate laterally to a much greater extent than through Reach 7 because of its greater belt width (wide undeveloped floodplain). There is only one short section of Reach 7 through which the landowner has removed any wetland or riparian vegetation and has mowed turfgrass to the edge of the channel. Invasive reed canarygrass dominates the riparian vegetation in these reaches.

Although marked as wetland on the 1855 platmaps, reaches 7 and 8 were meandering channels through farmland with narrow riparian buffers in the 1937 aerial photographs (Figure 23). Crops were grown to within 100 feet of the channel, and channel migration was restricted to within this narrow riparian corridor. Since this period of drought and intense farming, the area has reverted back to a wetland; many invasive

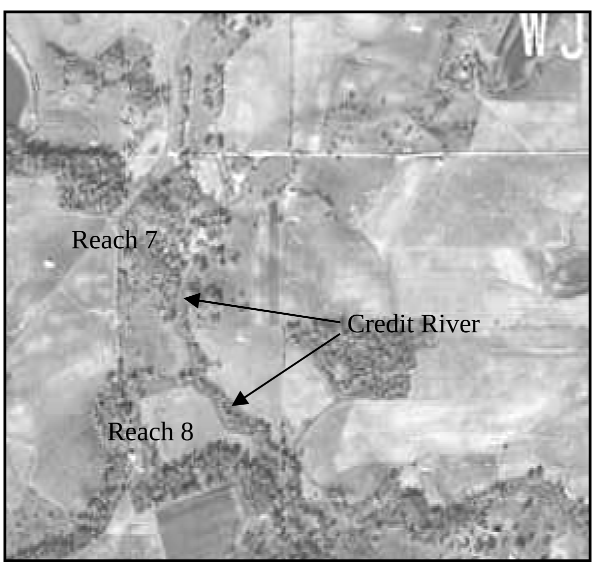

Figure 23: In 1937, the channel in Reach 7 and 8 had a narrow riparian buffer separating it from adjacent agriculture fields.

plant species thrive in disturbed areas, and the reed canarygrass likely spread throughout the farmland soon after it was abandoned.

Tributary 5 joins the Credit River from the west side of the wide wetland of Reach 8. It is a meandering channel with active, wooded floodplains before it reaches the wetland through which it meanders before joining the Credit River. Though a dirt driveway does cross over this tributary, there are no major areas of concern apart from reed canarygrass monoculture in the riparian wetland areas.

3.3.8. Reach 9

Reach 9 extends 1.72 miles from just downstream of Hampshire Road to just downstream of Murphy Lake Boulevard. The channel through the entire reach is sinuous with no evidence of historic straightening, ditching, or other channel reconstruction. However, we divided this reach into three subreaches based on channel type (Figure 24). Subreach 1 is primarily a single-thread meandering reach with forested floodplains and surrounding hillsides. The valley width is approximately 0.6 miles (3100 feet) and there is farmland to the north and some residential development to the south. However, the floodplains are active with riparian vegetation of varying maturity and relatively minimal human disturbance. Historic channels through the floodplains likely become activated during floods, increasing habitat potential. The channel maintains regularly spaced gravel-dominated riffles and sand-dominated pools;

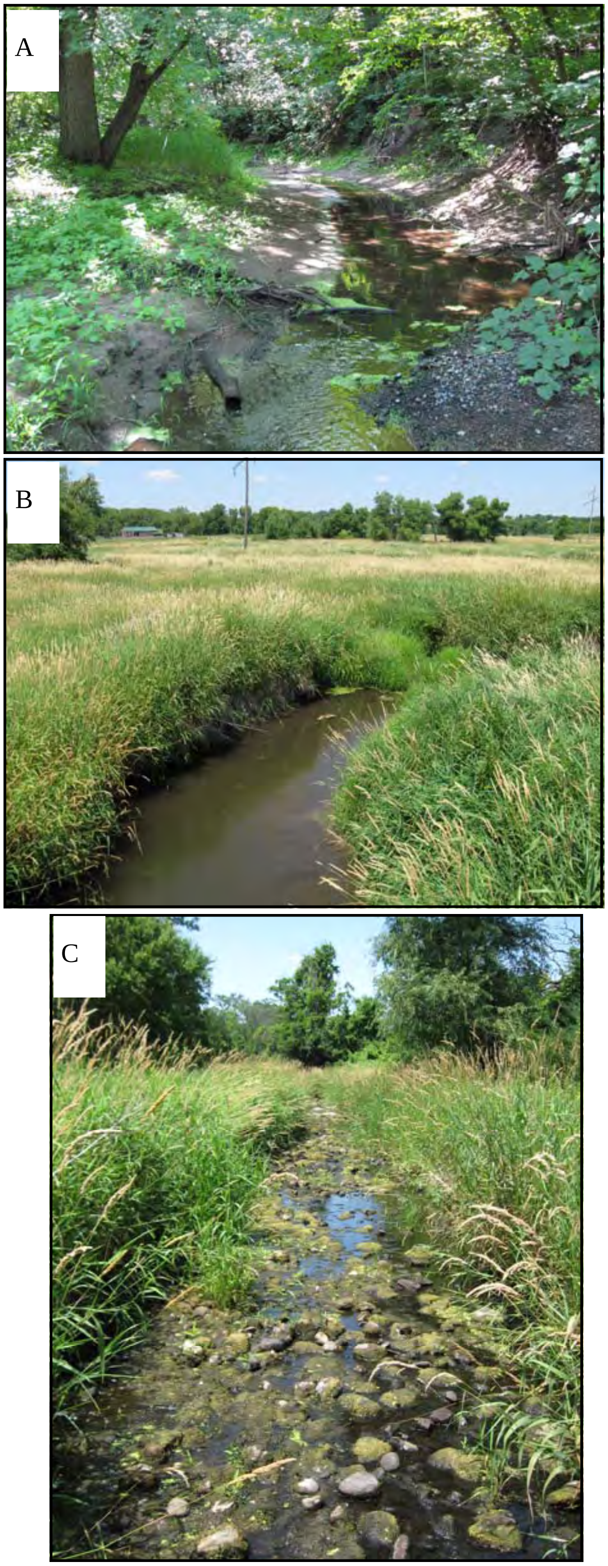

Figure 24: Reach 9, (A) Subreach 1 at station 58900 looking upstream, (B) Subreach 2 at station 63450 looking downstream, (C) Subreach 3 at station 65900 looking downstream.

undercut banks and canopy cover provide good protection from predators.

Subreach 2 is a wetland reach and the channel is sinuous with multiple active and abandoned side channels. Though there is farmland on the adjacent hillsides, the wetland is up to 800 feet wide and the valley crests are over a mile apart. This wetland appears to have remained intact through the drought of the 1930s, though it is difficult to determine with the low quality of the aerial photographs. However, cultivated row crops are not apparent near the channel and there appears to be open land with sporadic mature trees, indicating that it could have been a wetland in 1937 with similar characteristics as today. In the 1957 aerial photographs, the wetland is present with a few trees growing throughout the wetland. There is no distinct channel through the wetland indicating that flows were diffuse and then came together as a single channel at the upstream and downstream extents of the subreach. Channel migration is common in this subreach, as evidenced by the frequent active or abandoned side channels. The bed consists mainly of sand and the channel is dominated by runs with many pools of varying depths. A few riffles with small gravel on the bed are also apparent. A covered bridge about 1000 feet upstream from Hampshire Road crosses the Credit River and the structure that was built below it to provide water flow is a complete barrier to fish passage. Below the covered bridge is a solid concrete foundation with four, 2.5-foot pipes for water flow. On the downstream end of this foundation is a 7.5-foot by 18-foot concrete apron that is perched 1 foot above the channel. At low flows, fish are completely blocked from upstream or downstream travel.

Subreach 3 has a steeper gradient than Subreaches 1 and 2 and the channel has a cobble bed. The alluvial valley is narrower and there are steep hillsides to the west and south. There is less canopy cover in this subreach than in Subreach 1 as much of the riparian and surrounding vegetation has been removed.

3.3.9. Reaches 10-14

We grouped Reaches 10 through 14 in this discussion because these reaches have been heavily impacted by human engineering since agriculture began in the region. Reaches 10 through 14 span 5.85 miles of the Credit River and are primarily straightened agriculture ditches with little or no riparian buffer between the crops and channel. The water flow is not continuous through these reaches during periods of low flow, which is likely due to dewatering. Reach 10 has a slightly meandering channel with wide, active floodplains that are heavily vegetated. An abandoned railroad berm restricts channel migration 100 feet downstream from Murphy Lake Boulevard and the concrete box culvert under Murphy Lake Boulevard is perched 1 foot on the downstream side, acting as a fish passage barrier at low flows.

The remaining four reaches have ditched channels with no sinuosity (Figure 25). In Reach 11, levees up to 15 feet above the channel bed separate farmland from the channel and prevent any overbank flooding. Reaches 12 through 14 are primarily wetland reaches, but the channels are straightened ditches with few curves. A railroad berm divides the wetland about 0.4 miles upstream from Cleary Lake Road in Reach 12 (Station 81500). This berm and the accompanying bridge over the channel were active in the 1937 and 1957 aerial photographs, but today the bridge is gone, and only the berm and wooden piers remain. The berm continues to restrict channel migration within the wetland.

Many of the areas that are currently wetland

Figure 25: Reach 11 at station 71500 looking upstream. Beaver have constructed a small dam creating the pool covered with duckweed.

were row crops in the 1937 aerial photographs, and those crop rows are still visible in the 2003 aerial photographs. Some of these crops were already abandoned and were reverting back to wetland ecosystems when the 1957 aerial photographs were taken. Reach 13, which is currently open water within a wetland, was dry land with a single channel flowing through it in 1937 and was a pond about half its current size by 1957. Complete wetland and channel restoration, coupled with the return of the natural hydrology, are required for these reaches to return to fully functioning riparian and wetland ecosystems.

Tributary 6 flows into the Credit River 200 feet downstream from 175th St. in Reach 11 (Station 73500). This is a straightened ditch emanating from an earthen dam and reservoir within a nature preserve about 1500 feet to the east of the Credit River (Figure 26). The dam is less than 50 years old as it is not present in the 1957 aerial photographs. In 1937 and 1957, this tributary was a straightened ditch that originated further east amongst farmland and wetland.

Figure 26: Tributary 6 looking upstream from dirt road that is approximately 100 feet from the confluence with the Credit River at station 73500. The former wetland is visible in the background.

Tributary 7 flows into the Credit River 300 feet upstream from 175th St. in Reach 11. This tributary has been a straightened ditch between row crops since 1937, though the location of its confluence with the Credit River has changed over the years. This tributary provides no habitat as it is dry for parts of the year, maintains no channel or habitat complexity, and receives all of the runoff from the surrounding farms.

Tributary 8 flows into the Credit River about 0.5 miles downstream from County Road 68. It originates in farmland to the southeast and flows through straightened ditches before it flows under County Road 68. The 4-foot culvert under County Road 68 is perched 4 inches and is a fish passage barrier at low flows due to inadequate depth and perching. Downstream of this culvert, the tributary meanders through a narrow forested riparian corridor between developments before entering The Legends Golf Club. After flowing through the golf course, the tributary flows through a culvert under Brookwood Road and meanders into the wetland before joining the Credit River.

Tributary 9 joins the Credit River in Reach 13, the reach that is currently a small pond within a wetland. This tributary originates in a small pond to the south and has been straightened and ditched since 1937. This tributary provides little aquatic habitat with no channel or habitat complexity and little canopy cover.

Tributary 10 joins the Credit River near the upstream end of Reach 14. It is a short tributary that has been straightened and ditched since 1937. The channel is about 10 feet wide and lies predominantly within a wetland. The bed of the channel consists of 1 to 2 feet of fine silt and sand that has aggraded since the channel was constructed. As with the other ditches in the watershed, this tributary provides little high quality aquatic habitat.

3.3.10. Reaches 15-20

We grouped these six reaches for similar reasons as Reaches 10 through 14: these reaches represent a long section of river, 4.24 miles, that has been substantially altered by human activities (Figure 27). Reach 15 contains a meandering channel with active, wooded floodplains, but there are multiple culverts under private driveways that are fish passage barriers. Reaches 16 through 19 are straightened agricultural ditches with little or no riparian buffer between crops and the channel. There is essentially no sinuosity, canopy cover, or channel or habitat complexity in these reaches. Two fish passage barriers in Reach 16 include a 1.5-foot concrete dam and a 7-foot culvert under County Road 8 that is perched 6 inches on the downstream end. The amount of water in these ditches is variable with dewatering likely the main cause. The channel through Reach 20 is a straightened ditch through wetland. The crop rows of the early 20th century are still visible, but the wetland is now dominated by reed canarygrass. Farming is still active adjacent to the wetland and new residential developments are currently being constructed. The channels through these straightened reaches generally have sand/silt beds with occasional cobble riffles.

Figure 27: Reach 20 at station 116650 looking up-stream.

Though the 1937 aerial photographs only extend the upstream extent of Reach 16, the form of the channel through Reaches 15 and 20 has remained the same since 1937 and 1957. Reach 16 is the only reach that contains sections of channel that were slightly more sinuous in 1957 than they are currently. Portions of these six reaches that are currently wetland were likely farmland in 1937, but were beginning to be converted into wetland by 1957. The channels through these wetlands, however, have remained straightened and ditched.

3.4. Surface Water Hydrology

Seventeen years of mean daily discharge data have been recorded on the Credit River 0.6 and

0.9 miles upstream from the confluence with the Minnesota River between 1989 and 2006 (data for 2002 was not available). The annual hydrograph indicates that the Credit River peak flow generally coincides with the spring snowmelt, but that flows are flashy through the rest of the year and driven by rainstorm events (Figure 28). Winter flows were generally

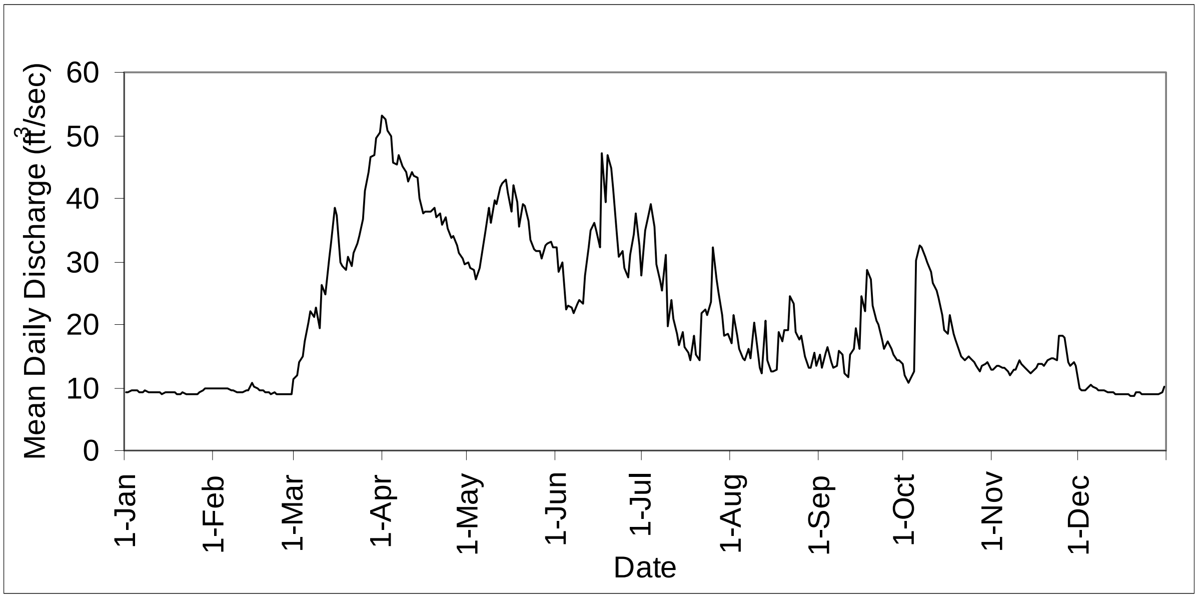

Figure 28: Hydrograph of the Credit River based on average mean daily discharge values from 1989 to 2006 (data for 2002 were not available.

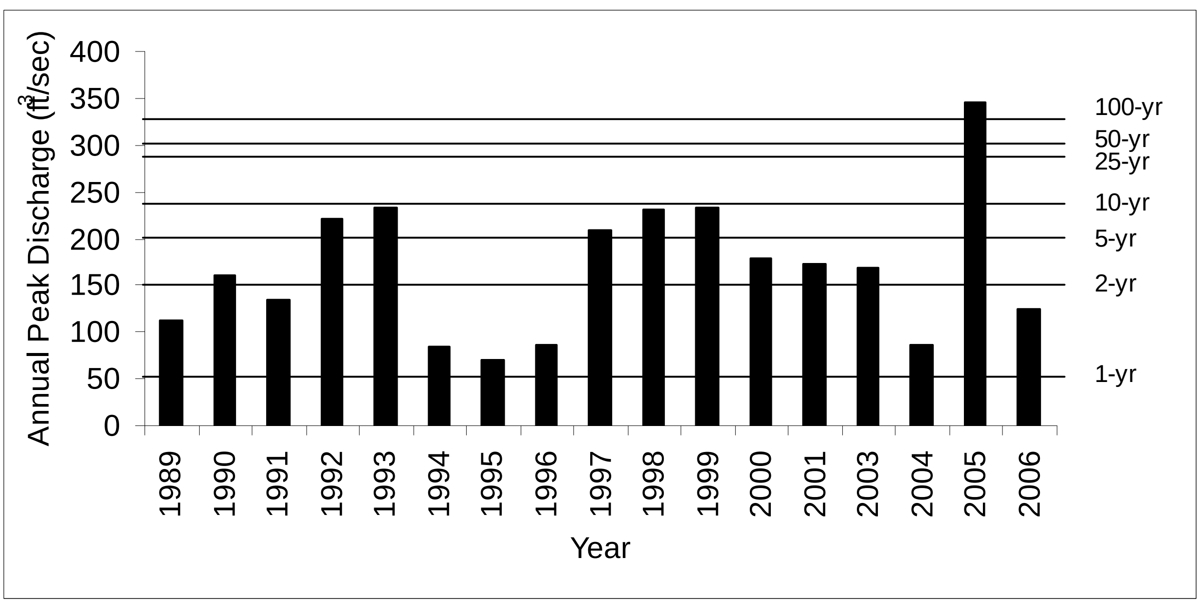

Figure 29: Annual peak discharge for the Credit River based on the greatest mean daily discharge value for each year. Flow data for 2002 was not available. Horizontal lines indicate the magnitude of discharges for the recurrence intervals noted on the right side of the figure.

estimated as a result of ice cover; therefore, base flows of 10 ft^3/sec between early December and early March do not represent actual flow magnitudes.

Though data for only a short period of time were available, analysis of peak flows indicates that periods of wet and dry years occur in cycles of roughly 10 years (Figure 29). Between 1989 and 1993, floods in two of the five years exceeded the magnitude of the 5-year recurrence interval; between 1997 and 2003, floods in three of the six exceeded the magnitude of the 5-year recurrence interval and all exceeded the magnitude of the 2-year recurrence interval. These periods of high flows were separated by floods that did not exceed 100 ft^3/sec. The flood of record occurred in 2005, between two years of flows that did not exceed the magnitude of the 2-year recurrence interval. The flood in 2005 was 346 ft^3/sec and exceeded the magnitude of the 100-year recurrence interval.

The peak flow data indicate that the Credit River floods with a high degree of variability in its magnitude. Through field investigations, we found that the reaches that had not been straightened and ditched had retained functional floodplains. We found recent overbank deposition and piles of woody debris on the floodplains indicating recent overbank flooding. This flooding is important for floodplain plant regeneration and the flux of nutrients between the channel and the floodplains. Floodplains are constructed in response to current hydrologic conditions and available sediment (Wolman and Miller, 1960; Andrews, 1980; Leopold, 1994); the active floodplains adjacent to the Credit River are likely built by relatively common floods similar in magnitude to floods with a 2-year recurrence interval.

These hydrologic analyses only apply to the downstream reaches of the Credit River that are below substantial tributaries. The upstream reaches, particularly those that have been straightened into agricultural ditches, likely operate differently as there are no active floodplains, rainwater drains quickly off of the farmland in to the channel, and there is much less water in the system.

4. Management Recommendations

The following descriptions outline the project types shown in the Priority Project Ranking system. Many projects involve some aspect of more than one of the types listed. The ranking system lists infrastructure as a project type, meaning simply that some infrastructure (building, road, bridge etc.) would be affected by the project. No specific description is given below.

4.1. Project type – Natural channel restoration/ Relocation

Channel relocation is also called natural channel restoration, natural channel design, or re-meandering and all involve actually building a portion of stream channel different from the existing plan and profile. Inter-Fluve typically refers to channel relocation projects when discussing the movement of a channel to avoid some planned infrastructure. For instance, when new roads are constructed, it is sometimes cost effective to move a stream channel out of the path of the road or to construct a more stable crossing alignment. These situations are often good opportunities to restore channelized reaches into a more geomorphically and ecologically stable configuration.

Natural channel restoration projects involve the construction of a meandering channel with habitat and geomorphic features mimicking natural forms. Gravitational forces, the rotation of the earth, and the friction of water on soil all combine to cause flowing water to assume a sinuous planform. Steeper streams in rockier terrain tend to be straighter and dissipate energy readily through cascading riffles or waterfalls. Lower down in the watershed, or in flatter areas like the Midwest, streams erode slowly through sand, silt and loam to form lazy, winding rivers and streams. Minnesota has several million acres of drained land, with over 80% of that drainage achieved through ditches and channelized stream segments. It is very likely that all ditches with perennial flow were at one time meandering streams, and many of our dry summer ditches were at one time intermittent stream channels or wetlands. Restoring the geomorphic function of these ditches through natural channel restoration can lead to dramatic improvements in habitat and water quality. Ditches are generally deeper and more incised than their sinuous predecessors. Incised streams move flood water quickly, and they do so by concentrating more of the flood flow in a large channel rather than across the floodplain. By adding sinuosity, we can decrease the slope of the channel and in some cases raise the bed of the stream, thereby reconnecting the stream with its former floodplain. Restoring floodplain connectivity slows the exit of water off of the land and allows for greater infiltration, higher baseflows, lower stream temperatures and lower peak flood flows. Restoring incised ditches can be accomplished in three main ways. The first and most inexpensive way is to introduce roughness elements that encourage the formation of a sinuous channel inside the ditch cross-section, essentially using natural forces to carve out a floodplain over a long period of time. The other methods involve either lowering the floodplain through excavation, or raising the channel bed. Clearly, restoring meanders to a stream requires that the stream occupy a wider swath of land than did the straightened ditch. In the upper Credit River, many of these headwater areas are bordered by wide uncultivated wetlands, and thus restoration would not encroach upon existing agricultural land. In areas where little or no buffer currently exists, restoration would need to include expansion of the buffer. The meander limit, or belt width of a stream, is generally a function of the watershed area and the discharge of the stream. For small, upper watershed channels on the Credit River, a reasonable belt width might be in the range of 50 to 100 feet (assuming a channel top width of 15 to 30 feet).

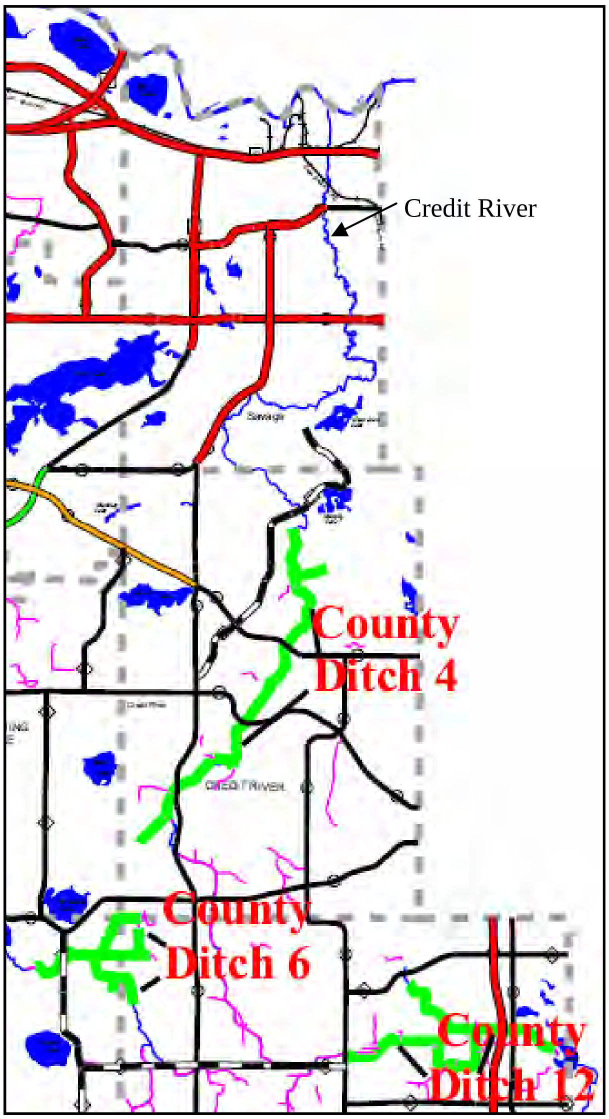

Figure 30: The Credit River is considered a county ditch (#4) between Reaches 11 and 14 and a private ditch (pink line) from Reach 15 to the headwaters at Reach 20. All tributaries upstream from Reach 11 are private ditches. (Modified from map produced by Scott County.)

Scott County has identified 42% (9.5 miles) of the Credit River as either public or private ditch (Figure 30). Public ditches make up 23% (5.2 miles) of the Credit River extending from Station 69800 to Station 97400 and including Reaches 11-14. Private ditches make up 19% (4.2 miles) of the Credit River extending from Station 97400 to the headwaters at Station 119700, which includes Reaches 15-20. In addition to the upper 42% of the Credit River being designated as public or private ditch, Tributaries 6 through 10 are also ditches. This means that a substantial proportion of the Credit River watershed could be restored through natural channel restoration or relocation.

Hydraulic modeling and hydrologic analysis are important components of stream restoration in regulatory drainages. Flood peaks spreading out on downstream farmland can actually be reduced by attenuating the flashy floods upstream through floodplain reconnection and stream restoration. Ditch construction in the

Midwest typically occurs without any hydraulic modeling of flood flows to see if ditching actually accomplishes the intended goal. Computer modeling of flood elevations can now be used to determine the practical value of ditches and determine the impact of channel restoration.

Natural channel restoration involves several steps, the first of which is dewatering. Given enough floodplain width, this can be accomplished with little or no effort by simply building the new channel completely off line from the existing ditch. The new channel is constructed "in the dry" adjacent to the existing ditch. Rough channel excavation is completed, with the spoils either removed off site or stockpiled near the existing stream for later filling. Fine grading involves bank stabilization, riffle and pool construction where appropriate, and incorporation of habitat elements. Once the channel has been stabilized, either using fabric methods or by allowing vegetation to grow for a period of time, then water is diverted permanently into the new sinuous channel and the old one is filled in to the floodplain level (Figure 31).

Natural channel restoration in farmed headwater systems can be complicated by the elevation of road crossing inverts. Many modern culvert crossings were installed flush with the bottom of the ditch at the time of construction. The elevation of the channel bottom at the time of culvert installation was more than likely much lower than the elevation of the channel bed prior to ditching, when the stream was a smaller, sinuous channel with good floodplain access. Restoration projects in agricultural areas don't typically involve raising the channel bed at road crossings, which would require replacement of the culvert to minimize or eliminate any upstream rise in flood elevation. The cost of creating an incipient floodplain on a restored stream, or raising the channel and possibly replacing crossings can limit the amount of restoration that a local group can reasonably accomplish.

Figure 31: Stream restoration in agricultural areas can sometimes involve reconstructing a new valley form or incipient floodplain (photograph: Inter-Fluve).

New stream channel construction can vary greatly in cost between \$50 and \$200 per foot, depending on constraints and floodplain restoration strategies. A large project might restore a mile of stream channel, placing the cost between $200,000 and $1 million. Granting programs in the Midwest are fairly limited in their ability to fund many large projects of this type, and many coastal and Great Lakes programs are currently focused on fish passage. Hopefully, future granting programs, farm bills and state restoration programs will recognize the importance of headwater stream restoration in our agricultural watersheds.

4.1.1. Restoration and Ditch Law

A major obstacle in restoring headwater streams is current drainage law, governed in Minnesota by Minnesota Statutes, Chapter 103. The best option for restoring a farm ditch would be abandonment of the public drainage easement, which is a very difficult process in Minnesota. The State Water Resources Board (later BWSR) originally authorized the creation of watershed districts, who in turn could govern drainage systems within their geographic boundaries. County boards were required by law to assess the potential environmental and natural resources impacts of drainage projects, but much of this was done before watershed issues were deemed important to the general public. Since the 1960s, more watershed residents have raised questions about drainage and water quality, and whether the current drainage law protects the public good in the best possible way. The Clean Water Act and subsequent farm bills have placed more of an emphasis on wetland protection, but because the existing laws are designed to increase drainage, not reduce it, abandonment is still challenging. In Scott County, the County is the drainage authority responsible for operation, inspection and maintenance of drainage ditches. A ditch is owned by the landowners, and therefore the costs for maintenance of ditches is typically borne by the landowners. The three main ways of achieving some restoration in regulatory ditches are full abandonment, partial abandonment, and impoundment. Full abandonment requires initiation by landowners, a signed petition by 51% of the landowners assessed for the system, and final approval by the authority. This is usually done in urban areas where the ditch is no longer in existence or in areas with few landowners. Abandonment through the RIM program is possible but often requires an engineering study and some drainage modifications to prevent downstream flooding from worsening. Partial abandonment is not usually done because the drainage authority can be lost if some portion of the system is abandoned. The third option involves installation of water control structures to restore wetland conditions, but those structures must be maintained by the landowner.

Wetland restoration as floodplain management ties directly into the discussion of ditch management and natural channel restoration. Although the upper watershed has many reaches with wide wetland buffers, there is still a central ditch and its associated tile lines draining the landscape. Wetland restoration and/or wetland stream restoration would need to include managing tile drainage and minimizing or eliminating ditch drainage so that water stays on the wetland longer. In recent projects completed with the Oneida Tribe in Green Bay, Wisconsin, Inter-Fluve has combined wetland and stream restoration with buffer management in headwater tributaries to a small agricultural stream. In just four years, the water quality of the system has improved to the point where trout will be re-introduced (Snitgen and Melchior 2007). Many such examples of a headwater restoration approach can be found around the Midwest.

A major obstacle to native plant wetland restoration is the ubiquitous presence of reed canarygrass (*Phalaris arudinacea*), giant reed grass (*Phragmites australis*) and cattail (*Typha angustifolia*). These invasive species have taken over most of the wetlands in the Midwest, with reed canarygrass often colonizing disturbed sites to become monoculture. The fecundity of these plants, their ease of seed spreading, and their proximity to moving water make wetland restoration with native plants extremely difficult. However, the hydrologic benefits of invaded wetlands still remain. Eventually, better methods will be discovered that will help improve the diversity of restored wetlands and minimize invasion by exotic species.

4.2. Project type – Grade Control

In reaches with extreme incision or active downcutting, grade control is often prudent. Grade control involves the installation of an armored riffle or drop structure placed to prevent any further incision from traveling upstream. Grade controls can be discrete weirs, concrete structures or armored riffles. Inter-Fluve recommends the latter in natural stream systems to avoid blocking fish passage. Grade control is only warranted at two culvert crossings on the Credit River, where the channel bed could be raised downstream to prevent perching and further undermining of the crossing. In the lower section downstream of County Highway 13, grade control would be incorporated into any natural channel restoration.

4.3. Project type – Floodplain Management

Floodplain management projects vary considerably, but include expansion of riparian buffers, removal of infrastructure, and stormwater management. The Credit River has some development in the lower watershed, and this is expanding rapidly into the upper reaches. New development must capture stormwater and encourage as much infiltration as possible, or the stream will experience a sharp decline in water quality. Retrofitting of existing stormwater systems will help improve water quality and prevent incision and erosion problems. One example of retrofitting would be the detention and infiltration of parking lot runoff at Hidden Valley Park, where parking lot runoff currently runs directly into the stream.

4.4. Project type – Riparian Management

One way of improving filtration of nutrients, reducing stream temperature and restoring the connectivity of green corridors is to revegetate streambanks and riparian areas where row cropping and urban development have encroached on the channel. Revegetation projects are relatively simple to institute, and can be inexpensive. Plants can be purchased through local NRCS or nurseries, and can be planted by volunteer labor. Currently the Credit River system has only a few scattered urban lots that have been cleared down to the edge of the stream. However, were more landowners to repeat this pattern, the water quality of the system could sharply decline. Removal of the forest canopy exposes the channel to more direct sunlight and removal of soil binding tree roots can result in major bank erosion. Organisms dependent on forest leaf litter for energy can be impacted, and fertilizer from expanding lawns typically drains directly and quickly into the channel, resulting in increased algal growth and decreased oxygen levels. The streamside natural area is critical to the connectivity of watersheds. Migratory birds and other animals use these green corridors through their range or to migrate seasonally. Removal of these buffers fragments habitat for already stressed organisms. This pattern can be reversed however, by increasing natural buffers of both native grasses and forested riparian areas.

Although small ditches in the headwater areas of New Market, Credit River Township and Prior Lake may seem insignificant, it is extremely important to buffer these channels. Water pollution in rivers is cumulative. Once you have poor water quality, it doesn't generally improve as you travel downstream. The headwaters of the Credit River are fairly well protected by wide buffers of grass and forest, but improvements can always be made. Any attempts at reforestation should consider the impact of exotic species such as reed canarygrass and buckthorn. Special measures such as removal and herbicide treatment must be taken before establishing native species.

4.5. Project type – Crossing

Fish passage barriers on the Credit River are of two types, perched culverts and small dams. The dams in question are essentially rock piles placed in the stream, and are not permanent structures by any means. However, during low flow periods, these small rock dams may act as fish passage barriers. The former barrier type, a perched culvert, is found throughout the lower Credit River, particularly at box culvert crossings. Perching is caused by either incorrect placement of the culvert above the downstream channel bed or by incision traveling upstream and causing the channel bed below the culvert to downcut. Most warmwater fish have poor leaping ability, so even a six inch perch can present problems. Perched culverts can be made passable by raising the channel bed downstream, backwatering through the culvert or by replacing the culvert. Culvert replacement should consider bottomless arch options or culverts that are partially buried to mimic a natural channel

Figure 32: Bottomless arch that is partially buried for better habitat and fish passage conditions.

bottom (Figure32). Future road design in Scott County should include training of Public Works officials on the design and installation of fish-friendly culverts.

Low flows can present a passage barrier at any culvert, and this is not only a function of the culvert design, but also the hydrology of the system. During midsummer, when flows are very low, all culverts may be impassible. However, low flow can be concentrated or backwatered through a culvert to minimize passage problems. For instance, flow up to a certain elevation can be easily diverted (eg. low concrete weir) into one box of a double box culvert, essentially doubling the amount of water in the culvert at low flow.

4.6. Bank Stabilization

Bank stabilization projects in urban and agricultural areas seek to minimize soil loss and prevent stream channel migration and property loss. Urban and agricultural streams are often in a state of flux, that is the streams are trying to adjust their cross-section (get bigger) to accommodate the increase in flows. The Credit River has made some adjustments over time, but appears to be reaching an equilibrium with the existing hydrology. The only areas of major bank erosion noted were those induced by human activity, generally the clearing of trees and other vegetation from the banks. For the most part, the Credit River is remarkably stable given its watershed landuse. This is mainly due to the presence of wetlands throughout the corridor.

Bank stabilization along the Credit River should consider infrastructure constraints, future channel migration patterns and riparian buffer protection. A simple bank restoration project is to plant trees away from the eroding bank and allow those trees to grow to maturity before the channel has a chance to erode to their base. By the time the channel has moved, the trees will be large enough to provide deep rooted bank stabilization. The most successful trees for this purpose would be cottonwood, black willow and silver maple, all common riparian or “wet feet” trees capable of withstanding frequent inundation. Another approach is to provide some toe protection in the form of rock or encapsulated gravel combined with planting. Rock is sized or protected such that it remains stable long enough for vegetation to grow. Bioengineering fabrics can be used to provide structural stabilization and to prevent the piping of soils during high flow. These materials biodegrade once the vegetation is established. (Figure 33)

The least expensive bank stabilization is simply for landowners to leave the stream alone.

Figure 33: Grasses are beginning to grow through biodegradable bioengineering fabric along this restored stream (photograph: Inter-Fluve).

New and existing landowners in forested reaches should be encouraged to remove exotics such as buckthorn and garlic mustard, but to otherwise leave the streamside vegetation to manage itself (Figure 34). This encourages natural stabilization and habitat formation. In most cases, our best intentions are actually detrimental to the stream environment. Erosion and deposition of streambank sediment are the essential physical forces behind stream and floodplain formation. Some degree of bank erosion is natural.

Figure 34: The root structure of trees hold the bank material together to stabilize the banks against rapid erosion.

However, when watershed changes or riparian landuse practices cause the stream to be out of equilibrium, abnormal erosion rates can result. What constitutes abnormal erosion is somewhat subjective, and depends on sediment pollution concerns, habitat degradation and on concerns over nearby infrastructure such as roads, houses and underground conduits. Prior to undertaking a project, it is therefore important to obtain professional opinions from land managers, geomorphologists, and engineers. If the erosion appears dramatic, but the erosion rate is extremely low, there may be no real basis for a stabilization project. Conversely, erosion may not appear dramatic, but the rate may be high, requiring some immediate stabilization. Determining the risk of no action is extremely important.

Often times, people see a downed tree, or a scour area around a rootwad or tree base, and associate bank erosion with trees. In fact, had the tree not been there until it fell, the bank would have probably eroded at a much greater rate. Boxelder trees are primary colonizers, and are very quick to establish in areas where trees have fallen and clearings result. This association of boxelder with unstable banks also leads to the misconception that boxelders, and thus all trees cause erosion. Common riparian trees have evolved over time to do just the opposite. Eastern cottonwood, black willow and silver maple, our three most common streamside trees, have evolved deep, water searching root systems to provide for added stability in the dynamic streamside environment. Black willow roots can travel dozens of feet up and downstream, creating an extremely well armored bank.

Native grasses provide adequate streambank root protection down to approximately 3 to 4 feet, and are useful in smaller streams or areas where prairie restoration makes sense. Larger streams or incised channels with banks taller than 3 feet need deeper and stronger root protection. No vegetation can provide long term stability beyond five feet of streambank height, and the root protection is then limited to trees and grasses in the upper banks. The Minnesota River is a good example of this dynamic.

4.7. General Recommendations

The Credit River is in remarkably good geomorphic condition for a stream near a major urban center with expanding development and a headwater area dominated by row crop agriculture. However, the stream still suffers from high nutrient inputs, warming and inadequate stormwater management. The Credit River could undergo major landuse changes in the next few years, and preventative measures should be taken to ensure long term stability and stream health. We recommend a top down or headwaters approach to restoration. Installing the most up to date best management practices and innovative stormwater management solutions can improve the health of the Credit River. By focusing on the headwaters and moving downstream, you can isolate problem areas and prioritize overall stream recovery in a systematic way.

4.8. Specific Potential Projects

Inter-Fluve identified 48 potential projects along the main stem of the Credit River as well as seven potential projects along the tributaries (Appendix D). Each of these potential projects were ranked (Appendix E) and described in details. We have provided few specific details regarding the solutions for the problems discussed as the purpose of this study was the completion of a geomorphic assessment, which does not include detailed restoration designs. Once specific problem areas are designated for restoration, more detailed studies and designs must be completed.

In an erosion inventory study completed by the Scott County Watershed Management Organization in 2006, no areas of moderate or severe erosion were identified. The cause of the majority of areas with slight erosion was channel migration and erosion of the outside banks. Recommended solutions were generally a combination of riprap and bioengineering. We did not identify many of these areas as potential project areas as slight erosion on the outside of bends is part of the natural channel migration. However, we did have a few potential projects where bank stabilization was necessary; our solutions focused on bioengineering rather than the placement of riprap.

5. References

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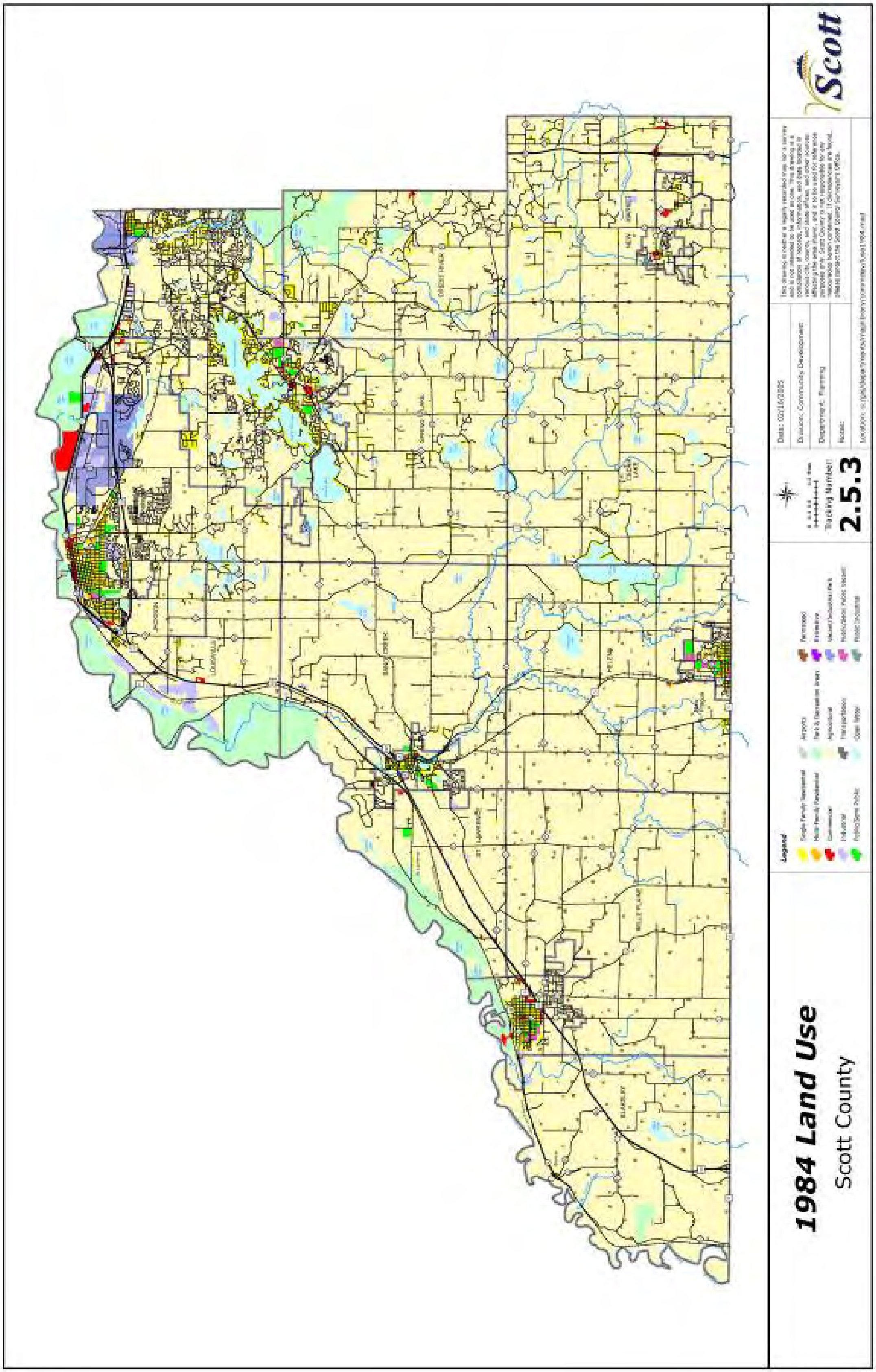
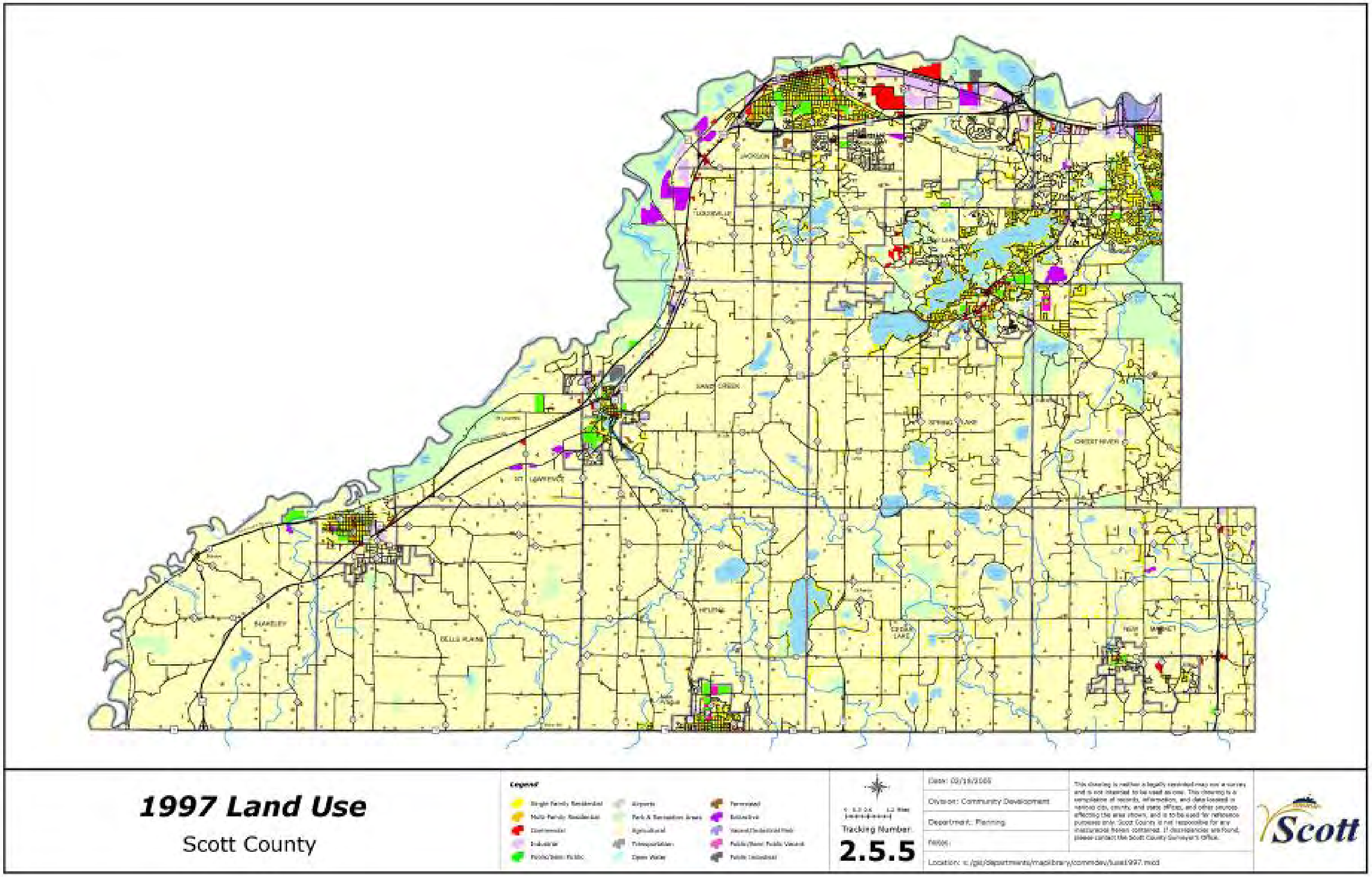
http://www.city-data.com/county/Scott_County-MN.html

http://www.co.scott.mn.us/wps/portal/ShowPage?CSF=876&CSI=35146192801002ps

http://land.umn.edu/quickview_data/index.html



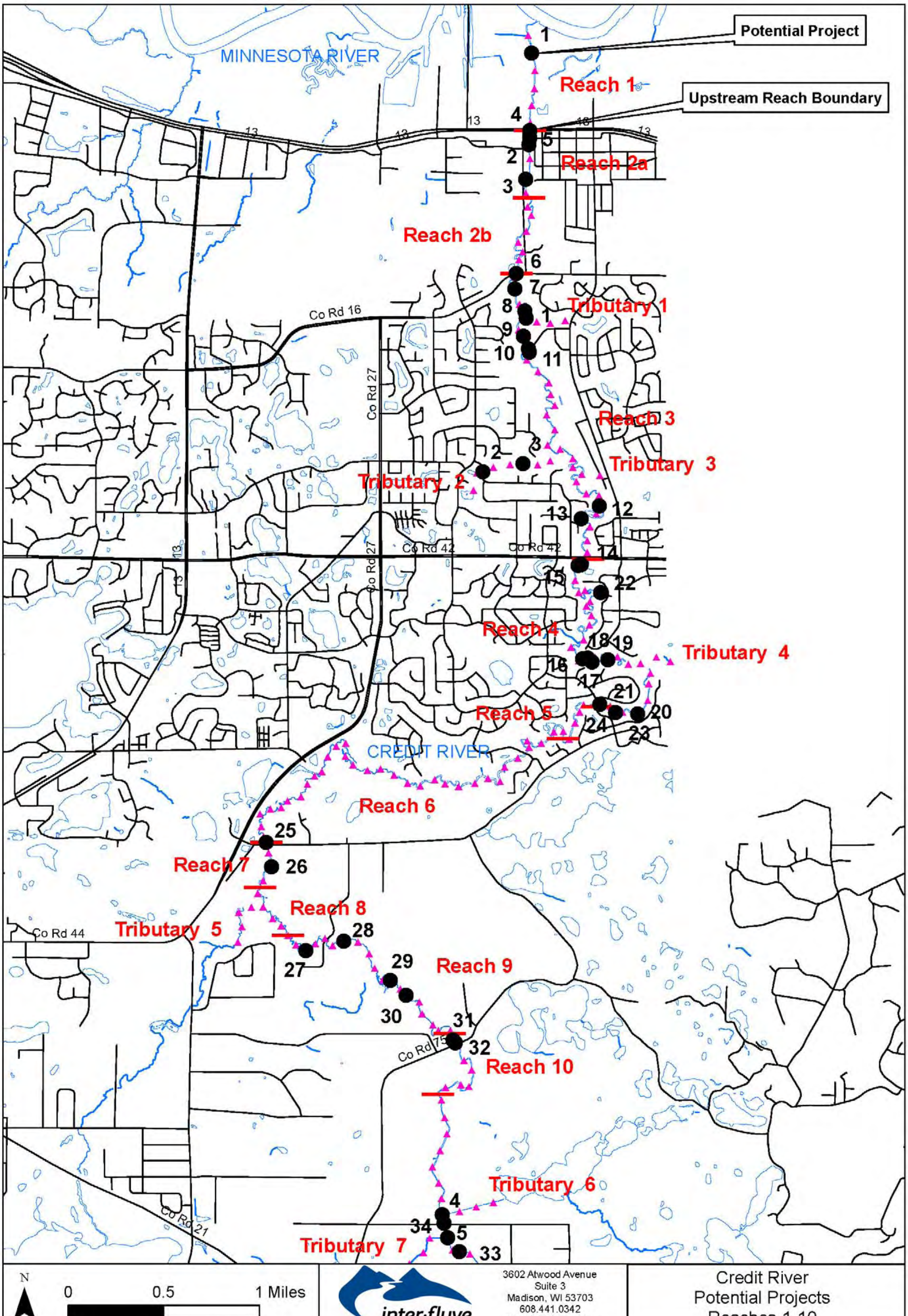
Appendix A: 1984 land use for Scott County (courtesy of Scott County).



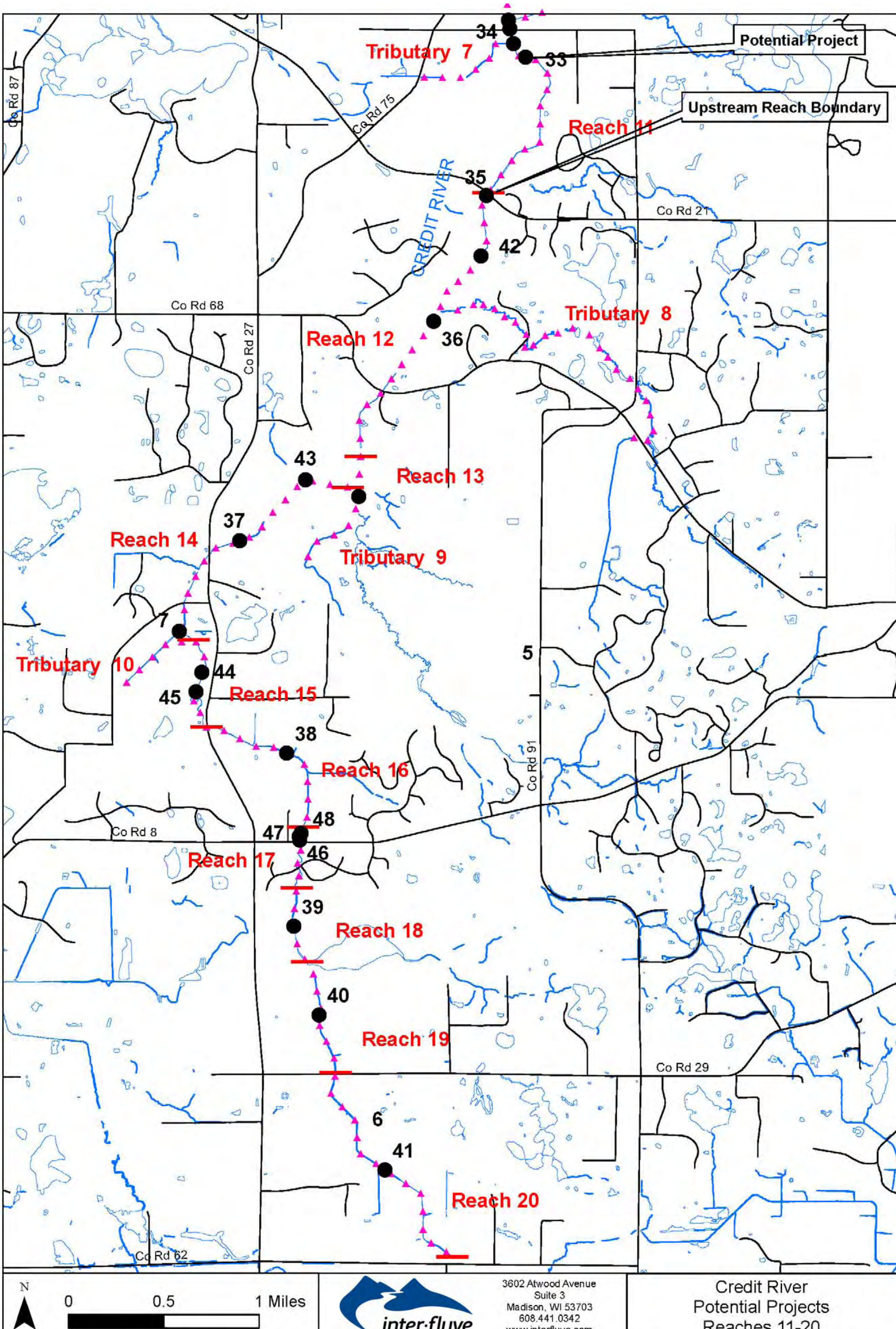
Appendix B: 1997 land use for Scott County (courtesy of Scott County).

Scott County website	http://www.co.scott.mn.us/wps/portal/Home?CSF=742
Scott County GIS website	http://www.co.scott.mn.us/wps/portal/ShowPage?CSF=1382
Scott County Historical Society	http://www.scottcountyhistory.org/index.html
History of Scott County	http://www.scottcountyhistory.org/scotthistory.html
Geology—maps	http://www.co.scott.mn.us/wps/portal/ShowPage?CSF=873
Geology—text	http://www.co.scott.mn.us/wps/portal/ShowPage?
Soils data—tabular and spatial for GIS	http://soildatamart.nrcs.usda.gov/Survey.aspx?State=MN
Water data from stream monitoring stations	http://www.metrocouncil.org/environment/RiversLakes/Streams/StreamResults.htm
GIS layers—topos, air photos, historic air photos, soil maps, etc.	http://deli.dnr.state.mn.us/ http://deli.dnr.state.mn.us/data_search.html http://www.datafinder.org/index.asp http://seamless.usgs.gov/ http://www.lmic.state.mn.us/chouse/northstarmapper.html
PDFs of county data in map form	http://gis.co.scott.mn.us/maps/countymaps.html

Appendix C: Online resources for Scott County.



Appendix D: Potential projects on the Credit River (black circles). Pink triangles indicate 500-ft increments along the channel centerline. Scott County provided the channel, road, and watershed layers; some of the smaller tributaries were not included in these layers.



Appendix D continued: Potential projects on the Credit River (black circles). Pink triangles indicate 500-ft increments along the channel centerline. Scott County provided the channel, road, and watershed layers; some of the smaller tributaries were not included in these layers.

A

Project Number	Station Number	Project type	*Inf. Risk*	*Channel stability*	*Project Complexity*	*Location*	*Sed/Nutrient Loading*	*Cost*	*Aesthetic impact*	*Fish passage*	*Public Education*	*In-stream Ecological*	*Riparian Ecological*	*Total Score*
PP01	0-2000	N	1	5	3	1	3	5	2	1	3	7	7	**38**
PP02	3450-3700	R	2	3	7	1	3	7	5	1	4	2	7	**42**
PP03	4000-5200	R	2	3	7	1	3	7	5	1	4	2	7	**42**
PP04	3200	C	1	1	7	1	1	7	1	5	3	4	1	**32**
PP05	3450	C	1	1	7	1	1	7	1	5	3	4	1	**32**
PP06	8400	C	1	1	7	3	1	7	1	4	3	4	1	**33**
PP07	9000-9100	B,F,R	1	1	7	1	3	7	5	1	3	1	3	**33**
PP08	9850-9900	R	1	3	7	1	3	7	5	1	3	2	3	**36**
PP09	10800	I,B,F	3	3	4	1	3	7	5	1	5	1	1	**34**
PP10	11400	I,B,R,F	2	1	5	1	5	6	5	1	7	3	3	**39**
PP11	11450-11500	B,R	1	1	7	1	3	7	5	1	7	2	2	**37**
PP12	19400-19500	R,F,B	1	1	7	1	3	7	5	1	3	1	3	**33**
PP13	20600	I,R	1	1	7	1	3	7	3	5	1	3	3	**35**
PP14	22700-22900	R	1	2	7	1	3	7	5	1	4	2	3	**36**
PP15	22900-23000	R	1	2	7	1	3	7	5	1	4	2	3	**36**
PP16	28700-28750	R	1	1	7	2	3	7	5	1	4	2	3	**36**
PP17	28800-29100	R	1	2	7	2	3	7	5	1	4	2	3	**37**
PP18	29200	R	1	1	7	2	3	7	5	1	4	2	3	**36**
PP19	30100-30200	R	1	1	7	2	3	7	5	1	4	2	3	**36**
PP20	33500	R	1	1	7	2	3	7	5	1	4	2	3	**36**
PP21	34200-34300	R	1	1	7	2	3	7	5	1	4	2	3	**36**
PP22	25000-25100	B,F,I	2	1	6	1	2	7	3	1	1	1	1	**26**
PP23	33500	I	1	3	7	3	3	7	1	5	2	4	1	**37**
PP24	34900	B,R,F	4	3	5	3	1	7	5	1	4	2	3	**38**
PP25	53700	C	1	1	7	3	1	7	1	3	3	3	1	**31**
PP26	54200-54650	R	1	3	7	3	3	7	6	1	4	3	5	**43**
PP27	58600-58700	R	1	1	7	3	1	7	3	1	2	1	3	**30**
PP28	60500	C,I,F	3	3	3	5	3	3	3	5	2	3	1	**34**
PP29	63000	I,R	3	1	7	5	1	7	4	1	1	1	3	**34**
PP30	63900	I,R	3	1	7	5	1	7	4	1	1	1	3	**34**
PP31	66800	I,F,R	1	3	5	5	1	5	3	1	4	3	5	**36**
PP32	66950	C,G	1	1	7	5	1	7	1	3	3	3	1	**33**
PP33	69800-79600	N,R	1	7	3	5	3	1	7	3	7	7	7	**51**
PP34	73700	C	1	1	7	5	3	7	1	4	3	3	1	**36**
PP35	79700	C	1	1	7	5	3	7	1	4	3	3	1	**36**
PP36	79600-88500	N,R	1	7	3	5	3	1	7	3	7	7	7	**51**
PP37	89500-97400	N,R	1	7	3	6	3	1	7	3	7	7	7	**52**
PP38	100500-105300	N,R	1	7	3	7	3	1	7	3	7	7	7	**53**
PP39	107400-109600	N,R	1	7	3	7	3	1	7	3	7	7	7	**53**
PP40	109600-112900	N,R	1	7	3	7	3	1	7	3	7	7	7	**53**
PP41	112900-119700	N,R	1	7	3	7	3	1	7	3	7	7	7	**53**
PP42	81500	F,I,R	1	1	7	5	1	5	5	1	3	1	4	**34**
PP43	90700	I,R	3	3	5	6	3	7	2	1	1	1	3	**35**
PP44	98500	F,R	1	3	7	6	1	7	3	1	1	1	3	**34**
PP45	99000-99200	B,R	1	3	7	7	3	7	5	1	3	3	3	**43**
PP46	105700	C,G	3	3	5	7	3	5	1	4	1	3	1	**36**
PP47	105600	I,N,F	1	4	5	7	3	5	2	5	5	3	3	**43**
PP48	105550	I	3	3	7	7	1	7	4	1	1	1	1	**36**

B

Project Number	Credit River Station	Project type	*Inf. Risk*	*Channel stability*	*Project Complexity*	*Location*	*Sed/Nutrient Loading*	*Cost*	*Aesthetic impact*	*Fish passage*	*Public Education*	*In-stream Ecological*	*Riparian Ecological*	*Total Score*
PP01	10100	G	3	5	5	1	5	5	1	1	3	3	1	**33**
PP02	15700	G,C,I,N	5	5	3	1	7	1	3	1	5	3	3	**37**
PP03	15700	G,R	1	3	7	1	3	7	4	1	1	7	7	**42**
PP04	73400	N,R	1	3	3	6	5	2	5	5	7	7	7	**51**
PP05	74100	N,R	1	7	3	5	3	1	7	3	7	7	7	**51**
PP06	89000	N,R	1	3	5	6	3	3	3	1	5	3	5	**38**
PP07	96600	N,R	1	3	5	6	3	5	3	1	5	1	5	**38**

B = Bank Stabilization
G = Grade Control
C = Culvert or Other Crossing
N = Natural Channel Restoration/Relocation
F = Floodplain Management
I = Infrastructure (outfalls, buildings, etc.)
R = Riparian Management

Appendix E: Scoring of potential projects for (A) the mainstem and (B) the tributaries of the Credit River .

Appendix E. Quality Assurance and Quality Control Review Memorandum

Scott Watershed Management Organization
200 Fourth Avenue West
Shakopee, MN 55379-1220
952-496-8054 Fax 952-496-8840
www.co.scott.mn.us

Memorandum

To: File

From: Paul Nelson, Scott WMO Administrator; Jaime Rockney, Scott SWCD; Melissa Bokman, Senior Water Resources Planner

Subject: Credit River Turbidity TMDL – QA/QC Field Results

Date: May 7, 2010

This memorandum presents the results of the analysis of portions of the QAQC program for the Credit River Turbidity TMDL. Results are summarized for Precision, Accuracy, Completeness and Representativeness.

Precision

Over the course of the study, field duplicates were collected for the analysis of precision and assessment of whether or not there were systematic problems with the collection of samples. The measurement of precision used was relative percent difference (RPD). Relative percent difference is expressed as a percent and is calculated as:

RDP = ((Sample Value – Duplicate Value)/((Sample Value + Duplicate Value)/2) x 100

The data quality objectives (DQO) for various parameters with respect to RPD are shown in Table 1.

Table 1: Data Quality Objectives for RPD

Parameter	RPD Objective
NOx	10%
TSS	30%
VSS	30%
TP	30%
TDP	30%
Chloride	20%
Chl-a	30%
Transparency Tube	10%
Turbidity	30%

Duplicate samples were collected on 6 dates in 2008 and 4 dates in 2009. Duplicate samples collected on these dates were analyzed for the full suite of parameters thereby representing hundreds of duplicate analyses.

Individual analyses from the Scott WMO sites that exceeded the RPD data quality objectives are shown in Table 2. In general, results of the assessment of precision using duplicates were good and no systematic problems attributable to sampling were identified. Individual duplicates occasionally exceeded the data quality objective for specific parameter, but other parameters from the same sample meet RPD objectives. In addition, most of the exceedences of the data quality objective were at low concentrations where resolution of the analysis was the cause of the exceedence. No individual analyses were rejected.

Analysis of precision of flow measurements through the completion of duplicate flow gauging measurements is presented in a separate memorandum (Credit River Watershed Turbidity TMDL – Flow Value Development). Over the course of the project a number of duplicate flow measurements were completed. All of the duplicate measurements were in close agreement with each other.

Table 2. Analyses Exceeding Relative Percent Difference (RPD) Data Quality Objectives

Site	Date	Parameter	RPD %	Value 1	Value 2	Decision
C68	4-22-08	Nitrogen, Total Nitrate_mg/L	28%	0.04	0.03	Accept results; exceedence due to resolution
C68	4-8-09	Phosphorus, Total_mg/L	43%	.2	.129	Accept results; other analyses meet objectives at the site on that date
154	5-6-08	Turbidity NTRU	40%	3	2	Accept results; exceedence due to resolution
154	6-17-08	Turbidity NTRU	40%	6	4	Accept results; exceedence due to resolution
154	5-5-09	Solids, Volatile Suspended_mg/L	67%	~1	~2	Accept results; exceedence due to resolution
154	8-11-09	Nitrogen, Total Nitrate_mg/L	18%	.36	.3	Accept results; exceedence due to resolution
154	8-11-09	Solids, Volatile Suspended_mg/L	40%	3	2	Accept results; exceedence due to resolution
154	9-9-09	Chlorophyll-a, Trichromatic Uncorrected_ug/L	32%	9.4	6.8	Accept results; close to objective
154	9-9-09	Solids, Volatile Suspended_mg/L	67%	2	1	Accept results; exceedence due to resolution

154	9-9-09	Suspended Solids_mg/L	40%	4	6	Accept results; exceedence due to resolution

Accuracy
Accuracy for the field measurements of water quality parameters was controlled by on-going calibrations of various meters used. The Hydrolab MS5 and Quanta multi-parameter sondes used for grab sampling, synoptic and continuous in-situ monitoring were calibrated in the office on a regular basis. The parameters calibrated included dissolved oxygen, pH, specific conductivity and turbidity.

Dissolved oxygen was calibrated using an air-saturated water method and was done every time the sonde is used. Specific conductance was calibrated using a 1413µS standard on a weekly basis, if needed. Turbidity was calibrated using the Hach StablCal <0.1 and 100 NTU standards on a monthly basis. pH was routinely checked and calibrated using a 7 and 10 pH standard weekly, if needed.

A Hach 2100P turbidimeter was used with the Hydrolab Quanta and was calibrated as needed, following the same protocols as mentioned above. However, the Quanta dissolved oxygen was calibrated using the water-saturated air method.

The calibration results were logged and entered into the METC Water Quality Database and the data was flagged accordingly.

Completeness
Completeness was assessed as the number of samples and/or monitoring events planned versus the number completed. Results are presented in Table 3. In general data collection was completed as planned. The exception was the number of samples which was limited to less than plan by the lack of water, intermittent flow at some sites, and dry conditions over the sampling period.

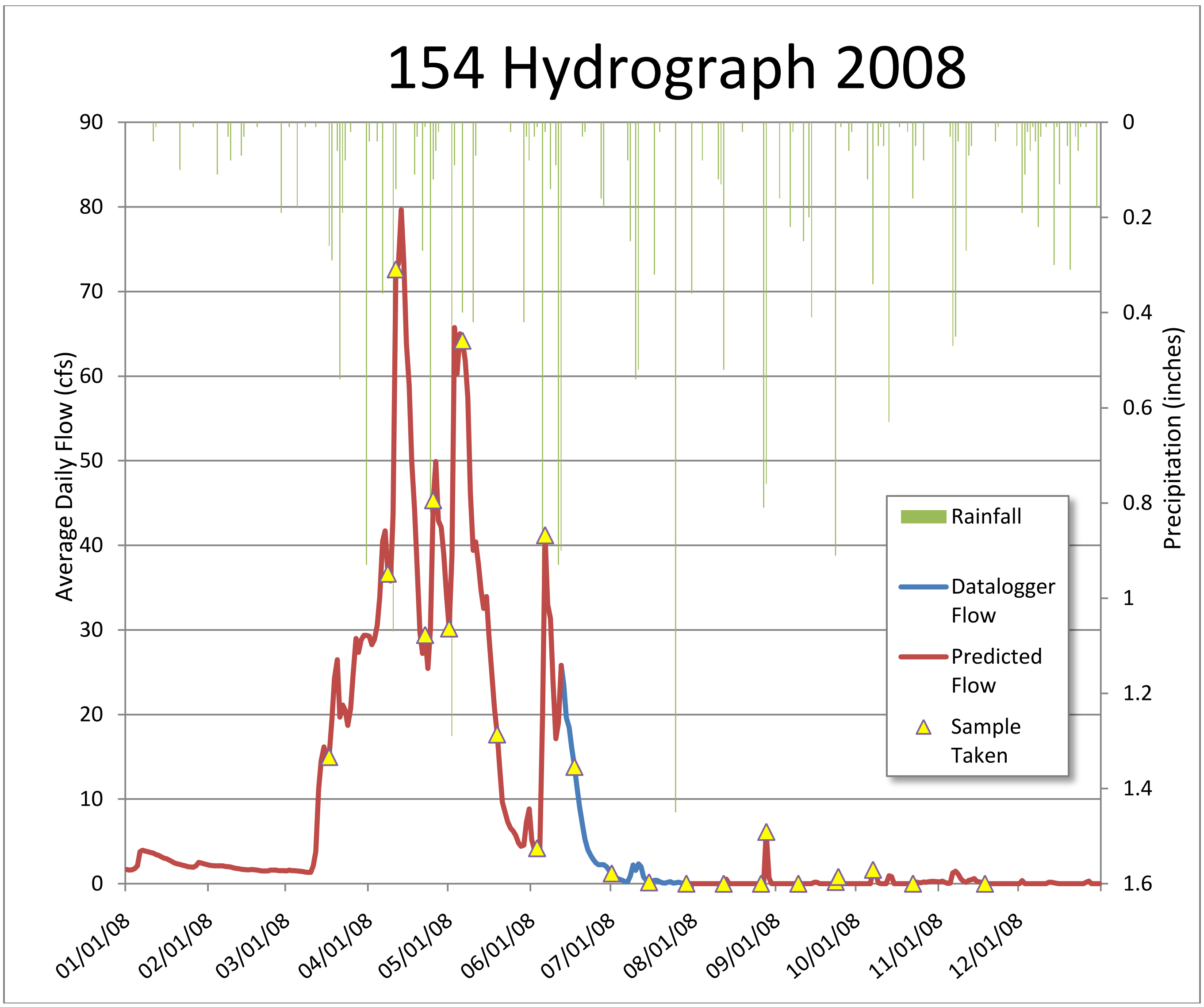
Table 3: Environmental Field Measurement Completeness

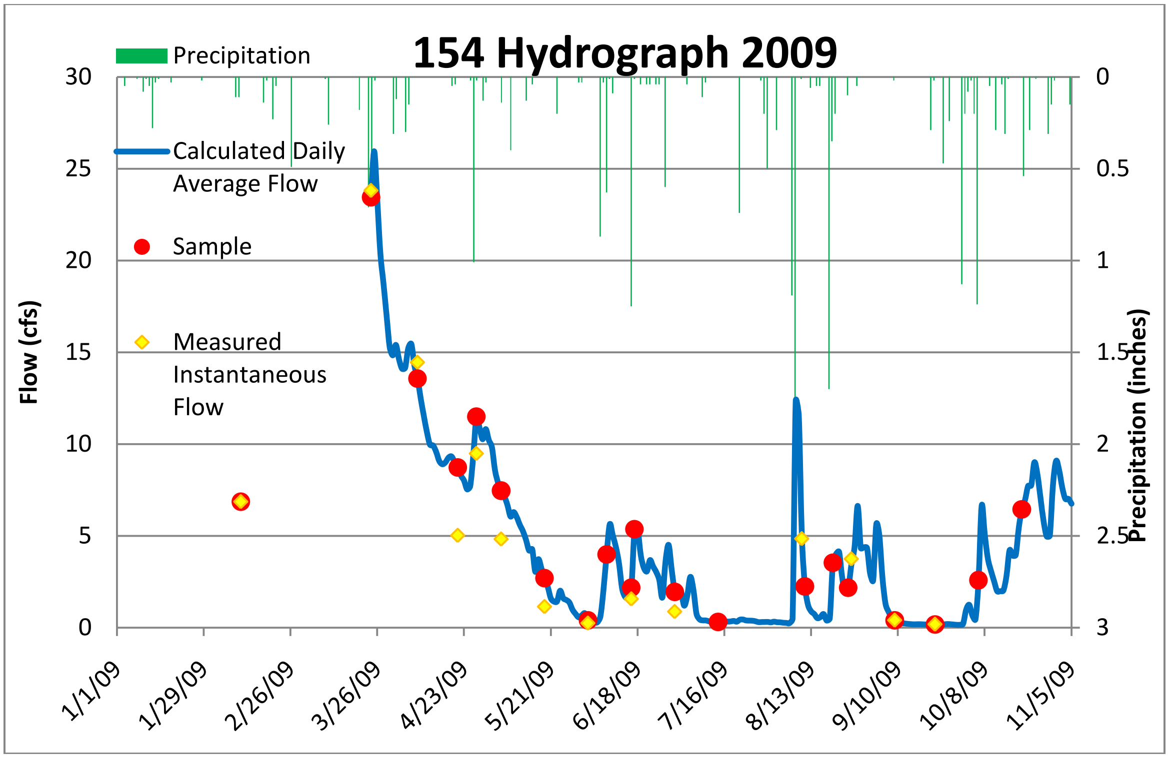
Completeness

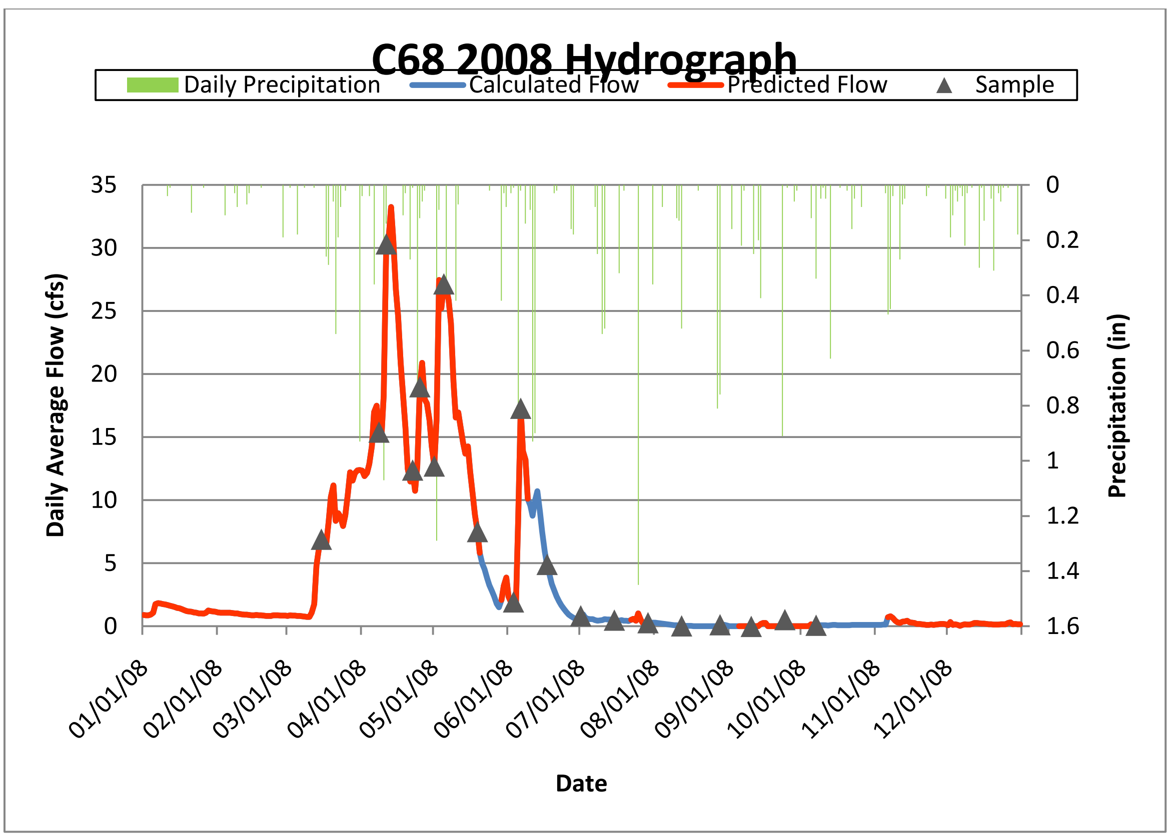
	Planned		Completed		Notes
	2008	2009	2008	2009	
Synoptics	6	0	7	0	
Sonde Deployments	4	0	3	0	
Samples: 25/site/1st yr; 16/site/2nd year	50	32	42	32	
Flow measurements: 7-8/site/yr	14-16	14-16	23	14	

Representativeness

Representativeness of the samples collected to the flow conditions over the monitored years was evaluated by plotting the sample collection dates on the hydrographs for sites with continuous flow records. These hydrographs are attached. Review of the hydrographs and sample collection dates show that samples collected are representative of the range of flows observed. They are also spread throughout the year and include snow melt samples. With respect to the hydrographs it should be noted that large parts of the 2008 hydrographs are predicted based on a relationship developed between stage at the two sites and the MCES site located near the mouth of the river. For 2009 flows could not be predicted to fill in those parts of the year where stage was not measured at the two sites, because there were problems at the MCES site.




154 Hydrograph 2009
Precipitation
Calculated Daily Average Flow
Sample
Measured Instantaneous Flow
Flow (cfs)
Precipitation (inches)
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
1/1/09
1/29/09
2/26/09
3/26/09
4/23/09
5/21/09
6/18/09
7/16/09
8/13/09
9/10/09
10/8/09
11/5/09


C68 2008 Hydrograph
Daily Precipitation
Calculated Flow
Predicted Flow
Sample
Daily Average Flow (cfs)
Precipitation (in)
35
30
25
20
15
10
5
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
01/01/08
02/01/08
03/01/08
04/01/08
05/01/08
06/01/08
07/01/08
08/01/08
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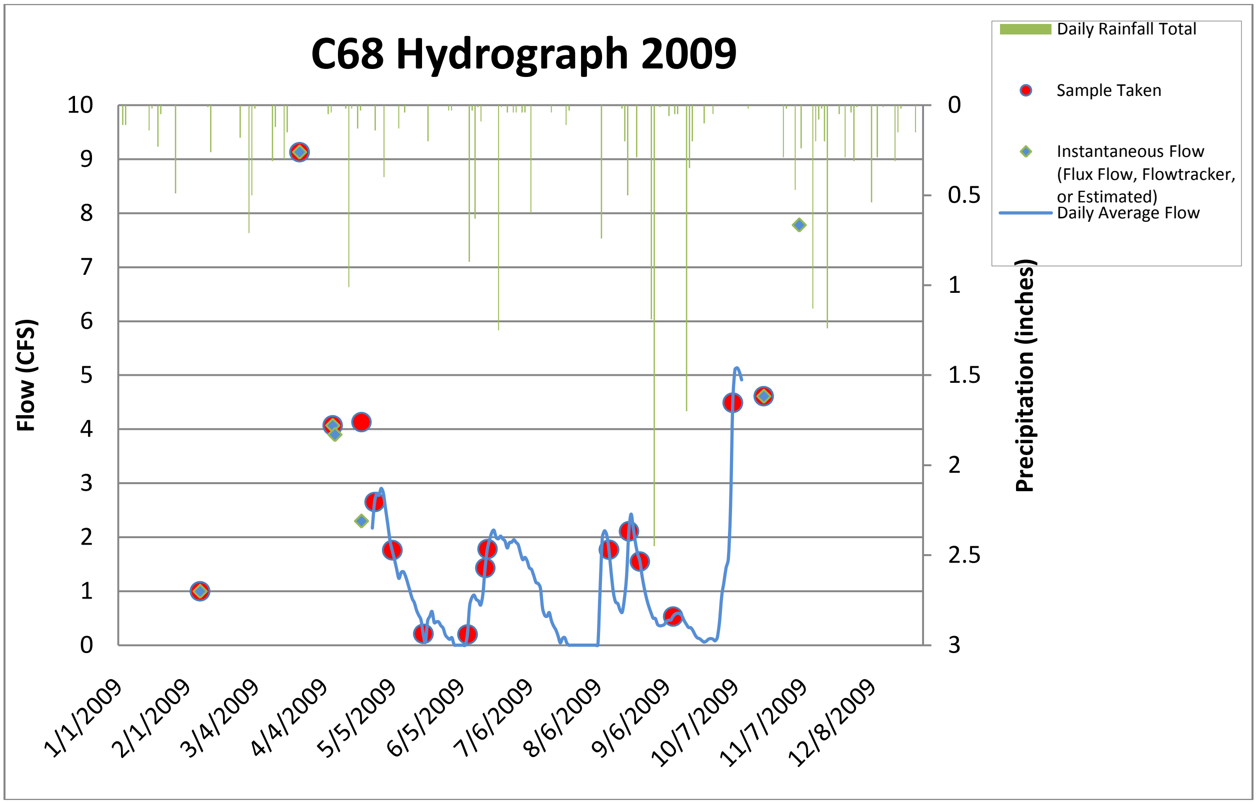
10/01/08
11/01/08
12/01/08
Date


C68 Hydrograph 2009
Flow (CFS)
Precipitation (inches)
10
9
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
1/1/2009
2/1/2009
3/4/2009
4/4/2009
5/5/2009
6/5/2009
7/6/2009
8/6/2009
9/6/2009
10/7/2009
11/7/2009
12/8/2009
Daily Rainfall Total
Sample Taken
Instantaneous Flow (Flux Flow, Flowtracker, or Estimated)
Daily Average Flow

Appendix F. Rating Curve Development Memorandum

Scott Watershed Management Organization
200 Fourth Avenue West
Shakopee, MN 55379-1220
952-496-8054 Fax 952-496-8840
www.co.scott.mn.us

Memorandum

To: File

From: Paul Nelson, Scott WMO Administrator; Jaime Rockney, Scott SWCD Water Resource Specialist

Subject: Credit River Watershed Turbidity TMDL – Rating Curve Development

Date: February 16, 2011

This memorandum documents the procedures used to convert recorded stage levels to flow at the continuous recording monitoring sites operated during the Credit River Watershed Impaired Waters Study. Flow measurements were collected in 2008 and 2009. Flow gauging measurements were typically taken with a Marsh-McBirney or FlowTracker flow meter. For very low flows, a USGS modified Parshall Flume was used. When no data was available to record stage or flow, a predicted flow equation was used.

Quality Control

The WMO adheres to a quality control program which includes: 1) collection of duplicate measurements to assess precision, 2) flow measurement training of staff in the spring of 2007 by the USGS, 3) checking calculations of the Marsh–McBirney measurements by a second staff person, 4) sending the Marsh-McBirney into the manufacturer to check calibration (2-17-07), and 5) comparison of the maximum recorded daily average stage with the maximum flow measured stage. The maximum observed stage was compared to the maximum flow measured stage to assess whether the curves generated were representative of the full range of stage recorded. The Flow Tracker was a new piece of equipment in 2007 and was calibrated by the manufacturer before shipping. However, it was also checked against results generated by the Marsh-McBirney. Field notes were also kept and were checked to assess whether cross sections on measurement dates could have been affected by ice, beaver dams, or other conditions.

Flow Measurements

Eleven duplicate flow measurements were taken within Scott County in 2008 and 2009 using the same equipment, methods, and staff (see Table 1). Three of these duplicates were in the Credit River. In general, the duplicate measurements had reasonable agreement with no consistent discernable errors detected indicating systematic error or measurement problems. The data is reliable and meets quality control objectives. The sites had maximum observed average daily stage levels close to, or within the range of, maximum measured flow stages (Table 2).

Rating Curves

Rating curve development is summarized in Table 3, with spreadsheets used to develop the curves provided as attachments. In 2008 and 2009, “maximum recorded stage” matches well with the “stage at maximum measured flow” values at these sites. Around 8/26/08, beavers began building a dam downstream of the 154 monitoring station making the 2008 rating curve inapplicable after that time. a new rating curve was established for 2009. A couple flow measurements were taken after the dam was built, but not enough to apply a rating curve. During times when the stream is iced over or no continuous data is available, a relationship formula was developed using the Metropolitan Council Credit River station in order to get stage and flow information.

Predicted Flows

There were times when neither flow nor stage data available at the WMO monitoring sites due to ice in the stream, equipment malfunction, or beavers. However, the Metropolitan Council also has a water quality monitoring station downstream of 154 and C68, so a “predicted flow” equation was developed using 2008 data to predict flows at 154 and C68 based on flows at the Metropolitan Council Site. Unfortunately, the Metropolitan Council’s monitoring equipment malfunctioned in 2009 resulting in inaccurate flow data. The predicted flow equations are included in Table 4. The equations were developed with paired data when both the Metropolitan Council Site and the other sites were simultaneously operating.

Table 1: Results of Duplicate Flow Measurements

Site	Date	Stage (ft)	Measurement 1 (cfs)	Measurement 2 (cfs)
UT	5/28/08	7.18	7.18	7.43
West Raven	5/22/08	1.94	5.46	4.94
West Raven	6/26/08	1.49	2.37	2.39
ER2	7/14/08	0.51	2.33	2.38
SPW	5/12/08	2.90	1.44	1.25
CR2	7/8/08	0.84	9.89	9.48
CR2	8/11/08	0.66	6.22	6.25
CLD	6/12/08	3.14	2.07	2.00
C68	8/10/09	4.10	1.78	2.10
C68	9/9/09	3.72	.18	.20
154	9/22/09	.85	.19	.18

Table 2: Maximum Recorded Daily Average Stage versus Maximum Measured Flow Stage for Continuous Recording Sites during Ice-Free Conditions (3/1 – 11/1)

Site	Maximum Recorded Average Daily Stage (ft)		Stage at Maximum Measured Flow (ft)	
	2008	2009	2008	2009
154	3.09	2.97	3.04	2.87

C68	4.91	4.20	5.41*	4.34*

*Stage at Maximum Measured Flow is higher than Maximum Recorded Average Daily Stage because the datalogger was not yet logging stage at the time of flow measurement.

Table 3: Rating Curve Summary

Site	Stage	Equation	Attachment
154 (2009)	For Stages < 0.71: For Stages 0.71 - 1.59: For Stages 1.60-2.51: For Stages > 2.51:	Flow = 0 $y = 12.128x^3 - 33.783x^2 + 31.642x - 9.7557$ $y = 2.544x^2 + 0.8222x - 3.91$ $y = 10.764x^2 - 30.048x + 21.43$	A
154 (2008)	For stages ≤ .85: For stages > .85' and ≤ 1.05: For stages ≥ 1.05:	Flow = 0 y = 59.13x2 - 100.08x + 42.345 y = 6.0095x2 - 1.7099x - 2.5792	B
C68 (2009)	For Stages < 3.62: For Stages ≥3.62:	Flow = 0 $y = 4.327x^2 - 28.83x + 47.695$	C
C68 (2008)	For Stages ≤ 3.06: For Stages > 3.06 and < 3.82: For Stages ≥ 3.82:	Flow = 0 y = 0.7885x - 2.4161 y = 4.6995x2 - 31.694x + 53.108	D

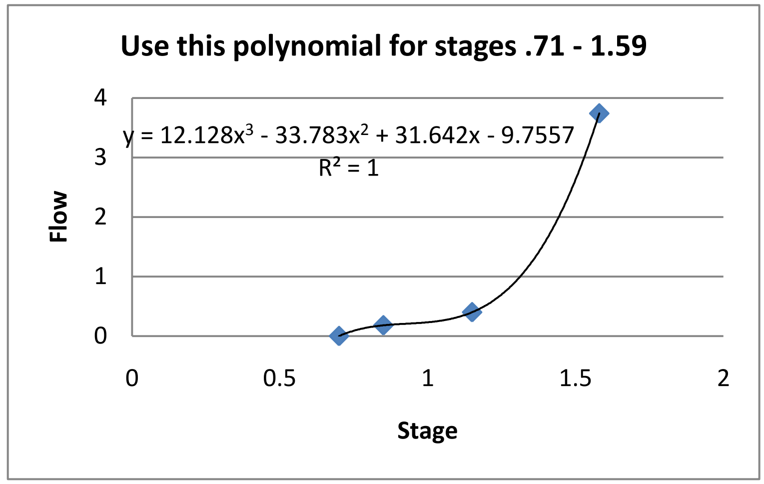
Table 4: Predicted Flows

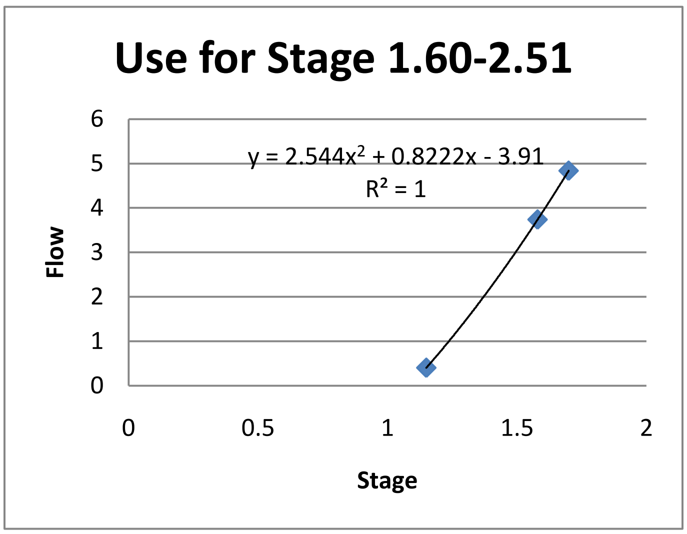
Site	Predicted Flow Equations	
	2008	2009
154	y=0.8388x - 2.0952	Not Available*
C68	y = 0.348x - 0.6672	Not Available*

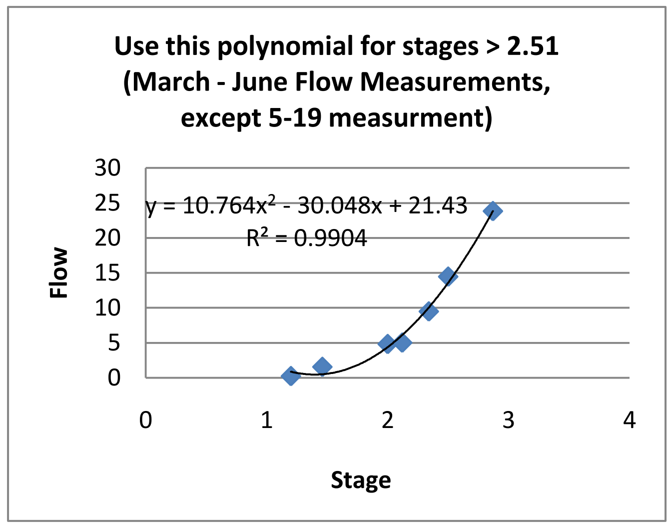
*MCES flow data used for predicted flows are not reliable in 2009 due to equipment malfunctions.

Attachment A – 2009 154 Rating Curve Development

Date	Stage (ft)	Measured Flow (cfs)	Calculated Flow (cfs)
3/24/2009	2.87	23.81	23.85
4/8/2009	2.5	14.45	14.05
4/21/2009	2.12	5.02	9.27
4/27/2009	2.34	9.48	11.94
5/5/2009	2	4.82	7.91
5/19/2009	1.53	1.14	3.01
6/2/2009	1.2	0.24	0.52
6/16/2009	1.46	1.56	2.17
8/10/2009	1.7	4.84	4.84
8/26/2009	1.58	3.74	3.74
9/9/2009	1.15	0.4	0.40
9/22/2009	0.85	0.18	0.18
estimated	0.7	0	0.00

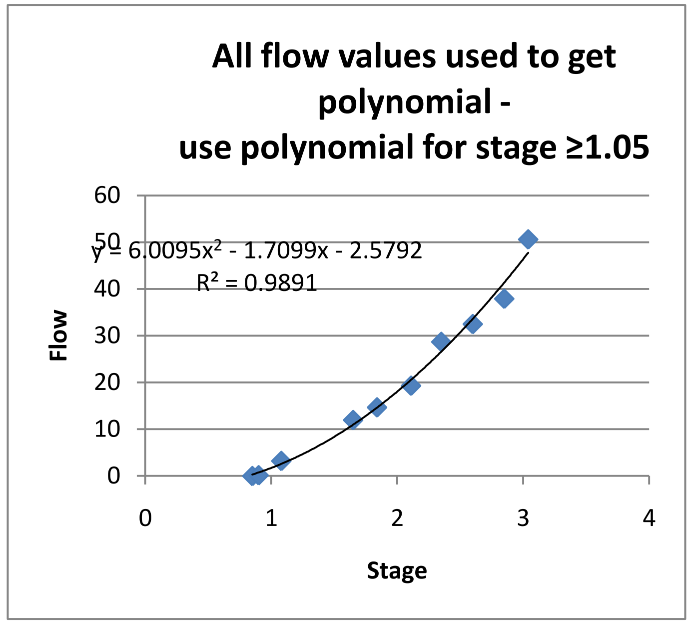


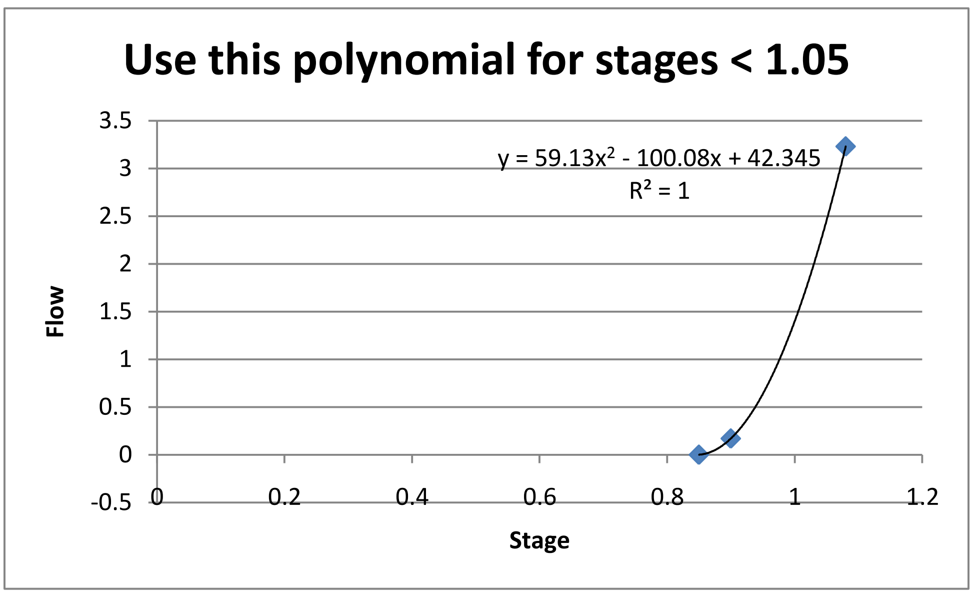




Attachment B – 2008 154 Rating Curve Development

Date	Stage (ft)	Measured Flow (cfs)	Calculated Flow (cfs)
7/29/2008	0.85	0	0
7/15/2008	0.9	0.17	0.1683
6/3/2008	1.08	3.23	3.227832
5/19/2008	1.65	11.98	10.96033
6/17/2008	1.84	14.69	14.62035
6/9/2008	2.11	19.32	20.56781
4/21/2008	2.35	28.69	26.59
4/10/2008	2.6	32.5	33.59928
4/25/2008	2.85	37.91	41.35975
5/8/2008	3.04	50.61	47.7601

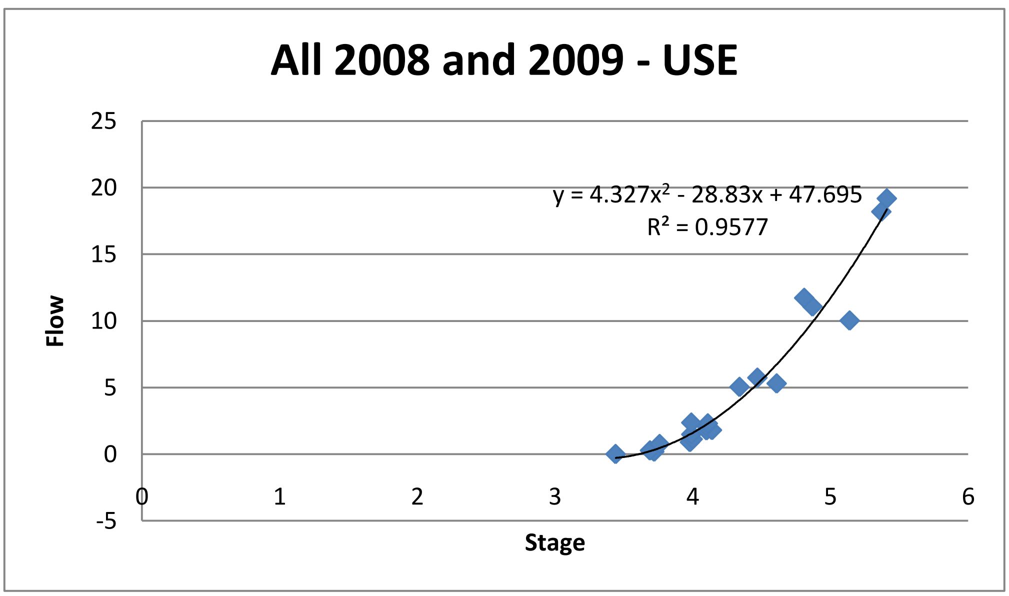




Attachment C – 2009 C68 Rating Curve Development

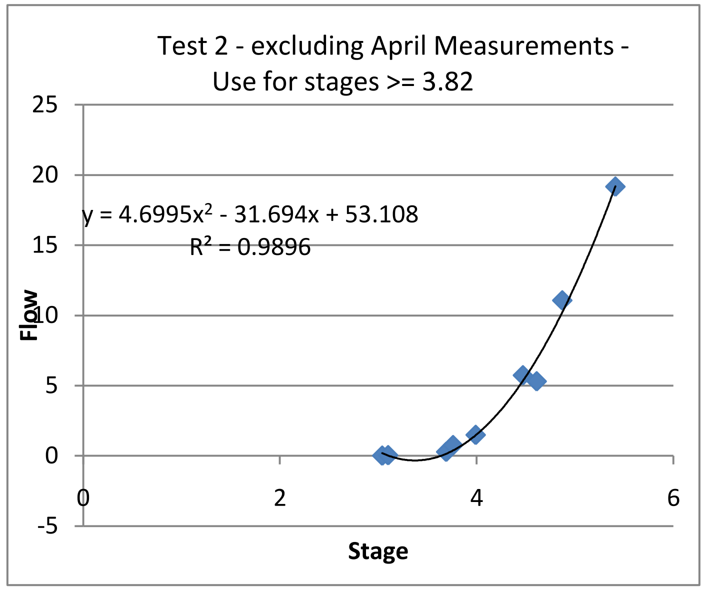
Date	Stage (ft)	Measured Flow (cfs)	Calculated Flow (cfs)
7/29/08	3.44	0	0.00
6/2/09	3.62	0	0.03
7/15/08	3.69	0.27	0.11
9/9/09	3.72	0.19*	0.17
7/1/08	3.76	0.75	0.26
6/16/09	3.98	0.9	1.51
6/2/08	3.99	1.48	1.58
5/5/09	3.99	2.36	1.58
8/26/09	4	1.12	1.66
8/10/09	4.1	1.94*	2.42
4/21/09	4.11	2.3	2.50
8/21/09	4.14	1.8	2.75
4/8/09	4.34	5.04	4.59
6/17/08	4.47	5.73	5.95
5/19/08	4.61	5.3	7.56
3/24/09	4.81	11.72	10.14
6/12/08	4.87	11.07	10.98
4/22/08	5.14	10.02	15.09
4/8/08	5.37	18.19	19.04
5/7/08	5.41	19.18	19.77

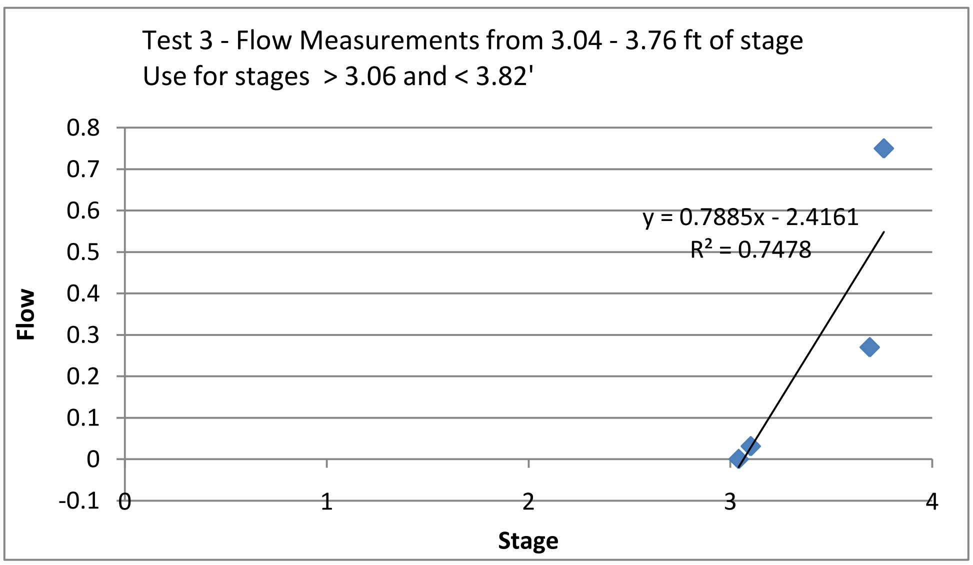
*Average of Duplicate Flow Measurements



Attachment D – 2008 C68 Rating Curve Development

Date	Stage (ft)	Measured Flow (cfs)	Calculated Flow (cfs)
8/12/2009	3.1	0.031	0.03
7/29/2008	3.44	0.02	0.30
7/15/2008	3.69	0.27	0.49
7/1/2008	3.76	0.75	0.55
6/2/2008	3.99	1.48	1.47
6/17/2008	4.47	5.73	5.34
5/19/2008	4.61	5.3	6.87
6/12/2008	4.87	11.07	10.22
4/22/2008	5.14	10.02	14.36
4/8/2008	5.37	18.19	18.43
5/7/2008	5.41	19.18	19.19





Appendix G. Hydrograph Development Memorandum

Scott Watershed Management Organization
200 Fourth Avenue West
Shakopee, MN 55379-1220
952-496-8054 Fax 952-496-8840
www.co.scott.mn.us

Memorandum

To: File

From: Jaime Rockney, Water Resource Specialist

Subject: Credit River Watershed Impaired Waters Study - Hydrograph Development

Date: February 16, 2011

This memorandum documents the development of 2008 and 2009 hydrographs used to show representativeness of sampling protocols and the changes in daily average flow over time. Continuous stage, rating curves, and prediction equations were used to determine daily average flows. The documentation of the development of the rating curves is in a separate memorandum (see Credit River Watershed Turbidity TMDL – Rating Curve Development dated 2/16/11). The Scott WMO water quality sites on Credit River, "154" and "C68" (WMO sites), are included in this memorandum.

Hydrographs

Equations used to develop the hydrographs (rating curves and prediction equations) are summarized in Table 1. Rating curve equations were used to calculate daily average flows when continuous stage data was available. For dates with ice conditions or missing stage data, the prediction equation was used. A prediction equation was developed by comparing the flow at a Scott WMO site to the flow at the downstream water quality site on Credit River operated by Metropolitan Council Environmental Services (MCES site). When both sites had flow values, the resulting equations were used to estimate flows when no stage data was available for the WMO sites. Note that the flows at the MCES site were also estimated during ice conditions, which introduced more uncertainty to the already predicted values. Precipitation data for 2008 and 2009 was used from a volunteer rainfall monitor gauge in Prior Lake.

Table 1. Rating Curve and Prediction Equation Summary

Site	Rating Curve Equations Used	Year	Prediction Equations Used	Comparison Site
154	**For Stage < 0.71:** y = 0 **For Stages 0.71 - 1.59:** y = 12.128x3 - 33.783x2 + 31.642x - 9.7557 **For Stages 1.60-2.51:** y = 2.544x2 + 0.8222x - 3.91 **For Stage ≥ 2.51:** y = 10.764x2 - 30.048x + 21.43	2009	N/A	N/A
154	**For stages ≤ .85:** y = 0 **For stages > .85 and ≤ 1.05:** y= 59.13x2 - 100.08x + 42.345 **For stages > 1.05:** y = 6.0095x2 - 1.7099x - 2.5792	2008	y = 0.8388x - 2.0952	MCES Credit River
C68	**For Stage < 3.62:** y = 0 **For Stage ≥ 3.62:** y = 4.327x2 - 28.83x + 47.695	2009	N/A	N/A
C68	**Stage ≤ 3.06 :** y = 0 **Stage >3.06 and <3.82 :** y = 0.7885x - 2.4161 **Stage ≥3.82 :** y = 4.6995x2 - 31.694x + 53.108	2008	y = 0.348x - 0.6672	MCES Credit River

<u>154</u>

The 154 WMO water quality site was located on the main stem of Credit River at the 154th Street West crossing in Prior Lake, MN. The site was equipped with a continuous stage recorder (radar sensor), which collected continuous 15-minute stage measurements year round. When available, continuous stage and rating curve equations were used to calculate daily average flows.

For the days with in-stream ice conditions or no stage data in 2008, a prediction equation was used to estimate the daily average flow (Attachment E). Instances when the prediction equation was used include: prior to monitoring equipment being installed on June 12th, after beavers began building a dam in August of 2008, and during the presence of ice in winter. A prediction equation was not used in 2009 because the MCES site experienced equipment malfunctions, which led to inaccurate stage and flow data.

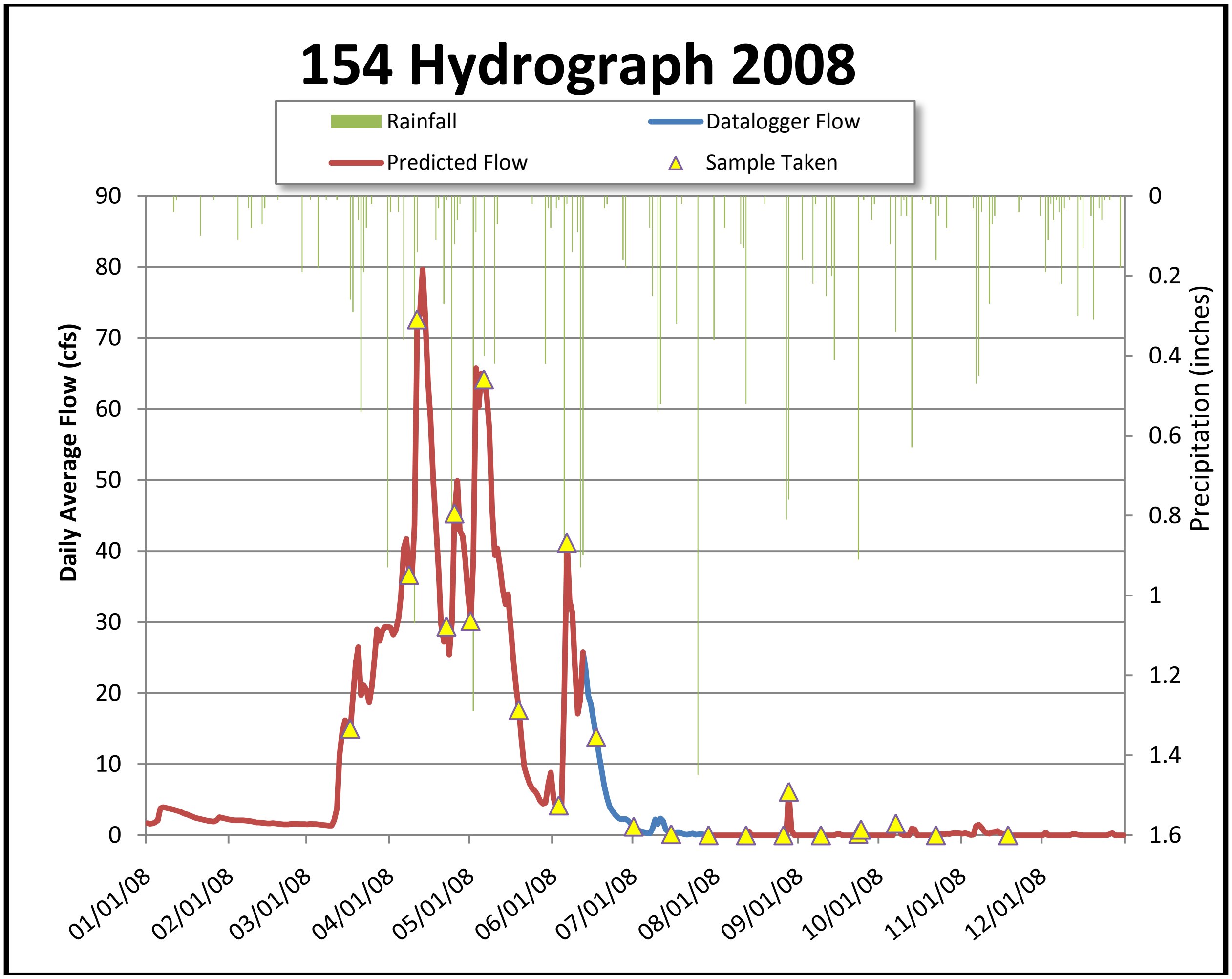
The maximum measured flow for this site is 50.61 cfs. In the 2008 hydrograph (Attachment A), there is a short duration of six days in April and six days in May where the daily average flows exceed the maximum measured flow. There is already some uncertainty with these flows because they are estimated using a prediction equation with the MCES site. The 2009 flows are well below 50.61 cfs (Attachment B).

<u>C68</u>

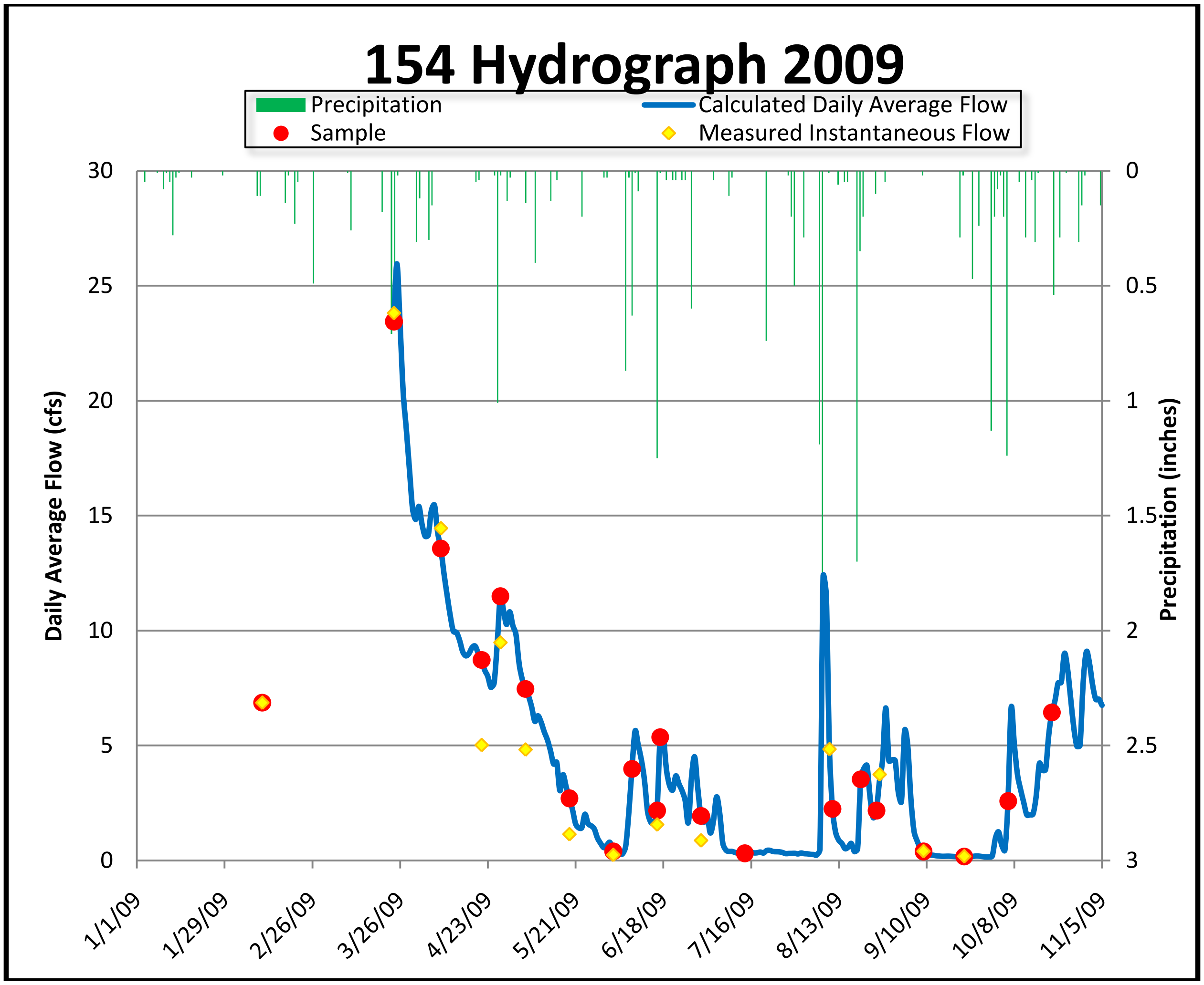
The C68 site was located on the main branch of Credit River at the County State Aid Highway 68 crossing in Credit River Township. The site was equipped with a continuous stage recorder (pressure transducer) taking 15-minute stage readings during ice-free conditions. The daily average flows were estimated using a prediction equation with the MCES site during 2008 when continuous stage and flow data was unavailable (Attachment F). Stage and flow data was unavailable prior to equipment installation on June 2, 2008 and after equipment removal on

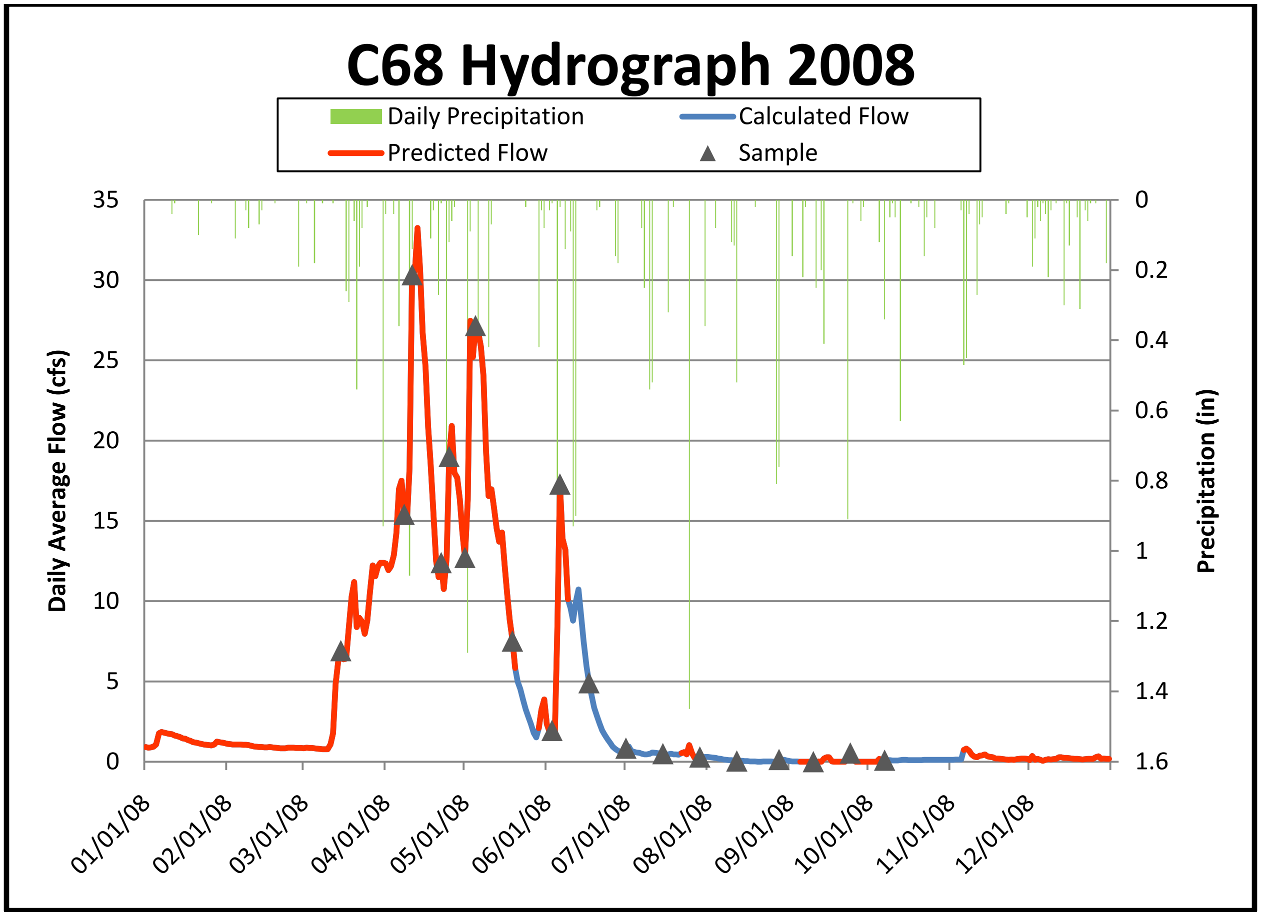
November 5, 2010.   A prediction equation was not used in 2009 due to MCES equipment malfunctions.

The maximum measured flow at C68 is 19.18 cfs. For the 2008 hydrograph (Attachment C), the daily average flow exceeded the measured flow for 10 days in April and 7 days in May. Otherwise, the flows are well within the range of measured flows leaving little uncertainty that is introduced. The 2009 flows (Attachment D) are well below the maximum measured flow.

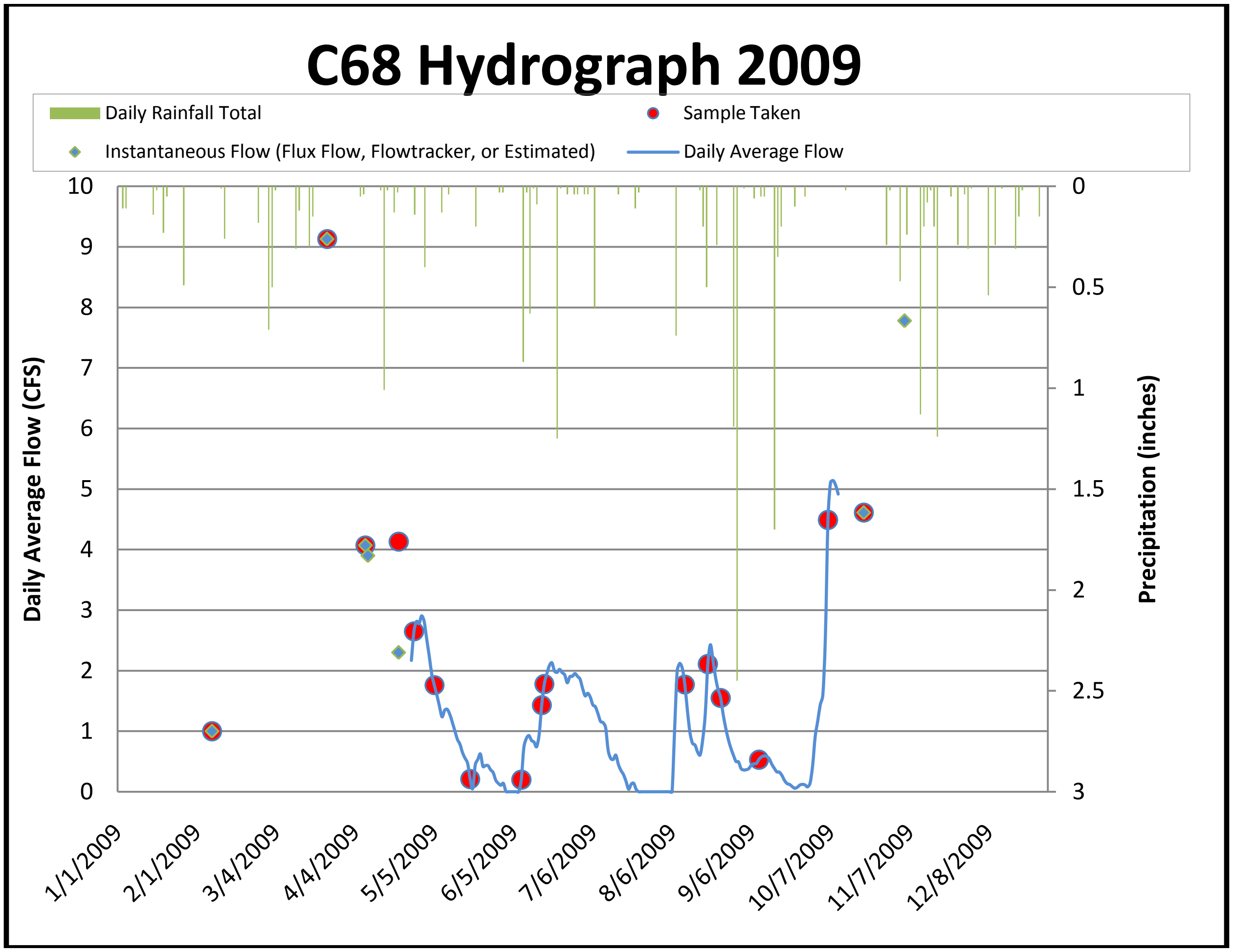

154 Hydrograph 2008
Rainfall
Datalogger Flow
Predicted Flow
Sample Taken
Daily Average Flow (cfs)
Precipitation (inches)
90
80
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
01/01/08
02/01/08
03/01/08
04/01/08
05/01/08
06/01/08
07/01/08
08/01/08
09/01/08
10/01/08
11/01/08
12/01/08

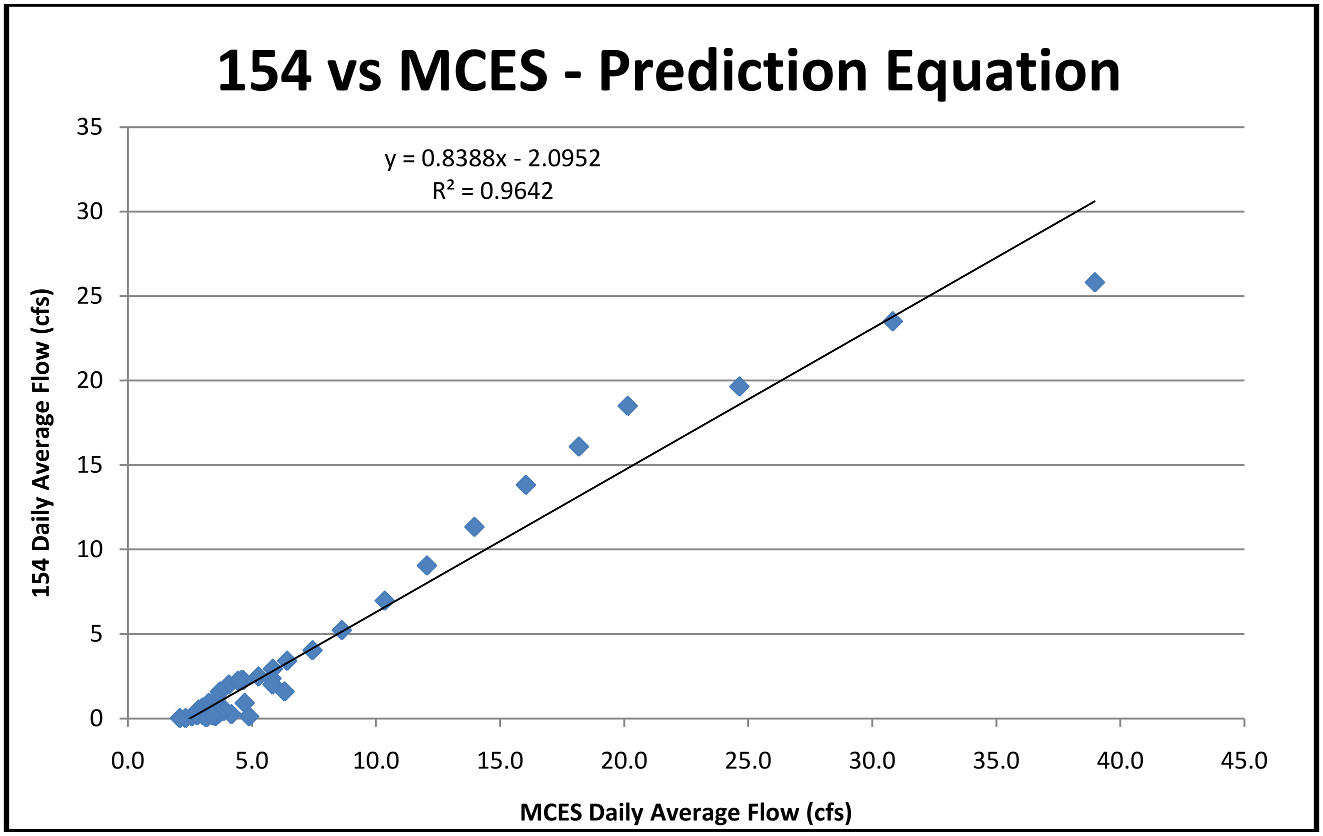
Attachment B



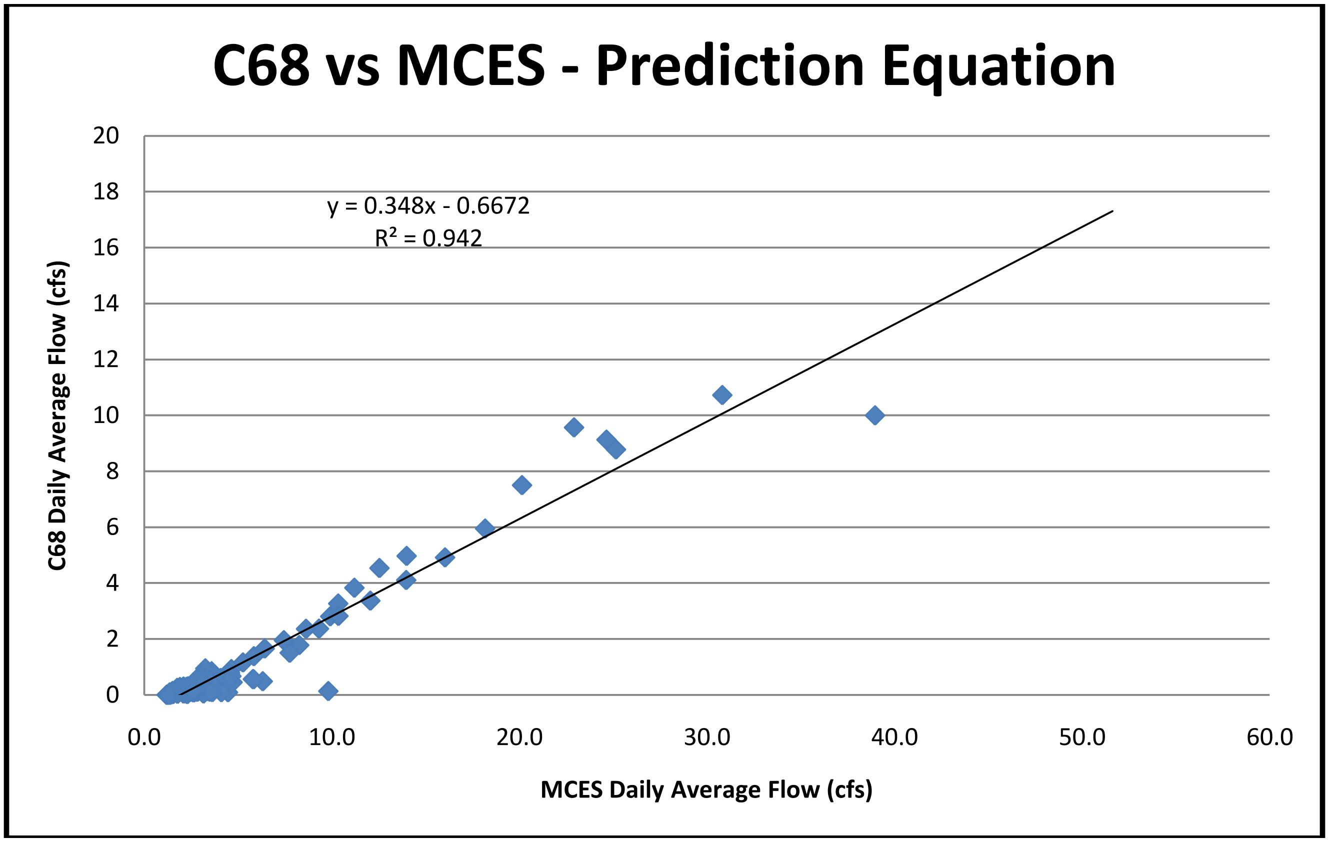

C68 Hydrograph 2008
Daily Precipitation
Calculated Flow
Predicted Flow
Sample
Daily Average Flow (cfs)
Precipitation (in)
35
30
25
20
15
10
5
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
01/01/08
02/01/08
03/01/08
04/01/08
05/01/08
06/01/08
07/01/08
08/01/08
09/01/08
10/01/08
11/01/08
12/01/08

Attachment D




154 vs MCES - Prediction Equation
y = 0.8388x - 2.0952
R² = 0.9642
154 Daily Average Flow (cfs)
MCES Daily Average Flow (cfs)
0
5
10
15
20
25
30
35
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0

Attachment F



Appendix H. Management Gaps Analysis Matrix

Credit River Protection Plan Gaps Analysis

Program Element	Description	Status	Target	Gaps Identified
Programs				
Scott WMO Technical Assistance and Cost Share (TACS)	The Scott WMO TACS program provides Technical Assistance, cost share funds and incentives for landowners to adopt conservation practices. The draft Lower Minnesota River Watershed District (LMRWD) Plan update also has a Cost Share Incentive Program that includes "Credit River Restoration Projects" estimated at $10,000 per year for 5 years. Other programs such as the NRCS EQIP and CRP programs are passively promoted.	Scott WMO program is in-going, but is generally passively promoted in the Credit River Watershed. Have had about ½ dozen projects over the last four years. These include stream bank stabilizations with private land owners along the creek, and several innovative projects with the Cities of Savage and Prior Lake involving Low Impact Development (LID) practices. The program targeted riparian landowners and improvements in 2009. LMRWD program is new.	Existing Land in the Scott WMO and LMRWD	None – continue existing efforts
Targeted Projects/ Capital Improvement Programs	The Scott WMO Plan and Local Water Plans by the Cities in the area have identified capital improvements for completion. The Lower Minnesota River Watershed District plan currently under revision will also identify capital improvements.	The targeted projects/capital improvements identified in the Scott WMO Plan for the Credit River have all been completed in partnership with the City of Savage. These include: the Utica Ravine Stabilization and the 133rd Street grade stabilization.	Existing Land in the Scott WMO and LMRWD	None – the Scott WMO and the Cities routinely update their CIP list. Scott WMO does so every two years. New potential CIPs identified can be added.
Education	The Scott WMO has an education program and participates with MS4 communities to promote water quality education through the joint Scott County Water Education Program (SCWEP). The Cities of Prior Lake and Savage, and the Credit River and Spring Lake Townships are also part of the partnership. This partnership not only helps members satisfy MS4 public education and outreach efforts, it also provides targeted education and information. The draft LMRWD Plan also has education programming, but it will target Minnesota River issues.	One full time staff person to implement SCWEP is housed at the Scott SWCD. A contract is in place to continue the partnership through 2011. The Scott WMO together with the Scott SWCD is also hosting a series of rain garden workshops in 2011 patterned after the Blue Thumb program. Participants will receive a small cost share incentive for installing a rain garden through the TACS program.	All residents – program emphasis may change from year to year	Education efforts targeting hobby farms and continuation of SCWEP beyond 2011 are gaps or uncertainties. The discontinuation of SCWEP may not be a gap in education program delivery since the MS$ partners will still need to continue education efforts in their permits. However, education programs may not be as efficient.
Scott County Household Hazardous Waste Facility	Scott County operates a Household Hazardous Waste recycling facility located in the northeast corner of Spring Lake Township. The facility can accept items from residents that are flammable, corrosive, toxic, poisonous, or reactive such as: paint products, wood preservatives or bleaches, household chemicals, yard chemicals, automotive chemicals, adhesives and putties, aerosol spray products, fuels and solvents, and mercury. Appliances, electronics, tires are accepted for a small fee. Having an option for proper disposal of waste is designed to reduce discharge into the environment.	Currently operating and open: Wednesday: 12:00 noon to 6:00 p.m. Thursday: 12:00 noon to 4:00 p.m. Saturday: 8:00 a.m. to 12:00 noon Should be operational into the foreseeable future although hours of operation and services provided may change from year to year.	All residents – household hazardous waste	None – continue existing efforts
Natural Area Corridors	The Credit River has been identified as a Natural Area Corridor in the Scott County 2030 Comprehensive Land Use Plan. Land in Natural Area Corridors is given a priority for participation in the Scott WMO TACS program (described above) and development is eligible for Public Values Incentives (described below under Regulations). These efforts are designed to promote green infrastructure, although participation is voluntary.	Currently on-going. Ordinances are in place allowing Public Value Incentives and the County has designed an approach for the acquisition and management of easements.	Owners of land within the Natural Area Corridors. The corridors primarily have a riparian focus.	None – although the program is new and no developments using the incentives have been completed to date (May 2011).
Municipal Stormwater Inspection and Maintenance Programs	All three cities have on-going stormwater inspection and maintenance programs. When these programs identify problems or needs the cities may choose to upgrade if it is a priority, is feasible and has a benefit. The Scott WMO has an LGU cost share strategy to encourage projects with LGUs.	On-going. The Cities and the Scott WMO routinely update their CIP list. Scott WMO does so every two years. New potential CIPs identified can be added.	Urban Areas	None

Program Element	Description	Status	Target	Gaps Identified
Projects				
Subwatershed Assessment and Retrofit Project	The Scott SWCD is working on a subwatershed assessment with the City of Savage to identify the most cost-effective urban BMPs that could be implemented in a retrofit fashion. The study is a dynamic document to guide the City on how to best spend funds allocated for stormwater improvements over time. The types of projects that can be constructed include pond modifications, bioretention systems, pavement reductions, new storage opportunities, etc. Funding may be available from the Clean Water Fund for implementation.	Assessment is complete - implementation funding from the Clean Water Fund under the current biennium.	Existing Urban	Current funding has been used for other projects. However, expecting to be able to access unused funds from other projects.
City of Savage – Rain Garden Funds/Incentives	The City of Savage has $15,000 for implementation rain gardens.	To be implemented together with the rain garden workshops and the Scott WMO TACS program.	Existing Urban	Currently only identified for completion in 2011. ***Sam can you confirm?*** The Scott WMO will evaluate the 2011 workshop and decide on the value of continuing the workshops in 2012 as part of its annual review of the WMOs cost share and incentive program docket (completed annually in December).
Orchard Lake Curly Leaf Pondweed Control	City of Lakeville has been working on Curly Leaf Pondweed control in Orchard Lake for several years. The DNR is providing grant assistance. Reduction of Curly Leaf Pondweed may help control phosphorus and reduce algae turbidity. The affect on the Credit River is not expected to be significant, but the effort contributes to the overall health of the watershed.	The City has received DNR grant funding for the past two years, however, they were unable to complete treatments in 2010 due to plant conditions	Lake Algae Productivity	NA
Orchard Pond Aeration	City of Lakeville is planning to aerate a pond that drains to Orchard Lake as a way of reducing phosphorus discharged to the lake. This in intended to reduce phosphorus in the lake and algae growth. There may be some reduction in algae turbidity. The affect on the Credit River is not expected to be significant, but the effort contributes to the overall health of the watershed.	On-going	Lake Algae Productivity	NA
Geomorphic Study Potential Projects	As part of the Geomorphic Study completed by the Scott WMO 48 potential projects that would improve the stability and help maintain the dynamic equilibrium of the river were identified. A number of property owners have been contacted where some of the projects were identified and some of the projects have been completed. The focus to date has been on those potential projects that would improve riparian vegetation. Other projects (particularly some of the wetland restorations) has been identified as not feasible.	The Scott WMO is current still following up with some property owners where contacts have been made. The LMRWD has identified the completion of those in their District in their draft Plan update.	The stream corridor and primary tributaries	A systematic approach to assess, track and follow-up on the potential projects is needed. More detailed feasibility and benefits analyses need to be completed with property owner contacts on those deemed feasible and beneficial.

Program Element	Description	Status	Target	Gaps Identified
Regulations				
Stormwater Standards for New & Redevelopment	In general, Scott County and cities use five management approaches for new development that can be generalized as follows. 1) All the Local Government Units (i.e., the county and the cities) require retention of ½ inch of surface water runoff from new impervious surfaces to mitigate the anticipated increases in runoff volume associated with new development. 2) All of the Local Government Units (LGUs) require some form of peak runoff rate control. For the cities in Scott County the requirement is that the peak runoff rates cannot exceed the peak rate that occurred under the pre-development land use. For the unincorporated areas of the County, the requirement is that the peak runoff rate cannot exceed the peak rate that occurred under pre-settlement land use. 3) All of the LGUs require some form of post construction water quality treatment, typically a water quality pond constructed in conformance with the MPCA specifications in the NPDES Construction General permit. 4) All of the LGUs require buffers adjacent to water courses and wetlands. The County and the Cities of Savage and Prior Lake have requirements equivalent to the Scott County WMO, which requires wetland buffer widths from 25 to 65 feet (depending on wetland quality) and watercourse buffer widths of 30 feet. 5) All of the LGUs have construction erosion control programs to control erosion during construction.	All requirements under the current Scott WMO Plan are in County ordinance and are being applied. Other Local Units of Government are required to update their Local Water Plans to include the new WMO requirements by the end of May, 2011, and will then have 180 days to begin implementation. However, new WMO requirements are largely the same as there were under the previous WMO Plan, the biggest exceptions being the need for a buffer adjacent to waterways such as the Credit River. The Cities of Savage and Prior Lake have Local Water Plans approved as equivalent under previous Scott WMO Plan. Thus, cities are largely implementing the standards. Scott County, the Cities of Savage, Prior Lake, and Lakeville; and Credit River Township all have Construction Erosion Control programs for development. Scott County and Credit River Township use the Scott SWCD to complete inspections.	New Development, redevelopment with less than 1 acre of new impervious surface has to meet some of the requirements	None – Technical Advisory Committee felt that existing control were reasonably affective in combination with other programs.
MS4 NPDES Permits	The entire Credit River watershed is covered by MS4 communities with Stormwater Pollution Prevention Plans (SWPPPs) under the Clean Water Act National Pollution Discharge Elimination System (NPDES) program, except the southernmost part of the watershed in New Market Township.	Scott County, the Cities of Savage, Prior Lake, and Lakeville; and Credit River and Spring Lake Townships all have MS4 permits and SWPPPs. The three cities also have nondegradation plans.	Implementation of the SWPPPs is on-going. The current general permit under which the communities are operating expires May 31, 2011. A new general permit is not expected to be produced by the MPCA until the end of 2011.	None – development occurring in New Market Township is subject to the some controls as the MS4 portion of the County and Credit River Township.
Land Use Planning	The Cities of Savage, Prior Lake and Lakeville, and the County have recently completed Comprehensive Land Use Plan Updates. Scott County portions of the area are guided as urban expansion and rural residential. Urban expansion is guided for 40 acre lots with the expectation that the area would not be annexed until after 2030. Rural residential is 2.5 acre lots, although clustering and community septic systems can be used allowing smaller lots.	County ordinances are in place for the zoning, and a Detailed Area Plan has been completed identifying the infrastructure needs for developing at rural residential densities of 2.5 acre lots.	New development	None – a majority of future development in the watershed is guided for large lot rural residential.

Program Element	Description	Status	Target	Gaps Identified
Regulations con't				
Development Incentives	Scott County has Public Value Incentives for development in the rural residential areas to promote Planned Urban Developments that incorporate attributes that benefit the public. In exchange for incorporation of these attributes, incentives such as extra density of a few lots can be considered. Specific Public Values that may help protect the Credit River include preserving land in Natural Area Corridors, dedicating parkland, restoring wetlands, dedicating lands for regional stormwater facilities, or using Low Impact Development practices.	Necessary ordinances have been written and adopted.	New development in unincorporated areas	None
Spring Lake Township LID Requirements	Spring Lake Township has developed requirements for new development in addition to the County's and Scott WMO's stormwater management standards. These include the requirements to use Low Impact Development practices.	The Township has written the necessary ordinances.	New development in Spring Lake Township	None
Cleary Lake TMDL	Cleary Lake is considered water quality impaired due to excessive nutrients. This means that a Total Maximum Daily Load (TMDL) study is required to determine the necessary phosphorus load reduction to achieve the standard. This may affect MS4 stormwater permits, and improve the quality of discharges from the lake to the Credit River.	The TMDL study is scheduled to start in 2014 and be complete by 2018.	The Cleary Lake subwatershed	To be completed
Hobby Farm Requirements	County ordinances set maximum number of animal units based on acreage.	Current in ordinance	The unincorporated rural residential area	Education efforts targeting hobby farms are a gap. Education on livestock exclusion is a gap.

Program Element	Description	Status	Target	Gaps Identified
		Monitoring		
MCES Outlet Monitoring	MCES operates a monitoring station at RM0.9 where data on flow and a number of water quality parameters is collected. MCES also collects information on macroinvertebrates.	Water quality monitoring at RM0.9 is expected to remain in place. The macroinvertebrate monitoring was completed for only a few years (2004 through 2007), and funding to continue is uncertain.	Credit River	There is a gap with respect to funding and sustaining biomonitoring. The Metropolitan Council, Scott WMO and LMRWD to coordinate to ensure macroinvertebrate monitoring occurs every other year. Will be coordinated with the 2014 biomonitoring by MPCA to prevent duplication.
Lakes	Orchard Lake is monitored annually through the MCES CAMP program. Cleary Lake and other Lakes in the Murphy Harahan Regional Park are monitored by the Three Rivers Park District. Markley Lake is not monitored, but is land locked and does not discharge.	On-going	Lakes	None
MPCA Biomonitoring	MPCA is scheduled to complete its monitoring program for the Lower Minnesota River Basin in 2014. This will include biomonitoring on the Credit River for both macorinvertebrates and fish.	Scheduled for completion in 2014 and then every 10 years.	Credit River	None - There currently is a gap on fish community information which will be filled by this monitoring program.

Program Element	Description	Status	Target	Gaps Identified
Inventory and Assessment				
Water Quality Trend Analysis	On-going or periodic assessment of water quality trends is important for a protection program in order to have early detection of trends and have a basis for making adaptive management decisions.	Metropolitan Council has not completed a trend analysis of the data at the RM0.9 site, but is currently completing such an analysis with publication of results in expected in 2011. They expect to do additional trend analyses on a periodic basis, but a schedule has not been established.	Credit River	Metropolitan Council to consider assessing trends on a 5 year cycle.
Water Quality Data Assessments	The Metropolitan Council assesses and publishes the CAMP Lake monitoring data annually. Three Rivers Parks also assesses their lake monitoring data annually and provides summary reports to local WMOs to publish on their websites. MPCA will assess the data they collect as part of the Lower Minnesota River Basin monitoring effort in the years immediately following data collection. Results will be disseminated through reports and publications of the MPCA.	Annual assessments First monitoring cycle by the MPCA is scheduled for 2014. Data analysis is expected to be completed in 2015 and 2016, and then on 10 year cycles.	Lakes The Basin, including Credit River	Three Rivers Parks District Lake summary reports have not been provided to the Scott WMO. Scott WMO and Three Rivers Park District to coordinate to get summary reports posted on the WMO website.
Observation of Sediment Delta Formation	The Lower Minnesota River Watershed District receives reports and observes sediment delta formation where the Credit River discharges to the Minnesota River.	On-going	Minnesota River and impact on port facilities	Observations need to be relayed to the Scott WMO. LMRWD and Scott WMO to coordinate transfer of information.
Groundwater Assessment and Planning	The Scott County Groundwater Management Plan expired in 2009. Efforts in the old plan were voluntary. Recent studies have shown that projected develop will negatively affect the baseflow of the river. Cities are currently assessing whether they can work together more through cross connections to maintain supply. Scott WMO is planning a well sampling effort to screen for pesticides and nitrates in the unincorporated areas. This effort is scheduled for the summer of 2011.	The County is assessing whether to complete a new plan. To make that decision the County is waiting for the results of the study by the cities and the rural well pesticide screening. It is expected that these studies will be complete early summer of 2011, with the County anticipating on revisiting the planning process in the fall of 2011.	Ground water	There is a gap regarding how to mitigate predicted baseflow reductions in the river. County to consider updating County-wide Groundwater Plan, Cities to consider connecting systems and additional conservation. Additional ideas to be considered as art of the planning process for the Groundwater Plan update.
Minnesota Land Cover Classification System Update	The Minnesota Land Cover Classification System (MLCCS) inventory completed by the County provides an important tool for managing natural systems and the Natural Areas Corridor.	The current inventory for the unincorporated areas of the watershed was completed in 2007. The Scott WMO is planning to update portions of the inventory in 2013.	Natural areas	Uncertain whether the update planned for 2013 will focus on the Credit River watershed or other portions of the Scott WMO. Priority areas will be determined early 2013.
Plan Progress Tracking and Review	There needs to be on-going tracking of progress and assessment of the effectiveness regarding implementation of this Protection Plan.	Scott WMO has metrics for measuring implementation of the Scott WMO Plan that are assessed and reported on in the WMO Annual Report. The Scott WMO Plan was recently amended to add the Credit River Protection Plan as an implementation strategy.	Decision makers	There is not a specific metric for tracking and reporting implementation of the Protection Plan. Scott WMO will add a metric for the Protection Plan.
Reviewing and Updating the Protection Plan	There needs to be a process for reviewing and updating the plan.	Since the Protection Plan is currently under development a process has not yet been developed.	Decision makers	The implementation section of the plan will include a process for updating the plan; 1) when trend analyses or the annual assessment of progress (metric) suggest a change is needed, and 2) after a set period of time. It is most efficient to update the plan concurrent with the Scott WMO Plan update so that it could again be included as an implementation strategy and tracked as part of the WMO Plan. The Scott WMO Plan is scheduled to be updated in 2019.

Appendix I. 2011 Scott WMO Cost Share Docket

2011 SCOTT WMO COST SHARE PROGRAM
CONSERVATION PRACTICE PAYMENT DOCKET

The Scott Watershed Management Organization (WMO) Cost Share Program was created to provide funds to landowners within the legal boundary of the Scott WMO for the implementation of conservation practices that protect and improve water quality. Landowners, citizen groups and local units of government can request financial and technical assistance from the Scott WMO and the Scott Soil and Water Conservation District (SWCD) through the cost share program for implementation of conservation practices. All requests are subject to approval by the WMO Board.

This Conservation Practice Payment Docket lists practices that have been authorized for payments under the Scott WMO Cost Share Program. The docket consists of three parts: Program Provisions, General Conservation Practice Provisions, and Specific Conservation Practice Provisions. The Program and General Conservation Practice Provisions list the requirements that are applicable to all or multiple practices. The Specific Provisions list the payment method, rates and limits, practice lifespan, and specific provisions for each conservation practice.

PROGRAM PROVISIONS

The following provisions are requirements for cost share funding under this program:

ELIGIBILITY:

1. Scott WMO Cost Share Program payments are only authorized for practices listed in the docket. Non-docket practices required for the implementation of a docket practice shall be considered components of and subsidiary to the docket practice. Conservation payments for components will be included with the docket practice.

2. Conservation Practice Payments are authorized for practices:
    a. Implemented following the contents of appropriate and most current technical standards, including but not limited to: the NRCS Field Office Technical Guide, MPCA Stormwater Manual, MPCA Protecting Water Quality in Urban Areas, NPDES General Stormwater Permit for Construction Activity, Minnesota Urban Small Sites BMP Manual, and other applicable local, state and federal regulations and standards.
    b. Implemented following the general and specific conservation practice provisions for each practice included in the docket.
    c. Where positive environmental benefits from the benchmark condition can be documented.
    d. Where erosion was not a result from the direct impacts of development, unless the development occurred prior to applicable standards, such as NPDES permitting or the 2007 Scott WMO Rules.

    Payments are not authorized for, or on, existing, in-place practices.

3. Applicants who start a practice before a contract is approved by the Scott WMO Board do so at their own risk and are not guaranteed funding. Work that starts before the applicant signs the contract is ineligible for Scott WMO financial assistance for that practice.

PAYMENT METHODS:

4. Two types of payment methods are used in this program: incentive payments and cost sharing.
    a. Incentive Payments:
        1. One Time Incentive Payment – Payment is made upon certification of practice implementation.
        2. Annual Incentive Payment – Payment is calculated for a specified number of years. Payment is made in two installments: the first ½ of the incentive is given upon certification of installation and the second ½ upon certification of establishment.
    b. Cost Sharing Payments: Cost sharing is reimbursement to a participant to help offset the construction costs associated with implementing a practice. The maximum cost share rate for 2011 Scott WMO contracts with private landowners or land occupiers is listed for each practice and shall be considered the maximum rate of actual construction costs or the estimated cost (whichever is less) of implementing the practice.
        1. The maximum cost share rate for municipalities cannot exceed 50%.
        2. Individuals with the appropriate technical approval authority must be involved in the preparation of cost estimates, either as preparer or reviewer.

5. The maximum rates listed in this docket are not guaranteed rates. The Board may reduce the maximum rate depending on the public benefit.

6. WMO funds should be combined with other funds when possible. The total payment to the landowner shall not exceed the maximum cost share or incentive rate listed in the WMO Cost Share Docket. Other program rules regarding maximum payment rates and other limitations shall be observed.

7. The amount to be cost shared will be limited to that required for the practice to be installed. When additional or alternative work or material is performed or used at the landowner's request, any costs greater than the minimum required for the practice will be borne by the owner.

8. Practices that cost share on seeding will include all associated costs needed to implement the seeding plan.

APPROVAL PROCESS:

9. Applications for funding are scored using a ranking worksheet and reviewed twice annually by the Screening Committee. A recommendation for funding is made by the Screening Committee to the Watershed Planning Commission (WPC). The recommendation will be reviewed by the WPC and forwarded to the WMO Board for final approval or disapproval.

10. To expedite implementation during optimum field conditions, time sensitive projects can be sent directly to the WPC without going through the Screening Committee first. The eligible project must score 16 or higher on the Scott WMO Ranking Worksheet in order to be considered for this fast tract option.

11. Filter strip applications will be accepted on a continuous sign-up basis. Review and approval decisions will be made by the Scott SWCD Board until designated funds are depleted. If additional filter strip applications are submitted, the extra applications can be sent to the Screening Committee and will follow the process outlined above.

12. Approvals of applications for cost share are subject to the availability of funding.

EARNEST ACCOUNT:

13. Applicants for Scott WMO cost share funds will be required to provide earnest money of 10% of the Scott WMO contribution up to $500.00 per application. These funds will be returned upon certification of the completed practice. Projects cancelled by the applicant will forfeit the earnest money.

14. Practices that qualify for incentive payments do not require an earnest account be set up.

REPAYMENT OF FUNDS:

15. Should the applicant remove or fail to maintain the practice during its effective life, the applicant is liable to the Scott WMO for the full amount of financial assistance received to install and establish the practice. The applicant is not liable for cost-share assistance received if the failure was caused by reasons beyond the applicant's control.

GENERAL CONSERVATION PRACTICE PROVISIONS

The following provisions apply to the design and construction of conservation practices:

1. Soil Testing: A soil test may be required for any practice that targets the reduction of soil loss. The purpose of the soil test is to determine nutrient content of the soil so that more accurate estimates of phosphorus loading and reductions can be made. A soil test shall be performed for any practice requiring the application of liming materials, commercial fertilizer, and/or manure for the establishment of vegetation. All soil tests shall be from a soil testing laboratory shown on the Minnesota Department of Agriculture's list of approved Soil Testing Laboratories. Application rates of lime, commercial fertilizer, and manure shall be based on University of Minnesota recommendations, or from North Dakota's or South Dakota's Land Grant University. Soil testing requirements may be waived if acceptable soil tests from the site were taken within the previous three years.

2. Wetland Protection: NRCS Wetland Policy as found in the General Manual 190, Part 410 must be followed. This policy provides direction to the agency for compliance with the National Environmental Policy Act (NEPA). This policy prohibits NRCS from providing technical or financial assistance to participants that will adversely affect wetlands, unless the lost functions are fully mitigated.

3. Upland Treatment: As a requirement of eligibility, participants are required to perform upland treatment actions, through a conservation plan, according to Minnesota Conservation Planning Policy, and adequately address potential adverse impacts to conservation practices. Adverse impacts to conservation practices could include, but are not limited to, increased siltation by water and/or wind borne soils, excessive runoff, degradation of vegetation practice components by pesticides transported in runoff and sediment, and degradation of wildlife habitat.

4. Materials: New materials must be utilized in the construction of practices, unless approved by an Authorized Engineer **PRIOR** to installation.

5. Land Rights: Participants wanting to construct practices on land they do not own are responsible for obtaining easements, permits, right-of-way, water rights or other permission necessary to perform and maintain the practices. Expenses incurred due to these items are not cost shared. The permission from the authority must be in writing and a copy must be provided to the Scott SWCD office prior to installation being made on the practice.

6. Permits: The applicant is responsible for obtaining all permits required in conjunction with the installation and establishment of the practice prior to starting construction of the project.

7. Operation and Maintenance: The applicant is responsible for the operation and maintenance of the conservation practice for the minimum lifespan listed in the specific provisions of this document.

SPECIFIC CONSERVATION PRACTICE PROVISIONS

The following specific provisions exist for each conservation practice as listed below:

PRACTICE STANDARD 712 – BIORETENTION BASINS

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Bioretention Basin (Redevelopment/Community)	712			50% of actual construction costs, not to exceed 50% of cost estimate	10 years
Residential Rain Gardens (if identified in Local Water Plan)				50% of actual construction costs, not to exceed 50% of cost estimate	10 years
Residential Rain Garden (other)		1 time	$250		10 years

1. Upland treatment is required. See General Conservation Practice Provision #3.
2. Eligible materials include plants, biologs, erosion control blankets, site preparation materials, edging, mulch, stakes and other items critical to the proper function of the rain garden. Materials not eligible for cost share include those items that do not benefit practice function, such as ornamental rock or other decorative items.
3. To qualify for the residential rain garden incentive payment, the applicant must participate in an approved rain garden class. To qualify for cost sharing, the rain garden must be identified as a priority project in an approved Local Water Plan.

PRACTICE STANDARD 342 – CRITICAL AREA PLANTING

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Critical Area Planting	342			75% of actual construction costs, not to exceed 75% of cost estimate	10 years

1. Upland treatment is required. See General Conservation Practice Provision #3.
2. Critical Area Planting (342) must be completed following an approved establishment and management plan.

PRACTICE STANDARD 362 – DIVERSION

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Diversion	362			50% of actual construction costs, not to exceed 50% of cost estimate	10 years

1. Upland treatment is required. See General Conservation Practice Provision #3.
2. The use of tile or other underground pipe to drain hillside seeps, low or wet spots in fields is not an eligible single component of this practice.
3. Diversion (362) is allowed as a stand-alone practice for feedlots when used as a clean water diversion.
4. If a Diversion (362) is a component of Wastewater and Feedlot Runoff Control (784), cost sharing is **NOT** authorized for the Diversion (362) as a stand-alone practice. The cost will be included in the cost of Wastewater and Feedlot Runoff Control (784).

PRACTICE STANDARD 393 – FILTER STRIP

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Filter Strip (Non-harvestable)	393	Annual	$250.00/ac		10-15 years
Filter Strip (Harvestable: Natives)	393	Annual	$200.00/ac	75% of actual construction costs, not to exceed 75% of cost estimate	10 years
Filter Strip	393	Annual	$200.00/ac		10 years

(Harvestable: Non-Natives)					
Sensitive Field Border (Harvestable)	393	Annual	$200.00/ac		10 years

1. Soil testing is required for filter strips. See General Conservation Practice Provision #1.
2. New Scott WMO Filter Strip Incentives are limited to land to be enrolled in the Continuous Conservation Reserve Program (CCRP) practice number CP-21 or within the adjacent 120 feet of practice CP-28.
3. The combined annual incentive payment authorized by the Scott WMO on eligible acres and the annual Continuous Conservation Reserve Program (CRP) rental payment for new filter strips shall not exceed $250.00/acre/year.
4. The payment rate for the renewal of existing harvestable filter strip contracts that are not eligible for enrollment in the Continuous Conservation reserve program (CCRP) shall not exceed $200.00/acre/year.
5. Sensitive field borders include the edges of fields that are not included in Standard 393, such as road ditches, drainage ditches without seasonal perennial stream characteristics, or other areas deemed sensitive. Minimum width is 33'.
6. Filter Strips located in areas where the maintenance of permanent natural vegetation is used to meet the requirements under Chapter 70-8-11, Scott County Zoning Ordinance, shall not be eligible for renewal funding starting in 2012, or first-time funding after 2013.

PRACTICE STANDARD 410 – GRADE STABILIZATION STRUCTURE

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Grade Stabilization	410			90% of actual construction costs, not to exceed 90% of cost estimate	10 years

1. Upland treatment is required. See General Conservation Practice Provision #3.
2. Cost is for earthwork and any seed and seeding expenses.

PRACTICE STANDARD 412 – GRASSED WATERWAY

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Grassed Waterway	412			75% of actual construction costs, not to exceed 75% of cost estimate	10 years

1. Upland treatment is required. See General Conservation Practice Provision #3.
2. Cost is for earthwork and any seed and seeding expenses.

PRACTICE STANDARD – INNOVATIVE PRACTICES

	Incentive Payment		Cost Sharing	Lifespan
	Type	Amount $	Maximum Eligible Cost Share Rate	
Innovative Practices (Redevelopment/Community)			50% of actual construction costs, not to exceed 50% of cost estimate	10 years
Innovative Practices (New Development)			50% of actual construction costs, not to exceed 50% of cost estimate	10 years

1. Initial interest for innovative practices is discussed with Scott WMO staff.
2. Applications are taken by Scott SWCD staff.
3. Applications move directly to the WPC and are not reviewed by the Screening Committee. The WPC makes a recommendation to the WMO Board, who makes the final approval/disapproval decision.
4. Approved applications are assigned to Scott SWCD for technical assistance.
5. Eligible practices include regenerative dustless street sweepers, porous pavers, porous pavement, green roofs, and other practices determined on a case by case basis.

PRACTICE STANDARD – NATIVE GRASS

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Native Grass Planting (Parcel size: 10+ acres)		1 Time	$175/ac/yr	50% of actual construction costs, not to exceed 50% of cost estimate	10 years
Native Grass Planting (Parcel size: 5-10 acres)		1 Time	$150/ac/yr	50% of actual construction costs, not to exceed 50% of cost estimate	10 years
Native Grass Planting (Parcel size: 2-5 acres)		1 Time	$125/ac/yr	50% of actual construction costs, not to exceed 50% of cost estimate	10 years

1. Native Grass Incentives are available for private properties located within the Scott Watershed Management Organization and where the land use is primarily row crop. Additional area of non-native vegetation may be eligible.
2. WMO cost share payments for establishment shall be up to 50% after WHIP and/or EQIP payments have been applied.
3. Upland treatment is required. See General Conservation Practice Provision #3.

PRACTICE STANDARD – NATURAL SHORELINE RESTORATION and/or STABILIZATION

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Natural Shoreline Restoration >500 linear feet				75% of actual construction costs, not to exceed 75% of cost estimate	10 years
Natural Shoreline Restoration <500 linear feet		1 time	$500		10 years
Shoreline Stabilization	580			50% of actual construction costs, not to exceed 50% of cost estimate	10 years

1. To qualify for natural lakeshore restoration funds, the applicant must participate in an approved natural lakeshore restoration class and complete a "Score Your Shore" assessment in consultation with a SWCD Conservationist.
2. Applications for cost share funding will be reviewed twice per year by the Screening Committee. Projects recommended for approval will be forwarded to the WPC. Other applications will be eligible for the incentive payment.
3. Project designs shall meet the intent of restoring the shoreline to predominantly natural conditions, including but not limited to the use of natural and native vegetative buffers, limiting turf grass, and using bioengineering methods.
4. Funding for hard armor practices (e.g. rock riprap) are not eligible for funding unless bio-engineering methods are determined to be an insufficient means of needed stabilization.
5. Upland treatment is required. See General Conservation Practice Provision #3.

PRACTICE STANDARD 590 – NUTRIENT MANAGEMENT: Manure Testing

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Manure Testing	590			100% of Actual Cost	1 year

1. Manure testing is a practice pre-approved by the Scott WMO. An application does not need to be sent to the Scott WMO Board for approval. A voucher can be processed immediately and sent to the Scott SWCD Board for approval.
2. Manure testing kits are available through Scott SWCD.

PRACTICE STANDARD 338 – PRESCRIBED BURNING

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Prescribed Burning	338	1 Time	$200.00/ac.		5 years

1. A detailed burn plan describing the practice objective, species to control and species to be benefited, timing, weather conditions and management guidelines will be developed.

2. Technical assistance will be provided by a technically qualified and adequately insured individual.
3. All laws and regulations pertaining to burning will be followed.
4. **The conservation plan must document that the landowner has been notified in writing that they are subject to all liability due to damages caused by fire.**
5. It is the landowner's responsibility to obtain all permits and to notify surrounding landowners that may be affected.
6. Cost share is eligible once every 5 years.
7. Associated costs with obtaining and notification of neighbors, units of government, and agencies are entirely the landowner's expense.
8. The incentive payment listed is the maximum eligible payment between ALL programs.

PRACTICE STANDARD 391 – RIPARIAN FOREST BUFFER

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Stream Buffer >5 ac parcel	391			75% of actual construction costs, not to exceed 75% of cost estimate	10 years

1. Technical assistance is available for parcels greater than one acre, but smaller than five acres even though cost share assistance is not available to cover construction costs.
2. Adjacent land owners may combine their parcels to reach the 5 acre minimum to qualify for cost share assistance.
3. A potential tax credit exists for parcels greater than 20 acres.
4. Projects can be either new establishment or renovation.

PRACTICE STANDARD 600 – TERRACE

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Terrace	600			75% of actual construction costs, not to exceed 75% of cost estimate	10 years

1. Upland treatment is required. See General Conservation Practice Provision #3.
2. The use of Subsurface Drain (606) or Underground Outlet (620) to drain hillside seeps, low or wet spots in fields is not an eligible single component of this practice. The land user shall identify, in writing the purpose of the larger tile and indicate the area that it will serve. The difference in cost of installing tile larger than that specified by the technician will be borne by the producer.
3. Cost sharing for Underground Outlet (620) is limited to the diameter and length needed to convey water from surface intakes to a safe outlet as determined by the designer.
4. Cost sharing for Subsurface Drain (606) is limited to drains needed in the impounded area of the terrace as determined by the designer.

PRACTICE STANDARD 620 – UNDERGROUND OUTLET: Rock tile inlets

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Rock Tile Inlets	620			75% of actual construction costs, not to exceed 75% of cost estimate	10 years

1. Cost sharing is limited to replacing existing tile inlets.

PRACTICE STANDARD 635 – VEGETATED TREATMENT AREA (formerly Wastewater Treatment Strip)

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Level 2 to 4 Vegetated Treatment Area – lot size of 1 acre or less	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years

Level 2 to 4 Vegetated Treatment Area – lot size of 1.1 acre to 2 acres	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Level 2 to 4 Vegetated Treatment Area – lot size 2.1 to 5 acres	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Level 2 to 4 Vegetated Treatment Area – lot size greater than 5 acres	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Level 5 Control – vegetated buffer	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years

1. Payment is limited to where the implementation of this practice will correct an existing pollution problem. As outlined by the EQIP manual, any EQIP contract that includes an animal waste storage or treatment facility will provide for the development of a CNMP prior to implementation of the storage or treatment. MPCA's definition is used to define a pollution problem.
2. Consult EQIP General Provision 12 for Comprehensive Nutrient Management Plan (CNMP) requirements.
3. Consult EQIP General Provision 13 for requirements related to manure application land base and/or manure applications on land not owned or controlled by the EQIP contract holder.
4. Payment for Vegetated Treatment Area on operations with pollution problems less than 5 years old is not authorized.
    a. Examples:
        i. Producer A has had a dairy farm operation for 20 years. Producer B purchases the dairy and continues milking cows. This pollution problem is greater than 5 years old and producer B meets this eligibility requirement for Payment assistance.
        ii. A producer has a dairy operation on farm A. He purchases farm B and moves the dairy operation to farm B where there was no previous pollution problem. Farm B would be considered a new facility and would not be eligible for Payment assistance.
5. Payment is not authorized for Vegetated Treatment Area on operations where the system establishment is required as a result of judicial or court action. MPCA Stipulation Agreement and Schedule of Compliance (SOC) are not considered a judicial or court action, and practice implementation is still considered voluntary for EQIP eligibility purposes, even if fines have been levied by the MPCA.

PRACTICE STANDARD 313 – WASTE STORAGE FACILITY

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Concrete or Metal Tank	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Stacking Slab	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Pond – composite liner	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Pond – membrane liner	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Pond – no liner	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Pond – soil liner	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Concrete slab	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Non liquid tight deep pack – concrete wall	313			90% of actual construction costs, not to exceed 90% of cost estimate	10 years

1. The eligible volume of storage is the total storage volume, including the design storage volume plus freeboard as required in the standard. As outlined in Waste Storage Facility (313), the maximum design storage period is 14 months.
2. The maximum allowable storage volume is based on the current capacity of the existing facility plus up to 25% expansion.
3. Payment is limited to where the implementation of this practice will correct an existing pollution problem. As outlined by the EQIP manual, any EQIP contract that includes an animal waste storage or treatment facility will provide for the development of a CNMP prior to the implementation of the 313. MPCA's definition is used to define a pollution problem.
4. Consult EQIP General Provision 13 for Comprehensive Nutrient Management Plan (CNMP) requirements.
5. Consult EQIP General Provision 14 for requirements related to manure application land base and/or manure applications on land not owned or controlled by the EQIP contract holder.
6. For purposes of this practice, "waste" refers to raw manure and urine; runoff water contaminated through contact with manure and urine; milking center wastewater; and silage leachate as appropriate.
7. Silage storage facilities are not eligible components. Payment for components addressing silage leachate concerns under Waste Storage Facility start at the edge of the silage storage facility.
8. For livestock operations that are not or will not be permitted under the NPDES system, silage leachate systems can be funded as stand-alone practices if these systems are the only livestock related practices being requested. The development of a CNMP IS required with a silage leachate system but the CNMP does NOT have to be implemented.
9. Payment is authorized for tanks that serve as foundations for buildings, however eligible costs are those associated with the storage function only. Payment is not authorized for production oriented building components.
10. Payment for Concrete Slab is authorized for concrete agitation and pump out pads, pond lining, ramps and chutes within the pond.
11. Payment is authorized for feedlot relocation, with the following provisions:
    a. The payment for relocation shall be based on the most practical and feasible waste management facility at the existing site.
    b. Payment at the new site is only authorized for components applicable to the transfer, storage, or treatment of wastes.
    c. Existing location is to be abandoned in an environmentally safe manner as outlined in MPCA guidelines.
    d. Operator must agree to permanently remove all livestock from the existing location along with any other designated pollution sources. The following statement shall be included in the EQIP contract: "As a condition of EQIP Payment on feedlot relocation, the producer agrees to permanently eliminate all animals and designated pollution sources at this facility. Failure to comply with this provision may result in a recovery of federal Payment funds."
    e. In the event of a change in ownership, the abandoned lots will permanently not be eligible for future USDA Payment on waste management practices.
12. Payment for Waste Storage Facility (313) on operations with pollution problems less than 5 years old is not authorized.
    a. Examples:
        i. Producer A has had a dairy farm operation for 20 years. Producer B purchases the dairy and continues milking cows. This pollution problem is greater than 5 years old and producer B meets this eligibility requirement for Payment assistance.
        ii. A producer has a dairy operation on farm A. He purchases farm B and moves the dairy operation to farm B where there was no previous pollution problem. Farm B would be considered a new facility and would not be eligible for Payment assistance.
13. Payment is not authorized for Waste Storage Facility (313) on operations where the system establishment is required as a result of judicial or court action. MPCA Stipulation Agreement and Schedule of Compliance (SOC) are not considered a judicial or court action, and practice implementation is still considered voluntary for EQIP eligibility purposes, even if fines have been levied by the MPCA.
14. State NRCS Conservationist approval is required for systems involving agricultural waste generated off-site.
15. Payment for Waste Storage Facility is capped at $250,000. This cap applies to the total facility being installed under 313. Other components such as manure transfer, safety fence, etc are allowed in the contract in addition to the capped $250K for the 313 practice.

16. Non Liquid Tight Deep Pack – Concrete Wall is authorized only for stacking slabs where enough bedding or organic matter is added to the manure to eliminate liquid runoff or leaching and therefore a concrete floor is not required. The manure and organic pack resulting from the operation of a "Compost Barn" as defined by the University of Minnesota meets this definition.

PRACTICE STANDARD 629 – WASTEWATER TREATMENT

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Flocculation Treatment	629			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Vegetated Dosing Area	629			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Bark Bed	629			90% of actual construction costs, not to exceed 90% of cost estimate	10 years
Aerobic Treatment	629			90% of actual construction costs, not to exceed 90% of cost estimate	10 years

1. Payment is limited to where the implementation of this practice will correct an existing pollution problem. As outlined by the EQIP manual, any EQIP contract that includes an animal waste storage or treatment facility will provide for the development of a CNMP prior to implementation of the storage or treatment. MPCA's definition is used to define a pollution problem.
2. Consult EQIP General Provision 13 for Comprehensive Nutrient Management Plan (CNMP) requirements.
3. Consult EQIP General Provision 14 for requirements related to manure application land base and/or manure applications on land not owned or controlled by the EQIP contract holder.
4. Payment for Wastewater Treatment on operations with pollution problems less than 5 years old is not authorized.
    a. Examples:
        i. Producer A has had a dairy farm operation for 20 years. Producer B purchases the dairy and continues milking cows. This pollution problem is greater than 5 years old and producer B meets this eligibility requirement for Payment assistance.
        ii. A producer has a dairy operation on farm A. He purchases farm B and moves the dairy operation to farm B where there was no previous pollution problem. Farm B would be considered a new facility and would not be eligible for Payment assistance.
5. Payment is not authorized for Wastewater Treatment on operations where the system establishment is required as a result of judicial or court action. MPCA Stipulation Agreement and Schedule of Compliance (SOC) are not considered a judicial or court action, and practice implementation is still considered voluntary for EQIP eligibility purposes, even if fines have been levied by the MPCA.
6. Payment rate includes components needed for the actual waste treatment. Components needed for temporary storage and transfer of wastes are covered under separate practices.

PRACTICE STANDARD 638 – WATER AND SEDIMENT CONTROL BASIN

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Water & Sediment Control Basin	638			90% of actual construction costs, not to exceed 90% of cost estimate	10 years

1. The use of Subsurface Drain (606) or Underground Outlet (620) to drain hillside seeps, low or wet spots in fields is not an eligible single component of this practice. The land user shall identify, in writing the purpose of the larger tile and indicate the area that it will serve. The difference in cost of installing tile larger than that specified by the technician will be borne by the producer.
2. Upland treatment is required. See General Conservation Practice Provision #3.
3. Cost sharing for Subsurface Drain (606) is limited to drains needed in the impounded area of the basin as determined by the designer.

PRACTICE STANDARD 351 – WELL DECOMMISSIONING (Unused Well Sealing)

	NRCS Code	Incentive Payment		Cost Sharing	Lifespan
		Type	Amount $	Maximum Eligible Cost Share Rate	
Well Decommissioning	351			75% of actual construction costs, not to exceed 75% of cost estimate	10 years

PRACTICE STANDARD 657 – WETLAND RESTORATION

Wetland restorations cost share and incentive payments are covered under the Wetland Restoration and Enhancement Program (WREP).