Prepared by:
Emmons & Olivier Resources, Inc.
for the Bois de Sioux Watershed District, JOR Engineering,
and the Minnesota Pollution Control Agency

Mustinka River Turbidity TMDL Implementation Plan

November 2010

water | ecology | community

wq-iw5-04c

Cover Image
Mustinka River.
Photo courtesy of the Minnesota Center for Environmental Advocacy.

Mustinka River Turbidity TMDL Implementation Plan

November 23, 2010

Primary Authors

EOR water ecology community

Andrea Plevan
Tom Miller
Jason Naber

JOR Engineering

Charlie Anderson

Contributors

Bois de Sioux Watershed District

Jon Roeschlein

Minnesota Board of Water & Soil Resources

Pete Waller

SWCD

Big Stone SWCD
Grant SWCD
Stevens SWCD
Traverse SWCD
West Otter Tail SWCD

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

The Federal Clean Water Act requires states to adopt water quality standards to protect the nation's waters. These standards define how much of a pollutant can be in a surface or ground water while still allowing it to meet its designated uses, such as for drinking water, fishing, swimming, irrigation, or industrial purposes. Many of Minnesota's water resources do not currently meet their designated uses because of pollution problems from a combination of point and non-point sources.

For each pollutant that causes a water body to fail to meet the state water quality standards, the Federal Clean Water Act requires that the Minnesota Pollution Control Agency (MPCA) conduct a total maximum daily load (TMDL) study. A TMDL study identifies both point and non-point sources of each pollutant that is causing a water quality impairment. Water quality sampling and computer modeling determine the pollutant reductions needed, for each pollutant source, to enable the water quality standard to be met. Individual water bodies may have several TMDLs, each one determining the limit for a different pollutant.

This implementation plan addresses two reaches of the Mustinka River with an aquatic life impairment due to high turbidity, and it includes implementation measures to decrease the turbidity in these reaches so that the turbidity water quality standard is met. Beginning in 2010, the MPCA and project partners are initiating a watershed assessment and TMDL project for the entire Mustinka River watershed. This project will include an assessment of the watershed, identification of stressors impacting the biota, TMDL allocations for all impaired reaches, and an implementation plan that focuses on restoration of the impaired reaches in addition to protection of the water bodies that are not impaired.

1.1 303d Listings

In 2004 two reaches on the Mustinka River were listed on the EPA's 303(d) list of impaired water bodies as being impaired for aquatic life due to excessive turbidity (Table 1). The TMDL report was approved by the EPA in 2010. The following applies to both impaired reaches:

Impaired Use:	Aquatic life
Pollutant or Stressor:	Turbidity
Hydrologic Unit Code:	09020102

Table 1. Impaired Waters Listing

Reach Name	Reach Description	Assessment Unit ID (AUID)	Year Listed	Target Start/Completion	CALM Category*
Mustinka River	Grant/Traverse County line to Fivemile Cr	09020102-518	2004	2005/2009	5C
Mustinka River	Unnamed cr to Lk Traverse	09020102-503	2004	2005/2009	5A

*5A: Impaired by multiple pollutants and no TMDL study plans are approved by EPA
5C: Impaired by one pollutant and no TMDL study plan is approved by EPA

1.2 Watershed and Water Body Description

The Mustinka River Watershed is 562,099 acres, and lies within three ecoregions: the northeastern portion is in the North Central Hardwood Forests, the Northern Glaciated Plains covers the eastern and southern portion of the watershed, and the remainder is within the Lake Agassiz Plain (Figure 1). The majority of the watershed is within the Glacial Lake Plain, and the soils are derived from glacial materials. The predominant soils in the lake plain are poorly drained clays; these areas are extensively drained by ditches and tile drainage systems. Coarser soils are found in the other parts of the watershed.

The watershed is mostly agricultural, with crop cultivation constituting approximately 74% of the watershed; the majority of the crops are soybeans and corn.

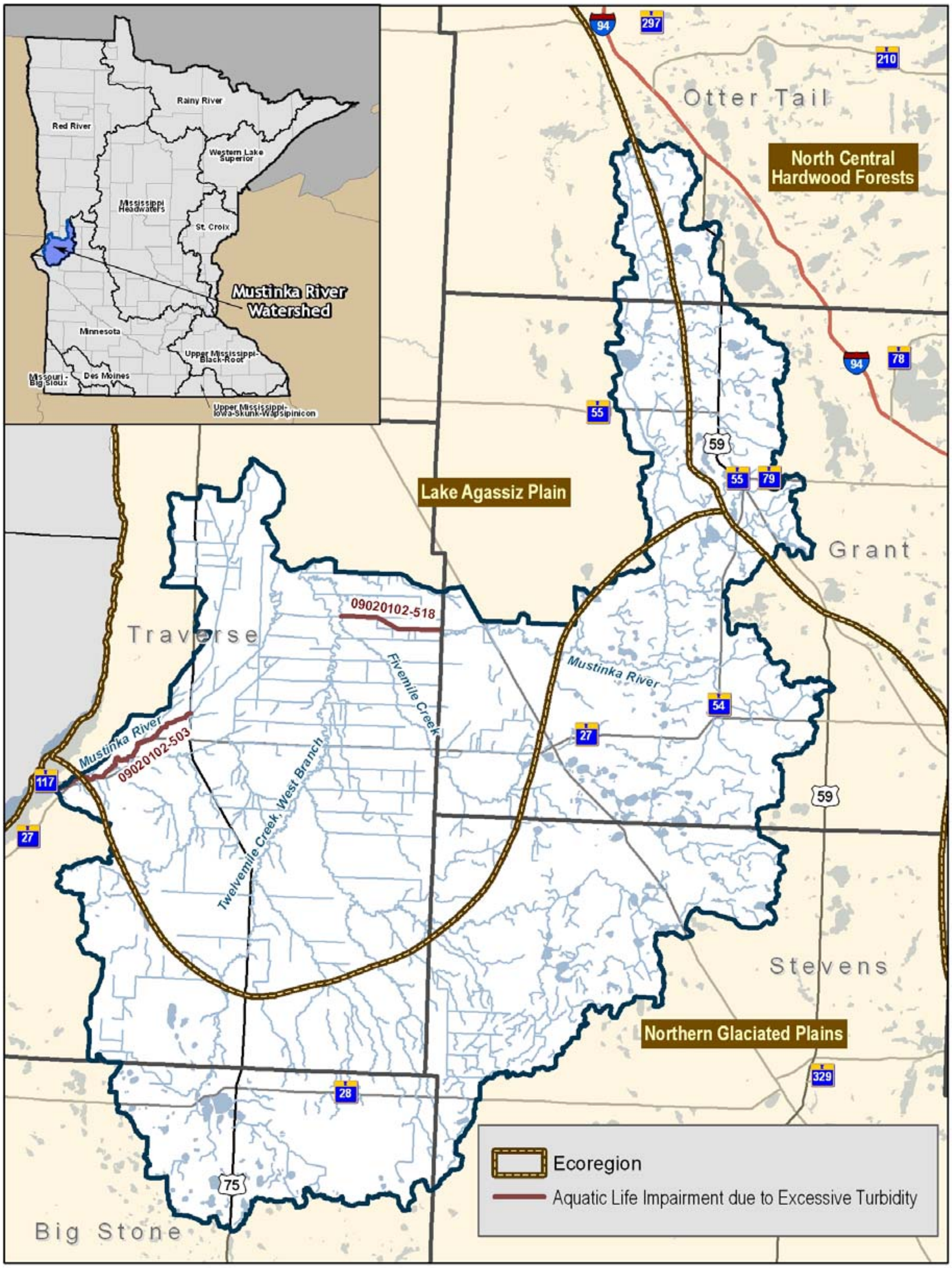


Figure 1. Study Area and Impaired Reaches

1.3 Existing Water Quality and Standards

Water quality standards are established to protect the designated uses of the state's waters. The impaired reaches of the Mustinka River are classified as Class 2B and 3B waters and are protected for aquatic life and recreation. The Class 2B water quality standard is 25 NTU (nephelometric turbidity units). This standard is a chronic standard, which is the highest concentration of a pollutant to which organisms can be exposed indefinitely without causing chronic toxicity.

The TMDL report used total suspended solids (TSS) as a surrogate measure for turbidity, since turbidity is not a load-based measurement. Paired turbidity-TSS measurements from the Lake Agassiz Plain were used to develop a TSS equivalent of the turbidity standard. Using linear regression, 25 NTU was equivalent to 47 mg/L TSS, which was used as the water quality target and the basis of the TMDL allocations.

1.4 Turbidity Sources

The entities that may contribute to excess turbidity and are regulated by a National Pollutant Discharge Elimination System/State Disposal System (NPDES/SDS) permit are municipal wastewater treatment facilities (WWTF, Table 2), industrial facilities, concentrated animal feeding operations (CAFOs, Table 3), and construction activities.

Nonpoint sources are the primary contributors to the turbidity impairments, and are mostly due to field soil erosion and streambank erosion.

Table 2. Municipal wastewater treatment facilities

City	NPDES Permit #
Wendell	MNG580153
Dumont	MN0064831
Elbow Lake	MNG580082
Herman	MN0023647
Wheaton	MN0047278
Graceville	MNG580159
Hutterite Colony	MNG580168

Table 3. Confined animal feeding operations

Name	NPDES Permit #
Big Stone County Hutterite Colony Feedlot	MNG440392
Scott Andrews Farm	MNG440755
Anthony Arens Farm	MNG440495
Ryan and Lyle Pederson Farm	MNG440876
Craig Lichtsinn Farm	MNG440304
Valley Pork LLP	MNG440400

All the CAFOs have been issued NPDES/SDS permits under the State of Minnesota General Livestock Production Permit. These facilities are assigned a zero waste load allocation. This is consistent with the conditions of the permit, which allows no discharge of pollutants from the production area of the CAFO.

2. DERIVATION OF TMDL ALLOCATIONS

This section is a summary of the derivation of the TMDL allocations described in the TMDL report. The methods and assumptions used to calculate the wasteload and load allocations are described here briefly. For additional information please refer to the TMDL report.

2.1 Loading Capacity

The loading capacity was calculated for five different flow regimes on each impaired reach through the use of load duration curves. The loading capacity, or TMDL, is represented by the load duration curve at the midpoint of each flow regime (low through high).

2.2. Allocations

The following tables include the TSS allocations for the impaired reaches. Details on how they were developed can be found in the TMDL report.

Table 4. TSS loading capacities and allocations: Mustinka River, Grant/Traverse County line to Fivemile Creek (AUID 09020102-518)

	Flow Zone				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Tons/day				
TOTAL DAILY LOADING CAPACITY	11.359	1.592	0.334	0.058	0.002
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	0.325	0.325	**	**	**
Construction and Industrial Stormwater	0.004	<0.001	<0.001	<0.001	<0.001
Load Allocation	9.89	1.106	**	**	**
Margin of Safety	1.14	0.16	Implicit	Implicit	Implicit
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	2.86%	20.4%	**	**	**
Construction and Industrial Stormwater	0.04%	0.04%	0.04%	0.04%	0.04%
Load Allocation	87.1%	69.56%	**	**	**
Margin of Safety	10%	10%	Implicit	Implicit	Implicit

*Facilities are listed in Table 4 of the TMDL report

Table 5. TSS loading capacities and allocations: Mustinka River, Unnamed Creek to Lake Traverse (AUID 09020102-503)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	65.28	9.19	2.01	0.53	0.04
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	0.986	0.986	0.986	**	**
Construction and Industrial Stormwater	0.026	0.003	<0.01	<0.01	<0.01
Load Allocation	57.74	7.28	0.82	**	**
Margin of Safety	6.53	0.92	0.2	Implicit	Implicit
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	1.5%	10.7%	49.1%	**	**
Construction and Industrial Stormwater	0.04%	0.04%	0.04%	0.04%	0.04%
Load Allocation	88.46%	79.26%	40.86%	**	**
Margin of Safety	10%	10%	10%	Implicit	Implicit

*Facilities are listed in Table 4 of the TMDL report

The TMDL report compared the 90th percentile TSS load in each flow zone to the loading capacity in each zone to estimate the percent load reductions needed for the Mustinka River to meet the turbidity standard (Table 6). The percent reductions needed range from 33% to 91%, suggesting that restoration of these reaches will require a large effort, including programmatic initiatives, capital projects, and significant financial resources. This effort will be focused on reduction of TSS loads from non-point sources; the point sources identified in the TMDL report are either in compliance with their NPDES permits and/or are expected to represent a minimal contribution to the instream turbidity. Point sources are not addressed in this implementation plan.

Table 6. Comparison of current 90th percentile daily load to capacity at the mid-point zone

• capacity is mid-point for flow zone • current load is 90th percentile value for flow zone		Flow Zone				
		High Flows	**Moist Conditions**	**Mid-Range Flows**	**Dry Conditions**	**Low Flows**
		values expressed as tons/day TSS				
09020102-518	**Capacity**	11.359	1.592	0.334	0.058	0.002
	Current Load	104.66	10.41	1.68	0.27	0.01
	% Red. Needed	89%	85%	80%	78%	80%
09020102-503	**Capacity**	65.28	9.19	2.01	0.53	0.04
	Current Load	756.26	78.17	3.72	2.31	0.06
	% Red. Needed	91%	88%	46%	77%	33%

3. PARTNERS AND FUNDING OPPORTUNITIES

To improve the water quality within the Mustinka River and meet the goals of the TMDL, reductions in TSS loading will be needed from instream sources and watershed sources. To achieve these goals, a variety of measures will be implemented. Multiple partners will be involved in this implementation process, and a coordinated effort will be needed to successfully carry out the implementation plan.

The BdSWD led the development of this implementation plan, with input from the BWSR, the MPCA, and the five SWCDs that are in the watershed: Big Stone, Grant, Stevens, Traverse, and West Otter Tail. Two meetings were held with this group during which the implementation approach was discussed and input was provided regarding the types of practices, programs, and funding opportunities that are most applicable in this watershed. This group also reviewed and commented on draft versions of the implementation plan.

The BdSWD will lead and coordinate the implementation of this plan, and the MPCA will help facilitate the coordination. The BdSWD will work with the SWCDs, the BWSR, and the MPCA to develop specifics for each of project and program to be implemented to address the turbidity impairments. The group will meet regularly to establish responsibilities of each partner in the implementation process, and to provide updates on implementation projects and programs.

3.1 Implementation Partners

Multiple partners will provide guidance, as appropriate, regarding the actions outlined in this implementation plan. The core partners include representatives from:

Core Implementation Partners:

- Agricultural representatives and community
- Big Stone Soil and Water Conservation District
- Board of Water and Soil Resources (BWSR)
- Bois de Sioux Watershed District
- Farm Service Agency (FSA)
- Grant County Soil and Water Conservation District
- Gorton Township
- Minnesota Department of Agriculture (MDA)
- Minnesota Department of Natural Resources (DNR)
- Minnesota Department of Transportation (Mn/DOT)
- Minnesota Pollution Control Agency (MPCA)
- Natural Resources Conservation Service (NRCS)
- Redpath Township
- Red River Watershed Management Board (RRWMB)
- Stevens Soil and Water Conservation District
- Traverse Soil and Water Conservation District

- United States Army Corps of Engineers (USACOE)
- United States Fish and Wildlife Service (USFWS)
- West Otter Tail Soil and Water Conservation District

3.2 Funding Opportunities

A combination of grants, in-kind staff time, and cash matches will be used to fund the implementation activities described in this plan.

Agriculture Best Management Practices Loan Program (AgBMP Loan Program) – AgBMP Loan Program is a program of the MDA. It is administered through local SWCDs, and offers low interest loans (currently 3%) for implementation of best management practices to improve water quality problems that are caused by agricultural activities or failing septic systems.

Bois de Sioux Watershed District – The District has the ability to fund capital improvement projects and administer programs that are consistent with their watershed plan.

Conservation Reserve Program – This US Department of Agriculture (USDA) program shares the cost of establishing conservation practices with the landowner and provides landowner land rental payments for a minimum of 10 years. Landowners must enter into a contractual agreement with the USDA, and are required to meet minimum federal standards.

Continuous Conservation Reserve Program (CCRP) – This USDA program shares the cost of establishing conservation practices with the landowner and provides landowner land rental payments for a minimum of 10 years. Landowners must enter into a contractual agreement with the USDA, and are required to meet minimum federal standards.

Clean Water Act Section 319 Programs – Financial assistance is provided to address non-point source water pollution, including the study of water bodies with pollution problems, development of action plans, and implementation of the action plans. These funds can not be used to address point sources of pollution.

Environmental Quality Incentives Program (EQIP) – EQIP is a program of the NRCS whose funds are provided through the Federal Farm Bill. It is designed to help private landowners with technical assistance and a cost-share of up to 50% in order to protect local soil and water resources. They fund such things as nutrient management plans, designs for animal waste structures, wetland restoration, rotational grazing management plans, and conservation tillage.

Farm Service Agency (FSA)- The FSA offers USDA-sponsored voluntary conservation programs to agricultural producers to help them safeguard environmentally sensitive land. Landowners who enroll in conservation programs receive incentive payments for installing specific conservation practices that help protect environmentally sensitive land, decrease erosion, restore wildlife habitat, and safeguard ground and surface water. Conservation programs include CRP, CCRP, and CREP.

In-Kind Contributions – Many of the actions will be implemented by counties, municipalities, and others using in-kind funding and Capital Improvement Plans.

Landowners – For actions aimed at decreasing the total sediment and phosphorus load from individual landowner sites, landowners can, on a voluntary basis, provide a percentage of the cost of the installation of the management practice. The CRWP, county, SWCD, and municipalities will work directly with landowners on specific improvements.

Minnesota Outdoor Heritage Fund and Clean Water Fund – Passage of the Clean Water, Land and Legacy Amendment in 2008 made funding available for TMDL implementation activities. Four state agencies are involved in distributing the funds: the BWSR, the MPCA, the MDA, and the DNR.

Non-profit Organizations – Groups such as Ducks Unlimited, Pheasants Forever, and The Nature Conservancy are national/international non-profits that partner with government and private entities on conservation initiatives in western Minnesota.

Partners for Wildlife Program – This USFWS financial assistance program helps to establish wildlife habitat projects such as wetland rehabilitations and riparian rehabilitations.

State Conservation Easement Programs (RIM, CREP) – This BWSR program is locally administered by SWCDs, and purchases conservation easements and provides funding for establishment of best management practices (BMPs). Easements between the State of MN and the landowner are perpetual.

State Cost-Share – State Cost-Share is a program of the Minnesota BWSR. It is administered through local SWCDs and is designed to provide base grants of up to 75% of a project cost in order to help local landowners/occupiers with projects that protect and improve water quality, such as controlling soil erosion and reducing sedimentation.

Wetland Reserve Program (WRP) - This USDA program provides technical and financial support to help landowners to protect, restore, and enhance wetlands on their property. Landowners must enter into a contractual agreement with the USDA and are required to meet minimum federal standards.

4. IMPLEMENTATION ACTIVITIES

BMPs can be used throughout the watershed that will improve water quality in the impaired reaches. Implementation will be focused on addressing the primary contributors to the turbidity impairments, which are field soil erosion and streambank erosion. The two strategies to address these sources are 1) minimize watershed erosion, runoff, and overland flow, and 2) manage the drainage system to maintain capacity without destabilizing the streambanks. Through minimizing watershed runoff, the target is to reduce runoff volumes and rates, which decreases the transport of sediment to the drainage system. Maintaining adequate capacity within the drainage system prevents overland flow from picking up additional sediment from fields. Maintaining streambank stability allows the drainage system to transport the flow without eroding the banks and beds. Addressing the turbidity problem from both of these angles (watershed management and drainage system management) will improve water quality while maintaining productive use of the watershed. The specific recommendations below all address this implementation strategy.

This section of the implementation plan will guide prioritization of BMP implementation, will describe existing practices that are helping to reduce sediment loading to the impaired reaches, and will recommend additional practices. Recommended practices range from programmatic solutions to detailed projects to more general practices that can be implemented throughout the watershed. The number of projects needed is not specified in this implementation plan; the high TSS reductions needed will require a comprehensive effort and progress will be monitored as projects are implemented.

Discharge from WWTFs is not considered to contribute to the turbidity impairments, and all facilities within the watershed are in compliance with their NPDES/SDS permits. This implementation plan therefore does not target WWTFs. Additionally, due to the limited area under permit coverage for construction and industrial stormwater, suspended sediment from these sources is expected to be low and is not addressed in this implementation plan.

4.1 Implementation Framework

Implementation options should be selected based on watershed size, gradient, and channel material geology. The *Red River Biotic Impairment Assessment* (MPCA 2009) discusses these characteristics with respect to restoring waters with impaired biota due to high turbidity and/or sedimentation. Table 7 summarizes the implementation framework presented in MPCA (2009).

Table 7. Implementation options for Minnesota portion of Red River watershed (adapted from MPCA 2009)

Category	Example	Characteristic	Implementation Options
Watershed Size			
< 10 mi2	Mostly ditches and field gullies	1st order streams and wetlands	Restore grass swales; control gully erosion in fields; re-meander channelized streams
10-200 mi2	Fivemile Creek	Small streams	Restore grass swales; control gully erosion in fields; re-meander channelized streams; two-stage ditches
200-1500 mi2	Twelve Mile Creek, Mustinka River	2nd to 5th order streams (approximately)	Control reaches of excessive streambank erosion; narrowing overwidened channels to scour aggraded sediment; add large wood debris; improve connectivity for fish passage
East-West gradient			
Lake plain	Flat part of Agassiz Lake Plain	Fine-textured soils, flat topography; sediment aggradation and embeddedness	Aggradation / embeddedness management in upper lake plain; mass wasting control in lower
Beach ridge	Slight ridge rising out of lake plain	Coarse soils, steeper; high potential for channel incision and bank collapse	Streambank stabilization; bed erosion control
Channel Material Geology			
Alluvial	Mustinka River, Twelvemile Creek	Sandy soils prone to mass-wasting / bank collapse	Control excessive mass-wasting of streambanks
Glacial till and moraine	Upper parts of Mustinka River, Twelvemile Creek	More cohesive; less mass-wasting / bank collapse	Control excessive streambank erosion when necessary; protect gravel spawning reaches

4.2 Existing Water Quality Improvement Programs

Many organizations have been successfully implementing water quality improvements within the Mustinka River watershed during the past 10 years. In addition, farmers, residents, and other governmental and non-governmental organizations have been working to improve water quality. Listed below are several resources identifying specific goals and activities being conducted by local organizations.

- Overall Plan, Bois de Sioux Watershed District (BdSWD 2003)
- County Water Management Plans (Traverse, Grant, Stevens, Big Stone)
- SWCDs (Traverse, Grant, Stevens, West Otter Tail)
- Red River Basin Water Quality Plan, draft (MPCA 2010, available from Molly.Macgregor@state.mn.us)

4.3 Proposed Watershed Activities

The following are watershed activities that can be implemented to reduce sediment loading to the Mustinka River. The overall goal is to reduce sediment sources from overland flow, through source control, water quality treatment, or runoff control. Some of these activities already exist within the watershed; in these cases, expanding the existing program would provide additional water quality benefits.

A SWAT model that can be used to prioritize watershed activities and estimate sediment reductions was created for the Mustinka River watershed. This SWAT model is explained with results in more detail in *Section 4.5.1: Prioritization, SWAT*.

4.3.1 Agricultural BMPs

For additional resources regarding many of these agricultural BMPs, the NRCS maintains a list of practices and standards at http://www.nrcs.usda.gov/technical/standards/nhcp.html. Listed below are several additional resources pertaining to the design of agricultural BMPs.

- Board of Water and Soil Resources (http://www.bwsr.state.mn.us/drainage/index.html)
- Department of Agriculture (http://www.mda.state.mn.us/protecting/bmps.aspx)
- University of Minnesota Extension (http://www.extension.umn.edu/DrainageOutlet/)
- Minnesota Pollution Control Agency (http://www.pca.state.mn.us/)

Additionally, the following paper provides information on the effectiveness of agricultural BMPs in the Red River Basin:

- The Effectiveness of Agricultural Best Management Practices for Runoff Management in the Red River Basin of Minnesota (http://www.rrwmb.org/files/FDRW/TP03.pdf), Larson 1998

Hydrology Management

Hydrology management addresses managing flow rates that originate in agricultural fields. This can be accomplished through practices such as drain tiling, which decreases overland flow rates and volumes; ditch system improvements, which allow the system to support the existing watershed runoff and prevents it from flowing across cultivated fields; and culvert sizing to increase temporary floodwater storage and allow for settling out of sediment. Watershed practices for hydrology management are described here; in-stream activities are discussed *in Section 4.4: Proposed In-Stream Activities*.

Side Inlets

Side inlets are located on the field side of a ditch spoil pile and connect the field directly to the ditch. A benefit of side inlets is that gully erosion can be reduced through bypassing the ditch spoil pile and side slope. However, side inlets have similar drawbacks as drain tile (see below) in that they provide a direct connection between agricultural fields and downstream resources. Erosion can also occur where the side inlet discharges to the ditch, if unarmored.

Culvert Sizing

Culvert sizing can help manage runoff timing and peak flows within a drainage system by providing temporary storage within a channel and on adjacent lands upstream (Solstad et al. 2009). The goal is to reduce downstream flood damages while providing adequate drainage and minimizing risk to developed properties upstream. Culvert sizing is ideally implemented in an entire subwatershed at the same time, but an incremental approach can also be taken. The BdSWD has culvert sizing guidelines that are generally implemented incrementally when permitting drainage activities. Temporary ponding upstream from each culvert allows time for some of the sediment to settle before the water leaves the field. Through managing peak flows, reductions in erosion are also achieved by reducing the occurrence of out-of-bank flows and reducing downstream flow rates.

Grassed Waterways

Grassed waterways are shaped or graded vegetated channels used to prevent gully erosion. They can also reduce sediment transport from overland flow through the settling of particulates within the vegetated channel.

Open Tile Inlet Retrofits

Tile inlets are generally set in depressions to expedite drainage, maintain field conditions dry enough to allow equipment in the field, and prevent crop loss during wet periods. Tile inlets can reduce the amount of sediment transported by surface water runoff by reducing the distance that runoff travels as overland flow. However they provide a direct connection between agricultural fields and downstream resources, typically bypassing water quality BMPs such as conservation buffers and serving as a direct pathway for sediment-laden surface water to reach open ditches and directly connected downstream water bodies. Where open tile inlets exist, they should be replaced with alternative tile structures that minimize the amount of sediment and associated pollutants that are exported from agricultural fields through tile drainage.

An alternative to open tile inlets is intensive pattern tiling. Pattern tiling uses closely spaced (approximately 10-ft spacing) tile in place of open tile inlets. See NRCS (2008) for a tile intake replacement standard. The closely spaced tile allow for rapid drainage and water quality treatment of sediments in the native soils. These systems also remove the obstruction of the open tile inlet from the field, reducing the risk of damage to the drainage system from agricultural activities.

Other alternative tile inlets exist such as the slotted riser (Hickenbottom) or rock intake. French drains in agricultural settings are gravel filled pits containing draintile that are covered with soil and farmed. Although some pollutant removal may be associated with these other types of inlets, the pattern tile inlet provides the greatest pollutant removal and lowest risk of failure.

The extent or number of open tile intakes and tile discharges to receiving waters within the watershed is unknown. Because much of the tile is located in private drainage systems, the most efficient way to map the tile inlets and outlets will likely be to conduct a survey of each farmer. This survey could also include education materials and ask for level of interest in converting open tile inlets to a pattern tile system and other alternatives that provide water quality treatment. Monitoring of tile discharges to streams could also be conducted to understand the effect of different practices on water quality. This program would likely be housed at the counties or SWCDs and would likely involve additional staff resources.

Stream and Ditch Buffers

Buffers provide a direct reduction of runoff pollution and stream erosion through the processes of settling and filtering. Intermittent streams and waterways often have no buffer at all or are completely farmed. Buffers along public ditches should be promoted as tools that decrease the need for ditch maintenance, in addition to improving water quality. It is a priority for all drainageways and buffers to contain a perennial vegetative cover. The current objective of the BdSWD is to accelerate the installation of vegetated buffers strips and participation in retirement programs by establishing buffers strips on 85% of shoreland areas and 50% of other eligible lands (BdSWD 2003). To accomplish this goal, the watershed district supports the SWCDs through providing funds to implement these programs. Opportunities to convert cropland to permanent riparian cover should be explored, and existing riparian cover should be continued and preferably made permanent.

A tool for estimating the pollution reduction as a result of buffer strips is provided by BWSR:
http://www.bwsr.state.mn.us/elinkupdate/Pollution_Reduction_Calculator_Manual.pdf
http://www.bwsr.state.mn.us/elinkupdate/Pollution_Reduction_Estimator_ water.xls

Agricultural land uses adjacent to lakes, rivers, and streams require a buffer strip of permanent vegetation that is 50 feet wide unless the areas are part of a resource management system plan (MN Rule 6120.330 Subp. 7). Additionally, for any new ditches or ditch improvements, the land adjacent to public ditches must include a buffer strip of permanent vegetation that is usually 16.5 feet wide on each side (MN Statute 103E.021).

Water and Sediment Control Basins

A water and sediment control basin is an earth embankment or a combination ridge and channel that forms a sediment trap and water detention basin. These basins are generally constructed across the slope and minor watercourses and can reduce gully erosion, trap sediment, reduce downstream runoff, and improve downstream water quality.

Ponds

Dry ponds are a type of sedimentation basin primarily used to control runoff rates. Wet ponds maintain a permanent pool of water, which allows sediments to settle out. Wet ponds can remove from 60 to 90% of total suspended solids (MPCA 2005). However, wet ponds are not as flexible as dry ponds to position on the landscape and can not be farmed.

Windbreaks

Windbreaks are plantings of trees or shrubs, established to protect areas from wind erosion. A goal in the BdSWD's Overall Plan is to plant 245 miles of field windbreaks, using native plant species wherever possible, in critical areas identified in the SWCD and County Water Plans (BdSWD 2003).

Conservation Tillage

Conservation tillage reduces soil erosion and nutrient runoff. Conservation tillage is any method of soil cultivation that leaves the previous year's crop residue (such as corn stalks or soybean stubble) on fields before and after planting the next crop, to reduce soil erosion and runoff. To provide these conservation benefits, at least 30% of the soil surface must be covered with residue after planting the next crop. Some conservation tillage methods forego traditional tillage entirely and leave 70% residue or more. Each method requires different types of specialized or modified equipment and adaptations in management. Conservation tillage is especially suitable for erosion-prone cropland.

Conservation tillage techniques include minimum tillage, mulch tillage, strip tillage, and no-till. No-till farming is a form of conservation tillage in which the crop is planted directly into vegetative cover or crop residue with little disturbance of the surface soil. Minimum tillage farming involves some disturbance of the soil, but uses tillage equipment that leaves much of the vegetation cover or crop residue on the surface. The BdSWD's goal from their 2003 plan (BdSWD 2003) is to add 318,000 acres of conservation tillage adjacent to ditches, waterways, and wetlands.

Conservation Crop Management

Other agricultural BMPs address cropping practices and aim to reduce the amount of sediment leaving the fields through source control. The following practices are included in conservation crop management:

- Crop diversification: hay, alfalfa, bioenergy crops (switchgrass), agroforestry crops (nut crops, orchards, vineyards, timber)
- Strip cropping
- Crop rotation
- Cover crops
- Contour farming
- Terracing

Feedlot and Pasture Management

Although feedlots and pasture were not identified as a substantial source of sediment to the Mustinka River, many registered and NPDES-permitted feedlots exist in the watershed and are a potential source of sediment. Open feedlots have the potential to degrade nearby water resources if they are not constructed or managed properly. There are several management practices that can be used to minimize the feedlot impacts on soil, water, and air of the surrounding areas, including lot construction, lot maintenance, diversions, and runoff controls. SWCDs and the NRCS provide technical and financial assistance to producers who want to construct or improve their feedlot.

Pasture management includes practices such as rotational grazing, fencing, and overgrazed area restoration.

4.3.2 Wetland Restoration

Wetland restoration within the Mustinka River watershed has the potential to restore the natural hydrology of the area and improve water quality treatment on the landscape. Historically this area was dotted with small shallow wetlands that were created by the Wisconsin Glaciation. It is estimated that 90% of these types of wetlands have been drained for agriculture purposes in portions of Minnesota. Restoration of these prairie pothole wetlands would improve downstream water quality by retaining stormwater and sediment in the upland portions of the watershed.

A geospatial assessment should be performed for the project area to determine the potential for wetland restorations as a tool for improving stream water quality. The wetlands can be then assessed and classified by their potential for wetland restoration. Additionally, non-wetland areas can be identified where stormwater management practices would have the greatest benefit. Areas can be prioritized by maximizing the area that will receive treatment, treating the largest incoming sediment load, and the feasibility of restoration. The assessment should use the Minnesota DNR's Lakeshed and Drained Wetlands shapefiles and the US Fish & Wildlife Service's National Wetland Inventory shapefile.

The BdSWD's management plan includes the following related goals: 1) Assist the SWCDs and NRCS in restoring 10,000 acres of drained or cropped wetlands and upland buffer fringe, and restore wetlands in critical areas using local, state and federal restoration programs. 2) Assist the USFWS in achieving their goal to acquire 13,770 acres in wetland management districts. 3) Assist Pheasants Forever in acquiring 3,000 acres of permanent wildlife habitat (BdSWD 2003).

4.3.3 Moist Soil Management Units

Moist soil management units are gaining favor with the MNDNR and conservation organizations as a method to improve waterfowl and shorebird habitat, control flooding, and improve water quality. Management units are flat areas containing dikes and water control structures that are managed as wetlands (flooded) for portions of the year and are drawn down during portions of the year to allow other uses. Commonly used in the southern US, the practice has been recently put into use at Lac qui Parle Wildlife Management Area and the Bois de Sioux Watershed District's North Ottawa Impoundment Project.

While the primary target of these projects is often flood damage reduction and/or creation of wildlife habitat, they also provide water quality benefits through settling of sediment and improving the altered hydrograph. The Red River Basin Commission's flow reduction strategy aims to reduce peak flows along the Red River by 20%. The BdSWD's *Application of the Flow Reduction Strategy in the Bois de Sioux Watershed* (Appendix A, BdSWD 2010) identifies storage sites within the watershed that have the capacity to provide the Bois de Sioux Watershed's portion of the required Red River flow reduction (98,256 ac-ft). Figure 2 and Table 1 of Appendix A identify the approximate locations of the storage sites and areas of the watershed that they will control. In its watershed management plan, the BdSWD aims to provide 150,000 acre-ft of storage throughout the Bois de Sioux River watershed (BdSWD 2003).

4.3.4 Education and Outreach Program

The MPCA is developing an approach to civic engagement for watershed projects. The goal is to encourage civic dialogue, collaboration, and a sense of community, with the ultimate goal being improved water quality. The BdSWD will support the MPCA's efforts and will work collaboratively with them to ensure the goals of the civic engagement effort are met.

The MPCA plans on completing the following activities for watershed projects: 1) identify and recruit stakeholders, 2) hold meetings and provide informational and supporting materials, 3) survey stakeholders before and after projects to measure knowledge of watershed and water quality issues and whether the study has helped introduce key concepts to the public at large, 4) develop and implement a communications strategy, 5) evaluate participation in the project and the effectiveness of the watershed study in achieving project goals.

This work will take place as part of the larger, more comprehensive Mustinka River Watershed Assessment and TMDL (2010-2014). These activities will be further developed as the project progresses.

4.4 Proposed In-Stream Activities

Streambank erosion and channel downcutting have been shown to be significant sources of the sediment load to Minnesota streams impaired due to turbidity. Stream restoration and bank stabilization can decrease instream erosion. Rate and volume control activities in the watershed (discussed in Section 4.3) reduce instream erosion by reducing shear stresses and instream velocities in the channel.

4.4.1 Stream Restoration

Stream restoration involves restoring a ditched stream to its original course or engineering a new stable naturalized channel that matches the current hydrogeomorphic conditions. Methods for stream restorations include increasing channel sinuosity, increasing floodplain connectedness, and reducing flows in the stream. Because of the abundance of ditching that has occurred in the watershed, stream restorations should be the main instream activity undertaken to address these turbidity impairments. The Redpath Project is one of the stream restorations currently being planned in the watershed, and is expected to lead to substantial reductions in instream turbidity in the upstream impaired reach. Additional restoration opportunities can be identified through the prioritization process.

<u>Redpath Project</u>

The Redpath Project is a multipurpose BdSWD project that incorporates stream restoration and flood control (see *Section 4.3.3: Moist Soil Management Units*) with water quality and wildlife habitat benefits. This project has been designed and is waiting for funding to begin construction. This project includes construction of a 7.3-mile long riparian corridor, a five pool impoundment structure, and restoring flow to an 8.8-mile reach of natural channel that was previously isolated by the Mustinka River Cutoff. The location of the proposed stream channel is in one of the impaired reaches (AUID 09020102-518) of the Mustinka River. This project is expected to lead to substantial reductions in instream turbidity along this reach, and is a high priority for addressing the turbidity impairment.

4.4.2 Bank Stabilization

Bank stabilization along eroding stream reaches can be accomplished by using rock armoring or vegetation. Stabilization projects are good for reducing localized erosion prone areas if a larger stream restoration project is not possible or necessary. Landowners are often interested in stabilizing streambanks to avoid loss of land. Many options exist for bank stabilization and each site will be unique. The following is a list of practices that may be employed although many other techniques exist.

- Stream barbs (cross vanes, bendway weirs, etc.) – Stream barbs are rock piles that start at the upper streambank and project across the stream's thalweg. The main purpose of these structures is to reduce streambank erosion with the secondary benefit of improved habitat. Erosion is reduced by redirecting streamflows toward the center of the stream, away from the eroding bank.
- Two-stage ditch – Two-stage ditches can be built in place of traditional ditches to improve ditch stability, reduce maintenance costs and decrease the transport of sediment and nutrients. A two-stage ditch incorporates a floodplain area into the ditch design allowing the water to spread out over a larger area, decreasing velocities in the channel. This design provides adequate drainage while more closely matching the hydraulics of a natural stream system.
- Stream geomorphic alterations – Stream bed and bank modifications can be used to redirect shear stresses from eroding banks.
- Rip rap – Using rock stabilization directly on an eroding streambank can stabilize erosion problems.
- Plantings – Live stakes and plantings can be used to stabilize eroding streambanks by adding root structure to a bank.

4.5 Prioritization

In addition to improving water quality within the watershed, many implementation practices will also address flood control and will improve fish and wildlife habitat. For example, wetland restoration will provide all of these benefits while pattern tile inlets are strictly a water quality and field access improvement. All benefits, including the effective life of the activity, should be considered when prioritizing which implementation activity is the best fit for each site.

BMP programs are not typically focused on a specific water body and are used only by farmers who proactively search out information and funding for BMPs. A focused subwatershed approach is needed that will include working directly with all farmers in priority watersheds to install BMPs. Priority watersheds can be identified with the prioritization techniques described here.

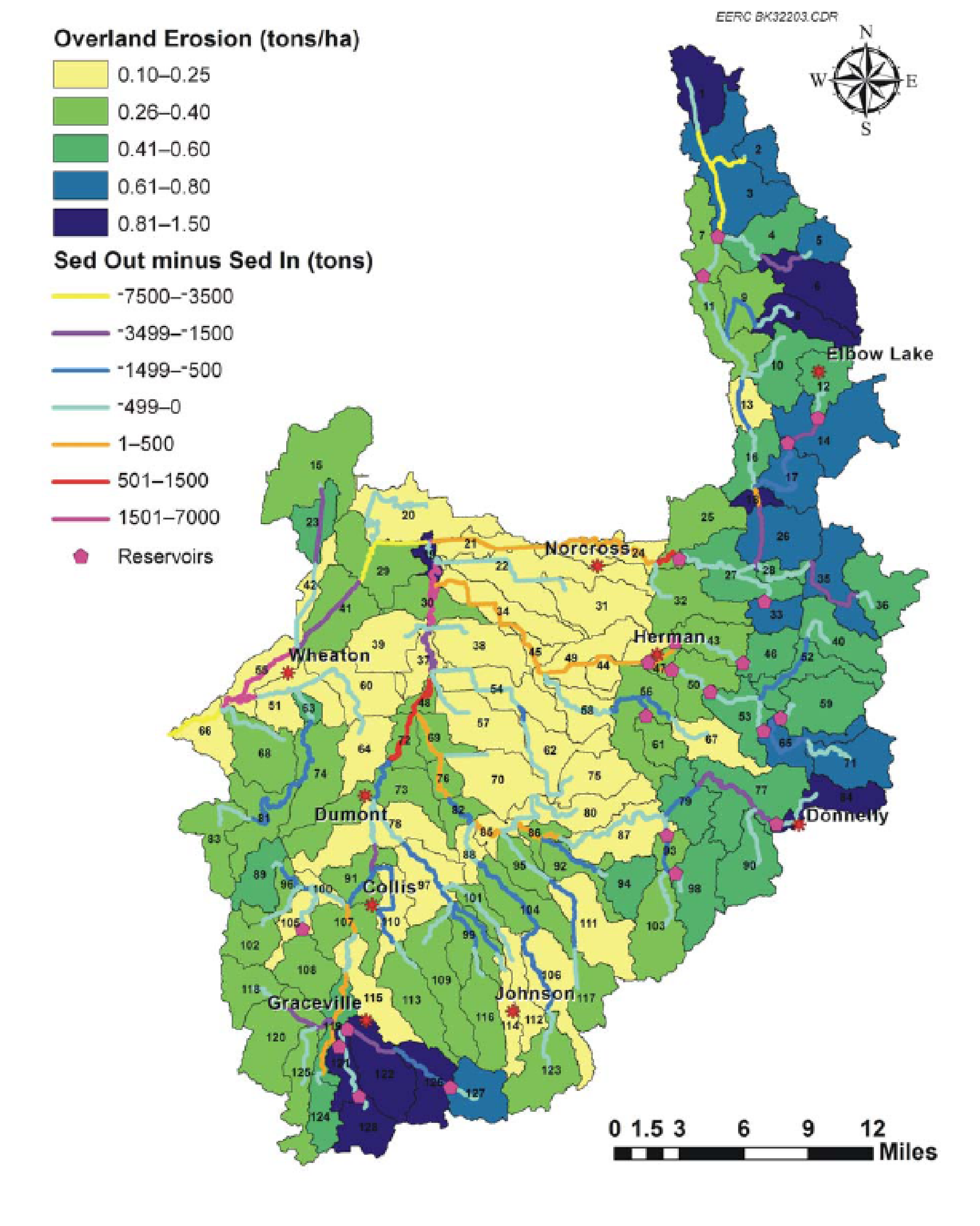
The following characteristics will be taken into account when prioritizing implementation activities:

- Expected benefits – water quality projects that provide for flood control and wildlife habitat will be prioritized
- Cost to benefit – The cost of potential projects will be weighed against water quality benefits of potential projects and priority given to the most cost-effective projects.
- Problem areas located closer to and within the impaired reaches will be addressed
- Permanent practices will be given priority over temporary practices
- Areas with high slope often yield high sediment loads and will be targeted

The following are tools that can provide information regarding the above priority areas.

4.5.1 SWAT

The Soil and Water Assessment Tool (SWAT) model created for the Bois de Sioux Watershed (Energy and Environmental Research Center 2008) should be used to preliminarily prioritize in-stream and watershed activities. Areas identified by the model (Figure 2) to yield high sediment loads should be ground checked and further refined through monitoring and stream assessment. The SWAT model uses land cover and slope to predict sediment loads and should be combined with the other prioritization tools to prioritize implementation activities. The SWAT model may also be used to estimate reductions in sediment load for some of the recommended watershed practices.



Estimated average annual sediment erosion from the landscape and net sediment loading (upstream inputs minus subbasin outputs) within the waterways of the Mustinka River Watershed.

Figure 2. Implementation Activity Prioritization Map.
Watershed implementation activities should be concentrated in subwatersheds shown in blue. In-stream implementation activities should focus on stream reaches colored orange, red and purple.

4.5.2 Terrain Analysis

The first step to targeting the most beneficial areas to implement BMPs is to use terrain analysis. Terrain analysis is the process of using high resolution topographic data and GIS analysis to identify the most erosion-prone reaches of the watershed. These techniques use county-wide LIDAR to efficiently determine the most beneficial locations to implement BMPs. Terrain analysis allows for quick identification of concentrated flow inlets to drainage ditches and streams and artificially drained upland depression restoration opportunities. Concentrated flow inlets are locations where concentrated drainage enters a waterway laterally; this can be an intermittent stream or field-scale drainageway. This method can also help identify the most beneficial locations for wetland restoration. The LIDAR data for the state will be completed by 2012; LIDAR for the Mustinka River watershed is available now. LIDAR data need to be processed to produce products useful for prioritization.

4.5.3 Anecdotal Information

Surveying landowners throughout the watershed can provide on-the-ground details regarding erosion problems that may be missed by office-based methods. The timing, severity, and likely influences on erosion can be useful for focusing efforts. Communication and discussion with landowners should be undertaken whenever possible.

4.5.4 Stream Assessment

Stream restoration and bank stabilization projects should be identified throughout the watershed based on a geomorphic assessment of stream reaches. Two sites have already been surveyed by DNR Fisheries. Additional sites should be assessed, which will likely take place as part of the Mustinka River Watershed Assessment and TMDL project (2010-2014). The assessment can guide prioritization throughout the watershed and help identify sources of sediment (streambank vs. field contributions). Approaches that may be used include modeling methods, field evaluation methods, and a combination of the two.

4.5.5 Implementation Costs

The recommended implementation items are presented in Table 8 with unit costs. The scope of the overall effort is enormous and will require substantial financial input.

Table 8. Implementation Costs

Implementation Category	Implementation Activity	Unit	Cost Low	Cost High	Pollutant Removal[1]	Priority[2]	Source of Cost Estimate
Watershed Activities	Side Inlets	EA	$200.00	$600.00	Medium	High	Estimate
	Culvert Sizing	EA	$0[3]	$5,000.00	Medium	High	BdSWD
	Grassed Waterways	LF	$1.06	$2.14	Medium	High	EQIP
	Open Tile Inlet Retrofits	EA	$400.00	$600.00	High	High	CRWP
	Stream and Ditch Buffers	AC	$473.00	$564.00	High	High	EQIP
	Water and Sediment Control Basins	EA	$750.00	$9,000.00	Medium	High	EQIP
	Ponds	EA	$1,331.00	$11,223.00	Medium	Medium	EQIP
	Windbreaks	AC	$45.48	$187.06	Low	Medium	EQIP
	Conservation Tillage	AC	$23.00		Medium	High	EQIP
	Crop Diversification	AC	$40.00	$53.00	Low	Medium	EQIP
	Strip Cropping	AC	$39.00		Low	Medium	EQIP
	Crop Rotation	AC	$40.00	$53.00	Low	Low	EQIP
	Cover Crops	AC	$23.00	$40.00	Medium	High	EQIP
	Contour Farming	AC	$10.00		Low	Medium	EQIP
	Terracing	LF	$0.98	$4.13	Low	Low	EQIP
	Fencing	LF	$0.89	$1.49	Low	Low	EQIP
	Clean Runoff Water Diversions	LF	$2.69	$6.03	Low	Low	EQIP
	Manure Management	-	Variable	Variable	Low	Low	EQIP
	Rotational Grazing	AC	$37.00		Low	Low	EQIP
	Wetland Restoration	AC	$3,000.00	$4,500.00	Medium	High	EQIP and WHIP
	Moist Soil Management Units		Variable		High	High	NA
	Education and Outreach		Part of existing programs		NA	High	NA

Implementation Category	Implementation Activity	Unit	Cost Low	Cost High	Pollutant Removal[1]	Priority[2]	Source of Cost Estimate
Instream Activities	Stream Restoration	LF	$9.00	$250.00	Medium	Medium	Range of 3 sources[4]
	Redpath Project	LS	$28,000,000		High	High	Engineer's Report: Redpath Plan and Projects (BdSWD 2009)
	Bank Stabilization	SF	$0.80	$2.88	High	High	EQIP

[1]Pollutant removal refers to the degree to which the practice is expected to contribute to meeting water quality goals.
[2]Priority is the preliminary priority list based on existing information (costs and pollutant removals); further refinement of prioritization is proposed in this plan.
[3]Incidental costs when part of a road reconstruction project
[4]Smith, et al. (undated), The River Institute (undated), Puget Sound Shared Strategy (2003)

4.6 Implementation Schedule

The priority ranking in Table 8 indicates implementation schedule. High priority action items will occur first, followed by the medium priority items. If the Mustinka River is still impaired, the lower priority items will be addressed. This implementation plan will guide implementation until the overall Mustinka River Watershed Assessment and TMDL Implementation Plan is complete, which is expected to be in approximately 2015.

The Redpath Project is currently under way. In 2011, a ditch system will be realigned to create space to construct the retention areas for the project. Land rights acquisition, final engineering, and permitting will also occur in 2011, with construction of the actual project likely to occur in 2012.

5. MONITORING

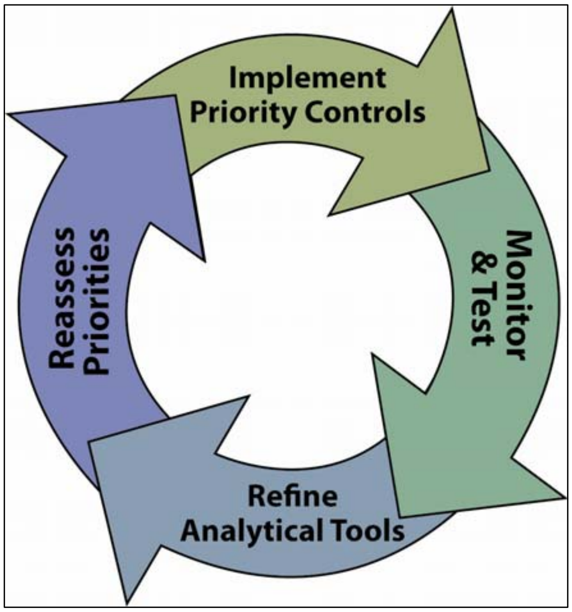
The following monitoring activities will evaluate the impairment status of the Mustinka River and expected water quality improvements:

- The Mustinka River Watershed will be monitored with a comprehensive set of monitoring locations and parameters in 2010 as part of the MPCA's watershed approach to condition monitoring and assessment. Under this approach, watershed monitoring will occur every ten years; the next monitoring and assessment for the Mustinka River watershed will occur in 2020. TSS and turbidity monitoring are components of the watershed monitoring.
- Bois de Sioux Watershed District stream gaging program – consists of approximately 40 to 50 long term monitoring sites throughout the Bois de Sioux Watershed District; sites are linked to River Watch monitoring sites.
- Red River Watershed Management Board's River Watch – River Watch is a citizen stream monitoring program that uses schools and other groups to collect stream and ditch water quality monitoring data. Sites are monitored monthly during ice-off conditions for water quality variables that include stage, temperature, transparency, turbidity, pH, conductivity, and dissolved oxygen. The BdSWD will work with the River Watch program to ensure that appropriate water quality and flow monitoring will be conducted to evaluate the progress on implementation projects and the restoration of the impaired reaches.
- USGS flow monitoring – The USGS maintains a long-term flow monitoring site (#05049000) on the Mustinka River, above Wheaton.
- After implementation of the Redpath project, flow and water quality monitoring will be used to assess the long term effectiveness of the project.
- As projects are implemented, the monitoring required in E-Link will be completed, including visual evaluations and documentation.

6. ADAPTIVE MANAGEMENT AND MILESTONES

6.1 Adaptive Management

The implementation actions outlined in this management plan are intended to improve water quality. However, at this stage of plan development it is not known to what extent the recommended implementation activities will be pursued nor the magnitude and scope to which the recommended activities will be realized. Since the cumulative effect on water quality therefore is also unknown, an ongoing assessment process will be implemented to evaluate the impact (effectiveness) of implementation activities on instream water quality and then tailor future implementation actions. This on-going assessment and resultant changes to the implementation approach is referred to as adaptive management and is illustrated in the circular flow path in Figure 3.



As management practices are being implemented, water quality will be monitored to evaluate the impact that the implementation actions have on turbidity in the impaired reaches. If water quality is improving, this suggests that the current approach is working and the same course will be followed. If water quality is not improving, this suggests that the approach being taken is not sufficient, or is targeted to the wrong sources. In this case, the approach will be evaluated and adjusted so that tangible water quality improvements can be realized.

Figure 3. Adaptive Management Process
(Adapted from Nicholas Institute for Environmental Policy Solutions, 2007)

6.2 Interim Measures

Completion of construction of the Redpath Project will serve as the primary interim measure. After completion of the Redpath Project, instream turbidity should be evaluated with several years of monitoring data to determine the project's impact on turbidity. MPCA's watershed monitoring and assessment planned for the Mustinka River watershed in 2020 may fall at an appropriate time to evaluate the Redpath Project. This evaluation will be tied into adaptive management.

7. REFERENCES

Board of Water and Soil Resources (BWSR), 2009. Performance Review and Assistance Program. Level II Performance Review Report for Bois de Sioux Watershed District. Final Report.

Bois de Sioux Watershed District (BdSWD), 2003. Overall Plan, Bois de Sioux Watershed District. Prepared by HDR Engineering, Inc.

Bois de Sioux Watershed District (BdSWD), 2009. Engineer's Report: Redpath Plan and Projects. Prepared by JOR Engineering.

Bois de Sioux Watershed District (BdSWD), 2010. Application of the Flow Reduction Strategy in the Bois de Sioux Watershed. Prepared by JOR Engineering.

Larson, G., 1998. Technical Paper No. 3: The Effectiveness of Agricultural Best Management Practices for Runoff Management in the Red River Basin of Minnesota. Technical and Scientific Advisory Committee, Red River Watershed Management Board. Available at: (http://www.rrwmb.org/files/FDRW/TP03.pdf)

Minnesota Pollution Control Agency (MPCA), 2009. Red River Valley Biotic Impairment Assessment. Prepared by Emmons & Olivier Resources, Inc.

Minnesota Pollution Control Agency (MPCA), 2005. Minnesota Stormwater Manual. Prepared by Emmons & Olivier Resources, Inc. and Center for Watershed Protection.

Natural Resource Conservation Service (NRCS), 2008. Conservation Practice Standard: Tile Intake Replacement. Interim Code IA-980. Available at: http://efotg.nrcs.usda.gov/references/public/IA/Interim980apr08.pdf

Puget Sound Shared Strategy, 2003. A Primer on Habitat Project Costs. Prepared by Evergreen Funding Consultants.

The River Institute. Undated. From Ditching to Stream Restoration: What are your projects?.

Smith, W., M. Catania, D. Eagar, Undated. A Landowner's Guide to Streambank Protection and Stabilization.

Solstad, J., A. Kean, and C. Anderson, 2009. Culvert Sizing for Flood Damage Reduction, Phase 1 – Preliminary Guidelines. Red River Basin Flood Damage Reduction Work Group, Technical and Scientific Advisory Committee, Technical Paper No. 15, October 2007**.** Available at: http://www.rrbdin.org/communication/filebank/files/TP15.pdf

ATTACHMENT A. APPLICATION OF THE FLOW REDUCTION STRATEGY IN THE BOIS DE SIOUX WATERSHED

Application of the Flow Reduction Strategy in the Bois de Sioux Watershed

Bois de Sioux Watershed District
Red River Basin Commission

June 4, 2010

JOR
ENGINEERING

Application of the Flow Reduction Strategy in the Bois de Sioux Watershed

Bois de Sioux Watershed District
Red River Basin Commission

June 4, 2010

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

Charles L. Anderson, PE

Date 6-4-2010 Registration No. 12775

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

Michael A. Bakken, PE

Date 6/4/2010 Registration No. 42682

Table of Contents

Figures

Tables

Introduction

Flooding has been a persistent problem in the Red River Basin. In the past, flood damage reduction strategies have often focused on protecting localized areas. Examples of these are urban levees, diversion channels, agricultural dikes, and farmstead ring dikes. The Red River Basin Commission is developing a strategy that would reduce flood damages throughout the basin by reducing the flood volume enough to reduce peak flows along the entire length of the Red River by 20%. This strategy is known as the “Flow Reduction Strategy”. Flow would be reduced primarily by storing floodwater within the contributing watersheds. The amount of flow reduction required was estimated by the Basin Commission using a Mike 11 hydrodynamic model of the 1997 spring flood.
The study reported herein was done by the Bois de Sioux Watershed District at the request of, and with funding assistance from, the Red River Basin Commission. The goal of the study was to identify, if possible, storage sites within the Bois de Sioux Watershed with the cumulative capacity to provide the Bois de Sioux's allocated portion of the required Red River flow reduction.

Background

The confluence of Bois de Sioux River and Ottertail River forms the headwaters of the Red River. As shown on the map in Figure 1, the Bois de Sioux drainage basin includes lands in Minnesota, North Dakota, and South Dakota with a total area of 1,936 square miles. A little over 2/3 or 1,414 square miles of this drainage area is in Minnesota and is organized as the Bois de Sioux Watershed District.

At the headwaters of the Bois de Sioux River is the Lake Traverse Project that was constructed by the US Army Corps of Engineers in 1942. It includes two reservoirs, Lake Traverse and Mud Lake. These reservoirs are controlled by Reservation Dam and White Rock Dam, respectively. They are operated for recreation and flood control. During spring floods the project can hold about 160,000 acre feet (ac ft), which is equivalent to about 2.3” of runoff from its contributing drainage area, before water is released. An additional 1.7” of ungated storage is provided between the flood stage that the operating plan calls for opening the gates and the top of the dam. The drainage area for this project is 1,298 square miles of which about ¾ is from the Minnesota side of the basin, 961 square miles.

The only other existing flood control reservoir is the North Ottawa Project. This project is located in the Rabbit River Basin. It was placed in service after the 1997 flood. Therefore, it is included with the other proposed sites in this study. This project provides 16,000 ac ft of gated storage which is equivalent to 4.1” of runoff from its drainage area and 2000 ac ft of ungated storage below the emergency spillway which is equivalent to an additional 0.5” of runoff control.

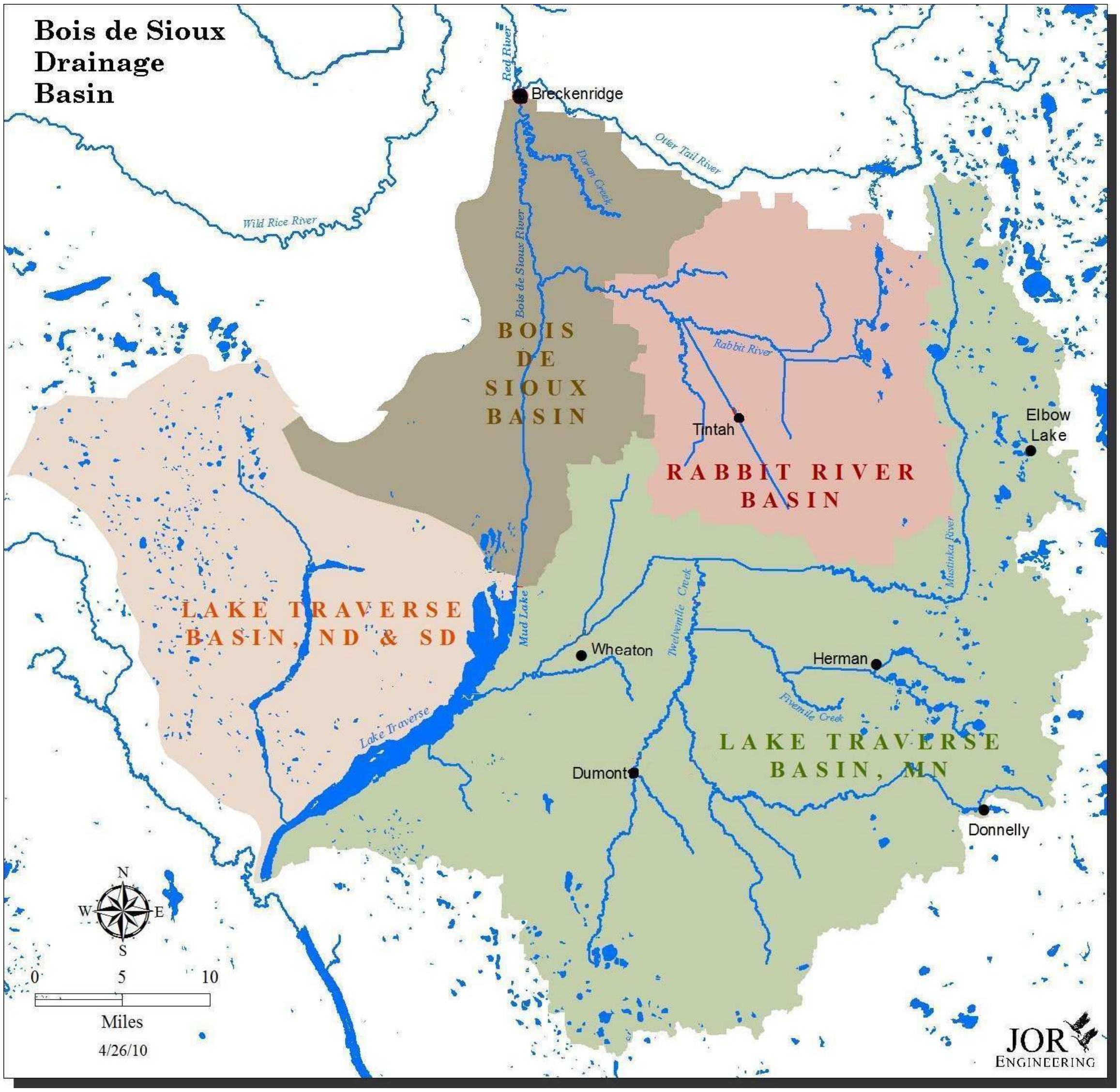


Figure 1. Bois de Sioux Drainage Basin

Site Selection

This study focused on placing storage within the Bois de Sioux Watershed District. A total of 26 sites or potential projects were identified within the District. The storage was placed in the Lake Traverse and Rabbit River basins. Site selection was based primarily on the need for local flood control. Flooding problems are widespread in the Bois de Sioux Watershed District. The Watershed Board looks forward to partnering with regional interests to help solve its local flooding problems in ways that will also benefit the mainstem. This strategy will promote local support for the projects.

The map in Figure 2 shows approximate locations of the storage sites and the areas of the watershed that they will control. Table 1 lists the individual sites and the volume of storage that will be constructed. It is broken down into gated and ungated storage. Gated storage removes flow from the flood hydrograph and the removed water will not be released until flooding downstream has abated. Ungated storage delays the water and generally reduces peak flows, but some or all of the water may be released during the flood period.

In addition to the 26 sites within the Bois de Sioux Watershed District, approximately 11,000 ac ft of hypothetical storage was placed in South Dakota in the Lake Traverse Basin.

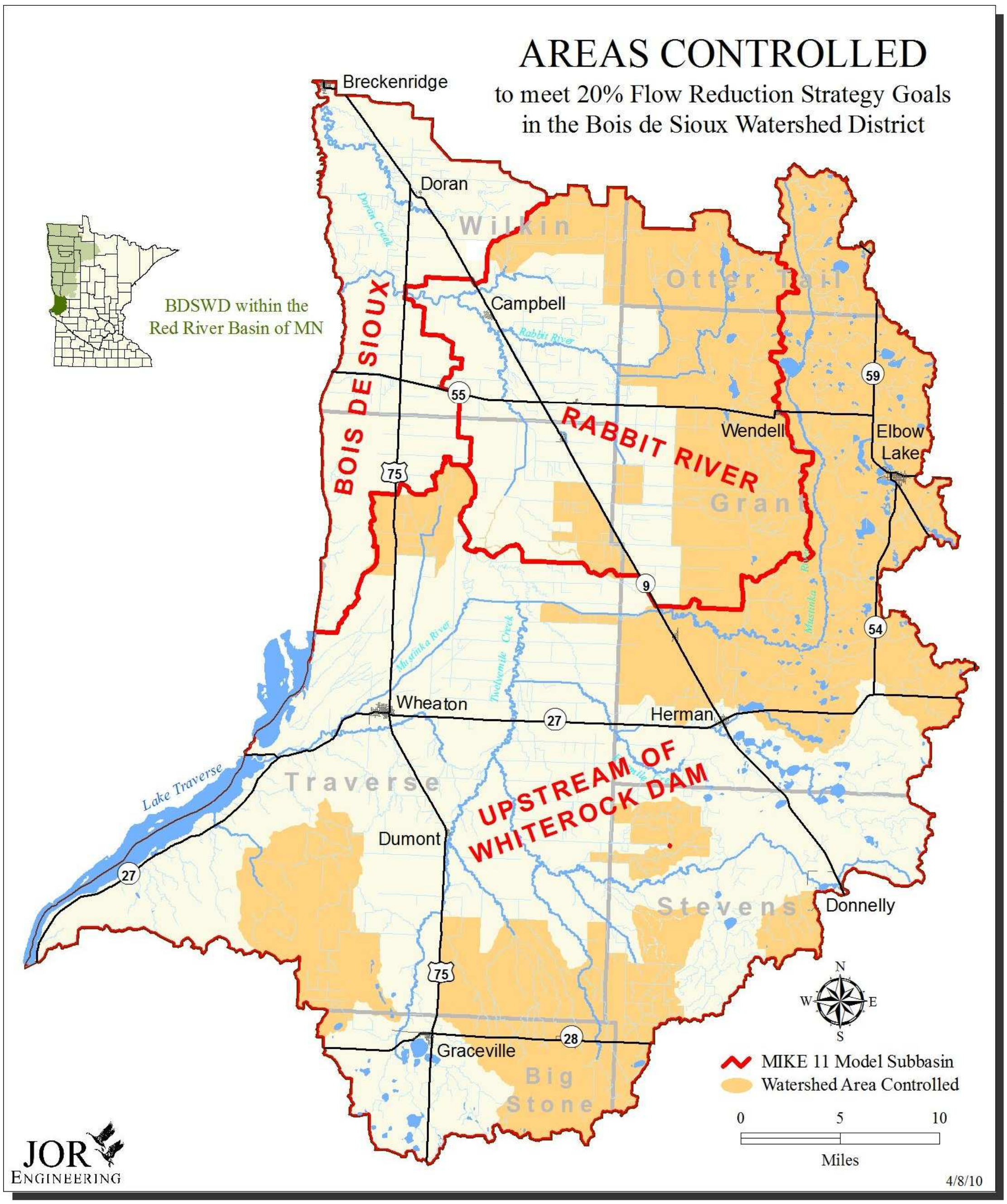


Figure 2. Areas Controlled for 20% Flow Reduction

Table 1

Impoundment sites included in Flow Reduction Strategy Bois de Sioux Watershed District 4/19/2009	Gated Storage (ac ft)	Ungated Storage (ac ft)	Total Storage (ac ft)	RRBC 20% plan Reduction (ac ft)
White Rock watershed				
Red Path	13100	3100	16200	
Red Path West	5501	545	6046	
Eldorodo 7	1700	755	2455	
Big Lake	463	1325	1788	
Moonshine Lake	2723	686	3409	
Moonshine 13	1520	328	1848	
Moonshine 4	885	322	1207	
Leonardsville 31E	1046	413	1459	
Dollymount 30	5484	872	6356	
Leonardsville 31W	1592	350	1942	
Tara 12	3071	843	3914	
Leonardsville 12	6630	1031	7661	
Croke 17	2142	605	2747	
Dollymount 24	1499	552	2051	
Walls 36	1897	850	2747	
Moose Head	1622	896	2518	
Walls 30	3831	937	4768	
Delaware 17	1695	518	2213	
Everglades	1965	890	2855	
Township Slough	3802	950	4752	
South Dakota site(s)	8771	2193	10964	
Subtotal	**70939**	**18961**	**89900**	**61760**
Rabbit watershed				
North Ottawa	16160	2050	18210	
Brandrup S23	3020	980	4000	
Bradford S34	3042	627	3669	
Lawrence S19	5892	1061	6953	
Tintah S34	833	160	993	
Daniels	867	223	1090	
Subtotal	**29814**	**5101**	**34915**	**24377**
Bois de Sioux Ungaged				
Subtotal	0	0	0	**12119**
Total BdS watershed	**100753**	**24062**	**124815**	**98256**

Hydrologic Analysis

The analysis was done using the HEC-HMS (HMS) software developed by the USACE. The following paragraphs describe the methodologies used in building the hydrologic model.

Runoff

The amount of runoff generated by the 100 year and 500 year frequency spring runoff events were modeled using the Hydrologic Curve Number (CN) method developed by the Soil Conservation Service (SCS). The curve number takes into account the soil type, topography, land cover, and cultural practices of the watershed and relates precipitation to runoff. SCS curve numbers were developed using Geographic Information System (GIS) based analysis.

The required data layers to determine the curve numbers are land cover and hydrologic soil group. The hydrologic soil groups are based on expected rates of infiltration. They are A, B, C, and D, varying from most to least permeable. For some soil types, two classes are given, depending on whether or not the soil has been drained. These were reclassified by processing the data within the GIS system, using the assumption that all lands shown as agricultural had been drained for present conditions.

The land cover data used for the model was developed in the early 1990's by The International Coalition (TIC). The TIC data was developed from 1990 vintage aerial photography.

Snowmelt runoff was also considered. The amount of the 10 day runoff for spring flood event was based on information in the Minnesota Hydrology Guide and is shown in Table 2. The 500 year runoff was estimated by extending that curve. This runoff was distributed over the watershed based on 24 hour curve numbers using the precipitation amounts shown in the table. The precipitation amount was distributed over a 10 day period using the distribution shown in Figure 3.

Table 2
Estimated Spring 10 day Runoff

	Snowmelt (inches)	Runoff (inches)
500 year	9.69	6.6
100 year	8.66	5.6
50 year	8.03	5.13
25 year	7.40	4.56
10 year	6.50	3.76

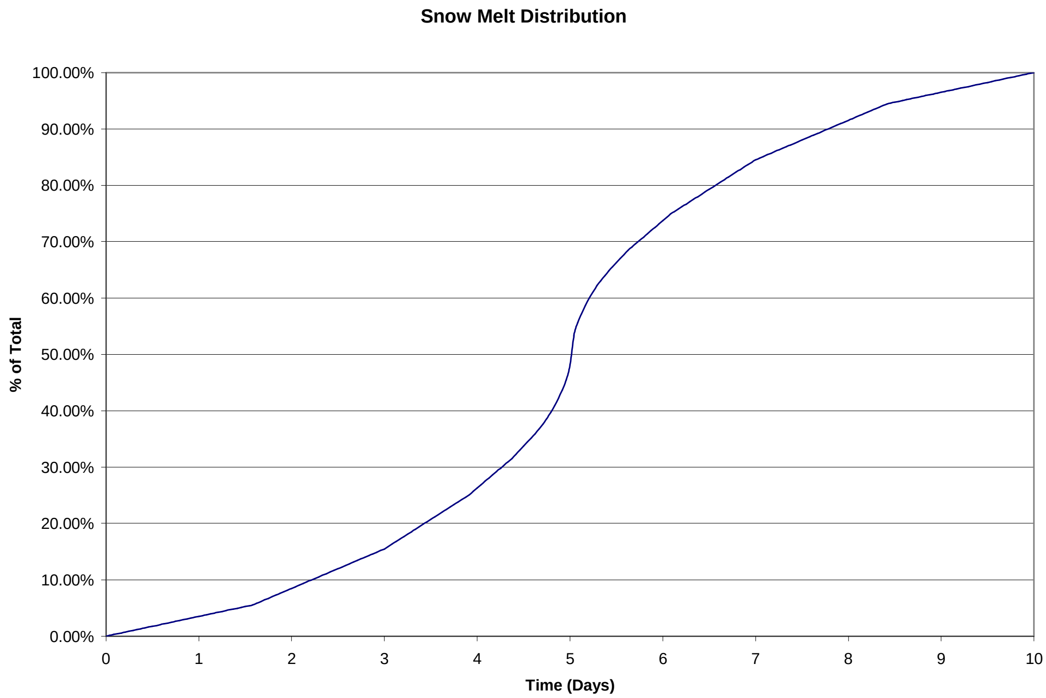


Figure 3. Snow Melt Distribution

Hydrograph Development

For the purpose of hydrograph development at a subbasin level, the watershed was divided into 265 subwatersheds. Runoff within each subwatershed is determined, as discussed above, by the SCS curve number method.

The Clark Unit hydrograph method was used in the model to transform runoff excess to outflow from each subwatershed. This method requires determination of two runoff parameters related to, time of concentration and storage. Time of concentration (Tc) is the travel time required for runoff to flow from the most hydrologically distant point of the subwatershed to the outlet. The time of concentration was calculated for each subwatershed, using a GIS routine developed by the Minnesota Department of Natural Resources. This routine allows the user to specify when overland flow will become concentrated and when concentrated flows switch to low retardance channel flow. These numbers were set at 2 acres and 40 acres respectfully. The storage coefficient is related to time of concentration. In general, R=K*Tc where R is the storage parameter, K is a coefficient reflecting watershed topography and size. These parameters are adjusted during model calibration based on gage data and other local information.

The North Dakota and South Dakota portion of the basin was developed for the Corps by West Consulting. They also used the Clark method but may have used different methodologies to develop the runoff parameters.

1997 Flood

The 97 flood was modeled using precipitation and 24 hour curve numbers. A total of 9.25” of precipitation was applied to the model at rates to simulate the melt and freeze up during the blizzard and subsequent melt of that event. A comparison of inflows for the Lake Traverse Project of modeled flows and USACE estimated flows is shown in Figure 4. Oscillations, including negative inflows, in the corps estimate of flows are probably the result of wind affecting gage readings on the reservoir.

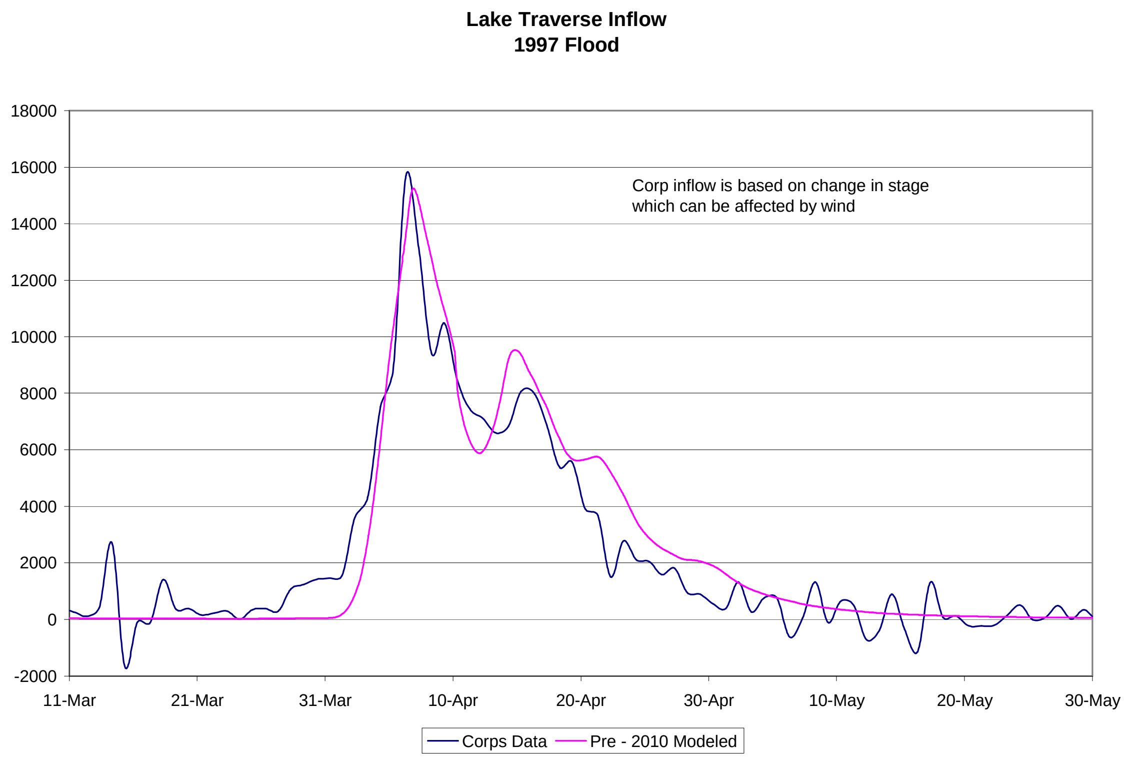


Figure 4. Lake Traverse Inflow

A comparison at the USGS gage site just downstream of the White Rock Dam of published flows and the HMS model flows is provided in Figure 5. HMS does not have a feature that allows for operation of gates, so we developed a rating curve for the outlet that we believe comes fairly close to representing the Corps' normal operation of the gates.

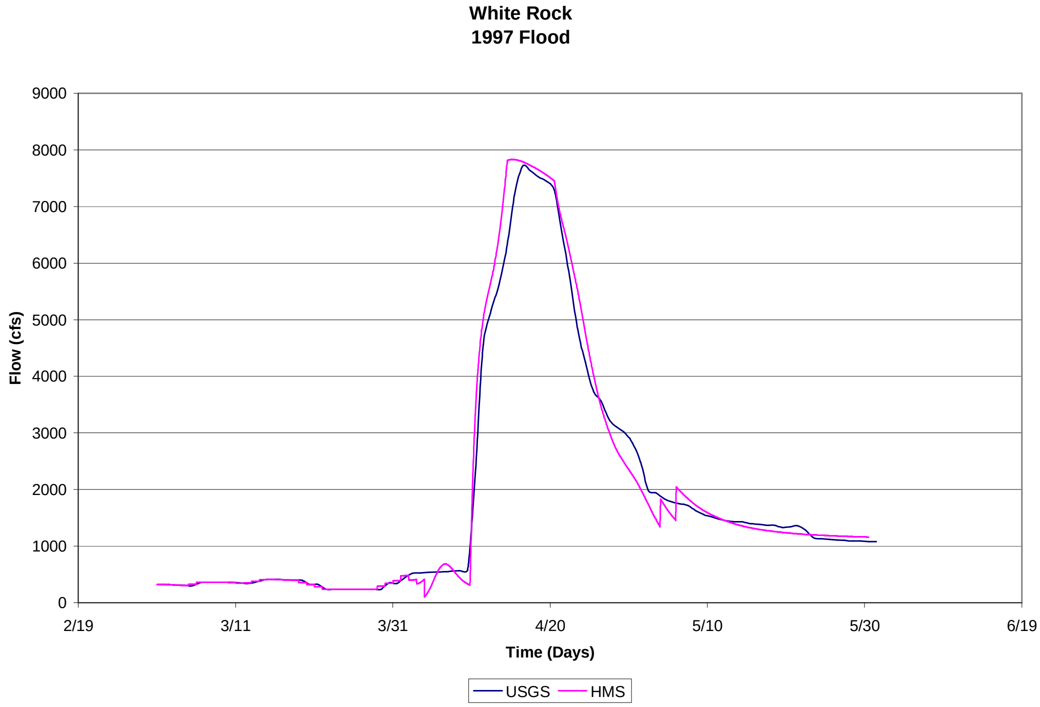


Figure 5. Bois de Sioux River near White Rock

Figure 6 shows a comparison of the Mike 11 model of the Bois de Sioux at Breckenridge and the results of the HMS modeling for conditions in 1997.

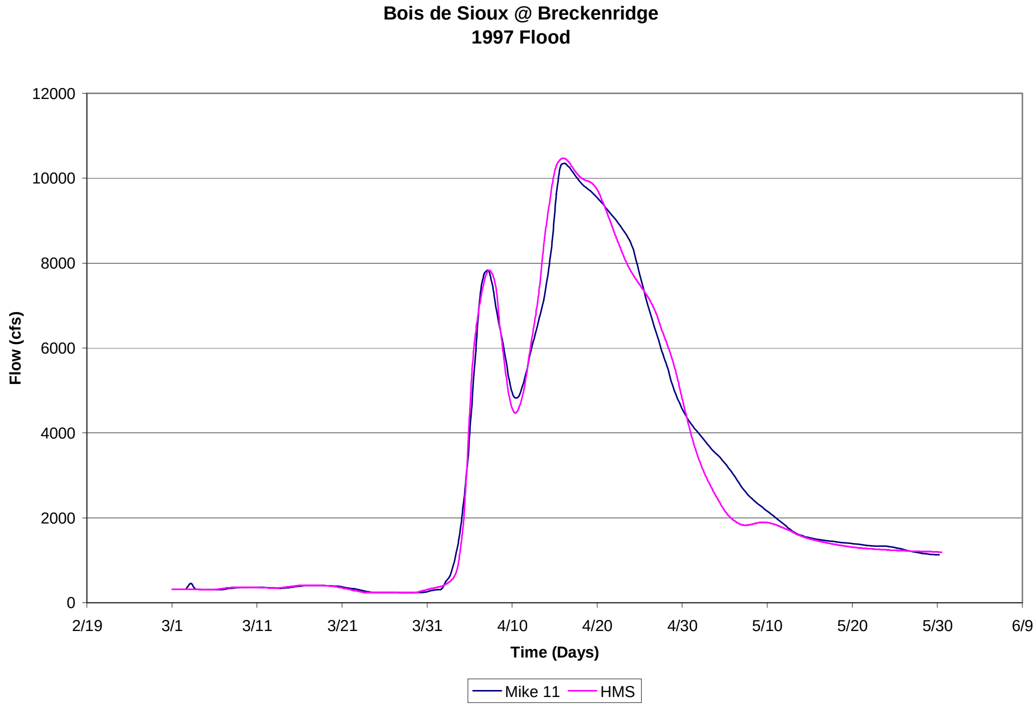


Figure 6. Bois de Sioux River at Breckenridge, MN

Results

The affects of the flow reduction strategy were compared at various locations within the basin. These sites can be seen in Figure 7. Table 3 on page 18 presents the flow reductions accomplished for the various flood events at these locations.

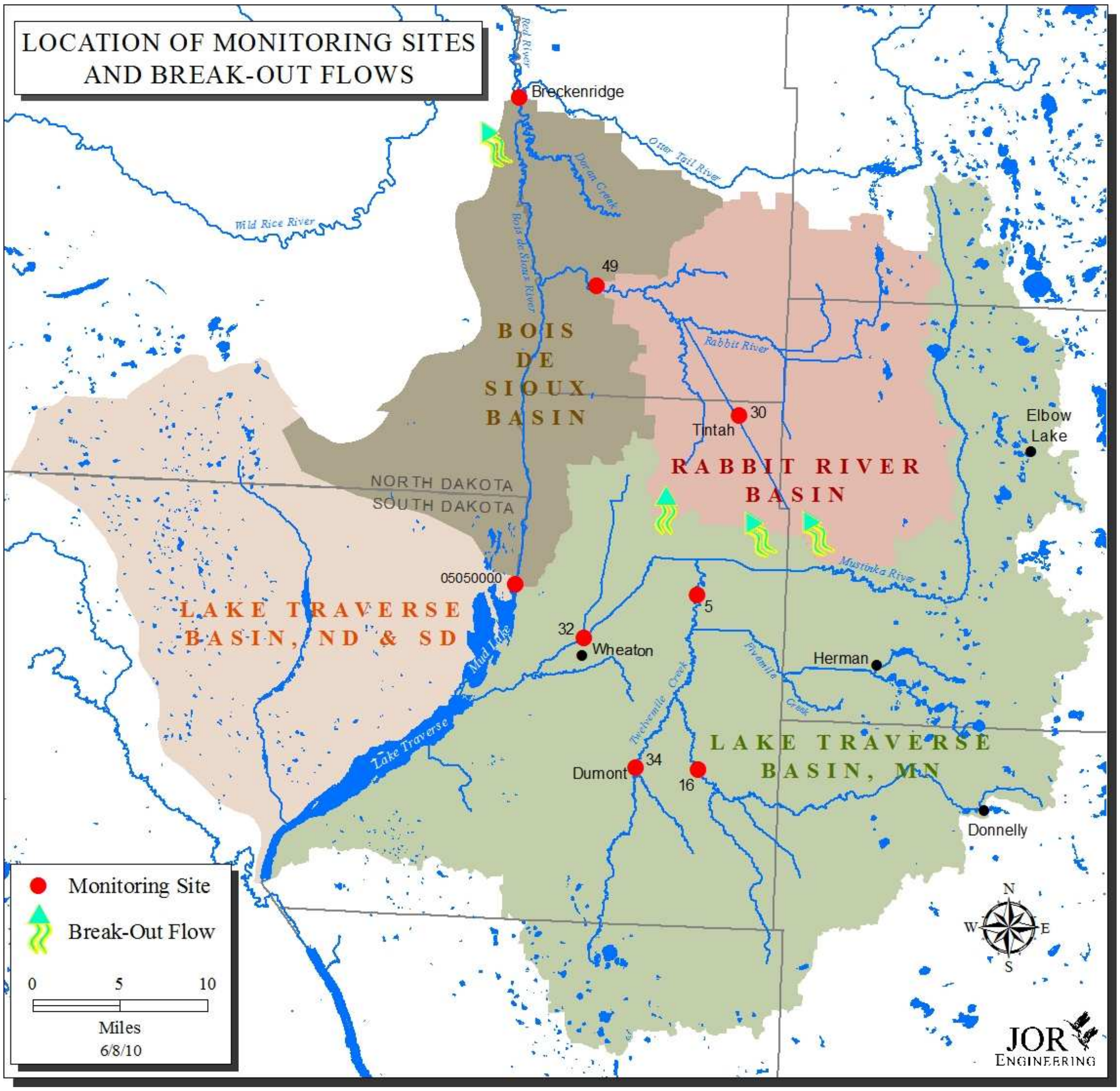


Figure 7. Location of Monitoring Sites

The comparison of the Bois de Sioux River near White Rock is shown in Figure 8 for the 1997 flood between the existing conditions and the Flow Reduction Strategy condition. Storage upstream from Traverse delays the point at which the Corps has to begin releasing water and also reduces the peak outflow. The longer the delay in release of water the less likely that those waters will contribute to peak flows downstream.

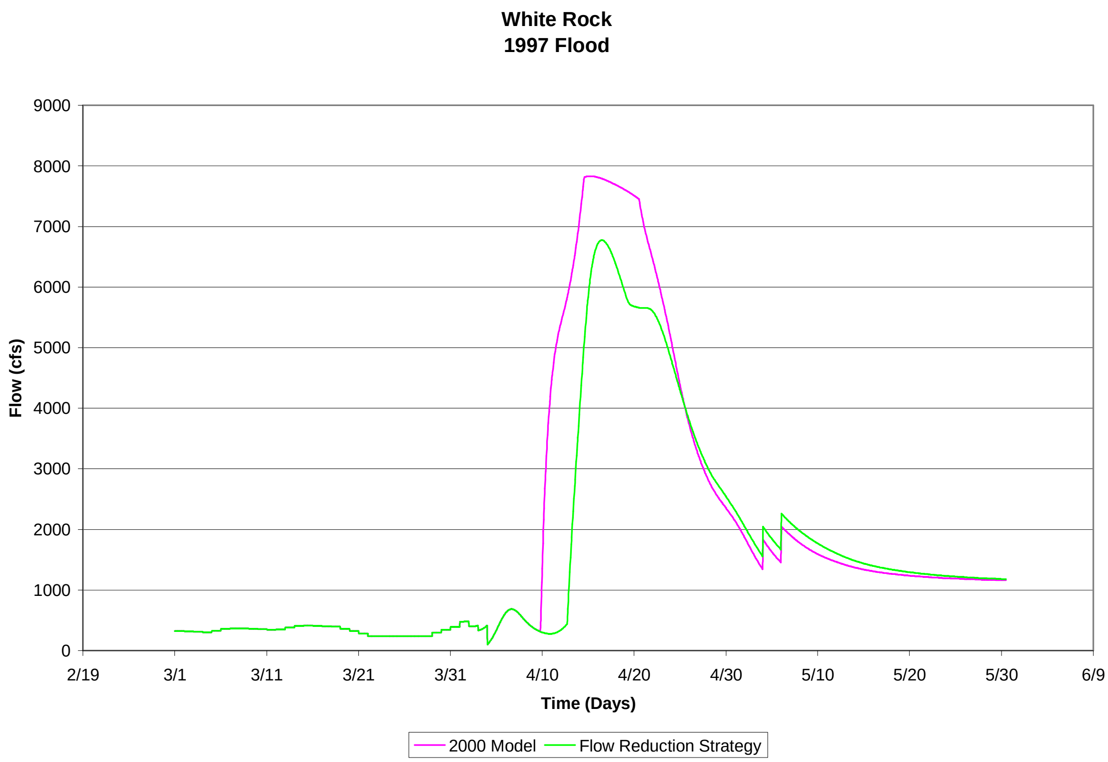


Figure 8. Bois de Sioux near White Rock 1997

Figure 9 shows a comparison of the flows for the Rabbit River at the gaging station on Highway 75 for the 1997 flood. Some of the reduction in flow is from storage in the Lake Traverse basin which reduces the breakout flows from the Mustinka River to the Rabbit River.

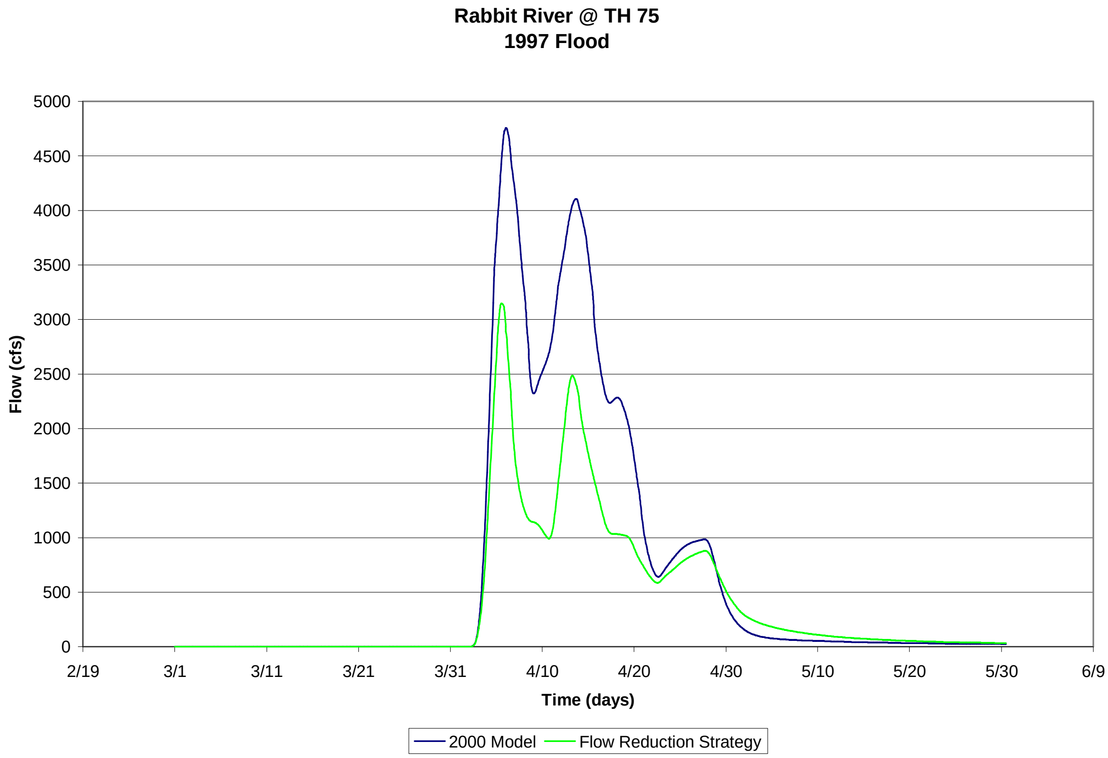


Figure 9. Rabbit River 1997 Flood

Red River Impacts

The identified storage sites, including the storage in South Dakota, are essentially able to meet Bois de Sioux Watershed's allocated share of the RRBC Flow Reduction Strategy requirements. The most significant difference is related to White Rock Discharges. The RRBC Mike 11 modeling effort assumed a 20% peak flow reduction at White Rock and a 20% reduction in volume. The achieved results at White Rock were a 13% reduction in peak flow and a 16% reduction in volume. The difference in volume reduction is that a large part of the flow reduction, 27,622 ac ft or approximately 30% of the storage allocated to the Traverse Basin, was in breakout flows from the Mustinka to the Rabbit, that occur in the area along the Mustinka River where the river comes down out of the beach ridge and enters the lake plain as shown in Figure 7. Therefore, storage in the Mustinka (Traverse) Basin reduces flows on the Rabbit River

The hydrographs from HMS for White Rock and the Rabbit River were used as input to the Mike11 model, to model the affects of the Bois de Sioux Watershed's flow reduction at Breckenridge, Fargo, Halstad, and Grand Forks. The model was run with just the Bois de Sioux reduction and with proposed reductions for each tributary. The results for this modeling are shown in Figures 10 – 13. Bois de Sioux Basin reductions result in 20.8% and 9.3% peak flow reduction on the Red River at Wahpeton and Fargo, respectively, in the model of the 1997 flood. Including reductions in the Mike 11 model from the other

Red River Tributaries, the peak flow reduction is 20.9% and 21.8%, respectively, which exceeds the 20% flow reduction goal.

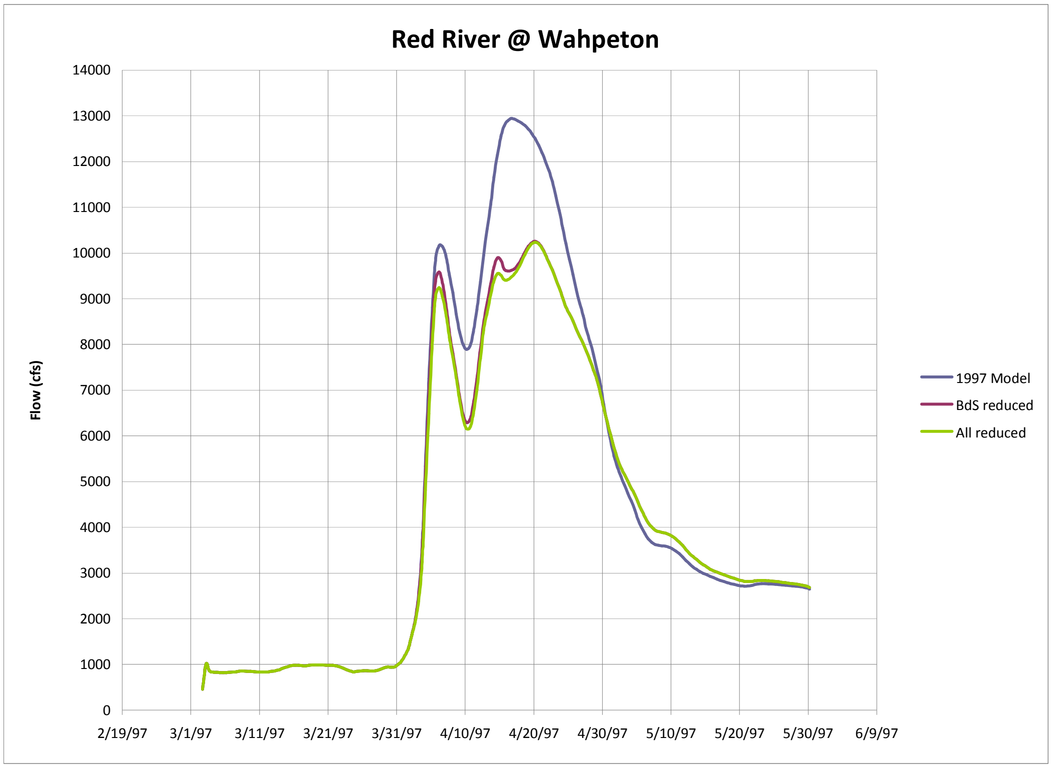


Figure 10. Red River @ Wahpeton, ND

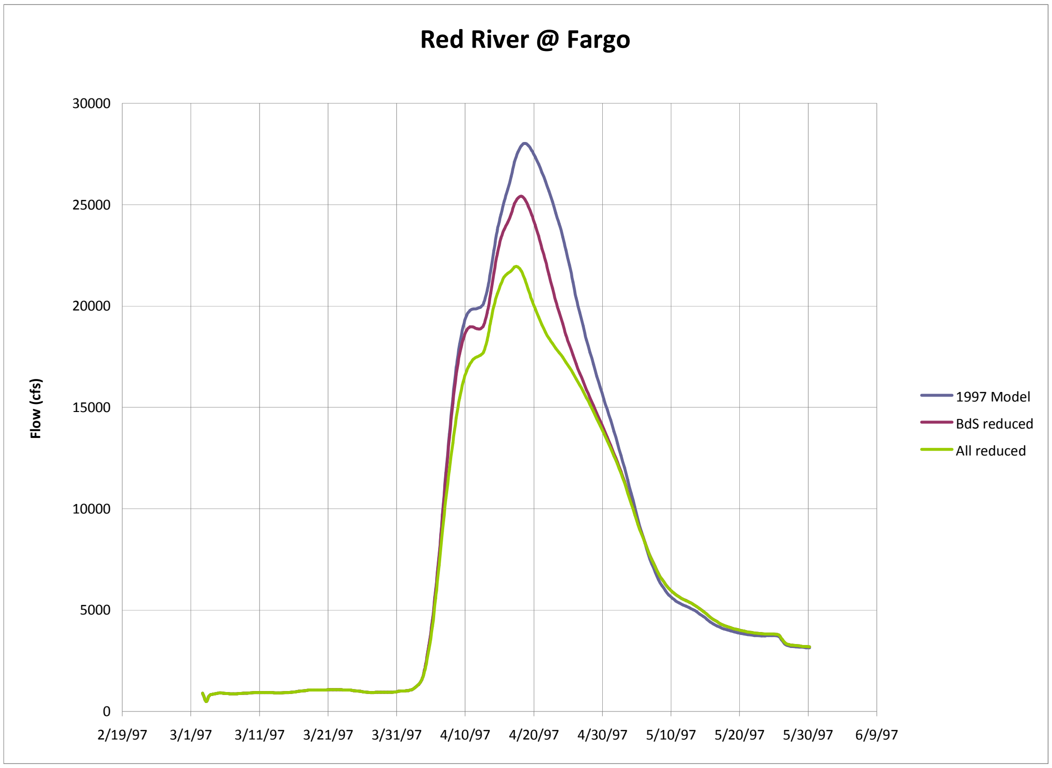


Figure 11. Red River @ Fargo, ND

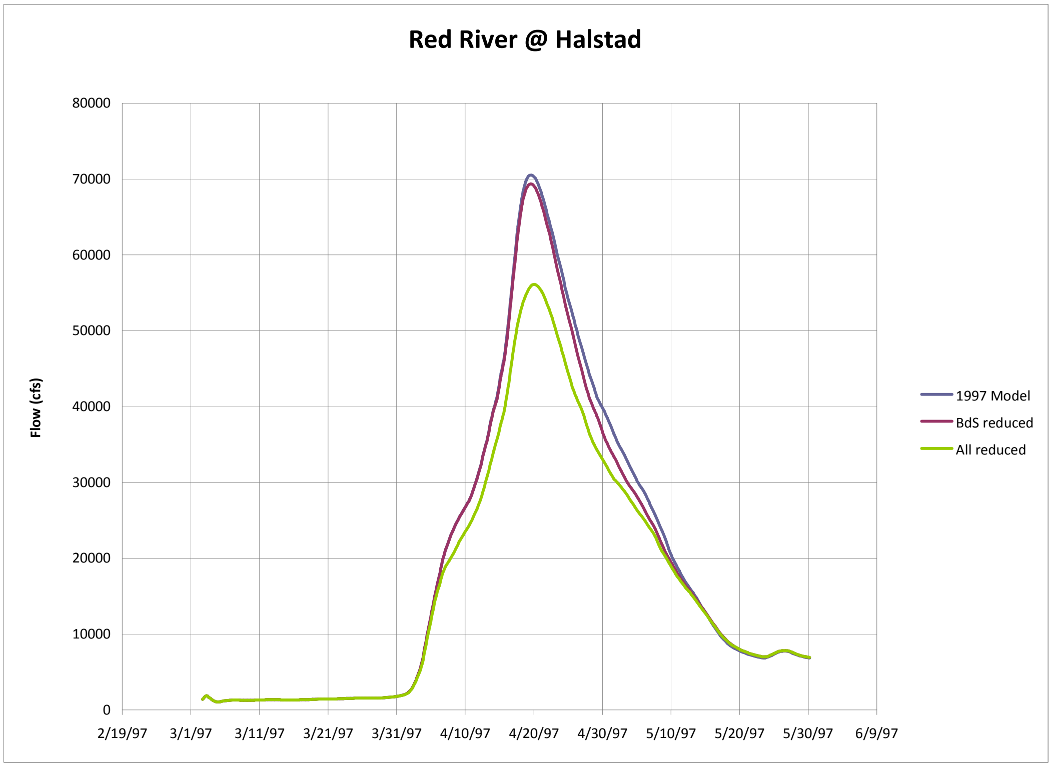


Figure 12. Red River @ Halstad, MN

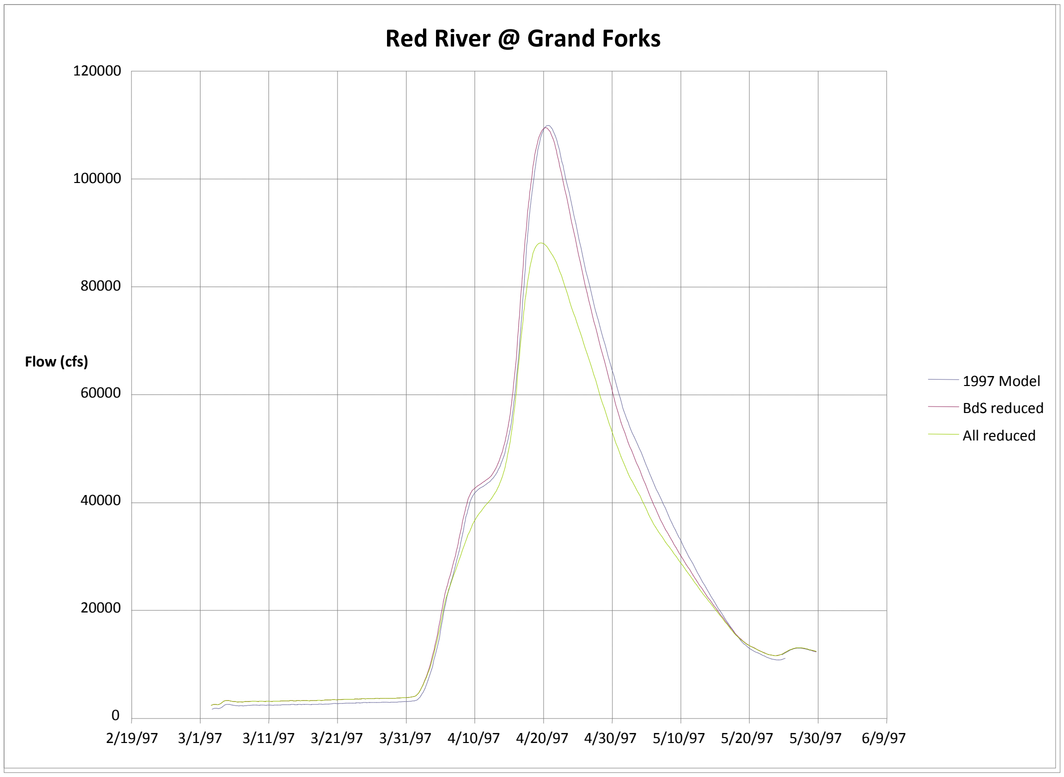


Figure 13. Red River @ Grand Forks, ND

As can be seen in these hydrographs the affect of the Flow Reduction Strategy in just the Bois de Sioux Watershed slowly diminishes until there is only a 0.5% effect at Grand Forks. However, if every tributary basin does their share of flow reduction the effect can be significant and will meet the RRBC Flow Reduction Strategy goals.

Hypothetical Spring Runoff Events

The 100 year and 500 year spring runoff events were also modeled to analyze the Flow Reduction Strategy effect on those floods. The 20% flow reduction goal at Breckenridge is met not only for the 1997 and 100 year floods, but also for the 500 year flood.

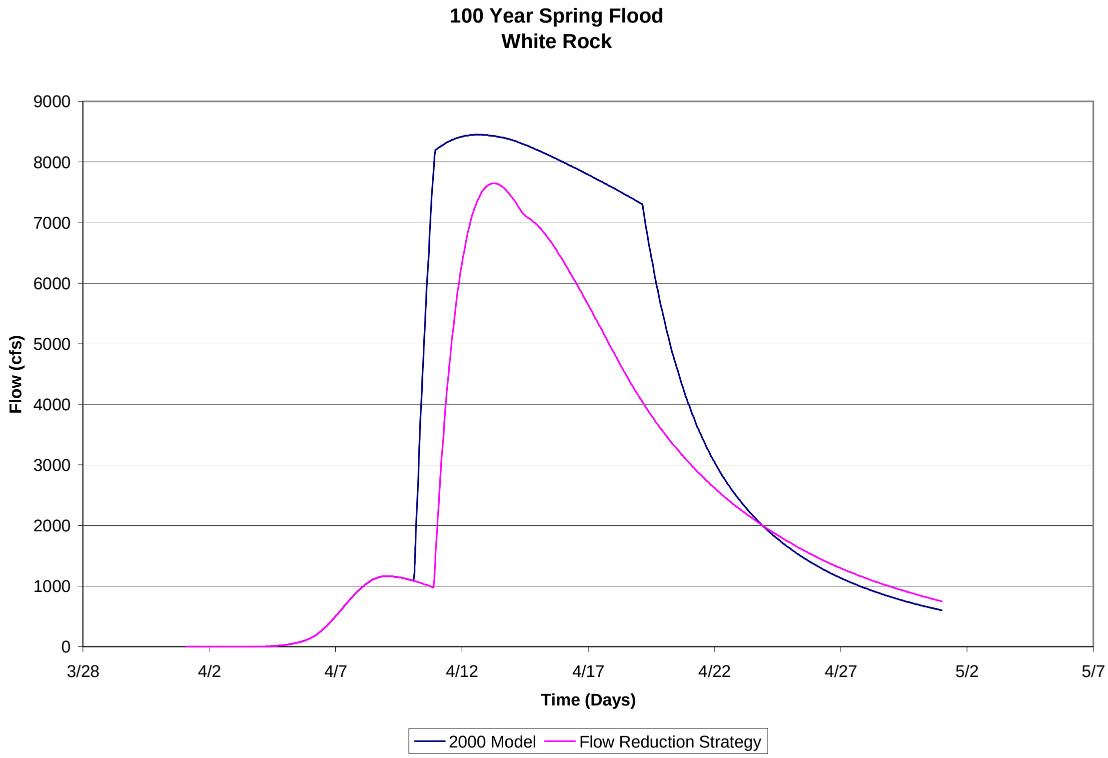


Figure 14. Bois de Sioux near White Rock - 100 year

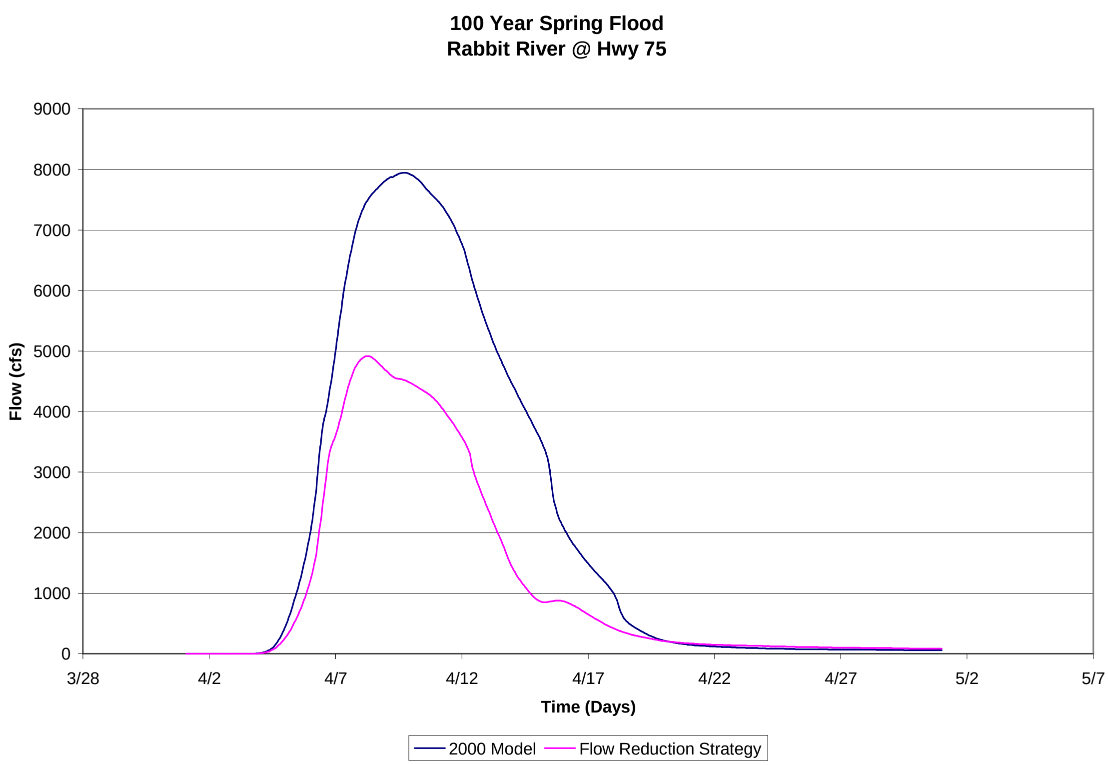


Figure 15. Rabbit River - 100 year

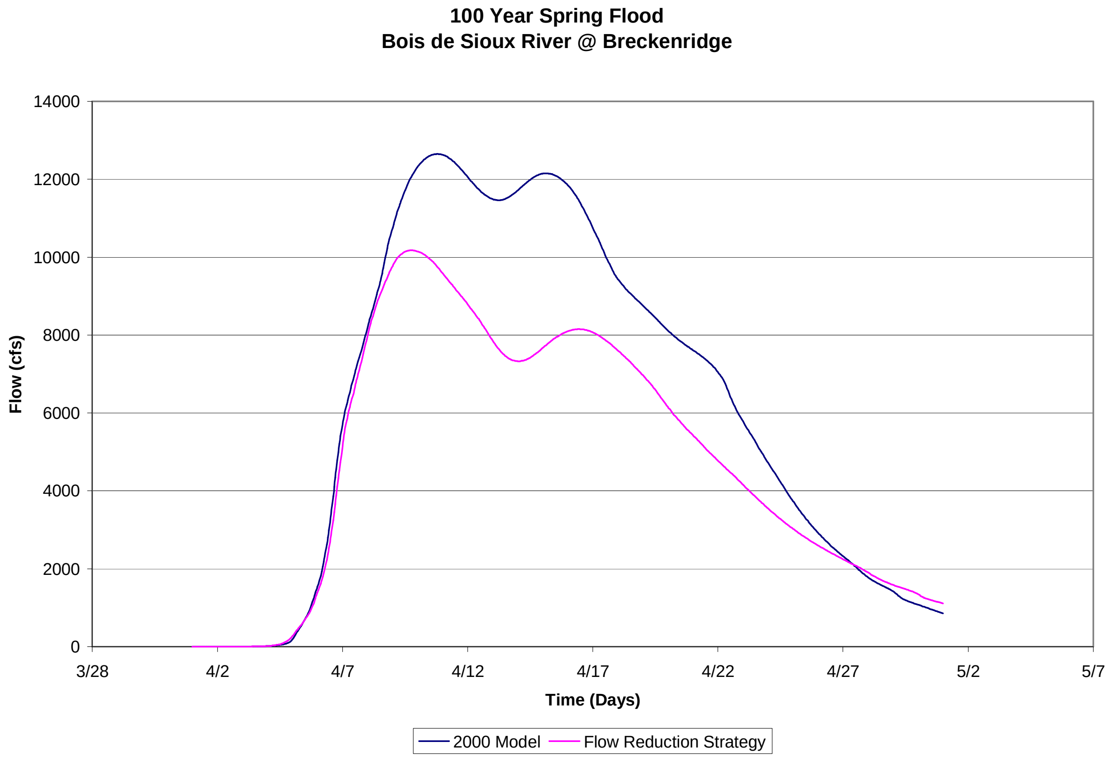


Figure 16. Bois de Sioux @ Breckenridge - 100 year

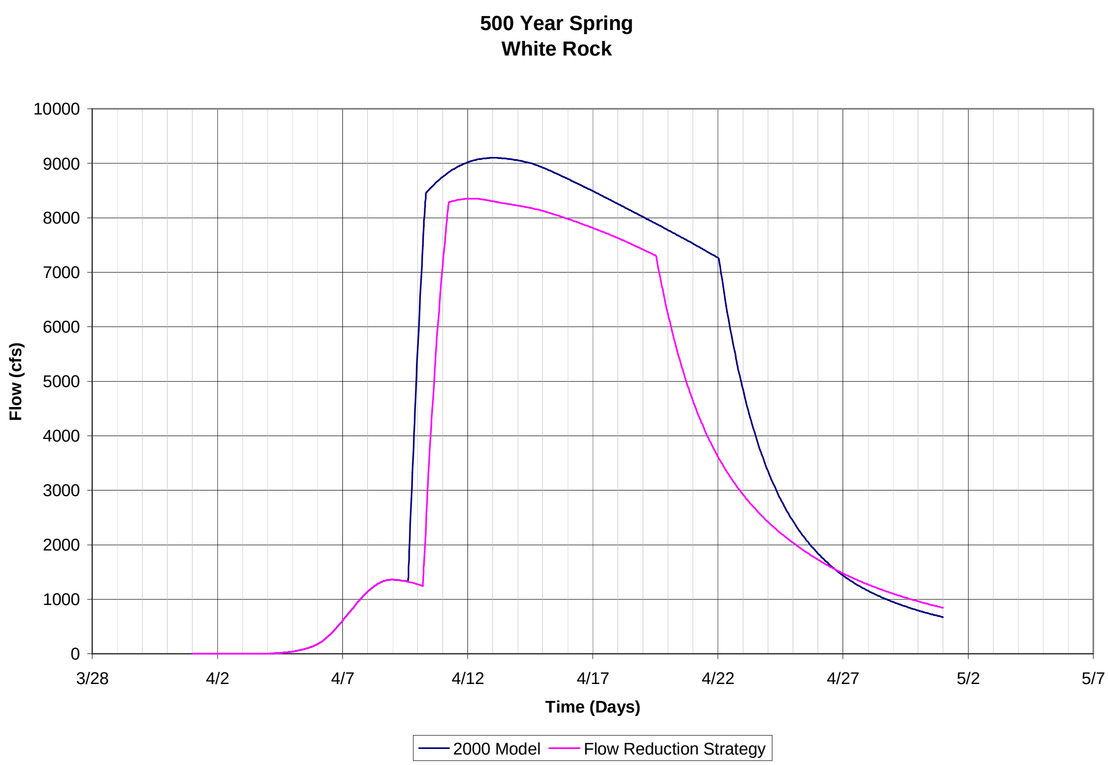


Figure 17. Bois de Sioux near White Rock - 500 year

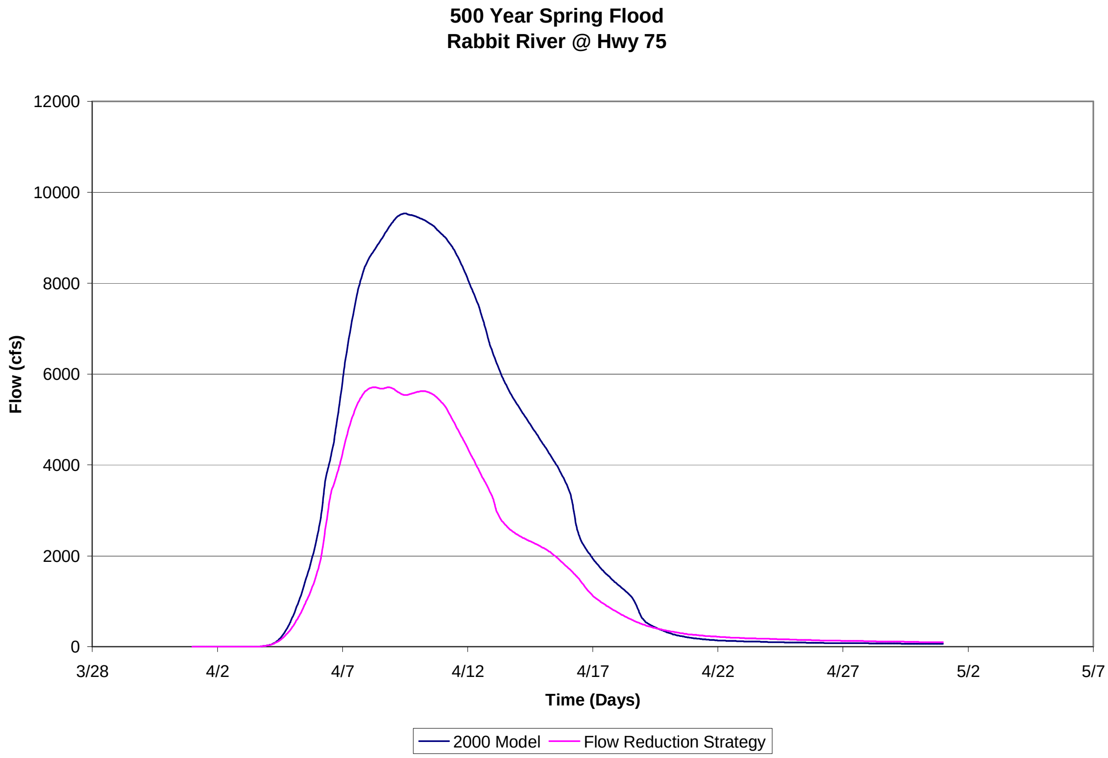


Figure 18. Rabbit River - 500 year

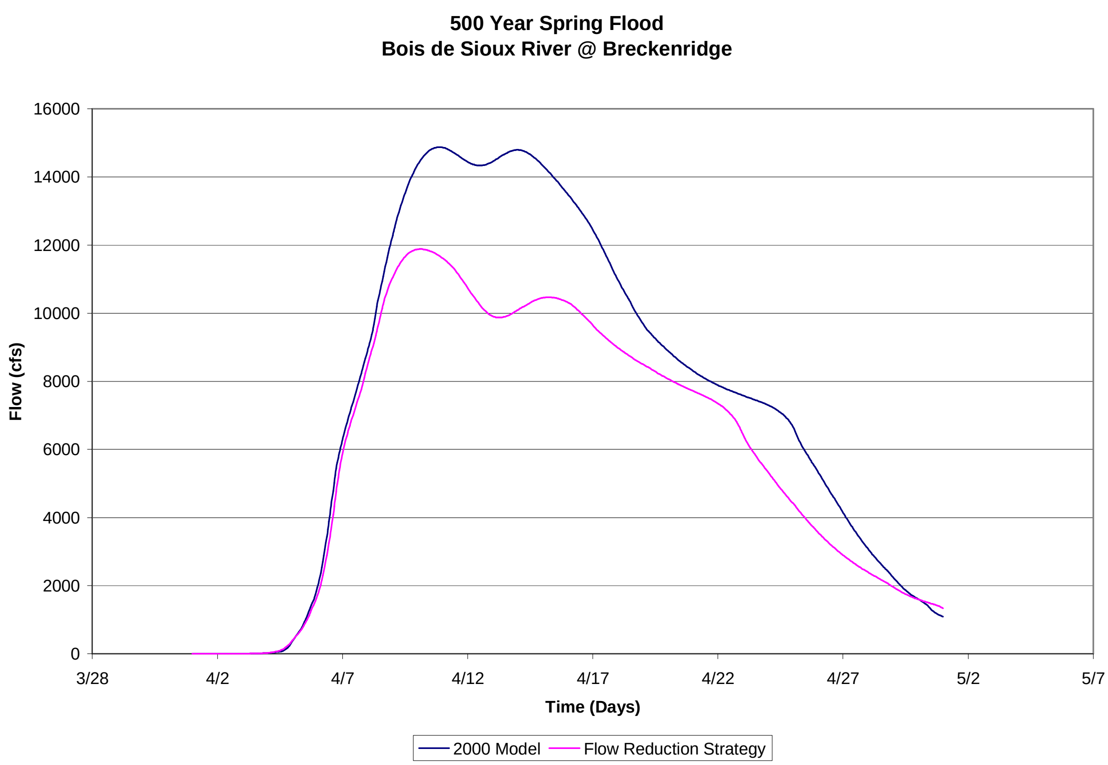


Figure 19. Bois de Sioux at Breckenridge - 500 year

The flow reductions on the main stem from White Rock and the Rabbit River are substantial. However, flow reductions within these subwatersheds as shown in Tables 3 and 4 are even more substantial. For example, peak flows at Dumont (34) are reduced by 43% to 46%. Peak flows at Tintah (30) are reduced by 45% to 65%.

Table 3

	Peak Flow Reduction								
	1997 Spring Flood			**100 Year Spring Flood**			**500 Year Spring Flood**		
	2000 Model Peak Flow (cfs)	FRS Model Peak Flow (cfs)	Percent Reduction	2000 Model Peak Flow (cfs)	FRS Model Peak Flow (cfs)	Percent Reduction	2000 Model Peak Flow (cfs)	FRS Model Peak Flow (cfs)	Percent Reduction
34	2901	1568	45.9%	4434	2540	42.7%	5206	2977	42.8%
16	2101	973	53.7%	2895	1248	56.9%	3424	1665	51.4%
5	6348	4244	33.1%	10156	6184	39.1%	12027	7246	39.8%
Breakout Flows to Rabbit River	1914	746	61.0%	4049	1292	68.1%	5050	1858	63.2%
32	7055	5056	28.3%	10325	6789	34.2%	11743	7563	35.6%
05050000	7831	6775	13.5%	8451	7956	5.9%	9100	8354	8.2%
30	821	454	44.7%	1581	642	59.4%	2062	719	65.1%
49	4756	3149	33.8%	7944	4919	38.1%	9533	5707	40.1%
Breakout Flows to Wild Rice River	1681	885	47.4%	2031	1651	18.7%	2388	1908	20.1%
Bois de Sioux @ Breckenridge	10472	8022	23.4%	12650	10177	19.5%	14875	11883	20.1%

As shown in this table, flow reductions are greatest in areas close to the storage sites and become smaller further downstream. Table 5 presents the reductions in volume at the same sites.

Table 4

	Volume Reduction											
	1997 Spring Flood				100 Year Spring Flood				500 Year Spring Flood			
	2000 Model Volume (ac ft)	FRS Model Volume (ac ft)	Volume Reductn (ac ft)	Percent Reductn	2000 Model Volume (ac ft)	FRS Model Volume (ac ft)	Volume Reductn (ac ft)	Percent Reductn	2000 Model Volume (ac ft)	FRS Model Volume (ac ft)	Volume Reductn (ac ft)	Percent Reductn
34	51787	37609	14178	27.4%	46302	32378	13924	30.1%	54543	39906	14637	26.8%
16	44275	30593	13682	30.9%	39738	25679	14059	35.4%	46625	32244	14381	30.8%
5	158972	124368	34604	21.8%	140538	106249	34289	24.4%	164985	129138	35847	21.7%
Breakout Flows to Rabbit River	27733	8465	19268	69.5%	43563	16522	27041	62.1%	57214	25185	32029	56.0%
32	219732	181728	38004	17.3%	175686	143824	31862	18.1%	199859	172393	27466	13.7%
05050000	339312	286695	52617	15.5%	198427	160373	38054	19.2%	250791	207476	43315	17.3%
30	20713	5493	15220	73.5%	28771	5199	23572	81.9%	37956	6222	31734	83.6%
49	121802	73472	48330	39.7%	127802	70581	57221	44.8%	155764	93531	62233	40.0%
Breakout Flows to Wild Rice River	42082	17256	24826	59.0%	46563	28605	17958	38.6%	59961	44013	15948	26.6%
Bois de Sioux @ Breckenridge	516767	440910	75857	14.7%	369729	292169	77560	21.0%	450913	360984	89929	19.9%

Effectiveness of Constructed Storage

The cumulative effects of the proposed storage sites meet the requirements of the RRBC Flow Reduction Strategy which called for about 98,256 ac ft of flow reduction. The total constructed storage volume proposed in this report for the Bois de Sioux Watershed is 124,815 ac ft, including the site(s) in South Dakota, of which 100,753 ac ft is gated and 24,062 is ungated. This indicates, as expected, that the storage is not 100% effective. The least effective storage is the ungated portion. Assuming the ungated at 30% effective and the gated storage at 90% effective yields an estimated effective storage of 97,896. Overall, the effectiveness factor is about 80% These factors seem reasonable for the type and location of the projects proposed.