Minnesota River Turbidity TMDL

Work Plan

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Minnesota Pollution Control Agency

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I. Background and Problem

A. Description of Project

This project concerns turbidity impairments in Minnesota River Basin. The project area begins near Lac Qui Parle and ends at Jordan and involves 18 reaches on the mainstem and lower tributaries. It includes the Chippewa, Redwood, Cottonwood, Blue Earth, Hawk Creek, Yellow Medicine, Watonwan, and Le Sueur Rivers (Table 1).

Table 1. Turbidity impairments Minnesota River turbidity TMDL will target.

	Reach
Minnesota River; Blue Earth R to Shanaska Cr	07020007-502
Minnesota River; Cottonwood R to Little Cottonwood R	07020007-503
Minnesota River; Swan Lk Outlet to Minneopa Cr	07020007-505
Minnesota River; Eight Mile Cr to Cottonwood R	07020007-508
Minnesota River; Beaver Cr to Birch Coulee	07020007-514
Blue Earth River; Le Sueur R to Minnesota R	07020009-501
Blue Earth River; Rapidan Dam to Le Sueur R	07020009-509
Le Sueur River; Maple R to Blue Earth R	07020011-501
Minnesota River; Shanaska Cr to Rogers Cr	07020007-501
Minnesota River; Rush R to High Island Cr	07020012-503
Minnesota River; Chippewa R to Stoney Run Cr	07020004-501
Watonwan River; Perch Cr to Blue Earth R	07020010-501
Yellow Medicine River; Spring Cr to Minnesota R	07020004-502
Minnesota River; Timms Cr to Redwood R	07020004-509
Hawk Creek; Spring Cr to Minnesota R	07020004-587
Chippewa River; Watson Sag Diversion to Minnesota R	07020005-501
Redwood River; Ramsey Cr to Minnesota R	07020006-501
Cottonwood River; JD #30 to Minnesota R	07020008-501

Turbidity in water is caused by suspended soil particles, algae, etc. that scatter light in the water column making the water appear cloudy. Turbidity limits light penetration and inhibits healthy plant growth on the river bottom. Aquatic organisms may have trouble

finding food, gill function may be affected, and spawning beds may be covered. Sediment on the river bottom can destroy habitat. In addition to being a problem in the Minnesota River, sediment from this basin is also a major source of aggradation in Lake Pepin.

The water quality standard for turbidity in class 2B waters is 25 Nephelometric Turbidity Units (NTUs). The NTU is a measure of the degree to which light is scattered in water. Light can be scattered by suspended particles and soluble colored compounds.

B. Impaired Waters Listing Decisions

The MPCA is required to assess the water quality of rivers and lakes in Minnesota. This was established in the 1972 amendments to the federal Clean Water Act. Waters not meeting water quality standards and not meeting beneficial uses (e.g. aquatic life, recreation, etc.) are designated as impaired. The MPCA submits a list of all assessed waters every two years to the U.S. Congress. This report is known as the 305(b) list.

In order to designate a water body as impaired for turbidity and include it on the impaired waters list, a minimum of ten data points over a ten-year period are required. If greater than ten percent of the samples exceed the water quality standard, the water body is listed. Waters designated as impaired are included on a state's 303(d) list, or impaired waters list. The listing of a water body on a 303(d) list requires a TMDL analysis.

Total suspended solids (TSS) measurements can also be used as a substitute for turbidity. A very large data set of paired TSS and turbidity values from samples taken in the Minnesota, Lower Mississippi, Cedar, Des Moines and Missouri River basins indicate that it is possible to use TSS values to reliably predict turbidity. Correlation analysis shows a strong relationship between turbidity and TSS measurements. Using data from all five basins combined resulted in a correlation coefficient (r) of 0.86. This allows the MPCA to use TSS as a surrogate for turbidity at sites where there are an inadequate number of turbidity observations. The TSS values selected as the surrogate thresholds are 58 and 66 mg/L in the Western Corn Belt Plains and Northern Glaciated Plains ecoregions, respectively. These are the 75^{th} percentile values in the distribution of TSS values measured at the less impacted sites in the two ecoregions (Fandrei et al. 1988). The 75^{th} percentile represents a reasonable value in the upper end of the TSS range, such that only a few truly impaired waters will be missed, while minimizing the number of waterbodies falsely identified as impaired. The MPCA has used this concept of comparing monitoring data to "ecoregion expectations" in assessments for a variety of pollutants. Because TSS is a surrogate, at least 20 TSS observations are required rather than 10 for turbidity.

Much of the discussion in this document involves TSS. The USGS measures sediment as suspended sediment (SS). Both have units of mg/l. In a suspended sediment study, Tornes noted that average concentrations of SS in the Minnesota River Basin were around 100 mg/l. Concentrations exceeded 2,000 mg/l in some locations (USGS, 1985).

C. Water Quality Conditions

There are a variety of geographic and environmental conditions that exist in the state. Ecoregions have been developed to deal with this variability. An ecoregion is a relatively large expanse of land containing a geographically distinct collection of plants, animals, natural communities, and environmental conditions. There are seven in the state and three in the Minnesota River Basin. These include the Northern Glaciated Plains in southwest and west-central Minnesota; the Western Corn Belt Plains in the middle and southern part of the basin; and the Northern Glaciated Plains in the north-east part of the Basin (the Lower Minnesota and part of the Middle Minnesota River Watersheds). Table 2 shows the 25^{th} and 75^{th} percentiles for summer turbidity and TSS in three ecoregions. The time period was from 1970 through 1992.

Table 2. Summer turbidity and TSS levels by ecoregion (25^{th} and 75^{th} percentiles).

Ecoregion	Turbidity (NTU)	TSS (mg/l)
North Central Hardwood Forest	4.9-10	7.6-18
Northern Glaciated Plains	20-37	37-89
Western Corn Belt Plains	13.5-27	26-75.5

D. Nature, Degree, and Causes of Turbidity Impairments

From Preliminary 305b Assessment for 2006 Assessment Cycle
http://www.pca.state.mn.us/publications/reports/tmdl-305b-minnesotabasin-04.pdf

	Reach	Observations over standard	Total Observations	Range	Mean	Years
Minnesota River; Blue Earth R to Shanaska Cr	07020007-502	-				
Minnesota River; Cottonwood R to Little Cottonwood R	07020007-503	TURB 24	31			
Minnesota River; Swan Lk Outlet to Minneopa Cr	07020007-505	-				
Minnesota River; Eight Mile Cr to Cottonwood R	07020007-508	-				
Minnesota River; Beaver Cr to Birch Coulee	07020007-514	TURB 10 TSS 14	28 30			
Blue Earth River; Le Sueur R to Minnesota R	07020009-501	TURB 22 TSS 30	37 47			
Blue Earth River; Rapidan Dam to Le Sueur R	07020009-509	-				
Le Sueur River; Maple R to Blue Earth R	07020011-501	-				
Minnesota River; Shanaska Cr to Rogers Cr	07020007-501	TURB 21 TSS 35	26 38			
Minnesota River; Rush R to High Island Cr	07020012-503	TURB 25 TSS 33	31 38			
Minnesota River; Chippewa R to Stoney Run Cr	07020004-501	-				

Watonwan River; Perch Cr to Blue Earth R	07020010-501	TURB 18 TSS 23	37 53			
Yellow Medicine River; Spring Cr to Minnesota R	07020004-502	TURB 10 TSS 18	34 49			
Minnesota River; Timms Cr to Redwood R	07020004-509	TURB 14 TSS 15	32 32			
Hawk Creek; Spring Cr to Minnesota R	07020004-587	-				
Chippewa River; Watson Sag Diversion to Minnesota R	07020005-501	TSS 5	20			
Redwood River; Ramsey Cr to Minnesota R	07020006-501	TURB 13	34			
Cottonwood River; JD #30 to Minnesota R	07020008-501	TURB 20 TSS 29	37 49			

E. Other studies

Sediment sources have been a topic of discussion and the subject of various studies. Both streambanks and uplands are sources of sediment in the Minnesota River. Generally, the contributions vary from the two sources by watershed, geography, etc.

In a technical memorandum Barr (2003) provided an estimate of streambank erosion as part of an assessment of phosphorus sources. According to the memo, the Blue Earth River also produces significant streambank erosion, accounting for 31 to 44 percent of the sediment in the flow that discharges to the Minnesota River (Sekely et al., 2002). Sekely et al. (2002) also estimated that streambank slumping accounts for 7 to 10 percent of the annual contributions to total phosphorus load in the Blue Earth River. Bauer (1998) estimated that streambank slumping accounted for 36 to 84 percent of the total suspended solids load in the Blue Earth River. Water quality modeling calibrated for major watersheds within the Minnesota River basin indicates that bank and bluff erosion should account for 40 percent of the modeled total sediment load in the Blue Earth River watershed, approximately 35 percent for the Cottonwood and Le Sueur River watersheds, 20 to 25 percent for the Watonwan and Redwood River watersheds, and 2 percent of the Yellow Medicine River watershed for the 1986-1992 time period (TetraTech, 2002).

Particulate and dissolved pollutants also vary by season. A 1995-1998 study evaluated the quantity and quality of surface runoff entering surface tile inlets draining natural depressions of lacustrine soils in the Watonwan River Watershed. Most of the dissolved pollutants were associated with snowmelt runoff while most of the particulate pollutants were associated with rainfall runoff. Some of the particulate pollutants settled out in ponds surrounding the tile inlets during major storms because the capacity of the tile systems were exceeded (Ginting, et al., 2000).

F. Watershed Reports

This section provides a summary of diagnostic activities, goals and implementation plans by watershed. Pollutant source inventories, goal setting, and implementation planning

have been completed within many watersheds. Turbidity and sediment related constituents are emphasized.

The State of the Minnesota River Report has annually summarized monitoring results since 2000. The Report uses flow-weighted mean concentrations as one way of quantifying TSS values. The flow-weighted mean concentration is the mean TSS level over a monitoring season. Since it's a mean, daily TSS levels can be far above or far below the mean. From 2000 - 2002, flow-weighted mean concentrations for TSS at Minnesota River mainstem stations ranged from a low of 107 mg/l at the Minnesota River at Judson in 2001 to a high of 415 mg/l at the Minnesota River at St. Peter in 2000. Flow-weighted mean concentrations of TSS at the mouths of the upper Minnesota River watersheds were often below 100 mg/l TSS. Similar locations in the middle and lower parts of the basin had TSS concentrations of over 100 mg/l to over 500 mg/l. The two highest flow-weighted mean concentrations of TSS were the Cottonwood River with 638 mg/l and the Le Sueur River with 918 mg/l. Both were in 2000 (MSU, 2003). Both are significantly above the thresholds of 58 and 66 mg/l TSS, which are used as surrogate thresholds for the turbidity standard of 25 NTU.

Middle Minnesota River - Seven-Mile Creek

Results from a three-year study in the Seven-Mile creek watershed showed high sediment levels. Seven Mile Creek delivers about 6,712 tons of sediment each year to the Minnesota River during the growing season (April through September) or about 570 pounds per acre. The average flow-weighted mean concentration of TSS for the study period was 227 mg/l. Sediment modeling results indicated that about 42 percent of the sediment is derived from bank erosion sources, 37 percent upland, 13 percent riparian corridor, and 8 percent from open tile intakes. The western portion of the 23,551 acre watershed is less than 2 percent slope. The eastern part of the watershed is steeper with slopes of 40 to 60 percent.

Additional field research was also completed in May, 2001. Results from a transect tillage transect survey indicated that, of the fields surveyed, 35 percent were considered out of conservation tillage and 65 percent were in conservation tillage. Conservation tillage is defined as corn planted into greater than 15 percent residue and soybeans planted into greater than 30 percent residue. An open tile intake survey indicated approximately 9 intakes per square mile on cultivated land in the watershed. The average drainage area per intake was ten acres.

An implementation plan was developed to reduce nutrients, sediment, and bacteria. The plan's reduction target for TSS was 20 percent. Sediment reduction activities in the plan include adoption of vegetative practices, including land enrollment in CREP and the use of rye as a cover crop; Farmed Wetland Pilot Program; and installation of riparian buffer strips and grass waterways. Primary tillage system conservation techniques such as strip tillage and minimum tillage of soybean residue will be promoted. Structural changes will also be emphasized to include installation of innovative floodplain rock-cross vanes, wetland restorations, and tile outlets (BNC Water Quality Board, 2001).

Blue Earth, Watonwan and Le Sueur Rivers
A diagnostic study was conducted in the Blue Earth, Watonwan, and Le Sueur River from April through September, 1996. TSS and turbidity samples were collected. Turbidity levels ranged from less than 10 NTUs to over 700 in the Watonwan River Watershed. The upper range in the Le Sueur and Blue Earth River Watersheds were much higher. The TSS flow-weighted mean concentrations in the watersheds ranged from 23 to 356 mg/l (South Central Minnesota County JPB, 2000 a, b, and c).

The implementation plans developed for the three watersheds each call for a 40 percent reduction in TSS. To do this, the management alternatives identified include riparian buffers, streambank stabilization, water storage, surface tile intake buffers or replacements, crop residue management, among others. The Watonwan River Watershed Plan also called for adoption of the River Friendly Farmer criteria, which involves residue use, appropriate nutrient rates, etc.

G. Estimated Impact of Point and Nonpoint Source Reductions on Turbidity
Several studies have been completed that examine the impact of pollutant reductions at various subwatershed and watershed scales. The summarized material is intended to show the possible practices that may be effective in improving water quality. A study for the Minnesota River Turbidity TMDL project will need to be completed to add to the knowledge base.

A study in the Sand Creek Watershed (south of Jordan) examined the impact of alternative management strategies on achieving sediment and phosphorus TMDLs. The ADAPT model was used to evaluate practices such as conservation tillage, conversion of cropland to pasture, and changes in phosphorus application rates. A 59 percent reduction in sediment was estimated to be needed to meet the TMDL. Increasing conservation tillage from the present 40 percent to 75 percent of cropland reduced sediment losses by 16 percent. Combining the increased adoption of conservation tillage with converting 10 percent of cropland to pasture resulted in a reduction of sediment losses by another 7 percent. Conservation tillage on 75 percent of the cropland, conversion of 10 percent cropland to pasture, and a 20 percent reduction in spring applied phosphorus fertilizer rates reduced phosphorus losses by 23 percent. Switching fertilizer application timing from fall to spring provided a 9 percent reduction in phosphorus losses. To meet the TMDL for phosphorus required an 85 percent reduction in phosphorus load. Results of the study showed that these practices would decrease sediment and phosphorus. However, model results indicated further reductions would be needed to achieve the TMDLs. (Target load not identified, 1 NTU was assumed to be 4.4 mg/l of sediment) (Dalzell et al, 2004).

The Multiple Benefits of Agriculture Study performed an economic, environmental and social analysis on two watersheds. Wells Creek, located in Goodhue and Wabasha counties; and the Chippewa River. The Wells Creek Watershed is 40,172 acres while Chippewa River is 44,445 acres. Agricultural uses comprise 71 percent of the land use in Wells creek and 81 percent in the Chippewa River Watershed. Average slope in the Wells Creek Watershed is 6.5 percent and 61 percent of the land is cultivated and is in

corn and soybeans. Alternatively, the Chippewa River Watershed is relatively flat with an average slope of 2.2 percent and includes significant artificial drainage. Eighty-one percent of the land is cultivated, mostly in corn and soybeans.

Four scenarios were used in the ADAPT model to determine the impact of alternative practices:

Scenario A – Extension of current trends – fewer and larger farms with increasing acreage in row crops and no significant trend toward the application of best management practices.

Scenario B – Adoption of best management practices – conservation tillage, 100-foot buffers along streams, and recommended nutrient application rates on all farmland.

Scenario C – Expanded community and economic diversity – higher diversity and increased farm profitability beyond the BMPs in scenario B along with wetland restoration, increased crop diversity, and perennial crops. A five year crop rotation included more small grains and alfalfa and less corn, soybean, and sugar beets.

Scenario D – Managed year-round cover – when possible, continuous plan cover on working farms. Scenario D extended scenario C and added perennial cover. Grasslands replaced cultivation lands on an additional 7 to 14 percent of the area. Riparian buffers that were converted to grass or tress were widened to 300 ft and all row crops were planted to cover crops.

In the Chippewa River Watershed, scenario B (conservation tillage practices, 100 ft buffers, etc.) resulted in a 31 percent reduction in sediment. Scenario C (expanded diversity, restored wetlands, increased small grain and alfalfa) decreased sediment deposition by 50 percent, and scenario D (managed year-round cover, grassland increased) by 84 percent. Scenarios B, C and D reduced phosphorus from 40 to 75 percent. Results in the Wells Creek watershed were similar. Additionally, perennial vegetation reduced runoff as much as 35 percent in both watersheds.

Sediment concentrations causing fish to die or get sick were slightly higher in the Chippewa River then Wells Creek. Days per year lethal to fish ranged from 10.2 to 11.6 in the Chippewa and 0.2 to 7.6 days in Wells Creek. Scenario A had more mean annual days with lethal sediment concentrations than scenarios B or C. In the Chippewa River study area, lethal events did not change with any of the scenarios. The number of sublethal events did fall across the scenarios, but not at a statistically significant level. Scenario A in the Wells Creek Watershed indicated more mean annual days of lethal sediment concentrations than did scenarios B or C. The study also involved greenhouse gasses, bird populations, economic benefits, and policy recommendations (Land Stewardship, 2001).

Another study using the ADAPT model examined the effects of cropland conversion to short-rotation woody crops (Updegraff, 2004). Conversion of 10, 20, and 30 percent of cropland to hybrid poplar was modeled in the High Island Creek watershed. The

modeling period was five years. Assumptions in the model included fall tillage with further tillage and planting the following spring, weed control via herbicide, rotary hoe tillage seven times in the first year and twice in the second and third years. Results of the simulations indicated reductions in peak flows and sediment and nitrate delivery following the conversion from agricultural land to short rotation woody crops. At the 30% conversion level, mean annual runoff was reduced by up to 9%, sediment loads by 28%, and nitrogen loads by 15%. However, total phosphorus loads increased by 2% relative to the no short-rotation woody crops. The conclusion of the study notes that "On the whole, the model results suggest that while cropland conversion to short-rotation woody crops may be very effective at reducing sediment delivery to streams, its effect on nutrient delivery will likely be contingent on overall management and the extent to which drainage remains an important factor in this watershed."

II. Main Technical Issues

A. Lab and data variability - Variability in turbidity and TSS data between agencies exists. Compare lab methods and equipment from labs used in listing reaches. Determine the reasons for lab variability and possibly a method to convert the data from lab to lab.

B. Establish relationships between TSS and turbidity. This may be by stream reach, watershed, or agroecoregion. Factors such as slope, soil type, geology, precipitation, and others may influence these relationships.

C. Sources of turbidity and TSS
   1. Determine the significance of algae in turbidity exceedances. This may consist of chlorophyll-a, VSS, and total phosphorus. The MPCA's periphyton study is an additional data source;
   2. Estimates of sediment sources between streambank and upland erosion; and
   3. Consider additional sources of turbidity including snowmelt, tannins, road salt and others.

D. Selecting a goal for the TMDL
   1. Percent exceedance of the standard, flow based, load duration curves, duration based exeedances, etc.
   2. Estimation of natural-background sources ["Natural background means pollution resulting from the multiplicity of factors in nature that determine the physical, chemical, and biological conditions in a water body but does not include measurable and distinguishable pollution that is attributable to human activity or influence." – Impaired Waters Stakeholder Policy Work Group, 2004].

E. System dynamics
   1. Data from a study on the Rush River and High Island Creek indicated that highly erodible land near the mouth of the watershed is the source of 75 to 90 percent sediment. Further research is needed to determine the sediment delivery from highly erodible land documenting the load contributions from upland, gully and streambank sources.

2. Short term deposition and subsequent re-suspension of sediment within a channel complicates analysis of annual sediment load calculations. The rate of sediment cycling is not well understood. The number and magnitude of runoff events likely impact the rate at which deposited and re-suspended sediment is transported through the reach. The portion of runoff load that is deposited in the channel during flow recession of an event could remain in place until it is re-suspended the following year.
3. Artificial drainage reduces the temporary storage of water and the time it takes for water to reach a stream. The increased energy can intensify erosion.
4. Consider the impact of climatic variability when assessing the problem and developing solutions.

F. Identification of practices that will reduce TSS and turbidity levels:
1. Estimating conditions reflecting "best attainable" management of current land use practices or modeling a best case scenario. A best case scenario could include adding water storage or increasing grass cover. Costs of attaining the changes should be considered.
2. Examining previous and current work including modeling the Minnesota River Assessment Project recommendations (treat cropland currently exceeding soil loss tolerances, treat cropland in riparian areas and other areas where sediment delivery is highest, and treat remaining cropland acres), expanding the Multiple Benefits of Agriculture Study (where grasslands, wetlands and buffer strips were increased), analysis of available watershed project data, U of M open tile intake studies (Moncrief), other work that has been done.
3. Monitoring data indicates much of the TSS comes from a few storm events per year, often in spring and early summer. Practices should be evaluated that would reduce the impact of these storms early in the cropping season. A more effective suite of BMPs may be needed. Minimal crop canopy from after planting through mid-summer leaves the soil open to erosion.
4. Insufficient water storage causes higher flood peaks. Results from a study by Boonestro indicated increasing wetlands in a watershed by 5 percent would reduce flows by 40 percent. Higher flood peaks can cause more erosion due to the increased energy of the water. Water storage may help to reduce these peaks, thereby moving less sediment.
5. Consider the impact of pattern tile on storage and retention (controlled drainage).

III. Project Tasks and Schedule

The TMDL project is expected to be completed in multiple phases. Phases I and II will provide an assessment of existing water quality data and develop the work plan. Phase III provides additional information needed in the development of the Request for Proposals (RFP). Phases IV and V include modeling and the identification of feasible practices from stakeholders and scientists to reduce turbidity. The TMDL Report is completed at the end of phase V.

Phase 1: Organizing the project (MPCA)
January '05 – April '05

1. Develop background materials.
2. Begin preliminary analysis of data. Establish relationships between algae and turbidity as well as TSS and turbidity

Phase II: Develop work plan (MPCA, advisory committee)
April '05 – August '05

1. Form Stakeholder Advisory Committee.
2. Develop communication plan with assistance from Public Information Office.
3. Begin work plan. Identify existing staff resources and areas where contracted services will be needed.

Phase III: Begin special studies. August '05 – May '06

1. Form Sediment Reduction Advisory Panel in conjunction with Turbidity TMDL Advisory Committee and Lake Pepin committee.
2. Finalize TMDL work plan.
3. Recommend additional monitoring and/or specialized field studies.
4. Begin special studies. Examples include:
    a. Geochemical fingerprinting to estimate streambank erosion (summer 2006)
    b. HSPF- Minnesota River gaps analysis (spring – summer 2006)
    c. Algae's impact on turbidity – lab work and data review
    d. Sediment fractionation study (summer 2006)
    e. Small watershed modeling studies of estimate effect of land use changes on runoff (late 2006 – 2007)
    f. Pollutant source inventory estimation including tile intakes, streambank condition, ISTS compliance, etc. (2006)

Phase IV: Develop Request for Proposals (RFP) for contracted services. Evaluate practices to reduce turbidity problems. (MPCA, advisory committee, sediment reduction advisory committee). May '06 – February '07

1. Assemble existing data sets to include in RFP.
2. Draft modeling approach to include in RFP.
3. Develop final RFP for Minnesota River Turbidity TMDL modeling tasks (by December 06).

4. Submit RFP to list of contractors requesting of them proposals to complete tasks. MPCA Program Admin. Unit sends RFP to TMDL master list of contractors.
5. Evaluate proposals and select contractor(s).
6. Evaluate agricultural practices, social, and economic issues.
7. Meet with Advisory Committee and Sediment Reduction Advisory Committee

Phase V: Develop TMDL report (MPCA, advisory committee)
February '07 – October '08

1. Meet with Advisory Committee and Sediment Reduction Advisory Committee to determine scenarios to test in model.
2. Model scenarios and report results.
3. Meet with Advisory Committee and adjust scenarios to model.
4. Model adjusted scenarios and report results.
5. Meet with Advisory committee.
6. Prepare Draft TMDL and send to EPA for review prior to final document.
7. Meet with Advisory Committee, Sediment Reduction Advisory Committee, and watershed groups to share results of Draft TMDL Report.

Develop TMDL Implementation Plan – 2009 (This may be completed at the watershed scale or basin scale, depending on assessment results.)

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