Lower Minnesota River Model

Project Proposal

Proposal to Develop an Advanced Water-Quality Model of the Minnesota River, Jordan to the mouth, and Conduct River Monitoring and Studies to Support the Model

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1 PROJECT SYNOPSIS

The goal of this project is to build an assessment and management tool for water quality in the metro-area reach of the Minnesota River, or roughly the lower forty miles of the river from Jordan, Minnesota, to its confluence with the Mississippi River in St. Paul, Minnesota. All or portions of this reach are listed as impaired due to low oxygen, turbidity, bacteria, mercury, and PCBs on Minnesota's list of impaired waters. The lower Minnesota River also contains excessive levels of sediment, nutrients, and algae. A tool is needed to set effluent limitations for wastewater treatment plants and other permitted dischargers, establish goals for pollutant load reductions from nonpoint sources, test alternative management scenarios, and manage and monitor the river.

The proposed tool is an advanced water-quality model. A versatile computer model with advanced functions is needed to adequately capture hydrodynamics, sediment transport, and eutrophication in the lower Minnesota River. Hydrodynamics describe the underlying physics of water movement. Sediment is an issue in itself and also a key factor in transporting phosphorus and determining light conditions for algae. The eutrophication model tracks nutrient and algal dynamics and relationships to oxygen production and demand. While phosphorus typically controls algal growth in Minnesota, nitrogen is a concern due to potential ammonia toxicity and nitrate loads to the Gulf of Mexico. The sediment bed is a significant source of oxygen demand under low flow conditions and may also be a source of phosphorus and ammonia. The model should account for the exchange of oxygen and nutrients across the sediment-water interface.

The model should accurately represent spatial and temporal differences in the lower Minnesota River. This reach contains many backwaters, the lower 22 miles have been channelized, and dam operation in the Mississippi River affects water elevations. The model may need to be 2D or 3D to simulate vertical and lateral differences in water quality. The river experiences strong seasonal and annual differences and is subject to large loading events from its mostly agricultural watershed. A time-variable model is required to track these temporal differences. A multiyear model representing all seasons and various flow regimes would capture these differences and gauge the impacts of pollutant loads during high flows on water-quality conditions during low flows.

River monitoring and special studies are needed to collect data to build and test the model. River monitoring over a period of years and range of flows provides information on temporal differences and variable loading rates. The Metropolitan Council supports programs to monitor the river at five locations and nine tributaries, but different stations, variables, and sample types may be required to address specific issues. More intensive monitoring during low river flows would help calibrate the model for critical low-oxygen conditions. Special studies are needed to define key model inputs, such as reaeration rates, and gauge the importance of potential factors, such as groundwater.

This project is estimated to take six years (2003-2008) and cost one million dollars.

2 STUDY AREA DESCRIPTION

The Minnesota River drains much of southwestern Minnesota and minor portions of Iowa and South Dakota. Its watershed covers approximately 16,900 square miles and represents nearly one-fifth of the total area of the State of Minnesota. The river runs 330 miles from its origin in Big Stone Lake on the South Dakota border to its confluence with the Mississippi River in the heart of the Twin Cities. The Minnesota River Valley was formed by the Glacial River Warren, which flowed from the southern end of Glacial Lake Agassiz at the end of the last glacial period roughly ten thousand years ago (Waters, 1977). Today's river is much smaller and is considered "under fit" compared to the wide glacial river valley, across which the river now meanders.

The glaciers left behind relatively flat topography and rich soils—both well suited to agriculture. Soils in the basin are generally fine textured, fertile, and highly productive. In 1997, 73 percent of the areal coverage in the Minnesota River Basin was classified as "cultivated cropland," which includes row crops, drilled crops, and hay or pasture in rotation (National Resources Inventory). Another 10 percent represented pastureland and acres set aside in the federal Conservation Reserve Program. The remaining 17 percent represented a variety of land uses, including forests (3%), water (3%), and urban development (3%). The great majority (~90%) of original wetlands in the basin have been tiled and drained for agricultural uses.

The focus of this project is the reach of the Minnesota River lying within the seven-county Twin Cities Metropolitan Area (Metro Area) (Figures 1 and 2). The Metropolitan Council provides planning, wastewater, and transit services to the Metro Area and would like to develop a water-quality model for facility planning. This reach of the Minnesota River also represents a critical gap in water-quality modeling efforts. The Minnesota River Basin Model, developed by the Minnesota Pollution Control Agency (MPCA) and Tetra Tech, ends at the city of Jordan, near the southwestern boundary of the Metro Area (Tetra Tech, 2002). The Advanced Eutrophication Model of the Mississippi River, developed by the Metropolitan Council and HydroQual, Inc., starts at Lock and Dam No. 1 and ends at the outlet of Lake Pepin (HydroQual, 2002a). In the Mississippi River model, the Minnesota River is represented as a single loading point. A water-quality model of the lower Minnesota River will bridge the gap between these two models and facilitate assessments of the impacts of this major tributary to the Mississippi River.

The Minnesota River enters the Metro Area from the southwest and forms the border between Carver and Scott Counties. Farther downstream, Hennepin and Dakota Counties border the river before it flows into the Mississippi River in St. Paul. Near river mile 40, the river flows by the city of Jordan (Figure 1). While the river enters the Metro Area some distance upstream of Jordan, this location is the best choice for the upstream boundary of the model because the U.S. Geological Survey (USGS) maintains a long-term gaging station and Metropolitan Council Environmental Services (MCES) maintains a long-term water-quality monitoring station on a bridge crossing the river near Jordan. MCES also monitors Bevens Creek (Figure 2), which is a large tributary located a short distance upstream of Jordan whose loads should be represented in the model.

Figure 1. Map of the portion of the Minnesota River Basin lying with the Twin Cities Metropolitan Area (Matthew McGuire, MCES).

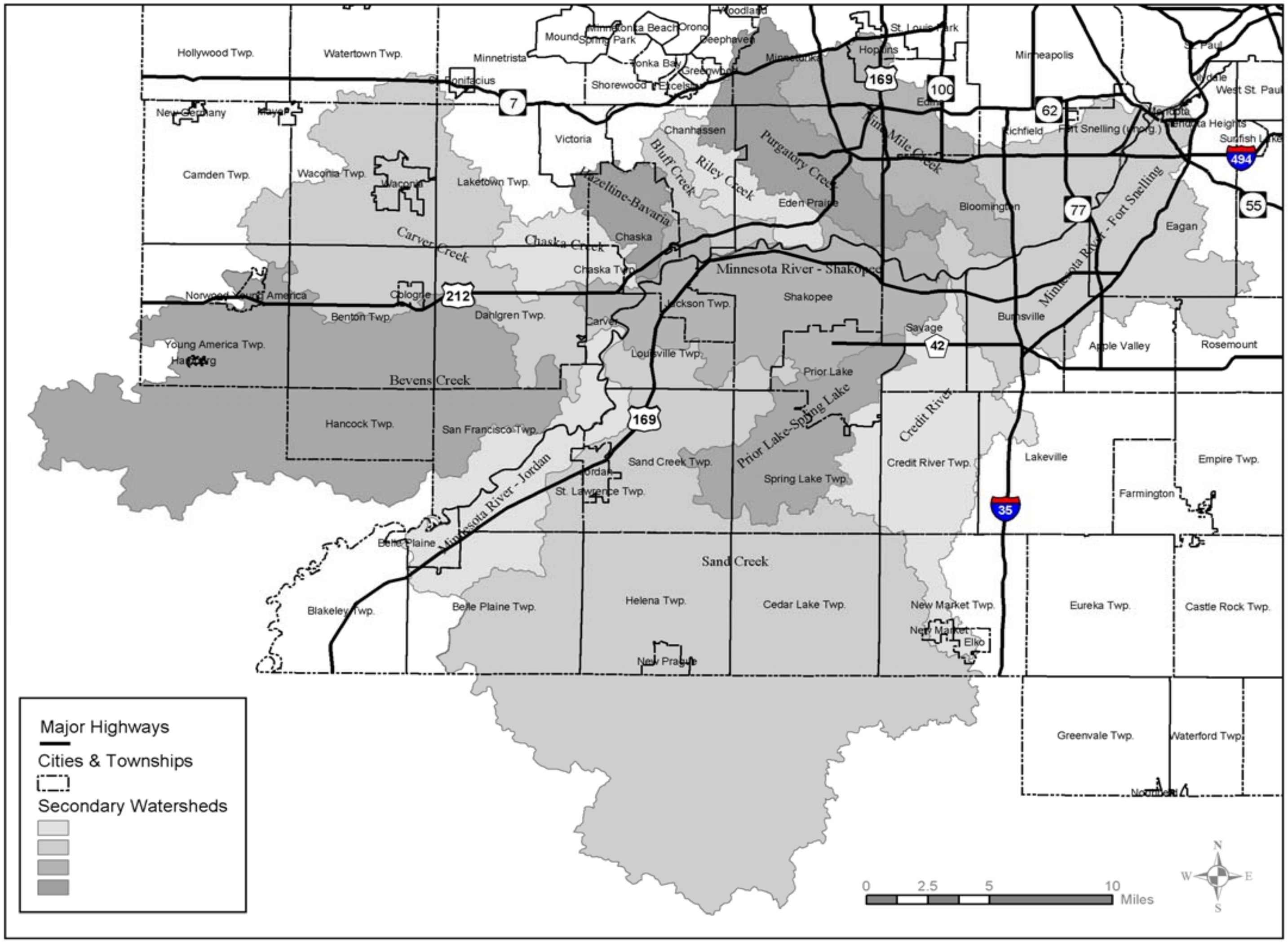
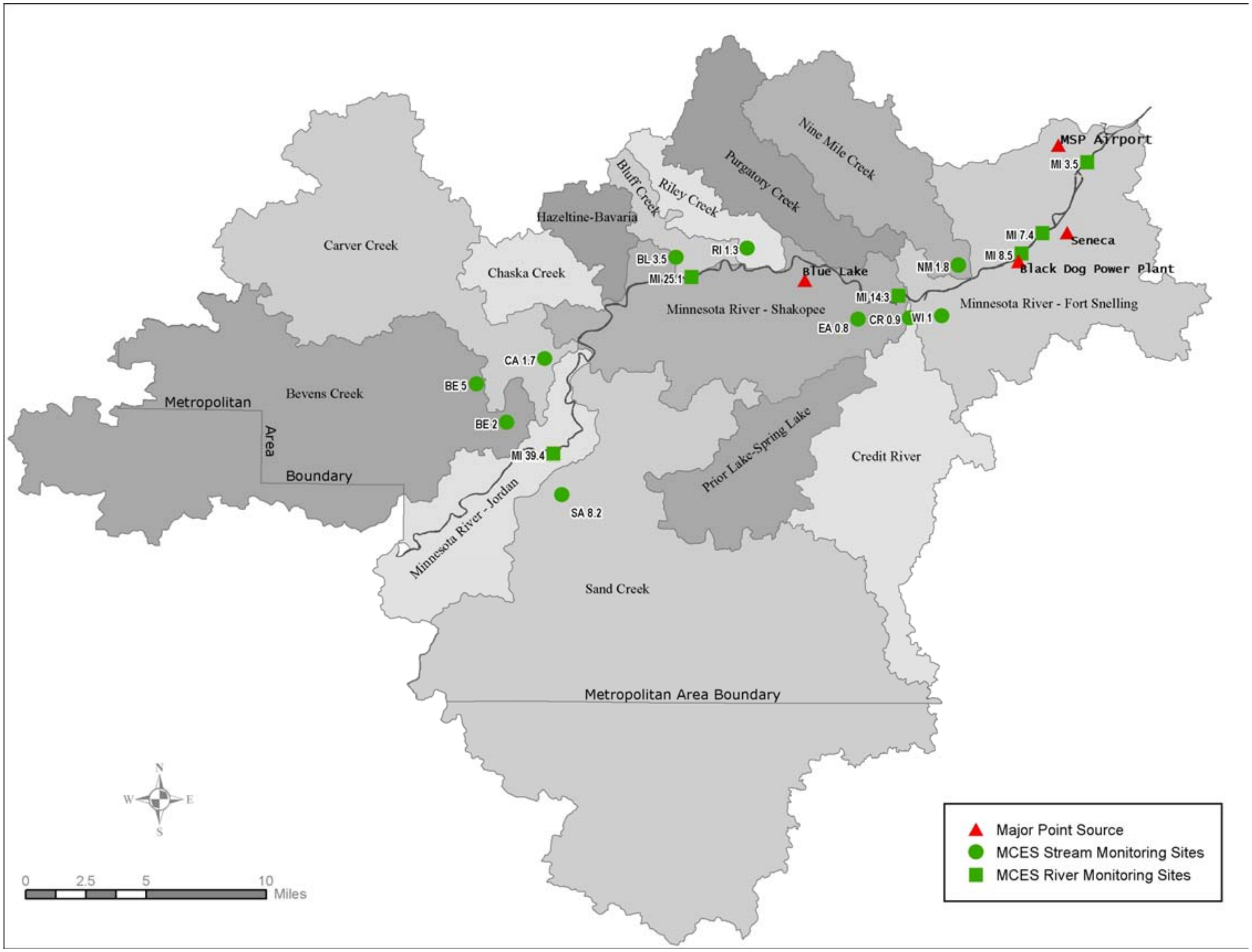


Figure 2. Map of minor watersheds, major point sources, and MCES monitoring stations in the study area (Matthew McGuire, MCES).



Since 1937 the National Weather Service has operated a meteorological station at the Minneapolis-St. Paul international airport, which is located near the mouth of the Minnesota River (Figure 2). The airport lies on top of the river bluff. Normal daily maximum temperatures at this station range from 20.7°F in January to 84.0°F in July (National Climate Data Center). Normal annual precipitation is 28 inches. The wettest months are generally May-August (three to four inches per month), and the driest months are generally December-February (an inch or less per month). Normal annual snowfall is 56.0 inches.

During water years 1935 through 2001, the annual mean flow of the Minnesota River at Jordan was 4487 cfs, with the highest annual mean flow (16,910 cfs) occurring in 1993 and the lowest annual mean flow (687 cfs) occurring in 1940 (Mitton *et al.*, 2002). Ten percent of daily mean flows exceeded 12,000 cfs, 50 percent exceeded 1,840 cfs, and 90 percent exceeded 320 cfs. Extended drought conditions were last experienced during the period 1987-1990, followed by generally wet conditions in the 1990s. In the most recent wasteload allocation study (MPCA, 1985), seasonal 7Q10 flows were established for the Minnesota River at Shakopee (mile 22):

Spring (March-May)	289 cfs
Summer (June-September)	282 cfs
Fall (October-December)	216 cfs
Winter (December-March)	189 cfs

Extreme low flow conditions occurred in both the Minnesota and Mississippi Rivers during 1988. Mean daily flows in the Minnesota River at Jordan during the summer months were 1004 cfs (June), 367 cfs (July), 297 cfs (August), and 246 cfs (September).

Numerous lakes and wetlands are located in the wide floodplain of the lower Minnesota River. The area was considered so valuable for wildlife that in 1976 Congress established the Minnesota Valley National Wildlife Refuge to protect the floodplain between Jordan and Fort Snelling State Park (Figure 3). The refuge contains 14,000 acres of forest, marsh, and wet meadows. Wetlands cover 1,500 acres. The refuge is managed to provide habitat for migratory waterfowl, fish, and other wildlife species threatened by development. Management includes dikes and other water control structures on many lakes and wetlands in the floodplain. The final four miles of the Minnesota River and its floodplain are part of the Mississippi National River and Recreation Area, established by Congress in 1988. Fort Snelling State Park lies near the confluence of the two rivers and contains historical sites, lakes, and forested floodplain and bluffs.

The Lower Minnesota River Watershed District (LMRWD) coincides with much of the study area. The District covers 64 square miles in the Minnesota River valley, bluff to bluff, from Carver, Minnesota, to the mouth, or approximately 32 river miles. The LMRWD Water Management Plan (1999) provides a detailed inventory of land and water resources within the District, including lakes (Table 1).

Figure 3. Map of the Minnesota Valley National Wildlife Refuge (from the Refuge's Web Site http://midwest.fws.gov/MinnesotaValley).

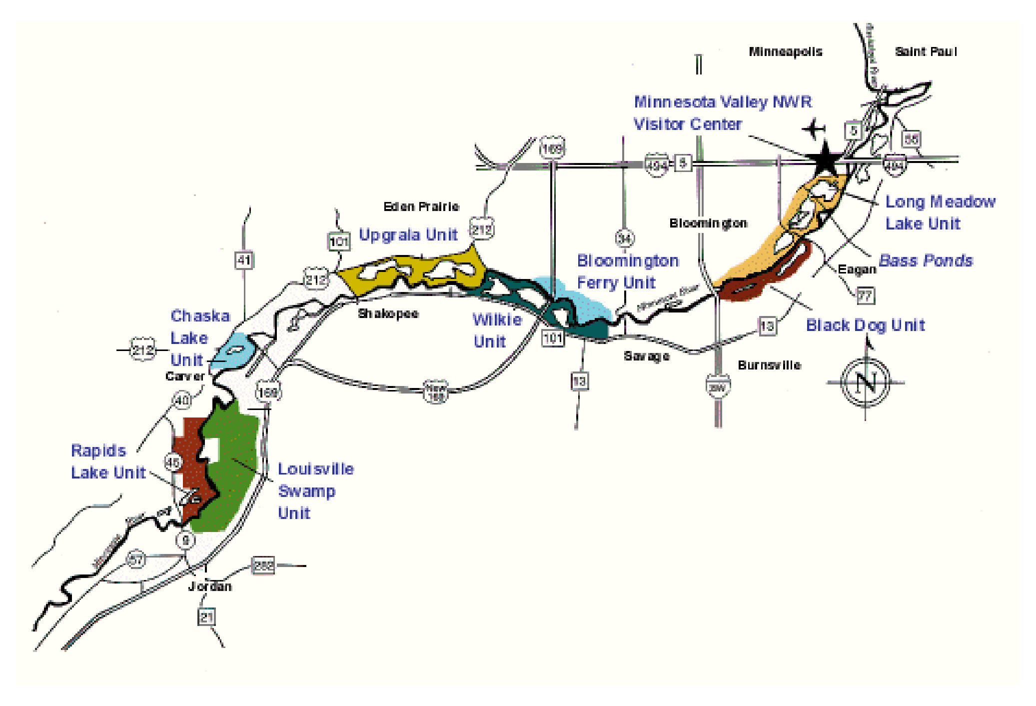


Table 1. Lakes within the Lower Minnesota River Watershed District (LMRWD, 1999).

Lake Name	**Area (acres)**	**Depth (max., feet)**
Snelling	119	12.0
Long Meadow	1,188	3.5
Coleman	114	3.5
Grass	467	3.5
Rice	517	3.0
Courthouse	12	Unknown
Lake (Cy Ess)	11	Unknown
Chaska	46	3.5
Gifford	116	Unknown
Nyssens	185	4.0
Dean	216	5.0
Blue	203	3.0
Fisher	284	3.0
Rice	259	3.0
Black Dog	391	3.0-4.0
Gun Club	1,216	2.5

Most of the lakes are classified as floodplain lakes, receiving inputs at times from the Minnesota River and discharging to the river at other times. A few lakes were formed from abandoned quarries and Dean Lake is a groundwater-table lake. Courthouse Lake, a former quarry, is a designated trout lake.

The lower Minnesota River lies within an artesian basin containing glacial sediment and bedrock aquifers with large groundwater reserves (LMRWD, 1999). Groundwater is another important source of water to the floodplain area and may contribute significant amounts of water to the Minnesota River.

The hydrology of the river changes considerably in the lower 25 miles. The combined effects of channel dredging in the Minnesota River and the backwater pool created by Lock and Dam No. 2 in the Mississippi River transform the river from a relatively shallow, free-flowing stream to a deeper, low-velocity channel maintained for commercial navigation (MPCA, 1985). Lock and Dam No. 2 near Hastings, Minnesota, became operational in 1931, raising the water surface at the mouth of the Minnesota River about one foot and at Shakopee, about 0.2 foot. A nine-feet deep, 100-feet wide channel is maintained by the U.S. Army Corps of Engineers (USACE) for commercial barge navigation from the mouth of the Minnesota River to river mile 14.7, one-half mile upstream of the railroad bridge near the city of Savage. Formerly, a four-foot channel was maintained upstream to mile 25.6 in Shakopee.

The LMRWD was initially formed to provide local participation to the USACE on the construction of the navigation channel. While the District's interests have expanded to many other issues, it is still involved in channel maintenance. An average of 21,000 cubic yards of dredged material are removed each year, with the most frequently dredged areas between miles 1-2, 4-5, and 12-13 (LMRWD, 1999). Barge traffic is heavy at times in the navigation channel. Fifty percent of the grain exiting Minnesota is loaded in Savage, and the average number of barge loads between 1980 and 1997 was 2900 (LMRWD, 1999). The standard barge is 35 by 195 feet and carries 1500 tons of cargo. In 2002 a total of 5.5 millions tons of grain, fertilizer, and other goods were shipped in and out of Savage, Minnesota: 0.9 million inbound and 4.6 million outbound (Dennis Erickson, USACE, personal communication). Five million tons translate to approximately 3,600 barges or 18 barges per day, assuming a 200-day shipping season. Barge traffic is likely to affect water quality in the river, including reaeration, mixing, and sediment resuspension. Barges also pose safety and other issues to consider in designing monitoring programs.

2.1 Tributaries

Table 2 lists the major tributaries that enter the lower 40 miles of the Minnesota River, and Figure 2 displays their watersheds. Land use is primarily agricultural in the western watersheds but becomes increasingly developed as the river flows north and east toward its confluence with the Mississippi River. While rain falls mainly on farm fields in the western watersheds of Bevens and Sand Creeks, it falls mainly on suburban developments in the eastern watershed of Nine Mile Creek. The western counties are experiencing rapid population growth. Between 1990 and 2000, Carver and Scott Counties grew by 46.5% and 54.7%, respectively (U.S. Census).

In 1987 the Metropolitan Council and MPCA entered into an agreement to study nonpoint source pollution in six Metro Area tributaries of the Minnesota River. The agreement resulted from a wasteload allocation study conducted by the MPCA (1985), which concluded that the water-quality standard for dissolved oxygen could not be met without pollutant load reductions from both point and nonpoint sources. During the period 1989-1991, stage-recording and water-sampling equipment were deployed at Bevens Creek, Sand Creek, Carver Creek, Bluff Creek, Credit River, and Nine Mile Creek (Figure 2 and Appendix A). Monthly grab samples and event-based composite samples are collected at these sites. Similar equipment was installed to collect event-based samples from the Minnesota River at Jordan to compare headwater loads to those of the tributaries.

Table 2. Major tributaries to the lower 40 miles of the Minnesota River.

Tributary	**Confluence (river mile)**	**Area (mi^2)**	**Dominant Land Use**	**Monitored? (agency, start)**
Bevens Creek	41.4	130[1]	Rural	MCES, 1989
Sand Creek	33.5	260[1]	Rural	MCES, 1990
Carver Creek	32.1	83[2]	Rural	MCES, 1989
Chaska Creek	~30	16[3]	Mixed	Carver County, 1998
East Chaska Creek[4]	~29	12[3]	Mixed	Carver County, 2003
Bluff Creek	22.5	9[2]	Mixed	MCES, 1991
Riley Creek	22.3	13[1]	Mixed	MCES & partners, 1999
Purgatory Creek	18.3	36[1]	Mixed	Watershed District
Eagle Creek	15.8	7[1]	Mixed	MCES & partners, 1999
Credit River	13.4	51[2]	Mixed	MCES, 1989
Nine Mile Creek	11.0 & 12.5	38[2]	Urban	MCES, 1989
Willow Creek	11.1	42[1]	Urban	MCES & partners, 1999

[1] Source: Bonestroo *et al.*, 2001 [2] Source: MetroGIS [3] Source: Carver County

[4] Also known as Hazeltine-Bavaria

In 1990 the Minnesota Legislature mandated that the Metropolitan Council develop target pollutant loads for Metro Area watersheds (MN Statute 473.157). The objectives of this legislation were to help achieve federal and state water-quality standards, provide effec tive water pollution control, and help reduce unnecessary investments in advance wastewater treatment. To collect information needed to set targets, the Metropolitan Council, with the help of local partners, began monitoring three additional tributaries in the Minnesota River Basin in 1999: Riley Creek, Eagle Creek, and Willow Creek (Figure 2 and Appendix A). These stations are part of a Metro Area Watershed Outlet Monitoring Program (WOMP). The monitoring program is similar to that for the original six tributaries to the lower Minnesota River.

Carver County Environmental Services and the Minnesota Department of Agriculture (MDA) monitor Chaska Creek (Greg Aamodt, Carver County, personal communication). County staff monitor flow and collect baseline grab samples and a few event-based composite samples. The samples are analyzed for a set of conventional pollutants at the MCES laboratory. The MDA collects composite samples and runs analyses for pesticides and herbicides. In 2003, Carver County initiated WOMP-like monitoring of East Chaska Creek (also known as Hazeltine-Bavaria Creek). At high flows, East Chaska Creek is diverted near County Road 17 and routed directly to the Minnesota River; three monitoring locations were required to adequately estimate loads. The Riley-Purgatory-Bluff Creek Watershed District monitors Purgatory Creek near the mouth and several other locations in the watershed district (Barr, 2001).

In addition to these major tributaries, there are numerous minor tributaries to the lower 40 miles of the Minnesota River. Many of these smaller tributaries drain lakes and wetlands in the floodplain, which are replenished by springs, stormwater, or streams. The LMRWD Water Management Plan (1999) lists a total of 47 streams in the District, which extends from Carver, Minnesota, to the mouth.

2.2 Point Sources

Table 3 contains a preliminary list of the point sources permitted to discharge directly to the lower 40 miles of the Minnesota River. The list also contains indirect dischargers whose loads may not be captured by stream monitoring programs. All permitted dischargers are required to monitor effluent flows and specific effluent characteristics. This information is reported monthly to the MPCA and stored in a database. Data submitted to the MPCA prior to 1990 were lost in a fire at an archival storage facility. Some dischargers, such as MCES, maintain records of effluent data and collect additional information. Following the table are notes on the four major dischargers to the lower Minnesota River: Blue Lake and Seneca Wastewater Treatment Plants, Minneapolis/St. Paul International Airport, and Black Dog Generating Plant. See Figure 2 for the locations of the major dischargers.

Table 3. Preliminary List of Permitted Discharges to the Lower Minnesota River (Source: Carol Sinden, MPCA, 11/18/02)

		Discharge		Design flow (mgd) *					
Permit #	**Permittee**	**(river mile)**	**Receiving water**	**AWW**	**MD**	**AD**	**Months**	**Station**	**Wastewater type**
MN0020869	Jordan WWTP	~35	Sand Creek to Minnesota River	1.289			Continuous	SD001	Domestic wastewater
MN0053457	Carver WWTP	~32	Carver Creek (1.5 mi. to Mn River)	0.361			Continuous	SD001	Domestic wastewater
MN0022446	MA Gedney Co.	~28	Minnesota River		1.5	1.03	Apr-Jun/Sep-Nov	SD001	Industrial process
MNG250005	United Sugars Corp	~28	Unnamed stream (0.3 miles to Mn River)		0.025	0.017	Continuous	SD001	Noncontact cooling water
MNG640078	Riverview Terrace MHP WTP	~28	Ehlers Ave Discharge T115,R23,S.3				Intermittent	SD001	Water treatment plant backwash
MN0031917	Rahr Malting Co.	25.2	Minnesota River		2.5	1.5	Continuous	SD001	Noncontact cooling water
MN0031917	Rahr Malting Co.	25.2	Minnesota River		3.5	1.5	Continuous	SD002	Facility effluent
MN0003042	Anchor Glass Container	~21.7	Wetland (0.2 miles to Mn River)			0.016	Intermittent	SD001	Recirculating cooling tower
MN0003042	Anchor Glass Container	~21.7	Wetland (0.2 miles to Mn River)				Inactive	SD002	Noncontact cooling water
MN0003042	Anchor Glass Container	~21.7	Wetland (0.2 miles to Mn River)			0.005	Periodic/seasonal	SD003	Recirculating cooling tower
MN0003042	Anchor Glass Container	~21.7	Wetland (0.2 miles to Mn River)			0.200	Intermittent (1/yr)	SD004	Quench, CB2 furnace #1
MN0003042	Anchor Glass Container	~21.7	Wetland (0.2 miles to Mn River)			0.200	Intermittent (1/yr)	SD005	Quench, CB3 furnace #2
MN0029882	Blue Lake WWTP	20.5	Minnesota River	42			Continuous	SD002	Domestic wastewater
MN0029882	Blue Lake WWTP	20.5	Minnesota River				Periodic	SD003	Dewatering discharge
MN0063584	Superior Minerals Co.	14.5	Minnesota River (via settling pond)			0.008		SD001	Industrial: wash barges with river water
MNG255004	Silgan Container	~13.5	Minnesota River		0.125	0.080	Continuous	SD001	Noncontact cooling water
MN0002224	Edward Kraemer & Sons Inc.	~12	Minnesota River		13		Continuous	SD001	Dewatering discharge from quarry
MN0000876	Black Dog Generating Plant	~10.7	Minnesota River		650	175	Continuous	SD001	Cooling lake discharge (Lyndale)
MN0060101	Pepsi Bottling Group	~10	Wetland near Black Dog Lake		0.110	0.080	Continuous	SD001	Cooling water & tower blowdown
MN0000876	Black Dog Generating Plant	~8.8	Minnesota River		5	1.43	Continuous	SD003	Intake screen backwash
MN0000876	Black Dog Generating Plant	~8.8	Black Dog Lake		431	120	Continuous	SD004	Condensor cooling discharge
MN0000876	Black Dog Generating Plant	~8.4	Black Dog Lake		13.5	5	Continuous	SD005	Ash pond effluent
MN0000876	Black Dog Generating Plant	~7.6	Minnesota River		650	270	Continuous	SD002	Cooling lake discharge (Cedar)
MN0030007	Seneca WWTP	6.7	Minnesota River	38			Continuous	SD001	Domestic wastewater
MN0056723	Cypress Semiconductor	~6.6	Pond to Long Meadow Lake			0.800	Continuous	SD001	Process & noncontact cooling water
MN0064661	Polarfab LLC	~6.5	Pond to Long Meadow Lake		0.213	0.131	Continuous	SD001	RO reject, softener backwash
MN0054194	Northwest Airlines	4.1	Minnesota River				Inactive	SD001	Cafeteria noncontact cooling water
MN0054194	Northwest Airlines	4.1	Minnesota River				Inactive	SD002	Maint. bldg noncontact cooling water
MN0054194	Northwest Airlines	4.1	Minnesota River		0.0067	0.004	Apr-Sep	SD003	Bldg B cooling tower blowdown
MN0054194	Northwest Airlines	4.1	Minnesota River		0.0086	0.0056	Periodic	SD004	Bldg C cooling tower blowdown
MN0054194	Northwest Airlines	4.1	Minnesota River			0.020	Mar-Nov	SD005	Cooling tower bleedoff from york chiller
MN0065404	Mpls/St Paul Intl Airport	4.1	Minnesota River via storm sewer					SD001-10	Contaminated ground water pumpout
MN0002101	Mpls/St Paul Intl Airport	4.1	Minnesota River via storm sewer				Continuous	Outfall 040	Contaminated storm water from deicing
MN0002101	Mpls/St Paul Intl Airport	3.8	Minnesota River via storm sewer				Continuous	Outfall 020	Contaminated storm water from deicing
MN0002101	Mpls/St Paul Intl Airport	3.0	Minnesota River via storm sewer				Continuous	Outfall 030	Contaminated storm water from deicing
MN0053945	Midwest Coca Cola Bottling		Mn R. via storm sewer, Lone Oak & 35E			0.170	Continuous	SD001	Nanofiltration concentrate discharge

* **AWW** Average Wet Weather Design Flow **MD** Maximum Daily Design Flow **AD** Average Daily Design Flow

Blue Lake and Seneca Wastewater Treatment Plants

The Blue Lake and Seneca Wastewater Treatment Plants (WWTP) are owned by the Metropolitan Council and operated by its Environmental Services (MCES) division. They are the third and fourth largest facilities in Minnesota with average wet weather design flows of 42 and 38 million gallons per day (mgd), respectively.

In 1992 Blue Lake and Seneca were expanded and upgraded, providing advanced secondary treatment with nitrification and chlorination/dechlorination. Monthly average CBOD5 effluent limitations in the summer are 12 and 15 mg/L, respectively, but both facilities consistently produce summer average concentrations below 4 mg/L (Table 4). Since the mid-1990s, the two facilities have been operated to optimize phosphorus removal, producing annual average effluent phosphorus concentrations below 1.5 mg/L. Biological phosphorus removal to 1.0 mg/L will be fully implemented by the end of the next five-year permit (2008). Effluent flows and quality are monitored frequently by MCES, and electronic records date back to 1981.

Table 4. Mean Annual Effluent Concentrations, Blue Lake and Seneca Wastewater Treatment Plants, Before and After 1992 Upgrades

	Blue Lake WWTP		Seneca WWTP	
	1985-90	1992-96	1985-90	1992-96
TSS (mg/L)	9	5	17	4
CBOD5 (mg/L)	11	4	14	3
NH4 (mg/L)	11.57	1.68	15.21	0.44
NO3 (mg/L)	3.32	10.82	1.61	10.33
TP (mg/L)	3.35	2.68[1]	3.21	1.76[1]

[1] With process optimization, mean TP concentrations fell to 0.73 mg/L at Blue Lake and 1.15 mg/L at Seneca during 1996-2000.

The Blue Lake WWTP is a regional facility that will continue to service the growing communities of the southwest Metro Area. Its ultimate size is currently projected to be 60-70 mgd, but the current design capacity will serve the near future. Both Blue Lake and Seneca WWTPs discharge to a reach of the lower Minnesota River listed as impaired due to low dissolved oxygen on the State's 303(d) list of impaired waters. As a consequence, loads of oxygen-demanding materials to the impaired reach from these and other permitted dischargers are frozen at current permit levels. The likely implications for an expanded Blue Lake facility are very stringent effluent limitations, which would require costly tertiary treatment with filters.

No expansions are planned for the Seneca facility. However, effluent limitations for an expanded Blue Lake facility may involve pollutant trading with Seneca and other sources. Note that effluent aeration to increase dissolved oxygen (DO) concentrations to at least 16 mg/L is required at Seneca when river flows fall below 1,200 cfs for seven consecutive days during the summer months (June through September). The effectiveness of effluent aeration on raising river DO concentrations merits additional study.

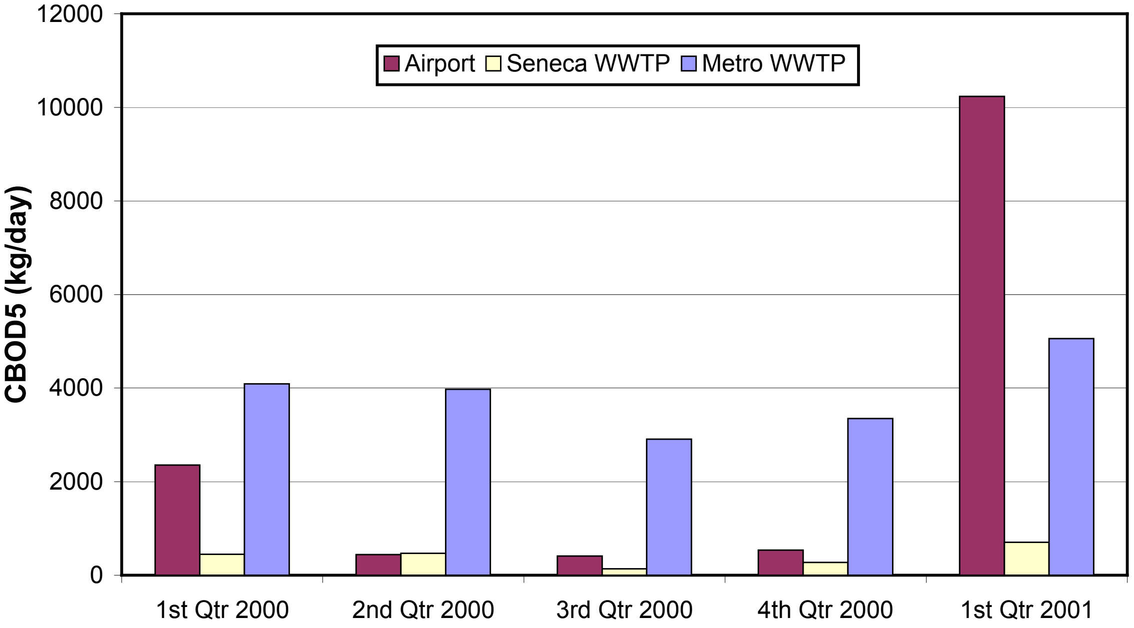
Minneapolis/St. Paul International Airport

The international airport serving the Minneapolis/St. Paul metropolitan area is located near the mouth of the Minnesota River. Stormwater discharges from the airport are regulated under the National Pollutant Discharge Elimination System (NPDES). Airport stormwater is collected and discharged to the Minnesota River at three outfalls between river miles 4.1 and 3.0. The discharge has been reliably monitored since 1995, and the river is monitored twice a week at one upstream and one downstream site.

Monitoring through 2002 revealed high levels of CBOD5 in the stormwater from de-icing and anti-icing alcohols, propylene and ethylene glycol (Figure 4). Before recent upgrades, the Metropolitan Airports Commission (MAC) recovered approximately 40% of the total glycol used for deicing; the remainder was lost to the environment. The MAC is permitted to discharge 900 tons of CBOD5 per year but exceeded this limit in both 2001 and 2002.

While the airport discharges more CBOD5 during the de-icing season (October-April), summer loads are also substantial. During 1997-2000, mean summer CBOD5 loads ranged from 800 to 1200 lb/day, which were 8-12 times higher than the amount (100 lb/day) used in the 1985 wasteload allocation study. The airport's mean summer CBOD5 load in 2000 was nearly double the combined load of the Blue Lake and Seneca WWTPs.

Figure 4. Quarterly CBOD5 Loads from the International Airport, Seneca WWTP, and Metro WWTP in 2000.



An airfield improvement plan, currently being implemented, includes a number of construction projects that will improve the recovery of aircraft de-icing fluids (ADFs) and reduce CBOD loads to the river (www.mspairport.com/msp/airport_expansion/airfield/deicing). In 2004, the last of five new de-icing pads will be constructed. The pads contain spent ADFs and minimize their movement to stormwater. A new and larger recycling and storage facility for recovered glycol will become operational in fall 2004. In addition, two new stormwater detention ponds are nearing completion, which will capture spent glycol and other contaminants before they can enter the river.

Understanding the effects of stormwater ADFs on the river presents a challenging model application for the following reasons:

- CBOD decay rates and ultimate to 5-day ratios of ADF are not known.
- Seasonal CBOD decay rates in the river are not known.
- The extent of ice cover in the river and its effect on reaeration is not known.
- At times, The Mississippi River backwashes into the Minnesota River.
- Some of the oxygen demand will be expressed in the Mississippi River.

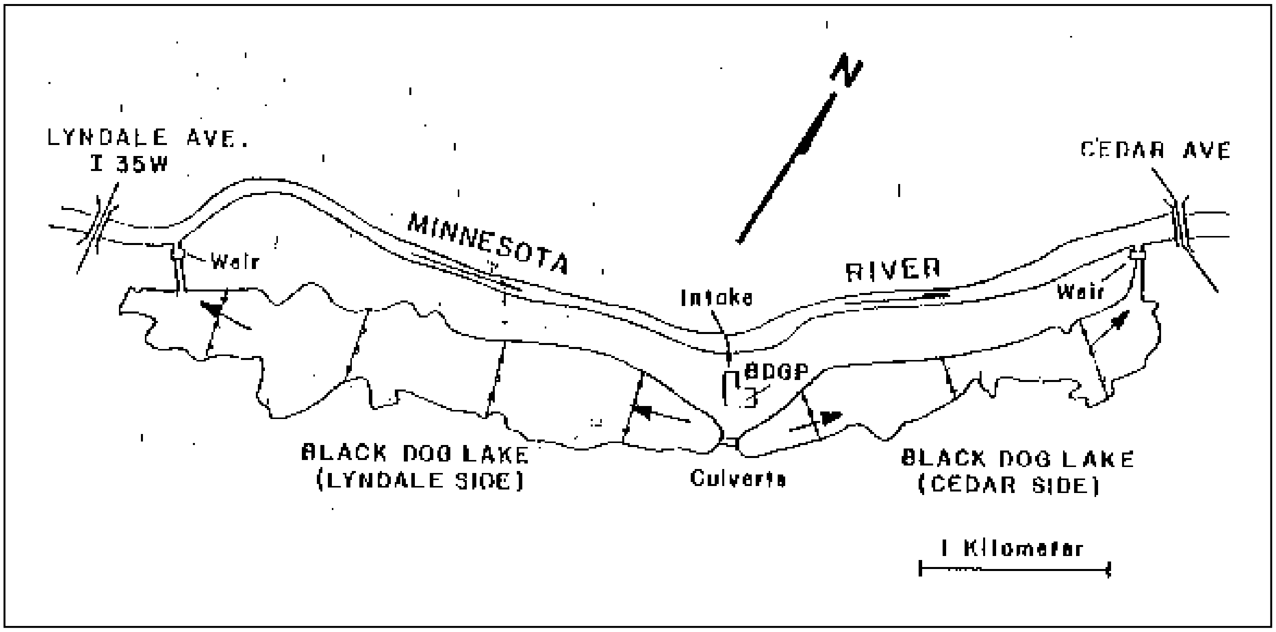
Nationally, only a few groups have experience with modeling ADF-impacted stormwater.

Black Dog Generating Plant

Xcel Energy (formerly, Northern States Power Company) owns and operates the Black Dog Generating Plant, which is located in the floodplain on the south side of the Minnesota River between Interstate 35W (old Lyndale Avenue) and State Highway 77 (old Cedar Avenue) (Figures 2 and 5). Black Dog is a four-unit, 538-megawatt facility that was upgraded in 2002 from strictly coal-fired to combined coal- and gas-fired. The facility pumps water from the Minnesota River to cool condensers. Intake water is pumped from the river near mile 8.8 at a maximum permitted rate of 268,175 gallons per minute (597 cfs). The Minnesota Department of Natural Resources (MDNR) regulates water appropriations by Black Dog (Permit # 610270) and other users. The facility has an open-cycle cooling system: water is pumped from the river, passed through condenser chambers once, and discharged to east side of Black Dog Lake.

Black Dog Lake functions as a cooling lake to reduce the temperature before the water is discharged to the Minnesota River. The cooling water flows by gravity to two distinct parts of the lake: west (“Lyndale Lake”) and east (“Cedar Lake”). Each end has a controlled weir outlet structure to manage water retention and cooling. Discharges to the river are located at miles 10.7 (Lyndale outlet) and 7.5 (Cedar outlet). The MPCA issues the permit to discharge to the lake and river (Black Dog, Permit # MN0000876). When the river temperature is greater than 39ºF and river flow is less than 1,000 cfs, the permit requires the temperature of the discharge to be no greater than 9ºF above river temperature. Under other conditions, the discharge temperature must be within 13ºF of ambient.

Figure 5. Sketch of Black Dog Lake marking the intake and discharge points for the Black Dog Generating Plant (Bodensteiner and Giese, 1999).



Cooling water requirements vary with energy demand. During a recent two-year period of relatively high river flows (November 1996 through September 1998), the percentage of daily withdrawal rate at Black Dog to river flow at Jordan varied from 0-26% (Bodensteiner and Giese, 1999). A higher portion of the river is withdrawn during hot or cold weather (i.e., high energy demand) when river flows are low. Table 5 shows the mean monthly withdrawal rates compared to river flows during the hot, dry summer of 1988. While rates would have varied from day to day, the Black Dog facility pumped a large portion of the river flow in 1988. The recent facility upgrade may affect withdrawal rates and times.

Table 5. Mean monthly withdrawal rates by the Black Dog Generating Plant compared to mean monthly river flows, June -September, 1988.

Month	Black Dog Plant At Mile 8.8 Mean Withdrawal[1] (cfs)	Minnesota River At Jordan (MI39.4) Mean Flow (cfs)
June	312	1043
July	282	367
August	348	297
September	282	246

[1] Based on total volume pumped during the month.
Source: Sean Hunt, MDNR.

Effects of the Black Dog facility on the river under summer low flow conditions are not known but may be important. A noticeable effect on water quality was measured during a 1974 river survey (MPCA, 1985), during which Black Dog withdrawals averaged 547 cfs, or 72% of the river flow measured at Shakopee. Discharges from the facility appeared to increase dissolved oxygen concentrations in the river. In a time-of-travel study during the 1976 drought, the USGS noted that the Black Dog plant influenced travel times in this reach of the river.

As part of their 1996 permit, Northern States Power was required to conduct an environmental study of Black Dog Lake (Bodensteiner and Giese, 1999). The lake contains long and shallow stretches of open water. Table 6 provides the morphometry of the two ends of the lake at normal water-surface elevation (695 feet above mean sea level). The study found that the lake exhibits some wetland characteristics and some characteristics more typical of open water or rivers. The wetland characteristics are enhanced by periodic drawdowns done in cooperation with the US Fish and Wildlife Service to increase migratory bird use. Drawdowns were conducted infrequently during the 1990s due to high river flows. The cooling lake was in flood-bypass mode for much of this wet period, especially 1993 and 1997.

The environmental study of Black Dog Lake included comparisons of water quality in the discharges compared to water quality at river sites upstream and downstream of Black Dog Lake (Bodensteiner and Giese, 1999). River flows were mostly high during the study period (1997-98), and when flows were low (August-September 1998), a drawdown was implemented. No conclusions can be drawn from this study on the effects of the Black Dog facility on river water quality under low flow conditions. However, on the four sampling dates during this two-month period, temperature, pH, and ammonia tended to increase and dissolved oxygen tended to decrease between the upstream and downstream river sites. At all flows, the study noted that the effect of the cooling lake on dissolved oxygen varied seasonally. Additional environmental studies are required in the current NPDES permit.

Table 6. Morphometric characteristics of the Cedar and Lyndale Ends of Black Dog Lake (Bodensteiner and Giese, 1999).

	Cedar	**Lyndale**
Length (miles)	1.5	2.0
Mean Width (feet)	950	1570
Depth (feet)	1.5	3.3
Area (acres)	162	335

The Black Dog Generating Plant has the potential to affect dissolved oxygen and unionized ammonia concentrations in the Minnesota River, as well as BOD, algae, nutrients, and solids. Influences include hydraulic modification, thermal inputs, biocide usage, lake/wetland effects, and settling/resuspension of solids. A biocide is applied to the intake water to control biofouling; its use is restricted to two hours in any 24 hours. Toxicity tests indicate no significant impact on lake biota, but the effect on algae in the intake water is unknown. Water has a relatively fast turnover in the lake, but there may be some opportunity for algal growth and nutrient cycling. For example, "extensive algae growth" was noted when the lake was sampled during the drawdown. These potential effects merit close monitoring during low flow conditions and appropriate consideration in the model.

3 ISSUES

All or portions of the lower 40 miles of the Minnesota River are listed as impaired due to low oxygen, turbidity, and bacteria on Minnesota's 2002 list of impaired waters. This reach is also listed for fish consumption advisories based on unacceptable levels of mercury and PCBs in fish tissue. Similarly, the Minnesota River Assessment Project Report to the Legislative Commission on Minnesota Resources (MPCA, 1994) identified the pollutants of greatest concern throughout the length of the Minnesota River as bacteria, sediments, nutrients, and oxygen-demanding substances.

To address low DO and high ammonia concentrations in the lower 22 miles of the Minnesota River, a wasteload allocation (WLA) study was completed by the MPCA in 1985 (amended in 1987), using data from intensive river surveys in 1974 and 1980 and river monitoring data from 1971 to 1980. The WLA study is the basis for BOD and ammonia effluent limitations for dischargers to the lower 22 miles and for a load reduction goal of 40% for oxygen-demanding materials from nonpoint sources upstream of Shakopee. Ammonia is a concern for two reasons: 1) nitrification of ammonia to nitrate nitrogen uses oxygen, and 2) the un-ionized form of ammonia can be toxic to aquatic life at high concentrations.

Much has changed in the river basin since 1980: Blue Lake, Seneca, and other WWTPs have been upgraded, various best management practices have been adopted on rural and urban landscapes, and many acres have been set aside in programs to improve water quality. A recent trend analysis by the MPCA (2002) found reductions of 34, 31, and 84 percent in BOD, suspended solids, and ammonia concentrations, respectively, in the Minnesota River at Jordan for the period 1977-2001. In addition, phosphorus concentrations at Fort Snelling dropped by 32 percent from 1992 to 2001. It is time to revisit the wasteload allocation study and collect new river information so appropriate effluent limitations are set for Blue Lake and other expanded facilities. Also, an updated assessment tool is needed to evaluate load-reduction goals for nonpoint sources, including target pollutant loads for Metro Area watersheds.

The WLA study used a steady-state model called RMA-12, which was a customized version of the EPA-supported model QUAL-2. RMA-12 ran on a mainframe and was not converted to run on personal computers, so the original model is no longer available. MPCA has converted the WLA model to QUAL-2E, but it has not been fully tested. In 1992 the Metropolitan Council contracted EnviroTech Associates to develop time-variable mass transport for the EPA-supported WASP4 models of the lower 40 miles of the Minnesota River for the years 1988, 1990, and 1991 (EnviroTech, 1992). The WASP4 mass transport was tested against measured total dissolved solids, conductivity, total suspended solids, and total phosphorus. Later, water-quality models (steady-state and time-variable) were partially developed for 1988, 1990, and the 1980 synoptic survey. The models were to be used to help determine target pollutant loads for minor watersheds in the Metro Area, but this approach was dropped.

Because the WLA study concluded that the dissolved oxygen standard could not be met by load reductions at point sources alone and recommended a 40% reduction in headwater BOD loads, it is considered an early example of a Total Maximum Daily Load (TMDL) study. To fully realize the TMDL study and allocate pollutant loads to sources upstream of Shakopee, the MPCA and its consultant, Tetra Tech, Inc., are nearing completion of an HSPF model of 9 of the 13 major watersheds in the Minnesota River Basin. The model extends from Lac Qui Parle Dam to Jordan and does not include the Lower Minnesota River Watershed. The calibration period is 1986-1992, and the validation period is 1980-1985. The TMDL study is scheduled for completion in 2004.

A new water-quality model of the lower Minnesota River is also needed for assessments of nutrients, sediment, and other issues. Nutrient standards for streams and rivers are slated for adoption in Minnesota in the next 5-10 years. MPCA has already conducted studies on the Minnesota and other rivers that link phosphorus to algal growth and, consequently, to increased oxygen demand (Heiskary and Markus, 2001). Farther downstream in the Mississippi River, Spring Lake and Lake Pepin are listed as impaired due to excess nutrients in Minnesota's 2002 list of impaired waters. During the 21-year period from 1976 to 1996, the Minnesota River contributed 45 percent (1540 mt/yr) of the total phosphorus load to the Mississippi River upstream of Lake Pepin (Meyer and Schellhaass, 2002). The Minnesota River contributed an estimated 85 percent (876,000 mt/yr) of the sediments deposited in Lake Pepin in the 1990s (Engstrom and Almendinger, 2000). A trend analysis by the MPCA (2002) indicated no trends in the concentrations of nitrate-nitrogen in the Minnesota River, yet this basin delivers up to 70 percent of the state's contribution to the zone of hypoxia in the Gulf of Mexico.

In a number of studies, pollutant loads from the Minnesota River have been shown to impact water quality in the Mississippi River. An MCES consultant, HydroQual, Inc. (2002a, 2002b) developed an advanced water-quality model of the Mississippi River from Lock & Dam 1 through Lake Pepin. However, we lack a model for the lower Minnesota River to bridge the Minnesota River Basin Model and Mississippi River model and study the impacts of resource management in the Minnesota River Basin on the water quality of the Mississippi River.

4 ADVANCED WATER-QUALITY MODEL

In 1994 the Metropolitan Waste Control Commission (now MCES) sponsored a workshop to discuss the type of model needed to address eutrophication in the Mississippi River, Lock and Dam No. 1 through Lake Pepin. In attendance were modelers, scientists, engineers, and managers from regional, state, and federal agencies involved with managing the Mississippi River. Also participating were other interested groups, such as the University of Minnesota and consulting firms. Invited to help with the process were national modeling experts, including Robert Ambrose (EPA CEAM), Mark Dortch (USACE-WES), Harvey Jobson (USGS), and Wu-Seng Lung (EnviroTech Associates). The workshop resulted in a list of recommendations for the modeling effort. In 2001 MPCA and MCES staff met to discuss the type of model needed to address the various issues faced by the lower Minnesota River. The group agreed that a model similar to that built for the Mississippi River was needed for the lower Minnesota River. Sections 4.1 and 4.2 list the recommended model features and capabilities and model selection criteria taken from the 1994 workshop and adapted to the lower Minnesota River.

The proposed tool is an advanced water-quality model. A versatile computer model with advanced functions is needed to adequately capture hydrodynamics, sediment transport, and eutrophication in the lower Minnesota River. Hydrodynamics describe the underlying physics of water movement. Sediment is an issue in itself and also a key factor in transporting phosphorus and determining light conditions for algae. The eutrophication model tracks nutrient and algal dynamics and relationships to oxygen production and demand. While phosphorus typically controls algal growth in Minnesota, nitrogen is a concern due to potential ammonia toxicity and nitrate loads to the Gulf of Mexico. The sediment bed is a significant source of oxygen demand under low flow conditions and may also be a source of phosphorus and ammonia. The model should account for the exchange of oxygen and nutrients across the sediment-water interface.

The model should accurately represent spatial and temporal differences in the lower Minnesota River. This reach contains many backwaters, the lower 22 miles have been channelized, and dam operation in the Mississippi River affects water elevations. The model may need to be 2D or 3D to simulate vertical and lateral differences in water quality. The river experiences strong seasonal and annual differences and is subject to large loading events from its mostly agricultural watershed. A time-variable model is required to track these temporal differences. A multiyear model representing all seasons and various flow regimes would capture these differences and gauge the impacts of pollutant loads during high flows on water-quality conditions during low flows.

For model calibration, a combination of historical data from past years and data collected specifically for this project is advised. The Advanced Eutrophication Model was calibrated against the years 1985-1996, and the Minnesota River Basin Model was calibrated against the years 1980-1992. The most recent drought period was 1987-1990. Therefore, the periods 1986-92 (seven historic years) and 2004-2006 (three project years) are recommended for calibrating the model, yielding a total of ten calibration years.

4.1 Model Features and Capabilities

Basics

- Mass-balance framework
- Standard state variables for a eutrophication model (i.e., dissolved oxygen, oxygen demand, nitrogen forms, phosphorus forms, silica, and phytoplankton)
- Time-variable (a steady-state version for low flow conditions would be useful)
- Adequate temporal resolution to capture runoff events
- Year-round simulations to capture seasonal differences, including the effects of ice cover and cold temperatures in winter
- Simulation of multiple consecutive years representing a range of flows
- Adequate spatial resolution to fit observed vertical, longitudinal, and lateral differences
- Suitable for linking the Minnesota River Basin Model and the Advanced Eutrophication Model of the Mississippi River

Hydrodynamics

- Sound hydraulic routines
- Adequate simulation of mixing and dispersion
- Links to temperature and solids concentrations in the water-quality model
- Suitable for the study area (e.g., can handle backwashing from the Mississippi River and withdrawals and discharges from Black Dog Generating Plant)

Sediment and Phosphorus Transport

- Simulation of suspended solids, including support of
  - different soil types,
  - settling rates,
  - deposition and resuspension, and
  - a computational link to light extinction in the water-quality model
- Simulation of phosphorus, including support of
  - all important fractions, inorganic and organic, and
  - partitioning into dissolved and particulate forms

Sediment-Bed Interactions

- Simulation of exchanges over the sediment-water interface (specifically, oxygen, ammonia, and phosphate)
- Possible simulation of sediment-bed diagenesis and depuration

Biology

- Reliable predictions of total phytoplankton and linkages to oxygen production, oxygen demand, phosphorus concentrations, and nitrogen concentrations
- Suitable measures of algal intensity, such as concentration, density, biomass, and bloom frequency
- Possible simulation of multiple phytoplankton groups with different kinetics

Nonpoint-Source Loadings

- Adequate simulation of nonpoint-source loading events
- Interfaces well with watershed models

4.2 Model Selection Criteria

Characteristics

- Technically reliable; well-tested
- Open framework: flexible and expandable
- Reasonable data requirements
- Generally accepted by scientific community
- Runs on standard computing platforms supported by the MPCA and MCES

Applicability

- Suitable for the lower Minnesota River, including the following features:
    - northern temperate with variable ice cover in winter
    - freshwater
    - hypereutrophic
    - high suspended solids
    - significant point- and nonpoint-source loads
    - backwater lakes and wetlands
    - nine-foot channel for barge traffic in lower 22 miles
- Previously applied to similar systems

Ease of Use

- Can be "owned and operated" by local modelers
- Local modelers are familiar with the model
- Level of complexity and dependence on modeler's skill and experience
- Easy to learn (e.g., training, interface, documentation)
- Good technical support available now and in the future
- Easy to compile model inputs; fast startup
- Preprocessor available

Costs and Scheduling

- Data requirements and collection
- Development, calibration, and application
- Maintenance
- Technical support
- Staff versus consultant time
- Hardware and software
- Execution time

Planning Needs

- Accepted by regulators
- Appropriate for wasteload allocation and TMDL studies
- Appropriate for wastewater treatment facility planning
- Allows assessment of a variety of point- and nonpoint-source scenarios and provides a tool for evaluating remedial actions
- Flexible and expandable for future uses

Customization

- Requires minimal customization
- Allows addition of submodels
- Easy to customize and test; simplicity of code
- Minimizes potential problems during future projects
    - customized code is adequately documented
    - can incorporate future enhancements
    - minimal dependence on consultants

Model Results

- Tables, graphs, and statistics
- Postprocessor
- Easy to interpret by modelers and non-modelers
- Easy to transfer to other software
- Allows quick assessments

5 RIVER MONITORING AND SPECIAL STUDIES

River monitoring and special studies are needed to collect data to build and test the model. River monitoring over a period of years and range of flows provides information on temporal differences and variable loading rates. The Metropolitan Council supports long-term monitoring programs to monitor the Minnesota River and nine tributaries (Appendix A), along with the effluents of the Blue Lake and Seneca WWTPs. However, additional monitoring and field studies will be required to fully support the model.

With the advice of partnering agencies, MCES designed a monitoring program in support of the Lower Minnesota River Model (Larson, 2003). The program consists of three main elements:

1. Base monitoring program. MCES will conduct year-round monitoring to meet basic model-recommended data requirements. In general, variables were added and sampling frequencies were adjusted in the long-term monitoring program.

2. Summer low-flow monitoring. MCES will conduct more intensive monitoring at low river flows to capture oxygen, algal, and nutrient dynamics under critical low-oxygen conditions.

3. Special field studies. Special studies are needed to define key model inputs, such as reaeration rates, and gauge the importance of potential factors, such as groundwater.

Monitoring for the model was initiated in October 2003 and will continue for the next three years (2004-2006).

Special Studies. Special studies may be needed to justify key model inputs to the Lower Minnesota River Model. Following is a list of currently proposed or contracted studies:

- Oxygen dynamics assessment, including reaeration, sediment oxygen demand, community oxygen production, and community respiration
- CBOD studies, including decay rates and ultimate-to-5-day ratios
- Phosphorus bioavailability
- Phosphorus sorption dynamics
- Budgetary analyses of suspended solids and nutrients
- Sediment nutrient fluxes (specifically, phosphate and ammonia)
- Seepage study to gauge the importance of groundwater inputs
- Additional groundwater studies to quantify flows and loads
- Study of mixing characteristics of the river
- Synoptic low-flow surveys
- Sediment-bed assessment and mapping

The wasteload allocation study (MPCA, 1985) offers some insight into model inputs that may be important. A sensitivity analysis was conducted in which specific model inputs were alternately increased and decreased by a percentage and the resulting changes in DO, ammonia, and chlorophyll concentrations were measured. A total of 21 inputs were individually tested. The analysis was run using model inputs for a future summer (year 2000), after upgrades at the Blue Lake and Seneca WWTPs and a 40% reduction in headwater BOD loads. Table 7 lists the highest ranking model inputs to which the model was most sensitive.

Table 7. Highest ranking model inputs in the sensitivity analysis for the wasteload allocation study (MPCA, 1985).

Model Input	Sensitivity Rank	Change in Model Input	Change in DO (MI 0.5, mg/L)
Temperature (ºF)	177	± 10%	1.77
Reaeration Rate	90	± 50%	4.49
Algal Respiration Rate	43	± 50%	2.17
Turbidity	34	± 50%	1.70
Algal Growth Rate	33	± 50%	1.66
Sediment Oxygen Demand	29	± 50%	1.47
Headwater CBOD	25	± 25%	0.62
WWTP CBOD	25	± 50%	1.27
CBOD Decay Rate	24	± 50%	1.19

In the Minnesota River Basin Model, model-estimated values were higher than MCES-measured values at Jordan for total suspended solids and total phosphorus and lower for chlorophyll-a (Tetra Tech, 2001). It was suspected that at least part of the difference was due to the model estimating concentrations for the entire water column, including bed load, while MCES grab samples are collected at a single point in the water column (mid-channel, one meter below the surface). If the Lower Minnesota River Model is to serve as a bridge between the basin model and Mississippi River model, it will be important to investigate the difference between MCES grab samples and integrated samples more representative of the entire water column and cross section.

6 BUDGET, SCHEDULE, AND PARTNERS

The schedule for the Lower Minnesota River Model project is as follows:

2003	Design and initiate monitoring
2004-2006	Conduct monitoring
2004-2007	Develop and test model
2008	Complete final report

The estimated cost of the six-year project is one million dollars. As of 1/15/04, the following agencies have committed funds or services to the project:

Metropolitan Council	$373,000
Minnesota Pollution Control Agency	$ 82,280
U.S. Geological Survey	$ 74,835
Lower Minnesota River Watershed District	$ 41,450
Total	$571,565

Additional requests have been submitted to various agencies.

Developing a tool for setting effluent limitations for the expanded Blue Lake WWTP and other point sources is the top priority for MCES. Second is determining pollutant load contributions from the headwaters and tributaries and reductions needed to meet water-quality standards. Dissolved oxygen and ammonia standards top the list, followed by nutrients and then sediment. In addressing these priority issues, other issues may be explored to some degree. Other partners will be polled about their priorities.

7 DATA SOURCES

Following is a preliminary list of sources of data that may be used to develop the model:

Hydrodynamics

- USGS, continuous stage and discharge, Jordan (mile 39.4), 1934-present
- USGS, time-of-travel studies, Jordan to Ft. Snelling, August 1976 and May 1977. [Several earlier dye studies are mentioned in the 1985 wasteload allocation study (MPCA, 1985).]
- USGS, survey of 41 cross sections and a river profile, miles 37-15, 2001
- USGS, cross-sectional survey, Jordan to Ft. Snelling, October 1971
- USACE, update of cross sections surveyed in 1971 using dredging information, mile 15 to mouth, for flood-profile study in 2002. USACE also has cross-sectional data for the reach upstream of mile 37 (Carver Rapids).
- Federal Water Pollution Control Administration, hydrographic studies, upstream of Jordan to mouth (FWPCA, 1965)
- St. Anthony Falls Hydraulic Laboratory, travel time and longitudinal dispersion, Jordan to mouth (Falch *et al*., 1979)
- St. Anthony Falls Hydraulic Laboratory, mixing zone study, Blue Lake and Seneca WWTPs (Stefan *et al*., 1984)
- MCES, continuous stage and discharge, nine tributaries (see Water Quality)
- MCES and MPCA, effluent flow, point sources (see Water Quality)
- MDNR, water withdrawals, Black Dog Generating Plant and others

Meteorology

- National Weather Service, meteorological data, Minneapolis/St. Paul international airport, 1938-present
- University of Minnesota, St. Paul Campus, solar radiation
- Flying Cloud Airport, meteorological data
- Xcel, meteorological data, Black Dog Generating Plant
- MCES, continuous precipitation at some stream monitoring stations (Bevens, Bluff, Riley, Eagle, and Willow Creeks)
- MDNR, Precipitation Observer Network

Sediment

- MCES, sediment monitoring program, Jordan and Ft. Snelling, intermittently since 1981 (particle size, total organic carbon, and toxic chemicals)
- USGS, 200 sediment samples, Jordan (physical and chemical characteristics)
- USACE, sediment information from dredging activities

Water Quality

- MCES long-term river monitoring program, five stations (miles 39.4, 25.1, 14.3, 8.5, and 3.5), 1976-current, grab samples at one meter below surface, program includes water quality, sediment, and biological monitoring (Figure 2 and Appendix A)
- MCES, nonpoint source monitoring program, Minnesota River at Jordan and six tributaries (Bevens, Sand, Carver, Bluff, Credit, and Nine Mile), 1989-current, continuous flow and temperature, grab and event sampling for water quality (Figure 2 and Appendix A)
- MCES and partners, watershed outlet monitoring program, three tributaries (Riley, Eagle and Willow), 1999-present, continuous flow and temperature, grab and event sampling for water quality (Figure 2 and Appendix A)
- MCES, continuous water-quality monitoring, Ft. Snelling, 1973-present, five variables (turbidity, pH, temperature, conductivity, and dissolved oxygen)
- MCES, effluent flow and quality, Blue Lake and Seneca WWTPs (and closed Chaska and Savage WWTPs), 1981-present.
- MPCA, effluent flow and quality, monthly discharge monitoring reports, permitted point sources, 1990-present (including daily flow and temperature at the two discharge points for the Black Dog Generating Plant)
- MPCA, milestone river monitoring, Fort Snelling, 1974-present
- MPCA and Metropolitan Waste Control Commission (MWCC, now MCES), synoptic low-flow surveys in 1974 and 1980
- Carver County, stream monitoring program, Chaska Creek
- Barr Engineering Co., stream monitoring program, Purgatory Creek (Barr, 2001)
- MPCA, sediment oxygen demand, 1980 (see also MPCA, 1985)
- EPA Region IV for MWCC, community oxygen metabolism and community substrate oxygen demand, 1995

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Appendix A.
MCES River and Stream Monitoring Programs
For the Minnesota River Basin

Metropolitan Council Environmental Services
River Monitoring Program
Minnesota River, Conventional Pollutants

Last Revised: 1/9/03, CEL

Site	**Weekly***	**Semi-Monthly**	**Monthly**	**Bi-Monthly**	**Semi-Annually**
MI 3.5	Ammonia Nitrogen	BOD 5-day		Hardness	Oil and Grease
	Dissolved Oxygen	CBOD 5-day		Cyanide	Ultimate BOD (filtered)
	Fecal Coliform Bacteria	Chlorophyll-a, Total		Phenols	Ultimate BOD (not filtered)
	pH	Chlorophyll-a, Corrected		Total Silver	Ultimate CBOD (filtered)
	Temperature	Total Phosphorus		Total Aluminum	Ultimate CBOD (not filtered)
	Turbidity	Total Dissolved Phosphorus		Total Arsenic	
	Snow Depth	Ortho Phosphorus (filtered)		Total Boron	
	% Snow Cover	Ortho Phosphorus (not filtered)		Total Berylium	
	Ice Depth	Total Particulate Phosphorus		Total Cadmium	
	% Ice Cover	Total Suspended Solids		Total Chromium	
		Volatile Suspended solids		Total Copper	**Annually**
		Total Dissolved Solids		Total Zinc	
		Total Nitrate/Nitrite Nitrogen		Total Iron	Volatile Organics
		Silica (filtered)		Total Mercury	Acid-Extractable Organics
		Alkalinity (filtered)		Total Manganese	Base-Neutral Organics
		Alkalinity (not filtered)		Total Nickel	Pesticides
		Dissolved Chloride		Total Lead	PCBs
		Dissolved Sulfate		Total Antimony	
		Dissolved Sodium		Total Selenium	
		Dissolved Potasium		Total Thallium	
		Dissolved Calcium			
		Dissolved Magnesium			
		Total Kjeldahl Nitrogen			
		Particulate Kjeldahl Nitrogen			
		Specific Conductance			
		Total Organic Carbon			
		Dissolved Organic Carbon			
		Ammonia Nitrogen (filtered)			

Site	Weekly*	Semi-Monthly	Monthly	Bi-Monthly	Semi-Annually
MI 8.5	Ammonia Nitrogen	BOD 5-day	Dissolved Chloride	Hardness	Oil and Grease
	Dissolved Oxygen	CBOD 5-day	Dissolved Sulfate	Cyanide	Ultimate BOD (filtered)
	Fecal Coliform Bacteria	Chlorophyll-a, Total	Dissolved Sodium	Phenols	Ultimate BOD (not filtered)
	pH	Chlorophyll-a, Corrected	Dissolved Potasium	Total Silver	Ultimate CBOD (filtered)
	Temperature	Total Phosphorus	Dissolved Calcium	Total Aluminum	Ultimate CBOD (not filtered)
	Turbidity	Total Dissolved Phosphorus	Dissolved Magnesium	Total Arsenic	
		Ortho Phosphorus (filtered)	Total Kjeldahl Nitrogen	Total Boron	
		Ortho Phosphorus (not filtered)	Part. Kjeldahl Nitrogen	Total Berylium	
		Total Particulate Phosphorus	Specific Conductance	Total Cadmium	
		Total Suspended Solids		Total Chromium	
		Volatile Suspended solids		Total Copper	**Annually**
		Total Dissolved Solids		Total Zinc	
		Total Nitrate/Nitrite Nitrogen		Total Iron	Volatile Organics
				Total Mercury	Acid-Extractable Organics
				Total Manganese	Base-Neutral Organics
				Total Nickel	Pesticides
				Total Lead	PCBs
				Total Antimony	
				Total Selenium	
				Total Thallium	
				Alkalinity	
MI 14.3	Ammonia Nitrogen				
	Dissolved Oxygen				
	Fecal Coliform Bacteria				
	pH				
	Temperature				
	Turbidity				

Site	Weekly*	Semi-Monthly	Monthly	Bi-Monthly	Semi-Annually
MI 25.1	Ammonia Nitrogen Dissolved Oxygen Fecal Coliform Bacteria pH Temperature Turbidity	BOD 5-day CBOD 5-day			
MI 39.4	Ammonia Nitrogen Dissolved Oxygen Fecal Coliform Bacteria pH Temperature Turbidity	BOD 5-day CBOD 5-day Chlorophyll-a, Total Chlorophyll-a, Corrected Total Phosphorus Total Dissolved Phosphorus Ortho Phosphorus (filtered) Ortho Phosphorus (not filtered) Total Particulate Phosphorus Total Suspended Solids Volatile Suspended solids Total Dissolved Solids Total Nitrate/Nitrite Nitrogen Chloride	Dissolved Chloride Dissolved Sulfate Dissolved Sodium Dissolved Potasium Dissolved Calcium Dissolved Magnesium Total Kjeldahl Nitrogen Part. Kjeldahl Nitrogen Specific Conductance	Hardness Cyanide Phenols Total Silver Total Aluminum Total Arsenic Total Boron Total Berylium Total Cadmium Total Chromium Total Copper Total Zinc Total Iron Total Mercury Total Manganese Total Nickel Total Lead Total Antimony Total Selenium Total Thallium Total Alkalinity	Oil and Grease Ultimate BOD (filtered) Ultimate BOD (not filtered) Ultimate CBOD (filtered) Ultimate CBOD (not filtered) **Annually** Volatile Organics Acid-Extractable Organics Base-Neutral Organics Pesticides PCBs

* Weekly from March through October
Semi-monthly from November through February

Metropolitan Council Environmental Services **Last Revised: 1/9/03, CEL**
Stream Monitoring Program
Minnesota River, Conventional Pollutants

Nonpoint-Source Monitoring Program (Since 1989) and Watershed Outlet Monitoring Program (Since 1999)

Sites	**Program**	**Variables: Continuous (15-minute)***	**Variables: Most Baseline Grabs and Event Composites**	**Variables: Some Baseline Grabs and Some Event Composites ****
MI 39.4	NPS			
Bevens 2.0	NPS	Temperature	Total Organic Carbon	BOD5 (~half of the events)
Bevens 5.0	NPS	- All sites	Total Alkalinity	CBOD5 (~half of the events)
Sand 8.2	NPS		Chemical Oxygen Demand	Orthophosphate (~half of the events)
Carver 1.7	NPS	Conductivity	Turbidity	Fecal Coliform Bacteria (<half of the events)
Bluff 3.5	NPS	- Nine Mile and	Total Suspended Solids	Total Chloride (<half of the events)
Credit 0.9	NPS	WOMP sites	Volatile Suspended Solids	Total Metals (few, mainly Nine Mile)
Nine Mile 1.8	NPS		Total Kjeldahl Nitrogen	Chlorophyll-a, Total (few)
		Precipitation	Total Nitrate Nitrogen	Chlorophyll-a, Pheo-Corrected (few)
Eagle 0.8	WOMP	- Bluff, Bevens and	Total Nitrite Nitrogen	
Riley 1.3	WOMP	WOMP sites	Ammonia Nitrogen	
Willow 1.0	WOMP		Total Phosphorus	
			Total Dissolved Phosphorus	
			Total Sulfate	
			pH (in lab)	
			Conductivity (in lab)	
			Hardness	

* Temperature probes are installed at all sites except Jordan, Bevens, Carver, and Bluff. Currently at these four sites, temperature is measured when baseline grab samples are taken, but temperature probes will eventually be installed.
Dissolved oxygen is not measured at any frequency; pH is measured in the lab only.

** The number of samples are dependent on stream and sample conditions.
Many of these variables have holding-time constraints.