U.S. Environmental Protection Agency Region 7

Middle Fork Grand River
Worth and Gentry Counties, Missouri
Ringgold County, Iowa

Total Maximum Daily Load

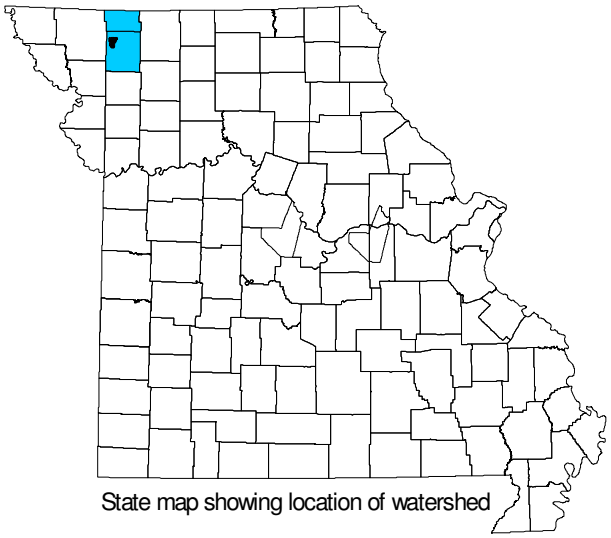
September 2006

Approved by:

/s/ 11/15/2006

William A. Spratlin **Date**
Director
Water, Wetlands, and Pesticides Division

Total Maximum Daily Load (TMDL)
For Middle Fork Grand River
(Main Fork Grand River)
Pollutant: Sediment


State map showing location of watershed

Name: Middle Fork Grand River
(Main Fork Grand River)

Location: Gentry and Worth Counties, in Missouri and Ringgold County in Iowa

Hydrologic Unit Code (HUC): 10280101-050005

Water Body Identification (WBID): 468

Missouri Stream Classification: Class P[1]

Beneficial Uses[2]:
- Irrigation
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Human Health Protection (Fish Consumption)
- Whole Body Contact, Category A
- Secondary Contact Recreation

Size of Impaired Segment: 25 miles

Location of Impaired Segment[3]: From (upstream) mouth in Worth county to (downstream) Section 12, T66N, 31W in Gentry County

Pollutant Source: Agricultural Nonpoint Sources

Pollutant: Sediment

TMDL Priority Ranking: High

1. Introduction

This Middle Fork Grand River Total Maximum Daily Load (TMDL) for sediment is being established in accordance with Section 303(d) of the Clean Water Act, because the state of Missouri determined on the 1998 and the 2002 303(d) lists of impaired waters that the water quality standards (WQS) for Middle Fork Grand River were exceeded due to sediment. The Middle Fork Grand River name was changed to Main Fork Grand River on the 2002 303(d) list. To meet the milestones of the 2001

[1] Class P streams maintain permanent flow even in drought periods. See Missouri WQS 10 Code of State Regulations 20-7.031(1)(F). The WQS can be found at the following uniform resources locator (URL): www.dnr.mo.gov/env/wpp/rules/index.html#Chap7.
[2] For Beneficial uses see 10 CSR 20-7.031(1)(C) and Table (H)
[3] See Table H 10 CSR 20-7

Consent Decree, American Canoe Association, et al. v. EPA, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001, EPA is establishing this TMDL.

The purpose of a TMDL is to determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. The TMDL also establishes the pollutant load allocation necessary to meet the WQS established for each waterbody based on the relationship between pollutant sources and in-stream water quality conditions. The TMDL consists of a wasteload allocation (WLA), a load allocation (LA), and margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL that accounts for the uncertainty associated with the model assumption and data inadequacies.

2. Background and Water Quality Problems

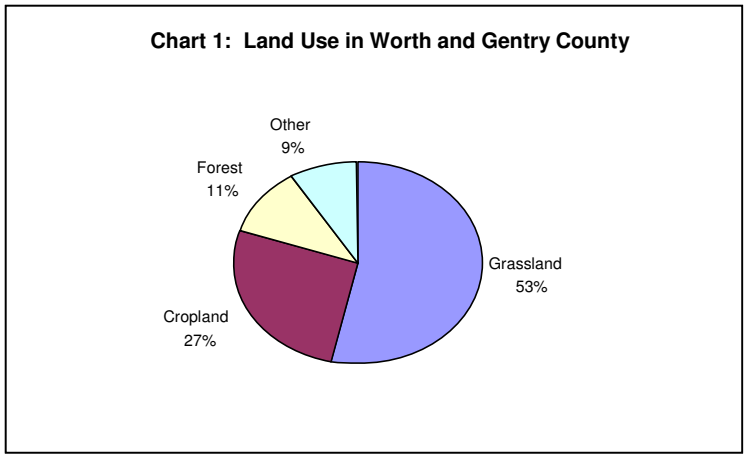
Background

The Middle Fork Grand River flows southerly into northwest Missouri (Worth and Gentry Counties) from Iowa (Ringgold County). In Missouri, the stream travels for approximately twenty-five miles to its confluence with the West Fork Grand River, where it becomes the Grand River. Twenty-five miles of Middle Fork Grand River is listed as impaired for sediment. The drainage area of the impaired segment of Middle Fork Grand River is approximately 226 square miles with a 36-mile long channel. Predominant landuse is approximately 53% grassland, 27% cropland, and 11% deciduous forest, see Chart 1[4].

Historically, the basin was best characterized as long narrow prairies generally oriented north-south and divided by timbered ridge tops and streams valleys. Much of the agricultural activity began by clearing trees for firewood and planting row crops. Channelization and levee construction are viewed by landowners as legitimate stream management practices throughout the basin[5]. The basin is characterized as rural with a declining population and no major urban areas. The most compelling evidence of loss or impairment of aquatic habitat is the historical change in distribution of fishes in Missouri.

All waters of the State, as per Missouri WQS, must provide suitable conditions for aquatic life. The conditions include both the physical habitat and the quality of the water. TMDLs are not written to address habitat, but are written to correct water quality conditions. Because the water body addressed by this TMDL was assessed as to its biological function, many factors may have contributed to the impairment. The State of Missouri continues to do field evaluation and in the future, may define the role sediment is playing in the potential biological impairment of this waterbody. However, the water quality condition for which Middle Fork Grand River is currently listed is sedimentation; therefore, this TMDL addresses sediment. The State of Missouri may submit and EPA may approve another TMDL or a modified 303d listing for this water at a later time to address new information on the impairment.

[4] MDNR, Biological Assessment Report, Middle Fork Grand River, 2004-2005.
[5] Grand River Watershed Inventory and Assessment, Missouri Department of Conservation, Water Quality, MDNR



Water Quality Problems

Middle Fork Grand River was placed on the Missouri 1998 and 2002 303(d) lists for excessive sediment problems from agriculture nonpoint sources. The principal water quality problems in north Missouri streams are suspended sediment, elevated water temperatures, pesticide spills, and the loss of pool habitat[6]. Excessive sedimentation clouds the water, which reduces the amount of sunlight reaching aquatic plants, covers fish spawning areas and food supplies, and clogs the gills of fish. In addition, other pollutants like phosphorus, pathogens, and heavy metals are often attached to the soil particles winding up in the streams with the sediment[7]. Many species of fish no longer appear in portions of the state where they once lived. The water quality condition addressed by this TMDL is sediment. Since little sediment data exists to directly document sediment as a significant impact to Middle Fork Grand River, biological assessments of Middle Fork Grand River were conducted in Worth and Gentry Counties by MDNR's Environmental Services Program (ESP) in fall of 2004 and spring of 2005; the data is shown in Appendix B.

The quality and quantity of habitat for aquatic life have been affected generally in Missouri. A combination of natural geology and land use in the prairie portions of the state is believed to have reduced the amount and impaired the quality of habitat for aquatic life. The major problems are extensive channelization, vertical banks, and poor riparian zones. In many cases row crops are planted to the edge of stream banks, thereby decreasing the quality of the riparian corridor and leading to unstable banks and loss of woody debris input to the stream. Channelization causes a loss of channel structure, habitat heterogeneity and changes in basin hydrology that increase flood flows and prolong low flow conditions. The lack of top predator fish has been shown to be related to channeled streams and the resulting lack of pools.[8] Many species of fish no longer appear in portions of the state where they once lived. However, as mentioned above, habitat loss is not an appropriate TMDL target to correct the water quality conditions. Other water quality measures must be assessed. This TMDL addresses sediment in Middle Fork Grand River.

[6] Missouri Soil and water Districts Commission, March 2003, Needs Assessment, Plan to Address Identified Needs & Summary to Date.
[7] Agricultural Nonpoint Source (AgNPS), Special Area Land Treatment (SALT) Program, NPS Problems,
[8] Grand River Watershed Inventory and Assessment, Northwest Regional Fisheries, Missouri. http://mdc.mo.gov/fish/watershed/grand/contents/140cotxt.htm

3. Description of Sources

Point Sources

Potential point sources of sediment include facilities with permits through the National Pollution Discharge Elimination System (NPDES). There are two active Missouri state operating NPDES permitted water treatment facilities (WTF) within the Middle Fork Grand River watershed in Missouri: Grant City West Sanitary Lagoon and Middle Fork Water Company see table 1.

The City of Mount Ayr, Iowa waste water treatment facility (WWTF) (NPDES IA-0023574) discharges into the Middle Fork Grand River watershed and is not a significant source for sediment.

Livestock in the watershed includes many horses, cattle, and hogs held in pastures, feedlots, and Concentrated Animal Feeding Operations (CAFO). Two operations are registered, certified or permitted within the watershed, see table 1. CAFOs are animal feeding operations in which animals are confined to areas that are totally roofed. CAFOs typically utilize earthen or concrete structures to contain and store manure prior to land application.

All permitted livestock facilities have waste management systems designed to minimize runoff entering their operations or detaining runoff emanating from their areas. Such systems are designed for the 25-year, 24-hour rainfall/runoff event. NPDES permits, also non-discharging, are issued for facilities with more than 1,000 animal units (AU). Total potential animal population for all facilities in the Middle Fork Grand River watershed is approximately 8,891 AU. The actual number of AU on site is variable, but typically less than potential numbers.

Table 1. Missouri State Permitted Facilities

Facility – CAFOs	Permit number	County	Design Flow (MGD)
CG, Ruckman Farm	MO-0118451	Gentry	Non discharging
New Dominion Farms, Inc	MO-G010192	Gentry	Non discharging
Facility-Municipal			
Grant City West Sanitary Lagoon	MO-0027600	Worth	0.14
Facility-Non-Municipal			
Middle Fork Water Company	MO-G640081	Gentry	Treatment plant discharges of filter backwash water and treated sludge blow down.

NonPoint Sources

The main source of sediment is believed to be runoff from agricultural nonpoint sources. Overland runoff can easily carry sediment into the stream. Soil from exposed land washes into the river, increasing the turbidity and concentration of total suspended solids (TSS) and decreasing the transparency. Background levels of TSS come from natural fluvial processes. Sediment becomes suspended during high flow events as soil along the banks is eroded. Sediment loading in the Middle Fork Grand River watershed comes predominantly from nonpoint source pollution. Cropland that is adjacent to and drains into Middle Fork Grand River could contribute to the sediment impairment, see Appendix A. The agricultural areas of the basin also contain livestock which are not held in permitted CAFOs, see Tables 3 and 4. Most rainfall in the basin runs off the surface of the land rather than soaking into the soil due to a glacial till (a clayey material that greatly retards movement of water to the

subsurface) that covers the basin. Unconfined livestock have free access to many smaller streams throughout the basin, which further contributes to stream bank instability and erosion.[9]

Table 3. Missouri Livestock Estimates per County[10]

	Gentry	Worth
	Animal Units	
Cattle	---	---
Beef	---	---
Milk	542	(D)
Cow/Calf	38,221	19,497
Horses/Ponies	713	515
Hogs/Pigs	(D)	1,703
Sheep/Lambs	---	489
Poultry	---	---
Layers	---	318
Broilers	750	---

(D) Withheld to avoid disclosing data for individual farms.

Table 4. Iowa Livestock Estimates per County[11]

	Ringgold Animal Units
Cattle	---
Beef	---
Milk	356
Cow/Calf	51,608
Horses/Ponies	776
Hogs/Pigs	101,710
Sheep/Lambs	1,031
Poultry	(D)
Layers	1,890
Broilers	(D)

(D) Withheld to avoid disclosing data for individual farms.

4. Description of the Applicable Water Quality Standards and Numeric Water Quality Targets

Beneficial Uses

The designated uses of Middle Fork Grand River, WBID 468, are:

- Irrigation
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Human Health Protection (Fish Consumption)
- Whole Body Contact, category A

[9] Grand River Watershed Inventory and Assessment
[10] USDA-NASS Quick Stats (Livestock) 2002 Census of Agriculture, volume 1 Chapter 2: Missouri County level
[11] USDA-NASS Quick Stats (Livestock) 2002 Census of Agriculture Iowa County level

- Secondary contact recreation

The stream classifications and designated uses may be found at 10 CSR20-7.031(1) (C) and (F) and Table H.

Use that is impaired:

Protection of Warm Water Aquatic Life

Antidegradation Policy

Missouri's WQS include the EPA "three-tiered" approach to antidegradation, and may be found at 10 CSR 20-7.031(2).

Tier 1 – Protects existing uses and provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after November 29, 1975, the date of EPA's first WQS Regulation, or uses for which existing water quality is suitable unless prevented by physical problems such as substrate or flow.

Tier 2 – Protects the level of water quality necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water in waters that are currently of higher quality than required to support these uses. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economical or social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices (BMPs) for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

Tier 3 – Protects the quality of outstanding national resources, such as waters of national and state parks, wildlife refuges and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality (with the exception of some limited activities that result in temporary and short-term changes in water quality).

Specific Criteria

The impairment of this waterbody is based on exceedence of the general, or narrative, criteria contained in Missouri's WQS, 10 CSR 20-7.031(3) (A), (C) and (G).

(A) Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.
(B) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.
(C) Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

When the WQS is expressed as a narrative value, a measurable indicator of the pollutant may be selected to express the narrative as a numeric value. There are many quantitative indicators of sediment, such as, TSS, turbidity, and bedload sediment, which are appropriate to describe sediment in rivers and

streams.[12] TSS was selected as the numeric target for this TMDL because it enables the use of the highest quality data available, including permit conditions and monitoring data.

5. Calculation of Load Capacity

Load capacity (LC) is defined as the maximum pollutant load that a waterbody can assimilate and still attain WQS. This total load is then divided among a WLA for point sources, a LA for nonpoint sources and a MOS. The LC for this TMDL has been defined as a curve over the range of flows for Middle Fork Grand River; see Figure 2, where the solid (red) curve is the TMDL. Measurements are shown in Figure 2, where round (black) points are loads calculated from TSS concentrations in Miami Creek and any corresponding horizontal bars (red) are the percent reduction required to meet the TMDL.

The biological assessment (Appendix B) concluded that Middle Fork Grand River is supporting the aquatic life use except for sampling site #2, which is partially supporting. This sediment TMDL is set at no increase in the current sediment loading and a 10% reduction in the current condition is required as a MOS. Turbidity measurements taken during the biological assessment were used to estimate TSS concentrations using relationships developed by Doisey and Rabeni (2004)[13].

Modeling Approach

In cases where pollutant data for the impaired stream is not available a reference approach is used. In this approach, the target for pollutant loading is the 25th percentile of the current EDU condition calculated from all data available within the EDU in which the waterbody is located. Therefore, the 25th percentile is targeted as the TMDL load duration curve. For a full description of the development of suspended sediment targets using reference load duration curves refer to Appendix C. Specific data sources for this TMDL's flow and EDU-wide TSS data are listed in Appendix D. Table 5 shows estimates of discharge at flow percent.

[12] Framework for Developing Suspended and Bedded Sediments (SABS) Water Quality Criteria, U.S. Environmental Protection Agency, EPA-822-R-06-001, May 2006.
[13] Doisey, K>E> and C.F. Rabeni, 2004, Effects of Suspended Sediment on Native Missouri Fishes: A Literature Review and Synthesis, University of Missouri.

Figure 2. TMDL curve over the range of flows.

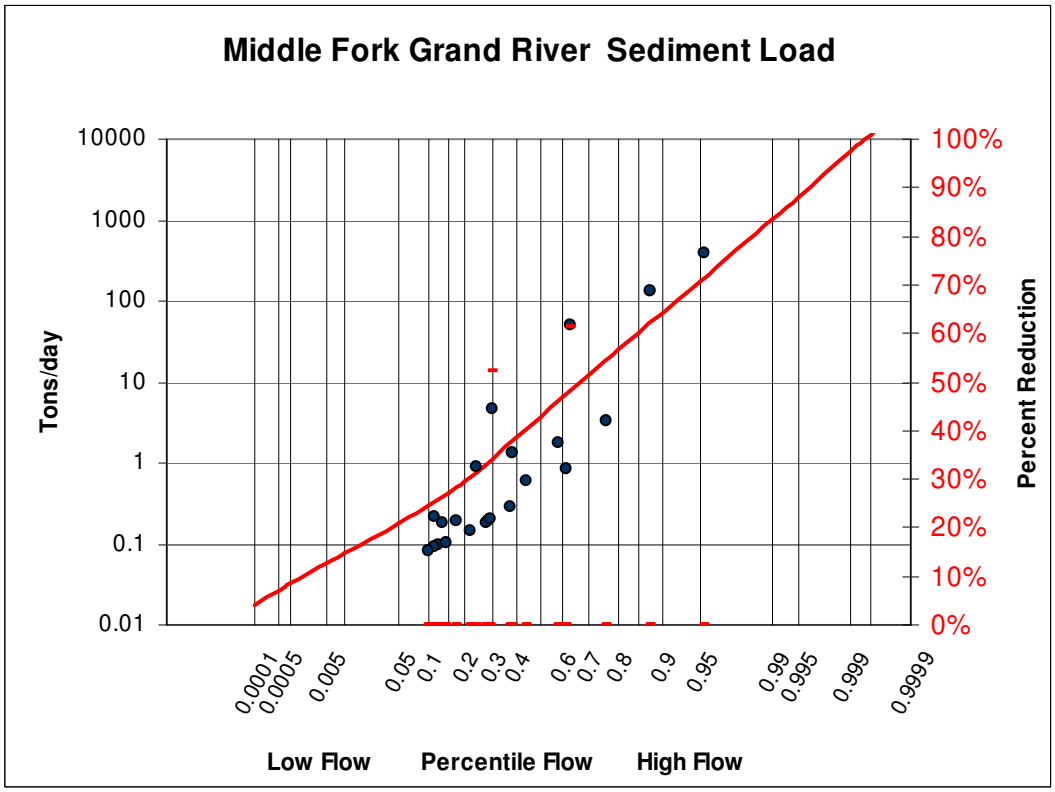


Table 5. Estimated flow for range of percentiles at the impaired segment outlet

	Percent of Flow Occurrence	Discharge (cubic feet per second)
Flow estimate for Middle Fork Grand River based on drainage area and synthetic ecological drainage unit flow.	10	2.3
	30	6.6
	50	14.3
	70	31.6
	90	105

6. Waste Load Allocation (Point Source Loads)

WLA is the allowable amount of the pollutant that can be assigned to point sources. There is one facility in the Missouri portion of the Middle Fork Grand River watershed with a permitted discharge, Grant City West Sanitary Lagoon. The WLA is set to the lesser of current permit limits or technology based effluent limits (TBELs). TBELs are defined in a permit based on facility type. Mechanical WWTFs' permit limits are a weekly average TSS concentration of 45 mg/L and a monthly average TSS concentration of 30 mg/L. Secondary equivalent WWTFs' permit limits are a weekly average TSS concentration of 60 mg/L and a monthly average TSS concentration of 45 mg/L. Wastewater treatment lagoon facilities' permit limits are up to a weekly average TSS concentration of 120 mg/L and a monthly average TSS concentration of 80 mg/L. Additionally, permits can be written to target lower limits if the specific facility is capable of performance exceeding TBELs. Table 6 lists the permitted point sources in the watershed and WLAs based on their current permit limits and permitted design flows. In addition, any general permits need further evaluation to determine if a site specific permit is needed to address sediment loading. Based on the assessment of sources, point sources do not contribute to water quality

impairment relative to sediment impacts on stream biology. Thus, the WLAs are zero percentage net reduction in sediment load. These facilities' WLAs are set at the current permit limits and conditions. The WLAs listed in this TMDL do not preclude the establishment of future point sources of sediment loading in the watershed. Any future point sources should be evaluated in light of the TMDL established and the range of flows into which any additional load will impact.

Table 6. WLAs for permitted facilities

Facility – CAFOs	Permit number		WLA (tons/day) d/w/m*
CG, Ruckman Farm	MO-0118451		0
New Dominion Farms, Inc	MO-G010192		0
Facility-Municipal			
Grant City W Sanitary Lagoon	MO-0027600		NA/0.07/0.05
Facility-Non-Municipal			
Middle Fork Water Company	MO-G640081		Maximum daily settleable solids of 1 mL/L/hr and inclusion of BMPs

*Permit limit concentrations where d=daily, w=weekly average, m=monthly average.

Stormwater runoff from all permitted facilities also discharges to the stream. Compliance with the Missouri Storm Water Permit will ensure construction sites meet the TMDL area weighted loadings.

Permittees will develop a Storm Water Pollution Prevention Plan (SWPPP). The SWPPP ensures the design, implementation, and maintenance of BMPs. EPA assumes that construction activities in the watershed will be conducted in compliance with Missouri's Storm Water Permit including monitoring and discharge limitations. Compliance with this permit should lead to sediment loadings from the construction site at or below applicable targets. Therefore, the WLAs for general permits are set to current conditions plus inclusion of site-specific BMPs. Additionally, facilities in this watershed should be evaluated to ensure that a general permit is appropriate.

7. Load Allocation (Nonpoint Source Loads)

LA is the allowable amount of the pollutant that can be assigned to non-point sources. The LA is set to 90% of the TMDL (Figure 2). Based on measured data from the creek, the percentage of reduction in sediment load ranges to 61% over the range of flows.

8. Margin of Safety

A MOS is added to account for the uncertainties inherent in the calculations and data gathering. The MOS is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the MOS can be achieved through one of two approaches:

(1) Explicit – Reserve a numeric portion of the LC as a separate term in the TMDL.
(2) Implicit – Incorporate the MOS as part of the critical conditions for the WLA and the LA calculations by making conservative assumptions in the analysis.

Available data for Middle Fork Grand River shows instances where load exceeds the TMDL (Figure 2). To account for uncertainties in the modeling an explicit 10% MOS is assigned to this TMDL. For example, at the flow probability of 0.7, the TMDL is approximately 8 tons/day. The LA would therefore be 7.2 tons/day. The MOS would be 0.8 tons/day.

9. Seasonal Variation

The TMDL curve represents flow under all seasonal conditions. The LA and TMDL are applicable at all flow conditions, hence all seasons. The advantage of a LDC approach is to avoid the constraints associated with using a single-flow critical condition during the development of a TMDL. Therefore, all flow conditions including seasonal variation are taken into account for TMDL calculations. Bioassessment data used in this TMDL was generated by MDNR's ESP; invertebrate samplings were collected for two seasons, fall 2004 and spring 2005, see Appendix B.

10. Monitoring Plans for Middle Fork Grand River

The department conducted bioassessments on upper and lower Middle Fork Grand River in 2004-2005, as well as gathering chemistry data from 2000-2005. No future monitoring has been scheduled for Middle Fork Grand River at this time. However, the department will routinely examine physical habitat, water quality, invertebrate community, and fish community data collected by the Missouri Department of Conservation under its Resource Assessment and Monitoring (RAM) Program. This program randomly samples streams across Missouri on a five to six year rotating schedule. In addition, the U.S. Geological Survey currently collects ambient water quality data every other month on the river near Grant City and Worth County. The survey gathers a variety of field and laboratory parameters in this on-going program. .

11. Public Participation

EPA regulations, 40 CFR 130.7, require that TMDLs be subject to public review. EPA is providing public notice of this TMDL for Middle Fork Grand River on the EPA, Region 7, TMDL website: http://www.epa.gov/region07/water/tmdl_public_notice.htm. The response to comments and final TMDL will be available at: http://www.epa.gov/region07/water/apprtmdl.htm#Missouri.

This water quality limited segment of Middle Fork Grand River in Gentry and Worth Counties, Missouri, is included on the approved 1998 and 2002 303(d) lists for Missouri. This TMDL is being produced by EPA to meet the requirements of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001. EPA is developing this TMDL in cooperation with the State of Missouri, and EPA is establishing this TMDL at this time to fulfill the *American Canoe* consent decree obligations. Missouri may submit and EPA may approve another TMDL for this water at a later time.

As part of the public notice process, MDNR will assist EPA by providing a distribution list of interested persons to which EPA will provide an announcement of the Middle Fork Grand River TMDL. Groups that receive the public notice announcement will include the Missouri Clean Water Commission, the Missouri Water Quality Coordinating Committee, Stream Team Volunteers in the county, state legislators, and potentially impacted cities, towns and facilities. The EPA public noticed this TMDL from September 29, 2006, to October 29, 2006, and the Summary of Response to Comments is posted on the EPA website: http://www.epa.gov/region07/water/apprtmdl.htm#Missouri.

12. References

Doisey, K.E. and C.F. Rabeni, 2004, Effects of Suspended Sediment on Native Missouri Fishes: A Literature Review and Synthesis, University of Missouri.

Upper Grand River Basin-10280101, Department of Natural Resources, Water Protection Program, Water Quality Monitoring and Assessment Section, Watershed Information Sheet.

USDA- NASS Quick Stats (Livestock) 2002 Census of Agriculture, Volume 1 Chapter 2: Missouri County Level Data http://www.nass.usda.gov/census/census02/volume1/mo/st29_2_001_001.pdf

Missouri Department of Conservation
http://www.mdc.mo.mdc.mo.gov/fish/watershed/grand/140cotxt.htm

U.S. Department of Agriculture, Soil Conservation Service (USDA-SCS). 1982. The land and water resources of the northern Missouri River tributaries basin - Iowa and Missouri.

U.S. Geological Survey 1988. Water Resources Data Missouri Water Year 1988. United States Department of the Interior, Geological Survey. Rolla, Missouri.

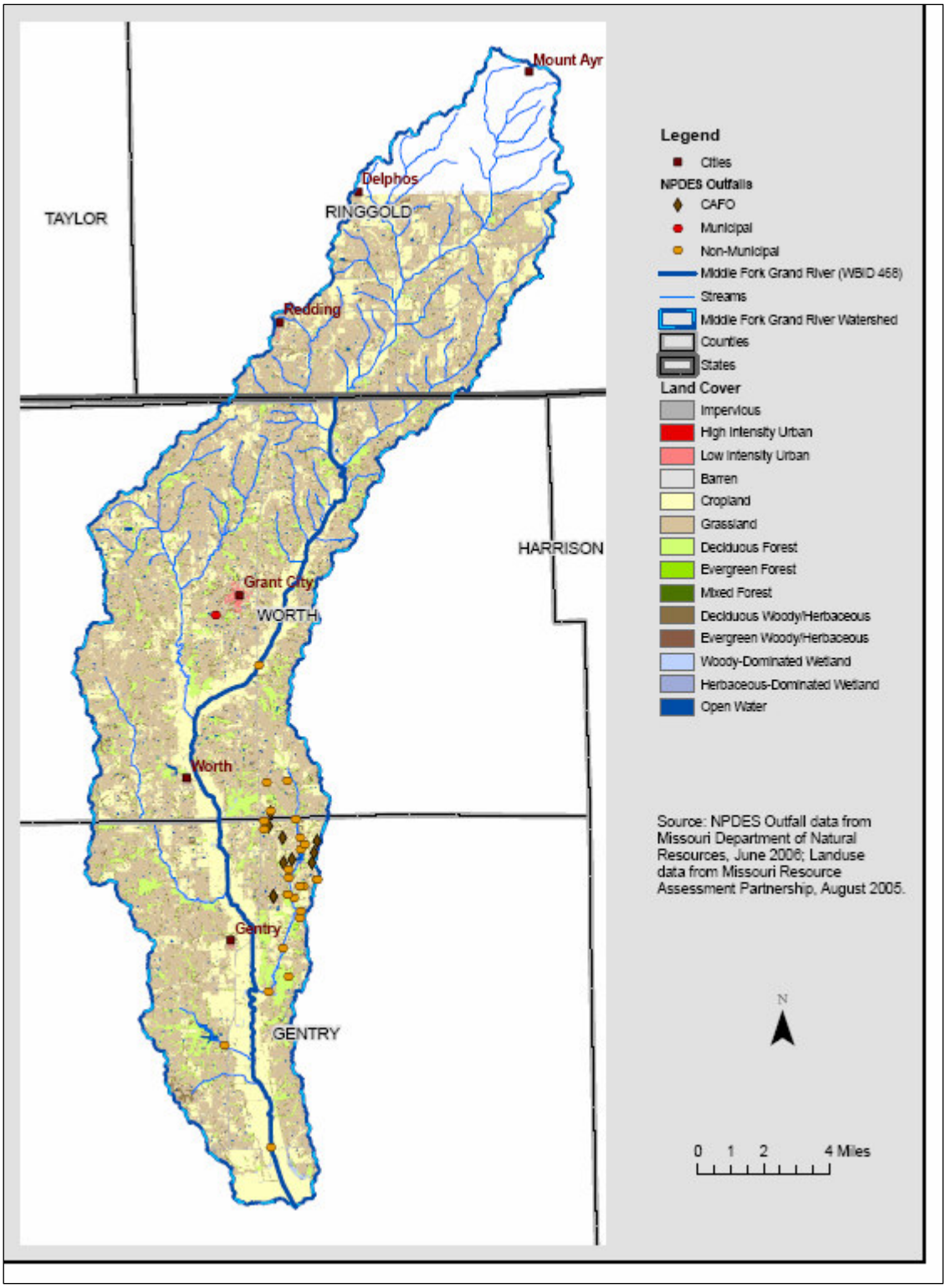
U.S. Army Corps of Engineers (USCOE). 1963. Report on survey for flood control, Grand River and tributaries, Missouri and Iowa. U.S. Army Engineer District, Kansas City, Missouri.

13. Appendices

Appendix A – Maps of Middle Fork Grand River, impaired segment WBID_468 and sampling sites
Appendix B – Middle Fork Grand River Invertebrate Data and Chemistry Data
Appendix C – Development of Suspended Sediment Targets using Reference Load Duration Curves
Appendix D – Data Sources Used to Develop TMDL
Appendix E – Total Maximum Daily Load Information Sheet for Middle Fork Grand River
Appendix F- Biological Assessment and Habitat Study for Middle Fork Grand River

Appendix A

Map of Middle Fork Grand River Watershed and Impaired Segment – WBID 468



SAMPLING SITES

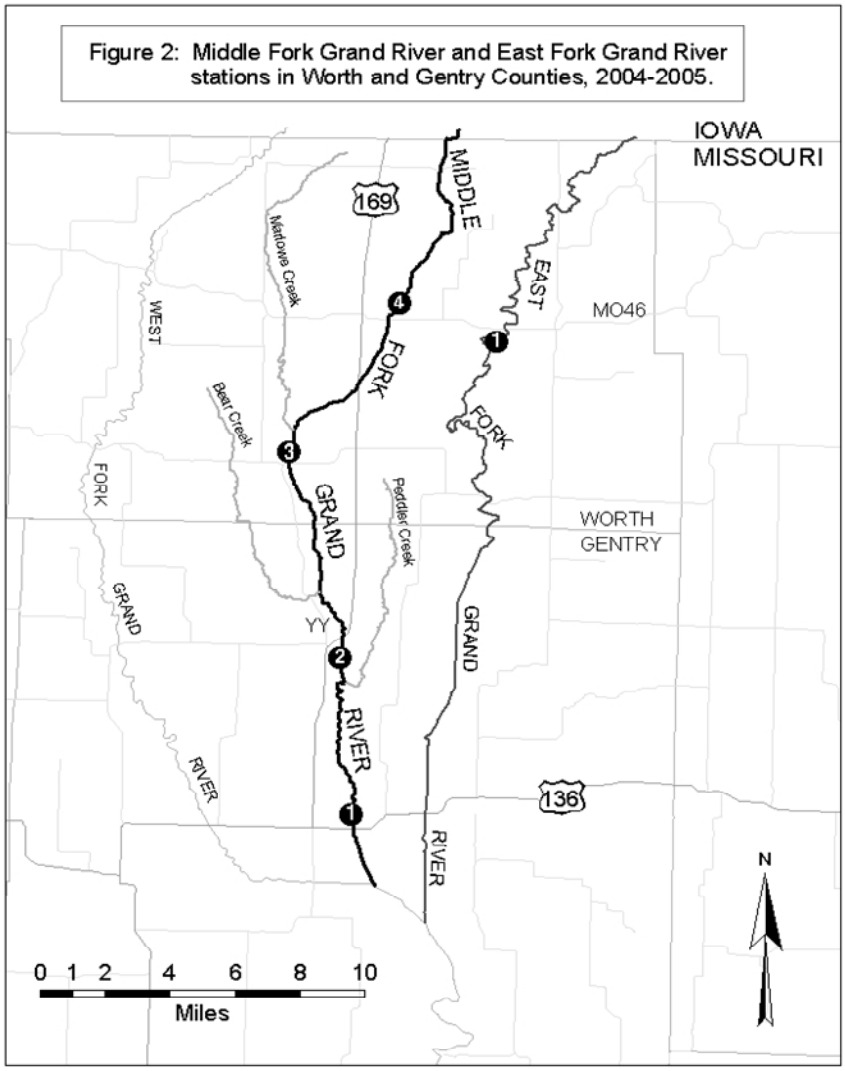


Figure 2: Middle Fork Grand River and East Fork Grand River stations in Worth and Gentry Counties, 2004-2005.

Appendix B

Middle Fork Grand River Biological Assessment Data

Middle Fork Grand River Invertebrate Data

Middle Fork Grand River-WBID		
Aquatic Invertebrate Data by MDNR		
Location	**Fall 2004**	**Spring 2005**
Site 1	20	16
Site 2	20	**14**
Site 3	20	18
Site 4	20	16

Invertebrate scores of 15 or greater are judged to indicate unimpaired streams. Scores less than 15 are judged to be impaired.

Middle Fork Grand River Water Chemistry Data

Site	Site Name	Year	Mo	Day	Flow	C	DO	PH	SC	KJN	NH3N	NO3N	TP	Cl
1	M. Fk. Grand R. nr Grant City	1999	11	10	2	10	10	7.9	572	0	0.03	0.17	0	18
1	M. Fk. Grand R. nr Grant City	2000	1	12	2	0	14.7	8.3	584	0.4	0.0099	0.02499	0.03	0
1	M. Fk. Grand R. nr Grant City	2000	3	22	1.9	16	12.2	8.5	578	0.5	0.02	0.02499	0.07	22
1	M. Fk. Grand R. nr Grant City	2000	5	17	0.18	24	11.7	8.4	500	0.4	0.0099	0.02499	0.2499	0
1	M. Fk. Grand R. nr Grant City	2000	7	12	2	34	7.7	8.3	543	0.7	0.08	0.02499	0.15	0
1	M. Fk. Grand R. nr Grant City	2000	9	7	0.09	23	8.2	8.1	568	0.5	0.08	0.02499	0.11	0
1	M. Fk. Grand R. nr Grant City	2000	11	29	1.2	3	12.3	7.8	533	1.1	0.49	0.25	0.07	19
1	M. Fk. Grand R. nr Grant City	2001	1	4	0.31	0	8.9	63	641	0.68	0.33	0.16	0.05	0
1	M. Fk. Grand R. nr Grant City	2001	3	13	239	3	12.1	7.9	205	2.9	0.64	1.74	1	
1	M. Fk. Grand R. nr Grant City	2001	5	1	74	24	7.5	8.1	327	2.8	0.05	0.87	0.81	23
1	M. Fk. Grand R. nr Grant City	2001	7	12	4.2	24	8.1	8.3	501	0.36	0.0199	0.02499	0.09	
1	M. Fk. Grand R. nr Grant City	2001	9	19	4.5	16	9.1	8.2	468	0.33	0.0199	0.04	0.07	
1	M. Fk. Grand R. nr Grant City	2001	11	7	3.2	18.5	10.6	8.3	519	0.34	0.0199	0.02499	0.09	49.1
1	M. Fk. Grand R. nr Grant City	2002	1	16	2.3	0.5	13.2	8.3	688	0.82	0.26	1.79	0.04	
1	M. Fk. Grand R. nr Grant City	2002	3	13	4.4	6	11.4	8.2	519	0.46	0.05	0.59	0.06	
1	M. Fk. Grand R. nr Grant City	2002	5	8	28	18.5	7.9	8.1	387	1.3	0.07	1.23	0.38	35.4
1	M. Fk. Grand R. nr Grant City	2002	7	31	0.4	24	7	8.1	533	0.37	0.0199	0.02499	0.09	
1	M. Fk. Grand R. nr Grant City	2002	9	4	0.15	20.5	7.3	8	506	0.37	0.0199	0.02499	0.09	
1	M. Fk. Grand R. nr Grant City	2002	11	6	0.96	4.5	11.6	7.9	555	0.28	0.0199	0.0299	0.06	55
1	M. Fk. Grand R. nr Grant City	2003	1	15	0.41	0.5	12.6	8	749	0.25	0.0199	0.0299	0.02	
1	M. Fk. Grand R. nr Grant City	2003	3	27	0.46	11	9.5	8.2	560	0.4	0.0199	0.0299	0.06	
1	M. Fk. Grand R. nr Grant City	2003	5	21	4.2	15	9.1	8.2	577	0.6	0.03	0.46	0.09	50
1	M. Fk. Grand R. nr Grant City	2003	7	16	0.39	22.5	6.6	8	505	0.66	0.0199	0.0299	0.15	
1	M. Fk. Grand R. nr Grant City	2003	9	3	0.01	28.5	9.1	8.2	507	0.32	0.0199	0.0299	0.08	
1	M. Fk. Grand R. nr Grant City	2003	11	5	22	5.5	80	7.9	311	1.4	0.21	1.8	0.64	19
2	M. Fk. Grand R. ab.Hwy 136	2004	9	14	8.29	24.5	7.7	7.7	485	0.52	0.01499	0.02	0.07	
3	M. Fk. Grand R. bl.Hwy 169	2004	9	14	5.2	25.5	7	7.7	519	0.41	0.01499	0.00499	0.08	
4	M. Fk. Grand R. ab. Hwy YY	2004	9	14	3.32	28.5	7.9	8.3	549	0.57	0.01499	0.00499	0.09	
5	M. Fk. Grand R. @Grant City	2004	9	15	3.27	21	6.3	7.6	534	0.53	0.01499	0.03	0.1	
1	M. Fk. Grand R. nr Grant City	2004	1	22	1.1	0.5	14.9	7.9	311	1.4	0.21	1.8	0.64	30
1	M. Fk. Grand R. nr Grant City	2004	3	24	8.2	10	11.2	7.8	472	1.3	0.49	1.19	0.09	
1	M. Fk. Grand R. nr Grant City	2004	5	19	40	24.5	7.4	8.1	510	0.53	0.0199	1.89	0.09	
1	M. Fk. Grand R. nr Grant City	2004	7	8	5.7	21	9.3	8	386	2.3	0.21	4.97	0.73	21
1	M. Fk. Grand R. nr Grant City	2004	9	9	3.5	27	7.8	8.4	543	0.7	0.0199	0.04	0.11	
2	M. Fk. Grand R. ab.Hwy 136	2005	3	23	19.3	5.5	13.4	8.2	531	0.46	0.0199	0.0299	0.1	
3	M. Fk. Grand R. bl. Hwy 169	2005	3	23	19.7	6	13.4	8.2	523	0.2	0.01499	0.00499	0.06	
4	M. Fk. Grand R. ab. Hwy YY	2005	3	23	16.3	7	13.5	8.1	532	0.24	0.01499	0.00499	0.05	
5	M. Fk. Grand R. @Grant City	2005	3	23	9.8	9	13.5	8.2	558	0.3	0.01499	0.01	0.07	
								8.2	526	0.25	0.01499	0.00499	0.07	
Water Quality Standard						32	5	6.5-9			2.0*			230

The ammonia standard is water temperature and pH dependent. The 2.0 mg/L estimated standard is based on typical summer water

Appendix C

Development of Suspended Sediment Targets using Reference Load Duration Curves

Overview

This procedure is used when a lotic system is placed on the 303(d) impaired waterbody list for a pollutant and the designated use being addressed is aquatic life. In cases where pollutant data for the impaired stream is not available a reference approach is used. The target for pollutant loading is the 25th percentile calculated from all data available within the ecological drainage unit (EDU) in which the waterbody is located. Additionally, it is also unlikely that a flow record for the impaired stream is available. If this is the case a synthetic flow record is needed. In order to develop a synthetic flow record calculate an average of the log discharge per square mile of USGS gaged rivers for which the drainage area is entirely contained within the EDU. From this synthetic record develop a flow duration from which to build a load duration curve for the pollutant within the EDU.

From this population of load durations follow the reference method used in setting nutrient targets in lakes and reservoirs. In this methodology the average concentration of either the 75th percentile of reference lakes or the 25th percentile of all lakes in the region is targeted in the TMDL. For most cases available pollutant data for reference streams is also not likely to be available. Therefore follow the alternative method and target the 25th percentile of load duration of the available data within the EDU as the TMDL load duration curve. During periods of low flow the actual pollutant concentration may be more important than load. To account for this during periods of low flow the load duration curve uses the 25th percentile of EDU concentration at flows where surface runoff is less than 1% of the stream flow. This results in an inflection point in the curve below which the TMDL is calculated using this reference concentration.

Methodology

The first step in this procedure is to locate available pollutant data within the EDU of interest. These data along with the instantaneous flow measurement taken at the time of sample collection for the specific date are recorded to create the population from which to develop the load duration. Both the date and pollutant concentration are needed in order to match the measured data to the synthetic EDU flow record.

Secondly, collect average daily flow data for gages with a variety of drainage areas for a period of time to cover the pollutant record. From these flow records normalize the flow to a per square mile basis. Average the log transformations of the average daily discharge for each day in the period of record. For each gage record used to build this synthetic flow record calculate the Nash-Sutcliffe statistic to determine if the relationship is valid for each record. This relationship must be valid in order to use this methodology. This new synthetic record of flow per square mile is used to develop the load duration for the EDU. The flow record should be of sufficient length to be able to calculate percentiles of flow.

The following examples show the application of the approach to one Missouri EDU.

The watershed-size normalized data for the individual gages in the EDU were calculated and compared to a pooled data set including all of the gages. The result of this analysis is displayed in the following figure and table:

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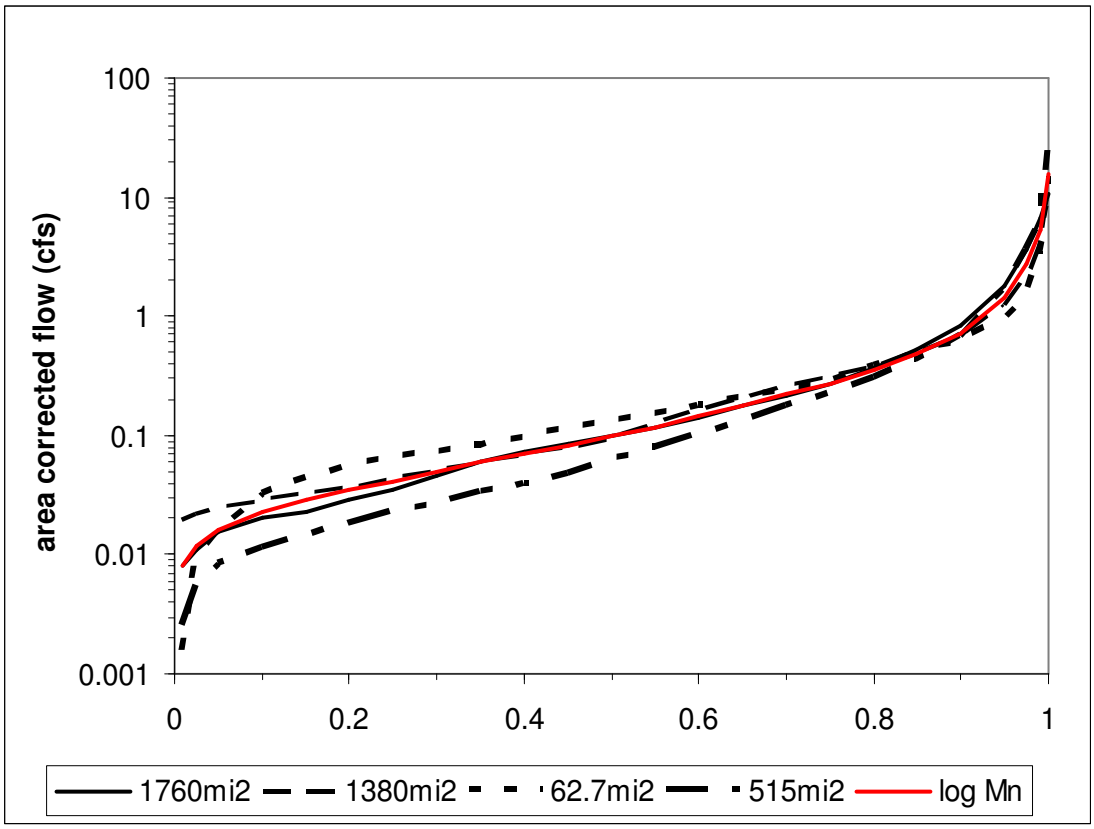
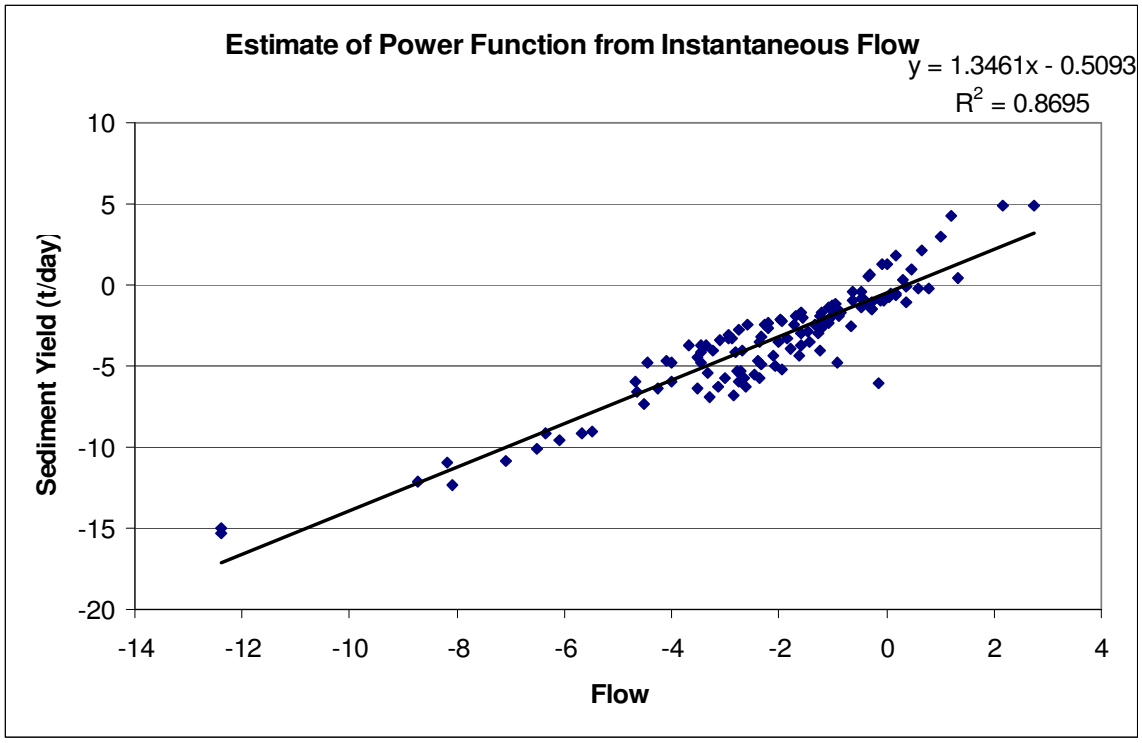


Gage	gage	area (mi^2)	normal Nash-Sutcliffe	lognormal Nash-Sutcliffe
Platte River	06820500	1760	80%	99%
Nodaway River	06817700	1380	90%	96%
Squaw Creek	06815575	62.7	86%	95%
102 River	06819500	515	99%	96%

This demonstrates the pooled data set can confidently be used as a surrogate for the EDU analyses.

The next step is to calculate pollutant-discharge relationships for the EDU, these are log transformed data for the yield (tons/mi^2/day) and the instantaneous flow (cfs/mi^2.) The following graph shows the EDU relationship:



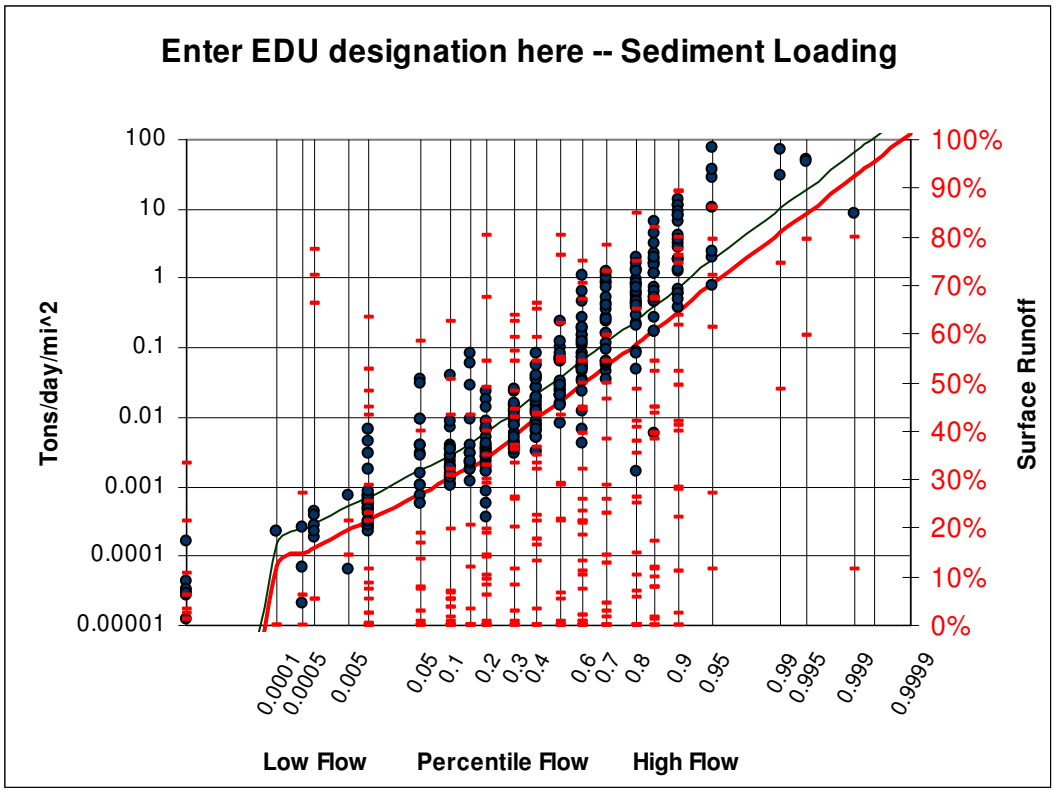
Further statistical analyses on this relationship are included in the following Table:

m	1.34608498	b	-0.509320019
Standard Error (m)	0.04721684	Standard Error (b)	0.152201589
r^2	0.86948229	Standard Error (y)	1.269553159
F	812.739077	DF	122
SSreg	1309.94458	SSres	196.6353573

The standard error of y was used to estimate the 25%ile level for the TMDL line. This was done by adjusting the intercept (b) by subtracting the product of the one-sided Z_{75} statistic times the standard error of (y). The resulting TMDL Equation is the following:

*Sediment yield (t/day/mi^2)=exp(1.34608498 * ln (flow) - 1.36627)*

A resulting pooled TMDL of all data in the watershed is shown in the following graph:



To apply this process to a specific watershed would entail using the individual watershed data compared to the above TMDL curve that has been multiplied by the watershed area. Data from the impaired segment is then plotted as a load (tons/day) for the y-axis and as the percentile of flow for the EDU on the day the sample was taken for the x-axis.

For more information contact:
Environmental Protection Agency, Region 7
Water, Wetlands, and Pesticides Division
Total Maximum Daily Load Program
901 North 5th Street
Kansas City, Kansas 66101
Website: http://www.epa.gov/region07/water/tmdl.htm

Appendix D

USGS stream gages used to generate synthetic flow

Grand River nr Gallatin	06897500
Thompson River at Trenton	06899500
Grand River nr Sumner	06902000
East Fork Little Chariton nr Huntsville	06906300
Mussel Fork nr Mussel Fork	06906000
East Fork Little Chariton nr Macon	06906200

USGS stream sample sites used to generate EDU TMDL

Chariton River nr Prairie Hill	06905500
Mussel Fork nr Mystic	06905725
Mussel Fork nr Mussel Fork	06906000
North River nr Dunlap	06899580
Thompson River nr Mount Moriah	06898100
Weldon River nr Princeton	06898800
Little Medicine Creek nr Harris	06900100
Locust Creek nr Unionville	06900900
East Fork Little Chariton nr Macon	06906200
East Fork Little Chariton nr Huntsville	06906300

Appendix E

Missouri Department of Natural Resources
Total Maximum Daily Load Information Sheet

For Streams with Aquatic Habitat Loss that are Listed for Sediment

Waterbody Segment at a Glance:

Location: Streams in Northern and West Central Missouri and in the Mississippi Embayment of
Southeast Missouri and the Missouri and Mississippi Rivers.

Impairment: In 1998 the Department of Natural Resources listed 38 streams with habitat impairment due to agricultural nonpoint source problems. Twelve of them were delisted because new data showed they were higher quality reference streams, not impaired by sediment. One of them was retained on the list for "unknown" pollutants. The other 25 of them appear on the 2002 US EPA 303(d) list for Missouri as being impaired by "sediment".

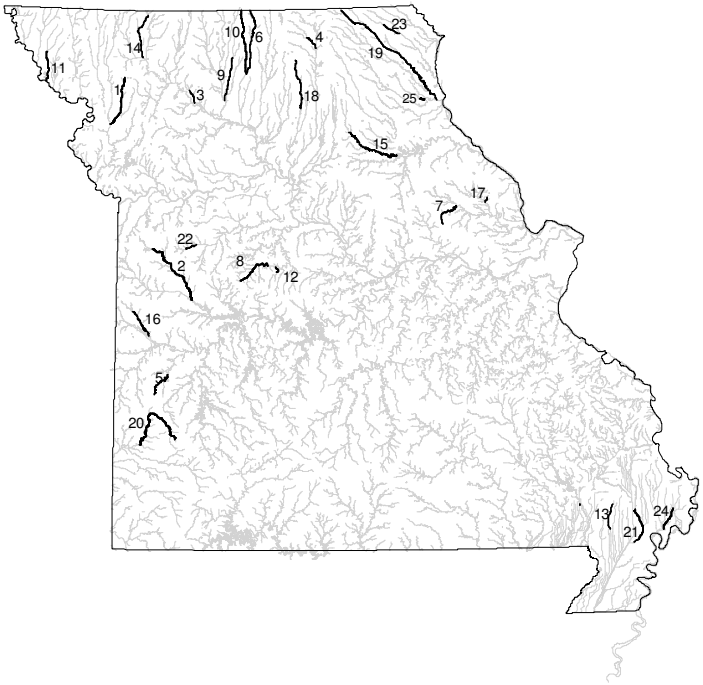
Description of the Problem

All of these waters, as per Missouri Water Quality Standards, must provide a suitable home for aquatic life. A combination of natural geology and land use in the prairie portions of the state and the Mississippi Embayment is believed to have reduced the amount and impaired the quality of aquatic habitat. The major problems are excessive rates of sediment deposition due to streambank erosion and sheet erosion from agricultural lands, loss of stream length and loss of stream channel heterogeneity due to channelization, and changes in basin hydrology that have increased flood flows and prolonged low flow conditions. Loss of tree cover in riparian zones has caused elevated water temperatures in summer and a reduction in woody debris, a critical aquatic habitat component in prairie streams. The most compelling evidence of loss or impairment of aquatic habitat is the historical change in distribution of fishes in Missouri. Many species of fish no longer appear in portions of the state where they once lived.

The department proposed changing the listing of "sediment" to "habitat loss." This change was proposed because sediment is often an important, but certainly not the only, pollutant or condition causing degradation of aquatic habitat in these streams. With this proposed change, other problems such as channelization, alteration of streambanks and riparian zones, and alteration of normal flow regimes would be included as conditions contributing to impairment. The US Environmental Protection Agency denied this change because habitat loss is "pollution", not a specific "pollutant" that can be measured and calculated. This is necessary because a TMDL (Total Maximum Daily Load) is a numeric calculation.

The department is developing a sediment protocol to determine if sediment is actually the pollutant in these streams and a standard way to measure sediment.

Missouri Streams with Loss of Habitat due to Agricultural Non-Point Source Pollution



#	Waterbody	County (lower section)	Miles affected		#	Waterbody	County (lower section)	Miles affected
1	3rd Fork Platte River	Buchanan	31.5		14	M. Fork Grand River	Gentry	25
2	Big Creek	Henry	49		15	M. Fork Salt River	Monroe	49
3	Big Muddy Creek	Daviess	8		16	Miami Creek	Bates	18
4	Clear Creek	Adair	10.5		17	Mill Creek	Lincoln	4
5	Clear Creek	Vernon	18		18	Mussel Fork	Macon	29
6	E. Fork Medicine Cr.	Grundy	36		19	N. Fabius River	Marion	82
7	Elkhorn Creek	Montgomery	19		20	N. Fork Spring River	Jasper	51.5
8	Flat Creek	Pettis	20		21	Old Channel Little R.	New Madrid	20
9	Honey Creek	Livingston	23		22	S. Fork Blackwater R.	Johnson	5
10	Little Medicine Creek	Grundy	40		23	S. Wyaconda River	Clark	9
11	Little Tarkio Creek	Holt	17.5		24	Spillway Ditch	New Madrid	13.5
12	Lake Creek	Pettis	5		25	Troublesome Creek	Marion	3.5
13	Lateral #2 Main Ditch	Stoddard	11.5					

Appendix F

Biological Assessment and Channel Evaluation Report

Middle Fork Grand River
Worth and Gentry Counties,
Missouri

2004-2005

Prepared for:
Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Program
Water Pollution Branch

Prepared by:
Missouri Department of Natural Resources
Field Services Division
Environmental Services Program
Water Quality Monitoring Section

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Appendix B Channel Measurement Comparisons: Mann-Whitney Rank Sum Tests (mw) or Studentized t-Test (ttest)

1.0 Introduction

The Middle Fork Grand River flows southerly into northwest Missouri from Iowa (Figure 1). In Missouri, the stream travels for approximately 25 miles to its confluence with the West Fork Grand River, where it becomes the Grand River (Figure 2). The Middle Fork Grand River has a 226-sq. mi. drainage area with a 36-mile long channel (Funk 1968).

The Middle Fork Grand River is considered a class "P" stream, which maintains permanent flow even in periods of drought. The Middle Fork Grand River has designated uses (MDNR 2005c) for irrigation (**IRR**); livestock and wildlife watering (**LWW**); protection of warm water aquatic life and human health-fish consumption (**AQL**); whole body contact (**WBC**), category A; and secondary contact recreation (**SCR**).

1.1 Justification

The Middle Fork Grand River, Worth and Gentry Counties is on the Missouri Department of Natural Resources 2002 list of impaired waters under section 303(d) of the Federal Clean Water Act. Middle Fork Grand River is included on the 303(d) list for excessive sediment problems from agriculture non-point sources (**Ag.NPS**). The section 303(d) listed reach has a "Medium" priority for evaluation.

The Middle Fork Grand River study was conducted at the request of the Missouri Department of Natural Resources (**MDNR**), Water Protection Program (**WPP**), Water Pollution Control Branch (**WPCB**).

A biological assessment was conducted on Middle Fork Grand River, Worth and Gentry Counties in the fall of 2004 and spring of 2005. A stream habitat assessment was conducted and channel morphology was measured in fall 2004. The Aquatic Bioassessment Unit of the Environmental Services Program (**ESP**), Water Quality Monitoring Section (WQMS) coordinated this study. Kenneth B. Lister, David Michaelson, and staff of the Water Quality Monitoring Section conducted the study.

1.2 Purpose

Determine if Middle Fork Grand River is biologically impaired in the 303(d) listed study reach.

1.3 Objectives

1) Assess the macroinvertebrate community integrity and water quality in Middle Fork Grand River.

2) Assess the stream habitat quality of Middle Fork Grand River.

3) Measure and compare stream morphology and channel modifications.

1.4 Tasks

1) Conduct a stream habitat assessment for Middle Fork Grand River and East Fork Grand River.

2) Conduct a biological assessment, including macroinvertebrate and water physicochemical collection and analyses, for Middle Fork Grand River.

3) Compare biological assessment results to wadeable/perennial stream biological criteria and metrics between stations.

4) Compare physicochemical water quality from upstream to downstream as well as with Water Quality Standards (MDNR 2000).

5) Record and analyze channel measurements at Middle Fork Grand River and compare with East Fork Grand River, an unchannelized stream.

1.5 Null Hypotheses

Stream habitat assessment will be similar between test stations and the stream habitat control station.

Middle Fork Grand River, Worth and Gentry Counties will be similar to wadeable/perennial stream biological criteria, as well as between all stations.

Physicochemical water quality will be similar at all stations and acceptable with Missouri Water Quality Standards (MDNR 2005c).

Channel measurements will be similar between the test stations and control station.

2.0 Methods

The study area, station descriptions, Ecological Drainage Units (**EDUs**), and land use are identified. The study timing is outlined. Methods are included for stream habitat assessments, biological assessments, and physicochemical water quality collection.

2.1 Study Area and Station Descriptions

The study area included approximately 25 miles on Middle Fork Grand River in Worth and Gentry Counties (Table 1; Figure 1). Four stations were allocated for this study and were positioned approximately five miles apart (Table 1; Figure 2). Station #4 was located upstream of Missouri Highway 46, approximately one mile east of Grant, Missouri. Station #3 was located upstream of the Highway YY bridge, north of Worth, Missouri. Station #2 was located downstream of U.S. Highway 169, 0.5 miles east of Gentry, Missouri. Station #1 was located upstream of U.S. Highway 136 approximately five miles west of Albany, Missouri. A single station was allocated for stream habitat assessment and channel measurement controls on East Fork Grand River, Worth County. This station was approximately five miles east of Grant, Missouri and downstream of Missouri Highway 46.

Table 1
Location and Descriptive Information for Middle Fork Grand River and East Fork Grand River, Worth and Gentry Counties, 2004-2005

Stream-Station Number	Location-Section, Township, Range	Description	County
Middle Fork Grand River #4	SE ¼ sec. 27, T. 66 N., R. 31 W.	Upstream bridge MO Hwy. 46	Worth
Middle Fork Grand River #3	SE ¼ sec. 24, T. 65 N., R. 32 W.	Upstream bridge County Road YY	Worth
Middle Fork Grand River #2	SE ¼ sec. 20, T. 64 N., R. 31 W.	Downstream bridge U.S. Hwy. 169	Gentry
Middle Fork Grand River #1	SW ¼ sec. 21, T. 63 N., R. 31 W.	Upstream bridge U.S. Hwy. 136	Gentry
East Fork Grand River #1 (SHAPP and Channel Measure)	N ½ sec. 32, T. 66 N., R. 30 W.	Downstream bridge MO Hwy. 46	Worth

2.1.1 Ecological Drainage Unit

The Middle Fork Grand River is within the Plains/Grand/Chariton EDU (Figure 1). Ecological Drainage Units are delineated drainage units in which similar size streams are expected to contain similar aquatic communities and stream habitat conditions. Comparisons of biological and physicochemical results between test streams and similar size reference streams within the same EDU should then be appropriate.

2.1.2 Land Use Description

Land cover of the Plains/Grand/Chariton EDU was compared to the 14-digit Hydrological Unit (**HUC-14**; Table 2) land cover of each station on Middle Fork Grand River and the East Fork Grand River. Percent land cover data were derived from Thematic Mapper (TM) satellite data collected between 2000 and 2004 and interpreted by the Missouri Resource Assessment Partnership (**MoRAP**).

The dominant land cover in the immediate watershed of all stations was grassland, followed by crops (Table 2). All stations were relatively similar in percentages, with grassland in the range of 54-64 percent and crops in the range of 23 to 35 percent. The EDU was similar to the individual HUCs with 53 percent grassland and 30.3 percent crops. All other categories were similar between stations and the EDU. Similarities suggest that land use should not effect interpretation of the findings.

2.2 Study Timing

Sampling was conducted in the fall of 2004 and the spring of 2005. Stream habitat assessments were conducted and channel measurements recorded at Middle Fork stations on September 7 and 8, 2004. Fall macroinvertebrate and physicochemical water

sampling was conducted on September 14 and 15, 2004. East Fork Grand River channel measurements were recorded on October 5, 2004. Spring sampling included macroinvertebrate collections and physicochemical samples and measurements on March 23, 2005.

Table 2

Percent Land Cover in the Middle Fork Grand River and East Fork Grand River Stations and Plains/Grand/Chariton EDU

Stations	HUC-14	Urban	Crops	Grassland	Forest	Swamp
Middle Fork Grand River #4	10280101050004	0.1	24.3	64.1	11.2	0
Middle Fork Grand River #3	10280101050005	0	31.1	57.1	11.4	0
Middle Fork Grand River #2	10280101050007	0	32.8	54.2	12.7	0
Middle Fork Grand River #1	10280101050008	0	34.7	55.8	9.2	0
East Fork Grand River #1	10280101060008	0	23.4	61.4	14.9	0
Plains/Grand/ Chariton EDU	--	0.2	30.3	53.0	15.2	0.1

2.3 Stream Habitat Assessment Project Procedure

The standardized Stream Habitat Assessment Project Procedure (**SHAPP**) was followed as described for Glide/Pool prevalent streams (MDNR 2003d). Stream habitat assessment scores were compared between test stations from upstream to downstream and between the scores at test and control stations. According to the SHAPP, the quality of an aquatic community is based on the stream's ability to support the aquatic community. If SHAPP scores at test stations are ≥75% of the mean control scores, the stream habitat at the test station is considered to be comparable to the reference (control) stream. East Fork Grand River, Worth County was used as the control (Figure 2). Stream habitat assessment scores were compared from upstream to downstream and with the SHAPP control.

2.4 Biological Assessment

Sampling was conducted as described in the MDNR Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (**SMSBPP,** MDNR 2003c). Biological assessments consisted of macroinvertebrate community and physicochemical water collection and analyses. Macroinvertebrates and physicochemical water variables were analyzed at four stations in Middle Fork Grand River, Worth and Gentry Counties.

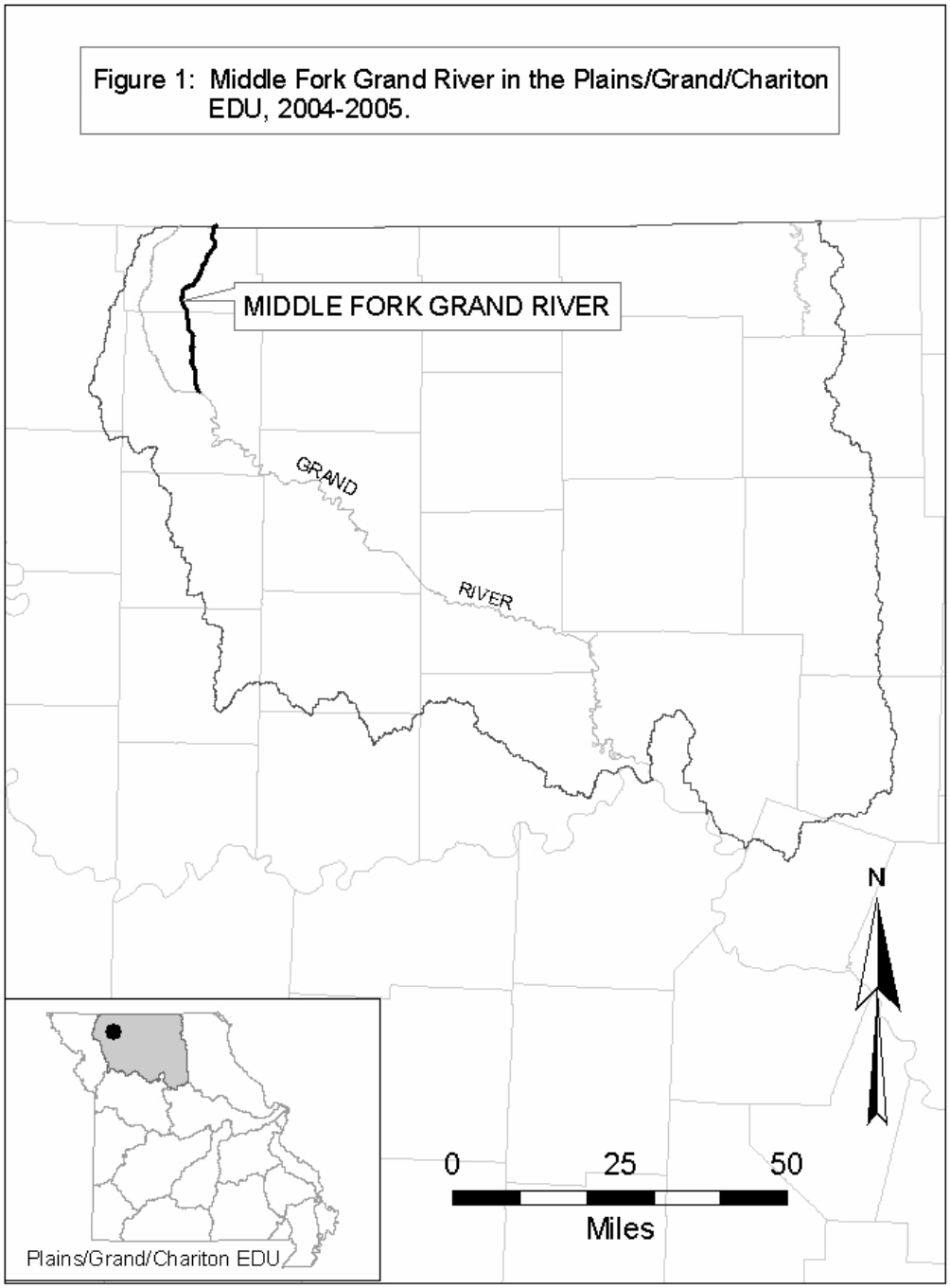

Figure 1: Middle Fork Grand River in the Plains/Grand/Chariton EDU, 2004-2005.

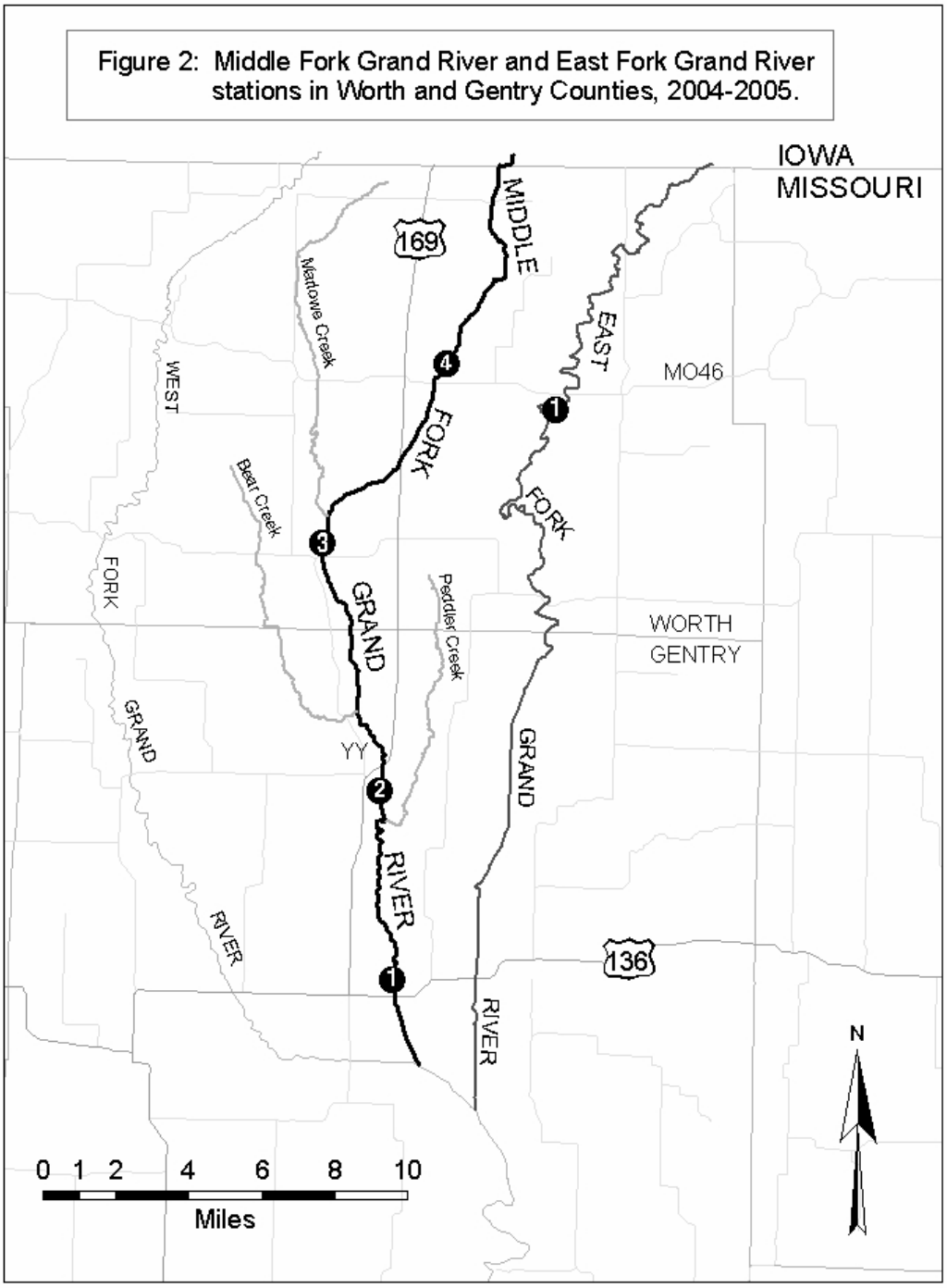

Figure 2: Middle Fork Grand River and East Fork Grand River stations in Worth and Gentry Counties, 2004-2005.

2.4.1 Macroinvertebrate Sampling

Macroinvertebrates were sampled from multiple habitats as described in the SMSBPP. Middle Fork Grand River is considered a glide/pool dominant stream and habitats were sampled accordingly. Non-flowing water over depositional substrate (**NF**), large woody debris (**SG**), and rootmat (**RM**) habitats were sampled.

Macroinvertebrate community data were analyzed using three strategies. Stream Condition Index (**SCI**) scores, individual biological criteria metrics, and dominant macroinvertebrate families (**DMF**) were examined and compared from upstream to downstream.

A Stream Condition Index is a qualitative rank measurement of a stream's aquatic biological integrity (Rabeni et al. 1997). The SCI was further refined for reference streams within each EDU in Biological Criteria for Perennial/Wadeable Streams (**BIOREF,** MDNR 2002).

A station's SCI score is a compilation of rank scores that were assigned to individual biological criteria metrics as a measure of biological integrity. Four primary biological criteria metrics were used to calculate the SCIs per station: 1) Taxa Richness (**TR**); 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**); 3) Biotic Index (**BI**); and 4) Shannon Diversity Index (**SDI**). Metric scores were compared to the BIOREF scoring range (SCI Scoring Table, Tables 4 and 5) and rank scores (5, 3, 1) were assigned to each metric (Tables 4 and 5). For each station, rank scores were compiled from all metrics and the SCI was completed. The SCI scores are interpreted as follows: 20-16 = full biological support; 14-10 = partial biological support; and 8-4 = non-support of the biological community. SCI scores were compared between stations and grouped by season.

Secondly, the individual biological criteria metrics for each station were compared to the BIOREF scoring range to identify the level of integrity for each individual metric. Variations in the metrics may help identify how a community is affected and the potential source of impairment.

The third biological analysis was an evaluation of the "dominant macroinvertebrate families" (**DMF**) per station. The DMFs are listed as a percentage of the total number of individuals in the sample. Dominance by certain families may also help identify the type and source of impairment. A taxa list reported by season and station is attached as Appendix A.

2.4.2 Physicochemical Water Sampling

Physicochemical water samples were handled according to the appropriate MDNR, ESP Standard Operating Procedure (**SOP**) and/or Project Procedure (**PP**) for sampling and analyzing physicochemical water samples. Results for physicochemical water variables were examined by season and station.

Fall 2004 and spring 2005 physicochemical water parameters consisted of field measurements and grab samples that were returned to the ESP environmental laboratory. Water was sampled according to the SOP MDNR-FSS-001 Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations (MDNR 2003b). All samples were kept on ice during transport to ESP.

Temperature (C^o), pH, conductivity (uS), dissolved oxygen (mg/L), and discharge (cubic feet per second-**cfs**) were measured in the field. The ESP, Chemical Analysis Section (**CAS**) in Jefferson City, Missouri conducted analyses for ammonia-nitrogen (mg/L), nitrate+nitrite-nitrogen (mg/L), Total Kjeldahl Nitrogen (**TKN**; mg/L), chloride (mg/L), and total phosphorus (mg/L). Turbidity (NTU) was measured and recorded in the WQMS biology laboratory.

Physicochemical water parameters were compared between stations from upstream to downstream as well as with acceptable limits in Missouri's Water Quality Standards (**WQS**, MDNR 2005c). Interpretation of acceptable limits in the WQS may be dependent on a stream's classification and its beneficial-use designation (MDNR 2005c). Middle Fork Grand River is a class "P" stream, with designated uses for IRR, LWW, AQL, WBC, and SCR. Furthermore, acceptable limits for some parameters may be dependent on the rate of exposure. These exposure or toxicity limits are based on the lethality of a toxicant given long (chronic toxicity, **c**) or short-term exposure (acute toxicity, **a**).

2.4.3 Discharge

Stream flow was measured using a Marsh-McBirney Flowmate™ flow meter at each station. Velocity and depth measurements were recorded at each station according to SOP MDNR-WQMS-113 Flow Measurement in Open Channels (MDNR 2003a).

2.5 Channel Measurements

Channelized streams may be wider and shallower than non-channelized streams (MDNR 2005a). Basic channel morphology was measured to illustrate the size and shape of the stream as well as potentially identify channelization.

Channel measurements included wetted width, depth, channel width, and sinuosity. Wetted width included the width that contained water and was measured from edge to edge of the water filled channel. The depth of the stream was measured within the wetted width and was taken at three depth measurement points which correspond to ¼, ½, and ¾ wetted width distance. The standard deviation of depth (S.D. of Depth) was calculated to illustrate variability of depth. Channel width included the width of the normal high water channel between the top of the lower banks as described in MDNR 2003d. A wetted width to channel width ratio illustrated the normal low flow width to high flow width at each station. Channel measurements were recorded (in feet) at ten transects within each station. Stream length is the length of each station, which is defined as approximately 20 times the average channel width (MDNR 2003c).

Sinuosity is a ratio of the actual distance per straight-line (aerial) distance between two points that are approximately two miles apart. The sampling station was located near the center of the two-mile segment.

The data was examined for similarities between stations as well as with the control station. Further data analysis included statistical comparisons of channel measurements using SigmaStat, Version 2.0 (1997).

2.6 Quality Control

Quality control was utilized in accordance with MDNR SOPs and Project Procedures.

3.0 Results and Analyses

Results are grouped by stream habitat assessment, biological assessment, and channel measurements. Trends and exceptional results are highlighted.

3.1 Stream Habitat Assessment

Stream habitat assessment scores (Table 3) decreased slightly from upstream to downstream with an average of 90.5. The test stations were comparable to the SHAPP control score.

Table 3
Stream Habitat Assessment Scores for Middle Fork Grand River (MFG) and East Fork Grand River (EFG), Fall 2004

	MFG #4	MFG #3	MFG #2	MFG #1	EFG #1
SHAPP Scores	106	95	83	78	95
Percent of SHAPP Control Score (East Fork Grand River)	112	100	87	82	--

3.2 Biological Assessment

Biological assessments consist of macroinvertebrate community analyses and physicochemical water quality analyses. Results are compared between stations from upstream to downstream.

3.2.1 Macroinvertebrate Community Analyses

The macroinvertebrate community is examined in this section. Stream condition index (SCI) scores, individual metric scores, and dominant macroinvertebrate families are examined from upstream to downstream.

3.2.1.1 Stream Condition Index Scores and Individual Biological Criteria Metrics

All stations were placed in the "full biological support category" in the fall (Table 4). Furthermore, all stations received SCI scores of 20. The BIOREF "optimum" scores were exceeded by all individual metrics that derived the SCI.

Table 4

Fall 2004 Biological Criteria (n=15) Metric Scores and Stream Condition Index (SCI) Scores for Middle Fork Grand River (MFG) Stations, Worth and Gentry Counties

Stream Station Number	Sample No.	TR	EPTT	BI	SDI	SCI	Biological Support Category
MFG #4	0418721	65	14	7.02	2.92	20	Full
MFG #3	0418720	76	16	6.72	3.19	20	Full
MFG #2	0418719	74	17	6.49	3.24	20	Full
MFG #1	0418718	70	18	6.66	3.23	20	Full
BIOREF Score=5	--	>51	>9	<7.20	>2.68	20-16	Full
BIOREF Score=3	--	51-26	9-4	7.20-8.60	2.68-1.34	14-10	Partial
BIOREF Score=1	--	<26	<4	>8.60	<1.34	8-4	Non

(SCI Scoring Table in light gray)

The spring SCI (Table 5) indicates most stations were placed in the full biological support category, with the exception of #2. Station #2 was partially supporting of the macroinvertebrate community with an SCI score of 14. All stations were below the fall scores.

The EPTT and BI scores, each of which received a score of 3, affected the SCI score at station #4. Only the SDI score lowered station #3. Three metrics contributed to the lower scores at station #2 (Table 5). The TR, EPTT, and SDI were each in the BIOREF scoring range of 3. The BI at #2 was within the optimum BIOREF scoring range and scored 5 points. The SCI at station #1 was affected by the TR and SDI, which lowered each BIOREF score to 3.

Table 5

Spring 2005 Biological Criteria (n=21) Metric Scores and Stream Condition Index (SCI) Scores for Middle Fork Grand River (MFG) Stations, Worth and Gentry Counties

Stream Station Number	Sample No.	TR	EPTT	BI	SDI	SCI	Biological Support Category
MFG #4	0503013	56	**7**	**7.25**	2.66	16	Full
MFG #3	0503012	60	10	7.04	**2.46**	18	Full
MFG #2	0503011	**46**	**8**	6.84	**2.47**	**14**	Partial
MFG #1	0503010	**49**	10	7.20	**2.45**	16	Full
BIOREF Score=5	--	>51	>8	<7.24	>2.53	20-16	Full

BIOREF Score=3	--	51-26	8-4	7.24-8.61	2.53-1.26	14-10	Partial
BIOREF Score=1	--	<26	<4	>8.61	<1.26	8-4	Non

((SCI Scoring Table in light gray)

Individual metrics showed no distinct pattern from upstream to downstream in the spring (Table 5). The TR was consistent at stations #4 and #3, while stations #2 and #1 were consistent but much lower than upstream. The EPTT fluctuated from upstream to downstream with no obvious pattern. The BI was slightly higher at station #4 than the remaining stations. The SDI at #4 was within the optimum BIOREF range.

3.2.1.2 Dominant Macroinvertebrate Families

Three families were consistently among the most dominant macroinvertebrate families sampled in the fall (Table 6). Chironomidae dominated all stations. Caenidae was the second most dominant family. Hyalellidae was generally dominant thereafter.

Table 6
Dominant Macroinvertebrate Families (DMF) as a Percentage of the Total Number of Individuals per Station, Fall 2004

Stream/Station	MFG #4	MFG #3	MFG #2	MFG #1
Sample Number	0418721	0418720	0418719	0418718
Chironomidae	**43.2**	**57.6**	**49.8**	**56.1**
Caenidae	**24.6**	**14.7**	**15.4**	**14.5**
Hyalellidae	**13.1**	**6.7**	**--**	**5.4**
Leptoceridae	3.9	7.4	9.0	6.5
Baetidae	3.1	3.3	6.2	4.7
Coenagrionidae	2.7	1.3	2.0	1.2
Ceratopogonidae	1.8	--	--	--
Sphaeriidae	0.8	--	--	--
Ephemeridae	--	2.1	--	1.3
Dryopidae	--	1.0	1.5	--
Hydropsychidae	--	--	6.1	1.7
Leptohyphidae	--	--	2.5	--

Table 7
Dominant Macroinvertebrate Families (DMF) as a Percentage of the Total Number of Individuals per Station, Spring 2005

Stream/Station	MFG #4	MFG #3	MFG #2	MFG #1
Sample Number	0503013	0503012	0503011	0503010
Chironomidae	**77.6**	**84.4**	**82.9**	**91.9**
Caenidae	**14.5**	**7.3**	**7.6**	**2.9**
Hyalellidae	**2.3**	**2.3**	**1.1**	**1.6**

Ceratopogonidae	1.7	--	--	0.4
Coenagrionidae	0.9	--	--	--
Dytiscidae	0.7	--	--	--
Hydropsychidae	0.3	--	--	0.4
Leptoceridae	0.1	0.3	0.6	--
Simuliidae	--	1.0	3.9	1.0
Baetidae	--	0.5	0.7	--
Corixidae	--	--	0.5	--
Heptageniidae	--	--	0.4	0.3
Ephemeridae	--	0.3	--	0.2
Tubificidae	--	1.6	--	--

Three families were consistently ranked among the dominant families at all stations in the spring (Table 7). Chironomidae dominated all stations. The second most dominant family was Caenidae. Hyalellidae was the third most dominant family, with the exception of station #2. A taxa list identified a large number of dipterans, a decrease in ephemeropterans, and more precisely illustrates the dominance by these families (Appendix A).

3.2.2 Physicochemical Water Variables

Several physicochemical water parameters exhibited interesting trends during the fall 2004 season (Table 8). Conductivity was slightly elevated at all stations. Turbidity was higher at station #4 than the downstream stations. Chloride was detected and decreased slightly from upstream to downstream. The TKN was detected at low levels in all stations. Ammonia-N was not detected at any station. Total phosphorus was detected in very low levels at all test stations. No measure or concentration exceeded Missouri WQSs (MDNR 2005c).

Several physicochemical water parameters also exhibited interesting trends in the spring 2005 season (Table 9). Conductivity was similar at all stations. TKN was detected at low concentrations in all stations. Ammonia was not detected (<0.03) at any station. Chloride was detected and the concentration decreased from upstream to downstream. Total phosphorus was detected at very low levels in all stations. No measure or concentration exceeded Missouri WQSs (MDNR 2005c).

Table 8
Physicochemical Water Variables per Station,
Middle Fork Grand River (MFG), Worth and Gentry Counties, Fall 2004

Station Variable	MFG #4	MFG #3	MFG #2	MFG #1
Sample Number	0411656	0411655	0411654	0411653
pH (Units)	7.60	8.30	7.70	7.70
Temperature (C^0)	21.0	28.5	25.5	24.5
Conductivity (uS)	534	549	519	485
Dissolved O_2	6.32	7.90	6.99	7.70

Discharge (cfs)	3.27	3.32	5.20	8.29
Turbidity (NTUs)	18.1	5.14	5.19	4.40
Nitrate+Nitrite-N	0.03	<0.01	<0.01	0.02
TKN	0.53	0.57	0.41	0.52
Ammonia-N	<0.03	<0.03	<0.03	<0.03
Chloride	17.2	18.0	14.8	13.0
Total Phosphorus	0.10	0.09	0.08	0.07

(Units mg/L unless otherwise noted)

Table 9
Physicochemical Water Variables per Station,
Middle Fork Grand River (MFG), Worth and Gentry Counties, Spring 2005

Station Variable/ Date	MFG #4	MFG #3	MFG #2	MFG #1
Sample Number	0502946	0502945	0502944	0502943
pH (Units)	8.20	8.20	8.10	8.20
Temperature (C^0)	9.0	7.0	6.0	5.50
Conductivity (uS)	526	558	532	523
Dissolved O_2	13.5	13.5	13.4	13.4
Discharge (cfs)	9.80	16.3	19.7	19.3
Turbidity (NTUs)	5.81	8.14	6.57	3.86
Nitrate+Nitrite-N	<0.01	0.01	<0.01	<0.01
TKN	0.25	0.30	0.24	0.20
Ammonia-N	<0.03	<0.03	<0.03	<0.03
Chloride	22.0	20.0	16.8	16.0
Total Phosphorus	0.07	0.07	0.05	0.06

(Units mg/L unless otherwise noted)

3.3 Channel Measurements

Channel measurements were recorded at test stations on Middle Fork Grand River and compared to the SHAPP control at East Fork Grand River (Table 10). Several channel measurements at the Middle Fork Grand River appeared to illustrate a difference from the control station (Table 10; Appendix B). The Middle Fork Grand River was less sinuous than the control station. The channel width was significantly greater than the wetted width in both test ($p<0.001$; $t=13.248$, 78 d.f.) and control ($p<0.005$; $T=142.5$, $n=10$) streams. The channel width of the test stream was significantly wider (<0.001; $T=86.0$, $n=40$) than the channel width of the control stream ($n=10$; Appendix B). Finally, most test stations were slightly deeper and depth was slightly more variable (S.D. of Depth) at most test stations compared to the control. Wetted width measurements in the test stream were similar ($p=0.303$; $T=298.0$, $n=40$) to the control stream measurements ($n=10$).

4.0 Discussion

The discussion includes the stream habitat assessment, biological assessment, and channel measurements. Notable results or trends are highlighted from upstream to downstream.

Table 10
Channel Measurements for Middle Fork Grand River (MFG) Stations and East Fork Grand River (EFG)

	CW	WW	CW/WW	DEPTH	MAX DEPTH	S.D. OF DEPTH	SINUOSITY (actual/straight-line)	STREAM LENGTH
MFG4	61.8	27.5	2.25	0.63	1.75	0.45	1.06	3279
MFG3	67.5	42.9	1.57	0.91	1.63	0.37	1.07	3171
MFG2	83.3	35.9	2.32	0.90	3.50	0.76	1.10	3245
MFG1	89.0	41.0	2.17	0.92	2.33	0.53	1.03	3281
EFG1	57.0	40.3	1.41	0.70	1.97	0.49	1.48	3145

Mean of measures unless otherwise noted; channel width (CW); wetted width (WW); S.D. of Depth (standard deviation of depth).

4.1 Stream Habitat Assessment

Stream habitat at Middle Fork Grand was comparable to the SHAPP control station on East Fork Grand River. All test station scores exceeded 75 percent of the SHAPP control score. MDNR (2003d) methods identified relatively high quality habitat, which implied that the impairment was not related to stream habitat. Stream habitat assessments were conducted in the fall, when all stations were fully supportive of the macroinvertebrate community. Although the stream habitat quality scores decreased by nearly 30 points from upstream (#4) to downstream (#1), the slight decline in habitat quality did not appear to affect the macroinvertebrate community.

Prevalent habitat features included sand substrate at all stations and narrow riparian corridors, especially in some downstream areas. The quantity of in-stream fine sediment or other local influences may have effects on macroinvertebrate communities (Zweig and Rabeni 2001).

4.2 Biological Assessment

The biological assessment consisted of macroinvertebrate community analyses and physicochemical water quality analyses. All stations were fully supportive of the macroinvertebrate community in the fall. One station (#2) was slightly impaired in the spring.

4.2.1 Station #2, Spring Macroinvertebrate Community Analyses

Macroinvertebrate community analyses consisted of comparisons between the SCIs and individual metric scores to BIOREF streams. Station #2 was considered partially supporting of the macroinvertebrate community in the spring.

The SCI scores and individual metric scores illustrated a difference between stations in the spring. Station #2 was considered to be partially supportive of the macroinvertebrate community in the spring. Lower than optimum TR, EPTT, and SDI metrics illustrated fewer taxa, fewer sensitive taxa, less diversity, and less even distribution at #2 than BIOREF streams. The BI at #2 was well within the optimum BIOREF scoring range, which illustrated that organic contamination was probably not the contributor of a slight impairment.

Station #2 was considered to be partially supportive of the biological category by only a slight margin. The TR, EPTT, and SDI each had SCI scores of three. Two of the metrics (EPTT and SDI) very nearly scored within the optimum range. The EPTT was one taxon below the optimum range and the SDI was 0.07 of a point below the optimum. Had either of these metrics reached the optimum BIOREF score, station #2 would be considered fully supportive of the biological community (non-impaired).

The DMFs indicated that Chironomidae greatly increased from fall (ca. 50 percent) to spring (ca. 85 percent) at all stations as a percentage of the total number of individuals. This may be a normal early season occurrence and not due to impairment. This increase may be directly related to the BI increase and the decreased SDI. Indirectly, the TR and EPTT could be less abundant as a result of the Chironomidae subsampled. The TR, EPTT, and SDI did decrease at all stations from the fall to the spring while the BI was slightly higher. Chironomid and other dominant taxa abundance apparently had an effect on the scores during both seasons, however, did not obviously illustrate the impairment at station #2.

Although station #1 was not considered impaired, the TR was considerably lower than upstream TR scores. This indicates that something caused the TR to decline much as was found in #2. The optimum BI did not illustrate an obvious influence of organic contaminants.

4.2.2 Station #2, Physicochemical Water Quality

Physicochemical water quality did not obviously identify the cause of impairment at station #2. However, water quality variables may have identified a source for low level organic input.

Several constituents of organic pollution were present in low concentrations during both sample seasons. Conductivity, TKN, total phosphorus, and chloride were elevated or detected in all stations. Elevated TKN (organic nitrogen) and chloride identified animal waste as a possible source. All other components were within normal ranges or not detected and no parameter exceeded WQS (MDNR 2005c).

Upstream and downstream bracketing of tributaries (Figure 2) did not identify a specific cause of impairment at station #2. Concentrations at stations #3 and #1 were similar to #2, so no local source was indicated. Overall, organic constituents were similar from upstream to downstream stations, with upstream being slightly higher. The presence of the indicators in all stations suggested that the source for the organic influence was upstream of all the stations and not delivered from the bracketed tributaries. The BI was also higher at the upper-most station #4 during both seasons, which supports that contention.

Concentrations of organic constituents were similar between seasons, which suggested that the organic input was continuous and probably not from non-point sources. Concentrations were only slightly elevated or detectable, which suggested that normal concentrations in the study area were minor during normal flow periods. Spring

discharge was approximately three-fold higher than fall, yet concentrations of constituents were similar to the fall. Organic constituents did not increase with increasing runoff during higher flow periods, which suggested that they might originate from controlled point source(s) upstream, although no permitted point source was identified upstream of the study area within Missouri. Animal related point sources in the Iowa portion of the Middle Fork Grand River watershed should be researched.

4.3 Channel Measurements

Channelized streams tend to be straighter, wider, and shallower with less variation of depth given similar flow conditions (MDNR 2005a). Channel measurements on East Fork Grand River were similar at all stations and did not identify what caused the impairment at station #2.

There are no readily available sources of information and few public records of non-navigable river channelization, however, drainage project information can sometimes be found at county courthouses. An example is information found at the Gentry County Circuit Clerk and Recorder's Office in Albany, Missouri. Local drainage district records are available in the form of engineering plans and drawings concerning the channelization of a large portion of the Middle Fork Grand River (Plan for Reclamation, Middle Fork Drainage District, Gentry County, Missouri, 1920, submitted by Clark E. Jacoby Engineering Company of Kansas City, Missouri). The planned channelization reach encompassed all MDNR sampling locations for this study.

Natural sinuosity has not returned to Middle Fork Grand River since it was channelized. The sinuosity ratio indicated that the stream was straighter than the control station at the East Fork Grand River. It appears that actual distance was nearly equal to the straight-line (aerial) distance. Furthermore, the control station was approximately 50 percent more sinuous than the test stations, suggesting that unmodified streams in the EDU are not straight. This is consistent with previous findings (AFS 1971; MDNR 2005a). Topographic (7.5 min) maps also show that the stream is very straight and relicts of the old channel are visible in several areas.

A potential result of channelization may be wider wetted stream distance during normal flow conditions (AFS 1971; MDNR 2005a). Wetted width in the test stream was not significantly different ($p=0.303$) from wetted width in the control stream (Appendix B).

Increased channel width has also been found to be an important result of channel modification (MDNR 2005a). Channel width was significantly greater than the wetted width in both the test ($p<0.001$) and the control ($p<0.005$) streams. This suggests that normal high flow channels are much wider than their normal wetted width. This may be a function of soil type and/or riparian management in northern Missouri. However, channel width in the test stream was significantly wider (<0.001) than the channel width in the control stream. Since watershed size appeared to be similar between test and control streams, widening may have been either intentional when the stream was straightened, or as a result of being straightened, due to increased water velocity potential.

Channelized streams may have less variation in depth and generally have more homogenous habitat, which may not support a high quality macroinvertebrate community (AFS 1971; MDNR 2005a). However, measurements show that Middle Fork Grand River is deeper with similar or greater variability of depth when compared to the control stream.

Overall, the Middle Fork Grand River was straighter and had a wider channel than the control, but it also had similar wetted width, similar or greater variability of depth, and was greater average depth. MDNR's (2005a) findings that channelized streams are shallower and wider with less variability of depth did not fit channel conditions found at the time of sampling. Given these results, only sinuosity and channel width indicated poor stream conditions.

Fish community evaluations help to identify the impact of channelization on aquatic communities of northern Missouri streams (Congdon 1971; Vokoun and Rabeni 2003; Williamson and Todd 2005). Fish community evaluations should be conducted on Middle Fork Grand River to further address the ability of channelized streams to support biological integrity.

5.0 Conclusion

The goal of this study was to determine if Middle Fork Grand River, Worth and Gentry Counties was impaired in the TMDL listed 303(d) study area. Station #2 was partially supporting of the macroinvertebrate community in the spring, by a slight margin. While organic (animal waste) constituents were present during both seasons in low concentrations, organic exposure was not an obvious influence that altered the community. The source of impairment at station #2 was not identified. Stream habitat was comparable to the SHAPP control.

The hypotheses were tested. The stream habitat quality at the test stations was comparable to the SHAPP control. The macroinvertebrate community was slightly impaired at station #2 and a slight seasonal difference was observed. Physicochemical water conditions and concentrations were consistent between stations and similarly found in low levels during both seasons. Channel measurements were not all similar to the control and indicated that the stream channel was altered.

6.0 Recommendations

1) Stream habitat should be maintained according to best management practices.

2) Identify sources for organic water chemistry parameters.

2) Periodically monitor the water quality.

3) Use sinuosity of the channel as an indicator of channel modification.

4) Fish community evaluations should be conducted on Middle Fork Grand River to further evaluate biological integrity of channelized streams.

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Appendix A

Middle Fork Grand River Macroinvertebrate Bench Sheets
Fall 2004 and Spring 2005

(NF=non-flow, RM=rootmat, SG=snag habitats; -99=present)

Aquid Invertebrate Database Bench Sheet Report
Middle Fk Grand R [0418721], Station #4, Sample Date: 9/15/2004 11:15:00 AM

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina		1	
AMPHIPODA			
Hyalella azteca	1	79	61
COLEOPTERA			
Berosus		1	
Dubiraphia	3	3	
Helichus lithophilus		6	
Hydroporus	1		
Scirtes		1	
DIPTERA			
Ablabesmyia	6	2	12
Anopheles		6	
Ceratopogoninae	4	9	6
Chironomus	6		
Chrysops		1	
Cladotanytarsus	42		4
Cricotopus bicinctus	1	1	1
Cricotopus/Orthocladius			4
Cryptochironomus	12		
Cryptotendipes	14		
Dicrotendipes	16		34
Ephydridae		2	
Forcipomyiinae			1
Labrundinia	2	6	11
Mesosmittia		1	
Nanocladius			3
Ormosia	2		
Paracladopelma	7		
Paratanytarsus	9	10	9
Polypedilum convictum grp			1
Polypedilum halterale grp	8		
Polypedilum illinoense grp	4	32	1
Polypedilum scalaenum grp	7		
Procladius	1		1
Rheotanytarsus	6	12	8
Stempellinella	1		2
Stenochironomus			2
Tanytarsus	44	7	95
Thienemannimyia grp.		9	10

ORDER: TAXA	NF	RM	SG
Tipula		1	
undescribed Empididae		3	
EPHEMEROPTERA			
Caenis hilaris	2		2
Caenis latipennis	115	50	96
Callibaetis		4	
Hexagenia limbata	3		
Leptophlebiidae		4	
Paracloeodes	1	3	14
Procloeon	10	1	1
Stenacron		1	
Stenonema femoratum	1		
Tricorythodes	1		
HEMIPTERA			
Belostoma		-99	
Microvelia		1	
Neoplea		3	
Rheumatobates		1	
Trepobates		3	
LIMNOPHILA			
Physella		5	
ODONATA			
Argia		6	
Enallagma		23	1
Gomphus	3		
Progomphus obscurus	-99		
TRICHOPTERA			
Hydroptila			3
Nectopsyche	6	30	1
Oecetis		1	
Triaenodes		4	
TUBIFICIDA			
Limnodrilus hoffmeisteri			1
Tubificidae	1	5	1
VENEROIDEA			
Sphaeriidae	-99	9	

Aquid Invertebrate Database Bench Sheet Report
Middle Fk Grand R [0418720], Station #3, Sample Date: 9/15/2004 9:00:00 AM

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina			1
AMPHIPODA			
Hyalella azteca		67	8
ARHYNCHOBDELLIDA			
Erpobdellidae		-99	
COLEOPTERA			
Berosus			1
Dubiraphia	2	1	1
Helichus lithophilus		4	8
Hydroporus			1
Paracymus			1
Stenelmis		-99	
DIPTERA			
Ablabesmyia	3	2	9
Ceratopogoninae	3	1	
Chironomus	12		1
Cladotanytarsus	37		4
Corynoneura			1
Cricotopus bicinctus			1
Cryptochironomus	3		1
Cryptotendipes	38		
Dicrotendipes	19	9	26
Ephydridae	1		
Forcipomyiinae			1
Glyptotendipes		4	2
Harnischia	1	1	
Labrundinia		15	12
Nanocladius	5	7	
Ormosia	5		
Parachironomus		4	
Paracladopelma	2		
Paralauterborniella	2		
Paratanytarsus	5	10	9
Paratendipes			1
Phaenopsectra			4
Polypedilum		1	
Polypedilum convictum grp			3
Polypedilum fallax grp			2
Polypedilum halterale grp	14		1

ORDER: TAXA	NF	RM	SG
Polypedilum illinoense grp	8	11	40
Polypedilum scalaenum grp	3		21
Procladius	5		
Rheotanytarsus		16	34
Simulium			1
Stempellinella	8		1
Stenochironomus			1
Tanypus	1		
Tanytarsus	47	34	95
Thienemanniella			2
Thienemannimyia grp.		24	17
Tipulidae		1	
Zavrelimyia			1
EPHEMEROPTERA			
Brachycercus	7		
Caenis hilaris			1
Caenis latipennis	65	52	39
Callibaetis		1	
Heptageniidae			2
Hexagenia	24		
Leptophlebiidae		1	
Paracloeodes	1	3	11
Procloeon	21		
Stenacron	2		6
Stenonema femoratum			1
Tricorythodes		4	6
HEMIPTERA			
Belostoma		-99	
Corixidae	1		
Mesovelia		1	
Rheumatobates		1	
Trepobates	1	1	
LIMNOPHILA			
Physella		1	
ODONATA			
Argia		6	3
Enallagma		6	
Gomphidae	1		
Gomphus		2	
TRICHOPTERA			
Cheumatopsyche		2	2
Hydroptila			2

ORDER: TAXA	NF	RM	SG
Nectopsyche	1	78	3
Oecetis	1		
TUBIFICIDA			
Tubificidae	1	2	
VENEROIDEA			
Sphaeriidae		1	

Aquid Invertebrate Database Bench Sheet Report
Middle Fk Grand R [0418719], Station #2, Sample Date: 9/14/2004 2:30:00 PM

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina			1
AMPHIPODA			
Hyalella azteca	1	14	
COLEOPTERA			
Berosus		1	
Dubiraphia		4	
Helichus basalis		1	
Helichus lithophilus	4	11	
Scirtes			1
Stenelmis		1	
Uvarus	1		
DECAPODA			
Orconectes virilis		-99	
DIPTERA			
Ablabesmyia	13		1
Axarus	1		
Ceratopogoninae	1		
Chironomus	2		
Cladotanytarsus	23		3
Cricotopus bicinctus		1	1
Cricotopus/Orthocladius	1		5
Cryptochironomus	23		
Cryptotendipes	20		1
Dicrotendipes	10	1	33
Ephydridae	1		
Forcipomyiinae			8
Glyptotendipes		1	
Hemerodromia			3
Labrundinia	5	7	
Nanocladius		1	
Paracladopelma	5		
Paralauterborniella			1
Paratanytarsus	2	7	2
Paratendipes	4		
Polypedilum convictum grp		4	15
Polypedilum halterale grp	2		

ORDER: TAXA	NF	RM	SG
Polypedilum illinoense grp	19	1	13
Polypedilum scalaenum grp	2		3
Rheocricotopus		2	
Rheotanytarsus	14	63	25
Saetheria	2		
Simulium	1	2	
Stempellinella	5		
Stenochironomus			3
Tanytarsus	47	21	92
Thienemanniella	2		6
Thienemannimyia grp.	1	12	3
EPHEMEROPTERA			
Acerpenna		5	
Baetis		7	5
Brachycercus	11		
Caenis hilaris	5	18	
Caenis latipennis	38	90	3
Heptageniidae		1	
Isonychia		1	
Leptophlebiidae	1		
Paracloeodes	6		4
Procloeon	22	2	1
Pseudocloeon		15	
Stenacron	3	7	
Stenonema femoratum	2		
Tricorythodes	1	25	1
HEMIPTERA			
Rhagovelia			1
LIMNOPHILA			
Physella		2	
MEGALOPTERA			
Sialis		-99	
ODONATA			
Argia		18	
Calopteryx		2	
Enallagma	2	2	
Gomphidae	3		
Gomphus	-99	1	
Libellula		-99	
Progomphus obscurus	2		
TRICHOPTERA			
Cheumatopsyche	3	53	10

ORDER: TAXA	NF	RM	SG
Hydroptila			1
Nectopsyche	4	91	1
TRICLADIDA			
Planariidae		1	
TUBIFICIDA			
Enchytraeidae			1
Tubificidae	1		
VENEROIDEA			
Sphaeriidae	1	5	

Aquid Invertebrate Database Bench Sheet Report
Middle Fk Grand R [0418718], Station #1, Sample Date: 9/14/2004 12:30:00 PM

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina			6
AMPHIPODA			
Hyalella azteca	1	56	1
COLEOPTERA			
Berosus	1	1	
Dubiraphia	1		
Helichus		1	
Hydroporus		5	
DECAPODA			
Orconectes virilis		-99	
DIPTERA			
Ablabesmyia	4	2	
Anopheles	1	1	
Ceratopogoninae	2	5	
Chaoborus	-99		
Chironomus	7		
Cladotanytarsus	19		2
Cricotopus bicinctus			2
Cricotopus/Orthocladius	2		26
Cryptochironomus	7		
Cryptotendipes	21		
Dicrotendipes	7	2	56
Ephydridae	1		
Forcipomyiinae			6
Glyptotendipes		1	
Hemerodromia		1	3
Labrundinia	4	7	1
Nanocladius	2		
Paracladopelma	2		
Paralauterborniella	2		
Paratanytarsus	1	4	4
Paratendipes	1		
Polypedilum convictum grp	3		19
Polypedilum halterale grp	4		
Polypedilum illinoense grp	19	9	14
Polypedilum scalaenum grp		1	1
Procladius	2		6
Rheotanytarsus	5	38	63
Simulium		1	1

ORDER: TAXA	NF	RM	SG
Stempellinella	18		
Stenochironomus	1		8
Tanytarsus	60	23	84
Thienemanniella			6
Thienemannimyia grp.		11	12
EPHEMEROPTERA			
Baetis			5
Brachycercus	8		
Caenis hilaris	3	7	3
Caenis latipennis	63	65	4
Cercobrachys			1
Fallceon			2
Hexagenia	14		
Isonychia			2
Leptophlebiidae		3	
Paracloeodes	8	9	4
Procloeon	17	2	1
Pseudocloeon			2
Stenacron		1	
Stenonema		1	2
Tricorythodes	4	7	
HEMIPTERA			
Corixidae		1	
Neoplea			1
Trepobates	1		
LIMNOPHILA			
Physella		4	
ODONATA			
Argia	1	5	
Enallagma		7	
Gomphus	6		
Libellulidae	1		
Macromia	1		
Progomphus obscurus	-99		
TRICHOPTERA			
Cheumatopsyche		3	16
Cyrnellus fraternus		1	
Nectopsyche	17	52	
TUBIFICIDA			
Tubificidae	3	3	
VENEROIDEA			
Sphaeriidae	-99	8	

Aquid Invertebrate Database Bench Sheet Report
Middle Fk Grand R [0503013], Station #4, Sample Date: 3/23/2005 3:30:00 PM

ORDER: TAXA	NF	RM	SG
AMPHIPODA			
Hyalella azteca	4	16	4
COLEOPTERA			
Dineutus		-99	
Dubiraphia	1		
Dytiscidae	1		
Hydroporus	4	1	2
DIPTERA			
Ablabesmyia	11	1	1
Ceratopogoninae	18		
Chironomus	4	1	
Cladotanytarsus	5	1	1
Corynoneura	3	2	
Cricotopus bicinctus	2	10	11
Cricotopus/Orthocladius	23	104	114
Cryptochironomus	10		2
Cryptotendipes	1		
Dicrotendipes	10		11
Diptera	1		
Glyptotendipes			1
Hemerodromia	1		
Hydrobaenus	60	3	16
Labrundinia		2	
Nanocladius	2	12	
Ormosia			1
Paracladopelma	2		
Paralauterborniella	2		
Parametriocnemus	1		
Paraphaenocladius		2	
Paratanytarsus	15	57	45
Pericoma		1	
Phaenopsectra	2		3
Polypedilum		1	
Polypedilum convictum grp	1	3	
Polypedilum halterale grp	8		
Polypedilum illinoense grp		1	
Polypedilum scalaenum grp	8		
Procladius	2		
Pseudosmittia	1		
Rheotanytarsus		3	10

ORDER: TAXA	NF	RM	SG
Saetheria	8	1	
Stictochironomus	1		
Tanytarsus	98	7	35
Thienemanniella	1	3	6
Thienemannimyia grp.	2	18	14
Zavrelimyia	2	9	
EPHEMEROPTERA			
Caenis latipennis	44	38	67
Hexagenia limbata	1		
Leptophlebia		1	
Stenacron		2	
HEMIPTERA			
Sigara	2		
ODONATA			
Argia		1	
Enallagma	4	5	
Progomphus obscurus	-99		
TRICHOPTERA			
Cheumatopsyche		1	3
Nectopsyche			1
Oecetis			1
TUBIFICIDA			
Tubificidae	2		
VENEROIDEA			
Sphaeriidae	1		

Aquid Invertebrate Database Bench Sheet Report
Middle Fk Grand R [0503012], Station #3, Sample Date: 3/23/2005 2:00:00 PM

ORDER: TAXA	NF	RM	SG
AMPHIPODA			
Crangonyx	-99		
Hyalella azteca	5	18	
COLEOPTERA			
Dineutus		-99	
Helichus lithophilus		1	
Hydroporus		1	
Peltodytes	1		
DIPTERA			
Ablabesmyia	2	3	
Axarus	1		
Ceratopogoninae	2		
Chironomus	4		
Cladotanytarsus	2		
Corynoneura	2	1	1
Cricotopus/Orthocladius	21	121	204
Cryptochironomus	5		
Cryptotendipes	2		
Dicrotendipes	7	4	
Diptera	1		
Endotribelos			1
Hydrobaenus	43	8	12
Labrundinia		3	
Larsia		3	1
Nanocladius		7	
Ormosia	1		
Paracladopelma	4		
Parametriocnemus		3	3
Paraphaenocladius	1		
Paratanytarsus	13	89	22
Phaenopsectra	1	1	5
Polypedilum fallax grp			1
Polypedilum halterale grp	1		
Polypedilum scalaenum grp	9	10	2
Rheotanytarsus	8	9	1
Saetheria			1
Simulium		1	9
Stictochironomus	1		
Tanytarsus	74	47	4
Thienemanniella		4	23

ORDER: TAXA	NF	RM	SG
Thienemannimyia grp.	5	20	6
Tipula		-99	
Zavrelimyia	4	4	
EPHEMEROPTERA			
Acerpenna		4	1
Caenis latipennis	42	31	
Heptagenia		1	
Hexagenia limbata	3		
Leptophlebia		1	
Stenacron	1		
Stenonema femoratum	1		
HEMIPTERA			
Ranatra fusca		-99	
Sigara	2		
ODONATA			
Argia		-99	
Enallagma		1	
Hetaerina		1	
TRICHOPTERA			
Cheumatopsyche	1	1	
Hydropsyche			1
Nectopsyche	2	1	
TUBIFICIDA			
Enchytraeidae	2		
Limnodrilus cervix	1		
Limnodrilus claparedianus	2		2
Limnodrilus hoffmeisteri	1		1
Tubificidae	9		

Aquid Invertebrate Database Bench Sheet Report
Middle Fk Grand R [0503011], Station #2, Sample Date: 3/23/2005 12:15:00 PM

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina			1
AMPHIPODA			
Crangonyx		-99	
Hyalella azteca		13	
COLEOPTERA			
Berosus		-99	
Hydroporus		1	
DIPTERA			
Ablabesmyia	4	1	
Ceratopogoninae	1	3	1
Chironomus	16		
Cladotanytarsus	6		
Cricotopus bicinctus	10	37	4
Cricotopus/Orthocladius	24	79	241
Cryptochironomus	10		
Dicrotendipes		5	3
Hydrobaenus	45	2	
Nanocladius		4	
Ormosia		1	
Paracladopelma	8		
Paraphaenocladius		5	2
Paratanytarsus	10	46	
Paratendipes	4		
Phaenopsectra	1	1	
Polypedilum convictum grp		9	1
Polypedilum halterale grp	7		
Polypedilum illinoense grp		6	
Polypedilum scalaenum grp	2	1	
Rheotanytarsus	1	14	2
Simulium	1	2	40
Stictochironomus	7		
Tanytarsus	142	88	2
Thienemanniella	2	9	7
Thienemannimyia grp.	5	30	1
Zavrelimyia	2	2	
EPHEMEROPTERA			
Acerpenna	1	7	
Caenis latipennis	33	50	1
Hexagenia limbata	1		

ORDER: TAXA	NF	RM	SG
Leptophlebia		-99	
Stenacron	1	2	
Stenonema terminatum	1	1	
HEMIPTERA			
Sigara	6		
ODONATA			
Progomphus obscurus	1		
Somatochlora		-99	
TRICHOPTERA			
Cheumatopsyche	1	1	2
Nectopsyche		7	
TUBIFICIDA			
Enchytraeidae		1	
Limnodrilus hoffmeisteri		1	
Tubificidae	3	1	

Aquid Invertebrate Database Bench Sheet Report
Middle Fk Grand R [0503010], Station #1, Sample Date: 3/23/2005 10:45:00 AM

ORDER: TAXA	NF	RM	SG
AMPHIPODA			
Hyalella azteca		14	-99
COLEOPTERA			
Dineutus		1	
Hydroporus		1	
DIPTERA			
Ablabesmyia		1	
Ceratopogoninae	4		
Chironomus	3		
Cladotanytarsus	3	1	
Corynoneura	1	2	
Cricotopus bicinctus	6	79	49
Cricotopus/Orthocladius	25	31	146
Cryptochironomus	10		
Cryptotendipes	3		
Dicrotendipes	3	2	5
Harnischia	1		
Hydrobaenus	57	1	3
Labrundinia		1	1
Nanocladius		1	
Paracladopelma	7		
Paralauterborniella	1		
Paraphaenocladius	2	1	1
Paratanytarsus	8	25	6
Phaenopsectra	3		3
Polypedilum convictum grp		6	10
Polypedilum illinoense grp	1	8	
Polypedilum scalaenum grp	2		
Procladius	3		
Rheotanytarsus		18	8
Simulium	1		8
Stenochironomus			2
Tanytarsus	125	60	17
Thienemanniella	2	9	6
Thienemannimyia grp.		12	1
Tipula		-99	
Zavrelimyia	2	2	

ORDER: TAXA	NF	RM	SG
EPHEMEROPTERA			
Acerpenna		1	
Caenis latipennis	17	8	
Heptagenia		2	-99
Hexagenia limbata	2		
Leptophlebia		-99	
Stenacron	1	-99	
Stenonema femoratum		-99	
LIMNOPHILA			
Physella		1	
ODONATA			
Enallagma		1	
Ischnura		-99	
TRICHOPTERA			
Cheumatopsyche		4	
Nectopsyche		1	
Oecetis		1	
TUBIFICIDA			
Limnodrilus hoffmeisteri	1		
Tubificidae	1		

Appendix B

Channel Measurement Comparisons:
(SigmaStat, Version 2.0, 1997)

Mann-Whitney Rank Sum Tests (mw)
or
Studentized t-Test (ttest)

1) Wetted Width Control vs. Wetted Width Test Stream, $p=0.303$ mw
2) Channel Width Test Stream vs. Wetted Width Test Stream, $p<0.001$ttest
3) Channel Width Control vs. Wetted Width Control, $p=0.005$ mw
4) Channel Width Control vs. Channel Width Test Stream, $p<0.001$ mw

1) t-test Tuesday, January 17, 2006, 10:31:32

Data source: **Wetted Width Control (wwidthcont) v Wetted Width Test Stream (wwidthtest)**

Normality Test: Failed (P = 0.006)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Tuesday, January 17, 2006, 10:31:32

Group	N	Missing	Median	25%	75%
wwidthcont	10	0	37.000	32.000	47.000
wwidthtest	40	0	35.000	29.000	42.000

T = 298.000 n(small)= 10 n(big)= 40 (P = 0.303)

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; **there is not a statistically significant difference (P = 0.303)**

2) t-test Tuesday, January 17, 2006, 10:08:27

Data source: **Channel Width Test Stream (chwidthtest) v Wetted Width Test Stream (wwidthtest)**

Normality Test: Passed (P = 0.129)

Equal Variance Test: Passed (P = 0.020)

Group Name	N	Missing	Mean	Std Dev	SEM
chwidthtest	40	0	75.400	14.827	2.344
wwidthtest	40	0	36.825	10.921	1.727

Difference 38.575 t = 13.248 with 78 degrees of freedom. (P = <0.001)

95 percent confidence interval for difference of means: 32.778 to 44.372

The difference in the mean values of the two groups is greater than would be expected by chance; **there is a statistically significant difference between the input groups (P = <0.001).**

Power of performed test with alpha = 0.050: 1.000

3) t-test Tuesday, January 17, 2006, 10:06:52

Data source:**Channel Width Control (chwidthcont) v Wetted Width Control (wwidthcont)**

Normality Test: Failed (P = 0.002)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Tuesday, January 17, 2006, 10:06:52

Group	N	Missing	Median	25%	75%
chwidthcont	10	0	56.000	55.000	60.000
wwidthcont	10	0	37.000	32.000	47.000

T = 142.500 n(small)= 10 n(big)= 10 (P = 0.005)

The difference in the median values between the two groups is greater than would be expected by chance; **there is a statistically significant difference (P = 0.005)**

4) t-test Friday, January 13, 2006, 09:16:11

Data source: **Channel Width Control (chwidth) v Channel Width Test Stream (Chw test)**

Normality Test: Passed (P > 0.200)

Equal Variance Test: Failed (P = 0.002)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Friday, January 13, 2006, 09:16:11

Group	N	Missing	Median	25%	75%
chwidth	10	0	56.000	55.000	60.000
chw test	40	0	72.000	64.000	86.000

T = 86.000 n(small)= 10 n(big)= 40 (P = <0.001)

The difference in the median values between the two groups is greater than would be expected by chance; **there is a statistically significant difference (P = <0.001)**