Missouri Department of Natural Resources
Water Protection Program

Total Maximum Daily Loads (TMDL)

for

Village Creek
Madison County, Missouri

Completed: August 31, 2009
Approved: January 14, 2010

Total Maximum Daily Load (TMDL) for Village Creek
Pollutants: Inorganic Sediment and Lead

State map showing location of watershed

Name: Village Creek

Location: Madison County, Missouri

Nearby Cities: Fredericktown

Hydrologic Unit Code (HUC): 08020202-020003

Water Body Identification Numbers and Missouri Stream Classification[1]**:**

2863—Village Creek	P
2864—Village Creek	C

Beneficial Uses[2] **of Village Creek (both segments):**
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B

Length and Legal Descriptions of Impaired Segments:

Size of Impaired Segment, 2863 – Village Creek: 1.5 miles
Size of Impairment within Segment: 1.5 miles
Location of Impaired Segment: Mouth to Section 5, T33N, R7E

Size of Impaired Segment, 2864 – Village Creek: 3.0 miles
Size of Impairment within Segment: 3.0 miles
Location of Impaired Segment: Section 5, T33N, R7E to Section 34, T34N, R7E

Use that is Impaired: Protection of Warm Water Aquatic Life

Pollutants: Inorganic sediment (non-volatile suspended solids) and lead

Source: Mine La Motte abandoned mine lands

TMDL Priority Ranking: High

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[1] For stream classifications see 10 CSR 20-7.031(1)(F). Class P streams maintain flow even during drought - conditions. Class C streams may cease to flow in dry periods but maintain permanent pools, which support - aquatic life. -

[2] For beneficial uses see 10 CSR 20-7.031(1)(C) and Table (H) -

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1. Introduction

This Village Creek Total Maximum Daily Load (TMDL) is being established in accordance with Section 303(d) of the Clean Water Act. This water quality limited segment near Fredericktown, Missouri in Madison County is included on the U.S. Environmental Protection Agency (EPA) approved Missouri 2004/2006 303(d) list of impaired waters with the pollutants of concern being inorganic sediment and lead (MoDNR 2009).

The inorganic sediment pollutant replaces previous 303(d) listings of non-volatile suspended solids. Since non-volatile suspended solids and inorganic sediment have essentially the same meaning, the listing was changed to inorganic sediment to better characterize the impairment, but the two terms may be used interchangably. The data used to identify the impairment is also the same.

The purpose of a TMDL is to determine the pollutant loading a water body can assimilate without exceeding the water quality standards for that pollutant. The TMDL also establishes the pollutant load allocation necessary to meet the Missouri water quality standards established for each water body based on the relationship between pollutant sources and in-stream water quality conditions. The TMDL consists of a wasteload allocation, a load allocation, and a margin of safety. The wasteload allocation is the portion of the allowable pollutant load that is allocated to point sources. The load allocation is the portion of the allowable pollutant load that is allocated to nonpoint sources. The margin of safety accounts for the uncertainty associated with the model assumptions and data inadequacies. The model used to derive these TMDLs was completed by the EPA based on work completed by EPA contractor Parsons Corporation.

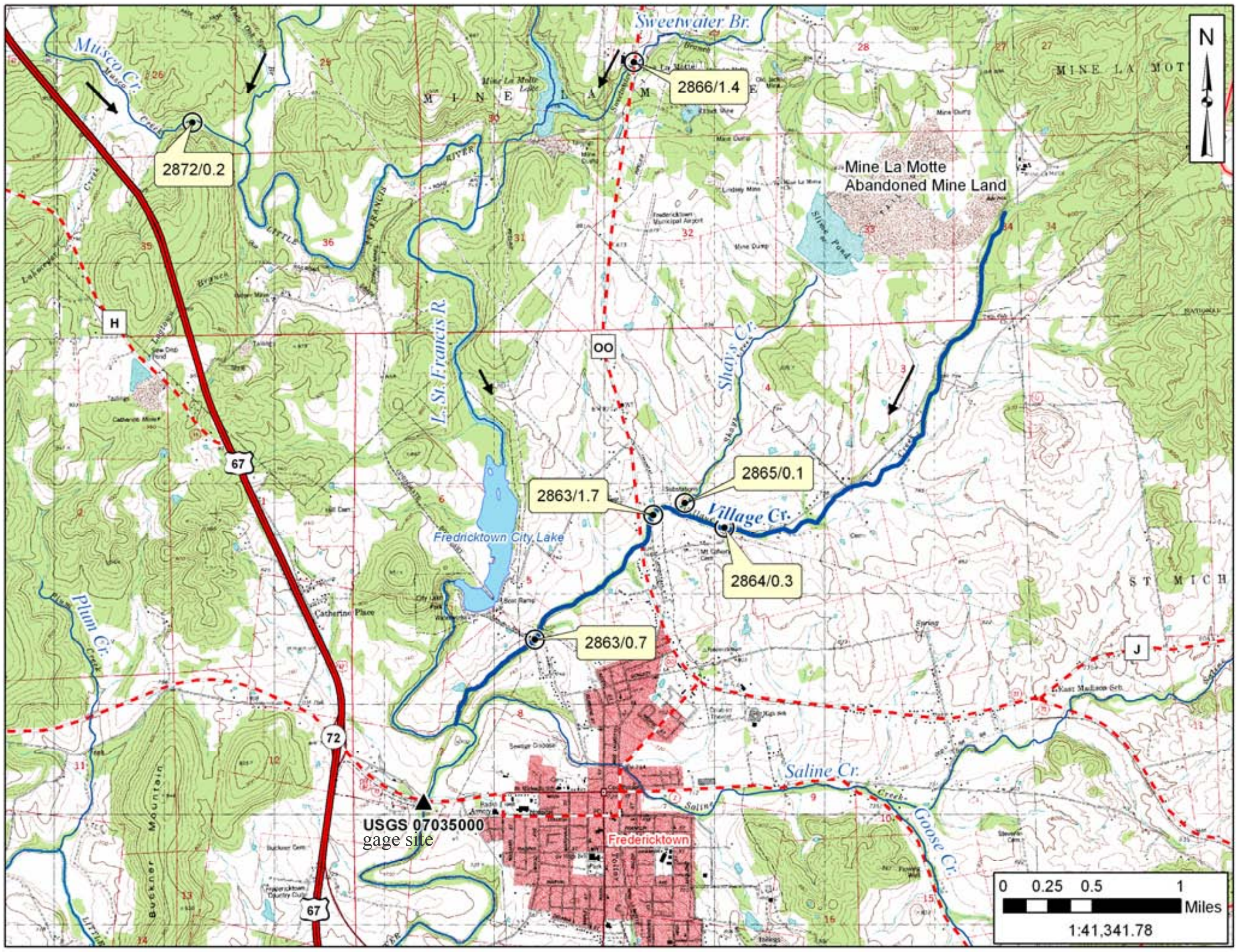
2. Background and Water Quality Problems

2.1 Watershed Description

The headwaters of Village Creek originate near a historical mining district near Mine La Motte in southeastern Missouri (Figure 1). The entire Village Creek watershed lies within the northern portion of Madison County and the watershed drainage area encompasses approximately 12.5 square miles.

Table 1 shows the general land use categories currently within the Village Creek watershed as derived using data from 2000 to 2004 at 30-meter resolution obtained from Thematic Mapper imagery (MoRAP 2005). The Village Creek watershed, which contains both stream segments, is predominantly covered by both forest and grassland (Table 1). There is also a limited amount of cropland and urban area within this watershed. Figure 2 graphically depicts the general land use categories occurring within the Village Creek watershed. Although the region is well known for its extensive historical mines, especially lead, none of these mines are currently active. Because the watershed is rural in nature, land development impacts to water quality in the Village Creek watershed are expected to be limited.

Figure 1: Location Map for Village Creek with Department Sampling Site Locations*

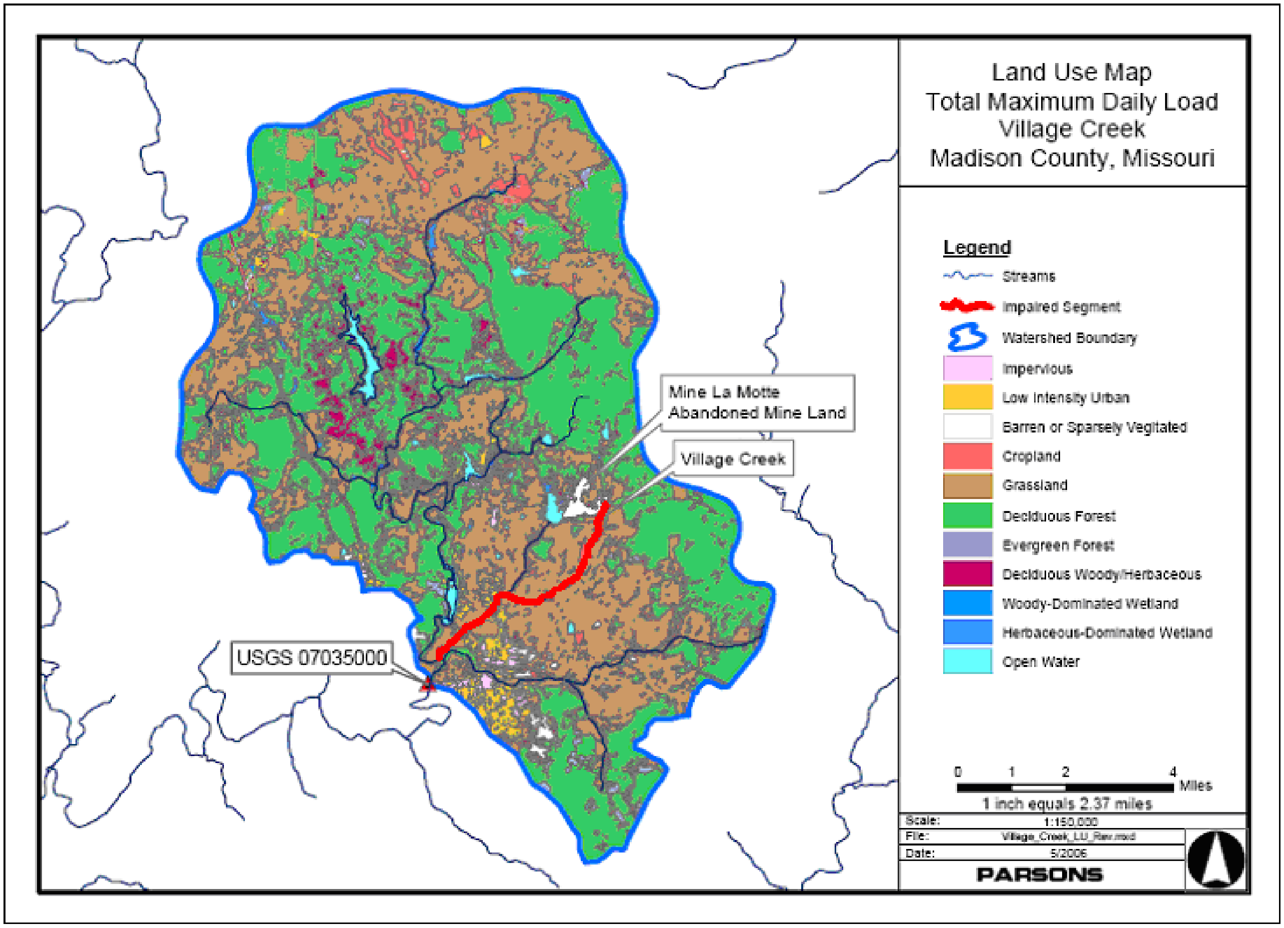


* Additional information on monitoring sites can be found in Tables 3 and 4.

Table 1: Village Creek Watershed Land Use Categories

Land Use Type	WBID 2863 Area (Acres)	Percent of WBID 2863 Total Area	WBID 2864 Area (Acres)	Percent of WBID 2864 Area
Barren or Sparsely Vegetated	243.0	3.0	157.3	5.3
Cropland	275.8	3.4	120.4	4.0
Deciduous Forest	3022.1	37.8	474.4	15.9
Mixed Forest	252.4	3.2	37.1	1.2
Evergreen Forest	2.9	<0.1	1.8	0.1
Grassland	3961.6	49.6	2003.1	67.2
Herbaceous-Dominated Wetland	5.3	0.1	2.4	0.1
Impervious	44.7	0.6	36.7	1.2
Low Intensity Urban	96.5	1.2	78.1	2.6
Open Water	88.5	1.1	69.0	2.3
Total	**7992.8**	**100.0**	**2980.3**	**99.9**

Figure 2: Land Use Map for Village Creek Watershed showing USGS 07035000 Gage Site.



2.2 Problem Identification and Current Conditions

Section 303(d) of the Clean Water Act and the EPA Water Quality Planning and Management Regulation (40 CFR Part 130) require states to develop Total Maximum Daily Loads for water bodies not meeting applicable water quality standards or designated uses under technology-based controls. TMDLs identify the maximum amount of a pollutant that a water body can assimilate and still meet water quality standards.

The Village Creek watershed is located in Madison County near Fredericktown, Mo in an area commonly referred to as the “Old Lead Belt”. This is the oldest lead mining area west of the Mississippi River, where mining activities began in 1720 and continued until the 1970s (EPA 2000; ATSDR 2005). Lead mines throughout this mining belt ranged from surface mines to those extending several hundred feet below the ground. This has resulted in massive tailings piles with elevated lead concentrations that potentially pose serious health risks. The majority of the abandoned mine works are located within six miles of each other and cover approximately 645 acres near the city of Fredericktown, Mo.

In 2003, these abandoned mine lands were added to the National Priority List[3] as part of the Madison County Mines Superfund Site. Superfund is a federal government program to clean uncontrolled hazardous waste sites. The National Priority List listing makes these sites eligible for future remediation and cleanup following further investigation and study. The Madison County Mines site has been broken down into six Operable Units. Each Operable Unit consists of tailings and mine areas specific to different sections of the Madison County Mines site. Tailings from Mine La Motte tailings are in Operable Unit-1, located in the northeast quarter of Madison County.

The Mine La Motte tailings area consists of approximately 495 acres owned by the Mine La Motte Recreation area, of which approximately 250 acres are covered with tailings. There is also an approximately 100-acre pond, known as the “Slime Pond”. This area was formerly used for producing and processing lead. Currently the property is used for recreational purposes including swimming, fishing, camping, boating, and hunting. The beach and approximately 50 camping sites are located on the western and southern areas of the lake on tailings. A children’s playground is located in the tailings of the beach area. The tailings pile to the east and northeast of the lake is used for recreational purposes such as riding all-terrain vehicles.

Over the past 15 years, the Missouri Department of Natural Resources has observed instream deposition of mine tailings in Village Creek adjacent to the Mine La Motte tailings. This eroded mineral material may include clay, silt, sand, or assorted sized pieces of rock or other non-organic materials and is referred to as inorganic sediment. Excessive instream inorganic sediment may be harmful to aquatic life because it can cover the natural benthic (stream bottom) community, smothering fish eggs and small aquatic organisms. Additionally, inorganic sediment deposition results in a reduction of available spawning habitat and food for fish (MoDNR 2004). Furthermore, the mine tailings that make up a portion of the inorganic sediment add to the stream’s lead load, exceeding the probable effect level of toxicity for some aquatic life. In addition to aquatic life, lead can also have negative affects on humans, causing damage to the nervous system, kidneys, and reproductive system (ATSDR 2007).

Two segments of Village Creek are listed as impaired for inorganic sediment and dissolved lead. The Mine La Motte abandoned mining area has been identified as the source of these impairments. In 2003, the department analyzed sediment samples from Village Creek for heavy metals contamination. This sampling followed sediment characterization at the Madison County Mines Site – Operable Unit 1 from April 2000 (ESC 2000). Sampling locations near Mine La Motte tailings piles (e.g., SD 9) reflect sediment compositions containing a higher percentage of mine tailings than downstream sampling locations (e.g., SD 7 and SD 3) that reflect compositions containing finer grained sediment with lead contamination. Results for lead (Pb) concentrations in sediment from the Village Creek watershed are summarized in Table 2. Samples collected by EPA from the Mine La Motte tailings pile in February 2000 show lead concentrations ranging from 490 to 3,970 mg/kg.[4]. These samples exceed the residential action level of 400 ppm set by EPA, as well as the consensus Threshold Effect Concentration of 35.8 ppm (MacDonald *et al*. 2000) and the Probable Effects Level for lead of 82 ppm in freshwater sediment based on Ingersoll *et al.* (2000).

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[3] The National Priorities List is the list of national priorities among the known releases or threatened releases of hazardous - substances, pollutants, or contaminants throughout the United States and its territories. The NPL is intended primarily to - guide the EPA in determining which sites warrant further investigation. -

[4] An alternate means of expressing mg/kg is parts per million, or ppm. -

EPA also collected in February 2000 samples of tailings for lead analysis from the Harmony Lake Tailings piles, the Basler tailings piles, and the Old Jack mine, which are all located within Operable Unit-1 of the Madison County Superfund site. Note that although these areas are part of the same Superfund site as the area of concern, they are not within the the Mine La Motte abandoned mine area nor even in the Village Creek watershed. As a result, although the information provided through sampling in these nearby areas is interesting for comparison, it does not influence Village Creek water quality. Lead concentrations for these samples collected outside the Mine La Motte abandoned mine area ranged from 166 to 19,100 ppm for the Harmony Lake tailings, to 19,100 to 22,000 ppm for the Old Jack mine site, and 1,520 to 10,200 ppm for the Basler tailings pile.

Table 2: Concentrations of Heavy Metals in the Sediments of Village Creek and Recommended Maximum Safe Levels for Aquatic Life (mg/kg) (MDNR, 2004)

Sample Location	Arsenic	Cadmium	Copper	Nickel	Lead	Zinc
Sediment Concentrations in Village Creek (mg/kg) segment 2863 (SD3) April 2000	57	0.23	--	--	139	66
Sediment Concentrations in Village Creek (mg/kg) segment 2864 (SD7) April 2000	66	0.34	--	--	108	65
Sediment Concentrations in Village Creek (mg/kg) segment 2864 (SD9) April 2000	5	0.18	--	--	403	11
Sediment Concentrations in Village Creek (mg/kg) segment 2864 (SD10) April 2000	11	0.15	--	--	139	62
Sediment Concentrations in Village Creek (mg/kg) in 2003	32.4	0.06	15.9	22.5	104	39.3
Sediment Concentrations in Village Creek (mg/kg) in 2006	18.2	0.34	32.2	35.3	223	63
Threshold Effect Concentration* (mg/kg)	9.79	0.99	31.6	22.7	35.8	121

* Threshold Effect Concentration - the level of metal contamination below which adverse effects on the aquatic biota are not expected to occur.

The TMDLs, including allocations and load reductions, were prepared with regard to instream lead concentrations in water as a TMDL surrogate for lead and sediment. This was done by applying an equilibrium partitioning methodology as well as by developing a bedded sediment relationship between mass of sediment and mass of lead in that sediment. Like other states, Missouri has not developed numeric criteria for freshwater sediment. In order to understand the extent to which lead in sediment could be contributing adverse effects to the aquatic environment in the Village Creek watershed, equilibrium partitioning methodology was applied (e.g., EPA 1999; Hassan *et al*. 1996; McIntosh 1991) to assess the level of lead contamination. This procedure involves a number of simplifying assumptions described below. Because lead follows well-defined partitioning behavior between pore water and sediment, measured lead and pH in sediment were used to estimate potential exposures in the water column based on equilibrium partitioning principles. These principles generally state that when lead resides in sediment, it exists in equilibrium with pore water, and when physical-chemical properties are known, the partitioning behavior of lead between the solid (sediment) and aqueous (pore water) phase can be predicted (Hansen *et al.* 2005). Pore water is important because it is known that the majority of toxicity from lead residues in an aquatic environment occurs in pore water.

Following this procedure, measured lead in sediment data were used to back-calculate pore water concentrations. Estimated pore water concentrations for the purposes of the TMDL development may then be compared to the hardness-dependent criteria promulgated by the department. Pore water concentrations (Pb_{pw}) are estimated by applying the following equation:

Equation 1: $Pb_{pw,\ \mu g/L} = Pb_{sed,\ mg/kg}/(K_{d,mL/g})*(1{,}000\ \mu g/mg)$

where Pb_{sed} is the lead in sediment concentration and K_d is the distribution coefficient. Based on "Partition Coefficients for Lead" from EPA (1999), a polynomial relationship existed between the K_d value and soil pH measurements as follows:

Equation 2: $(K_{d,\ mL/g}) = 1639 - 902.4(pH) + 150.4(pH)^2$

In addition, the relationship between the K_d value and equilibrium concentrations of lead at a fixed pH can be expressed as:

Equation 3: $(K_{d,\ mL/g}) = 9{,}550\ C^{-0.335}$

where C is the equilibrium concentration of lead in µg/L. EPA (1999) provides a look-up table for the estimated range (i.e. maximum and minimum) of K_d values for lead as a function of soil pH and equilibrium concentrations using the above equations.

Table 3 presents K_d values for lead using measured pH values and estimated pore water concentrations at equilibrium. Lead in sediment was measured at only two locations in Village Creek and the results are summarized in Table 3. The results from Village Creek at Catherine Mine Road in November 2003 and February 2006 of 104 mg/kg and 223 mg/kg, respectively, are considered excursions over existing sediment quality guidelines. This is because, in the absence of promulgated numeric criteria for sediment, this concentration exceeds the consensus Threshold Effect Concentration for lead of 35.8 mg/kg (MacDonald *et al*. 2000). In addition, sediment lead concentrations of 104 mg/kg and 223 mg/kg, using the above equations with both minimum and maximum K_d values, result in estimated pore water concentrations for lead from 20.9 to 146 µg/L and 44.9 to 314 µg/L, respectively. Although no matched hardness data were available for these two sediment samples, all of the predicted pore water concentrations are well in excess of the calculated hardness-dependent lead criteria shown in Table 4. A comparison of the predicted pore water concentrations and the instream concentration, measured the day prior to the sediment sample at Village Creek just above Shays Creek, indicates that the pore water concentrations were significantly higher than the instream measured concentration. This difference may be partially accounted for by dilution from instream flows. However, the use of pore water target concentrations addresses the critical condition and protects benthic invertebrate aquatic life living in close contact with pore water. This target also addresses conditions of low flow when water column concentrations of lead are likely to be higher as there is less dilution of pore water loading into the water column.

The department has also collected water quality samples from various locations within the Village Creek watershed. Table 4 summarizes both total and dissolved lead concentrations and compares the dissolved concentrations with both the acute and chronic criteria for dissolved lead. Hardness data used to derive the associated criteria can be found in Appendix B. Sample results exceeded the chronic criteria for dissolved lead; no acute criteria exceedances were observed.

Table 3: Estimated Lead Porewater Concentrations based on Measured Sediment Concentrations

Site	Site Name	Date (mo/year)	Sediment Pb Conc. (mg/Kg)	Max. Kd Value* (mL/g)	Min. Kd Value* (mL/g)	Assumed Equil. Pb Conc. (µg/L)	Estimated C_{pw} Based on Max. Kd (µg/L)	Estimated C_{pw} Based on Min. Kd (µg/L)
2863	Village Creek below Catherine Mine Rd	04/2000	$139^{\dagger}$	4,970	900	10-99.9	27.97	154.44
				2,300	710	100-200	60.43	195.77
2863/0.7	Village Creek at Catherine Mine Rd	11/2003	$104^{\dagger}$	4,970	900	10-99.9	20.93	115.56
				2,300	710	100-200	45.22	146.48
2863/0.7	Village Creek at Catherine Mine Rd	02/2006	$223^{\dagger}$	4,970	900	10-99.9	44.9	248
				2,300	710	100-200	97.0	314
2864	Village Creek above. Shays Creek	04/2000	$108^{\dagger}$	4,970	900	10-99.9	21.73	120.00
				2,300	710	100-200	46.96	152.11
2864	Village Creek adj. MLMRA Tailings	04/2000	$403^{\dagger}$	4,970	900	10-99.9	81.09	447.78
				2,300	710	100-200	175.22	567.60
2864	Village Creek below Route 217	04/2000	$139^{\dagger}$	4,970	900	10-99.9	27.97	154.44
				2,300	710	100-200	60.43	195.77
2864/0.3	Village Creek just above Shays Creek	08/2005	$74.3^{\dagger}$	4,970	900	10-99.9	14.95	82.56
				2,300	710	100-200	32.30	104.65

Note: C_{pw} = pore water concentration, MLMRA = Mine La Motte Recreation Area
* assumes average pH = 8.0
† exceeds the freshwater Threshold Effect Concentration for lead of 35.8 ppm

Table 4: Comparison of Instream Lead Concentrations with Paired Acute and Chronic Criteria

Site	Site Name	Date (mo/day/year)	Estimated Flow (cfs)	Hardness (mg/L)	Pb_{tot} (µg/L)	Pb_{diss} (µg/L)	Pb_{diss} Acute Criteria (µg/L)	Pb_{diss} Chronic Criteria (µg/L)
2863/1.7	Village Cr. below Shays Cr.	12/22/2005	18.0	202	--	0.12499	137.5259	5.362675
2863/1.7	Village Cr. below Shays Cr.	08/02/2005	3.2	232	1.57	0.66	159.2289	6.208962
2864/0.3	Village Cr. above Shays Cr.	08/01/2005	4.0	202	3.07	1.36	137.5259	5.362675
2865/0.1	Shays Cr. below Mine La Motte tailings pond	08/01/2005	4.0	246	15.7	9.01	169.3685	6.604345*
2866/1.4	Sweetwater Br. above Mine La Motte Lake	08/02/2005	3.2	160	34.4	21.5	107.2575	4.182395*
2866/1.4	Sweetwater Br. above Mine La Motte Lake	12/22/2005	18.0	150	--	1.56	100.0837	3.902659
2872/0.2	Musco Creek near mouth	08/02/2005	3.2	110	0.5	0.47	71.59998	2.791965
2872/0.2	Musco Creek near mouth	08/02/2005	3.2	87	0.28	0.34	55.45255	2.162314

Note: cfs = cubic feet per second, Pb_{tot} = total lead, Pb_{diss} = dissolved lead
*concentration exceeds criteria

3. Applicable Water Quality Standards and Numeric Water Quality Targets

3.1 Beneficial Uses

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B

3.2 Use that is Impaired

- Protection of Warm Water Aquatic Life

3.3 Antidegradation Policy

Missouri's Water Quality Standards 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 a level of water quality necessary to maintain and protect those uses. Tier I 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 Nov. 28, 1975, the date of EPA's first Water Quality Standards Regulation.

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. 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 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 and state resource waters, 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.

3.4 Specific Criteria

Village Creek is included on Missouri's 2004/2006 303(d) list of impaired waters for inorganic sediment and lead. The source of the inorganic sediment and lead impairment is believed to be from mine tailings originating upstream in the Mine La Motte area, which began lead extracting operations more than 200 years ago. The ultimate goal of this TMDL is to reduce inorganic sediment and lead in the two impaired segments of Village Creek (Water Body IDs 2863 and 2864).

3.4.1 Inorganic Sediment

Missouri has no numeric criteria for inorganic sediment. Excessive deposits of sediment in waters of the state are interpreted as violations of the general criteria of the water quality standards. The Missouri Water Quality Standards for general criteria [10 CSR 20-7.031(3)] state that:

> *(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 substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life* (MoSOS 2008)*;*

And from 10 CSR 20-7.031(4)(H),

> *Solids. Water contaminants shall not cause or contribute to solids in excess of a level that will interfere with beneficial uses. The stream or lake bottom shall be free of materials which will adversely alter the composition of the benthos, interfere with the spawning of fish or development of their eggs or adversely change the physical or chemical nature of the bottom* (MoSOS 2008).

3.4.2 Lead

Missouri's WQS Specific Criteria at 10 CSR 20-7.031(4)(A) states, in part, that:

> *The maximum chronic toxicity criteria in Tables A and B shall apply to waters designated for the indicated uses given in Tables G and H. All Table A and B criteria are chronic toxicity criteria, except those specifically identified as acute criteria. Water contaminants shall not cause or contribute to concentrations in excess of these values* (MoSOS 2008).

Additionally, Missouri WQS at 10 CSR 20-7.031(4)(B)1 state:

> *Water contaminants shall not cause the criteria in Tables A and B to be exceeded. Concentrations of these substances in bottom sediments or waters shall not harm benthic organisms and shall not accumulate through the food chain in harmful concentrations, nor shall state and federal maximum fish tissue levels for fish consumption be exceeded* (MoSOS 2008).

Lead water quality criteria for the protection of aquatic life designated use are expressed in as dissolved metals [10 CSR 20-7.031(4)(B)2.(II)]. These criteria are hardness dependent and calculated from the formulas shown below and found in Table A of 10 CSR 20-7.031. Hardness values for criteria determination were calculated per 10 CSR 20-7.031(1)(Y) (MoSOS 2008).

Equation 4: $\text{Acute} = e^{(1.273*\ln\text{(hardness)}-1.460448)}*(1.46203-(\ln(\text{hardness})*0.145712)) = \mu\text{g/L}$
Equation 5: $\text{Chronic} = e^{(1.273*\ln\text{(hardness)}-4.704797)}*(1.46203-(\ln(\text{hardness})*0.145712)) = \mu\text{g/L}$

3.5 Numeric Water Quality Targets

Most of the available monitoring data for the Village Creek watershed has been collected for lead rather than sediment. Most streams located in the Ozark physiographic province of Missouri have a low natural background of sediment loading and the land use in this watershed is dominated by deciduous forest and grasslands. This TMDL will therefore address the erosion of mine tailings as the source of inorganic fine sediments causing the impairment. The following discussion provides a basis for using lead, as well as fine sediments and suspended sediments, as TMDL endpoints for evaluating the impacts of sediment and lead in the pore water of Village Creek.

It would be difficult to accurately measure the volume of eroded sediment or mine tailings that have entered Village Creek and impaired its beneficial uses. Therefore, in the absence of sediment data, targeting pore water lead concentration becomes a valuable method to address both the sediment impairment and the lead toxicity impairment associated with lead in sediment. The following section provides the rationale why pore water lead resulting from lead in sediment was adopted to address lead and sediment in the Village Creek watershed:

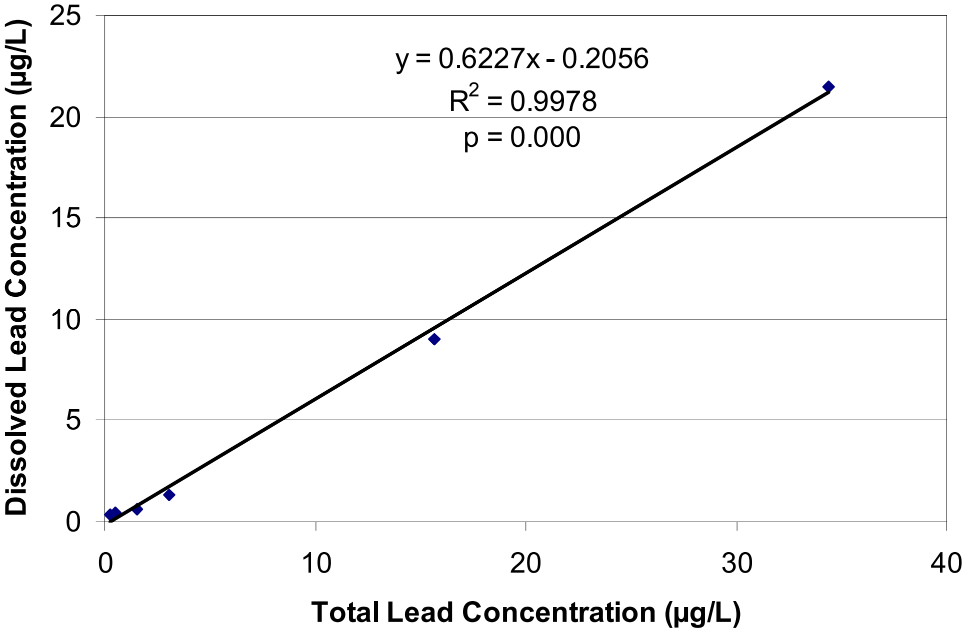
- The surrounding area upstream of Village Creek is highly erodible due to more than 200 years of lead mining from several principal mines (USGS 2003; EPA 2000; MoDNR 2004); this is the principal source of the lead and sediment causing the impairment to Village Creek;
- Visual observations of Village Creek over the past 15 years by the department have confirmed that instream deposition of mine tailings is due to erosion from upstream lead mine tailings piled adjacent to the creek;
- Extensive, detailed and consistent monitoring of these tailings have produced an excellent data set for lead;
- Jacobs Engineering Group (1995) reported that, while this region is rich in many metals such as copper, cobalt, nickel, iron, zinc, and silver, lead is predominant;
- Data reported by ATSDR (2005) indicate that filtered stream samples were "almost always non-detectable" for lead, suggesting that lead is strongly associated with suspended or bed sediments in streams;
- In contrast, downstream sediment samples have consistently ranged as high as approximately 7,000 ppm lead, verifying that most of the lead occurs in sediment rather than dissolved in the water column;
- It is well recognized that lead is chemically stable and rather strongly sorbs to sediment particles (Hassan *et al.* 1996; McIntosh 1991).

For these reasons, it is reasonable and appropriate to use dissolved lead in sediment pore water to address impairments for sediment as well as lead. In the case where the impairment is chemical in nature, the use of lead is believed to be a conservative assumption because lead is known to be more toxic than sediment in an aquatic ecosystem. With respect to physical impairment (e.g., smothering available benthic habitat), suspended sediment and percent fine sediment are appropriate targets based on evaluations performed by the department (MoDNR 2006).

The lead TMDL endpoints are hardness-dependent acute and chronic criteria derived using Equation 4 and Equation 5, respectively, from Missouri's Water Quality Standards and expressed as dissolved concentrations.

A simple statistical analysis of the relationship of total to dissolved lead concentrations was performed and the results are shown in Figure 3. A very strong statistical correlation ($r^2 = 0.9978$ and $p = 0.000$) between these two parameters suggests that dissolved lead concentration is a good predictor of total lead concentration in the water column. The TMDL endpoint for the Village Creek watershed is therefore based on dissolved lead concentrations. As discussed in Section 1.2, only exceedances of the chronic lead were observed in the water quality monitoring data. Therefore, the chronic criterion for dissolved lead is set as the water quality endpoint for the TMDL. An additional lead target is set such that the mass of lead in a given quantity of sediment is below the consensus based Threshold Effect Concentration of 35.8 ppm (MacDonald *et al.* 2000).

Figure 3: Correlation of Total to Dissolved Lead Concentrations



The sediment endpoints for the TMDL are derived based on two different methods. The first is a regional reference approach using the 25th percentile of regional total suspended solids data as the target to develop a Load Duration Curve. The second is set by targeting the percent fine sediment in Village Creek to that measured in a control stream in the region (MoDNR 2006).

4. Source Inventory and Assessment

Source assessment characterizes known and suspected sources of pollutant loading to the impaired water body. Pollutant sources identified within the watershed are categorized and quantified to the extent that information is available. Sources of inorganic sediment and lead may be point or nonpoint source in nature.

Point sources are defined under Section 502(14) of the federal Clean Water Act and are typically regulated through the Missouri State Operating Permit program[5]. There are currently no permitted dischargers within the Village Creek watershed that cause or contribute inorganic sediment and lead loading to the impaired segments. However, active and abandoned mine areas can be classified as point sources due to the nature of mining and milling activities, regardless if they are currently

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[5] The Missouri State Operating Permitting system is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program

covered by a discharge permit (EPA 1993a). The Mine La Motte abandoned mine land area can therefore collectively be considered a point source even though a discharge permit has not been issued for the area. Mine tailings from the Mine La Motte abandoned mine land area are the main contributor of inorganic sediment and lead loading to the impaired water body segments.

Nonpoint sources are diffuse sources of pollutant loading that typically cannot be identified as entering a waterbody at a single location. These sources involve runoff from non-mining areas and may contribute inorganic sediment and lead to surface waters as a result of runoff-producing storm events. Some examples include off-site haul and access roads not constructed of waste rock or spent ore from mining areas. When compared to the Mine La Motte abandoned mine land area, nonpoint sources of inorganic sediment and lead loading are expected to be minor. Undisturbed areas of the watershed are expected to only contribute minor amounts of inorganic sediment to the impaired segments. Additionally, while the available literature indicate some amount of lead in surface materials within Madison County (USGS 1984), undisturbed and vegetated areas within the watershed are expected to be insignificant sources of dissolved lead to the impaired segments. Areas covered with forests and grassland have vegetative cover and stable soils and are therefore not expected to contribute to inorganic sediment or lead loading.

Other potential sources of inorganic sediment and lead include roads and highways and storm water runoff from roads and parking lots, which may contain tire residues, exhaust fumes, battery fluid, and motor oil, all of which may be potential sources of lead. Given the location of these land use types within the Village Creek watershed, inorganic sediment and lead contributions from these sources would likely occur in the lower watershed only, below the documented impairments.

Within the Village Creek watershed, there are no agricultural nonpoint sources of lead that cause or contribute to the impairment. Likewise, inorganic sediment loading from agricultural sources is also expected to be minor. Agricultural areas, such as row crop, should not contribute during the growing season due to crop cover, but may contribute to the impairments during field preparation and tillage. However, these periods of disturbance are expected to be infrequent. Additionally, row crop area in the Village Creek watershed only accounts for about 3 percent of the total watershed land use thereby making any inorganic sediment or lead loading contributions minimal.

Additionally, although there are no state-permitted concentrated animal feeding operations, or CAFOs, in the watershed, the likely presence of lower density livestock populations on grassland pastures may also be a potential contributor of inorganic sediment to Village Creek. Livestock tend to concentrate near feeding and watering areas causing those areas to become barren of plant cover, thereby increasing the possibility of erosion during a storm event (Sutton, 1990). However, due to the close association of lead with sediment, as stated in Section 3.5, as well as observations made by the department for the past 15 years, livestock influences are expected to be minor when compared to contributions from the Mine La Motte abandoned mine land tailings pile.

5. Technical Approach and Methodology

A TMDL is defined as the total amount of pollutant that can be assimilated by a receiving water body while achieving water quality standards. A TMDL is expressed as the sum of all wasteload allocations (point source loads), load allocations (nonpoint source loads), and an appropriate margin of safety, which attempts to account for uncertainty concerning the relationship between effluent limitations, modeling and water quality. The TMDL, which is also known as the Load Capacity (LC) of the water body, can be expressed by the following equation:

Equation 6: $$\mathbf{TMDL = LC = \Sigma\ WLA + \Sigma\ LA + MOS}$$

where WLA is the sum of all wasteload allocations, LA is the sum of all load allocations, and MOS is the margin of safety. The objective of the TMDL is to estimate allowable pollutant loads and to allocate these loads to known pollutant sources within the watershed so appropriate control measures can be implemented and the water quality standard achieved. The Code of Federal Regulations (40 CFR § 130.2 (1)) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For lead contamination, TMDLs are expressed as pounds per day using a load duration curve and as a mass of lead in a given mass of bed sediment. The load duration curve represents the maximum one-day load the water body can assimilate and maintain the water quality criterion, while the given mass of lead per mass of sediment applies on any day in which the content in bed sediment is measured. For inorganic sediment, the TMDL is also expressed as a load duration curve and as a percent of bed sediment that can be comprised of fine sediments.

5.1 Developing a Load Duration Curve

A load duration curve was calculated for the chronic dissolved lead criterion by multiplying estimated flow values for the outlets of each segment of Village Creek by the chronic dissolved criterion for lead, which is hardness-dependent. Units for these load duration curves are pounds of dissolved lead per day (lb lead/day). The chronic criterion value was calculated using the 25th percentile water hardness value as outlined in Missouri Water Quality Standards at 10 CSR 20-7.031(1)(Y). The TMDLs were plotted as load duration curves and were used to derive wasteload allocations and load allocations for each impaired segment. The load duration curve that defines the TMDL for inorganic sediment is represented as the 25th percentile of total suspended solids concentrations in the region. The lead sediment target was set using the percent of lead in a given mass of sediment such that the Threshold Effect Concentration is below the target level. The inorganic sediment target is also represented by calculating the percent fine sediment by mass. Results and calculations are presented in Section 6.

5.2 Deriving TMDL Targets

5.2.1 Deriving the Chronic Dissolved Lead Criterion to Support the TMDL

Analysis of the dissolved lead data indicate that only chronic dissolved lead criteria were exceeded and no excursions were observed for the acute dissolved lead criteria. Therefore, the chronic dissolved lead criterion was used for this TMDL. The chronic dissolved lead criterion was calculated using Equation 5.

5.2.2 Deriving the Inorganic Sediment target to Support the TMDL

In the case of inorganic sediment where the TMDL is targeting a narrative standard, a reference approach is taken. A series of United States Geological Survey (USGS) sampling stations and results for non-filterable residue (Appendix B) were used to calculate the 25th percentile of suspended sediment concentrations at various flows across the region in which Village Creek is located. Using the data from these sites, the 25th percentile of suspended sediment concentrations is

5 mg/L. This concentration is used as a numeric translator for the narrative inorganic sediment standard. A more in-depth discussion of this procedure is outlined in Appendix C.

5.3 Stepwise Explanation of How TMDL Calculations were Performed

5.3.1 Load Duration Curves

The following discussion provides a summary of the steps involved in the calculation of key components of the Village Creek TMDLs for lead and inorganic sediment.

Step 1: Develop a flow duration curve. A flow duration curve is a graph depicting the percent of time in which a given flow is equaled or exceeded. An estimated flow duration curve for Village Creek was developed for this TMDL. A synthetic flow regime was developed based on the level of stream flow measured in gaged streams in the same region of the state. The USGS gage stations for the Little St. Francis River at Fredericktown, Mo (07035000), the East Fork Black River near Lesterville, Mo (07061270), and South Fork Saline Creek near Perryville, Mo (07020550) were used to develop a flow duration curve based on flow per square mile in the drainage area.

Step 2: Develop load duration curve (TMDL). Similar to a flow duration curve, the load duration curve depicts the percent of time in which a given dissolved lead or sediment load is equaled or exceeded. When using the chronic dissolved lead criterion or numeric non-volatile suspended solids translator to calculate the load duration curve, the resulting curve also represents the TMDL. In brief, the load duration curve is developed by multiplying the stream flows developed in Step 1 by the chronic dissolved lead criterion or numeric non-volatile suspended solids translator and by a unit conversion factor, as summarized by the following equation:

Equation 7. **Load (lb/day) = stream flow (cfs) * criterion (mg/L) * 5.394**

Step 3: Develop load duration curve with Margin of Safety. The margin of safety can be either implicit or explicit. In this case, the margin of safety is both implicit and explicit. The margin of safety for this TMDL is further explained in section 6.7 of this document.

Step 4: Estimate current point source loading. The main point source contributor of inorganic sediment and lead loading to Village Creek is the Mine La Motte abandoned mine land area. In light of the limited water quality data available for the Village Creek watershed, the maximum detected concentration of dissolved lead was used to estimate current dissolved lead loading from point sources. The current point source dissolved lead loading can be calculated using Equation 7 and the following values:

*Average current point source loading = maximum detected dissolved Pb concentration (mg/L) * estimated stream flow from sample date (cfs) * 5.394 (lb/day)*

The estimated current point source loading can then be used to calculate point source load reductions for the watershed (Step 8). In the case of inorganic sediment, there are no data for total suspended solids in Village Creek and a percent reduction cannot be calculated.

Step 5: Calculate Wasteload Allocation. The wasteload allocation portion of the TMDL is an instream pollutant allocation expressed as pounds per day (lb/day) and used to allocate pollutant loading to point sources of pollutants within the watershed. Such sources may be diverse and are predominantly subject to permitting requirements. The wasteload allocation is equal to the available load capacity after the margin of safety and load allocation are accounted for.

In the case of dissolved lead, the predominant land uses (i.e. forest and grassland) contribute a negligible amount of dissolved lead pollutant loading to the watershed. This is generally supported by water quality data collected from water bodies not likely to be affected by the abandoned mine lands (e.g., site 2872/0.2 at Musco Creek, see Figure 1). Due to the extremely minor contribution of dissolved lead from nonpoint sources within the watershed, it is reasonable to allocate the entire loading capacity for dissolved lead to point sources.

In the case of inorganic sediment, the predominant land uses (i.e. forest and grassland) may contribute a minor amount of the overall inorganic sediment pollutant loading to the watershed. However, the amount of inorganic sediment loading from forest, grassland, and agricultural land use types is not as significant as that derived from the abandoned mine land areas. The lack of total suspended solids data makes it problematic to calculate the amount, however small, that other land uses contribute to pollutant loading of inorganic sediment. There is reassurance, however, that sediment runoff from forest and grassland areas is likely to be minor due to the stability and nature of the available vegetative cover. The abundance of vegetation in these areas reduces the erosional effects of storm water runoff by limiting storm water velocity, lessening raindrop impact and providing greater soil infiltration (EPA 1993b). For these reasons, the amount of contribution from these sources is believed to be less than the explicit margin of safety used for this pollutant. Likewise, agricultural impacts are expected to be equally minimal due to the small percentage of land in the watershed (3.4 percent) that is row crop. Therefore, due to the small contribution of inorganic sediment from nonpoint sources in the watershed, it is reasonable to allocate the entire loading capacity for inorganic sediment to point sources.

The wasteload allocation for dissolved lead and inorganic sediment at any given percentile flow exceedance can be calculated from the TMDL load duration curve by solving Equation 6 for the wasteload allocation component:

Equation 8. **WLA (lb/day) = TMDL (lb/day) – MOS (lb/day) – LA (lb/day)**

where WLA equals wasteload allocation, MOS equals the margin of safety, and LA equals the load allocation.

Step 6: Estimate current nonpoint source loading. For the reasons detailed in Section 4 and in Step 5 above, nonpoint source loading of inorganic sediment and lead to the watershed are expected to be minor. This is generally supported by the lack of impairment for these pollutants in nearby streams and watersheds with similar land use types. Therefore, for the purposes of this TMDL, current nonpoint source loading of inorganic sediment and dissolved lead is set to zero.

Step 7: Calculate load allocation. The load allocation is also an instream pollutant allocation expressed in lb/day, similar to the wasteload allocation. It is used to allocate pollutant loading to nonpoint sources of pollutants within a watershed. Such sources may be diverse and difficult to identify and are not subject to permitting requirements. Because the predominant source of inorganic sediment and lead loading to Village Creek derives from point sources, the load allocation portion of the TMDL is set to zero.

Step 8: Estimate load reduction. Point source load reduction was calculated by subtracting the wasteload allocation (Step 5) from the current point source loading estimate (Step 4) as shown in the following equation:

Equation 9. *Point source load reduction (lb/day) = Current point source load (lb/day) – Wasteload Allocation (lb/day)*

The percent point source load reduction can be calculated using the following equation:

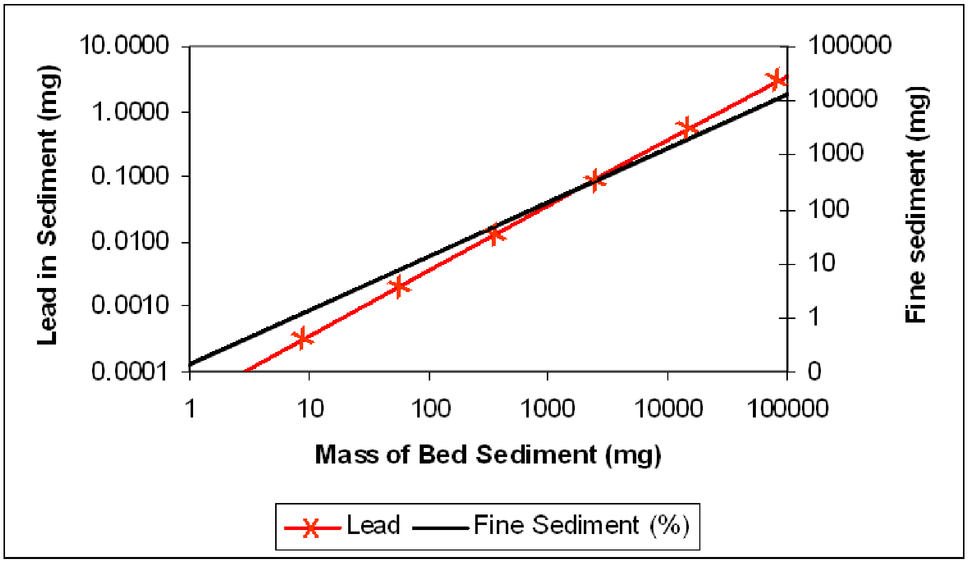
Equation 10. *Percent point source load reduction = (point source load reduction [lb/day]/ Current point source loading [lb/day]) * 100*

As stated in Step 6, load allocation reductions are not necessary because nonpoint source loading of inorganic sediment and lead are expected to be minor. Results of all the aforementioned calculations are discussed in Section 6.

5.3.2 Bed Sediment Mass Targets

To address the impairment for inorganic sediment as both percent fine sediment and lead in bed (bottom) sediment, a relationship was generated using data for percent fine sediment and the specific mass of sampled sediment from the stream bottom collected from the Castor River, which is a reference stream listed in the Missouri water quality standards (Figure 4). This relationship is independent of segment location and refers to any location from which a sample is taken. As such, the bed sediment TMDLs are instantaneous and apply on any given day.

Figure 4. TMDL for Bed Sediment, Lead and Percent Fine Sediment



The percent fine sediment target of 13.64 percent was developed using a control site on the Castor River (Water Body ID 2297) one mile downstream from the crossing of Route J (MoDNR 2006). The load capacity curve and table were developed based on the mass of fine sediment that could be contained within a bottom sediment sample of a given mass. For example, a 100 mg bottom sediment sample should contain no more than 13.64 mg of fine sediment.

The bed sediment lead load capacity was generated using the equilibrium partitioning methodology described in Section 2.2. The load capacity was calculated based on the percent of a sediment mass that could be composed of lead such that the threshold effect level was not exceeded. As with the percent fine sediment load capacity, the bed sediment lead load capacity applies on any given day.

5.4 Reduction Target

The advantage of load duration curve and bed sediment approaches is avoidance of the constraints associated with using a single-flow critical condition during the development of a TMDL. To determine the amount of load reduction necessary to comply with the chronic criterion for dissolved lead, in-stream critical conditions were evaluated. According to the load duration curve, water quality data were only available at relatively low flow conditions in the Village Creek watershed. Therefore, the percentage of pollutant load reduction was estimated based on this flow condition.

6. Results of TMDL and Pollutant Allocations

Following is a discussion of the results of the TMDL process for Village Creek and an evaluation of potential sources and pollutant allocations. Section 5.2 discussed the specific steps taken to develop each of these components.

6.1 TMDL Calculations

The TMDLs for bed sediment lead and percent fine sediment are shown in Figure 4. Table 7 provides a tabular expression of the TMDL at varying masses of sediment in any particular sample. These TMDLs are mass dependant and apply at any point in either segment of Village Creek.

Figures 5 and 6 show the dissolved lead load duration curves for both impaired segments of Village Creek. These load duration curves are the dissolved lead TMDLs for each water body. Section 5.2.1 discussed the specific steps taken to develop each of these components. As mentioned in Section 5.3, the wasteload allocation component is equal to the available load capacity after the margin of safety and load allocation are accounted for. Because the margin of safety for dissolved lead is implicit and the load allocation contribution to the impaired segments is negligible, the wasteload allocation is set at the load capacity. In Figures 5 and 6, the area below the TMDL curve would therefore equal the wasteload allocation component at each flow exceedance range.

Figures 7 and 8 show the inorganic sediment load duration curves for both impaired segments of Village Creek. These load duration curves are the inorganic sediment TMDLs for each water body. Section 5.2.2 discussed the specific steps taken to develop each of these components. As also mentioned in Section 5.3, the wasteload allocation component is equal to the available load capacity after the margin of safety and load allocation are accounted for. Because the margin of safety for non-volatile suspended solids is explicit (10 percent of the load capacity), the wasteload allocation is set at the load capacity minus the margin of safety and load allocation which is set at zero. In

Figures 7 and 8, the area below the TMDL curve would therefore equal the wasteload allocation and margin of safety components at each flow exceedance range.

Figure 5: TMDL Dissolved Lead - Village Creek (Water Body ID 2864)

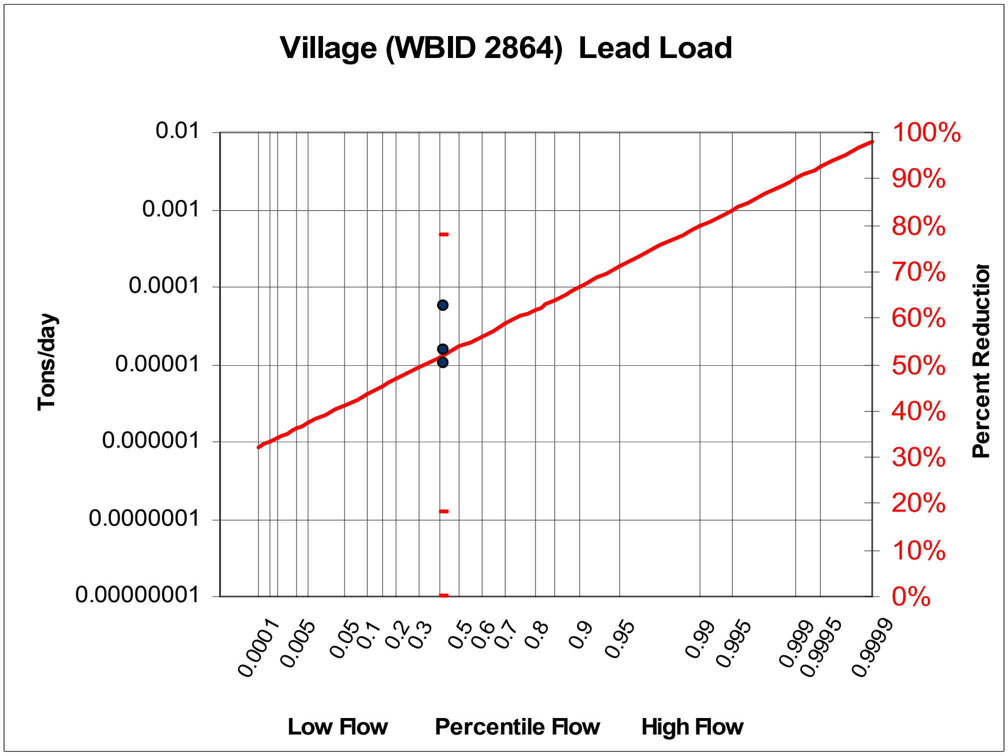


Figure 6: TMDL Dissolved Lead - Village Creek (Water Body ID 2863) -

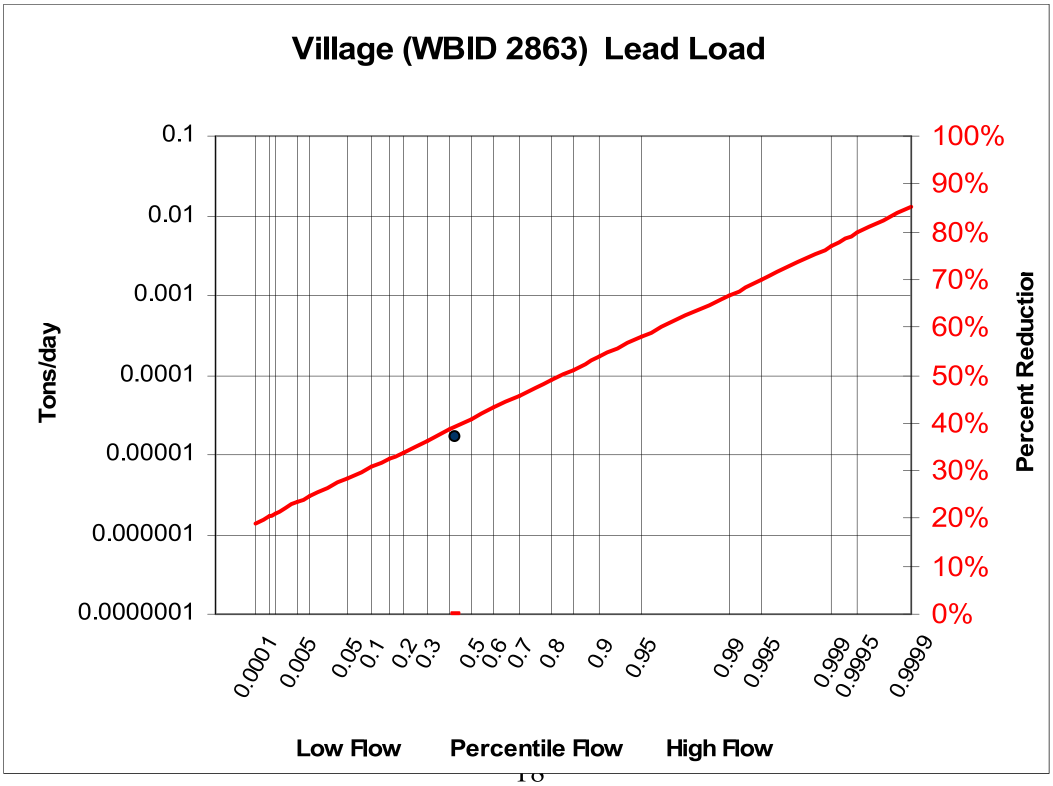


Figure 7: TMDL Inorganic Sediment - Village Creek (Water Body ID 2864) -

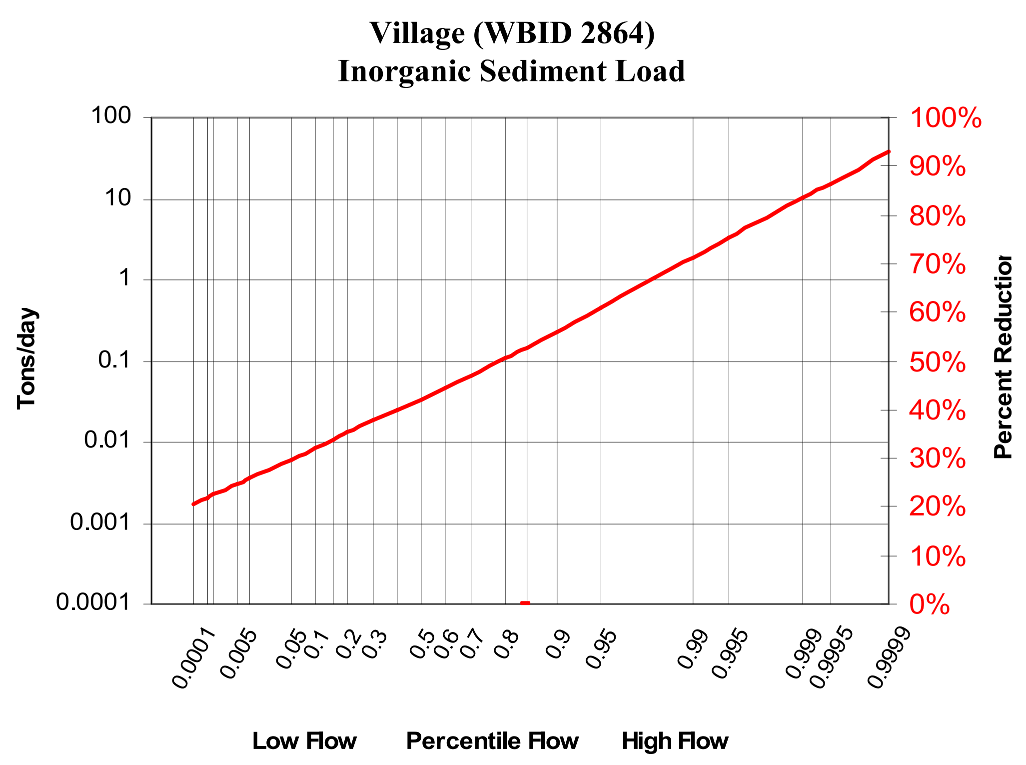
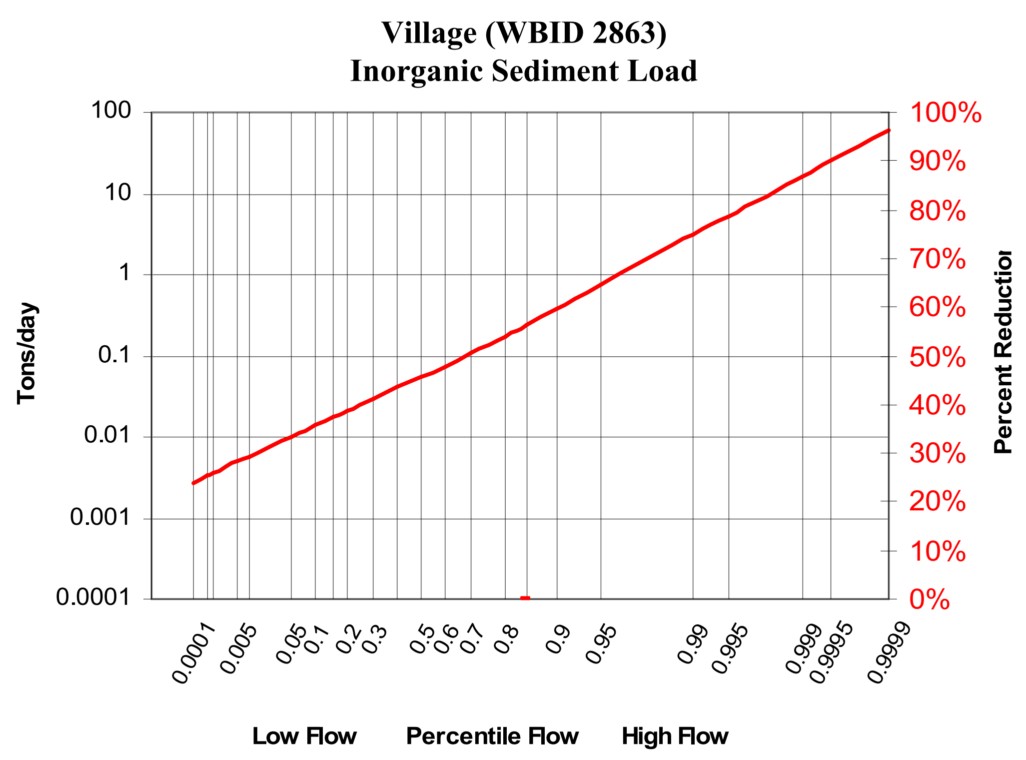


Figure 8: TMDL Inorganic Sediment - Village Creek (Water Body ID 2863) -



Tables 5 and 6 present Load Capacity (LC), Wasteload Allocation (WLA), Load Allocation (LA), and Margin of Safety (MOS) values for dissolved lead and inorganic sediment for each of the Village Creek impaired segments. TMDL load capacity values were converted from tons/day to lbs/day by dividing the load by a conversion factor of 2,000.

Table 5. TMDL Lead and Sediment - Village Creek (Water Body ID 2864)

% Flow Exceedance	Estimated Flow (cfs)	Lead TMDL (lbs/day)	Lead MOS* (lbs/day)	Lead LA (lbs/day)	Lead WLA (lbs/day)	Sediment TMDL (lbs/day)	Sediment MOS (lbs/day)	Sediment LA (lbs/day)	Sediment WLA (lbs/day)
99	0.266	0.004	--	0.0	0.004	7.24	0.72	0.0	6.52
95	0.456	0.006	--	0.0	0.006	12.3	1.2	0.0	11.1
90	0.633	0.008	--	0.0	0.008	17.1	1.7	0.0	15.4
80	0.978	0.013	--	0.0	0.013	26.3	2.6	0.0	23.7
50	2.53	0.034	--	0.0	0.034	67.8	6.8	0.0	61
20	7.78	0.104	--	0.0	0.104	212	21.2	0.0	190.8
10	15.1	0.203	--	0.0	0.203	463	46.3	0.0	416.7
5	27.4	0.368	--	0.0	0.368	928	92.8	0.0	835.2

*Lead Margin of Safety is implicit.

Table 6. TMDL Lead and Sediment - Village Creek (Water Body ID 2863)

% Flow Exceedance	Estimated Flow (cfs)	Lead TMDL (lbs/day)	Lead MOS* (lbs/day)	Lead LA (lbs/day)	Lead WLA (lbs/day)	Sediment TMDL (lbs/day)	Sediment MOS (lbs/day)	Sediment LA (lbs/day)	Sediment WLA (lbs/day)
99	0.446	0.006	--	0.0	0.006	11.6	1.2	0.0	10.4
95	0.763	0.010	--	0.0	0.010	19.8	2.0	0.0	17.8
90	1.06	0.014	--	0.0	0.014	27.5	2.8	0.0	24.7
80	1.64	0.022	--	0.0	0.022	42.3	4.2	0.0	38.1
50	4.23	0.057	--	0.0	0.057	109	10.9	0.0	98.1
20	13.0	0.175	--	0.0	0.175	341	34.1	0.0	306.9
10	25.4	0.341	--	0.0	0.341	745	74.5	0.0	670.5
5	45.8	0.615	--	0.0	0.615	1490	149.0	0.0	1341

*Lead Margin of Safety is implicit

Table 7. Village Creek Bed Sediment TMDLs

Mass of Sample (mg)	TMDL Mass Lead (mg)	TMDL Mass Fine Sediment (mg)
1	0.0000	0.136
10	0.0004	1.36
100	0.0036	13.6
1000	0.0358	136
10000	0.358	1360
100000	3.58	13600

6.2 TMDL Pollutant Allocation and Reductions

Any allocation of waste loads and loads will be made in terms of dissolved lead, sediment lead, suspended sediment, and percent fine bed sediment reductions. In calculating the TMDLs for these pollutants, the average condition was considered across seasons to establish both TMDL endpoints and desired reductions. To best represent the average condition, the dissolved lead criterion was multiplied by the median daily flow across all flow conditions. This is represented graphically by the integrated area under the lead load duration curve (Figures 5, 6, 7, and 8) and in tabular form (Tables 5 and 6). Bedded sediment targets are expressed graphically in Figure 4 and in tabular form in Table 7.

6.3 Wasteload Allocation for Village Creek Watershed

The wasteload allocation at the low flow condition (90th percentile flow exceedance) was estimated by using Equation 8 provided in Section 5:

Lead (implicit Margin of Safety)
WBID 2863: WLA (0.014 lb/day) = TMDL (0.014 lb/day) – LA (0.0 lb/day)
WBID 2864: WLA (0.008 lb/day) = TMDL (0.008 lb/day) – LA (0.0 lb/day)

Sediment (10 percent Margin of Safety)
WBID 2863: WLA (24.7 lb/day) = TMDL (27.5 lb/day) – MOS (2.8 lb/day) – LA (0.0 lb/day)
WBID 2864: WLA (15.4 lb/day) = TMDL (17.1 lb/day) – MOS (1.7 lb/day) – LA (0.0 lb/day)

The wasteload allocation for dissolved lead and inorganic sediment must be achieved at the outlets to each segment. As seen in Figures 5 and 6, wasteload allocation increases with increasing flow. The wasteload allocation for bedded sediment must be met at any point in each segment.

6.4 Load Allocation for Village Creek Watershed

The dissolved lead load allocation for the Village Creek watershed was set at zero due to negligible nonpoint source loading of dissolved lead to the impaired segments. The inorganic sediment load allocation for the Village Creek watershed was also set at zero due to minor inorganic sediment loading to the impaired segments. As stated in Section 5, the amount of contribution from these sources is believed to be less than the explicit margin of safety used for this pollutant so no allocation is necessary.

6.5 Point Source Load Reduction

Based on the prior assessment of sources and the distribution of excursions from water quality standards at monitoring locations, the loading of inorganic sediment and dissolved lead originates from the abandoned mine lands within the watershed. Miscellaneous land uses and natural background sources contribute a relatively small fraction of the overall pollutant source loading. This is generally supported by water quality data collected from water bodies not likely to be affected by the abandoned mine lands (i.e. site 2872/0.2 at Musco Creek). Therefore, the load reductions necessary to achieve water quality standards will be obtained from the Mine La Motte abandoned mine lands area. However, while a wasteload allocation was calculated for the unpermitted Mine La Motte mine land, any allocation given does not reflect an authorization to discharge from an unpermitted point source.

Since water quality data from Musco Creek was collected on the same day as the location likely to be affected by the abandoned mine lands (i.e. the location with the maximum detected lead concentration), loadings from these two locations can be directly compared because of similar flow conditions. Pollutant loading from both of these locations on the day of sampling can be estimated using the same methodology for calculating the current point source pollutant loading described in Section 5. Pollutant loading calculated using this methodology is considered conservative because the estimated loading from Musco Creek and Sweetwater Branch is likely overestimated due to higher flows at Village Creek (WBID 2863) compared to these tributaries. The dissolved lead loadings at Musco Creek (site 2872/0.2) and at Sweetwater Branch (site 2866/1.4) on August 2, 2005 were estimated to be 0.0070 lb/day and 0.3731 lb/day, respectively (Figure 1).

The anticipated average WLA reduction from point sources (i.e. Mine La Motte abandoned mine lands) was calculated by subtracting the average wasteload allocation during low flow conditions (90th percentile) from the total current point source loading estimated in Section 5.3, Step 4:

Village Creek (Water Body ID 2863)
*Average Current point source loading = max. dissolved Pb concentration (0.0215 mg/L) * estimated stream flow from sample date (1.82 cfs) * 5.394*
= 0.211 lb/day

Village Creek (Water Body ID 2864)
*Average Current point source loading = max. dissolved Pb concentration (0.0215 mg/L) * estimated stream flow from sample date (0.68 cfs) * 5.394*
= 0.0789 lb/day

For Village Creek (Water Body ID 2863), this yields a point source load reduction estimate of 0.197 lb/day ((0.211 lb/day - 0.014 lb/day)/0.211 lb/day * 100), which represents a 93.4 percent reduction of dissolved lead from current point source loading estimates. For lead concentration in bedded sediment, the load reduction percentage would be calculated as 83.9 percent ((223 mg/kg - 35.8

mg/kg)/223 mg/kg *100) from the maximum measured sediment lead concentration from Village Creek (2863/07) on February 27, 2006 and utilizing the consensus based Threshold Effect Concentration of 35.8 mg/kg.

For Village Creek (Water Body ID 2864), this yields a point source load reduction estimate of 0.0709 lb/day ((0.0789 lb/day - 0.008 lb/day)/0.0789 lb/day *100), which represents an 89.9 percent reduction of dissolved lead from current point source loading estimates. For lead concentration in bedded sediment, the load reduction percentage would be calculated as 91.1 percent ((403 mg/kg - 35.8 mg/kg)/403 mg/kg * 100) from the maximum measured sediment lead concentration from Village Creek (SD9) in April 2000 and utilizing the consensus based Threshold Effect Concentration of 35.8 mg/kg described in Section 2.2 of this document.

6.6 Nonpoint Source Load Reduction

Because there are negligible nonpoint source loading of dissolved lead and minor nonpoint source loading of inorganic sediment to the impairments in Village Creek, no reduction in nonpoint source loading is necessary under this TMDL.

6.7 Margin of Safety

Federal regulations at 40 CFR §130.7(c)(1) require that TMDLs take into consideration a margin of safety. The margin of safety is a conservative measure incorporated into the TMDL equation that accounts for the uncertainty associated with calculating the allowable pollutant loading required to ensure water quality standards are attained. EPA guidance allows for use of implicit or explicit expressions of the margin of safety, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the margin of safety is implicit. When a specific percentage of the TMDL is set aside to account for uncertainty, then the margin of safety is considered explicit. The net effect of the TMDL with a margin of safety is that the assimilative capacity of the watershed is slightly reduced.

This TMDL relies on both implicit and explicit margin of safety derived from a variety of calculations and assumptions. In deriving the dissolved lead TMDLs, an implicit margin of safety was applied by using the Threshold Effect Concentration for lead in sediment. The conservative assumptions and factors used in this method should account for any uncertainties in the loading calculations. Due to lack of available inorganic sediment data, an explicit margin of safety of 10 percent was applied when deriving the inorganic sediment TMDLs.

6.8 Uncertainty Discussion

This TMDL document was prepared using data and assumptions that contribute a degree of uncertainty to the process. Following is a list of operating assumptions needed to support the TMDL analysis and calculations.

- The estimated flow for the outlets of each segment is directly related to the flow per square mile of the three USGS gages used to develop the outlet flow record.
- The 25th percentile water hardness value of samples located in the area of Village Creek is representative of those conditions within Village Creek.

- Equilibrium partitioning calculations estimating pore water concentrations from bulk sediment were used to confirm the general nature of the impairment expressed as instream, aqueous phase concentrations.
- The contribution of dissolved lead from nonpoint sources in the Village Creek watershed is negligible. The contribution of inorganic sediment from nonpoint sources is minor and that any amount of contribution from these sources is believed to be less than the explicit MOS used for this pollutant.
- The current point source loading estimates calculated using the maximum detected dissolved lead concentration is representative of the actual point source loading at the low flow condition (90th percentile exceedance).

The load duration curve method was used to calculate pollutant specific TMDLs for the two impaired segments of Village Creek. Because the load duration curve method relies on measured water quality data, regional water hardness data, and a wide range of "flow exceedance" data, it represents a complete range of flows and pollutant loads anticipated in Village Creek. However, the lack of water quality data at mid to high stream flows did not allow for calculation of pollutant load reductions at these flow conditions. These data would have been beneficial to include in the analysis since the majority of inorganic sediment and lead in sediment can be expected to be contributed during mid to high stream flow conditions. As result, there is some uncertainty as to the actual pollutant reductions necessary to achieve water quality standards during these stream conditions.

6.9 Consideration of Critical Condition and Seasonal Variation

Federal regulations at 40 CFR §130.7(c)(1) require TMDLs take into consideration seasonal variation in applicable standards. Although there were insufficient water quality data to determine any seasonal pattern that may be occurring in the Village Creek watershed, the use of flow and load duration curves represents the allowable pollutant load under different flow conditions and across all seasons. The results obtained using the load duration curve method are therefore more robust and reliable over all flows and seasons when compared with those obtained under more limited conditions (e.g., critical low flow conditions).

7. Monitoring Plan for TMDLs Developed Under Phased Approach

Sediment monitoring was completed for Village Creek in May 2008. The department has not yet scheduled other monitoring for this water body. 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. Should additional water quality data be collected for the Village Creek watershed, these data will be evaluated in light of this TMDL.

8. Implementation Plan

Past metals mining in the Village Creek watershed left many tailings piles. When it rains, the water suspends the fine particles of metal and sediment and carries them to the waterways in the watershed. These particles impair aquatic life through metals toxicity and/or through loss of habitat due to excessive sedimentation. The following implementation strategies should be considered to ensure the improvement of water quality within the Village Creek watersheds addressed by this TMDL.

8.1 Point Sources

Point source reductions are typically implemented through discharge permits administered through the Missouri State Operating Permit program to meet the requirements of Missouri's WQS and the National Pollutant Discharge Elimination System (NPDES). The Mine La Motte abandoned mine lands, part of the Madison County Mines Superfund Site, have been identified as the source of the inorganic sediment and lead impairments to both segments of Village Creek. While the Mine La Motte and Madison County Mines Superfund site are currently not covered by an NPDES permit, future remedial actions must take into consideration the wasteload allocations established for dissolved lead and inorganic sediment found in this TMDL. These wasteload allocations and other requirements to improve water quality may be incorporated into an NPDES permit (either site-specific industrial or storm water) or other appropriate enforceable document (e.g., Applicable or Relevant and Appropriate Requirements, or ARARs).

Currently, EPA's Superfund program is in the process of prioritizing the operable units within the Madison County Mines area and has not formalized a plan for immediate cleanup of the area affecting Village Creek. A characterization study, by Potentially Responsible Parties with oversight by the EPA, is currently underway to determine the presence, concentration, and extent of heavy metal contamination in the Mine La Motte area. Superfund actions in other lead contaminated areas of Madison County are partially responsible for reducing the number of children tested in the county found to have high blood lead levels from 16 percent in 1999 to 6 percent in 2005 (EPA 2009). Although it is currently unknown what Superfund actions may occur in the Mine La Motte area, further reductions of children found to have high blood lead levels should be expected. Superfund activities that can aid in implementing this TMDL are stabilizing existing tailings piles from erosion and removing or remediating lead contaminated sediments. Adding vegetative cover to the tailings piles will aid in reducing both wind and water erosion thereby reducing the amount of lead contaminated sediment entering the impaired water bodies. Additionally, removing sediment and associated metals contamination from the affected watershed will provide similar if not greater recovery results.

8.2 Nonpoint Sources

Nonpoint source reductions are currently not necessary to reduce pollutant loading of dissolved lead and inorganic sediment to the Village Creek Watershed. Reductions obtained by implementing the wasteload allocations found in this TMDL should restore water quality in Village Creek. However, best management practices (BMPs) employed within the watershed must continue to be implemented to ensure antidegradation requirements are met. Further nonpoint source reductions in the watershed may be implemented through BMPs funded wholly or in part by Section 319 grants[6] or AgNPS SALT Program projects[7].

9. Reasonable Assurances

In most cases, "Reasonable Assurance" in reference to TMDLs relates to the certainty to which point sources will reduce pollutant loading to impaired water body segments. Currently, there are no permitted point source discharges of inorganic sediment and lead within the Village Creek watershed. However, the Mine La Motte abandoned mine lands are considered a point source for the purposes of this TMDL. Wasteload allocations to improve water quality may be incorporated into an NPDES permit (either site-specific industrial or storm water) or other appropriate enforceable document (e.g., Applicable or Relevant and Appropriate Requirements, or ARARs) to ensure wasteload allocation reductions are achieved. Any assurances that nonpoint source contributors of inorganic sediment or lead will implement measures to reduce their contribution in the future will not be found in this section. Instead, discussion of reduction efforts relating to nonpoint sources can be found in Section 8.2 of this TMDL.

10. Public Participation

These water quality limited segments are included on the approved 2004/2006 Missouri 303(d) List of impaired waters. EPA and the department's Water Protection Program developed this TMDL. This document was placed on 30-day public notice from July 27, 2009 through August 26, 2009. Groups that received the public notice announcement included the Missouri Clean Water Commission, the Water Quality Coordinating Committee, 25 Stream Team volunteers in the watershed and the two state legislators representing Madison County. In addition, the department posted the notice, the information sheet, and this document on the department's Web site, making them available to anyone with access to the Internet. Any comments received and the department's responses to those comments will be placed in the Village Creek file.

11. Administrative Record and Supporting Documentation

An administrative record on the Village Creek TMDL has been assembled and is being kept on file with the Missouri Department of Natural Resources. It includes any studies and the data and calculations this TMDL is based on.

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[6] Under section 319, State, Territories and Indian Tribes receive grant money that support a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects and monitoring to assess the success of specific nonpoint source implementation projects.

[7] Program that allows county soil and water conservation districts (SWCD) to direct technical and financial assistance to landowners with land identified and prioritized as having water quality impairments that address agricultural nonpoint source pollution problems.

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Appendices

Appendix A – Summary of Flow Data

Appendix B – Village Creek TMDL methodology

Appendix C - Reference Approach to Develop Suspended Sediment TMDL Load Duration Curves.

Appendix A – Summary of Flow Data

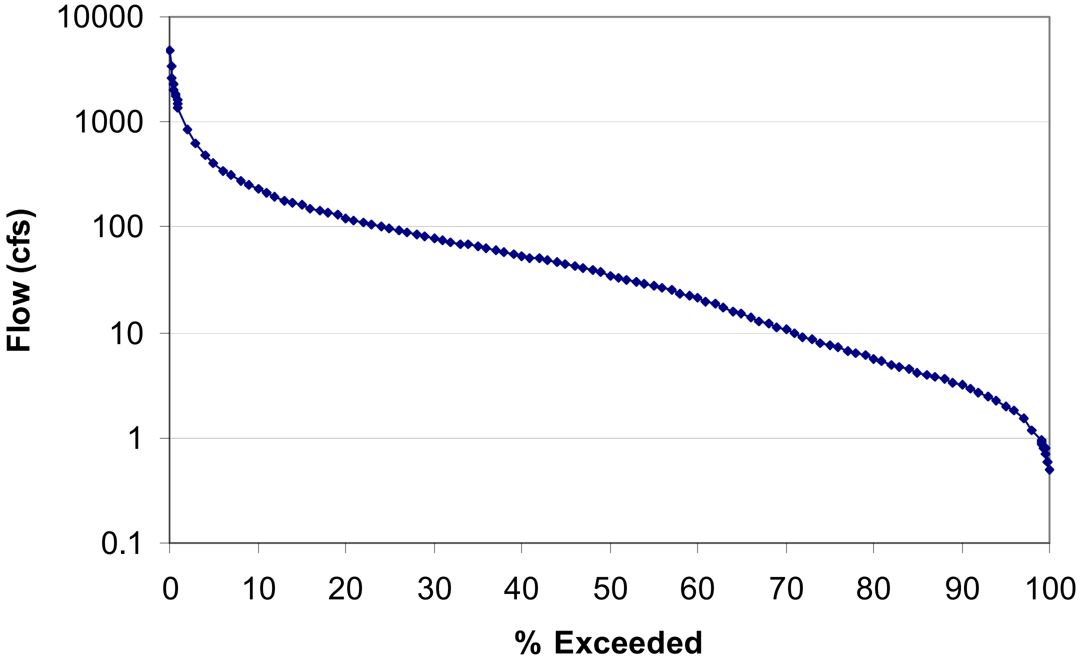


Figure A1: An Estimated Flow Duration Curve for Village Creek

Appendix B. Village Creek TMDL Methodology

To develop the dissolved lead load duration curve (LDC) for Village Creek, a synthetic flow duration curve was developed based on the level of stream flow measured in gaged streams within the same region of the state. The U.S. Geological Survey (USGS) gage stations used are shown in Table B-1.

Table B-1. Gage stations used to develop flow regime for segments 2863 and 2864.

USGS No.	Site Name	Drainage Area (mi^2)
07035000	Little St Francis River at Fredericktown, Mo.	90.5
07061270	East Fork Black River near Lesterville, Mo.	52.2
07020550	South Fork Saline Creek near Perryville, Mo.	55.3

The median discharge per square mile was calculated for these streams and applied to the two segments of Village Creek based on the drainage area of each segment.

Once a flow regime was calculated, an estimated Total Suspended Solids (TSS) concentration was derived from streams with measured concentrations in the region (Table B-2). The LDC for suspended sediment was generated based on the 25th percentile of all TSS data. The LDC for dissolved lead was generated based on the numeric criterion calculated using the 25th percentile of hardness data in the region (Table B-2)

Table B-2. Water quality sites used for calculation of 25th percentile total hardness and total suspended solids.

USGS No. or Agency	Site Name	Hardness Data	TSS Data
07061155	Strother Creek near Oates, Mo.	X	X
07020900	Castor River near Fredericktown, Mo.	X	
07033850	Brewers Creek near Roselle, Mo.	X	
07037300	Big Creek at Sam A Baker State Park, Mo.	X	X
07061600	Black River below Annapolis, Mo.	X	X
07036100	St. Francis River near Saco, Mo.	X	X

07061150	West Fork Black River at Centerville, Mo.	X	X
07021000	Castor River near Zalma, Mo.	X	X
07061300	East Fork Black River at Lesterville, Mo.	X	X
07061270	East Fork Black River near Lesterville, Mo.	X	X
MoDNR	Village Creek (WBID 2863)	X	
MoDNR	Village Creek (WBID 2864)	X	
MoDNR	Shays Creek (WBID 2865)	X	
MoDNR	Sweetwater Creek (WBID 2866)	X	
MoDNR	Musco Creek (WBID 2872)	X	
U.S. EPA	Trib from Mine La Motte Lake (Site 1 MCM Site*)	X	
U.S. EPA	Little St. Francis River (Site 3 MCM Site*)	X	
U.S. EPA	Unnamed trib to Saline Creek (Site 4 MCM Site*)	X	
U.S. EPA	Mill Creek (Site 5 MCM Site*)	X	
U.S. EPA	(Site 6 MCM Site*)	X	
U.S. EPA	St. Francis River (Site 9 MCM Site*)	X	

* Wooster-Brown, C. 2006. Ecological Risk Assessment, Madison County Mine (MCM) Operational Unit 3, Superfund Site CERCLIS ID#: MODO98633415-OU3, US EPA Region 7

To address the impairment for inorganic sediment as both percent fine sediment and lead in sediment, a relationship was generated using percent fine sediment data and the specific mass of sampled sediment from the stream bottom. This relationship is independent of segment location and refers to the location of the sample taken. As such, the bed sediment load capacities are instantaneous and apply on any given day.

The percent fine sediment target of 13.64 percent was developed using a control site on the Castor River (Water Body ID 2297) one mile downstream from the crossing of Route. J. The load capacity curve and table were developed based on the mass of fine sediment that could be contained within a bottom sediment sample of a given mass.

The bed sediment lead load capacity was generated using the equilibrium partitioning methodology described in the TMDL. The load capacity was calculated based on the percent of a sediment mass that could be composed of lead such that the Threshold Effect Concentration was not exceeded. As with the percent fine sediment target, this load capacity applies on any given day.

Table B-3. Data used in calculating applicable hardness value.

Site	Hardness (mg/L as $CaCO_3$)	Site	Hardness (mg/L as $CaCO_3$)
Black River below Annapolis, Mo (USGS 07061600)	130	Brewers Creek near Roselle, Mo (USGS 07033850)	28
	140		20
	140		14
	130		52
	130		54
	120		82
	98		82
	110		72
	100		36
	130		72
	140		70
	140		58
	140		25
	150		46
	150		64
	160		30
	150		54
	130	Castor River near Fredericktown, Mo (USGS 07020900)	120
	100		90
	78		110
	64		140
	94		90
	130		110

	140		120
	130		140
	130		81
	120		120
	120		100
	110		120
	120		110
	120		110
	110		86
	110		110
	94		110
	120		140
	110		160
	120		140
	120		150
	140		130
	150		160
	150		51
	140		150
	150		110
	150		54
	150		77
	110		110
	130		130
	120		160
	110		110

	120		130
	110		67
	130		110
	140		150
	140		100
	150	St. Francis River near Saco, Mo (USGS 07036100)	110
	94		110
	92		140
	110		100
	25		120
	90		56
	65		130
	140		81
	150		38
	120		61
	110		88
	140		100
	99		130
	140		76
	150		97
	110		58
	120		80
	120		130
	130		78
	120		130
	150		170

	160		190
	93		180
	130		190
	120		160
	140		190
	89		130
	93		82
	95		190
	130		140
	89		200
	130		99
	140	EPA data from ecological risk assessment	194
	80		129
	90		208
	120		114
	84		359
	110		108
	150	East Fork Black River near Lesterville, Mo (USGS 07061270)	110
	140		91
	120		50
	150		55
	120		66
	120		66
	140		100
	100		71

	140	East Fork Black River at Lesterville, Mo (USGS 07061300)	120
	140		97
	160		30
	110		56
	150		69
	130		54
	140		73
	120		73
	42	Castor River near Zalma, Mo (USGS 07021000)	80
	93		80
	120		64
	140	MDNR data near Village Creek (2865/0.1, 2866/1.4, and 2872/0.2)	246
	140		160
	100		150
	120		110
	130		87
	120	MDNR Village Creek (2863/1.7 and 2864/0.3)	202
	120		232
	120		202
	100	Strother Creek near Oates, Mo (USGS 07061155)	110
	34		110
	120		150
	130		170
	140		180
	150		160

	150		150
	160		120
	110		180
	120		190
	140		200
	120		200
	120		150
	110		200
	130		210
	86		250
	110		230
	110		220
	140		260
	150		190
	170		240
	150		270
	160		270
	140		180
	170		160
	54		200
	160		45
	99		170
	43		160
	95		270
	130		310
	140		280

	180		230
	120		240
	130		340
	71		
	130		
	140		
	140		
	160		
	170		
	150		
	110		
	120		
	130		
	140		
	110		
	150		
	130		
	110		

Appendix C. Reference Approach to Develop Suspended Sediment TMDL Load Duration Curves.

Overview

This procedure is used when a lotic system is placed on the 303(d) impaired water body 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 water body 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 percent of the stream flow. This results in an inflection point in the curve below which the TMDL is calculated using this reference concentration.

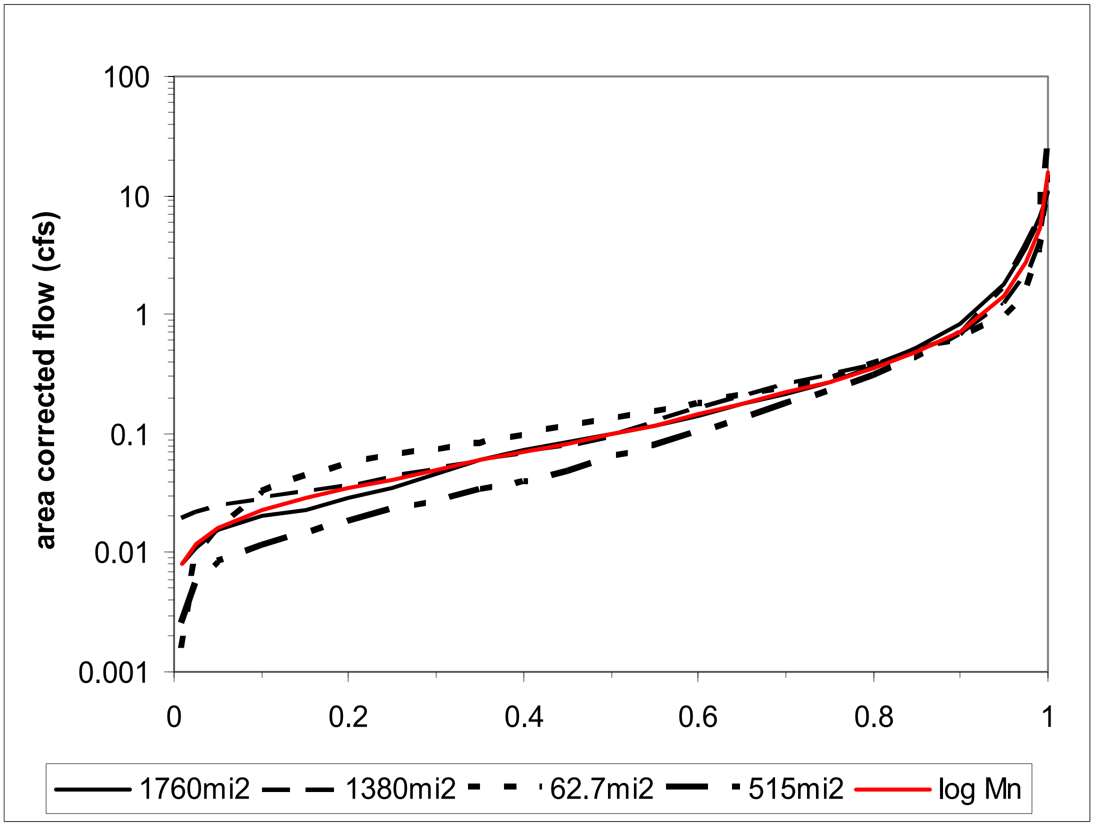
Methodology

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.

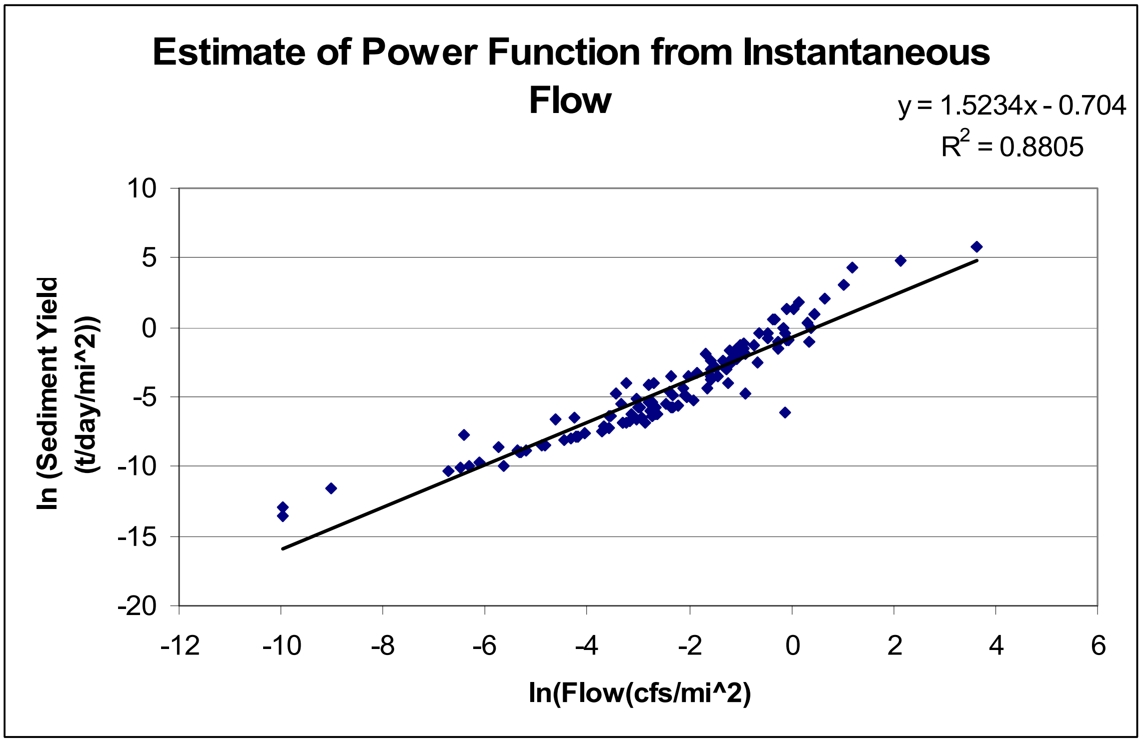
The watershed-size normalized data for the individual gages in the EDU were calculated and compared to a pooled data set including all of the gages. The result of this analysis is displayed in the following figure and table:



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:



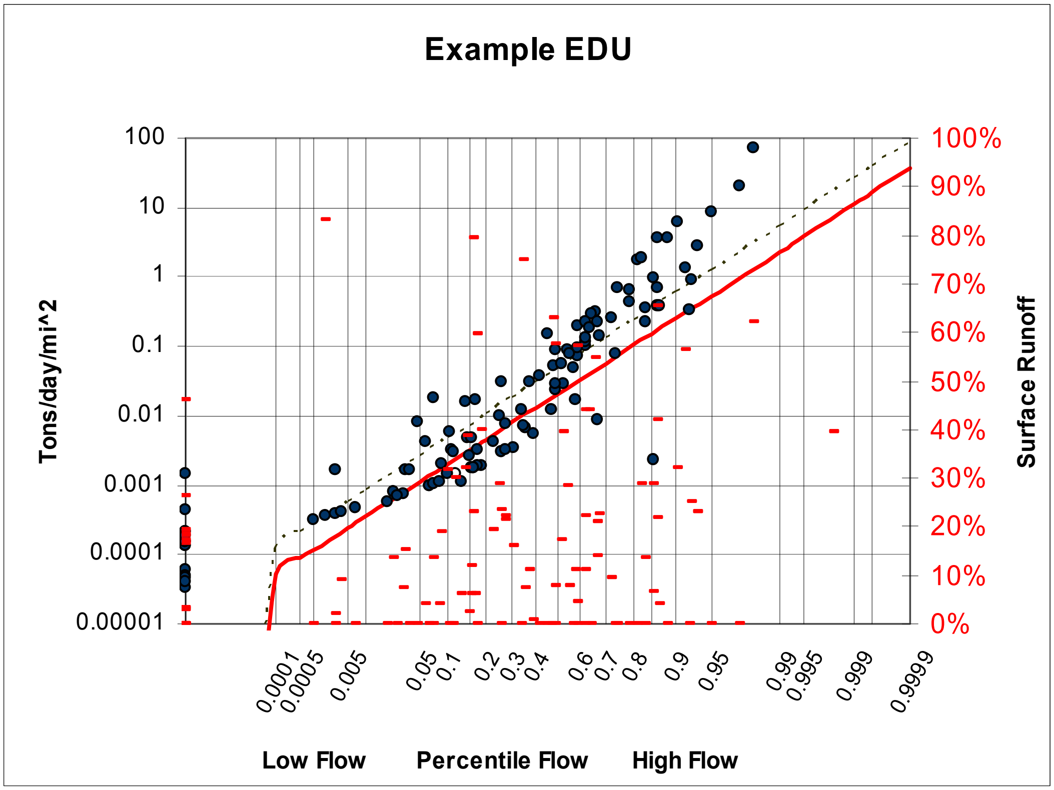
Further statistical analyses on this relationship are included in the following table: -

m	1.52343455	b	-0.704018113
Standard Error (m)	0.05211423	Standard Error (b)	0.170675885
r^2	0.88047953	Standard Error (y)	1.260455
F	854.545062	DF	116
SSreg	1357.655	SSres	184.2946296

The standard error of y was used to estimate the 25th percentile 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:
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Water, Wetlands, and Pesticides Division
Total Maximum Daily Load Program
901 North 5th Street
Kansas City, KS 66101
Web site: www.epa.gov/region07/water/tmdl.htm