Missouri Department of Natural Resources
Water Protection Program

Total Maximum Daily Loads (TMDL)

for

Indian Creek, Tributary to Indian Creek, and Courtois Creek

Washington and Crawford Counties Missouri

Completed: May 19, 2010
Approved:

Total Maximum Daily Loads (TMDLs) for Indian Creek (and tributary) and Courtois Creek Pollutants: Lead, Zinc and Metals

Name: Indian Creek
Name: Tributary to Indian Creek
Name: Courtois Creek[1]

State map showing location of watershed

Location: Washington and Crawford Counties
near Viburnum, Mo.

Hydrologic Unit Code (HUC): 07140102-040001

Water Body Identification Numbers and Missouri Stream Classifications[2]:

1943—Courtois Creek	P
1946—Indian Creek	P
3663—Tributary to Indian Creek	C

Designated beneficial uses[3]

- Livestock and wildlife watering
- Protection of warm water aquatic life
- Cool-water fishery (Courtois Creek only)
- Protection of human health (fish consumption)
- Whole body contact recreation
- Secondary contact recreation (Courtois Creek only)
- Outstanding state resource water (Courtois Creek in Crawford County only)

Length and locations of impaired segments

1943—Courtois Creek	30 miles, from mouth (downstream) to Section 17, T35N, R01W (upstream)
1946—Indian Creek	1.5 miles, from mouth to Section 18, T35N, R01W
3663—Tributary to Indian Creek	0.3 miles from mouth to Section 07, T35N, R01W

Length and locations of impairments within the segments

1943—Courtois Creek	2.6 miles, from Section 32, T36N, R01W (downstream) to Section 08, T35N, R01W (upstream)
1946—Indian Creek	1.5 miles, from mouth to Section 18, T35N, R01W
3663—Tributary to Indian Creek	0.3 miles from mouth to Section 07, T35N, R01W

TMDL Priority Ranking: High

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[1] Pronounced locally as "KOH'-tuh-way."
[2] 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 that support aquatic life.
[3] For designated beneficial uses see 10 CSR 20-7.031(1)(C) and Table (H)

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1. Introduction

This Indian Creek, Tributary to Indian Creek, and Courtois Creek Total Maximum Daily Load, or TMDL, for dissolved lead, zinc and metals is being established by the Missouri Department of Natural Resources, or department, in accordance with Section 303(d) of the federal Clean Water Act. These water quality limited segments in Washington and Crawford counties are included on Missouri's U.S. Environmental Protection Agency-approved 2008 303(d) list of impaired waters.

The purpose of a TMDL is to determine the pollutant loading a water body can assimilate without exceeding Missouri's water quality standards. Missouri's water quality standards consist of three components: designated beneficial uses, water quality criteria to protect those uses and an antidegradation policy. The TMDL establishes the pollutant load allocation necessary to meet the water quality standards established for each water body based on the relationship between pollutant sources and instream water quality conditions. A TMDL consists of a wasteload allocation, a load allocation and a margin of safety. The wasteload allocation is the fraction of the total pollutant load apportioned to point sources. The load allocation is the fraction of the total pollutant load apportioned to nonpoint sources. The margin of safety is a percentage of the TMDL that accounts for any uncertainty associated with the model assumptions as well as any data inadequacies.

Indian Creek and Courtois Creek are listed on the 2008 303(d) list of impaired waters as impaired by dissolved lead and metals in water. The listed source of the impairment is the Viburnum 29 mine. Tributary to Indian Creek is listed as impaired by dissolved lead and zinc in water with the Viburnum 29 mine again cited as the likely source of the pollutants. The pollutant listing of metals for Indian Creek and Courtois Creek is a change from Missouri's EPA-approved 2004/2006 303(d) list in which dissolved zinc was cited as the pollutant of concern. This document provides TMDLs for dissolved lead and zinc, because these are the pollutants for which there are available data that indicate an impairment of the protection of aquatic life designated use. Additionally, it is believed lead is the primary pollutant resulting in metal toxicity for which the current metals impairment is based. It is believed reducing lead concentrations to or below water quality standards will also result in eliminating the effects of metals toxicity to the streams' aquatic life.

2. Background

Indian Creek is located about three miles northeast of Viburnum, Mo. in the Upper Meramec River basin, and is in the Courtois Creek watershed where it is a tributary to Courtois Creek. Indian Creek flows for 1.5 miles until it joins with Courtois Creek at about 0.1 mile upstream of State Highway C in Washington County. Upstream about 0.5 miles from this point, a small tributary feeds Indian Creek. Tributary to Indian Creek runs for 0.3 miles and is entirely contained within Washington County. Courtois Creek flows for 30 miles into Crawford County until its confluence with Huzzah Creek, which then flows to the Meramec River. Twelve miles of Courtois Creek in Crawford County, from its mouth to State Highway 8, is designated as an outstanding state resource water[4].

2.1 Historic and Present Day Land Use

Pre-settlement Ozark uplands were comprised mostly of prairie and oak savannah, while thick deciduous and pine forests dominated steep valley slopes and bottoms. Early settlers cleared trees off valley bottoms and uplands for pasture and row crops. From 1880 to 1920, the Ozarks were subject to heavy timber cutting, leaving large expanses of eroding uplands and valley slopes. Increased pasture grazing and row cropping followed. Woodland grazing and seasonal burning became popular, resulting in increased soil

[4] Missouri's water quality standards at 10 CSR 20-7.031(1)(R) defines an outstanding state resource water as being a high quality water with significant aesthetic, recreational, or scientific value.

erosion and the suppression of young trees. Cutting of second growth forest began in the mid-1950s (Jacobson and Primm 1994).

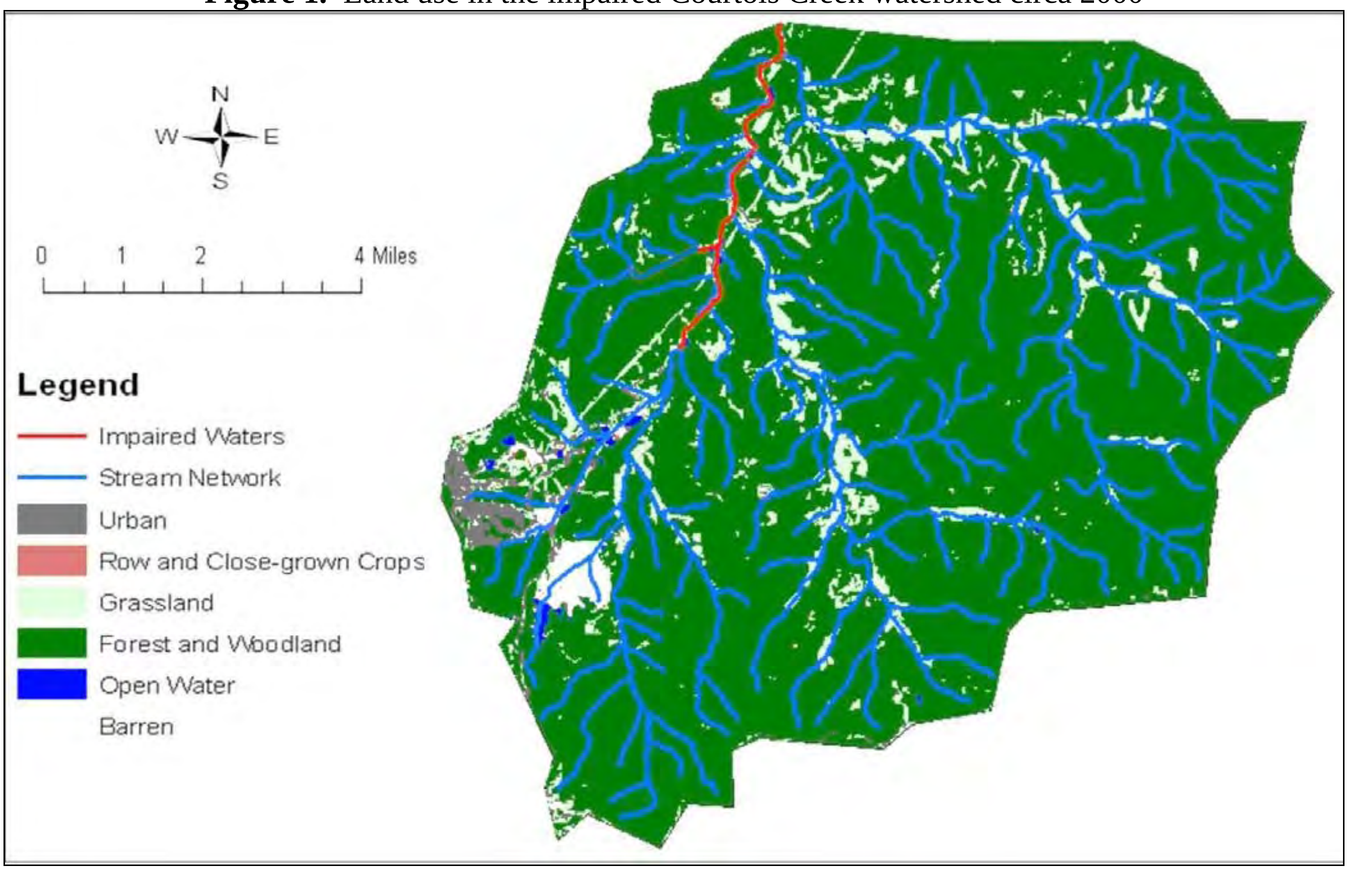
Current land use is based on data from 2000 to 2004 at 30-meter resolution obtained from Thematic Mapper imagery (MoRAP 2005). This information is summarized in Table 1. Overall, the impaired Courtois Creek watershed, which includes the Indian Creek and Tributary to Indian Creek watersheds, is comprised of nearly 89 percent forested land and eight percent grassland. Urban areas account for 1.31 percent of the current land use, followed by barren land (predominantly mine tailings impoundments), which accounts for 1.12 percent. The remaining area is comprised of open water and cropland. Figure 1 graphically presents the available land use data of the impaired Courtois Creek watershed.

Table 1. Land use in the impaired Courtois Creek watershed*

Land Use Type	*Sq. Miles*	*Acres*	*Hectares*	*Percentage*
Urban	0.96	615	248.76	1.31
Row and Close-grown Crop	0.16	99	39.87	0.21
Grassland	5.79	3,707	1,500.19	7.92
Forest and Woodland	64.95	41,569	16,822.93	88.86
Open Water	0.43	272	110.07	0.58
Barren (mine tailings, etc)	0.82	522	211.14	1.12
Totals:	73.11	46,784	18,932.96	100

*includes the Indian Creek (and tributary) watershed

Figure 1. Land use in the impaired Courtois Creek watershed circa 2000



2.2 Soils

The impaired Courtois Creek watershed covers approximately 73 square miles and includes several different soil types. The soils present in this watershed are in the Gravois-Goss Association where Gravois and Goss soils are the predominant soil types. The Gravois-Goss complex of soils typically has slopes of 3 to 15 percent and is stony. Gravois and similar soils account for 72 percent of the soil composition and are typically found on ridge tops and side slopes. Gravois soils are a silt loam soil and have 3 to 8 percent slopes. Goss and similar soils makeup 25 percent of the area's soil composition and are typically found on side slopes. Goss soils have a slope of 3 to 50 percent and may be extremely stony. Minor soils, such as Cedargap gravely silt loam and Sonsac, account for the remaining 3 percent. Cedargap gravely silt loam has a slope of 0 to 3 percent and is frequently flooded. Sonsac soils are included in the Sonsac-Moko-Rock complex, which has slopes of 15 to 50 percent and is extremely stony (Soil Survey Staff 2005).

2.3 Defining the Problem

2.3.1 Lead and Zinc Mining Activities in Missouri

For nearly 150 years, Missouri has been one of the world's largest producers of lead and zinc ore. Historically, lead and zinc ores in Missouri were mined, milled, and transported to smelters throughout the state to be processed into raw metals. It is common to find lead and zinc contamination in soil, groundwater and surface water surrounding lead and zinc mines, mills, smelter sites and transportation corridors. In fact, Missouri's 2008 303(d) list of impaired waters contains 24 lead impairments associated with mining activities for 21 water body segments and 15 zinc impairments associated with mining activities for 14 water body segments. These various lead and zinc impairments predominantly occur downstream of mining and milling site tailings impoundments, processing areas, and from underground mine workings via mine dewatering or contamination of shallow aquifers. Contamination around smelter sites comes from smokestack fallout, fugitive emissions from the production processes, and transportation of concentrate from mills to the smelter and slag piles. These types of operations have the potential to produce waste material containing high levels of lead, zinc and other metals that may be deposited in surface waters and soils, both on and surrounding the sites.

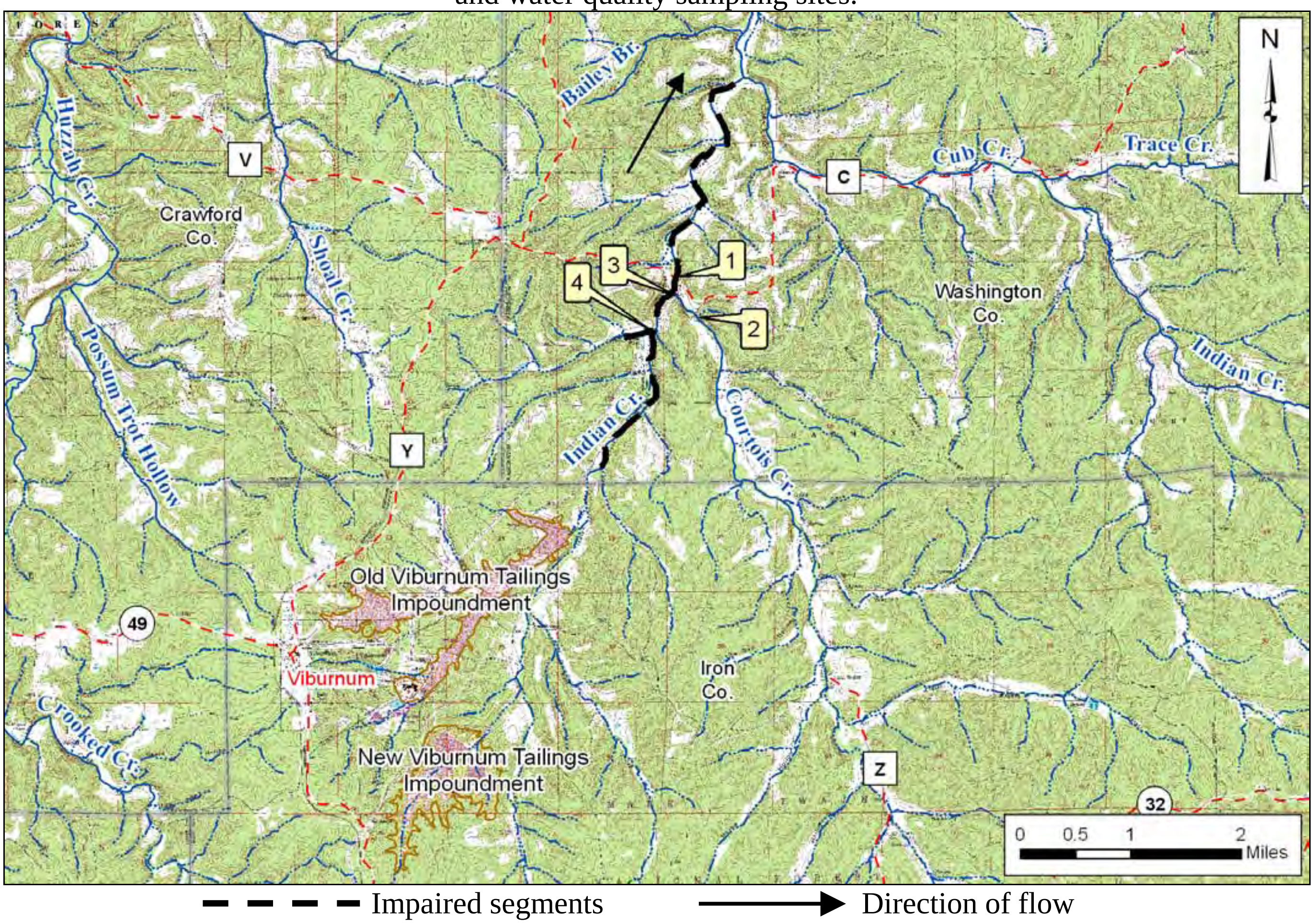
2.3.2 Lead and Zinc Mining Activities in the Impaired Watershed

The impaired portions of Indian Creek, Tributary to Indian Creek, and Courtois Creek are located near the "New Lead Belt" region of southeast Missouri. Refer to Figure 2 for a topographic map showing the location of the impaired segments. These segments were listed on Missouri's EPA-approved 2004/2006 303(d) List of impaired waters due to water quality data that show exceedances of the dissolved lead and dissolved zinc chronic criteria for the protection of aquatic life (Appendix C). Additionally, a biological assessment study of these streams conducted in 2001 and 2002 found the streams' aquatic invertebrate communities to be exhibiting lower species diversity and fewer individuals when compared to representative reference streams (MoDNR 2002). Results from the biological assessment study can be found in Appendix B. Recent studies also suggest nickel, because of its bioavailability, may be a problem in the New Lead Belt region (Besser et al. 2009). However, department data is insufficient to show that a nickel impairment exists in these streams. For this reason, nickel is not addressed in this TMDL.

The New Lead Belt region, where these lead and zinc impaired water body segments are located, is also referred to as the Viburnum Trend. This area was discovered in 1955 to have significant lead and zinc deposits. However, extraction of these deposits did not begin until the 1960s when the state's "Old Lead Belt" region in Washington County became nearly depleted of all economically extractable ore (Femmer 2004). Ten mines have operated in the New Lead Belt, with the most recent being the Doe Run Company-Viburnum Division (The Doe Run Company).

The Doe Run Company maintains several permitted outfalls that discharge to both Indian Creek and Tributary to Indian Creek, as well as manages two large tailings impoundments within the watershed. Additionally, the mining area is within the St. Joe Minerals Corporation-Viburnum Superfund site, which is named after Doe Run's predecessor. Superfund is a federal government program to clean uncontrolled hazardous waste sites and is administered by the EPA or a state agency with EPA approval. The St. Joe Mineral Corporation-Viburnum site is not included on EPA's National Priorities List of hazardous waste sites. The National Priorities List is the EPA's list of priorities among the known hazardous waste sites throughout the United States and is intended to aid in determining which sites warrant further investigation (USEPA 2009).

Figure 2. Topographic map showing the impaired water body segments, tailings impoundments, and water quality sampling sites.



Department Sampling Sites[5]

1 – Site 1943/29.0 Courtois Creek downstream of Indian Creek
2 – Site 1943/29.5 Courtois Creek upstream of Indian Creek
3 – Site 1946/0.1 Indian Creek at old Highway C
4 – Site 3663/0.1 Tributary to Indian Creek

[5] The naming convention for these sites is: the water body identification number of the segment/miles from the mouth of the segment/miles from the mouth of a tributary

3. Source Inventory and Assessment

Source assessment characterizes known, suspected and potential 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 lead and zinc may be point (regulated) or nonpoint (unregulated) in nature.

3.1 Point Sources

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[6] and include any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. The impaired Courtois Creek watershed contains six permitted facilities, which discharge into Indian Creek and Tributary to Indian Creek. Of these six facilities, three have site specific permits, one facility has a general permit, and two facilities have storm water permits (Table 2). There are no permitted concentrated animal feeding operations in this watershed.

In addition to these currently permitted facilities, Missouri's inventory of mines, occurances, and prospects also notes the former existance of nine historic lead and zinc mining sites in the impaired Courtois Creek watershed (Figure 3). These historic mine sites, three former Renault Lead Company mines and six unnamed sites, are all located outside the Indian Creek and Tributary to Indian Creek watersheds (MoDNR 2008). Therefore, any potential contributions of lead and zinc loading from these sites would be to Courtois Creek only. However, metals loading from the Indian Creek watershed has been identified as the primary source of lead and zinc to Courtois Creek. This was determined by analyzing data collected both above and below the confluence of Indian Creek and Courtois Creek. These data do not indicate that lead or zinc impairment exists on Courtois Creek above this confluence or that there are any significant lead or zinc inputs downstream of it. Because there are no tailings impoundments associated with the historic mine sites and seven of the nine sites are located near the downstream end of the impaired segment of Courtois Creek, potential contributions of lead and zinc from historic mine sites are not expected to be significant.

In addition to the nine historic lead and zinc sites, Missouri's inventory of mines, occurances, and prospects also shows 15 historic sand and gravel and other non-lead or zinc related mine sites within the impaired Courtois Creek watershed (MoDNR 2008). None of these sites are expected to significantly contribute lead or zinc to the impaired water bodies.

Of the permitted facilities in the impaired Courtois Creek watershed, only the Doe Run-Viburnum Operations facility (MO-0000086) has lead and zinc effluent limits and is considered to be a significant potential point source of lead and zinc to the impaired water bodies (Table 3). The Doe Run-Viburnum Operations facility has five permitted outfalls that discharge mine water, precipitation and runoff from the facility, tailings impoundments, and the upper watershed. One outfall also potentially receives effluent from the City of Viburnum wastewater lagoon (MO-0055751), which has an outfall approximately 2 miles upstream. The Doe Run Company also has a storm water permit for an outfall near the Old Viburnum Tailings Impoundment, a 427 acre tailings pile that is one of two tailings impoundments managed by the Doe Run Company in the Viburnum area (Figure 2). The second tailings impoundment, located just south of the first, is known as the New Viburnum Tailings Impoundment and spans approximately 403 acres. Both of these tailings impoundments are potentially significant contributers of lead and zinc loading to the impaired water bodies during large runoff-producing storm events.

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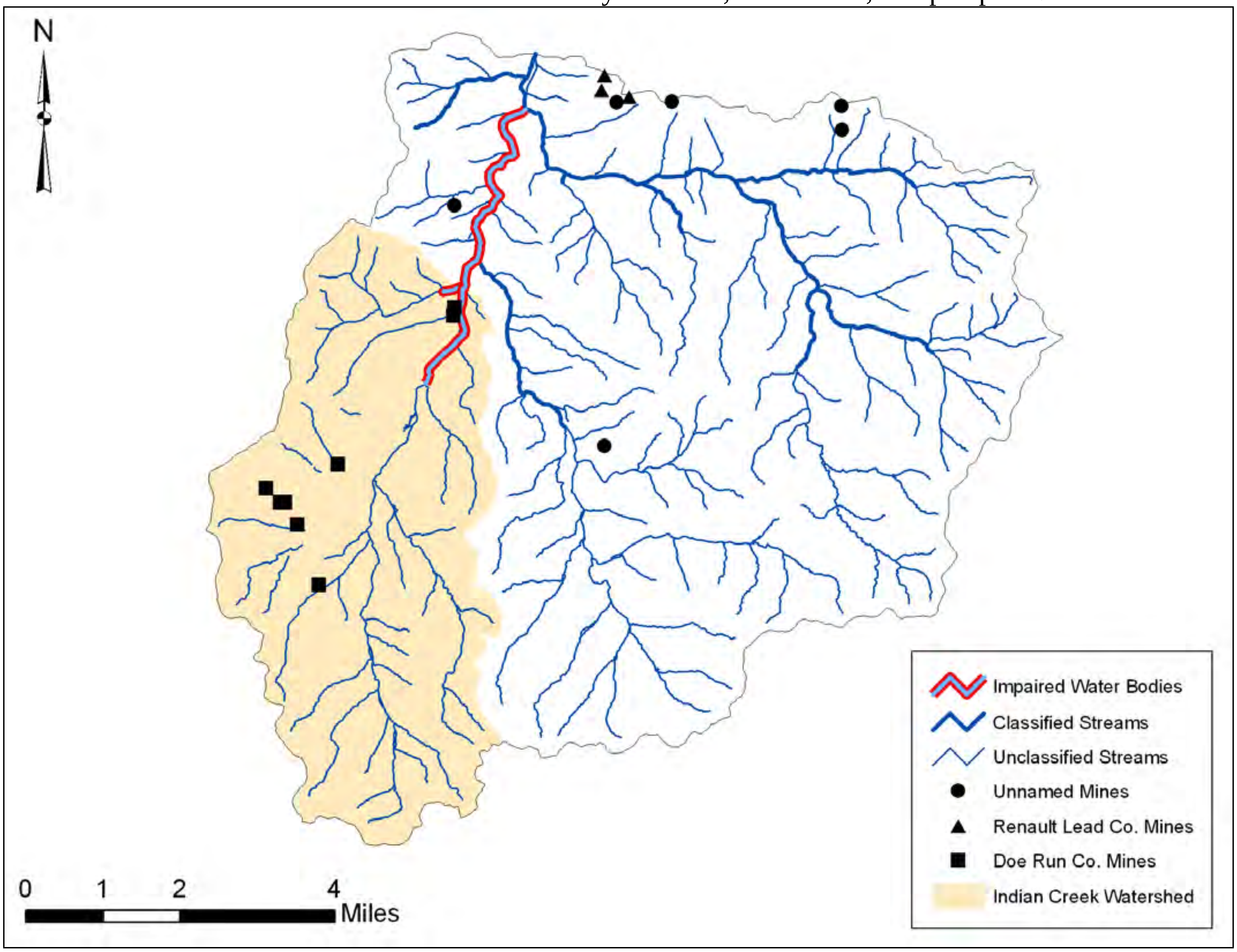
[6] The Missouri State Operating Permitting system is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program

In addition to the tailings impoundments, haul roads and other disturbed areas[7] within the Doe Run Company's mining area may contribute metals loading to the impaired water bodies as a result of runoff-producing storm events. These sources may involve runoff from areas with lead and zinc contaminated soils along the Doe Run Company's haul roads and in residential yards. Soil contamination of lead and zinc occurs in these areas as a result of mine concentrate or tailings being moved either unintentionally through vehicle debris or intentionally for use as fill material. As a result, these sources, which are part of the St. Joe Mineral Corporation-Viburnum Superfund site, may also contribute lead and zinc to surface waters as a result of runoff-producing storm events. However, completed Superfund removal or remediation activities has likely reduced the potential inputs from residential soils to insignificant levels. For these reasons, metal loading from the Doe Run Company's mining area, a point source that includes tailings piles, dewatering ponds, disturbed mining land, and the St. Joe Mineral Corporation-Viburnum Superfund site is expected to be the most significant contributor of lead and zinc loading to the watersheds.

Figure 3. Map of the impaired Courtois Creek watershed showing lead and zinc mining sites included on the state's inventory of mines, occurances, and prospects.



[7] In the context used for the TMDL, "disturbed areas" or "disturbed mining land" refers to those parts of the mining area that may be disturbed in some way (i.e., excavated, graded, reclaimed) but the disturbance is not related to the primary mining activities.

Table 2. Permitted facilities in the impaired Courtois Creek watershed

Permit No.	***Facility Name***	***Facility Type***
MO-0000086	Doe Run - Viburnum Operations	Lead Mine
MO-0055751	Viburnum Wastewater Lagoon	Publicly owned treatment works
MO-0103420	Viburnum Trailer Park Lagoon	Publicly owned treatment works
MO-G490268	Viburnum Quarry 1	Limestone Quarry
MO-R108711	Doe Run Buick SSA Borrow	Storm Water - Land Disturbance
MO-R22A227	Advanced Resaw LLC	Storm Water - Wood Products

Table 3. Current permit limits for total recoverable lead (Pb) and zinc (Zn) and existing loads (lbs/day)

Permit No.	***Expiration Date***	***Pb Limits* (µg/L)***	***Zn Limits (µg/L)***	***Indian Cr. Pb Load†***	***Indian Cr. Zn Load†***	***Tributary Pb Load†***	***Tributary Zn Load†***
MO-0000086	12/03/2014	600 / 10.3	1,000 / 188	18.6 / 0.0	97.8 / 0.0	18.6 / 0.0	50.4 / 0.0
MO-0055751	04/13/2015	MR‡	MR	no data	no data	no outfall	no outfall
MO-0103420	11/06/2013	none	none	no data	no data	no outfall	no outfall
MO-G490268	10/05/2011	none	none	no data	no data	no outfall	no outfall
MO-R108711	02/07/2007	none	none	no data	no data	no outfall	no outfall
MO-R22A227	03/04/2009	none	none	no data	no data	no outfall	no outfall

* Limits expressed as interim limits / final limits. Final limits effective 3 years from permit effective date.
† Loads expressed as maximum / minimum in lbs/day. Derived from facility discharge monitoring reports.
‡ MR = monitoring requirement only

Because the tailings impoundments are unlined, seepage of dissolved metals from the tailing impoundments into the groundwater represents a potential secondary source of metals contamination to the impaired water bodies. Although surface runoff may be significant during large storm events, isotope studies in the Meramec Basin suggest that after a typical storm event, stream water generally consists of flushed-in, pre-event water (Frederick and Criss 1999). Pre-event water includes groundwater found in soil zones above an aquifer, or shallow groundwater found in the upper fractured and weathered zone of the bedrock. As precipitation infiltrates tailing piles and moves through the subsurface, metals may become dissolved and enter the streams via the groundwater recharge pathway. Although the amount and extent of any seepage into groundwater as a possible secondary source of metals contamination is unknown, monitoring well data at depth suggests that little of the leachate reaches the deep groundwater. This is probably because deep groundwater in this part of the Ozarks may be pressurized.

3.2 Nonpoint Sources

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 lead and zinc 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 Doe Run Company's mine land area, nonpoint sources of lead and zinc loading are expected to be minor. Undisturbed and vegetated areas within the watershed are expected to be insignificant sources of lead and zinc to the impaired segments.

Within the impaired Courtois Creek watershed, there are no agricultural nonpoint sources of lead and zinc that cause or contribute to the impairment. 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 impaired Courtois Creek watershed only accounts for about 0.2 percent of the total watershed land use thereby making any lead and zinc loading contributions minimal.

While nonpoint sources of dissolved lead and zinc are minor or negligible under critical low-flow conditions, historic and legacy lead and zinc within the stream system can be sources of these metals, especially during higher flows. As conservative pollutants, these metals do not degrade and historic lead and zinc can become re-suspended into the water column and carried downstream via natural fluvial processes. Metals, including lead and zinc, may adsorb to organic and inorganic sediment surfaces, which may result in significant metals suspension and re-deposition during and immediately following high-flow storm events (Andrews et al. 2009). This process allows previously unavailable lead and zinc to enter the water column and become a water quality concern. It is therefore reasonable and necessary to have load allocations for lead and zinc at higher flows to account for nonpoint source instream loading of these pollutants.

4. Applicable Water Quality Standards and Numeric Water Quality Targets

The purpose of developing a TMDL is to identify the pollutant loading that a water body can assimilate and still achieve water quality standards. Water quality standards are therefore central to the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III (U.S. Code, 2009)). Water quality standards consist of three components: designated beneficial uses, numeric criteria, and an antidegradation policy.

4.1 Designated Beneficial Uses

Indian Creek and Tributary to Indian Creek

- Livestock and wildlife watering
- Protection of warm water aquatic life
- Protection of human health (fish consumption)
- Whole body contact recreation (Category B)

Courtois Creek

- Livestock and wildlife watering
- Protection of warm water aquatic life
- Cool-water fishery
- Protection of human health (fish consumption)
- Whole body contact recreation (Category A)
- Secondary contact recreation
- Outstanding state resource water (12 miles in Crawford County only)

4.2 Uses that are Impaired

- Protection of warm water aquatic life

4.3 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 economic and 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.

4.4 Specific Criteria

Missouri Water Quality Standards for metals found in 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.*

Current lead and zinc criteria for the protection of aquatic life use are expressed in dissolved form in units of micrograms per liter, or µg/L. These criteria are hardness dependent and calculated from the formulas shown below from Table A of 10 CSR 20-7.031:

Dissolved Lead

$\text{Acute} = e^{(1.273*\ln(\text{hardness})-1.460448)}*(1.46203-(\ln(\text{hardness})*0.145712)) = \mu g/L$

$\text{Chronic} = e^{(1.273*\ln(\text{hardness})-4.704797)}*(1.46203-(\ln(\text{hardness})*0.145712)) = \mu g/L$

Dissolved Zinc

$\text{Acute} = e^{(0.8473*\ln(\text{hardness})\ +\ 0.884211)} * 0.978 = \mu g/L$

$\text{Chronic} = e^{(0.8473*\ln(\text{hardness})\ +\ 0.785271)} * 0.986 = \mu g/L$

where "e" is the base of the natural logarithm (~2.718) and "ln" is the natural logarithm.

4.5 Numeric Water Quality Targets

4.5.1 Lead and Zinc

The 25th percentile hardness value must be used to calculate hardness dependent metals criteria per 10 CSR 20-7.031. The 25th percentile of hardness in the Courtois Creek watershed is 170 mg/L. Therefore, the corresponding dissolved chronic and acute lead targets for Courtois Creek are 4.5 and 114 µg/L respectively. Likewise, the dissolved chronic and acute zinc targets are 168 and 184 µg/L respectively. The 25th percentile of hardness in the Indian Creek watershed is 225 mg/L. Therefore, the corresponding dissolved chronic and acute lead targets for Indian Creek and Tributary to Indian Creek are 6 and 154 µg/L respectively. The dissolved chronic and acute zinc targets are 213 and 233 µg/L respectively.

The water quality targets for lead and zinc will be based on the chronic criteria to ensure aquatic life will be protected from acute and chronic toxicity. Targets for Courtois Creek are therefore 4.5 µg/L for lead and 168 µg/L for zinc. Targets for Indian Creek and the Tributary to Indian Creek are therefore 6 µg/L for lead and 213 µg/L for zinc.

4.5.2 Data for Target Development

The U.S. Geological Survey, or USGS, collected the majority of the water quality data in the Courtois Creek watershed and used two different laboratories that employed different analytical methods with different detection levels. In the Indian Creek watershed, the data were collected at or below base flow, corresponding to probability flows of 46 percent or greater. Where sampling sites were upstream of the watershed outlet, the average daily flows at those sites were normalized to the watershed area of the outlet. This adjustment was based on the ratio of their respective watershed area. Sampling locations for the Courtois Creek watershed are provided in Appendix C.

5. Calculating Load Capacity

Load capacity is the maximum pollutant load that a water body can assimilate and still attain water quality standards. It is equal to the sum of the wasteload allocation, load allocation and the margin of safety, and can be expressed as the equation:

$$LC = \sum WLA + \sum LA + MOS$$

where LC is the loading capacity, ∑WLA is the sum of the wasteload allocations, ∑LA is the sum of the load allocations, and MOS is the margin of safety.

5.1 Modeling approach and Synthesis of Flow Data

The Indian Creek watershed covers 13,760 acres including the watershed of Tributary to Indian Creek. The entire Courtois Creek watershed, which includes the impaired portion illustrated in Figure 1, drains approximately 135,680 acres. The Tributary to Indian Creek watershed covers 1,536 acres. The modeling approach for the impaired segments contained within these watersheds consists of creating a load duration curve at the outlet of the Indian Creek, Tributary to Indian Creek, and Courtois Creek watersheds and determining the TMDLs for each pollutant of concern at every flow probability. A load duration curve is the product of the criterion of concern (in mg/L), the expected flow at the corresponding probability (as ft^3/s) and a conversion factor (5.395). The resulting load is expressed in pounds per day (1 kilogram = 2.2 pounds). The 25^{th} percentile hardness value was selected (See section 4.5 Numeric Water Quality Targets) to calculate the target concentration.

Existing pollutant loads were calculated from flow and concentration records from the same day and site and are plotted against the TMDL curve based on their flow probability and corresponding plotting position (Figures 4 - 9). Only uncensored data were used to graph observed pollutant loads against target pollutant loads at corresponding probability flows. Where sampling sites were upstream of the watershed outlet, the average daily flows at those sites were adjusted to the watershed area of the outlet. This adjustment was based on the ratio of their respective watershed area. Because there were no flow data for either the Courtois Creek or Indian Creek watersheds, the average daily stream flow at the outlets of the watersheds was synthesized using the long-term discharge record from USGS stream gage data. Flow data from Oct. 1, 1982 to Feb. 22, 2009 from USGS stream gage 07013000 – Meramec River near Steelville, Mo was used. This gage was chosen because it is within the same hydrologic unit as Courtois Creek and is located in an area having similar topography and geology. Watershed area corrected flow using these data reasonably approximate flows for the Courtois Creek , Indian Creek, and Tributary to Indian Creek watersheds.

5.2 TMDLs and Existing Loading for Pollutants of Concern
Total Maximum Daily Loads and existing loads for Indian Creek, Tributary to Indian Creek, and Courtois Creek watersheds are graphically presented in Figures 4 – 9.

5.3 Pollutant Load Reductions
Tables 4 – 9 detail the greatest percent reductions of existing pollutant loads necessary to meet the TMDL loading targets within the Indian Creek, Tributary to Indian Creek, and the Courtois Creek watersheds. Likewise, flow values presented in Tables 4 – 9 correspond to the observed load requiring the largest percent reduction. In order to obtain representative values over the continuum of flows, exceedance ranges from which greatest percent reductions were chosen are: 80 – 100 %, 60 – 80 %, 40 – 60 %, 20 – 40 % and 0 – 20 %. Exceedance ranges where no data is presented indicate that no samples were collected at these flows.

Figure 4. Dissolved lead (DPb) TMDL and observed load in the Indian Creek watershed

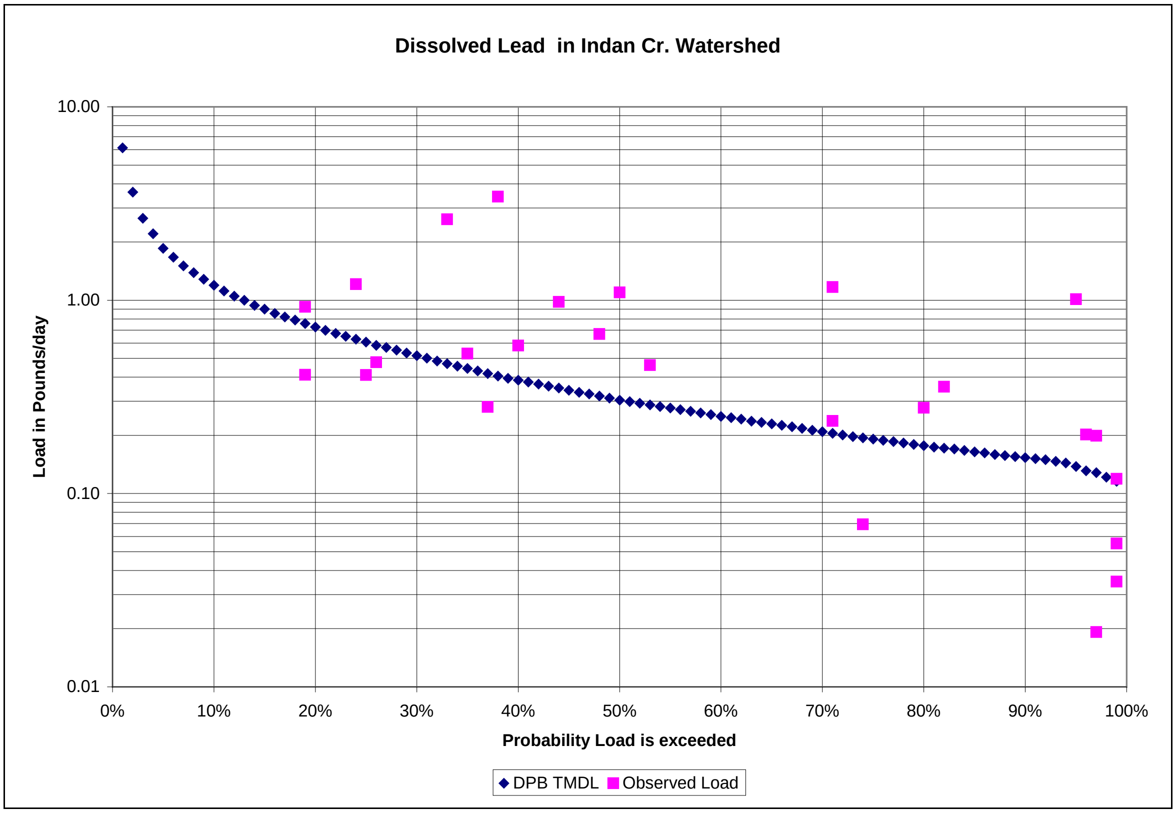


Figure 5. Dissolved Zinc (DZn) TMDL and observed load in the Indian Creek watershed

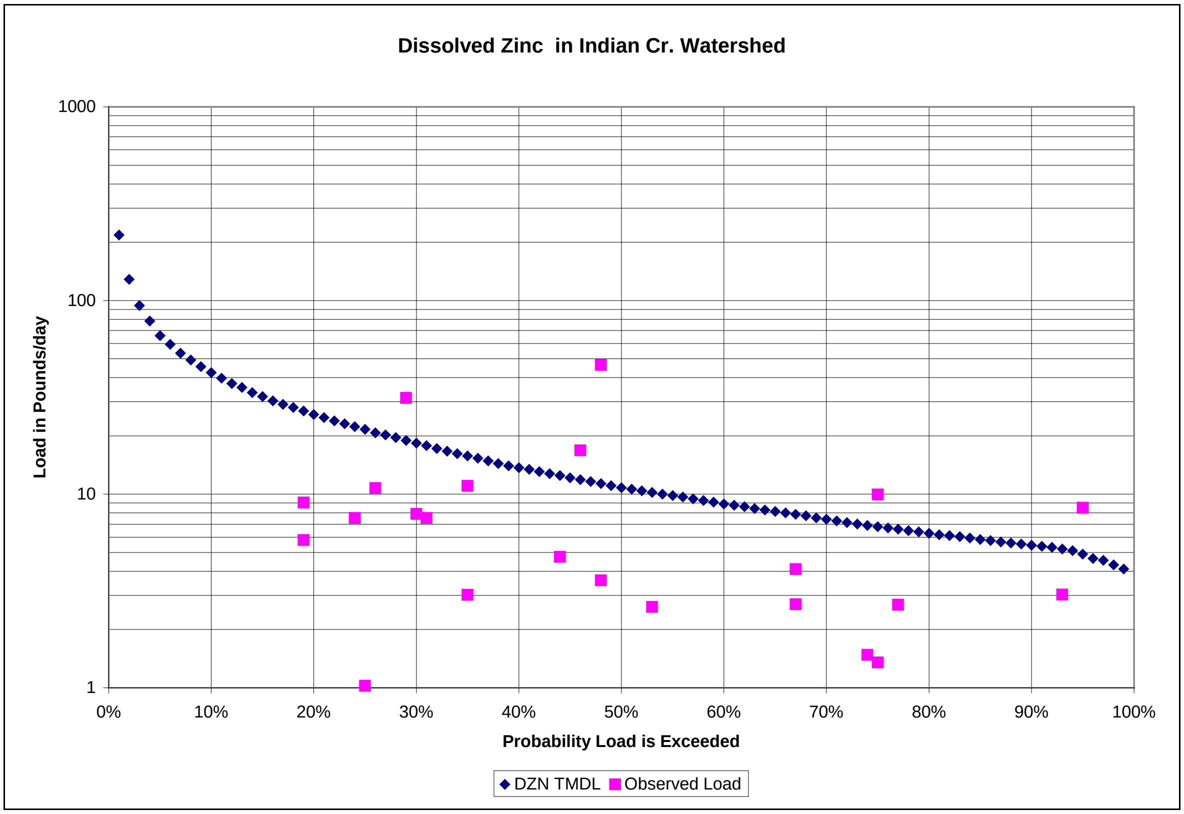


Figure 6. Dissolved Lead (DPb) TMDL and observed load in the Trib. to Indian Creek watershed

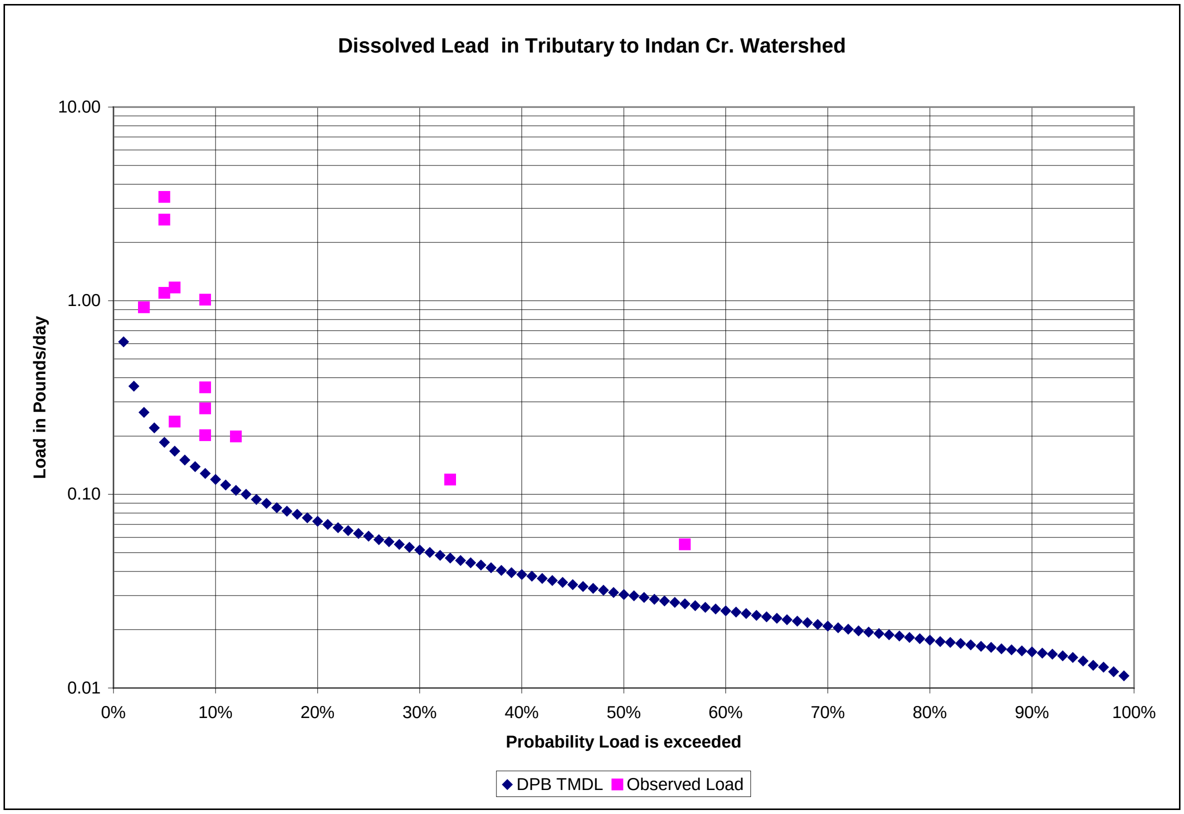


Figure 7. Dissolved Zinc (DZn) TMDL and observed load in the Trib. to Indian Creek watershed

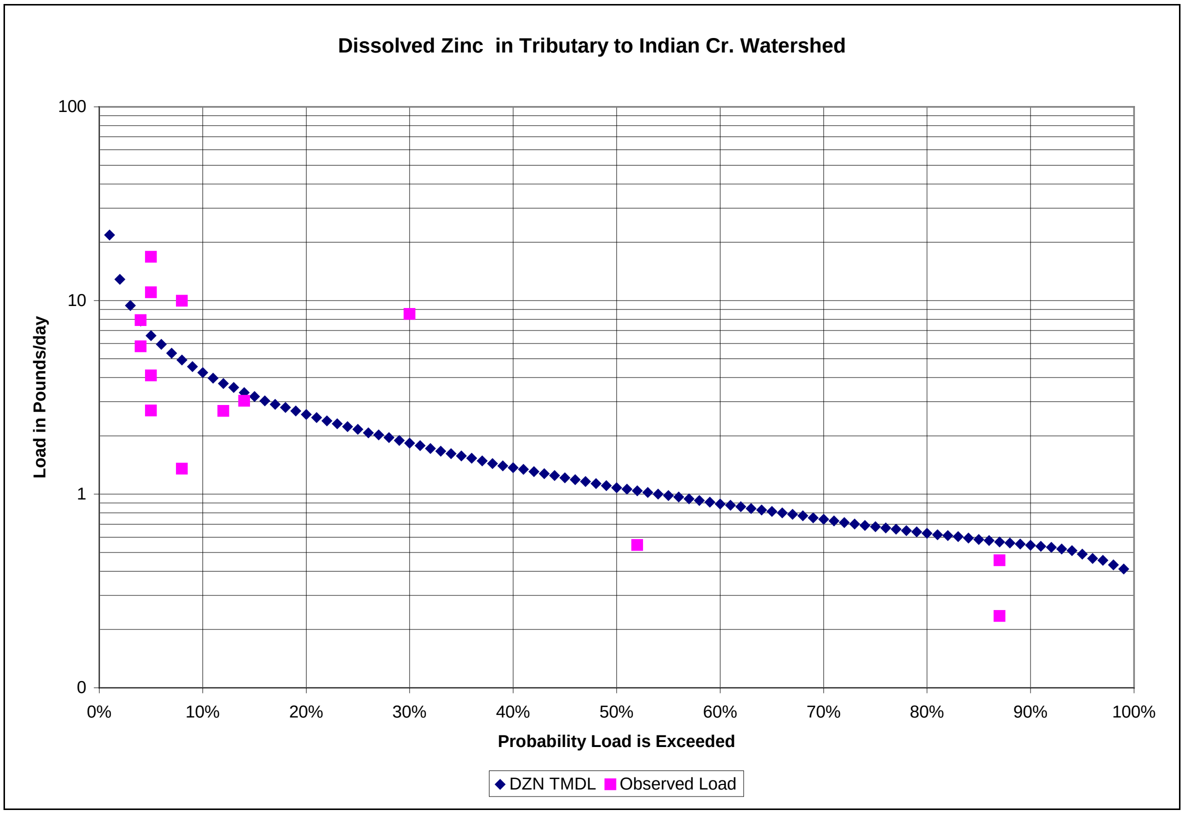


Figure 8. Dissolved Lead (DPb) TMDL and observed load in the Courtois Cr. Watershed

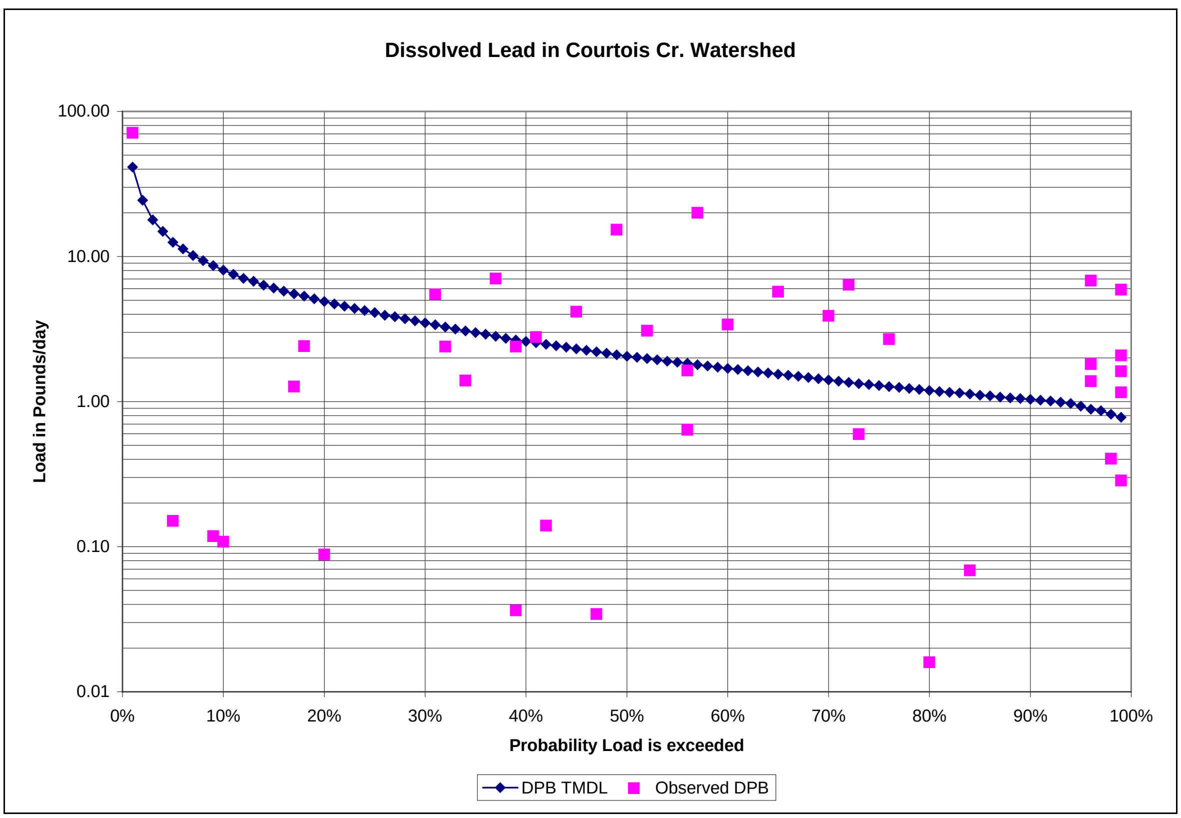


Figure 9. Dissolved Zinc (DZn) TMDL and observed load in the Courtois Cr. watershed

Table 4. Dissolved lead loads needing greatest percent reduction in the Indian Cr. watershed

Flow Exceedance	*Flow (cfs)*	*Observed Load (lb/day)*	*Target Load (lb/day)*	*Reduction (lb/day)*	*Percent Reduction*
95	4.26	1.01	0.14	0.87	86%
71	6.33	1.17	0.20	0.97	83%
50	9.39	1.10	0.30	0.80	73%
38	12.51	3.43	0.40	3.03	88%
19	23.37	0.92	0.76	0.16	17%

Table 5. Dissolved zinc loads needing greatest percent reduction in the Indian Cr. watershed

Flow Exceedance	*Flow (cfs)*	*Observed Load (lb/day)*	*Target load (lb/day)*	*Reduction (lb/day)*	*Percent Reduction*
95	4.26	8.52	4.90	3.62	42 %
75	5.91	9.96	6.80	3.16	32 %
48	9.87	46.48	11.35	35.13	76 %
29	16.47	31.38	18.94	12.44	40%
19	23.37	9.05	26.88	-17.83	0 %

Table 6. Dissolved lead loads needing greatest percent reduction in the Trib. to Indian Cr. watershed

Flow Exceedance	*Flow* (cfs)*	*Observed Load (lb/day)*	*Target Load* (lb/day)*	*Reduction (lb/day)*	*Percent Reduction*
80-100	0.48	-	0.01	-	-
60-80	0.65	-	0.02	-	-
56	0.84	0.06	0.03	0.03	50%
33	1.45	0.12	0.05	0.07	58%
2	11.19	3.43	0.36	3.07	90%

*Where Percent Load Exceeded is a range, data corresponding to the median flow value is used.

Table 7. Dissolved zinc loads needing greatest percent reduction in the Trib. to Indian Cr. watershed

Flow Exceedance	*Flow* (cfs)*	*Observed Load (lb/day)*	*Target load* (lb/day)*	*Reduction (lb/day)*	*Percent Reduction*
88	0.49	0.23	0.57	-0.34	0 %
60-80	0.65	-	0.74	-	-
52	0.91	0.46	1.04	-0.58	0 %
30	1.60	0.55	1.84	-1.29	0 %
3	8.19	46.48	9.42	37.06	80%

*Where Percent Load Exceeded is a range, data corresponding to the median flow value is used.

Table 8. Dissolved lead loads needing greatest percent reduction in the Courtois Cr. watershed

Flow Exceedance	*Flow (cfs)*	*Observed Load (lb/day)*	*Target Load (lb/day)*	*Reduction (lb/day)*	*Percent Reduction*
96	36.45	6.82	0.88	5.94	87%
72	55.89	6.40	1.36	5.04	79 %
57	73.98	20.03	1.80	18.23	91%
37	116.10	7.05	2.82	4.23	60%
1	1705.29	71.14	41.4	29.74	42%

Table 9. Dissolved zinc loads needing greatest percent reduction in the Courtois Cr. watershed

Flow Exceedance	*Flow (cfs)*	*Observed Load (lb/day)*	*Target Load (lb/day)*	*Reduction (lb/day)*	*Percent Reduction*
80	49.14	90.82	44.54	46.28	51%
72	55.89	84.27	50.66	33.61	40%
56	75.60	270.85	68.52	202.33	75%
31	139.32	96.55	126.27	-29.72	0 %
17	227.61	215.78	206.30	9.48	4 %

6. Wasteload (Point Source) and Load (Nonpoint Source) Allocation

6.1 Wasteload Allocations (Point Source Load)

The wasteload allocation portion of a TMDL is the maximum allowable amount of a pollutant that can be assigned to point sources. The wasteload allocations for these TMDLs is set to the 99 percent flow exceedance for dissolved zinc and dissolved lead in the Indian Creek, Tributary to Indian Creek, and Courtois Creek watersheds. This flow exceedance was chosen as it is most representative of critical low flow discharge conditions and is anticipated to be protective at all flow conditions.

6.2 Load Allocations (Nonpoint Source Load)

The Load Allocation portion of a TMDL is the maximum allowable amount of the pollutant that can be assigned to nonpoint sources. The dissolved lead and zinc load allocation for the Indian Creek, Tributary to Indian Creek, and Courtois Creek watersheds at the 99 percent flow exceedance was set at zero due to negligible nonpoint source loading of dissolved lead and zinc to the impaired segments at these flows.

6.3 TMDL Allocations

In the Indian Creek, Tributary to Indian Creek, and Courtois Creek watersheds, metal loading is coming exclusively from the Doe Run mining area, which includes tailings piles, overflowing dewatering ponds, and runoff from the disturbed mining land. For these reasons, the predominant load reduction will be achieved by reducing or eliminating pollutant loading from the Doe Run-Viburnum Operation facility. As stated in Section 6.1, the 99 percent flow exceedance load capacity was chosen as the wasteload allocation for point sources. The difference between the load capacity and wasteload allocation at each flow interval will be allocated as the load allocation since the margin of safety is implicit. See Tables 10 – 15 for wasteload and load allocations of dissolved lead and zinc in the Indian Creek, Tributary to Indian Creek, and Courtois Creek watersheds.

Table 10. Dissolved lead allocations for Indian Creek watershed (WBID: 1946)

Percent Load Exceeded	*Flow (cfs)*	*TMDL (lb/day)*	*WLA (lb/day)*	*LA (lb/day)*	*MOS* (lb/day)*
99	3.57	0.12	0.12	0.00	-
80	5.46	0.18	0.12	0.06	-
60	7.74	0.25	0.12	0.13	-
40	11.91	0.39	0.12	0.27	-
20	22.43	0.73	0.12	0.61	-

* implicit margin of safety

Table 11. Dissolved zinc allocations for Indian Creek watershed (WBID: 1946)

Percent Load Exceeded	*Flow (cfs)*	*TMDL (lb/day)*	*WLA (lb/day)*	*LA (lb/day)*	*MOS* (lb/day)*
99	3.57	4.11	4.11	0.00	-
80	5.46	6.28	4.11	2.17	-
60	7.74	8.90	4.11	4.79	-
40	11.91	13.70	4.11	9.59	-
20	22.43	25.80	4.11	21.69	-

* implicit margin of safety

Table 12. Dissolved lead allocations for Trib. to Indian Creek watershed (WBID: 3663)

Percent Load Exceeded	*Flow (cfs)*	*TMDL (lb/day)*	*WLA (lb/day)*	*LA (lb/day)*	*MOS* (lb/day)*
99	0.36	0.01	0.01	0.00	-
80	0.55	0.02	0.01	0.01	-
60	0.77	0.03	0.01	0.02	-
40	1.19	0.04	0.01	0.03	-
20	2.24	0.07	0.01	0.06	-

* implicit margin of safety

Table 13. Dissolved zinc allocations for Trib. to Indian Creek watershed (WBID: 3663)

Percent Load Exceeded	*Flow (cfs)*	*TMDL (lb/day)*	*WLA (lb/day)*	*LA (lb/day)*	*MOS* (lb/day)*
99	0.36	0.41	0.41	0.00	-
80	0.55	0.63	0.41	0.22	-
60	0.77	0.89	0.41	0.48	-
40	1.19	1.37	0.41	0.96	-
20	2.24	2.58	0.41	2.17	-

* implicit margin of safety

Table 14. Dissolved Lead Allocations for Courtois Creek Watershed (WBID: 1943)

Percent Load Exceeded	*Flow (cfs)*	*TMDL (lb/day)*	*WLA (lb/day)*	*LA (lb/day)*	*MOS* (lb/day)*
99	32.13	0.78	0.78	0.00	-
80	49.14	1.19	0.78	0.41	-
60	69.66	1.69	0.78	0.91	-
40	107.2	2.60	0.78	1.82	-
20	201.9	4.90	0.78	4.12	-

* implicit margin of safety

Table 15. Dissolved Zinc Allocations for Courtois Creek Watershed (WBID: 1943)

Percent Load Exceeded	*Flow (cfs)*	*TMDL (lb/day)*	*WLA (lb/day)*	*LA (lb/day)*	*MOS* (lb/day)*
99	32.13	29.12	29.12	0.00	-
80	49.14	44.54	29.12	15.42	-
60	69.66	63.14	29.12	34.02	-
40	107.2	97.15	29.12	68.03	-
20	201.9	183.0	29.12	153.9	-

* implicit margin of safety

7. Margin of Safety

A margin of safety is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The margin of safety is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the margin of safety can be achieved through one of two approaches:

(1) Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL.

(2) Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

The margin of safety for these TMDLs is implicit and is based on the conservative assumptions used in developing and applying the TMDL load duration curves. Using the load duration curve approach ensures water quality standards are achieved under all flow regimes. Conservative assumptions were also used in setting WLA values at the 99^{th} percent flow exceedance. This value is expected to be protective of water quality during low flow conditions in a conservative manner.

8. Seasonal Variation

The TMDL load duration curve represents flow under all possible stream conditions. The advantage of a load duration curve approach is that it avoids the constraints associated with using a single-flow critical condition during the development of the TMDL. Because the TMDL is applicable under all flow conditions, it is also applicable for all seasons. Seasonal variation is therefore implicitly taken into account within the TMDL calculations.

9. Monitoring Plan

Currently, the department's Water Protection Program's Water Quality Monitoring and Assessment Unit has recommended additional monitoring of metals in sediment for Courtois Creek and sediment toxicity sampling for Indian Creek. However, no specific monitoring plan has been developed.

Post-TMDL monitoring is usually scheduled and carried out by the department approximately three years after the approval of the TMDL or in a reasonable time period following completion of permit compliance schedules and the application of new effluent limits. Any available volunteer water quality monitoring or permittee instream monitoring that occurs on Indian Creek, Tributary to Indian Creek, or Courtois Creek will be used for screening purposes to compare the stream's current condition with future, post-TMDL conditions. Additionally, 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.

10. Implementation Plans

10.1 Point Sources

The impairments of the Indian Creek and Courtois Creek watersheds are mainly a result of discharge and runoff from the Doe Run Company-Viburnum Division mine site. Therefore, this part of the TMDL will be implemented through permit action. Effluent limits and monitoring requirements for the parameters of interest will be reevaluated to reflect the water quality targets set by the TMDL as the affected permit approaches renewal. Additionally, BMPs shall be adopted to reduce loading from storm water outfalls. The facility must also regularly measure instream pollutant concentrations to determine the efficacy of the control measures.

Since the Courtois Creek watershed contains the Indian Creek watershed, any land management action in the Indian Creek watershed with the goal to lessen runoff frequency and intensity, should also reduce metal loading in Courtois Creek. Stabilizing the tailings impoundments from erosion will reduce the amount of contaminated sediments entering the impaired water bodies. This can be done by adding vegetative cover to the piles, which will aid in reducing both wind and water erosion. Ideally, vegetation would consist of fast-growing plant varieties that will quickly stabilize exposed soils and perennial varieties that will provide long-term stability. Vegetating mining areas may also potentially reduce adjacent soil and ground water contamination due to plants' ability to take up heavy metals, stimulate microbial immobilization of heavy metals, and reduce the potential for leaching by increasing water demand through evapotranspiration (Zhu *et al.* 1999)

Although some vegetative plantings have been completed, large areas of barren tailings are still present. Stabilization of the tailings impoundments will be required by a Metallic Minerals Waste Management permit[8] administered by the department upon the mine's closure. In addition to establishing vegetation, the complete or partial removal of the mine waste or contaminated soils for remediation or placement in an engineered repository should also be considered

Contaminated sediments along haul roads and in residential yards are potential contributors to the Indian Creek and Courtois Creek impairments. However, due to Superfund actions, much of the contaminated soil from residential yards has been removed or remediated. Currently, EPA's Superfund division is reviewing an engineering evaluation/cost analysis to conduct soil removal actions on the haul roads (Jeffrey G. Weatherford, EPA, e-mail communication, Nov. 11, 2009). Future road contamination could be prevented through mining procedural practices, such as covering hauling vehicles and washing vehicle exteriors prior to leaving mining facilities.

10.2 Nonpoint Sources

Nonpoint source reductions are currently not necessary to reduce pollutant loading of dissolved lead and zinc to the Indian Creek and Courtois Creek watersheds. Reductions obtained by implementing the wasteload allocations found in this TMDL should restore water quality in Indian Creek, Tributary to Indian Creek, and Courtois Creek.

[8] Metallic Mineral Waste Management permit applications consist of financial assurance information and detailed waste management area closure and inspection-maintenance plans. Actual on-the-ground reclamation does not begin at these sites until mineral production is stopped, and mine closure begins.

11. Reasonable Assurances

The department has the authority to write and enforce Missouri State Operating Permits. Inclusion of effluent limits (determined from waste load allocations established by modeling) into a state permit, and at least quarterly monitoring of the effluent reported to the department, will result in compliance with water quality standards. In most cases, "Reasonable Assurance," in reference to TMDLs, relates only to point sources. As a result, any assurances that nonpoint source contributors of lead and zinc 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 9.2 of this document.

12. Public Participation

These water quality limited segments are included on Missouri's approved 2008 303(d) List of impaired waters. This document was first placed on a 30-day public notice from Sept. 8, 2009 through Oct. 8, 2009. This comment period was extended to October 22, 2009. Three comments were received during this comment period and resulted in revisions of TMDL targets and wasteload and load allocations. This document was then placed on a second 30-day public notice from Nov. 13, 2009 through Dec. 13, 2009. An additional comment was received and additional revisions to TMDL targets, calculated flows, and allocations were made. Following these additional revisions, this document was placed on a 45-day public notice from March 23, 2010 through May 07, 2010. Three comment was received during this final public notice period. Groups that received the public notice announcement include the Missouri Clean Water Commission, the Water Quality Coordinating Committee, the Missouri Department of Conservation, three Stream Team volunteers in the watershed, any affected facilities, individuals or organizations that commented during the first and second public comment periods, and the five state legislators who represent Washington, Crawford and Iron counties. In addition, the department posted the notice, information sheet, and this document on the department's Web site, making them available to anyone with access to the Web. Announcement of the public notice period for this TMDL was also issued as a press release to local media outlets in the proximity of the Indian Creek and Courtois Creek watersheds. Any comments received and the department's responses to those comments have been placed in the Indian Creek and Courtois Creek TMDL file.

13. Administrative Record and Supporting Documentation

An administrative record on the Indian Creek, Tributary to Indian Creek, and Courtois Creek TMDL has been assembled and is being kept on file with the Missouri Department of Natural Resources. It includes any studies, data and calculations upon which the TMDL is based.

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.

Appendix A – Water quality sampling site locations

WBID #	Site	Site Name	Latitude	Longitude
1943	1943/0.9	Courtois Cr. near mouth	38.0227	-91.1992
1943	1943/5.1	Courtois Cr. above Bass Creek Resort	37.9939	-91.1786
1943	1943/15.7	Courtois Cr. at Hwy 8	37.9176	-91.1020
1943	1943/23.4	Courtois Creek 4 miles north of Courtois, Mo.	37.8415	-91.0583
1943	1943/29.0	Courtois Cr. below Indian Cr., 2.2 miles below tailings	37.7666	-91.0708
1943	1943/29.5	Courtois Cr. above Indian Cr. at Old Hwy C	37.7616	-91.0680
1943	MP007	Courtois Cr. downstream of Indian Creek	37.7647	-91.0717
1946	1946/0.1	Indian Cr. at old Hwy C, 2 miles below Viburnum tailings	37.7644	-91.0715
1946	IC-US	Indian Cr. upstream of outfall 002 and trib.	37.7192	-91.0973
3663	3663/0.1	Trib. To Indian Cr. dwnstrm of Viburnum mine tailings	37.7596	-91.0752

Appendix B – Aquatic macroinvertebrate monitoring data[9]

Site	Location	Date	Score
1943/29.5	Courtois Cr. above Indian Cr.	Fall 2001	**14**
1943/29.5	Courtois Cr. above Indian Cr.	Spring 2002	**14**
1943/29.5	Courtois Cr. above Indian Cr.	Spring 2001	16
1943/29.5	Courtois Cr. above Indian Cr.	Spring 2002	16
1946/0.1	Indian Cr. near mouth	Spring 2001	**12**
1946/0.1	Indian Cr. near mouth	Fall 2001	**12**
1946/0.1	Indian Cr. near mouth	Spring 2002	**12**
1943/29.0	Courtois Cr. just below Indian Cr.	Fall 2001	**14**
1943/29.0	Courtois Cr. just below Indian Cr.	Spring 2002	**14**
1943/22.0	Courtois Cr. 7 miles below Indian Cr.	Fall 2001	16
1943/22.0	Courtois Cr. 7 miles below Indian Cr	Fall 2001	16

Appendix C – Water quality data from the Indian Creek and Courtois Creek Watershed[10]

Org	Site	Site Name	Year	Mo	Dy	Flow	Hard	DPb	DZn
USGS	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	1974	10	31	4.7	196	2	40
USGS	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	1974	10	31	14	304	7	40
USGS	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	1975	1	6	19	138	2	0
USGS	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	1975	4	21	11	178	2	0
USGS	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	1975	7	28	8.2	170	8	0

[9] Sampling sites receiving a score of 16 or more are considered to reflect unimpaired macroinvertebrate communities. Shaded cells and bold face values show an impaired condition.

[10] Hardness and observed data records are in mg/L; dissolved lead and dissolved zinc data and limits are in µg/L; flow is reported in cubic feet per second. Values followed by an asterisk denote censored data. Shaded cells with bold faced values show exceedance of water quality criteria.

Org	Site	Site Name	Year	Mo	Dy	Flow	Hard	DPb	DZn
USGS	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	1975	1	6	19	228	4	10
USGS	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	1975	4	21	13	254	4	0
USGS	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	1975	7	28	12	230	9	8
USGS	1943/15.7	Courtois Cr. @Hwy 8	1993	11	23	240			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1994	11	3	48			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1994	1	19	77	210	0.499*	6
USGS	1943/15.7	Courtois Cr. @Hwy 8	1994	3	11	170			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1994	4	26	189			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1994	6	23	82	210	0.499*	1.99*
USGS	1943/15.7	Courtois Cr. @Hwy 8	1994	8	29	74			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1995	11	21	49			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1995	1	12	85	210	0.499*	1.99*
USGS	1943/15.7	Courtois Cr. @Hwy 8	1995	3	20	88			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1995	4	17	123			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1995	6	7	186	170	1	5
USGS	1943/15.7	Courtois Cr. @Hwy 8	1995	8	7	45			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1996	11	12	145			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1996	1	17	62	160	0.499*	1.99*
USGS	1943/15.7	Courtois Cr. @Hwy 8	1996	3	5	69			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1996	4	9	140			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1996	6	24	47	170	0.499*	1.2
USGS	1943/15.7	Courtois Cr. @Hwy 8	1996	8	19	48			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1997	11	17	72			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1997	1	29	413	110	0.499*	5.7
USGS	1943/15.7	Courtois Cr. @Hwy 8	1997	3	10	240			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1997	4	1	170			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1997	6	19	313	140	0.499*	1.3
USGS	1943/15.7	Courtois Cr. @Hwy 8	1997	8	19	167			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1998	11	2	80			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1998	1	12	230	170	49.99*	9.99*
USGS	1943/15.7	Courtois Cr. @Hwy 8	1998	3	12	290			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1998	4	6	300			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1998	6	15	220	170	49.99*	9.99*
USGS	1943/15.7	Courtois Cr. @Hwy 8	1998	8	17	88			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1999	11	15	30	230	49.99*	18
USGS	1943/15.7	Courtois Cr. @Hwy 8	1999	1	7	82	250	49.99*	9.99*
USGS	1943/15.7	Courtois Cr. @Hwy 8	1999	3	4	88			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1999	4	8	359			
USGS	1943/15.7	Courtois Cr. @Hwy 8	1999	6	14	90	200	49.99*	9.99*
USGS	1943/15.7	Courtois Cr. @Hwy 8	1999	8	19	68			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2000	1	11	57			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2000	3	14	68			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2000	5	17	27	220	49.99*	15
USGS	1943/15.7	Courtois Cr. @Hwy 8	2000	7	6	25			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2000	9	7	12			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2000	11	15	39	240	0.06	8

Org	Site	Site Name	Year	Mo	Dy	Flow	Hard	DPb	DZn
USGS	1943/15.7	Courtois Cr. @Hwy 8	2001	1	10	36			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2001	3	22	60			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2001	5	10	43	200	0.0399*	
USGS	1943/15.7	Courtois Cr. @Hwy 8	2001	7	11	18			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2001	9	6	14			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2001	11	1	29	240	0.0399*	24
MDNR	1943/23.4	Courtois Creek 4 mi. N. of Courtois, MO.	2001	9	18	6.8	260	1.2499*	2.499*
MDNR	1943/29.0	Courtois Cr. bl. Indian Cr., 2.2 mi.bl. Tailings	2001	9	18		260	1.2499*	22.1
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2001	5	31	5.6		1.2499*	237
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2001	3	22	5.96	150		
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2001	6	28	2		0.99*	2.499*
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2001	9	18	1.2	190	1.2499*	2.499*
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2001	10	4	2		1.2499*	2.499*
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2001	5	31	16.7		1.2499*	348
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2001	3	22	8.97	260		
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2001	6	28	3.25		2	26.9
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2001	9	18	0.5	310	1.2499*	41.9
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2001	10	4	3		1.2499*	35.3
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2001	5	31	1.9		**9.1**	**361**
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2001	6	28	0.7		**14.8**	62.8
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2001	9	18		250	**9.1**	87
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2001	10	4	0.4		**12**	91.7
USGS	1943/15.7	Courtois Cr. @Hwy 8	2002	1	23	47			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2002	3	28	328			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2002	5	9	3250	78	3.21	47
USGS	1943/15.7	Courtois Cr. @Hwy 8	2002	7	30	31			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2002	9	3	32			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2002	11	12	57	220	0.0399*	20
MDNR	1943/23.4	Courtois Creek 4 mi. N. of Courtois, MO.	2002	4	3	84.9	170	0.99*	6.72
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2002	4	3	18.3	130	0.99*	2.499*
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2002	4	3	44.2	170	0.99*	34.4
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2002	7	2	4.67		1.2499*	156
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2002	11	6	6		0.99*	4.99*
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2002	4	3	23.8	210	3.2	70.4

Org	Site	Site Name	Year	Mo	Dy	Flow	Hard	DPb	DZn
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2002	7	2	9.94		1.2499*	866
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2002	11	6	6		2.14	45.7
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2002	4	3		210	**7.2**	45.1
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2002	7	2	2.57		**9.4**	**312**
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2002	11	6	2.5		**12.4**	86.6
MDNR	1943/0.9	Courtois Cr. nr mouth	2003	4	3	164	187	0.99*	15.3
USGS	1943/15.7	Courtois Cr. @Hwy 8	2003	1	13	97			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2003	3	3	150			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2003	5	6	441	130	0.05	2
USGS	1943/15.7	Courtois Cr. @Hwy 8	2003	7	29	35			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2003	9	11	61			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2003	11	10	37	240	0.0399*	3
USGS	1943/29.0	Courtois Cr. bl. Indian Cr., 2.2 mi.bl. Tailings	2003	9					45
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2003	3	13	10		0.99*	4.99*
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2003	7	10	6.5		1.55	31.7
MDNR	1943/5.1	Courtois Cr. ab. Bass Creek Resort	2003	4	3	156	183	0.99*	11.7
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2003	3	13	15.7		0.99*	88.9
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2003	7	10	4		0.89	0.499*
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2003	3	13	2.6		0.99	41.9
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2003	7	10	3		**6.88**	72.5
USGS	1943/15.7	Courtois Cr. @Hwy 8	2004	1	8	210			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2004	3	17	114			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2004	5	5	289	150	0.06	3
USGS	1943/15.7	Courtois Cr. @Hwy 8	2004	7	27	37			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2004	9	2	46			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2004	11	9	68	220	0.0399*	2.5
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2004	5	17	13.2		0.12499*	0.125
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2004	6	30	4		0.27	5.51
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2004	5	17	18.1		4.89	110
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2004	6	30	9		**9.5**	53.8
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2004	5	17	4.5		**21.2**	**301**
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2004	6	30	3		**33.9**	110
USGS	1943/15.7	Courtois Cr. @Hwy 8	2005	1	4	61			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2005	3	1	117			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2005	5	18	89	190	0.06	1.8
USGS	1943/15.7	Courtois Cr. @Hwy 8	2005	7	6	22			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2005	9	7	16			

Org	Site	Site Name	Year	Mo	Dy	Flow	Hard	DPb	DZn
USGS	1943/15.7	Courtois Cr. @Hwy 8	2005	11	22	82	200	0.25	3.5
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2005	5	5	14			
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2005	6	25	2.5		1.8	0.499*
MDNR	1943/29.5	Courtois Cr. ab. Indian Cr. @old Hwy C	2005	6	29	5		0.499*	0.499*
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2005	5	5	20		**11.2**	69.7
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2005	6	25	11		**16.5**	80
MDNR	1946/0.1	Indian Cr.@ old Hwy C, 2 mi.bl. Viburnum tailings	2005	6	29	10		**12.4**	66.4
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2005	5	5	7		**32.6**	91
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2005	6	25	6		**49.8**	148
MDNR	3663/0.1	Trib. To Indian Cr. DS of Viburnum mine Tailings	2005	6	29	2		**44**	122
USGS	1943/15.7	Courtois Cr. @Hwy 8	2006	1	10	54			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	1	12	21	228		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	2	16	16	200		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	3	14	201	120		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2006	3	21	311			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	4	18	13	205		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	5	18	22	165		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2006	5	9	162	170	0.08	2.4
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	6	19	7	214		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2006	7	6	19			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	7	18	2	241		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	8	7	1	212		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2006	9	5	18			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	9	18	2	225		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	10	10	3	261		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2006	11	8	75	230	0.0599*	3
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	11	14	7	227		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2006	12	13	67	175		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2007	1	9	74			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	1	24	21	152		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2007	2	14	264	170	0.06	6.3
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	2	21	24	158		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	3	13	16	185		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2007	3	14	76			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2007	4	2	414			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	4	18	73	137		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	5	8	41	153		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2007	5	8		214		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2007	5	22	72	200	0.07	3.1
USGS	1943/15.7	Courtois Cr. @Hwy 8	2007	6	5	43			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	6	20	12	246		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2007	6	20		334		

Org	Site	Site Name	Year	Mo	Dy	Flow	Hard	DPb	DZn
USGS	1943/15.7	Courtois Cr. @Hwy 8	2007	7	10	28			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	7	17	3	282		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2007	7	17		369		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	8	15	0.2	235		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2007	8	15		387		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2007	9	4	14			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	9	12	5	289		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2007	9	12		423		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	10	10	1	251		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2007	10	10		368		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2007	11	5	20	220	0.0399	2.2
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	11	8	3	285		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2007	11	8		356		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2007	12	6	7	309		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2007	12	6		367		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	1	9	38	233		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008	1	9		253		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2008	9	2	64			
USGS	1943/15.7	Courtois Cr. @Hwy 8	2008	1	23	35			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	2	20	150	162		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008	2	20		185		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	3	12	39	156		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008	3	12		214		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2008	3	24	355			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	4	17	73	201		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008	4	17		133		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	5	6	41	231		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008	5	6		269		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2008	5	19	174	140	0.0399	6.6
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	6	5	24	229		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008	6	5		294		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	7	11	21	260		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008	7	11		349		
USGS	1943/15.7	Courtois Cr. @Hwy 8	2008	7	21	80			
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	8	14	6	248		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008				381		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	9	11	21	218		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008	9	11		365		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	10	17	8	233		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008	10	17		353		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	11	5	10	281		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008	11	5		396		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2008	12	4	9	283		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2008	12	4		427		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2009	1	9	48	255		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2009	1	9		354		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2009	2	10	32	215		

Org	Site	Site Name	Year	Mo	Dy	Flow	Hard	DPb	DZn
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2009	2	10		194		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2009	3	4	50	217		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2009	3	4		334		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2009	4	3	39	190		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2009	4	3		253		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2009	5	4	29	132		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2009	5	4		152		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2009	6	4	37	195		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2009	6	4		217		
DOERUN	MP007	Courtois Cr. DS of Indian C.	2009	7	8	57	231		
DOERUN	IC-US	Indian Cr. upstream of Outfall 002	2009	7	8		318		